

---

## State Water Resources Control Board

May 31, 2017

Les Grober  
Deputy Director  
State Water Resources Control Board  
Division of Water Rights  
1001 I Street, 14<sup>th</sup> Floor  
Sacramento, CA 95814

**SUBJECT: REQUEST FOR EXTERNAL PEER REVIEW OF THE SCIENTIFIC BASIS FOR NEW AND REVISED WATER QUALITY OBJECTIVES FOR THE PHASE II UPDATE OF THE BAY-DELTA PLAN**

Dear Mr. Grober,

This letter responds to the attached April 18, 2017 request for external scientific peer review for the subject noted above. The review process is described below. All steps were conducted in confidence. Reviewers' identities were not disclosed.

To begin the process for selecting reviewers, I contacted the University of California, Berkeley (University) and requested recommendations for candidates considered qualified to perform the assignment. This service is supported through an Interagency Agreement co-signed by CalEPA and the University. The University was provided with the request letter and attachments. No additional material was asked for. The University interviews each promising candidate.

Each candidate who was both qualified and available for the review period was asked to complete a Conflict of Interest (COI) Disclosure form and send it to me for review, with Curriculum Vitae. The cover letter for the COI form describes the context for COI concerns that must be taken into consideration when completing the form. "As noted, staff will use this information to evaluate whether a reasonable member of the public would have a serious concern about [the candidate's] ability to provide a neutral and objective review of the work product."

In subsequent letters to candidates approved as reviewers, I provided the attached January 7, 2009 Supplement to the CalEPA Peer Review Guidelines, which, in part, serves two purposes: a) it provides guidance to ensure confidentiality through the course of the external review, and b) it notes reviewers are under no obligation to discuss their comments with third-parties after reviews have been submitted. We recommend they do not. All outside parties are provided opportunities to address a proposed regulatory action, or potential basis for such, through a well-defined rulemaking process.

Later, I sent letters to reviewers to initiate the review. These letters provided access instructions to a secure FTP site where all material to be reviewed was placed, including a Table of Contents for them. Attachment 2 to the request memorandum was highlighted as the focus for the review. Each reviewer was asked to address each topic, as expertise allows, in the order given. Thirty days were provided for the review. I also asked reviewers to direct enquiring third-parties to me after they have submitted their reviews.

Reviewers' names, affiliations, curriculum vitae, initiating letters and reviews are being sent to you now with this letter.

Approved reviewers:

1. Murdoch McAllister, Ph.D.  
Associate Professor, Quantitative Modeling Group  
Canada Research Chair in Fisheries Assessment  
UBC Institute for the Oceans and Fisheries  
University of British Columbia  
AERL, 2202 Main Mall  
Vancouver, BC Canada V6T 1Z4  
  
Telephone: 604-822-3693  
E-mail: [m.mcallister@oceans.ubc.ca](mailto:m.mcallister@oceans.ubc.ca)
2. Thomas Meixner, Ph.D.  
Professor & Associate Department Head  
Hydrology and Atmospheric Sciences  
The University of Arizona  
JW Harshbarger Bldg #11, Room 202  
1133 E. James Rogers Way  
Tucson, AZ 85721-0011  
  
Telephone: 520-626-1532  
E-mail: [tmeixner@hwr.arizona.edu](mailto:tmeixner@hwr.arizona.edu)
3. Thomas Miller, Ph.D.  
Professor & Director  
Chesapeake Biological Laboratory  
University of Maryland Center for Environmental Science  
146 Williams Street, P.O. Box 38  
Solomons, MD 20688-0038  
  
Telephone: 410-326-7276  
E-mail: [miller@umces.edu](mailto:miller@umces.edu)
4. N. LeRoy Poff, Ph.D.  
Department of Biology  
Colorado State University  
1878 Campus Delivery  
Fort Collins, CO 80523  
  
Telephone: 970-491-2079  
E-mail: [n.poff@colostate.edu](mailto:n.poff@colostate.edu)
5. Elowyn Yager, Ph.D.  
Associate Professor, Center for Ecohydraulics Research  
Department of Civil Engineering  
University of Idaho  
322 E. Front Street, Suite 340  
Boise, ID 83702  
  
Telephone: 208-364-4935  
E-mail: [eyager@uidaho.edu](mailto:eyager@uidaho.edu)

If you have any questions, or require clarification from the reviewers, please contact me directly.

Regards,



Gerald W. Bowes, Ph.D.  
Manager, Cal/EPA Scientific Peer Review Program  
Office of Research, Planning and Performance  
State Water Resources Control Board  
1001 "I" Street, 16<sup>th</sup> Floor  
Sacramento, California 95814

Telephone: (916) 341-5567

FAX: (916) 341-5284

Email: [GBowes@waterboards.ca.gov](mailto:GBowes@waterboards.ca.gov)

Attachments:

- (1) January 26, 2017 Request by Les Grober for Scientific Peer Review, revised April 18, 2017
- (2) Letters to Reviewers Initiating the Review
  - (1) Murdoch McAllister, Ph.D.
  - (2) Thomas Meixner, Ph.D.
  - (3) Thomas Miller, Ph.D.
  - (4) N. LeRoy Poff, Ph.D.
  - (5) Elowyn Yager, Ph.D.
- (3) January 7, 2009 Supplement to Cal/EPA Peer Review Guidelines
- (4) Curriculum Vitae
  - (1) Murdoch McAllister, Ph.D.
  - (2) Thomas Meixner, Ph.D.
  - (3) Thomas Miller, Ph.D.
  - (4) N. LeRoy Poff, Ph.D.
  - (5) Elowyn Yager, Ph.D.
- (5) Reviews
  - (1) Murdoch McAllister, Ph.D.
  - (2) Thomas Meixner, Ph.D.
  - (3) Thomas Miller, Ph.D.
  - (4) N. LeRoy Poff, Ph.D.
  - (5) Elowyn Yager, Ph.D.

---

## State Water Resources Control Board

Revisions (dated April 18, 2017) have been made to the original Cover Memorandum and to Attachments 1, 2 and 3 (dated January 26, 2017) for clarity.

**TO:** Gerald Bowes, Ph.D.  
Manager, CAL/EPA Scientific Peer Review Program  
Office of Research, Planning and Performance  
State Water Resources Control Board

**FROM:** Leslie Grober  
Deputy Director  
**DIVISION OF WATER RIGHTS**

**DATE:** January 26, 2017 (as revised April 18, 2017)

**SUBJECT:** AMENDED REQUEST FOR EXTERNAL PEER REVIEW OF THE SCIENTIFIC BASIS FOR NEW AND REVISED WATER QUALITY OBJECTIVES FOR THE PHASE II UPDATE OF THE BAY-DELTA PLAN

In accordance with Health and Safety Code section 57004, the State Water Resources Control Board (State Water Board), Division of Water Rights (Division), submits this amended request for a peer review of the State Water Board's report titled *Scientific Basis Report in Support of New and Modified Requirements for Inflows from the Sacramento River and its Tributaries and Eastside Tributaries to the Delta, Delta Outflows, Cold Water Habitat, and Interior Delta Flows* dated April 2017 (Science Report or Report). The Report discusses the scientific basis for developing new and revised water quality objectives for the Phase II update of the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan).<sup>1</sup>

The proposed Phase II changes to the Bay-Delta Plan are focused on protecting native fish and wildlife beneficial uses and include: new inflow requirements for the Sacramento River, its tributaries, and eastside tributaries to the Delta; new and modified Delta outflow requirements; new requirements for cold water habitat; new and modified interior Delta flow requirements; recommendations for complementary ecosystem protection actions that others should take; and adaptive management, monitoring, evaluation, special study, and reporting provisions. The Report contains a description of the proposed changes to water quality objectives and the program of implementation. The exact regulatory language, however, is still under development

---

<sup>1</sup> The Phase I update of the Bay-Delta Plan is focused on San Joaquin River flows upstream of Vernalis on the San Joaquin River for the protection of fish and wildlife beneficial uses and southern Delta salinity for the protection of agricultural beneficial uses. Phase I is a separate process from Phase II and is not the subject of this request.

and will be informed by the Science Report, environmental and economic analyses, and public comment as the planning process moves forward. The policy discussion is provided for context.

The State Water Board is on an expedited schedule and plans to consider potential changes to the 2006 Bay-Delta Plan by December 2017. Given the importance of the Bay-Delta Plan amendments, the Division requests that peer reviewers provide comments within 30 days of receipt of the peer review package.

The proposed regulations are focused on establishing flow and water project operational requirements for the protection of native fish and aquatic species in the Bay-Delta watershed. Reviewers should have general expertise related to aquatic ecology and fisheries sciences, and specific expertise in sensitive native Bay-Delta fish and aquatic organisms including: anadromous fish species (Chinook salmon, Central Valley steelhead, green and white sturgeon) and other native Bay-Delta estuarine-dependent fish and invertebrate species (longfin smelt, Delta smelt, Sacramento splittail, and California Bay shrimp).

Additional background information for the Phase II Bay-Delta Update is provided in Attachment 1. Scientific issues to be addressed by peer reviewers are listed in Attachment 2. Individuals involved in development of the Scientific Report are identified in Attachment 3. Attachment 4 contains electronic reprints of documents cited in the Science Report. Attachment 5 is the Science Report dated April, 2017.

Other documents associated with the Phase II update are available on the State Water Board's website:

[http://www.waterboards.ca.gov/waterrights/water\\_issues/programs/bay\\_delta/comp\\_review.shtml](http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/comp_review.shtml), including the 2006 Bay-Delta Plan ([http://www.waterboards.ca.gov/waterrights/water\\_issues/programs/bay\\_delta/wq\\_control\\_plans/2006wqcp/docs/2006\\_plan\\_final.pdf](http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/docs/2006_plan_final.pdf)).

A working draft version of the Report was released on October 19, 2017, to receive early scientific and public input on the science related to Phase II prior to submittal of the Report for external peer review. In recognition of the vision for "one Delta, one science" articulated in the Delta Stewardship Council's Delta Plan, the State Water Board requested that the Delta Independent Science Board (Delta ISB) conduct a review of the working draft Report. The Delta ISB's written comments on the working draft Report are posted at:

([http://www.waterboards.ca.gov/waterrights/water\\_issues/programs/bay\\_delta/comp\\_review\\_cmmt\\_isb.shtml](http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/comp_review_cmmt_isb.shtml)).

If you have any questions regarding this request, please contact Chris Foe at (916) 341-5432 or [Chris.Foe@waterboards.ca.gov](mailto:Chris.Foe@waterboards.ca.gov).

Attachments

bcc: Chris Foe  
Environmental Program Manager  
Division of Water Rights

Diane Riddle  
Environmental Program Manager  
Division of Water Rights

Matthew Holland  
Senior Environmental Specialist  
Bay Delta: Sacramento Unit

Karen Niiya  
Senior WRC Engineer  
Bay-Delta Unit

Samantha Olson  
Senior Staff Counsel  
Office of Chief Counsel

**Attachment 1: Summary of the Phase II Update****Background**

The State Water Resources Control Board (State Water Board or Board) is considering amendments to the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan) that was developed and adopted pursuant to the provisions of the Porter-Cologne Water Quality Control Act (Porter-Cologne) and the federal Clean Water Act. A water quality control plan consists of three parts: 1) designation of the beneficial uses to be protected; 2) establishment of water quality objectives; and 3) a program of implementation needed for achieving the water quality objectives. (Wat.Code, § 13050(j).) Water quality objectives are the limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses. (Wat. Code, § 13050(h).) Components of the Bay-Delta Plan when implemented also: 1) carry out provisions of the reasonable use doctrine (Cal. Const. Art. X, § 2; Wat. Code, §§ 100, 275, and 1050); 2) protect public trust resources (see *National Audubon Society v. Superior Court* (1983) 33 Cal.3d 419, 189 Cal. Rptr. 346); and 3) carry out statutory principles pertaining to water rights (Wat. Code, §§ 183, 1243, 1243.5, 1251, 1253, and 1256-1258). As such, the Bay-Delta Plan addresses the interrelated fields of water quality and water supply and plans for their coordination.

The Bay-Delta Plan currently includes various water quality, flow and water project operational objectives to protect beneficial uses in the Bay-Delta, including municipal and industrial, agricultural and fish and wildlife uses. Objectives for the protection of fish and wildlife are included in Table 3 on pages 14 and 15 of the 2006 Bay-Delta Plan and its associated footnotes, figures and tables. Among other requirements, Table 3 includes objectives for Delta outflows throughout the year, minimal mainstem Sacramento River inflows from September to December and water project operational constraints in the interior Delta expressed as yearround export limitations and Delta Cross Channel (DCC) gate closure requirements that apply from November through June. Currently, the Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) have primary responsibility for meeting the Bay-Delta Plan objectives as required by the Board's revised water right Decision 1641 (D-1641). In D-1641, the State Water Board accepted various agreements between DWR and Reclamation and other water users to assume responsibility for meeting specified Bay-Delta Plan objectives. As a result, the Board conditioned DWR and Reclamation's water right permits for DWR's State Water Project (SWP) and Reclamation's Central Valley Project (CVP) (collectively Projects) to require water releases and water management actions to meet the flow and water quality objectives. The State Water Board determined in 2009 that the Bay-Delta flow and water quality objectives were out of date and needed revision.

The Scientific Basis Report (Science Report or Report) has been prepared to support the Phase II update of the Bay-Delta Plan. The scientific evidence indicates that current Bay-Delta Plan flow and operational requirements are inadequate to protect fish and wildlife beneficial uses because requirements are nonexistent or not stringent enough. Higher and more comprehensive Delta outflow requirements and tributary inflow requirements from the Sacramento River basin and eastside tributaries to the Delta are needed. New cold water habitat requirements are also needed to ensure that necessary cold water supplies or other measures are taken to address existing cold water needs on tributaries primarily for the protection of salmonids that no longer have access to upstream cold water habitat due to reservoirs. In addition, new or revised interior Delta flow requirements are necessary to address elevated mortality and straying of fish caused by water diversions in the southern Delta to

complete the protections of fish through their migratory range from the tributaries out to the ocean.

The Science Report includes a determination that while there are other factors that contribute to impairments to fish and wildlife beneficial uses in the Sacramento River and Delta, flows remain a critical component for the protection of these beneficial uses. The Report further acknowledges that estimates of flow needed to protect fish and wildlife beneficial uses are imprecise. This is primarily due to the various complicating factors affecting the survival and abundance of native fish and invertebrate species. Nonetheless, the weight of the scientific evidence indicates that increased flow requirements are needed to protect fish and wildlife beneficial uses. Given the dynamic and variable environment that native fish are adapted to and the imperfect human understanding of these factors, precise flow objectives that will provide absolute certainty with regard to protection of fish and wildlife beneficial uses is likely not possible. The proposed changes to the Bay-Delta Plan are structured to address the complexities of the watershed while responding to new information and changing conditions and providing for meaningful action in the near term to protect the Bay-Delta ecosystem. The proposed changes are structured to work together and with other planning, science, restoration, and regulatory efforts in a timely, adaptive, flexible, and comprehensive manner so that meaningful action can be taken to ensure the protection of fish and wildlife before imperiled species in the watershed are no longer able to be restored.

### **Draft Phase II Changes to the 2006 Bay-Delta Plan**

The proposed Phase II changes to the Bay-Delta Plan include: new inflow requirements for the Sacramento River, its tributaries, and eastside tributaries to the Delta; new and modified Delta outflow requirements; new requirements for cold water habitat; new and modified interior Delta flow requirements (Old and Middle River (OMR) flows, Project export constraints, and DCC gate closure requirements); recommendations for complementary ecosystem protection actions that others should take; and adaptive management, monitoring, evaluation, special study, and reporting provisions. Together the proposed changes to the inflow, outflow, cold water habitat and interior Delta flow provisions of the Bay-Delta Plan, along with other habitat restoration actions are proposed to work together to provide comprehensive protection to native aquatic species from natal streams through the Delta and Bay. The Report contains a description of the proposed changes to water quality objectives and the program of implementation (together referred to as requirements). The exact regulatory language, however, is still under development and will be informed by the Science Report, environmental and economic analyses, and public comment as the planning process moves forward. The policy discussion is provided for context.

#### Tributary Inflows

New year round narrative and numeric inflow objectives are proposed for anadromous fish-bearing tributaries in the Sacramento River basin, and Delta eastside tributaries (Mokelumne, Calaveras and Cosumnes rivers). Year-round inflows are needed to protect anadromous and other native fish and wildlife species that inhabit the Bay-Delta and its tributaries throughout the year as juveniles or adults. Specifically, inflows are needed to provide appropriate habitat conditions for migration, spawning and rearing of anadromous fish species (primarily Chinook salmon and steelhead) that inhabit the Delta and its tributaries, and to contribute to Delta outflows needed to support migrating, spawning, and rearing of estuarine species. Preservation of high flow levels that are already being provided in some less impaired tributaries is also proposed where existing flows are providing important functions to ensure that those flows are not reduced (e.g., maintain existing protective conditions). The proposed changes to inflow

requirements are structured to provide necessary flexibility and adaptive management provisions (for specific functional flows, scientifically based experiments, and coordination with other complementary restoration efforts) to address the complexities of inflow needs and constraints in the watershed in a reasonable and protective manner. In recognition of the local expertise within tributaries and the potential benefit of collaborative solutions, the program of implementation would provide a period of time for regional and/or tributary based flow and other measures to be developed by stakeholders, approved, and implemented that achieve the inflow and cold water habitat requirements while also contributing to Delta outflows.

#### Delta Outflows

New and modified narrative and numeric Delta outflow objectives are proposed throughout the year to support and maintain the natural production of viable native fish populations residing in, rearing in, or migrating through the estuary. Delta outflows have been reduced over time as a result of water withdrawals, resulting in reduced suitable habitat for estuarine species. Existing Delta outflow requirements are far below existing Delta outflows and are likely to be reduced over time without additional requirements as water use intensifies. To ensure that minimum quantities of Delta outflow are provided to the estuary, base Delta outflows that range from 3,000 cubic-feet per second (cfs) to 8,000 cfs based on water year type from July through January and February through June flows of 7,100 cfs from the current Bay-Delta Plan would be maintained. In addition, a new inflow-based Delta outflow objective is proposed that would be consistent with the range for inflows discussed above. The objective specifies that the required inflows from the Sacramento and San Joaquin Rivers and their tributaries and the three Delta eastside tributaries are provided as outflows with appropriate adjustments for depletions and accretions, including adjustments for floodplain inundation flows and other side flows. Fall Delta outflow requirements consistent with the U.S. Fish and Wildlife Service (USFWS) Biological Opinion (BiOp) is also proposed. Like the inflow requirements, the outflow requirements would allow for adaptive management and shifting and sculpting of flows.

#### Cold Water Habitat

A new narrative cold water habitat objective is proposed to ensure that salmonids have access to cold water habitat at critical times and to ensure that adequate water is available for minimum instream flow purposes downstream of reservoirs. Salmonids require adequate cold water and flow conditions for spawning and rearing. Since construction of dams and other habitat alterations, access to cold water habitat has been eliminated or substantially reduced to the detriment of salmonid populations. Remaining populations are now dependent on maintenance of suitable conditions in the downstream reaches below dams. Effective management of cold water is a critical component of the conservation and recovery strategies for native salmonids, especially with the challenges posed by increasing water demands and climate change. Cold water habitat conditions in the tributaries will differ and the mechanisms for best implementing the narrative objective will vary among the tributaries; thus flexibility is needed to best achieve the objective. Depending on the specific conditions of a tributary, the narrative may be implemented through cold water storage requirements, temperature control devices, flow provisions, passage to cold water habitat, or other measures.

#### Interior Delta Flows

New and modified interior Delta flow objectives are proposed to protect native migratory and estuarine species from elevated mortality and straying of fish caused by water diversions in the southern Delta, including a new narrative objective and numeric objectives for DCC gate closures, OMR reserves flow limits and export constraints as a function of San Joaquin River flows consistent with existing regulatory requirements (included in the USFWS BiOp and

National Marine Fisheries Service BiOp) in an adaptive management framework informed by monitoring and evaluation efforts.

#### Program of Implementation, Monitoring, and Evaluation

There are a variety of water right and water quality authorities that the State Water Board may utilize to implement new or changed water quality objectives and the State Water Board has discretion in how it chooses to implement flow-dependent objectives in accordance with state law. (See, Wat. Code, § 13242 [program to achieve objectives shall include a description of the nature of the actions necessary to achieve objectives, including recommendations for appropriate action by any entity, public or private, a time schedule for actions to be taken, and monitoring to determine compliance].)

The proposed program of implementation would include early implementation measures, including the submittal of tributary plans by potentially responsible parties. The tributary plans would include a flow element and cold water management and drought planning and response elements, monitoring, evaluation and reporting elements, as well as other provisions. In each tributary, adaptive management of inflow requirements would allow flows to be sculpted in order to improve their functionality and provide the greatest benefits to fish and wildlife, as well as allow flows to move within a range in response to changed information or conditions. The proposed program of implementation provides a framework for accepting local agreements with alternative methods for enhancing protection of fish and wildlife in the tributaries, and for meeting the tributary inflow and cold water habitat narrative objectives. The program of implementation would direct the State Water Board to initiate a rulemaking or adjudicatory proceeding under its own authorities if a particular tributary plan is not developed or is found to be unsatisfactory.

Implementation of the inflow-based Delta outflow objective would correlate to the development, approval, and implementation of tributary plans. Like the inflow requirements, the inflow-based Delta outflow requirements would allow sculpting of flows and would require the development of implementation measures for adaptive management, in coordination with the Projects and other in-Delta users. Delta outflow implementation measures would include monitoring, evaluation and reporting provisions, development of biological goals, and provisions for coordination with inflows. The implementation measures would address accounting methods for the existing and new requirements, including integration with tributary plans, calculation of accretions and depletions, and evaluation of the existing and new methods of compliance with Delta outflows to ensure they are protective.

The proposed program of implementation would also include measures to ensure that water bypassed or released to meet water quality objectives is protected and actions to ensure that tributaries with flow levels that are already protective are not degraded, including updating the Fully Appropriated Streams list as appropriate and other actions.

The proposed program of implementation would also include monitoring and special studies necessary to fill information needs and determine the effectiveness of, and compliance with, the new and revised water quality objectives. The State Water Board has identified four primary goals for near and long-term monitoring in the Delta in order to: (1) evaluate compliance with specific implementation provisions by responsible parties, including the Projects, pursuant to water right conditions, other orders and/or regulations; (2) evaluate the effectiveness of management measures, management modifications, and remediation efforts aimed at meeting water quality objectives and improving conditions for beneficial uses; (3) track whether conditions are trending toward numeric targets, water quality objectives, and beneficial use

support; and (4) inform when and how to reevaluate the objectives and program of implementation. Approximately five years after adoption, State Water Board staff will conduct a formal assessment of the effectiveness of the implementation plan and make any necessary revisions using monitoring and reporting data, other studies and any other available data, as appropriate.

Finally, the program of implementation would provide recommendations of actions other entities could take that would contribute to achieving the overall goal of improving conditions for fish and wildlife. The program of implementation will include recommendations for non-flow measures that are complementary to the revised objectives and that are expected to improve habitat conditions or improve related science and management within the Bay-Delta watershed.

**Attachment 2: Scientific Conclusions to be addressed by Peer Reviewers**

The *Scientific Basis Report in Support of New and Modified Requirements for Inflows from the Sacramento River and its Tributaries and Eastside Tributaries to the Delta, Delta Outflow, Cold Water Habitat, and Interior Delta Flows* (Science Report or Report) dated April 2017 includes the draft regulations and scientific information on which the regulations are based. The statutory mandate for external scientific peer review (Health and Safety Code, § 57004) states that the reviewer's responsibility is to determine whether the scientific portion of any proposed rule is based on sound scientific knowledge, methods, and practices. We request that you make this determination for each of the following conclusions that constitute the scientific portion of any proposed regulatory action. An explanatory statement is provided for each issue to focus the review.

**1. Significant changes have occurred to the hydrology and hydrodynamics of the Sacramento River and its tributaries, Delta eastside tributaries, and the Delta.**

The Science Report focuses on the flow characteristics of the main stem Sacramento River, its tributaries, the three eastside tributaries to the Delta and the interior Delta. These flows are critical to supporting ecological processes and the species that depend on those processes, including native anadromous and estuarine species. The magnitude, duration, timing and frequency of flow in all these waterbodies were evaluated to assess the types of change in the flow regime that have occurred over time. This information is provided as background and supporting information for subsequent chapters. Diversions and exports have reduced average annual outflow, reduced winter and spring outflow and reduced seasonal variability (Figures 2.4-7 and 8 and Table 2.4-3) over time. Water development in regulated tributaries, such as the Sacramento River at Freeport, has resulted in reduced annual flows, a reduction and shift in spring inflow, an increase in summer inflow, and a decrease in hydraulic variability (Figure 2.2-5 and Table 2.2-2). Tributaries without large reservoirs generally have lower flows in summer and part or all of the fall. Project pumping in the south Delta has increased (Figures 2.4-4 and -5) and this has resulted in an increase in the magnitude and frequency of reverse (upstream) flows on Old and Middle rivers (Figure 2.4-5). This information is included in Chapter 2 of the Science Report.

**2. Changes to the flow regime of the Sacramento River and its tributaries and the eastside tributaries to the Delta, Delta outflows, cold water habitat, and interior Delta flow conditions have contributed to the impairment of the ecosystem and native fish and wildlife beneficial uses and could contribute to future impairments without additional regulations.**

Healthy aquatic ecosystems are dependent of stream flows of sufficient magnitude, duration, timing, spatial extent and quality to provide for biotic and abiotic processes critical to supporting native species, including sufficient inflows, cold water flows, Delta outflows and interior Delta flows. Water development in the Sacramento River basin, Delta eastside tributaries, and in the Bay-Delta estuary has resulted in reductions in flow and other changes to the flow regime that adversely affect fish and wildlife beneficial uses and current regulations are inadequate to

prevent further reductions and other changes in the flow regime. Population abundance of multiple native estuarine and anadromous fish species in the Bay-Delta watershed are in decline and several species are listed as threatened or endangered under the state and federal Endangered Species Acts. This includes Delta smelt, longfin smelt, Sacramento splittail, all four runs of Chinook salmon, and Central Valley steelhead.

Inflows to the Bay-Delta are highly modified by upstream water withdrawals and releases for water supply, power production, and flood control, as well as by channel modifications and obstructions, in ways that adversely affect native fish and wildlife. Currently, there are no inflow requirements included in the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan) Bay-Delta Plan for the area with the exception of minimal fall Sacramento River inflow requirements at Rio Vista. There are some flow requirements for other tributaries, but those requirements are not consistent between tributaries or coordinated with Bay-Delta Plan Delta outflow requirements. Some tributaries also have no environmental flow requirements at all. While conditions may currently be protective of fish and wildlife in some of these tributaries, future impairments to fish and wildlife could occur with increased water development. In addition, some of these tributaries may dry up at times of year impacting fish and wildlife due to the lack of flow requirements and others may have inadequate flow and water quality conditions to protect aquatic resources.

Adult salmonids require flows to support immigration, including homing fidelity, connectivity, egg viability during migration and other needs. Flows are needed to support spawning, including providing appropriate spawning gravel conditions (including appropriate substrates), temperatures, depths, velocities, dissolved oxygen conditions and other needs to support successful spawning and redd development. Inadequate inflows delay and reduce successful adult salmonid attraction, immigration and spawning. Juvenile salmonids also require flows of sufficient magnitude, duration, timing, spatial extent and quality to support successful rearing and emigration and to provide for healthy (larger more robust fish) fish entering the ocean. These flows are needed to support growth and development including flows that provide appropriate depths, velocities, temperature, dissolved oxygen and other water quality conditions, riparian and floodplain habitat and food resources. These flows are also needed to trigger and facilitate successful smoltification and downstream migration and survival through the estuary including providing connectivity, salinity gradients, turbidity and habitat conditions to support downstream migration. Inadequate inflows result in lower survival out of the Delta and in the ocean. Sacramento splittail, sturgeon and other species also require flows of sufficient magnitude duration, timing, spatial extent and quality to support migration, spawning and rearing.

In addition to modification to inflows, annual average Delta outflow has been reduced, with the January to June time period being the most hydrologically impaired. Median Delta outflow between January and June has declined and is now less than fifty percent of unimpaired flow. Monitoring of fish and invertebrate abundance in the Bay-Delta estuary shows the importance of Delta outflows for the protection of various species and the ecosystem. The location where lighter freshwater from the rivers mixes with heavy seawater from the ocean in the estuary (referred to as the low salinity zone or "LSZ") is correlated with the survival and abundance of

many species. This mixing concentrates suspended solids and aquatic organisms to compose the estuarine habitat that supports multiple life stages for a diversity of fishes and other species. The location of the LSZ is measured by the location of the two parts per thousand salinity isohaline (or X2) (as measured in kilometers (km) from the Golden Gate). Generally, the further X2 is located downstream of the confluence of the confined deep channels of the Sacramento and San Joaquin Rivers and the effects of the Project export facilities and downstream into the broad, shallow, cool channels of Suisun Marsh and Suisun Bay, the better fish and other species respond. These more westerly X2 positions generally provide significantly improved habitat conditions for native species. Fish species that respond positively to increased outflow include longfin smelt, Sacramento splittail, white sturgeon, and starry flounder. Invertebrate species that respond positively to increased outflow include California bay shrimp, *Eurytemora affinis* and *Neomysis mercedis*.

Dam construction has blocked salmonid access to up to 80 percent of cold water habitat above dams. Salmonids are now required to complete their life cycle below the rim reservoirs on the valley floor in river reaches that previously were predominately only used as migration corridors. Adult and juvenile salmonids require adequate cold water and flow conditions throughout the freshwater portion of their life cycle. Lack of flow and elevated water temperatures from reservoir operations and other diversions affects adult immigration, holding, and spawning and juvenile rearing and outmigration.

In the interior Delta, Old and Middle river (OMR) reverse flows are caused by large diversions in the Delta, including export pumping at the State Water Project (SWP) and Central Valley Project (CVP) pumping facilities. Historically, OMR reverse flows naturally occurred about 15 percent of the time and were seldom more negative than a few thousand cubic feet per second (cfs). Now, OMR reverse flows happen more than 90 percent of the time and may be as large as negative 12,000 cfs. Multiple native fish species including longfin smelt, Delta smelt, sturgeon and salmonids are present in the Delta in winter and spring. Entrainment and loss of individuals from these species decrease when export pumping at the SWP and CVP pumping facilities decline and OMR reverse flows become less negative. This information is included in Chapter 2 and 3 of the Science Report.

**3. To expeditiously address the impairments to native fish and wildlife beneficial uses in a very large, highly complex, and heavily-modified system such as the Bay-Delta, an approach based on the holistic method to the development of environmental flows that provides for flows of a more natural pattern that can then be further managed to maximize flow-related functions for the benefit of fish and wildlife beneficial uses is feasible and scientifically justified.**

Available scientific information indicates that while estimates of the flow needed to protect fish and wildlife are imprecise, more natural flows that more closely mimic the shape of the unimpaired hydrograph including the general seasonality, magnitude, and duration of flows generally provide flow-related functions that benefit fish and wildlife beneficial uses. Due to the altered nature of the watershed, it is also necessary to further manage such flows to maximize flow-related functions. Further management includes flow sculpting and cold water habitat

preservation requirements that may not exactly mimic the natural hydrograph, but nonetheless produce more natural temperature, salinity, or other water quality conditions for fish. This is the case to some extent in the summer and fall when it may be necessary to provide additional colder reservoir release flows for salmonids due to lack of access to historic upstream cooler spawning and rearing habitat after construction of dams. It may also be the case for pelagic species in the summer and fall that require more Delta outflow to position X2 in a hospitable habitat location where temperatures, food resources and other conditions are appropriate, since these conditions are no longer appropriate much of the time within the Delta.

There are significant challenges to establishing flow requirements for a modified watershed of this size and complexity that is critical to the State's water supply needs. There are also challenges to doing so in an expeditious manner considering the urgency of the problem in the Bay-Delta. A holistic instream flow approach applied at the programmatic and regional level is proposed to address these issues. In particular, the approach recognizes that (1) the flow regime is the primary determinant of structure and function in riverine ecosystems, (2) environmental flows should be based generally on the natural flow regime, (3) all features of the ecosystem should be considered and (4) that the reality of multiple needs for water must play a significant role. The use of unimpaired flows is proposed to create a water supply budget for the protection of the ecosystem and native fish and wildlife in the Sacramento River, its tributaries and eastside tributaries to the Delta. While unimpaired flow is not the same as natural flow, it is generally reflective of the frequency, timing, magnitude, and duration of the natural flows to which fish and wildlife have adapted, particularly in tributaries. Adaptive management provisions, including any necessary sculpting of that flow, would provide specific functional flows to improve fish and wildlife protection. Biological goals would be used to help inform adaptive management decisions. Information on the approach to environmental flow requirements is described in chapter 3 and in section 5.1.1 and the remainder of chapter 5 of the Science Report.

#### **4. Inflows that more closely mimic the natural flow and water quality conditions to which native migratory fish are adapted are needed in the Sacramento River basin and Delta eastside tributaries to provide spawning and rearing habitat and connectivity with the Delta.**

Available scientific information supports the proposed year round inflow requirements for the Sacramento River, its tributaries and the Delta eastside tributaries to promote the natural production of viable native fish populations rearing in and migrating to and from tributaries and the Delta. The purpose of the proposed changes to inflow requirements is to improve ecosystem functions by providing appropriate habitat conditions for adult salmonid immigration and holding and juvenile rearing and outmigration, and contributing to Delta outflow to support native anadromous and estuarine species. The proposed inflow requirements are also specifically intended to provide for increasing the frequency and duration of floodplain inundation for the benefit of native species, including for Sacramento splittail spawning and Sacramento splittail and salmonid rearing, as well as the production of estuarine food supplies for other species. Preservation of high flow levels that are already being provided in some less impaired tributaries is also proposed where existing flows they are providing important functions to ensure that

those flows are not reduced (e.g., maintain existing protective conditions). Salmonids use the seasonal timing, magnitude, duration and rate of change of flows to cue adult upstream migration, holding, and spawning and juvenile rearing and outmigration. Green and white sturgeon, American shad and striped bass also use increased Sacramento River inflow in spring to cue upstream spawning migrations and downstream transport of their young. Changes in the magnitude and timing of these natural flows have reduced the abundance of these species. Information on tributary hydrology is discussed in section 2.2 of the Science Report. The effect of changes in tributary inflows for salmonids, sturgeon, American shad and Striped bass are covered in sections 3.4, 3.6 and 3.12 of the Science Report.

**5. Delta outflows that more closely mimic the natural flow and water quality conditions to which native migratory fish are adapted are needed year round to support the migration, spawning and rearing of native estuarine and anadromous species.**

Available scientific information supports the proposed modifications to the existing Delta outflow requirements to promote the natural production of viable native estuarine species populations rearing in and migrating through the Delta, and to better integrate inflow and outflow requirements in a comprehensive framework for environmental flows. Populations of several estuarine dependent species of fish and shrimp vary positively with flow as do other measures of the health of the estuarine ecosystem. In addition, there is evidence that native species benefit from flows that place the low salinity zone downstream of the confluence of the Sacramento and San Joaquin Rivers during summer and fall.

Under pre-development conditions, Delta outflow in winter and spring increased in response to snow-melt and precipitation in the Central Valley. These higher flows supported a variety of important ecological functions including, but not limited to, creation of (1) brackish rearing habitat in Suisun Bay for longfin smelt and Delta smelt, (2) freshwater floodplain habitat for Sacramento splittail and juvenile salmonids, (3) upstream attraction flows for reproducing adult longfin smelt, Delta smelt, and sturgeon, (4) downstream transport for larval longfin smelt, Delta smelt, and salmonids and (5) upstream gravitational circulation to transport starry flounder and Bay shrimp into the Delta. Scientific information indicates that higher Delta outflow between January and June increases indices of population abundance of native estuarine species and the successful outmigration and survival of salmonid smolts. Scientific information also indicates that higher fall flows, and possibly summer flows, lead to higher abundance of Delta smelt in the following year. Information on Delta outflow hydrology is in section 2.4 of the Science Report. Biological effects of the changes in outflow for salmonids and estuarine species in section 3.4 through Section 3.12 of the Science Report.

**6. Cold water habitat is needed below reservoirs to compensate for natural cold water salmonid habitat lost by reservoir construction above dams.**

Scientific information supports the proposed narrative objective for the protection of cold water habitat below reservoirs. Effective management of cold water supplies will continue to be a critical component of the conservation and recovery strategies for native salmonids in the Bay-Delta watershed. With the demands of new inflow and outflow requirements and ongoing concerns about protection of cold water for salmonids, it is important that requirements

protecting cold water habitat and storage be developed to assure protection of fisheries resources in the tributaries of the Delta. Dam construction now blocks salmonids from their historic cold water habitat above reservoirs and has reduced population abundance and genetic resiliency. Creation of cold water habitat below reservoirs with the release of stored cold water can, at least in part, compensate for the loss of natural cold water habitat above dams. The release of stored reservoir cold water helps provide downstream conditions to mitigate for the loss of upstream habitat. An alternate, more natural long-term solution may be creation of passage around or through reservoirs to upstream salmonid cold water habitat. Tributary and reservoir specific cold water management requirements will be needed that take into consideration the unique design of each reservoir, the requirements of the native fish present, and the hydrological characteristics of the different tributaries. Information on the location of tributary rim reservoirs is in section 2.2 and the biological effects of loss of cold water habitat are in section 3.4 of the Science Report.

**7. Interior Delta flow requirements (Delta Cross Channel (DCC) gate closures, OMR reserves flow limits and export constraints) help protect resident and migratory species from entrainment and related effects in the southern Delta associated with CVP and SWP diversion activities.**

Historically, more than 85 percent of the time the natural flow pattern in the interior Delta was from the Central Valley to the ocean or downhill from east to west. Now, reverse upstream flows occur in the interior Delta, principally on Old and Middle rivers, more than 90 percent of time because of export pumping at the CVP and SWP facilities in the south Delta. OMR reverse flows have negative ecological consequences, particularly between December and June when native species use the Delta to spawn and rear. Negative effects include drawing large number of fish, including larval and juvenile longfin smelt, Delta smelt and salmonids, toward the export facilities where they experience high mortality from predation and salvage. Survival of tagged juvenile salmonids emigrating from both the Sacramento and San Joaquin River basins is greater when fish stay in the main river channels than when they are entrained into the interior Delta.

The probability of entrainment of juvenile Sacramento River salmonids into the interior Delta increases when the DCC gates are held open to decrease salinity in the south Delta near the SWP and CVP. Additional protection would occur if the DCC gates were closed in October when monitoring detects salmonids migrating down the Sacramento River.

Salvage data and particle tracking model results demonstrate that salvage increases exponentially with increasingly negative OMR reverse flows. An inflection point in the salvage data occurs for all species at about negative-5,000 cfs with much higher salvage rates at more negative reverse flows. Low salvage occurs at OMR reverse flows more positive than negative 1,250 cfs. New OMR reverse flow requirements from December through June between negative 1,250 and negative 5,000 cfs would help to reduce entrainment and salvage of Delta smelt, longfins smelt, and juvenile salmonids when monitoring indicates that individuals from these species are within the zone of influence of the SWP and CVP pumping facilities.

Existing export constraints are intended to reduce entrainment and provide general protection of the Delta ecosystem and a variety of fish and wildlife beneficial uses by limiting the portion of freshwater that may be diverted by the export facilities. Additional ecosystem benefits beyond reduced entrainment include reduction in losses of nutrients and other materials important for the base of the food web, food organisms, habitat suitability, and more natural flow and salinity patterns. Current export constraints are in place for April and May based on water year type. However, juvenile salmonids migrate out of the San Joaquin River basin from February through June. Additional protection from export-related mortality would occur if export restrictions were allowed to extend between the February through June time period when salmonids were emigrating down the San Joaquin River channel. Information about interior Delta hydrodynamics is in section 2.4 of the Science Report. The biological effects on salmonids and estuarine species in the interior Delta is described in sections 3.4, 3.5, and 3.8 of the Science Report.

### **8. Other aquatic ecosystem stressors have negative effects on fish and wildlife beneficial uses, and non-flow actions are also needed for ecosystem recovery.**

The Science Report focuses on flows because flows have been found to be a major factor in the decline of native species and because the State Water Board has primary authority over flow-related issues and the development of appropriate flow and associated water quality objectives. However, ecosystem recovery in the Central Valley and Delta depends on more than just adequate flows. The State Water Board's planning and implementation efforts are part of a multi-faceted approach needed to address the systemic ecological and water supply concerns in the Bay-Delta and reconcile an altered ecosystem. Scientific studies have identified the involvement of other aquatic ecosystem stressors including habitat loss, degraded water quality, introduction of nonnative species, fisheries management, and climate change as contributing factors in species declines. Other actions are important to protect the Bay-Delta ecosystem, such as habitat restoration, control of waste discharges, control of invasive species, and fisheries management. Some non-flow stressor actions may be enhanced by integrating them with a more natural pattern of tributary and Delta outflow. Information on biological effects of non-flow stressors and changes in hydrology for native species are in chapter 4 of the Science Report.

### **Other Conclusions**

Additionally, reviewers are not limited to addressing only the specific conclusions presented above, and are asked to contemplate the following "Big Picture" questions:

- In reading the Science Report, are there any additional scientific conclusions that should be a part of the scientific portion of the proposed rule that are not described above?
- Taken as a whole, is the scientific portion of the draft water quality requirements based upon sound scientific knowledge, methods, and practices?

Reviewers should note that some proposed actions may rely significantly on professional judgement in instances where scientific data and our understanding of the underlying processes are not as extensive as may be ideal. Nonetheless, the evaluation of the scientific data and use of professional judgement are appropriate in the context of current scientific knowledge

regarding such actions. In these situations, the proposed course of action is favored over no action.

The preceding guidance will ensure that reviewers have an opportunity to comment on all aspects of the scientific basis of the proposed State Water Board action. At the same time, reviewers also should recognize that the State Water Board has a legal obligation to consider and respond to all feedback on the scientific portions of the proposed rules. Because of this obligation, reviewers are encouraged to focus feedback on the scientific conclusions that are relevant to the central regulatory elements being proposed.

**Attachment 3: Individuals involved in development of the Science Report and Proposed Requirements**

**State Water Board Division of Water Rights staff:**

Diane Riddle	Dr. Chris Kwan
Karen Niiya	Ryan Babb
Dr. Brittany Kammerer	Scott Ligare
Dr. Chris Foe	Vadim Demchuk
Michael Meza	Dr. Matthew Holland

**State Water Board Office of Chief Council staff:**

Samantha Olson	Yuri Won
Tina Leahy	Erin Mahaney

**ICF and subcontractors, Sacramento CA**

Anne Huber	Andrew Draper
Dr. Lenny Grinaldo	Thomas Fitzhugh
Dr. Bruce Herbold	Charles Young
Nichole Williams	Brian Joyce
Rick Wilder	Jack Sieber
Tami Roberts	Pat Crain
Dr. Russ Brown	Bill Mitchell

**Attachment 4**  
**Electronic Reprints of all**  
**Citations**

**(On CD Only)**

**Attachment 5**  
**Science Report dated**  
**April 2017**

**Title page and Table of  
Contents Included Herein**

**(Full Report Only on CD)**

**Scientific Basis Report in Support of  
New and Modified Requirements for Inflows from the  
Sacramento River and its Tributaries and Eastside  
Tributaries to the Delta, Delta Outflows,  
Cold Water Habitat, and Interior Delta Flows**

Prepared By:

State Water Resources Control Board  
California Environmental Protection Agency  
P.O. Box 100  
Sacramento, CA 95812-0100

With Assistance From:

ICF  
630 K Street, Suite 400  
Sacramento, CA 95814



**April 2017**

# Contents

List of Tables and Figures .....	vi
List of Acronyms and Abbreviations.....	xviii

	<b>Page</b>
<b>Chapter 1 Overview.....</b>	<b>1-1</b>
1.1 Introduction .....	1-1
1.2 Final Draft Scientific Basis Report .....	1-3
1.2.1 The Bay-Delta Watershed .....	1-3
1.2.2 Purpose and Need for Bay-Delta Update .....	1-4
1.2.3 Bay-Delta Water Quality Control Planning Background.....	1-6
1.2.4 The Delta Reform Act and Delta Flow Criteria Report .....	1-7
1.2.5 Science and Technical Workshops to Inform Phase II.....	1-8
1.3 Response to Comments on Working Draft Report .....	1-9
1.3.1 Flow Requirements .....	1-9
1.3.2 Adaptive Management.....	1-11
1.3.3 Climate Change .....	1-11
1.3.4 Water Temperature .....	1-12
1.3.5 Non-Flow Stressors.....	1-13
1.3.6 New Science and Uncertainty .....	1-13
1.4 Potential Modifications to the Bay-Delta Plan .....	1-14
1.4.1 Coordination with other Science, Planning, and Regulatory Efforts.....	1-14
1.4.2 Environmental Flows, Adaptive Management and Biological Goals.....	1-15
1.4.3 Tributary Inflows .....	1-16
1.4.4 Delta Outflows.....	1-20
1.4.5 Cold Water Management.....	1-22
1.4.6 Interior Delta Flows .....	1-22
1.5 Next Steps .....	1-24
<b>Chapter 2 Hydrology.....</b>	<b>2-1</b>
2.1 Introduction .....	2-1
2.1.1 Natural and Unimpaired Flow .....	2-1
2.1.2 Watershed Overview.....	2-4
2.2 Hydrology of the Sacramento River and Major Tributaries.....	2-17
2.2.1 Sacramento River .....	2-17
2.2.2 Tributaries of Mount Lassen and Volcanic Buttes Region.....	2-23
2.2.3 Tributaries of the Chico Monocline .....	2-26

2.2.4	Tributaries of the Klamath Mountains .....	2-31
2.2.5	Tributaries of the Paleochannels and Tuscan Formation.....	2-32
2.2.6	Tributaries of the Northern Sierra Nevada .....	2-35
2.2.7	Tributaries of Eastside of the Delta .....	2-44
2.2.8	Tributaries of the Northern Coast Range, Northern .....	2-49
2.2.9	Tributaries of the Northern Coast Range, Southern .....	2-54
2.3	Flood Basins .....	2-58
2.3.1	Butte Flood Basin .....	2-58
2.3.2	Colusa Flood Basin.....	2-59
2.3.3	Sutter Flood Basin .....	2-60
2.3.4	American Flood Basin .....	2-62
2.3.5	Yolo Flood Basin .....	2-62
2.3.6	Sacramento Flood Basin .....	2-64
2.4	Sacramento–San Joaquin Delta .....	2-64
2.4.1	Delta Inflows.....	2-66
2.4.2	Delta Hydrodynamics .....	2-68
2.4.3	Delta Barriers.....	2-70
2.4.4	Delta Cross Channel Gate Operations .....	2-71
2.4.5	South Delta Exports and Old and Middle River Reverse Flows .....	2-72
2.4.6	Delta Outflow and X2 .....	2-74
2.5	Suisun Region.....	2-83
2.6	Drought .....	2-84
2.7	Climate Change .....	2-84
2.8	Conclusions .....	2-84
<b>Chapter 3</b>	<b>Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations .....</b>	<b>3-1</b>
3.1	Introduction .....	3-1
3.2	Flow and the Ecosystem .....	3-2
3.2.1	Riverine Flows .....	3-2
3.2.2	Freshwater Flow and Estuarine Resources .....	3-6
3.2.3	San Francisco Bay and Nearshore Coastal Ocean .....	3-10
3.2.4	Interior Delta Flows and Entrainment.....	3-10
3.3	Species-Specific Analyses.....	3-12
3.3.1	Updated Quantitative Analysis.....	3-12
3.4	Chinook Salmon ( <i>Oncorhynchus tshawytscha</i> ) and Central Valley Steelhead ( <i>Oncorhynchus mykiss</i> ) .....	3-14
3.4.1	Overview .....	3-14
3.4.2	Life History.....	3-14
3.4.3	Life History, Distribution, and Abundance Trends Over-Time .....	3-21

3.4.4	Dam and Reservoir Effects on Salmonids.....	3-34
3.4.5	Flow Effects on Salmonids.....	3-36
3.5	Longfin Smelt ( <i>Spirinchus thaleichthys</i> ).....	3-53
3.5.1	Overview .....	3-53
3.5.2	Life History.....	3-53
3.5.3	Population Abundance Trends Over Time .....	3-53
3.5.4	Flow Effects on Longfin Smelt .....	3-55
3.6	Green Sturgeon ( <i>Acipenser medirostris</i> ) and White Sturgeon ( <i>Acipenser transmontanus</i> ).....	3-60
3.6.1	Overview .....	3-60
3.6.2	Life History.....	3-60
3.6.3	Population Abundance Trends Over-Time .....	3-62
3.6.4	Flow Effects on Green and White Sturgeon .....	3-63
3.7	Sacramento Splittail ( <i>Pogonichthys macrolepidotus</i> ).....	3-66
3.7.1	Overview .....	3-66
3.7.2	Life History.....	3-66
3.7.3	Population Abundance Trends Over Time .....	3-67
3.7.4	Flow Effects on Sacramento Splittail.....	3-67
3.8	Delta Smelt ( <i>Hypomesus transpacificus</i> ) .....	3-70
3.8.1	Overview .....	3-70
3.8.2	Life History.....	3-70
3.8.3	Population Abundance Trends Over-Time .....	3-72
3.8.4	Flow Effects on Delta Smelt.....	3-73
3.9	Starry Flounder ( <i>Platichthys stellatus</i> ).....	3-80
3.9.1	Overview .....	3-80
3.9.2	Life History.....	3-81
3.9.3	Population Abundance and Trends Over Time .....	3-81
3.9.4	Flow Effects on Starry Flounder .....	3-82
3.10	California Bay Shrimp ( <i>Crangon franciscorum</i> ).....	3-85
3.10.1	Overview .....	3-85
3.10.2	Life History.....	3-85
3.10.3	Population Abundance Trends Over-Time .....	3-86
3.10.4	Flow Effects on Bay Shrimp .....	3-87
3.11	Zooplankton ( <i>Neomysis mercedis</i> and <i>Eurytemora affinis</i> ).....	3-89
3.11.1	Overview .....	3-89
3.11.2	Life History.....	3-90
3.11.3	Population Abundance and Trends Over Time .....	3-90
3.11.4	Flow Effects on Zooplankton .....	3-91

3.12	Nonnative Fish Species .....	3-94
3.13	Conclusion .....	3-95
<b>Chapter 4</b>	<b>Other Aquatic Ecosystem Stressors.....</b>	<b>4-1</b>
4.1	Introduction .....	4-1
4.2	Physical Habitat Loss or Alteration .....	4-2
4.2.1	Riparian Habitat and Open Channels .....	4-3
4.2.2	Tidal Marsh Habitat .....	4-4
4.2.3	Floodplain and Wetland Habitat .....	4-6
4.3	Water Quality.....	4-7
4.3.1	Contaminants .....	4-7
4.3.2	Dissolved Oxygen .....	4-16
4.3.3	Sediment and Turbidity.....	4-17
4.3.4	Temperature.....	4-18
4.3.5	Monitoring and Assessment.....	4-19
4.4	Nonnative Species.....	4-20
4.4.1	Fishes.....	4-20
4.4.2	Invertebrates .....	4-22
4.4.3	Aquatic Plants.....	4-24
4.5	Fishery Management .....	4-26
4.5.1	Harvest .....	4-26
4.5.2	Hatcheries .....	4-27
4.5.3	Unscreened Diversions.....	4-29
4.6	Climate Change .....	4-30
4.7	Summary .....	4-32
<b>Chapter 5</b>	<b>Recommended New and Revised Flow Requirements .....</b>	<b>5-1</b>
5.1	Introduction .....	5-1
5.1.1	Methods for Developing Environmental Flow Requirements.....	5-3
5.2	Tributary Inflows.....	5-8
5.2.1	Introduction.....	5-8
5.2.2	Current Bay-Delta Plan and D-1641 Requirements.....	5-9
5.2.3	Discussion .....	5-9
5.2.4	Conclusion and Proposed Requirements .....	5-15
5.3	Delta Outflow.....	5-17
5.3.1	Introduction.....	5-17
5.3.2	Current Bay-Delta Plan, D-1641 and Biological Opinion Requirements .....	5-18
5.3.3	Discussion .....	5-20
5.3.4	Conclusion and Proposed Requirements .....	5-32

5.4	Cold Water Habitat Below Reservoirs.....	5-34
5.4.1	Introduction.....	5-34
5.4.2	Existing Cold Water Habitat Requirements.....	5-35
5.4.3	Discussion.....	5-41
5.4.4	Conclusion and Proposed Requirements.....	5-42
5.5	Interior Delta Flows.....	5-43
5.5.1	Introduction.....	5-43
5.5.2	Discussion.....	5-43
5.5.3	Delta Cross Channel Gate Closure.....	5-44
5.5.4	Old and Middle River Reverse Flow Limits.....	5-45
5.5.5	Export Limits.....	5-46
5.5.6	Conclusion.....	5-47
5.6	Updates to the Program of Implementation.....	5-48
<b>Chapter 6</b>	<b>References Cited.....</b>	<b>6-1</b>
6.1	Literature Cited.....	6-1
6.2	Federal Register Notices.....	6-66
<b>Appendix A</b>	<b>Draft Modeling Approaches Used to Develop Unimpaired Watershed Hydrology</b>	

## Tables and Figures

---

Table	Page
2.1-1 Summary Information used in SacWAM for the Major Tributaries to the Sacramento River and the Eastside Tributaries to the Delta.....	2-15
2.2-1 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Sacramento River below Keswick Reservoir .....	2-19
2.2-2 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Sacramento River at Freeport .....	2-22
2.2-3 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Battle Creek .....	2-24
2.2-4 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Cow Creek.....	2-25
2.2-5 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Antelope Creek.....	2-27
2.2-6 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Deer Creek.....	2-29
2.2-7 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Mill Creek.....	2-30
2.2-8 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Clear Creek .....	2-32
2.2-9 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Butte Creek.....	2-34
2.2-10 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Feather River above Confluence of Yuba River .....	2-37
2.2-11 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Feather River at Confluence of Sacramento River .....	2-38
2.2-12 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Yuba River.....	2-40
2.2-13 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Bear River .....	2-42
2.2-14 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in American River .....	2-43

2.2-15 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Mokelumne River ..... 2-45

2.2-16 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Cosumnes River ..... 2-47

2.2-17 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Calaveras River ..... 2-49

2.2-18 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Stony Creek..... 2-50

2.2-19 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Cottonwood Creek ..... 2-52

2.2-20 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Thomes Creek..... 2-53

2.2-21 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Cache Creek ..... 2-55

2.2-22 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Putah Creek ..... 2-57

2.3-1 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Sutter Bypass ..... 2-61

2.3-2 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Yolo Bypass..... 2-64

2.4-1 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow for Delta Inflow ..... 2-68

2.4-2 Median Current Conditions as Percent of Unimpaired Flow for Delta Inflow by Major Tributary ..... 2-68

2.4-3 Cumulative Distribution of Current Conditions as Percent of Unimpaired Flow in Delta Outflow ..... 2-77

2.4-4 Simulated Unimpaired Contributions to Total Delta Outflow from Various Locations in the Project Area (percent of Delta outflow)..... 2-78

2.6-1 Sacramento Valley Unimpaired Runoff ..... 2-84

3.4-1 General Timing of Important Life Stages of Sacramento and San Joaquin River Basin Chinook Salmon and California Central Valley Steelhead ..... 3-15

3.4-2 Timing of Juvenile Chinook Salmon and California Central Valley Steelhead Entry into the Delta from the Sacramento River Basin by Month ..... 3-18

3.4-3 Summary of the Natural Production of All Four Runs of Chinook Salmon in the Sacramento and San Joaquin River Basins during the Central Valley Project Improvement Act (CVPIA) Baseline Period of 1967–1991 and 1992–2015 ..... 3-21

3.4-4 Timing of Adult Chinook Salmon and Steelhead Migrations through the Delta to Upstream Sacramento and San Joaquin River Spawning Tributaries ..... 3-38

3.4-5 State Water Board Staff Analysis of the Frequency of Common Flow Related Stressors for Spring-Run Chinook Salmon and Central Valley Steelhead in Twenty-Two Salmon Bearing Tributaries of the Sacramento River ..... 3-39

3.4-6 Salmon Returns on the Mokelumne River (from CDFG 2012) ..... 3-40

3.4-7 Sacramento River and Interior Delta Flows to Increase the Abundance and Survival of Chinook Salmon Populations ..... 3-48

3.5-1 Delta Outflow and OMR Reverse Flows Indicated to Be Protective of Longfin Smelt Recruitment..... 3-60

3.6-1 Delta Outflow (cfs) Indicated to Be Protective of White and Green Sturgeon ..... 3-66

3.7-1 Delta Outflow Indicated to Be Protective of Sacramento Splittail..... 3-70

3.8-1 Delta Outflow and OMR Flows Indicated to Be Protective of Delta Smelt ..... 3-76

3.9-1 Delta Outflow Indicated to Be Protective of Starry Flounder ..... 3-84

3.10-1 Delta Outflows Indicated to Be Protective of Bay Shrimp ..... 3-89

3.11-1 Delta Outflow Indicated to Be Protective of Zooplankton Species..... 3-92

3.13-1 Estuarine-Dependent Species Listed under the California (CESA) and Federal Endangered Species (ESA) Acts and Changes in Indices of Their Population Abundance in the San Francisco Estuary..... 3-95

3.13-2 Magnitude and Timing of Delta Outflows Indicated to Be Protective of Estuarine-Dependent Species..... 3-100

3.13-3 Functional Flow Needs for Estuarine-Dependent Species ..... 3-101

3.13-4 Summary of Interior Delta Flows Indicated to Be Protective of Salmonids and Estuarine-dependent Fish Species ..... 3-102

4.5-1 Summary of Recent Take Regulations to Reduce the Impact of Commercial and Recreational Harvest on Native Fish Species ..... 4-27

5.3-1 Existing Delta Outflow Objectives from July to January..... 5-19

5.3-2 SWP and CVP Supplemental Project Water Releases from 2000 to 2016 ..... 5-20

5.3-3 Summary of Frequency of Meeting Winter-Spring Delta Outflows to Benefit Estuarine Habitat and Species..... 5-31

5.3-4 Potential Percent Increase in Median Abundance Indices Relative to SacWAM  
Modeled Flows for Existing Regulatory Conditions Assuming No Additional  
Unregulated or Regulated Flows..... 5-32

<b>Figure</b>	<b>Page</b>
1.4-1	Major Tributaries of the Sacramento River and Eastside Tributaries to the Delta ..... 1-17
2.1-1	Quartile Distributions of Natural and Unimpaired Flows at Two Sample Rim Dam Locations, as Estimated by DWR (2016a)..... 2-2
2.1-2	Quartile Distributions of DWR Estimates of Historical, Natural, and Unimpaired Delta Inflow ..... 2-3
2.1-3	Quartile Distributions of DWR Estimates of Historical, Natural, and Unimpaired Delta Outflow ..... 2-3
2.1-4	Major Tributaries and Watersheds in the Project Area ..... 2-6
2.1-5	Elevation Map of Northern California ..... 2-7
2.1-6	Annual Precipitation in Northern California..... 2-8
2.1-7	Water Year Type Snow Water Equivalents ..... 2-9
2.1-8	Generalized Geologic Map of the Valley Floor..... 2-10
2.1-9	Map-C2VSim Model Groundwater Subregions..... 2-11
2.1-10	Simulated Impaired Flows as a Percentage of Unimpaired Flows Ranked by Water Year Index for the Sacramento River, Its Major Tributaries, and Eastside Tributaries to the Delta for January–June ..... 2-14
2.2-1	Annual Total Observed Imports from the Trinity River to the Sacramento Watershed via the Clear Creek Tunnel for Water Years 1985–2009 ..... 2-17
2.2-2	Sacramento River below Keswick Reservoir Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows ..... 2-19
2.2-3	Daily Hydrograph of the Sacramento River below Keswick Reservoir for Water Year 2011 with Unimpaired Flow (SHA) and Observed Flow (KWK) ..... 2-20
2.2-4	Daily Hydrograph of the Sacramento River below Keswick Reservoir for Water Year 2007 with Unimpaired Flow and Observed Flow ..... 2-21
2.2-5	Sacramento River at Freeport Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows ..... 2-22
2.2-6	Battle Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-24
2.2-7	Cow Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-25
2.2-8	Antelope Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows ..... 2-27

2.2-9 Deer Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-28

2.2-10 Mill Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-30

2.2-11 Clear Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-31

2.2-12 Butte Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-34

2.2-13 Feather River above Confluence with the Yuba River Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows ..... 2-36

2.2-14 Feather River at Confluence with the Sacramento River Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-38

2.2-15 Yuba River Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-40

2.2-16 Bear River Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-41

2.2-17 American River Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows ..... 2-43

2.2-18 Mokelumne River Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows ..... 2-45

2.2-19 Cosumnes River Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows ..... 2-47

2.2-20 Calaveras River Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows ..... 2-48

2.2-21 Stony Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-50

2.2-22 Cottonwood Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows ..... 2-51

2.2-23 Thomes Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-53

2.2-24 Cache Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-55

2.2-25 Putah Creek Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows..... 2-57

2.3-1	Sutter Bypass Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows.....	2-61
2.3-2	Yolo Bypass Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows.....	2-63
2.4-1	Generalized Delta Map.....	2-65
2.4-2	Delta Inflow Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows.....	2-67
2.4-3	Flow Direction in the South Delta .....	2-70
2.4-4	Total Seasonal SWP and CVP South Delta Exports by Decade .....	2-72
2.4-5	Cumulative Probability of OMR Flows from Fleenor et al. 2010.....	2-73
2.4-6	Delta Tidal Flows over a 25-Hour Cycle in Summer Conditions (values in cfs) .....	2-75
2.4-7	Delta Outflow Simulated Current Conditions (gray) and Unimpaired (white) Monthly Flows.....	2-77
2.4-8	Seasonal Net Delta Outflow Index by Decade.....	2-78
2.4-9	Time Series of X2 (thin line, left axis, scale reversed) and Outflow (heavy line, right axis, log scale), Annual Averages for January to June .....	2-79
2.4-10	Cumulative Probability of Daily X2 Locations, from Fleenor et al. 2010.....	2-80
2.4-11	Exceedance Frequency Distribution of Daily X2 Positions .....	2-81
2.4-12	Time Series of Fall X2 since 1967 .....	2-82
2.4-13	Dayflow, Flow-Based Estimation of X2 and CDEC Water-Quality Based X2 Values (Bourez 2012) .....	2-82
3.2-1	Variation in the Position and Extent of Low Salinity Habitat as a Function of X2.....	3-8
3.4-1	California Commercial and Recreational Chinook Salmon Ocean Catch, 1975 to 2014 .....	3-15
3.4-2	Annual Winter-Run Chinook Salmon Escapement from the Sacramento River Basin from 1975 to 2014 and the 40 Year Mean Population Size .....	3-23
3.4-3	Estimated Yearly Adult Natural Production and in-River Adult Escapement of Winter-Run Chinook Salmon in Central Valley Rivers and Streams .....	3-24
3.4-4	Annual Spring-Run Chinook Salmon Escapement to Sacramento River Tributaries from 1975 to 2014 and the 40-Year Mean.....	3-25
3.4-5	Estimated Yearly Adult Natural Production and in-River Adult Escapement of Spring-Run Chinook Salmon in the Central Valley Rivers and Streams .....	3-26
3.4-6	Estimated Yearly Adult Natural Production and in-River Adult Escapement of Late Fall-Run Chinook Salmon in Central Valley Rivers and Streams.....	3-28

3.4-7	Annual Late Fall-Run Chinook Salmon Escapement to the Sacramento River Watershed from 1975 to 2014 and 40-Year Mean .....	3-29
3.4-8	Annual Fall-Run Chinook Salmon Escapement to the Sacramento River Watershed from 1975 to 2014 and 40-Year Mean .....	3-31
3.4-9	Estimated Yearly Adult Natural Production and in-River Adult Escapement of Fall-Run Chinook Salmon in the Main Stem Sacramento River .....	3-31
3.4-10	San Joaquin River Basin Smolt Emigration Pattern 1988–2004 .....	3-32
3.4.-11	Estimated Yearly Natural Production and Instream Escapement of San Joaquin Adult Fall-Run Chinook Salmon.....	3-32
3.4-12	Mean Catch of Unmarked Chinook Salmon Smolt per Cubic Meter (x 1,000) in the Midwater Trawl at Chipps Island between April and June from (a) 1978 through 1997 versus Mean Daily Sacramento River Flow (cfs) at Rio Vista between April and June (from Brandes and McLain 2001), and (b) 1976–2015 (updated analysis by State Water Board staff).....	3-44
3.4-13	Relationship between the Mean Proportion of Flow Diverted into the Interior Delta in January and the Proportion of Juvenile Winter-Run Lost at the CVP and SWP Pumping Facilities (loses divided by the juvenile production index) October 1 through May 31, 1996–2006 (from Low and White 2006) .....	3-46
3.4-14	Relationship between the Mean Proportion of Flow Diverted into the Interior Delta in December and the Proportion of Juvenile Winter-Run Chinook Salmon Lost at the CVP and SWP Pumping Facilities (loses divided by the juvenile production index) October 1 through May 31, 1995–2006 (from Low and White 2006) .....	3-46
3.4-15	Relationship between OMR Reverse Flows and Entrainment at the Federal Pumping Facility, 1995–2007 (from NMFS 2009a).....	3-50
3.4-16	Relationship between OMR Reverse Flow and Entrainment at the State Pumping Facility 1995–2007 (from NMFS 2009a).....	3-50
3.4-17	Temperature Corrected (to 610F) Survival Indices for CWT Salmon Smolt Released at Jersey Point and Recovered at Chipps Island between 1989 and 1991.....	3-51
3.5-1	Inter-Annual Trend in the FMWT Index for Longfin Smelt (1967 to 2016) .....	3-54
3.5-2	FMWT Index Values for Longfin Smelt Regressed against January through June Average Daily Delta Outflow for 1967–2016 with Step Changes following 1987 and 2002.....	3-55
3.5-3	Probability of Positive Longfin Smelt Population Growth and 95 Percent Confidence Limits as a Function of January through June Average Daily Delta Outflow (1967 through 2016).....	3-56

3.5-4	Total Salvage of Longfin Smelt between December and March as a Function of Average Old and Middle River (OMR) Flows during the Same Period for Water Years 1982–1992 (squares) and 1993–2007 (diamonds).....	3-57
3.5-5	(A) Relationship between Average OMR Reverse Flows in April to June and the Sum of SWP and CVP Juvenile (age-0) Longfin Smelt Salvage during the Same Time Period, 1993–2007. (B) Presents the same regression as in (A) excluding 1998 when a protracted SWP export shutdown allowed longfin smelt larvae to grow to salvageable size in Clifton Court before pumping resumed and fish salvage recommenced .....	3-58
3.5-6	(A) Relationship between the Average Location of X2 between January and May and the Sum of Juvenile (age-0) Longfin Smelt Salvage between March and July at the SWP and CVP. (B) Relationship between the Average Location of X2 in April and June and the Sum of Juvenile (age-0) Longfin Smelt Salvage for April to June at the SWP and CVP .....	3-59
3.6-1	White Sturgeon Year Class Indices for San Francisco Bay from 1980 through 2015 .....	3-63
3.6-2	White Sturgeon Year Class Index (YCI) from San Francisco Bay Study Otter Trawl Catch versus Mean Daily Delta Outflow from November through February (numbers adjacent to points designate year classes [from Fish 2010]) .....	3-65
3.6-3	White Sturgeon YCI from San Francisco Bay Study Otter Trawl Catches versus Mean Daily Delta Outflow for March through July (Numbers adjacent to points designate select year classes .....	3-65
3.7-1	Sacramento Splittail Population Recruitment as Measured in the FMWT Survey (1967–2016) .....	3-68
3.7-2	Correlation between the Sacramento Splittail FMWT Index (1967–2016) and Average Daily Outflow (cfs) between February and May .....	3-69
3.7-3	Cumulative Frequency Distribution of Average Daily Outflow between February and May for 1967 to 1983 .....	3-69
3.8-1	Inter-Annual Trend in the FMWT Index for Delta Smelt (1967–2016).....	3-72
3.8-2	Adult (panel a, SKT) and Sub-Adult (panel b, FMWT from previous year) to Larval (20 mm survey) Recruitment Indices as a Function of Spring X2 (February–June).....	3-74
3.8-3	Delta Smelt Survival in Fall as a Function of Monthly Mean Delta Outflow (cfs), for July (top left), August (top right) and September (bottom).....	3-75
3.8-4	Plot of the Delta Smelt 20 mm Survey Abundance Index as a Function of the Location of the Previous Year’s Fall X2 (figure from Baxter et al. 2015).....	3-77
3.8-5	Cumulative Proportional Adult Delta Smelt Salvage by Week for 1993 to 2006 (from USFWS 2008) .....	3-78

3.8-6	Eight-Day Running Averages of Adult Delta Smelt Salvage, Total Outflow (m <sup>3</sup> /s), Turbidity (NTU) for the Eight Most Abundant Delta Smelt Salvage Years between December 1992 and April 2005 at the SWP and CVP .....	3-79
3.8-7	Salvage of Adult Delta Smelt as a Function of OMR Reverse Flows for December through March (from USFWS 2008) .....	3-80
3.9-1	Population Abundance of 1-Year-Old Starry Flounder as Measured in the San Francisco Bay Study (1980–2014) .....	3-82
3.9-2	Correlation between the Starry Flounder Bay Study Otter Trawl Age-1 Index (1980–2015) and Average Daily Outflow (cfs) between March and June .....	3-83
3.9-3	Cumulative Frequency Distribution of Monthly Average Daily Delta Outflow for March through June (1994–2013).....	3-84
3.10-1	Index of Juvenile <i>Crangon franciscorum</i> Abundance as Measured in the San Francisco Bay Otter Trawl Survey (1980–2015) .....	3-86
3.10-2	Relationship between Juvenile Bay Shrimp Abundance, as Measured by the San Francisco Bay Otter Trawl Survey (1980–2013), and Average Daily Outflow (cfs) between March and May of the Same Year.....	3-87
3.10-3	Cumulative Frequency Distribution of Average Daily Outflow for March to May (1980–2013) .....	3-88
3.10-4	Probability of Juvenile Bay Shrimp Population Growth as a Function of Delta Outflow from a Logistic Regression Analysis (P<0.01) .....	3-89
3.11-1	Mean Abundance (CPUE) in the Entrapment Zone as a Function of Delta Outflow (cfs) for <i>E. affinis</i> Adults and <i>Eurytemora</i> spp. Juveniles from March through June (1994 to 2015) (from Hennessy and Burris 2017). .....	3-92
3.11-2	Mean Suisun Bay Abundance (CPUE) as a Function of Delta Outflow (cfs) for Adult <i>P. forbesi</i> and Juvenile <i>Pseudodiaptomus</i> spp. from June to September (1989 to 2015) (from Hennessy and Burris 2017).....	3-93
3.13-1	Trends Over Time in Indices of Abundance for Native Fish and Invertebrate Species from the San Francisco Estuary.....	3-96
3.13-2	Comparison of the Change in Magnitude of FMWT Indices for Delta Smelt, Longfin Smelt, and Sacramento Splittail in Wet and Dry Water Years .....	3-99
4.2-1	Comparison of Historical and Modern Delta Waterways, Tidal Wetland, and Upland Areas (Whipple et al. 2012).....	4-5
4.3-1	Least Squares Regressions with 95 Percent Confidence Intervals for FMWT Species Abundance as a Function of Annual Pyrethroid Pesticide Use in Six Delta Counties (1978–2014) (From Fong et al. 2016).....	4-10

4.4-1	Clam Abundance and Chlorophyll Concentrations in the Low Salinity Zone before and after the Invasion of the Clam <i>Potamocorbula</i> in 1987 .....	4-23
4.6-1	Declining Trend in April–July Contribution to Total Water Year Runoff in the Sacramento River System, 1907–2010 (from Roos 2012).....	4-32
5.2-1	Frequency of Meeting April–June Sacramento River at Rio Vista Flows of 20,000 cfs for Current Conditions as Modeled by SacWAM, and 35 to 75 Percent of Unimpaired Flow at Rio Vista .....	5-12
5.2-2	Frequency of Meeting February–April Sacramento River at Rio Vista Flows of 20,000 cfs for Current Conditions as Modeled by SacWAM, and 35 to 75 Percent of Unimpaired Flow at Rio Vista .....	5-13
5.2-3	Exceedance Frequency of Monthly Flow at Freeport on the Sacramento River for November–May under Current Conditions as Modeled by SacWAM, and 35 to 75 Percent of Unimpaired Flow .....	5-14
5.3-1	Seasonal Comparisons of Minimum Required Delta Outflow (“MRDO”, orange line), SacWAM Modeled Delta Outflow (“Current”, black line), and Observed Delta Outflow. Observed Delta outflow is divided into four historical periods: prior to the completion of Shasta Reservoir (1930–1945, purple line), prior to the completion of Oroville Reservoir (1946–1967, cyan line), prior to the adoption of D-1641 (1968–1999, green line), and following the adoption of D-1641 (2000–2016, red line) (Dayflow data, DWR 2017). .....	5-23
5.3-2	Frequency of Meeting January–June Delta Outflows to Benefit Estuarine LSZ Habitat and Longfin Smelt for MRDO, Current Conditions as Modeled by SacWAM, and Inflow-Based Delta Outflow Scenarios Corresponding to Sacramento River and Eastside Delta Tributary Inflows from 35 to 75 Percent of Unimpaired Flow .....	5-26
5.3-3	Frequency of Meeting March–May Delta Outflows to Benefit California Bay Shrimp for MRDO, Current Conditions as Modeled by SacWAM, and Inflow-Based Delta Outflow Scenarios Corresponding to Sacramento River and Eastside Delta Tributary Inflows from 35 to 75 Percent of Unimpaired Flow .....	5-27
5.3-4	Frequency of Meeting March–June Delta Outflows to Benefit Starry Flounder for MRDO, Current Conditions as Modeled by SacWAM, and Inflow-Based Delta Outflow Scenarios Corresponding to Sacramento River and Eastside Delta Tributary Inflows from 35 to 75 Percent of Unimpaired Flow .....	5-28
5.3-5	Frequency of Meeting February–May Delta Outflows to Benefit Sacramento Splittail for MRDO, Current Conditions as Modeled by SacWAM, and Inflow-Based Delta Outflow Scenarios Corresponding to Sacramento River and Eastside Delta Tributary Inflows from 35 to 75 Percent of Unimpaired Flow .....	5-29

5.3-6      Frequency of Meeting March–July Delta Outflows to Benefit White and Green Sturgeon for MRDO, Current Conditions as Modeled by SacWAM, and Inflow-Based Delta Outflow Scenarios Corresponding to Sacramento River and Eastside Delta Tributary Inflows from 35 to 75 Percent of Unimpaired Flow ..... 5-30

5.5-1      Range for Combined CVP and SWP South Delta Exports as a Function of Delta Inflow from the San Joaquin River at Vernalis ..... 5-47

---

## State Water Resources Control Board

April 25, 2017

Murdoch McAllister, Ph.D.  
Associate Professor, Quantitative Modeling Group  
Canada Research Chair in Fisheries Assessment  
UBC Institute for the Oceans and Fisheries  
University of British Columbia  
AERL, 2202 Main Mall  
Vancouver, BC Canada V6T 1Z4

**SUBJECT: INITIATION OF REVIEW OF THE SCIENTIFIC BASIS FOR NEW  
AND REVISED WATER QUALITY OBJECTIVES FOR THE  
PHASE II UPDATE OF THE BAY-DELTA PLAN**

Dear Professor McAllister:

The purpose of this letter is to initiate the external peer review.

All components for the review, and a Table of Contents, are posted at a secure FTP site. They include, but are not restricted to, the following:

1. Revised January 26, 2017 memorandum from Leslie Grober, Deputy Director of the Division of Water Rights. The subject of the memorandum is "Request for External Peer Review of the Scientific Basis for New and Revised Water Quality Objectives for the Phase II Update of the Bay-Delta Plan transmitting the following attachments:
  - Attachment 1: Summary of the Phase II Update
  - Attachment 2: Scientific Issues to be addressed by Peer Reviewers
  - Attachment 3: Individuals involved in the development of the Science Report
  - Attachment 4: Folder containing electronic Reprints of all Citations
  - Attachment 5: Science Report, dated April 2017

**PLEASE NOTE: The first page of the memorandum has been modified at the top right corner to state: Revisions (dated April 18, 2017) have been made to the original Cover Memorandum and to Attachments 1, 2 and 3 (dated January 26, 2017) for clarity.**

2. January 7, 2009, Supplement to the Cal/EPA Peer Review Guidelines.

Comments on the Foregoing

1. **Please delete** the original January 26, 2017, request memorandum sent to you by Dr. Dan McGrath, University of California, Berkeley, Institute of the Environment. **Base your review on the revised April 2017 request and attachments 2 and 5 which are provided at the FTP site, access to which is given below.**
2. **Attachment 2 to the request memorandum provides focus for the review. I ask that you address all topics, as expertise allows, in the order listed.** The Staff Report sections that provide support for each of the eight conclusions are identified beside them.
3. The original five conclusions presented in Attachment 2 of the January 26, 2017 request have been expanded to eight conclusions in the April 18, 2017 revision. The relationship of the two sets of conclusions in the two requests are set forth in the table below.

There are no substantive changes in the content of the conclusions between the two versions. Changes were made to the 26 January version to simplify and clarify our request for review.

<b>26 Jan</b>	<b>18 April</b>	<b>Comment</b>
Conclusion 1	Conclusion 1	Same topic—Adequacy of hydrologic analysis to support subsequent biological conclusions
Conclusion 2	Conclusion 2	Same topic—Changes in the flow regime has impaired fish and the ecosystem.
Conclusion 3	Conclusion 8	Mostly the same topic—changes in non-flow stressors have impaired fish. The 26 January version also contained conclusions about the need for functional flows to support population abundance (first paragraph). Those conclusions are now discussed in Conclusions 4 and 5 of the April 18 version.
Conclusion 4a, b and c.	Conclusion 3, 4, 5, and 6	Conclusions 4a, 4b, and 4c in the 26 January version are the same as conclusions 4, 5, and 6 in the 18 April version. The conclusions address new or changed objectives for tributary inflow, delta outflow and cold water habitat to protect native fish. Conclusion 3 was previously embedded in 4a but is now explicitly stated.
Conclusion 5	Conclusion 7	Same topic—interior delta flow requirements are needed to protect native fish

4. January 7, 2009, Supplement. In part, the Supplement provides guidance to ensure the review is kept confidential through its course. It also notes reviewers are under no obligation to discuss their comments with third-parties after reviews have been submitted. We recommend they do not. All outside parties are provided opportunities to address a proposed regulatory action through a well-defined regulatory process. Please direct third parties to me.

Questions about the review, or material, should be for clarification, in writing – email is fine, and addressed to me. My responses will be in writing also.

Access to secure FTP site:

<https://ftp.waterboards.ca.gov/>

Username: PRFTP

Password: Water123

Please send your reviews to me on May 24, 2017 not before. I will subsequently forward all reviews to Leslie Grober, Division of Water Rights, with Curriculum Vitae for each reviewer. All this information will be posted at the State and Regional Water Boards Scientific Peer Review website, and at the Division of Water Rights program website for this proposal.

Your acceptance of this review assignment is most appreciated.

Sincerely,



Gerald W. Bowes, Ph.D.  
Manager, Cal/EPA Scientific Peer Review Program  
Office of Research, Planning and Performance  
State Water Resources Control Board  
1001 "I" Street, 16<sup>th</sup> Floor  
Sacramento, California 95814

Telephone: (916) 341-5567

FAX: (916) 341-5284

Email: [GBowes@waterboards.ca.gov](mailto:GBowes@waterboards.ca.gov)

## State Water Resources Control Board

April 25, 2017

Murdoch McAllister, Ph.D.  
Associate Professor, Quantitative Modeling Group  
Canada Research Chair in Fisheries Assessment  
UBC Institute for the Oceans and Fisheries  
University of British Columbia  
AERL, 2202 Main Mall  
Vancouver, BC Canada V6T 1Z4

**SUBJECT: INITIATION OF REVIEW OF THE SCIENTIFIC BASIS FOR NEW  
AND REVISED WATER QUALITY OBJECTIVES FOR THE  
PHASE II UPDATE OF THE BAY-DELTA PLAN**

Dear Professor McAllister:

The purpose of this letter is to initiate the external peer review.

All components for the review, and a Table of Contents, are posted at a secure FTP site. They include, but are not restricted to, the following:

1. Revised January 26, 2017 memorandum from Leslie Grober, Deputy Director of the Division of Water Rights. The subject of the memorandum is "Request for External Peer Review of the Scientific Basis for New and Revised Water Quality Objectives for the Phase II Update of the Bay-Delta Plan transmitting the following attachments:
  - Attachment 1: Summary of the Phase II Update
  - Attachment 2: Scientific Issues to be addressed by Peer Reviewers
  - Attachment 3: Individuals involved in the development of the Science Report
  - Attachment 4: Folder containing electronic Reprints of all Citations
  - Attachment 5: Science Report, dated April 2017

**PLEASE NOTE: The first page of the memorandum has been modified at the top right corner to state: Revisions (dated April 18, 2017) have been made to the original Cover Memorandum and to Attachments 1, 2 and 3 (dated January 26, 2017) for clarity.**

2. January 7, 2009, Supplement to the Cal/EPA Peer Review Guidelines.

Comments on the Foregoing

1. **Please delete** the original January 26, 2017, request memorandum sent to you by Dr. Dan McGrath, University of California, Berkeley, Institute of the Environment. **Base your review on the revised April 2017 request and attachments 2 and 5 which are provided at the FTP site, access to which is given below.**
2. **Attachment 2 to the request memorandum provides focus for the review. I ask that you address all topics, as expertise allows, in the order listed.** The Staff Report sections that provide support for each of the eight conclusions are identified beside them.
3. The original five conclusions presented in Attachment 2 of the January 26, 2017 request have been expanded to eight conclusions in the April 18, 2017 revision. The relationship of the two sets of conclusions in the two requests are set forth in the table below.

There are no substantive changes in the content of the conclusions between the two versions. Changes were made to the 26 January version to simplify and clarify our request for review.

<b>26 Jan</b>	<b>18 April</b>	<b>Comment</b>
Conclusion 1	Conclusion 1	Same topic—Adequacy of hydrologic analysis to support subsequent biological conclusions
Conclusion 2	Conclusion 2	Same topic—Changes in the flow regime has impaired fish and the ecosystem.
Conclusion 3	Conclusion 8	Mostly the same topic—changes in non-flow stressors have impaired fish. The 26 January version also contained conclusions about the need for functional flows to support population abundance (first paragraph). Those conclusions are now discussed in Conclusions 4 and 5 of the April 18 version.
Conclusion 4a, b and c.	Conclusion 3, 4, 5, and 6	Conclusions 4a, 4b, and 4c in the 26 January version are the same as conclusions 4, 5, and 6 in the 18 April version. The conclusions address new or changed objectives for tributary inflow, delta outflow and cold water habitat to protect native fish. Conclusion 3 was previously embedded in 4a but is now explicitly stated.
Conclusion 5	Conclusion 7	Same topic—interior delta flow requirements are needed to protect native fish

4. January 7, 2009, Supplement. In part, the Supplement provides guidance to ensure the review is kept confidential through its course. It also notes reviewers are under no obligation to discuss their comments with third-parties after reviews have been submitted. We recommend they do not. All outside parties are provided opportunities to address a proposed regulatory action through a well-defined regulatory process. Please direct third parties to me.

Questions about the review, or material, should be for clarification, in writing – email is fine, and addressed to me. My responses will be in writing also.

Access to secure FTP site:

<https://ftp.waterboards.ca.gov/>

Username: PRFTP

Password: Water123

Please send your reviews to me on May 24, 2017 not before. I will subsequently forward all reviews to Leslie Grober, Division of Water Rights, with Curriculum Vitae for each reviewer. All this information will be posted at the State and Regional Water Boards Scientific Peer Review website, and at the Division of Water Rights program website for this proposal.

Your acceptance of this review assignment is most appreciated.

Sincerely,



Gerald W. Bowes, Ph.D.  
Manager, Cal/EPA Scientific Peer Review Program  
Office of Research, Planning and Performance  
State Water Resources Control Board  
1001 "I" Street, 16<sup>th</sup> Floor  
Sacramento, California 95814

Telephone: (916) 341-5567

FAX: (916) 341-5284

Email: [GBowes@waterboards.ca.gov](mailto:GBowes@waterboards.ca.gov)

---

## State Water Resources Control Board

April 26, 2017

Thomas Meixner, Ph.D.  
Professor & Associate Department Head  
Hydrology and Atmospheric Sciences  
The University of Arizona  
JW Harshbarger Bldg #11, Room 202  
1133 E. James Rogers Way  
Tucson, AZ 85721-0011

**SUBJECT: INITIATION OF REVIEW OF THE SCIENTIFIC BASIS FOR NEW  
AND REVISED WATER QUALITY OBJECTIVES FOR THE  
PHASE II UPDATE OF THE BAY-DELTA PLAN**

Dear Professor Meixner:

The purpose of this letter is to initiate the external peer review.

All components for the review, and a Table of Contents, are posted at a secure FTP site. They include, but are not restricted to, the following:

1. Revised January 26, 2017 memorandum from Leslie Grober, Deputy Director of the Division of Water Rights. The subject of the memorandum is "Request for External Peer Review of the Scientific Basis for New and Revised Water Quality Objectives for the Phase II Update of the Bay-Delta Plan transmitting the following attachments:
  - Attachment 1: Summary of the Phase II Update
  - Attachment 2: Scientific Conclusions to be addressed by Peer Reviewers
  - Attachment 3: Individuals involved in the development of the Science Report
  - Attachment 4: Folder containing electronic Reprints of all Citations
  - Attachment 5: Science Report, dated April 2017

**PLEASE NOTE: The first page of the memorandum has been modified at the top right corner to state: Revisions (dated April 18, 2017) have been made to the original Cover Memorandum and to Attachments 1, 2 and 3 (dated January 26, 2017) for clarity.**

2. January 7, 2009, Supplement to the Cal/EPA Peer Review Guidelines.

Comments on the Foregoing

1. **Please delete** the original January 26, 2017, request memorandum sent to you by Dr. Dan McGrath, University of California, Berkeley, Institute of the Environment. **Base your review on the revised April 2017 request and attachments 2 and 5 which are provided at the FTP site, access to which is given below.**
2. **Attachment 2 to the request memorandum provides focus for the review. I ask that you address all topics, as expertise allows, in the order listed.** The Staff Report sections that provide support for each of the eight conclusions are identified beside them.
3. The original five conclusions presented in Attachment 2 of the January 26, 2017 request have been expanded to eight conclusions in the April 18, 2017 revision. The relationship of the two sets of conclusions in the two requests are set forth in the table below.

There are no substantive changes in the content of the conclusions between the two versions. Changes were made to the 26 January version to simplify and clarify our request for review.

<b>26 Jan</b>	<b>18 April</b>	<b>Comment</b>
Conclusion 1	Conclusion 1	Same topic—Adequacy of hydrologic analysis to support subsequent biological conclusions
Conclusion 2	Conclusion 2	Same topic—Changes in the flow regime has impaired fish and the ecosystem.
Conclusion 3	Conclusion 8	Mostly the same topic—changes in non-flow stressors have impaired fish. The 26 January version also contained conclusions about the need for functional flows to support population abundance (first paragraph). Those conclusions are now discussed in Conclusions 4 and 5 of the April 18 version.
Conclusion 4a, b and c.	Conclusion 3, 4, 5, and 6	Conclusions 4a, 4b, and 4c in the 26 January version are the same as conclusions 4, 5, and 6 in the 18 April version. The conclusions address new or changed objectives for tributary inflow, delta outflow and cold water habitat to protect native fish. Conclusion 3 was previously embedded in 4a but is now explicitly stated.
Conclusion 5	Conclusion 7	Same topic—interior delta flow requirements are needed to protect native fish

4. January 7, 2009, Supplement. In part, the Supplement provides guidance to ensure the review is kept confidential through its course. It also notes reviewers are under no obligation to discuss their comments with third-parties after reviews have been submitted. We recommend they do not. All outside parties are provided opportunities to address a proposed regulatory action through a well-defined regulatory process. Please direct third parties to me.

Questions about the review, or material, should be for clarification, in writing – email is fine, and addressed to me. My responses will be in writing also.

Access to secure FTP site:

<https://ftp.waterboards.ca.gov/>

Username: PRFTP

Password: Water123

Please send your reviews to me on May 24, 2017 not before. I will subsequently forward all reviews to Leslie Grober, Division of Water Rights, with Curriculum Vitae for each reviewer. All this information will be posted at the State and Regional Water Boards Scientific Peer Review website, and at the Division of Water Rights program website for this proposal.

Your acceptance of this review assignment is most appreciated.

Sincerely,



Gerald W. Bowes, Ph.D.  
Manager, Cal/EPA Scientific Peer Review Program  
Office of Research, Planning and Performance  
State Water Resources Control Board  
1001 "I" Street, 16<sup>th</sup> Floor  
Sacramento, California 95814

Telephone: (916) 341-5567

FAX: (916) 341-5284

Email: [GBowes@waterboards.ca.gov](mailto:GBowes@waterboards.ca.gov)

---

## State Water Resources Control Board

April 25, 2017

Thomas Miller, Ph.D.  
Professor & Director  
Chesapeake Biological Laboratory  
University of Maryland Center for Environmental Science  
146 Williams Street, P.O. Box 38  
Solomons, MD 20688-0038

**SUBJECT: INITIATION OF REVIEW OF THE SCIENTIFIC BASIS FOR NEW  
AND REVISED WATER QUALITY OBJECTIVES FOR THE  
PHASE II UPDATE OF THE BAY-DELTA PLAN**

Dear Professor Miller:

The purpose of this letter is to initiate the external peer review.

All components for the review, and a Table of Contents, are posted at a secure FTP site. They include, but are not restricted to, the following:

1. Revised January 26, 2017 memorandum from Leslie Grober, Deputy Director of the Division of Water Rights. The subject of the memorandum is "Request for External Peer Review of the Scientific Basis for New and Revised Water Quality Objectives for the Phase II Update of the Bay-Delta Plan transmitting the following attachments:

- Attachment 1: Summary of the Phase II Update
- Attachment 2: Scientific Issues to be addressed by Peer Reviewers
- Attachment 3: Individuals involved in the development of the Science Report
- Attachment 4: Folder containing electronic Reprints of all Citations
- Attachment 5: Science Report, dated April 2017

**PLEASE NOTE: The first page of the memorandum has been modified at the top right corner to state: Revisions (dated April 18, 2017) have been made to the original Cover Memorandum and to Attachments 1, 2 and 3 (dated January 26, 2017) for clarity.**

2. January 7, 2009, Supplement to the Cal/EPA Peer Review Guidelines.

Comments on the Foregoing

1. **Please delete** the original January 26, 2017, request memorandum sent to you by Dr. Dan McGrath, University of California, Berkeley, Institute of the Environment. **Base your review on the revised April 2017 request and attachments 2 and 5 which are provided at the FTP site, access to which is given below.**
2. **Attachment 2 to the request memorandum provides focus for the review. I ask that you address all topics, as expertise allows, in the order listed.** The Staff Report sections that provide support for each of the eight conclusions are identified beside them.
3. The original five conclusions presented in Attachment 2 of the January 26, 2017 request have been expanded to eight conclusions in the April 18, 2017 revision. The relationship of the two sets of conclusions in the two requests are set forth in the table below.

There are no substantive changes in the content of the conclusions between the two versions. Changes were made to the 26 January version to simplify and clarify our request for review.

<b>26 Jan</b>	<b>18 April</b>	<b>Comment</b>
Conclusion 1	Conclusion 1	Same topic—Adequacy of hydrologic analysis to support subsequent biological conclusions
Conclusion 2	Conclusion 2	Same topic—Changes in the flow regime has impaired fish and the ecosystem.
Conclusion 3	Conclusion 8	Mostly the same topic—changes in non-flow stressors have impaired fish. The 26 January version also contained conclusions about the need for functional flows to support population abundance (first paragraph). Those conclusions are now discussed in Conclusions 4 and 5 of the April 18 version.
Conclusion 4a, b and c.	Conclusion 3, 4, 5, and 6	Conclusions 4a, 4b, and 4c in the 26 January version are the same as conclusions 4, 5, and 6 in the 18 April version. The conclusions address new or changed objectives for tributary inflow, delta outflow and cold water habitat to protect native fish. Conclusion 3 was previously embedded in 4a but is now explicitly stated.
Conclusion 5	Conclusion 7	Same topic—interior delta flow requirements are needed to protect native fish

4. January 7, 2009, Supplement. In part, the Supplement provides guidance to ensure the review is kept confidential through its course. It also notes reviewers are under no obligation to discuss their comments with third-parties after reviews have been submitted. We recommend they do not. All outside parties are provided opportunities to address a proposed regulatory action through a well-defined regulatory process. Please direct third parties to me.

Questions about the review, or material, should be for clarification, in writing – email is fine, and addressed to me. My responses will be in writing also.

Access to secure FTP site:

<https://ftp.waterboards.ca.gov/>

Username: PRFTP

Password: Water123

Please send your reviews to me on May 24, 2017 not before. I will subsequently forward all reviews to Leslie Grober, Division of Water Rights, with Curriculum Vitae for each reviewer. All this information will be posted at the State and Regional Water Boards Scientific Peer Review website, and at the Division of Water Rights program website for this proposal.

Your acceptance of this review assignment is most appreciated.

Sincerely,



Gerald W. Bowes, Ph.D.  
Manager, Cal/EPA Scientific Peer Review Program  
Office of Research, Planning and Performance  
State Water Resources Control Board  
1001 "I" Street, 16<sup>th</sup> Floor  
Sacramento, California 95814

Telephone: (916) 341-5567

FAX: (916) 341-5284

Email: [GBowes@waterboards.ca.gov](mailto:GBowes@waterboards.ca.gov)

---

## State Water Resources Control Board

April 25, 2017

N. LeRoy Poff, Ph.D., Professor  
Department of Biology  
Colorado State University  
1878 Campus Delivery  
Fort Collins, CO 80523

**SUBJECT: INITIATION OF REVIEW OF THE SCIENTIFIC BASIS FOR NEW  
AND REVISED WATER QUALITY OBJECTIVES FOR THE  
PHASE II UPDATE OF THE BAY-DELTA PLAN**

Dear Professor Poff:

The purpose of this letter is to initiate the external peer review.

All components for the review, and a Table of Contents, are posted at a secure FTP site. They include, but are not restricted to, the following:

1. Revised January 26, 2017 memorandum from Leslie Grober, Deputy Director of the Division of Water Rights. The subject of the memorandum is "Request for External Peer Review of the Scientific Basis for New and Revised Water Quality Objectives for the Phase II Update of the Bay-Delta Plan transmitting the following attachments:
  - Attachment 1: Summary of the Phase II Update
  - Attachment 2: Scientific Issues to be addressed by Peer Reviewers
  - Attachment 3: Individuals involved in the development of the Science Report
  - Attachment 4: Folder containing electronic Reprints of all Citations
  - Attachment 5: Science Report, dated April 2017

**PLEASE NOTE: The first page of the memorandum has been modified at the top right corner to state: Revisions (dated April 18, 2017) have been made to the original Cover Memorandum and to Attachments 1, 2 and 3 (dated January 26, 2017) for clarity.**

2. January 7, 2009, Supplement to the Cal/EPA Peer Review Guidelines.

Comments on the Foregoing

1. **Please delete** the original January 26, 2017, request memorandum sent to you by Dr. Dan McGrath, University of California, Berkeley, Institute of the Environment. **Base your review on the revised April 2017 request and attachments 2 and 5 which are provided at the FTP site, access to which is given below.**
2. **Attachment 2 to the request memorandum provides focus for the review. I ask that you address all topics, as expertise allows, in the order listed.** The Staff Report sections that provide support for each of the eight conclusions are identified beside them.
3. The original five conclusions presented in Attachment 2 of the January 26, 2017 request have been expanded to eight conclusions in the April 18, 2017 revision. The relationship of the two sets of conclusions in the two requests are set forth in the table below.

There are no substantive changes in the content of the conclusions between the two versions. Changes were made to the 26 January version to simplify and clarify our request for review.

<b>26 Jan</b>	<b>18 April</b>	<b>Comment</b>
Conclusion 1	Conclusion 1	Same topic—Adequacy of hydrologic analysis to support subsequent biological conclusions
Conclusion 2	Conclusion 2	Same topic—Changes in the flow regime has impaired fish and the ecosystem.
Conclusion 3	Conclusion 8	Mostly the same topic—changes in non-flow stressors have impaired fish. The 26 January version also contained conclusions about the need for functional flows to support population abundance (first paragraph). Those conclusions are now discussed in Conclusions 4 and 5 of the April 18 version.
Conclusion 4a, b and c.	Conclusion 3, 4, 5, and 6	Conclusions 4a, 4b, and 4c in the 26 January version are the same as conclusions 4, 5, and 6 in the 18 April version. The conclusions address new or changed objectives for tributary inflow, delta outflow and cold water habitat to protect native fish. Conclusion 3 was previously embedded in 4a but is now explicitly stated.
Conclusion 5	Conclusion 7	Same topic—interior delta flow requirements are needed to protect native fish

4. January 7, 2009, Supplement. In part, the Supplement provides guidance to ensure the review is kept confidential through its course. It also notes reviewers are under no obligation to discuss their comments with third-parties after reviews have been submitted. We recommend they do not. All outside parties are provided opportunities to address a proposed regulatory action through a well-defined regulatory process. Please direct third parties to me.

Questions about the review, or material, should be for clarification, in writing – email is fine, and addressed to me. My responses will be in writing also.

Access to secure FTP site:

<https://ftp.waterboards.ca.gov/>

Username: PRFTP

Password: Water123

Please send your reviews to me on May 24, 2017 not before. I will subsequently forward all reviews to Leslie Grober, Division of Water Rights, with Curriculum Vitae for each reviewer. All this information will be posted at the State and Regional Water Boards Scientific Peer Review website, and at the Division of Water Rights program website for this proposal.

Your acceptance of this review assignment is most appreciated.

Sincerely,



Gerald W. Bowes, Ph.D.  
Manager, Cal/EPA Scientific Peer Review Program  
Office of Research, Planning and Performance  
State Water Resources Control Board  
1001 "I" Street, 16<sup>th</sup> Floor  
Sacramento, California 95814

Telephone: (916) 341-5567

FAX: (916) 341-5284

Email: [GBowes@waterboards.ca.gov](mailto:GBowes@waterboards.ca.gov)

---

## State Water Resources Control Board

April 25, 2017

Elowyn Yager, Ph.D.  
Associate Professor, Center for Ecohydraulics Research  
Department of Civil Engineering  
University of Idaho  
322 E. Front Street, Suite 340  
Boise, ID 83702

**SUBJECT: INITIATION OF REVIEW OF THE SCIENTIFIC BASIS FOR NEW  
AND REVISED WATER QUALITY OBJECTIVES FOR THE  
PHASE II UPDATE OF THE BAY-DELTA PLAN**

Dear Professor Yager:

The purpose of this letter is to initiate the external peer review.

All components for the review, and a Table of Contents, are posted at a secure FTP site. They include, but are not restricted to, the following:

1. Revised January 26, 2017 memorandum from Leslie Grober, Deputy Director of the Division of Water Rights. The subject of the memorandum is "Request for External Peer Review of the Scientific Basis for New and Revised Water Quality Objectives for the Phase II Update of the Bay-Delta Plan transmitting the following attachments:

- Attachment 1: Summary of the Phase II Update
- Attachment 2: Scientific Issues to be addressed by Peer Reviewers
- Attachment 3: Individuals involved in the development of the Science Report
- Attachment 4: Folder containing electronic Reprints of all Citations
- Attachment 5: Science Report, dated April 2017

**PLEASE NOTE: The first page of the memorandum has been modified at the top right corner to state: Revisions (dated April 18, 2017) have been made to the original Cover Memorandum and to Attachments 1, 2 and 3 (dated January 26, 2017) for clarity.**

2. January 7, 2009, Supplement to the Cal/EPA Peer Review Guidelines.

Comments on the Foregoing

1. **Please delete** the original January 26, 2017, request memorandum sent to you by Dr. Dan McGrath, University of California, Berkeley, Institute of the Environment. **Base your review on the revised April 2017 request and attachments 2 and 5 which are provided at the FTP site, access to which is given below.**
2. **Attachment 2 to the request memorandum provides focus for the review. I ask that you address all topics, as expertise allows, in the order listed.** The Staff Report sections that provide support for each of the eight conclusions are identified beside them.
3. The original five conclusions presented in Attachment 2 of the January 26, 2017 request have been expanded to eight conclusions in the April 18, 2017 revision. The relationship of the two sets of conclusions in the two requests are set forth in the table below.

There are no substantive changes in the content of the conclusions between the two versions. Changes were made to the 26 January version to simplify and clarify our request for review.

<b>26 Jan</b>	<b>18 April</b>	<b>Comment</b>
Conclusion 1	Conclusion 1	Same topic—Adequacy of hydrologic analysis to support subsequent biological conclusions
Conclusion 2	Conclusion 2	Same topic—Changes in the flow regime has impaired fish and the ecosystem.
Conclusion 3	Conclusion 8	Mostly the same topic—changes in non-flow stressors have impaired fish. The 26 January version also contained conclusions about the need for functional flows to support population abundance (first paragraph). Those conclusions are now discussed in Conclusions 4 and 5 of the April 18 version.
Conclusion 4a, b and c.	Conclusion 3, 4, 5, and 6	Conclusions 4a, 4b, and 4c in the 26 January version are the same as conclusions 4, 5, and 6 in the 18 April version. The conclusions address new or changed objectives for tributary inflow, delta outflow and cold water habitat to protect native fish. Conclusion 3 was previously embedded in 4a but is now explicitly stated.
Conclusion 5	Conclusion 7	Same topic—interior delta flow requirements are needed to protect native fish

4. January 7, 2009, Supplement. In part, the Supplement provides guidance to ensure the review is kept confidential through its course. It also notes reviewers are under no obligation to discuss their comments with third-parties after reviews have been submitted. We recommend they do not. All outside parties are provided opportunities to address a proposed regulatory action through a well-defined regulatory process. Please direct third parties to me.

Questions about the review, or material, should be for clarification, in writing – email is fine, and addressed to me. My responses will be in writing also.

Access to secure FTP site:

<https://ftp.waterboards.ca.gov/>

Username: PRFTP

Password: Water123

Please send your reviews to me on May 24, 2017 not before. I will subsequently forward all reviews to Leslie Grober, Division of Water Rights, with Curriculum Vitae for each reviewer. All this information will be posted at the State and Regional Water Boards Scientific Peer Review website, and at the Division of Water Rights program website for this proposal.

Your acceptance of this review assignment is most appreciated.

Sincerely,



Gerald W. Bowes, Ph.D.  
Manager, Cal/EPA Scientific Peer Review Program  
Office of Research, Planning and Performance  
State Water Resources Control Board  
1001 "I" Street, 16<sup>th</sup> Floor  
Sacramento, California 95814

Telephone: (916) 341-5567

FAX: (916) 341-5284

Email: [GBowes@waterboards.ca.gov](mailto:GBowes@waterboards.ca.gov)

**Supplement to Cal/EPA External Scientific Peer Review Guidelines –  
“Exhibit F” in Cal/EPA Interagency Agreement with University of California  
Gerald W. Bowes, Ph.D.**

**Guidance to Staff:**

1. Revisions. If you have revised any part of the initial request, please stamp “Revised” on each page where a change has been made, and the date of the change. Clearly describe the revision in the cover letter to reviewers, which transmits the material to be reviewed. The approved reviewers have seen your original request letter and attachments during the solicitation process, and must be made aware of changes.
2. Documents requiring review. All important scientific underpinnings of a proposed science-based rule must be submitted for external peer review. The underpinnings would include all publications (including conference proceedings), reports, and raw data upon which the proposal is based. If there is a question about the value of a particular document, or parts of a document, I should be contacted.
3. Documents not requiring review. The Cal/EPA External Peer Review Guidelines note that there are circumstances where external peer review of supporting scientific documents is not required. An example would be "A particular work product that has been peer reviewed with a known record by a recognized expert or expert body." I would treat this allowance with caution. If you have any doubt about the quality of such external review, or of the reviewers' independence and objectivity, that work product – which could be a component of the proposal - should be provided to the reviewers.
4. Implementation review. Publications which have a solid peer review record, such as a US EPA Criteria document, do not always include an implementation strategy. The Cal/EPA Guidelines require that the implementation of the scientific components of a proposal, or other initiative, must be submitted for external review.
5. Identity of external reviewers. External reviewers should not be informed about the identity of other external reviewers. Our goal has always been to solicit truly independent comments from each reviewer. Allowing the reviewers to know the identity of others sets up the potential for discussions between them that could devalue the independence of the reviews.
6. Panel Formation. Formation of reviewer panels is not appropriate. Panels can take on the appearance of scientific advisory committees and the external reviewers identified through the Cal/EPA process are not to be used as scientific advisors.
7. Conference calls with reviewers. Conference calls with one or more reviewers can be interpreted as seeking collaborative scientific input instead of critical review. Conference calls with reviewers are not allowed.

## Guidance to Reviewers from Staff:

### 1. Discussion of review.

Reviewers are not allowed to discuss the proposal with individuals who participated in development of the proposal. These individuals are listed in Attachment 3 of the review request.

Discussions between staff and reviewers are not permitted. Reviewers may request clarification of certain aspects of the review process or the documents sent to them.

Clarification questions and responses must be in writing. Clarification questions about reviewers' comments by staff and others affiliated with the organization requesting the review, and the responses to them, also must be in writing. These communications will become part of the administrative record.

The organization requesting independent review should be careful that organization-reviewer communications do not become collaboration, or are perceived by others to have become so. The reviewers are not technical advisors. As such, they would be considered participants in the development of the proposal, and would not be considered by the University of California as external reviewers for future revisions of this or related proposals. The statute requiring external review of science-based rules proposed by Cal/EPA organizations prohibits participants serving as peer reviewers..

### 2. Disclosure of reviewer Identity and release of review comments.

Confidentiality begins at the point a potential candidate is contacted by the University of California. Candidates who agree to complete the conflict of interest disclosure form should keep this matter confidential, and should not inform others about their possible role as reviewer.

Reviewer identity may be kept confidential until review comments are received by the organization that requested the review. After the comments are received, reviewer identity and comments must be made available to anyone requesting them.

Reviewers are under no obligation to disclose their identity to anyone enquiring. It is recommended reviewers keep their role confidential until after their reviews have been submitted.

### 3. Requests to reviewers by third parties to discuss comments.

After they have submitted their reviews, reviewers may be approached by third parties representing special interests, the press, or by colleagues. Reviewers are under no obligation to discuss their comments with them, and we recommend that they do not.

All outside parties are provided an opportunity to address a proposed regulatory action during the public comment period and at the Cal/EPA organization meeting where the proposal is considered for adoption. Discussions outside these provided avenues for comment could seriously impede the orderly process for vetting the proposal under consideration.

4. Reviewer contact information.

The reviewer's name and professional affiliation should accompany each review. Home address and other personal contact information are considered confidential and should not be part of the comment submittal.

**Murdoch K. McAllister, PhD, Associate Professor in Fisheries Assessment, UBC**

**Qualifications:** PhD, Fisheries Science - 1995, University of Washington Seattle, WA, USA; MSc, Natural Resource Management - 1990, Simon Fraser University Burnaby, B.C., Canada, Honours B.Sc., Behavioural Ecology - 1987, S.F.U.

**Professional Associations:** Scientific Adviser to Deepwater Fisheries Working Group, Namibia 1997-2000, Member of US scientific delegation to the International Commission for the Conservation of Atlantic Tunas 1999-2013, and Canadian Delegation starting in 2008, Member of the ICES scientific working group on Baltic salmon and sea trout 2002-3, Member of the US National Marine Fisheries Service Shark Evaluation Workshop 1998, 2002, Member of the ICES Scientific Working Group on Methods of Stock Assessment 2004. Member of the US SEDAR Gulf of Mexico Red Snapper Stock Assessment Workshop Panel 2004. Chair of the Fraser River White Sturgeon Science and Technical Committee 2011-2012.

**Research and Teaching:** Developing and applying Bayesian statistical methods for fisheries risk assessment, estimation, decision analysis and management strategy evaluation. Applying Bayesian methods to fisheries stock assessment and providing quantitative decision support to non-governmental organizations, corporate clients, intergovernmental organizations, and government agencies. Complex population dynamics, species interactions, and fisheries dynamics modeling. Statistical evaluation of model uncertainty in models fitted to data. Developing management strategy evaluation models for numerous different fisheries. Lectures and workshops at the postgraduate level in applying conventional and Bayesian statistical methods and quantitative decision analysis methods to fisheries management, ecological, environmental, and other related environmental and resource management problems. Current supervision of 7 PhD students, cosupervision of 3 PhD students, and two post doctoral researchers, Drs. Divya Varkey and Tom Carruthers at the UBC Institute for the Oceans and Fisheries and past supervision and co-supervision of fifteen graduated PhD students.

**Appointments**

2006-present Associate Professor & Canada Research Chair in Fisheries Assessment and Statistics, University of British Columbia Fisheries Centre  
 2002-2006 Senior Lecturer in Statistical Risk Assessment, Division of Biology, Imperial College  
 1997 -2002 Lecturer in Statistical Risk Assessment, Dept of Env. Science and Technology, Imperial College  
 1995-1997 Post Doctoral Research Fellow, Centre for Environmental Technology, Imperial College

**Experience:** Two decades of applied statistical modeling. Served as a fisheries stock assessment expert for the National Marine Fisheries Service in stock assessments of large coastal sharks on the U.S. east coast (1998, 2002) and Atlantic swordfish and bluefin tuna from 1999-2008; the ICES Group on Baltic salmon 2002,3; the New Zealand Fishing Industry Board on hoki in New Zealand (1991-1994); the Namibian Government on orange roughy in Namibia (1997-2000); and Department of Fisheries and Oceans, Canada, scientists, on Pacific Cod and rockfish, Atlantic redfish, eulachon, and lingcod in British Columbia (1994-1995, 2007-2017). Applications of Bayesian and other statistical methods also to B.C. pink salmon, yellowfin sole in the eastern Bering Sea, North Sea plaice, B.C. rockfish, white sturgeon, white marlin, Atlantic bluefin tuna, orange roughy, rig, elephantfish, jack mackerel, bluenose and hake in New Zealand, and marbled murrelet in B.C. Developing management strategy evaluation models for the B.C. west coast salmon troll fishery, the Hecate Strait Dungeness crab fishery, and the Gulf of Saint Lawrence redfish fishery. Developing predator-prey interaction models for land-locked sockeye and the Gerrard strain of rainbow trout in large B.C. lakes that predict how the population dynamics of both species are functions of the attributes of the modelled predator-prey interactions, within-population density dependence in growth and survival rates, and variations in the abiotic attributes of the large-lake environment. Developing empirically-based population dynamics models that account for historic variation in predation rates from marine mammals for Pacific rockfishes, Pacific salmon and Atlantic cod.

## Sample Publications

- Bertram, D.F., Drever, M.C., McAllister, M.K., Schroeder, B.K., Lindsay, D., & Faust, D. 2015. Estimation of Coast-wide Population Trends of Marbled Murrelets in Canada Using a Bayesian Hierarchical Model. *PLOS One*. 10(8) 13 p.
- Carruthers, T.R., Walter, J.F., McAllister, M.K., and Bryan, M.D., 2015. Modelling age-dependent movement: an application to red and gag grouper in the Gulf of Mexico. *Canadian Journal of Fisheries and Aquatic Sciences*. 72(8) 1159-1156.
- Carruthers, T.R, Punt, A.E., Walters, C.J., MacCall, A., McAllister, M.K., Dick, E.J., Cope, J., 2014. Evaluating methods for setting catch limits in data-limited fisheries. *Fisheries Research*. 153: 148-168.
- Carruthers, T.,R., Punt, A.E., Walters, C.J., MacCall, A., McAllister, M.K., Dick, E.J., Cope, J., 2015. Evaluating methods for setting catch limits in data-limited fisheries. *Fisheries Research*. 153: 148-168.
- Forrest, R., McAllister, M.K., Martell, S., Walters, C.J. 2013. Modelling the effects of density-dependent mortality in juvenile red snapper caught as bycatch in Gulf of Mexico shrimp fisheries: implications for management. *Fisheries Research*. 146: 102-120
- Kurota, H., McAllister, M.K., Parkinson, E.A., Johnston, N. T. 2016. Evaluating the influence of predator-prey interactions on stock assessment and management reference points for a large lake ecosystem. *Canadian Journal of Fisheries and Aquatic Sciences*. 73:1-17.
- Okamura, H., McAllister, M.K., Ichinokawa, M., Yamanaka, L., and Holt, K. 2014. Evaluation of the sensitivity of biological reference points to the spatio-temporal distribution of fishing effort when seasonal migrations are sex-specific. *Fisheries Research*. 158: 116-123.
- Taylor, N.G., McAllister, M.K., Lawson, G. L. Carruthers, T. and Block, B. A. 2011. Atlantic bluefin tuna: a novel multistock spatial model for assessment population biomass. *PLOS ONE*. 6(12): 1-10.
- Varkey, D., McAllister, M.K., Askey, P., Parkinson, E., Clarke, A., Godin. T., 2016. Multi-criteria decision analytic approach using Bayesian decision network (Stock-optim) for recreational trout fisheries in British Columbia, Canada. *North American Journal of Fisheries Management*. 36:6, 1457-1472.
- Ward, H. Askey, P. Post, J., Varkey, D. McAllister, M.K. 2012. Basin characteristics and temperature improve abundance estimates from standard index netting of small lakes. *Fisheries Research*. 131– 133: 52– 59.
- Whitlock, R.E., McAllister, M.K and Block, B.A. 2012 Estimating fishing and natural mortality rates for Pacific bluefin tuna (*Thunnus orientalis*) using electronic tagging data. *Fisheries Research*. 119-120: 115-127.
- Whitlock, R.E. and McAllister, M.K. 2012. Incorporating spatial and seasonal dimensions in a stock reduction analysis for lower Fraser River white sturgeon (*Acipenser transmontanus*). *Can. J. Fish Aquat. Sci.* 69: 1674–1697.

**Thomas Meixner**

**Professor of Hydrochemistry  
Department of Hydrology and Atmospheric Sciences  
University of Arizona, Tucson, Arizona 85721**

**Professional Preparation:**

University of Arizona	Hydrology and Water Resources	PhD 1999
University of Maryland	Soil and Water Conservation	B.S. 1992
University of Maryland	History of Science and Technology	B.A. 1992

**Appointments:**

**2012-Present** - Professor, Dept. of Hydrology and Atmospheric Sciences, University of Arizona

**2005-2012** Assoc. Prof., Dept. of Hydrology and Water Resources, University of Arizona

**1999-2004** Asst. Prof. Dept. of Env. Sciences, UC Riverside

**Related publications (55 total)**

Guido, Z., McIntosh, J. C., Papuga, S. A., & Meixner, T. (2016). Seasonal glacial meltwater contributions to surface water in the Bolivian Andes: A case study using environmental tracers. *Journal of Hydrology: Regional Studies*, 8, 260-273.

Simpson, S. C. and Meixner, T. (2012), The influence of local hydrogeologic forcings on near-stream event water recharge and retention (Upper San Pedro River, Arizona). *Hydrol. Process.* doi: 10.1002/hyp.8411

Simpson, S. C., Meixner, T., & Hogan, J. F. (2013). The role of flood size and duration on streamflow and riparian groundwater composition in a semi-arid basin. *Journal of Hydrology*, 488, 126-135.

Meixner, T., Manning, A. H., Stonestrom, D. A., Allen, D. M., Ajami, H., Blasch, K. W., ... & Flint, A. L. (2016). Implications of projected climate change for groundwater recharge in the western United States. *Journal of Hydrology*, 534, 124-138.

Meixner T, PD Brooks, JF Hogan, C Soto-Lopez, and SC Simpson, (2012), Carbon and nitrogen export from semiarid uplands to perennial rivers: Connections and missing links San Pedro River Arizona, USA, *Geography Compass*, 9(6), p. 546-559.

**Other Significant Publications**

Niraula, R., Meixner, T., & Norman, L. M. (2015). Determining the importance of model calibration for forecasting absolute/relative changes in streamflow from LULC and climate changes. *Journal of Hydrology*, 522, 439-451.

Ajami, H., P. A. Troch, T. Maddock III, T. Meixner, and C. J. Eastoe (2011), Quantifying mountain block recharge by means of catchment-scale storage-discharge relationships *Water Resour. Res.*, doi:10.1029/2010WR009598.

Simpson SC and T Meixner, (2012), Modeling effects of floods on streambed hydraulic conductivity and groundwater-surface water interactions, *Water Resources Research*, 48-DOI:10.1029/2011WR011022.

Gallo, E. L., Meixner, T., Aoubid, H., Lohse, K. A., & Brooks, P. D. (2015). Combined impact of catchment size, land cover, and precipitation on streamflow and total dissolved nitrogen: A global comparative analysis. *Global Biogeochemical Cycles*, 29(7), 1109-1121.

Gallo, E. L., Lohse, K. A., Ferlin, C. M., Meixner, T., & Brooks, P. D. (2014). Physical and biological controls on trace gas fluxes in semi-arid urban ephemeral waterways. *Biogeochemistry*, 121(1), 189-207.

#### **Five Synergistic Activities:**

Served on Tucson Water Citizens Advisory Water Committee (CWAC).

Public Talks - at Biosphere 2 to Upper San Pedro Partnership. and Tucson Water CWAC on "Climate Change and Sources of Water to Rivers in Arizona".

Fall 2009 AGU Hydrology section program chair

Associate Head of Department of Hydrology and Water Resources

Coordinated Riparian Biogeochemistry work for the NSF-Science and Technology Center based at the University of Arizona, SAHRA.

#### **Collaborators & Co-Editors**

Co-authors and co-investigators E. B. Allen (UCR), J. Baron (USGS), L. A. Bastidas (USU), A. D. Brown (LA-City College), D. H. Campbell (USGS), D. W. Clow (USGS), M. Fenn (USFS), H. V. Gupta (UA), B. Hibbs (CSULA), C. Kendall (USGS), J. Melack (UCSB), M. Poth (USFS), S. Sorooshian (UCI), J. Sickman (UCR), J. Schimel (UCSB), M. Thiemens (UCSD), M. W. Williams (CU-Boulder),.

**Post-Doctoral Scholars (5)** Adion Chinkuyu (City of Washington DC), Ann van Griensven (UNESCO-IHE), Yvonne Wood (Univ. of Calif), Xuyong Li (SERC), Fengming Yuan (UAF)

**Graduate Advisees (14)** Jennifer Wilson (UIUC), Kristi Bubb (ERG), Bridgette Valeron (BP), Carlos Soto (UA), Lissette de La Cruz (UA), Scott Simpson (UA), Caitlan Zlatos (UA), Jessica Driscoll (UA), Samantha Treese (UA), Navid Dejwakh (UA), Melanie Lindsey (UA), Iman Mallakapour (UA), Hadi Aoubid (UA), Kirsten Neff (UA).

#### **Thesis Advisor and Postdoctoral-Scholar Sponsor**

Ph.D. Advisor: Roger Bales (UC Merced)

Postdoctoral Advisor: none

**THOMAS J. MILLER**  
Chesapeake Biological Laboratory  
University of Maryland Center for Environmental Science  
Solomons, MD 20688-0038  
Tel : (410) 326-7276  
Email : miller@umces.edu  
WWW : hjort.cbl.umces.edu

Education:

- 1990 Ph.D. North Carolina State University, Zoology (Oceanography minor)
- 1984 M.S. North Carolina State University, Ecology
- 1981 B.Sc. (Hons). University of York, Human and Environmental Biology

Professional Background:

- 2011-present Director, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science
- 2006-present Professor, Chesapeake Biological Laboratory
- 2000-2006 Associate Professor, Chesapeake Biological Laboratory
- 1994-2000 Assistant Professor, Chesapeake Biological Laboratory
- 1990-1994 Post-doctoral Fellow, McGill University, Montreal

Awards and Special Recognition:

- 2015 Excellence in Fisheries Education. Tidewater Chapter, American Fisheries Society.
- 2015 Regents Faculty Award of Excellence. University System of Maryland Board of Regents.
- 2014 Mercer Patriarche Award for Best Paper of the Year. American Fisheries Society
- 2014 GEMSTONES Outstanding Mentor Award. GEMSTONES Honors Program, University of Maryland.
- 2008 Graduate Education Award for Excellence in Teaching. MEES Graduate Student Association, University of Maryland
- 2001 President's Award for Excellence in the Application of Science. University of Maryland Center for Environmental Science.
- 1998 Graduate Education Award for Excellence in Teaching. MEES Graduate Student Association, University of Maryland

Five most recent products

- Glandon, H. L. and T. J. Miller. 2016. No effect of high pCO<sub>2</sub> on juvenile blue crab, *Callinectes sapidus*, growth and consumption despite positive response to concurrent warming. *ICES Journal of Marine Science*.00:000-000.
- Rains, S. A. M, M. J. Wilberg and T. J. Miller. 2016. Sex-ratios and average sperm per female blue crab in six tributaries of Chesapeake Bay. *Marine and Coastal Fisheries*. 8(1):492-501. DOI:10.1080/19425129.2016/1208126.
- Ludsin, S., K. M. DeVanna Fussell, R. E. H. Smith, M. E. Fraker, L. Boegman, K. T. Frank, T. J. Miller, J. T. Tyson, K. K. Arend, D. Boisclair, S. J. Guildford, R. E. Heckey, T. O. Hook, O. P. Jensen, J. K. Llopiz, C. J. May, R. G. Najjar, L. G. Rudstam, C. T. Taggart and Y. R. Rao. 2016. A perspective on needed research, modeling, and management approaches that can enhance Great Lakes fisheries management under changing ecosystem conditions. *Journal of Great Lakes Research*. 42:743-752.
- Buchheister, A., T. J. Miller, E. D. Houde, D. H. Secor, R. J. Latour. 2016. Spatiotemporal dynamics of Atlantic menhaden (*Brevoortia tyrannus*) recruitment along the Northwest

Atlantic Ocean. ICES Journal of Marine Science 73(4):1147-1159. DOI 10.1093/icesjms/fsv260.

Wiedenmann, J., M. J. Wilberg, A. Sylvia, T. J. Miller. 2015. Autocorrelated error in stock assessment estimates: Implications for management strategy evaluations. Fisheries Research. 172:325-334. DOI 10.1016/j.fishres.2015.07.037.

#### Five other related products

- McDermott S. P., N. C., Bransome, S. E. Sutton, B. E. Smith, J. S. Link and T. J. Miller. 2015. Quantifying the contribution of diadromous species to the diets of marine predators in the Gulf of Maine. Journal of Fish Biology 86:1811-1829. DOI: 10.1111/jfb.12692. .
- Colton, A. R., Wilberg, M. J., V. J. Coles and T. J. Miller. 2014. An evaluation of the synchronization in the dynamics of blue crab populations in the western Atlantic. Fisheries Oceanography. 23:132-146. DOI: 10.1111/fog.12048
- Peer, A. C. and T. J. Miller. 2014. Climate change, migration phenology and fisheries management interact with unexpected consequences. North American Journal of Fisheries Management 34:94-110. DOI: 10.1080/02755947.2013.847877
- Frisk, M. G., A. Jordaan and T. J. Miller. 2014. Moving beyond the current paradigm in marine population connectivity: Are adults the missing link? Fish and Fisheries. 15:242-254. DOI: 10.1111/faf.12014.
- Huggett, R. J., J. J. Anderson, M. E. Campana, T. Dunne, J. Gilbert, A. E. Giorgi, C. A. Klein, S. N. Luoma, M.J. McGuire, T. J. Miller, S. G. Monismith, J. Obeysekera, H. W. Paerl, M. J. Pfeffer, D. J. Reed, K. A. Rose and D. D. Tullios, H. J. Vaux. 2012. Sustainable Water and Environmental Management in the California Bay-Delta. National Research Council. National Academies Press, Washington, DC. 260p.

#### Synergistic activities

1. Governor Appointee, Board of the Chesapeake Bay Trust (2013 – present)
2. Governor Appointee, Patuxent River Commission (2013 – present)
3. Chesapeake Bay Stock Assessment Committee (1999- present);
4. NOAA Mid-Atlantic Fishery Management Council's Scientific and Technical Committee member (2001-present, Vice-Chair 2009-present);
5. Atlantic States Marine Fisheries Commission Management and Science Committee (2006-present)
6. Scientific Advisor, Potomac River Fisheries Commission (2006 – present).
7. National Academies of Science Committee to Evaluate the NMFS Marine Recreational Information Program (Jan – Dec 016)
8. National Research Council. Bay Delta Conservation Plan Review Panel (2010 – 2012)
9. National Research Council. Panel of San Francisco Bay and Delta (2010 – 2012)

Graduate Students and Post-doctoral Fellows: **MS:** L. J. Bauer, K. K. Brewster-Geisz, B. J. Brylawski, V. Caceres, M. A. Chenery, J. M. Coakley, A. R. Colton, K. L. Curti, J. E. Edwards, E. A. Evarts, M. G. Frisk, C. J. Heyer, O. P. Jensen. A. Kauffman, D. Zaveta. **current:** N. Mehaffie, – **PhD:** L. O. Alade, M. G. Frisk, M. S. Kendall, J. A. Nye, A. Peer. **current:** R. Brodnik, H. A. Lane – **Post-doc** A. Buchheister, D. B. Bunnell, M. G. Frisk, T. Ihde, E. Karakoylu. **Current**

Advisors: **MS** – S. Mozley (NCSU, Retired), **Ph.D.** L. B. Crowder (NCSU, now Stanford

University), **Post-doc.** W. C. Leggett (McGill, now Emeritus Prof. Queens Univ. Ontario)

**N. LeROY POFF**

Department of Biology  
Colorado State University  
Fort Collins, CO 70523-1878

Phone: 970-491-2079 (office)  
FAX: 970-491-0649  
E-mail: n.poff@colostate.edu  
<http://rydberg.biology.colostate.edu/poff/>

**RESEARCH INTERESTS AND EXPERTISE**

- Stream and riverine ecology, environmental flows and river ecosystem sustainability, climate change adaptation

**PROFESSIONAL PREPARATION**

Hendrix College, Biology B.A., 1978  
Indiana University, Bloomington, Environmental Science M.S., 1983  
Colorado State University, Biology Ph.D., 1989  
University of Maryland Ecology Post-doc, 1990-1992

**PROFESSIONAL APPOINTMENTS**

1997 – present Full (2007-present), Associate (2002-2007) and Assistant (1997-2002) Professor, Department of Biology, CSU  
2016 – present Professorial Chair of Riverine Ecology and Environmental Flows, University of Canberra, Australia (partial, salaried appointment)  
2008 – 2016 Director, Graduate Degree Program in Ecology, Colorado State University  
1992 – 1997 Research Scientist, Department of Zoology, University of Maryland  
1996 – 1997 Senior Scientist, Trout Unlimited, Arlington VA

**PUBLICATIONS** (of >125 peer-reviewed articles and book chapters):

**Poff NL**, Schmidt JC. 2016. How dams can go with the flow: Small changes to water flow regimes from dams can help to restore river ecosystems. *Science* 353:7-8.  
**Poff NL**, Brown C, Grantham T + 8 others. 2016. Sustainable water management under future uncertainty with eco-engineering decision scaling. *Nature Climate Change* 6:25-45.  
Pyne M, **Poff NL**. 2017. Vulnerability of stream community composition and function to projected thermal warming and hydrologic change across ecoregions in the western United States. *Global Change Biology*, 23:77-93.  
**Poff NL**, Tharme R, Arthington A. Evolution of e-flows principles and methodologies. 2017. Pages XXX-XXX in A. Horne, A. Webb, M. Stewardson, B. Richter and M. Acreman (eds.), Water for the environment: Policy, Science, and Integrated Management. Elsevier Press. (in press)  
Wohl EE, Bledsoe B, Jacobson R, **Poff NL**, Rathburn S, Walters D, Wilcox A. The natural sediment regime in rivers: broadening the foundation for ecosystem management. *BioScience* 65:358-371.  
McCluney KE, **Poff NL**, et al. 2014. Riverine macroecology: a framework for understanding the sensitivity, resistance, and resilience of large river basins and responses to multiple human alterations. *Frontiers in Ecology & Environment* 12:48-58  
**Poff NL**, Olden JD, Strayer DS. 2012. Climate change and freshwater extinction risk. Pp 309-336 in *Saving a Million Species: Extinction Risk from Climate Change* (L Hannah, Ed.), Island Press.  
**Poff NL** +18 others. 2010. The Ecological Limits of Hydrologic Alteration (ELOHA): a new framework for developing regional environmental flow standards. *Freshwater Biology* 55:147-170.  
**Poff NL**, Zimmerman JKH. 2010. Ecological responses to altered flow regimes: a literature review to inform environmental flows science and management. *Freshwater Biology* 55:194-205.  
**Poff NL**, Olden JD, Merritt DM, Pepin D. 2007. Homogenization of regional river dynamics by dams and global biodiversity implications. *Proc. Natl. Acad. Sci.* 104:5732-5737.  
Arthington AH, Bunn SE, **Poff NL**, Naiman RJ. 2006. The challenge of providing environmental flow rules to sustain river ecosystems. *Ecological Applications* 16:1311-1318.  
**Poff NL**, Olden JD, Pepin DM, Bledsoe BP. 2006. Placing global streamflow variability in geographic and geomorphic contexts. *River Research & Applications* 22:149-166.

**Poff NL**, Bledsoe BD, Cuhaciyan CO. 2006. Hydrologic variation with land use across the contiguous United States: geomorphic and ecological consequences for stream ecosystems. *Geomorph.* 79:264-285.  
Lytle DA, **Poff NL**. 2004. Adaptation to natural flow regimes. *Trends in Ecol. & Evol.* 19:94-100.  
**Poff NL**, JD Allan, M Bain, J Karr, K Prestegard, B Richter, R Sparks, J Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. *BioScience* 47:769-784.  
**Poff, NL**, JD Allan. 1995. Functional organization of stream fish assemblages in relation to hydrologic variability. *Ecology* 76:606-627.

#### **AWARDS and ACTIVITIES**

Fellow, American Association for the Advancement of Science, 2012 (elected)  
Fellow, Ecological Society of America, 2016 (elected)  
Aldo Leopold Fellow, Ecological Society of America (One of 20 nationwide in 2004)  
President (elected), Society for Freshwater Science, 2006-2007. Past-President 2007-2008  
ISI Highly Cited Researcher (NL Poff on Web of Science), H-factor of 52 and 17,730 citations as of March 2017. Google Scholar H-factor of 63 and 32,622 citations [\[link\]](#)  
Scholarship Impact Award, Colorado State University, 2016. Sole university-wide recipient.  
Laureate, College of Natural Sciences, Colorado State University, 2010-2011  
Monfort Professor, Colorado State University (one of two university-wide), 2005-2006

#### **ACTIVE GRANTS**

National Science Foundation (Dimensions of Biodiversity (DEB-1046408) \$2,999,320. April 2011 – March 2017. “An Integrative Traits-Based Approach to Predicting Variation in Vulnerability of Tropical and Temperate Stream Biodiversity to Climate Change.” N.L. Poff (lead PI), with 8 co-PIs at CSU, Cornell, and Univ. Nebraska and in Ecuador  
National Science Foundation, RAPID (DEB-1434782), \$200,000. May 2014 – April 2016. “Effects of an Extreme Disturbance Event on Genomic Variation and Community Organization of Stream Insects.” N.L. Poff (PI), with co-PIs Chris Funk and Boris Kondratieff (CSU), and Alex Flecker (Cornell)  
National Science Foundation (IGERT, DEG-0966346) \$2,728,060. July 2010 – June 2017. “IGERT: WATER - Integrated Water, Atmosphere and Ecosystem Education and Research.” Jorge Ramirez (PI)

#### **RELEVANT SERVICE TO STATE AND FEDERAL ENTITIES**

State of California, Adaptive Management Forum (member) to review success of 3 CALFED-sponsored river restoration projects in the Central Valley, California, 2001-2003  
State of California, Scientific Steering Committee (member) for State of California Biological Objectives, directed by the Southern California Coastal Water Research Project, 2010-2013  
King County (Seattle), Washington, Science Review Team (member) for Normative Flows Project, King County Government, March 2002 - December 2005  
State of Massachusetts, final technical review for Department of Environmental Protection in support of the “Sustainable Water Management Initiative: Final Framework” [\[link\]](#)  
State of Florida, Department of Environmental Protection, contracted technical reviewer for prepared expert testimony to support Florida’s legal claim of “ecological impairment” of Apalachicola River and Floodplain caused by upstream hydrologic alteration by State of Georgia  
Reviewer for *The Connecticut River flow restoration study, a watershed-scale assessment of the potential for flow restoration through dam re-operation*, a 5-year study co-produced by The Nature Conservancy, US Army Corps of Engineers, U. Mass. Amherst and US Geological Survey  
Reviewer for 2016 *EPA-USGS Technical Report: Protecting Aquatic Life from Effects of Hydrologic Alteration*, U.S. Geological Survey Scientific Investigations Report 2016–5164, U.S. Environmental Protection Agency EPA Report 822-R-156-007, 156 pages [\[link\]](#)  
Potomac River Commission, Science Committee (member) for Potomac River “Flow-by” Policy, Potomac MD, April 2003  
State of Colorado – Non-consumptive flow needs modeling - Consultant to Colorado Water Conservation Board to develop a model framework for state-wide use in Non-consumptive Needs Assessment, as directed by the Colorado State Legislature

**Biographical Sketch – Elowyn Yager**  
**Faculty, Center for Ecohydraulics Research**  
**University of Idaho**

**Professional Preparation**

State University of New York at Buffalo, Buffalo, NY	Geology	B.A. 1998
University of California at Berkeley, Berkeley, CA	Geology	Ph.D. 2006
Arizona State University, Tempe, AZ	Geomorphology Postdoc	2006-2007

**Appointments**

- 2013 – Present: Associate Professor, Dept. of Civil Engineering, Center for Ecohydraulics Research  
University of Idaho, Boise, ID
- 2007 – 2013: Assistant Professor, Dept. of Civil Engineering, Center for Ecohydraulics Research  
University of Idaho, Boise, ID
- 2006 – 2007: Postdoctoral Scholar, Dept. of Geography, Arizona State University, Tempe, AZ
- 1998 – 2006: Graduate Student Researcher and Instructor, Dept. of Earth and Planetary Science,  
Berkeley, CA
- 1996 – 1998: Research Assistant, Dept. of Geology, SUNY at Buffalo, NY

**Five Products Most Closely Related to Proposed Project**

- Yager, E.M., J. Turowski, D. Rickenmann and B.W. McArdell (2012), Sediment supply, grain protrusion, and bedload transport in mountain streams, *Geophysical Research Letters*, 39, L10402, doi:10.1029/2012GL051654.
- Yager, E.M., W.E. Dietrich, J.W. Kirchner, and B.W. McArdell, (2012), Predictions of sediment transport in step-pool channels, *Water Resources Research*, 48, W01541, doi:10.1029/2011WR010829.
- Yager, E.M. and M.W. Schmeeckle, (2013) The influence of vegetation on turbulence and bedload transport, *JGR-Earth Surface*, 118, 1-17, DOI: 10.1002/jgrf.20085.
- A. Monsalve, E.M. Yager, J. Turowski, and D. Rickenmann, (2016) A probabilistic formulation of bed load transport to include spatial variability of flow and surface grain size distributions, *Water Resources Research*, 52, 3579–3598, doi:10.1002/2015WR017694.
- Buxton, T.H., J.M. Buffington, E.M. Yager, M.A. Hassan and A.K. Fremier, (2015) The Relative Stability of Salmon Redds and Unspawned Stream Beds, *Water Resources Research*, 51, 6074–6092, doi:10.1002/2015WR016908.

**Five Other Significant Products**

- Yager, E.M., W.E. Dietrich, J.W. Kirchner, and B.W. McArdell, (2012), Patch dynamics and stability in steep, rough streams, *JGR-Earth Surface*, 117, F02010, doi:10.1029/2011JF002253.
- Yager, E.M., J.W. Kirchner, and W.E. Dietrich (2007), Calculating bedload transport in steep, boulder-bed channels, *Water Resources Research*. 43, W07418, doi:10.1029/2006WR005432.
- Yager, E.M., M. Kenworthy, and A. Monsalve (2015), Taking the river inside: Fundamental advances from laboratory experiments in measuring and understanding bedload transport processes, *Geomorphology*, 244, 21-32, doi:10.1016/j.geomorph.2015.04.002.
- J. D. Pelletier, A.B. Murray, J.L. Pierce, P.R. Bierman, D.D. Breshears, B.T. Crosby, M. Ellis, E. Foufoula-Georgiou, A.M. Heimsath, C. Houser, N. Lancaster, M. Marani, D.J. Merritts, L.J. Moore, J.L. Pederson, M.J. Poulos, T.M. Rittenour, J.C. Rowland, P. Ruggiero, D.J. Ward, A.D. Wickert, and E.M. Yager, (2015), Forecasting the response of Earth’s surface to future climatic and land-use changes: A review of methods and research needs, *Earth’s Future*, doi: 10.1002/2014EF000290.

J. Turowski, E. Yager, A. Badoux, D. Rickenmann, P. Molnar, (2009), The impact of exceptional events on erosion, bedload transport and channel stability in a step-pool channel, *Earth Surface Processes and Landforms*, 34, 1661-1673.

### **Synergistic Activities**

- Reviewer for Journal of Geophysical Research, Earth Surface Processes and Landforms, Geomorphology, Geology, River Research and Applications, Water Resources Research, Geophysical Research Letters, Geology, and NSF (ad-hoc reviewer yearly, 4 panels to date).
- Organizer of Fall AGU meeting sessions in 2011-2015.
- STEM courses created: CE535 Fluvial Geomorphology (3cr), CE507 River Restoration (3cr), CE504 Reading, Writing and Communicating Scientific Content (3cr), and CE 504 CER Keystone Course (3cr).
- K-12 outreach through the Boise Watershed, Women in Science and Math Program, Women in Engineering, Teacher Outreach at the McCall Outdoor Science School. I have also helped develop and fund a math and science camp for middle and high school girls (WoWS).
- Member of 2011 NSF sponsored scientific panel to write a white paper for the Geomorphology community on SEES funding opportunities and strategies.

Review by Murdoch McAllister, PhD

Associate Professor in Fisheries Assessment and Statistics

Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, B.C.

Key term of reference:

The reviewer's responsibility is to:

*determine whether the scientific portion of any proposed rule is based on sound scientific knowledge, methods, and practices.*

May 24, 2017

**Review Conclusion 1. Significant changes have occurred to the hydrology and hydrodynamics of the main stem of the Sacramento River and its tributaries, Delta eastside tributaries, and the Delta.**

Chapter 2 of the Scientific report characterizes the attributes of the hydrology of the Sacramento River (SR), its tributaries, associated SR delta (Delta) area three east side tributaries to the Delta.

Current and recent historic hydrological conditions are compared with so-call “unimpaired conditions” to characterize the various changes in the flow regime that have occurred.

Section 2.1 Introduction

The hydrological analysis was carried out in this chapter lead to the following conclusions (from section 2.1):

- 1) Diversions and exports of water from the SR and its tributaries have reduced average annual outflow, reduced winter and spring outflow, and reduced seasonal variability.
- 2) Water development in regulated tributaries has resulted in reduced annual Delta inflow of water, a reduction in spring inflow, an increase in summer inflow and a decrease in hydrologic variability.
- 3) Tributaries without large reservoirs have lower flows in late spring and summer relative to unimpaired flows.
- 4) Project pumping in the south Delta and associated operations have increased the magnitude and frequency of reverse (upstream) flows on the Old and Middle Rivers.

Section 2.1.1 Natural and Unimpaired flow.

Definitions were provided of key terms:

1. Unimpaired flow represents an index of the total water available to be stored or put to any beneficial use within a watershed under prevailing physical conditions and land uses.
2. Natural flow represents flow that would have occurred absent human development of land and water supply. It is reasonably mentioned that “estimating natural flow requires assumptions about many physical attributes of the pre-development landscape, including the distribution of wetland and riparian vegetation, channel configurations, detention of overbank flows, and groundwater accretions. All of these conditions differ from the current physical condition and land use of the watershed to unknown degrees”.

Summary plots of model-produced quantile distributions of natural and unimpaired flows at two different Rim Dam locations are show in Figure 2.1-1. It is reasonably stated that the monthly flow trajectories show similar patterns but different magnitudes, e.g., with less extreme minimums and maximums in the natural flows compared to the unimpaired flows in one of two different Rim Dam locations. It is also appropriate that quantile distributions were shown to indicate the model generated uncertainty in the monthly flow trajectories. Summary plots of Delta inflow (Figure 2.1-2) and Delta

outflow for historic, natural and unimpaired flows over different historic periods show large differences especially between historic flows and the projected unimpaired and natural flows. In the most recent time block 2000-2014, the unimpaired flows are considerably higher than the natural flows and the actual flows are considerably less than the model projected natural flows from January through to May which spans the main months of juvenile anadromous salmon outmigration to the ocean.

The relationships between unimpaired and natural flows within the context of the geology, human modifications of the river basin, and ecology of the SR are subsequently discussed. It is for example mentioned that the differences between unimpaired and natural flows could be expected to be the “substantial at times” in the valley floor and Delta where considerably more significant development has occurred compared to the upper watershed. It is reasonably mentioned that the differences cannot be known with certainty.

The report mentions that recent published works have provided estimates of

- (1) evapotranspiration by pre-development natural vegetation (Howes et al. 2015),
- (2) the net Delta outflow as a function of these estimates of evapotranspiration and other attributes of hypothetical pre-development conditions, and
- (3) water flow the Bay-Delta watershed (DWR 2016a).

Estimates of the pre-development natural flow were “produced by routing historical unimpaired flows from the upper watersheds over a hypothetical, reconstructed valley floor and Delta”. It is mentioned that DWR (2016a) concludes that

1. “relative seasonal ... distributions of unimpaired and natural Delta outflow are not widely different” and
2. “unimpaired flow estimates are poor surrogates for natural flow conditions” due to differences in annual magnitude between estimates of unimpaired flow estimates and natural flow reconstructions.

The report points out two dominant flow patterns (page 2-12):

1. In watersheds with reservoirs, winter and spring runoff peaks are now lower and summer flows are now higher and warmer.
2. In watersheds without reservoirs but with substantial land use development, winter and early spring flows typically resemble unimpaired flows, and late spring through fall flows are reduced by direct diversion, mainly for irrigation.

Results from the SacWAM model were used to illustrate the hydrology under current conditions and unimpaired conditions rather than observed data. This was because stream gauges have not been located at the mouth of the tributaries. Because the SacWAM model and its results have previously been peer-reviewed, it is presumed that the results presented in Chapter 2 are all credible.

The flow regimes of different tributary and main stem watershed components are characterized throughout the main body of the chapter. A very few comments are provided on this part of the chapter.

For the Delta flow analysis, a modeling tool had been developed to estimate net delta outflow (NDO) and dayflow (NDOI). The chapter provides a review of some of the accuracy issues with these indices and outline ongoing work to seek to improve accuracy in these indices, both through research on modeling and improvements to monitoring.

For the Delta flow analysis, a second important variable is an index for the position of fixed salinity index value which indicates the extent of freshwater outflow into the estuary, called "X2". A high value reflects a low freshwater flow into the estuary. "Work by USFWS (Figure 2.4-12; USFWS 2011) has shown that since 1967 fall X2 has increased and variability has decreased through time." (2-79)

"[B]ased on increases through time in the storage and release of water, analysis for the entire 91 years showed increases in X2 through time (i.e., more salt water intrusion) during the period when water is most typically stored (November–June) and decreases in X2 (i.e., less salt water intrusion) during dry months when water is typically released from storage (August and September)." (2-80)

My first concern with the work directly presented in Chapter 2 was that the majority of flow estimates for the river basic components examined were provided through models that were fitted to various types of hydrological data but without showing fits to any of the data. It is common in other North American regions for there to be nearly continuous real-time monitoring of river flow volume and river levels which can be readily accessed on line. For example in western British Columbia, this is done on several dozen rivers of various sizes and locations throughout the region. The records of these flows and river levels show very predictable hour-to-hour variation in response to drought, rainfall and snowmelt events and very strong seasonality. I would have preferred to see for some of the depictions of model predictions of flow for some of the watershed components, the fit of the model prediction of flow to records of flow from in-river flow meters which must exist. This would have given me more assurances that the model predictions of flow at least in the last few decades when it is likely that such flow meters have been installed and working consistently actually predicted empirical measurements of flows on a monthly and annual basis.

A second concern is that the natural flow modeling for the river system components has been based on a set of assumptions about pre-development vegetation, river basin geomorphology, and riparian habitat structure for which no detailed records exist. I would have preferred to have seen some representations of how natural flow results were sensitive to different assumptions about the configuration of pre-development vegetation, river basin geomorphology and riparian habitat structure.

A third concern is that the main focus of evaluation of historic and recent flow patterns was on model-predicted unimpaired flow patterns. I believe it would have been also appropriate to attempt to compare throughout for the different watershed components model predicted flow patterns from a pre-development flow regime also. This is because it is likely that all native fishes have life history attributes

that have been at least partly shaped by and adapted to the pre-development flow regime and not the recent historic unimpaired flow regime.

In my view, apart from some minor concerns outlined above, the scientific portion of the regulatory actions following from Review Conclusion 1 are based on sound scientific knowledge and flow dynamics modeling methods that have been peer reviewed in workshops, meetings, reports and journal articles.

**Review Conclusion 2: Changes to the flow regime of the Sacramento River and its tributaries and the eastside tributaries to the Delta, Delta outflows, cold water habitat, and interior Delta flow conditions have contributed to the impairment of the ecosystem and native fish and wildlife beneficial uses and could contribute to future impairments without additional regulations.**

#### **Literature review.**

Numerous journal articles are cited that have found that the risk of ecological change from pre-development conditions increases and that fish abundance and diversity can deteriorate as flow regimes deviate more substantially in magnitude and pattern from natural flow conditions. A significant point made was as follows:

“Studies of river-delta-estuary ecosystems in Europe and Asia concluded that water quality and fish resources deteriorate beyond their ability to recover when spring and annual water withdrawals exceed 30 and 40–50 percent of unimpaired flow, respectively (Rozenfurt et al. 1987). Upstream diversions and water exports in the Delta have reduced median January to June and average annual outflow by 56 and 48 percent, respectively (Chapter 2; Fleenor et al. 2010).” (3-2)

The report makes an argument that retaining features of natural flow variations and patterns is essential for maintaining genetic diversity within native fish species and backs this up by citing peer-reviewed articles. However, the report goes further:

“Continuing to support those adaptations of genetic and life-history diversity through providing more naturally variable flows is an important management strategy in addressing climate change effects. This is particularly important for salmonid species, but also applies to the aquatic ecosystem as a whole, including the food web and other native warm and cold water fish communities.” (3-3)

The assertion that naturally variable flows helps to maintain the native and pre-development aquatic ecosystem and native non-salmonid fishes however was not backed up with references to peer-reviewed work.

The report emphasizes the findings of numerous studies that have found positive relationships between the abundance of numerous estuarine species and freshwater inflow into the Delta:

“Statistically significant inverse relationships have been demonstrated between the landward extent of X2 and the abundance of a diverse array of estuarine species ranging from phytoplankton-derived particulate organic carbon at the base of the food web through primary consumers, benthic fish, pelagic fish and piscivores (Jassby et al. 1995; Kimmerer 2002b; MacNally et al. 2010). The diverse taxonomy, biology, and distribution of these estuarine organisms showing these strong relationships indicates a broad positive response of the estuarine community to increasing outflow (Jassby et al. 1995). The X2-abundance relationships of many estuarine species have persisted since systematic sampling programs began in 1967.” (3-7)

“Evidence exists that migrating juvenile salmonids may use hydraulic, celestial (e.g., sun position), magnetic, and chemical (e.g., salinity) cues to direct their downstream migrations and navigate through

tidally dominated estuaries and bays (Williams 2006). Consequently, the greatly altered hydrology, migratory pathways, hydrodynamics, and salinity gradients of the Delta and estuary are considered stressors for successful spawning migration of adults and downstream migration of juveniles native salmon, steelhead, sturgeon, and lampreys.” (3-11)

### **Delta water export impact on fishes**

“In addition to high rates of predation that occur at the fish screens, much “indirect” mortality is thought to occur before fish enter the facilities at all, in the sloughs and channels leading to the export facilities. Small fish drawn into this part of the Delta, or which migrate in inappropriate directions to changes in channel flows have a very low chance of survival. Juvenile salmon from the Sacramento River, including listed winter- and spring-run salmon, steelhead, and green sturgeon enter the central Delta through the DCC or Georgiana Slough and have a lower chance of survival than fish staying in the Sacramento River’s main stem. (ERP 2014)” (3-12).

### **Methods to identify critical flow levels required to support native species**

1. Flow-abundance relationships: following the general methodology of Jassby et al. (1995) and Kimmerer (2002b), staff estimated the relationship between the logarithm of seasonal average Delta outflow and the respective species abundance indices using the most recent data available. Following the methods of Kimmerer (2002b), staff incremented abundance indices containing zero values for the purposes of this analysis and included one or more step changes for species that experienced a substantial decline immediately following the introduction of *Potamocorbula* or the pelagic organism decline. The regression was then used to predict the flow associated with the abundance goal. Staff did not use this method if the predicted flow fell outside of the range of the observed flow data.

2. Cumulative frequency distributions of flow: if staff could identify a period of years during which the abundance goal was attained and the population was not in decline, the median of the seasonal average flows over that period was used as an indicator of the flow that would be protective of the species.

3. Logistic regression estimates of the probability of population growth: for species that spawn predominantly at a single age, logistic regression was used to estimate the response of generation-over-generation population growth to seasonal average flow (TBI/NRDC 2010a). For a given population index  $N$ , the growth rates were estimated as  $N(t)/N(t-L)$ , where  $L$  is the age of reproduction. These rates were converted to a binary variable (1=growth, 0=decline) and regressed on the logarithm of average seasonal outflow using a general linear model with a logit link function. Staff interpreted the flow that predicted a fifty percent probability of population growth as a threshold flow that would benefit the species. (3-13)

One problem of identifying flow that gives 50% probability of population growth or desired population level from evaluation of the relationship between only the main focal variable of interest historic flows and population abundance: it is well-established that other factors unrelated to flow that also determine rate of population growth abundance over and above flow or in concert with flow, e.g. prey abundance, predator abundance, and other physical habitat attributes. For example for longfin smelt:

“As discussed in Chapter 4, multiple stressors in addition to flow may be responsible for the decline

(Sommer et al. 2007).” (3-53)

For delta smelt:

“The CDFW (2016d) hypothesizes that increased survival in summer may result from an increase in the quantity and quality of available food, a decrease in the magnitude and frequency of toxic cyanobacterial blooms, a reduction in ambient water temperature and a reduction in the risk of predation with an increase in summer flow.” (3-75)

Should the other factors that support the target population abundance be at different values than were the case where the flow attributes were identified, then the same future flows may be either excessive or insufficient, depending on how the set of environmental factors act in concert. In some of the evaluations other covariates were actually included in the statistical analyses. As mentioned, the presence of the introduced species, *Potamocorbula*, or the pelagic organism decline were included as explanatory factors for target species abundance. In some other instances, juvenile abundance was related to both flow volumes and also parental stage abundance to better identify the flow-abundance relationship. Thus, where possible some additional covariates and factors were appropriately introduced to enable more precise and accurate definition of the relationship between population abundance or rate of population change and flow volume.

“Rearing by juvenile Chinook salmon in the Bay-Delta appears to be an important life history component based on otolith microchemistry analysis and broad evidence from other estuaries (Reimers 1973; Healey 1980; Kjelson et al. 1982; Lott 2004; Miller et al. 2010; Sturrock et al. 2015). Peak migrations and estuarine abundance of fry in the Bay-Delta correlated with flow magnitude, with peak abundance and downstream extent of fry being highest following major runoff events (Kjelson et al. 1982; Brandes and McLain 2001).” (3-18, 3-19)

A large number of studies on juvenile salmonid use of the Delta area are cited to summarize knowledge about run timings, diurnal sub-habitat use, prey items, duration of residence, factors affecting growth and predation rates and so on.

Life history attributes and habitat use of adult chinook salmon in the Sacramento and San Joaquin Rivers are well documented with results from numerous studies.

The Section on Dam and Reservoir Effects on Salmonids cites a considerable body of peer-reviewed literature documenting studies on the various effects of dams and reservoirs on salmonids in the Central valley. The scientific research cited shows that dam construction has been a major factor contributing to historical declines in abundance and spatial distribution. This is due to “loss of access to historical spawning and rearing habitat above the dams and subsequent impacts of dams and reservoir operations on habitat below the dams” (3-34.)

### **Section on Juvenile Rearing and Emigration summarized the flow needs of Juvenile salmon.**

The following statements about flow requirements are made in this section:

“During their freshwater rearing and emigration periods, juvenile Chinook salmon and steelhead

require flows of sufficient magnitude to trigger and facilitate downstream migration to the estuary, provide seasonal access to productive rearing habitats (floodplains) and provide suitable food resources for growth and development (Raymond 1979; Connor et al. 2003; Smith et al. 2003).” (3-40)

It would be also important to identify how different flow rates have affected the availability of suitable food for juvenile salmonids that rear and grow in the Sacramento River system. It appears that other parts of the report have addressed this issue though not here. It would also be important to identify how different flow regime attributes affect the growth rates of juvenile salmonids in the river system (possible addressed elsewhere but not here). Additionally it would be important to review estimates of egg-to-smolt survival rates under different flow regimes. It would appear that these additional hypotheses about factors affecting population dynamics of salmon would need to be addressed to develop an understanding of the effects of different flow regimes on key population dynamics attributes of juvenile salmonids in the system and to develop improved predictive power on the short and long term effects different flow regimes on salmon populations native to the Sacramento-San Juaquin River systems.

I have a few minor concerns about using catch as an index of relative abundance, e.g., in the following statement:

“Brandes and McLain (2001) reported a positive relationship between abundance of unmarked emigrating Chinook salmon and April–June flow at Rio Vista flow (Figure 3.4-12 plot a). Catch appeared independent of flow between about 5,000 and 15,000 cfs, suggesting that there might be a lower threshold effect. Catch increased in a linear fashion between 20,000 and 50,000 cfs. State Water Board staff extended this analysis using Dayflow (DWR 2017) and Delta Juvenile Fish Monitoring Program (DJFMP) data (DJFMP 2016). The results of the updated analysis (Figure 3.4-12 b) are substantially similar to the earlier published results.” (3-41)

Higher catches with higher flow may not necessarily imply higher abundance, just higher catchability. I would prefer to have seen some supporting reference indicating that catch rate is also independent of flow rate.

“In summary, flows greater than 20,000 cfs are expected to improve the abundance of fall and winter-run salmon smolt migrating past Chipps Island between February and June (Table 3.4-7). These higher flows may be protective because they result in lower water temperatures, a lower proportion of flow diverted into the Central Delta, and reduced entrainment at agricultural pumps and export facilities in the South Delta (USDOI 2010).” (3-42)

“No similar flow abundance information is available specifically for spring-run Chinook salmon which has not been widely studied. However, these fish have similar life history characteristics as fall-run and it is likely that a similar magnitude of flow would also be beneficial for them. Peak emigration of juvenile spring-run Chinook salmon past Chipps Island is between February and May (NMFS 2014a). For emigrating steelhead, which peak in abundance at Chipps Island between March and April, higher flows during these spring months are likely to benefit this species as well (NMFS 2014a). Therefore, spring-run and steelhead are also expected to benefit from flows as high as 20,000 to 30,000 cfs at Rio Vista between February and May. (3-42)

It is mentioned that fewer studies on flow requirements of spring-run Chinook salmon and Steelhead were available. Assumptions are made that these stocks will have similar flow requirements as fall-run

chinook salmon. I would have preferred to see literature on studies from other river systems that addressed this assumption.

### **Longfin smelt**

Comment re: figure 3.5-4:

“Adult salvage was found to have an inverse logarithmic relationship to net OMR reverse flow (Figure 3.5-4). The OMR salvage relationship has an inflection point around -5,000 cfs with salvage often increasing rapidly at more negative reverse flows. The inflection point is used as justification for not allowing OMR reverse flow to become more negative than -5,000-cfs when adult longfin smelt are present.”

The plot shows no fitted model to the data. Whether a statistical approach was applied to estimate the inflection point was not indicated. The uncertainty in the estimate was not indicated either. The use of the point value of -5000 cfs for regulatory purposes would appear to require the application of a rigorous statistical methodology to estimate the inflection point and a 95% confidence interval for this inflection point.

### **Delta smelt**

I have a comment on the Fall midwater trawl survey index for Delta smelt.

“The Delta smelt FMWT index rebounded in 2011, a the wet year (Figure 3.8-1), when high outflows occurred throughout the year (including winter, early spring and fall) demonstrating that despite significant declines, Delta smelt are still able to respond positively to improved environmental conditions.” (3-72)

To what extent is midwater trawl catchability affected by the amount of outflow? Could increase or decrease with outflow, depending on how the gear works and on how fish are distributed in the water column. The catchability of different species to trawl survey gear has been found to vary systematically with environmental conditions, for example, water temperature, salinity, and turbidity<sup>1,2,3</sup>. I have not had time to read the cited studies in the scientific report on the midwater trawl survey studies; so this issue could already have been addressed within one or more of the midwater trawl study reports.

Figure 3.8-1 shows a linear fit to time series of midwater trawl index for delta smelt. the data show a decreasing then increasing trend from 1965-the mid-1980s, then an increase to about 2000 then a sharp decline to 2016 since 2000. The r-squared for the fit is 53%. However, there appears to be strong positive serial autocorrelation in the deviates from the fitted linear model. A non-linear time trend

---

<sup>1</sup> Swain, D.P., Poirier, G.A. and Sinclair, A.F. 2000. Effect of water temperature on catchability of Atlantic cod (*Gadus morhua*) to the bottom-trawl survey in the southern Gulf of St Lawrence. ICES J. Mar. Sci. 57: 56-68.

<sup>2</sup> Smith, S.J., Perry, R.I. and Fanning, L.P. 1991. Relationships between water mass characteristics and estimates of fish population abundance from trawl surveys. Environ. Monit. Assess. 17: 227-45.

<sup>3</sup> Huse, I., lilende, T, and Stromme, T. 2001. Towards a catchability constant for trawl surveys of Namibian hake. South African J. Mar. Sci. 23:1, 375-383.

model should be considered instead to more accurately describe the varying trends in abundance since the 1960s.

I have a few comments and questions on the determination of OMR flow levels that had Delta smelt salvage:

“The USFWS (2008) evaluated adult salvage by regressing average OMR between December and March against adult Delta smelt salvage for 1984–2007 (Figure 3.8-7). The USFWS found that salvage increased exponentially with increasingly negative OMR reverse flow. An inflection point occurred in the USFWS salvage data with higher salvage rates at more negative OMR flows than -5,000 cfs.” (3-79)

“The USFWS (2008) used a piecewise polynomial regression analysis to establish a break point in the data set and determined the reverse flow where smelt salvage first began to increase. The analysis indicated that this occurred at about -1,250 cfs suggesting a relatively constant amount of entrainment at OMR reverse flows more positive than -1,250 cfs.” (3-79)

“Together the analyses indicate that OMR flows should be maintained between -1,250 and -5,000 cfs depending upon the presence of Delta smelt and other physical and biological factors, including turbidity, that are known to influence entrainment (Table 3.8-1). These recommendations are consistent with the requirements of Actions 2-3 from the 2008 USFWS Delta smelt BiOp reasonable and prudent alternative.” (3-80)

It is not clear how the values of -5000 cfs and -1250 cfs was arrived at. Was this statistically determined? If so, a 95% confidence interval should be provided to indicate the extent of uncertainty in this point value.

## **Zooplankton**

I have a comment on the need to attempt distinguish indices of abundance from production rates and the effects of filter feeding and fish grazing on zooplankton abundance.

“Prior to 1987 the abundance of *N. mercedis* in summer increased as X2 moved downstream with higher Delta outflow (Kimmerer 2002b; Jassby et al. 1995; Orsi and Mecum 1996). After 1987 there was an inverse relationship: abundance showed a positive relationship with X2, low Delta outflows correlated with higher numbers of mysid shrimp (Kimmerer 2002b).”

With Zooplankton, rate of production is a more important ecological indicator than zooplankton abundance. This is due to grazing by animals that eat zooplankton. Abundance can reflect the effect of grazing more so than zooplankton population production rates.

I have a few other minor comments on the assumption of constant catchability of zooplankton in the sampling gear and its implications for the following conclusions.

“The abundance of adult and juvenile *N. mercedis* as a function of Delta outflow was reassessed using abundance data for the entrapment zone (Hennessy, A. and Z. Burris 2017). The entrapment zone was defined as a water mass moving up and down estuary with a bottom salinity between 1 and 3 ppt. Preliminary conclusions are that abundance increases as a function of mean daily outflow between March and May ( $R^2=0.32$ ;  $P<0.001$ ). These months were selected as the mysid is most

abundant then.”

“Preliminary conclusions are that abundance increases as a function of mean daily outflow between March and May ( $R^2=0.32$ ;  $P<0.001$ ). These months were selected as the mysid is most abundant then.”

It is not made clear the extent to which zooplankton catchability varies with outflow volume.

I have an additional concern about the following conclusion:

“In the preliminary analysis, the authors found a positive relationship between abundance in Suisun Bay and Delta outflow between June and September ( $R^2=0.39$ ,  $P<0.001$ ). Monthly outflows greater than about 5,000 cfs resulted in increasing abundance of *P. forbesi*.” (3-93)

Based on the plot, I would question whether the cut off should be at 5000 cfs, since the cpue is very low compared to at higher cfs.

In summary, to my understanding Conclusion 2 is based on sound scientific knowledge, methods and practices. I had only very minor concerns about some of the assumptions underpinning some of the conclusions as outlined above.

**Review Conclusion 3: To expeditiously address the impairments to native fish and wildlife beneficial uses in a very large, highly complex and heavily modified system such as the Bay-Delta, an approach based on the holistic method to the development of environmental flows that provide for flows of a more natural pattern that can then be further managed to maximize flow-related functions for the benefit of fish and wildlife beneficial uses is feasible and scientifically justified.**

The Holistic approach is “based on the premise that managed flow regimes need to generally resemble the natural flow regime to which native species are adapted, but that some deviation from the natural flow regime is needed in watersheds that must support other consumptive uses of water (Linnansaari et al. 2013)”. (5-4)

The suitability of the holistic approach for flow management of the Sacramento river, its tributaries, estuary and Delta, is explicitly based on at least five stated key principles:

- (1) The flow regime is the primary determinant of the structure and function in riverine ecosystems.
- (2) “Currently, the Bay-Delta Plan does not include adequate environmental flow and related requirements to provide for critical functions to protect beneficial uses within tributaries and in the Delta including appropriate migration, holding, spawning and rearing conditions. Inadequate or nonexistent requirements may lead to insufficient flows (including cold water flows) to protect fish and wildlife, redirected impacts to times of year when flow requirements are less strict or do not apply, and overreliance on one tributary to meet flow and water quality requirements.” (5-1).
- (3) “Given the dynamic and variable environment to which fish and wildlife adapted, and our imperfect understanding of these factors, developing precise numeric prescriptive flow requirements that will provide absolute certainty with regard to protection of fish and wildlife beneficial uses is not possible” (3-5)
- (4) “[M]ore natural flows [than have been the case] that more closely mimic the shape of the unimpaired hydrograph including the general seasonality, magnitude, and duration of flows generally provide those [ecosystem] functions.” (5-3)
- (5) “Due to the altered nature of the watershed, it is also necessary to consider flows and cold water habitat preservation requirements that do not mimic the natural hydrograph, but nonetheless produce more natural temperature, salinity, or other water quality conditions for fish in locations where these fish now have access to them.” (5-3)
- (6) “[H]olistic methods rely on a wide range of information, including hydrological data reflecting developed and undeveloped conditions, regional or location specific understanding of flow-ecosystem relationships, and more general ecological understanding of aquatic systems.
- (7) The multiple societal needs for water also require consideration.

A large body of scientific work on the Sacramento River and Delta system and on other fish-bearing river systems support principles (1)-(6) and Chapters 2, 3 and 5 of the report draw upon this research and make reference to it mostly from the Sacramento River system but other fish bearing river systems also that flow through regions with dense human populations that rely on freshwater extractions that reduce river flows.

The pronounced declines in assessed abundance of the majority of native fish populations that use the Sacramento river, its tributaries, estuary and Delta for spawning, growth and rearing habitats, documented in Chapter 3 that have occurred in recent decades including the last, and analyses that show higher survival rates of fishes with seasonal flows that are closer to the unimpaired seasonal flow levels strongly support the fourth principle.

“Scientific evidence presented in Chapter 3 shows that native fish and other aquatic species require more flow of a more natural pattern than is currently required under the Bay-Delta Plan to support

specific functions for anadromous and estuarine species that provide appropriate habitat quantity and quality.” (5-2)

It is therefore credible that the idea of managing water use to allow for the flow patterns to follow an unimpaired flow regime but subject to known habitat requirements of the key fish species (e.g., the monthly flow volume and cold water requirements of adult spawning salmon) has a likelihood of meeting the water flow and habitat requirements of the full set of native fish species present and in need of protection and restoration. Allowing for the tracking of a fairly high percentage of the monthly unimpaired flow volumes within the Sacramento River and its tributaries would appear to create flow volumes in the Sacramento River and its tributaries that would be consistent with some frequency the scientifically assessed freshwater flow volume requirements for both salmonids and non-salmonid native fish populations that use the Sacramento River, its tributaries and estuary and Delta. This is according to the assessed flow volume requirements of the native fish species populations that were documented in Chapter 3.

Within the Sacramento River main stem and its tributaries that have continued to be used as spawning and rearing habitat by chinook salmon and steelhead, the approach would need to maintain a minimal set of flow volumes and temperatures for the months in which the different salmon and steelhead populations have been known to use the main stream and tributary reaches. It was clearly established that within tributaries used by salmonids that water extractions especially in summer and autumn could dewater sections and cause high mortality rates of salmonid fishes already in the tributaries or prevent salmonid fishes from migrating through the tributaries. For example, it was stated:

Juvenile salmonids also require continuous tributary flows with adequate temperature and dissolved oxygen levels for rearing and successful emigration (5-11).

Flows must also be managed to avoid fluctuations that cause stranding and dewatering. (5-41)

The proposed narrative objective is as follows:

*Maintain stream flows and reservoir storage conditions on the Sacramento River and its tributaries and Delta Eastside tributaries to protect coldwater habitat for sensitive native fish species, including Chinook salmon, steelhead, and sturgeon. Coldwater habitat conditions to be protected include maintaining sufficient quantities of habitat with suitable temperatures on streams to support passage, holding, spawning, incubation, and rearing while preventing stranding and dewatering due to flow fluctuations. (5-42)*

More details on existing scientific approaches (e.g., field based and model-based) to address the question of the minimum monthly rates of flow within salmonid bearing tributaries basis that would allow sufficient rates of growth, migration and survival of juvenile salmonids within the Sacramento River tributaries could have been provided within the report to enable proper review of their appropriateness and rigor.

References to scientific reports that recognize the importance of setting up improved data collection protocols and developing improved hydrodynamic-river ecosystem models were provided later on in the chapter, e.g., (5-41):

“There has also been increasing recognition of the need for improvements in data collection and modeling to better understand the physical processes affecting the thermal dynamics of large reservoirs, and determine the most effective strategies (including both operational and facility modifications) for meeting the downstream temperature requirements of anadromous salmonids (Anderson et al. 2015). To the extent possible, cold water management planning efforts and decision-making should be based on the application of linked physical models that propagate the

thermal effects of proposed actions through the watershed, reservoir, and river system (Cloern et al. 2011). These model systems also provide a means of evaluating the potential roles of other habitat restoration measures (e.g., riparian habitat restoration, gravel replenishment, channel and floodplain rehabilitation) in enhancing cold water habitat by reducing heat inputs from other sources (e.g., tributary streams) or increasing surface-groundwater interactions (Tompkins and Kondolf 2007b). Cold water management efforts will also benefit from improved data collection and modeling efforts that provide more accurate predictions of the spatial and temporal distribution of sensitive life stages (Anderson et al. 2011) and take into account the effects of other environmental variables (e.g., intergravel oxygen) on thermal stress and tolerances of these life stages (e.g., Martin et al. 2016)”

However, the proposed new inflow requirements include both numeric and narrative components that are specific to the individual fish bearing tributaries:

“The proposed inflow requirements would dedicate a portion of the inflow of a watershed to environmental purposes based on the unimpaired flow of that stream. This dedicated quantity of environmental flows would then be provided based on the unique needs and circumstances of each tributary and on a regional basis to provide for critical functions within the streams and as contributory flows to the Delta.” (5-15)

More details on how the tributary-specific plans are to be developed are provided on 5-42,43. The described approach to developing plans appears to be appropriate and sufficiently rigorous.

One potential problem with the range-based percentage specification approach even with the adaptive management caveats is that it may still fail to establish minimal flow requirements for some periods of the year in some of the tributary streams. Some directed attention is needed to establish for regularly purposes for key fish bearing tributaries the minimum needed flow requirements within each month of the year to adequately sustain fish migration, rearing and spawning.

Due to lack of references and details provided, it was not possible to assess the rigor of scientific work that forms the basis of flow and water temperature management actions that have presumably been implemented on some of the tributaries, e.g., the Yuba River:

“Water Right Order 2008-0014 amended YWCA’s water right permits to include the flow schedules and other specified terms and conditions of the Lower Yuba Accord’s Fisheries Agreement. These include provisions for regular planning and coordination by the River Management Team (RMT) to implement flow and water temperature management actions, including planned operation of the upper and lower outlets at New Bullards Reservoir and any TCDs that might be built at Englebright Dam. Water Right Order 2008-0014 includes provisions for review and approval of recommended RMT actions by the fisheries agencies and State Water Board.” (5-38)

However, it appears that at least for some tributaries, e.g., Mokelumne River (5-39), Putah Creek (5-39) and Calaveras River (5-40), administrative frameworks have been established to support a formal adaptive management approach to implement flow regimes to support native fish populations:

“The coordination committee meets each year to review fisheries and water quality monitoring data, evaluate projected water year type conditions and operations plans, make recommendations for expenditure of the Partnership Fund, and develop proposed adaptive management actions to optimize habitat conditions in the lower Mokelumne River (EBMUD et al. 2008). In addition to these flow provisions, the JSA includes a number of non-flow measures, including cold water pool management to provide suitable water temperatures for all salmonid

and native fish life stages. This involves integrated operation of Camanche and Pardee reservoirs and water temperature monitoring, modeling, and forecasting to ensure sufficient storage of cold water during the winter and spring to prevent early turnover (destratification) of Camanche Reservoir, and to provide sufficient cold water for releases in the lower Mokelumne River through early November (EBMUD 2013).” (5-39)

One stated principle that appears to be treated inconsistently in different parts of the provided documentation is as follows: “all features of the ecosystem should be considered”.

In contrast on p 2-50: “Because the Bay-Delta ecosystem is exceedingly complex it is not possible to identify every function that drives a correlation relationship with certainty, particularly since it may change given different circumstances (e.g., temperature relationships may change as a result of availability of food).”

It is my opinion that for pragmatic reasons, scientific and regulatory focus can be placed on key indicators of ecosystem functioning and structure with regards to the various ecosystem features and in formulating regulatory approaches to restore and maintain the ecosystem features of concern. A focus on native fish species and some associated invertebrates that support fish (e.g., some Delta zooplankton species) as has been the case within the report would appear to be one viable approach to taking an ecosystem indicator approach to setting goals and regulations for water flow management.

Simulation modeling was applied in Chapter 5 to identify the frequency with which flow requirements were met under a set of discrete alternative percentages (35-75%) of the unimpaired flow volumes for recent historic sets of years “provided that adequate supplies are maintained for cold water and flows at other times” (5-7). This indicated that higher percentage values for unimpaired historic flow volumes met seasonal flow volume requirements of key native species populations with markedly higher frequency than lower percentage unimpaired flow volumes.

The modeling however was preliminary because it was mentioned that further modeling was needed to explore further some variations to percentage unimpaired flows that “consider the needs for cold water storage and other uses”. (5-7)

A large body of literature is referenced in which numerous researchers support the idea that implementing a flow regime that seasonally parallels an unimpaired flow regime helps to support and protect populations of native aquatic species (5-6). However, while there appears to be a lot of support for the idea and several implementations of it, there does not appear to be yet an accumulation of supportive evidence from existing holistic flow regime implementations, i.e., that changing from strongly altered flow regimes back to a flow pattern that mimics an unimpaired or natural flow regime has systematically restored river ecosystem structure and function and helped to facilitate the recovery of depleted native fish populations.

“After very high temperature-related mortality of winter-run eggs in the drought years of 2014 and 2015, NMFS and the State Water Board used the 55°F 7DADM along with other recommendations of the IRP in 2016 (in which there was a much greater quantity of cold water) to reduce uncertainty in meeting temperature needs for winter-run on the Sacramento River to avoid significant mortality for a third year, which was largely successful (at least in part due to the additional cold water supplies).” (5-36)

The implementation of a stronger regulatory measure for cold water management 2016 and finding that the measure was “largely successful” indicates some adherence to the intended adaptive management approach. However, it would have been of interest to have seen the quantitative results upon which the assessment was based.

In my view, apart from some minor concerns outlined above, the scientific portion of the regulatory actions following from Review Conclusion 3 is based on sound scientific knowledge, methods and practices.

**Review Conclusion 4. Inflows that more closely mimic the natural flow and water quality conditions to which native migratory fish are adapted are needed in the Sacramento River basin and Delta eastside tributaries to provide spawning and rearing habitat and connectivity with the Delta**

This conclusion is premised on several different presumptions. One key presumption is that unimpaired river and delta eastside tributary flows mimic the monthly flow variations and flow magnitudes of presumed natural flows in the Sacramento River basin, and Delta eastside tributaries. This presumption is made in the new flow control plans because the flow controls are actually designed to follow the monthly unimpaired flows. In Chapter 2, considerable attention is devoted to results from river flow models developed by the DWR (2016) that have been applied to construct unimpaired monthly river flows for historic years and also what could be expected to be natural flows from pre-development river basin morphologies and vegetation. For example quartile distributions for DWR (2016) model-based reconstructions of actual historical, natural and unimpaired delta inflows by four historical periods since 1930 are shown in Figures 2.1-2. These show that the model-based reconstructions of natural and unimpaired delta monthly inflows are more similar to each other than to the historical flows especially for 1968-1999 and 2000-2014. The unimpaired flows can be seen to follow the trends in the natural monthly flows through all twelve months. The quartile distributions are quite similar from about November to April with quartile distributions overlapping and the median values also quite close for these months. However, from about May to October, the unimpaired median flows are estimated to be substantially larger, e.g., seeming to range around 50% larger than the modelled natural flows. If a goal is to control the Sacramento River and tributary flows and eastside tributary flows to mimic natural flows throughout the year, the new flow control plans documented in the report which adhere to constant percentage values of unimpaired flows throughout the year do not appear to address the pronounced elevated values for monthly unimpaired flows May-October. It would appear that within-year adjustments to the percentage of unimpaired flows would be required to meet the within-year river flow and water temperature requirements of different life history stages of the native fishes that spawn and rear in and migrate through these river and tributary habitats. For example, to meet the cold water requirements of salmonids in the summer and autumn months, it would appear to be necessary to store more water in reservoirs in these months to provide the necessary volumes of cold water releases to support salmonids holding, spawning and rearing below key reservoirs in these months. It would appear however, that attempting to mimic the natural hydrograph e.g. from November to April each year could be successfully achieved by keeping flows to some high constant percentage (e.g., over 75%) of unimpaired flows.

In contrast, the plots of hydrographs for tributary rivers shown in Figure 2.1-1 shows that the quartile distributions for model estimated monthly unimpaired and natural flows follow similar but not identical seasonal patterns and magnitudes over all twelve months. Thus, following a high constant percentage of unimpaired flows throughout the year on at least some tributaries could mimic fairly closely the natural hydrographs for these tributaries. However, these model comparisons between natural and unimpaired flows was shown only for these two rivers. No such comparisons were shown for the numerous tributaries of the Sacramento river and eastside of the Delta whose current flows were

compared with unimpaired flows within Chapter 2. Since model comparisons were made between unimpaired and natural flow conditions for only two of the twenty two assessed tributaries (Table 2.2-1), it would not be appropriate to conclude that all natural and unimpaired flows could be expected to be similar for these numerous other tributary rivers. This is because tributary river valley morphologies and vegetation could be considerably different between the two tributary rivers and the other twenty.

The proposition that controlling flow to mimic natural flow levels would “improve ecosystem functions by providing appropriate habitat conditions for adult salmonid migration and holding and juvenile rearing and outmigration, and contributing to Delta outflow to support native anadromous fishes and estuarine species” in my view is supported by the scientific work on flow and habitat requirements of native fishes that is reported and discussed in Chapter 3. The recent historic Delta outflows from February-May have been markedly lower than the model-estimated natural and unimpaired flows. The scientific work evaluating how native fish population changes and abundance have correlated with Sacramento River, tributary, and eastside Delta tributary flows showed that positive rates of population increase and higher population abundances were associated with higher flows. Fish survival, growth, and successful migration and spawning were found to be considerably improved by higher freshwater river flows and Delta outflows that were closer to natural and unimpaired flow conditions. This was the case for all of the different fish populations considered and also the invertebrate populations important to the native fish species considered in the report.

The scientific studies reported for the four chinook salmon races in section 3.4 were highly supportive of the above proposition. The life history types represented by these different races were outlined and the specific flow requirements (e.g., river flow speeds and water depths for spawning and upstream migration and holding in pools), water quality (e.g., DO requirements), spawning substrate requirements, stream reach preferences, and water temperature requirements for both adults and river-rearing juveniles were outlined. All populations are at lower levels compared to a baseline period in the late 1900s (1967-1991). Assessments of the amount of river, stream and estuarine habitat lost to chinook salmon due to dam and reservoir construction and other river basin developments indicate that over 50% of freshwater and estuarine habitat formerly available for salmon production have been lost. However, this figure ignores the degradation in the quality of the remaining available freshwater habitat in terms of flow, temperature, water quality, food production and substrate quality.

However, the relative contributions of changes in marine conditions, fishery exploitation and freshwater conditions were not addressed. This could potentially have been done through the formulation of life-stage explicit population dynamics models that could be fitted to available time series of population abundance data for each of the chinook stocks. Also time series data are likely available that would provide time series of estimates of marine survival rates of the different chinook salmon populations. This would have then enabled a comparison in trends in freshwater recruits produced per spawner and allowed assessment of how marine conditions have contributed to chinook salmon population decline. Further north, e.g., in southern B.C., the main cause of chinook salmon population decline has been substantial declines in marine survival rates of chinook salmon, i.e., increased rates of natural mortality in the sea. While it is unlikely that the same mechanisms causing declines in marine survival rates of B.C. chinook salmon are also affecting Sacramento River chinook salmon, marine survival rates are

unlikely to be constant over years for any chinook salmon stock and it would be important for regulatory purposes to separate out the marine survival rate effects so as to more accurately assess the trends in freshwater production and survival of native Chinook salmon stocks and the potential effects of changes in river and estuarine habitat attributes on freshwater production and survival of native chinook salmon. A characterization of trends in (post-estuarine) marine survival rates for Sacramento and San Juaquin river chinook salmon would be important to evaluate the potential for population increases as a result of improvements to freshwater conditions for chinook salmon.

The reported scientific evaluations of how river flow attributes affect adult salmon straying and return to natal spawning areas showed strong relationships between how escapements and percentage straying varied with different components of river flow regimes, e.g., pulse flow management and DCC closure (e.g., Table 3.4-6). Reviews of scientific work also clearly demonstrated how the unnatural flow regimes in the River basin negatively affected juvenile habitat availability, migration and freshwater survival and growth of juvenile salmon (e.g., low flow and warm water temperatures have negatively affected rearing and emigration and diversions for agriculture and dams were main contributors to these impairments in 32 and 40 percent of evaluated tributaries (3-40)). Reduction in riparian vegetation which has been shown to be important for juvenile salmon rearing was also linked to flow reductions and reduced flow variations compared to previously natural flow conditions (3-41). The benefits for juvenile salmonid rearing of frequent floodplain inundation was also presented (3-41). The importance of pulse flows to trigger downstream smolt migrations and higher river flow ranges than have been the common in recent decades to improve survival of smolts based on numerous cited survival studies were also emphasized (3-42).

For green and white sturgeon, the scientific report cites studies finding that “[y]ears with high precipitation and large Delta outflow are associated with higher recruitment (Klimley et al. 2015; Fish 2010).”

The scientific report also cites several studies that indicate that American shad and striped bass “exhibit positive flow abundance relationships in the Bay-Delta estuary. More Delta outflow in spring results in more juvenile recruitment for both species.

In my view, apart from some minor concerns outlined above, the scientific portion of the regulatory actions following from Review Conclusion 4 is based on sound scientific knowledge, methods and practices.

**Review Conclusion 5. Delta outflows that more closely mimic the natural flow and water quality conditions to which native fish are adapted are needed year round to support the migration, spawning and rearing of**

Historical changes to the physical features of the Delta due to levee building and other developments that have altered the natural river channel and flood plain habitats of the Delta and historical changes to seasonal patterns of historical flow are well-documented in section 2.4 of the scientific report, e.g.,

“Winter flood peaks and spring snowmelt runoff from Delta tributaries have been greatly reduced by upstream storage and replaced by increased flows in summer and early fall, compared to pre-project hydrology (Kimmerer 2002a, 2004).” and “Current conditions in the spring are less variable and inflows are less than 57 percent of unimpaired flows in half of the years. The months of April and May are the most extreme where current Delta inflow is less than 50 percent of unimpaired flows more than 70 percent of the period.” (2-67)

A model called “Dayflow” developed by the DWR provides estimates of outflow, a net daily water outflow (net Delta outflow index (NDOI)) in the Delta to San Francisco Bay that has tidal signals removed. It is noted in section 2.4 that the outflow estimates are inaccurate particularly in times of low flow but that efforts are underway to develop improved estimates outflow, e.g., that better account for various Delta consumptive water uses.

A second index, X2, which marks the distance up the level 2 salinity east of the Golden Gate Bridge indicates deeper intrusions of salinity into the Delta area and lower variability in the position of the salinity gradient than prior to 1945 after which extensive diking and draining of the Delta occurred (e.g., Fig. 2.4-11).

Chapter 3, documents scientific evidence supporting the notion that restoration of more natural flows would improve rearing capacity for juvenile salmon. For example, “[s]tudies of juvenile rearing in the Yolo Bypass and Cosumnes River floodplain following connection of high winter and spring flows show that juveniles grow rapidly in response to high prey abundance in the shallow, low velocity habitat created by floodplain inundation (Benigno and Sommer 2008; Jeffres et al. 2008; Sommer et al. 2001).” Also for example: “Fall-run Chinook salmon smolt survival through the Delta is positively correlated with Delta outflow (USFWS 1987).” “State Water Board staff extended this analysis using Dayflow (DWR 2017) and Delta Juvenile Fish Monitoring Program (DJFMP) data (DJFMP 2016). The results of the updated analysis (Figure 3.4-12 b) are substantially similar to the earlier published results”.

Several studies finding a strong positive relationship between population abundance of the short-lived longfin smelt and Delta out flow were cited in section 3.5.4.1, especially between the months of January and June. The probability of population growth analysis applied in my view an appropriate statistical methodology. Uncertainty in estimates was appropriately shown for example with a 95% confidence interval on the estimated probability of population growth as a function of January-June Delta Outflow in Figure 3.5-3.

The scientific report summarized studies showing positive relationships between white sturgeon year class and Delta outflow. For example: “Fish (2010) analyzed white sturgeon year class data from Bay Study catch data for 1980 through 2006. The study found statistically significant positive correlations between catch and mean daily Delta outflow for November–February and for March–July (Figures 3.6-2 and 3.6-3).” (3-64)

Also summarized were studies showing positive relationships between Sacramento splittail abundance and Delta outflow between February and May and also with days of Yolo bypass floodplain inundation. "Increased outflow between February and May coincides with the timing of adult spawning and larval rearing in riverine floodplains and terraces and in the Delta (Moyle et al. 2004; Meng and Matern 2001). Increased flow increases both the amount of flooded habitat along vegetated channel margins and the acreage of inundated floodplain in the Central Valley (Moyle et al. 2004)." (3-67)

For Delta smelt, evidence supporting the notion that more natural Delta outflow patterns in the spring benefited the population was also cited: "Delta outflow during late spring and early summer affects the distribution of larval and juvenile smelt by actively transporting them seaward toward the LSZ (Dege and Brown 2004). Low outflow increases Delta smelt residence time in the Delta, probably leading to increased exposure to higher water temperatures and increased risk of entrainment at the CVP and SWP pumping facilities (Moyle 2002)." Also, "[R]apid changes in environmental conditions are a factor associated with population-level migrations (Grimaldo et al. 2009a; Sommer et al. 2011)" (3-71). "Emerging evidence also suggests that spring outflow may be more critical for the production of larvae and the maintenance of the adult population than was previously realized (Baxter et al. 2015). Delta outflow may also be important in summer and fall to provide critical habitat for Delta smelt (Feyrer et al. 2007; Baxter et al. 2015; CDFW 2016d)." However, "Baxter et al. (2015) report recommended that conclusions based upon the relationship between spring outflow and Delta smelt population abundance be considered preliminary until additional data, analyses and review were conducted to confirm the robustness of the results." (3-73, 74)

For starry flounder similar positive effects of more natural spring outflow was also found. "Age-one Starry flounder abundance is positively correlated with Delta outflow between March and June of the previous year (CDFG 1992c; Jassby et al. 1995; Kimmerer 2002b)." "[H]igher Delta outflows generate stronger upstream directed gravitational bottom currents that may assist larval immigration into the Bay." (3-83)

For Bay shrimp, "A positive correlation has been reported between abundance of 1-year old Bay shrimp and Delta outflow from March to May (Hatfield 1985; CDFG 1992c; Jassby et al. 1995; Kimmerer 2002b; Hieb 2008; Kimmerer et al. 2009)." The report mentioned a few possible mechanisms including stronger Delta "outflow increases gravitational bottom currents and passive transport of juvenile bay shrimp from marine to brackish water in the Delta (Siegfried et al. 1979; Moyle 2002; Kimmerer et al. 2009)".

One assumption of the biological survey data upon which this conclusion is based is as follows. Abundance indices were found to be higher for some of the resident fish species during years that had higher Delta outflows (e.g., a fall mid-water trawl indices for long fin smelt, Sacramento splittail and Delta smelt). Fishery independent surveying methods including a mid-water trawl survey were applied to develop population-specific abundance indices of particular life history stages of the resident fish and shrimp species in the Delta and estuary. To allow for the abundance indices to be comparable across years, the probability of capture of the species and life history stage of interest by the survey gear must be constant or practically constant over years. It is possible that the probability of capture of the gear for one or more of the species of interest could vary systematically with salinity, ambient water temperature or the volume Delta outflow. If it were the case that the probability of capture of the gear varied systematically with any of these, and especially the latter, then the validity of conclusion 5 would be called into question. For example, should the probability of capture vary positively with Delta outflow, the positive relationships found between native species population abundance and Delta

outflow could reflect simply higher probability of capture in years with higher Delta outflow but not necessarily higher abundance. Well-designed tagging experiments that spanned different a range of different Delta outflow volume and where one of the methods of recapture was via the sampling gear used to produce the abundance indices could help to resolve this issue.

In my view, apart from some minor concerns outlined above, the scientific portion of the regulatory actions following from Review Conclusion 5 is based on sound scientific knowledge, methods and practices.

**Review Conclusion 6. Cold water habitat is needed below reservoirs to compensate for natural cold water salmonid habitat lost by reservoir construction above dams.**

Numerous scientific studies that documented the cold water requirements of chinook salmon and steelhead while in freshwater habitats were documented in section 3.4. The temperature ranges required by the different salmon and steelhead population life history stages within the Sacramento River and tributaries were reviewed. Studies documenting the presence of juvenile and adult and pre-adult life history stages of salmon and steelhead in all twelve months within the river basin were also cited in the scientific report. The report reviewed studies that made the following clear: because these particular salmon and steelhead populations use river systems near to the southern extent of their northern hemisphere geographic range and river and tributary temperatures within all but the upper parts of the river basin tend to be above the water temperature preferences for these species for more than a few months of the year, this has meant that in pre-development times, salmon and chinook salmon that migrate into the river system in spring, summer and fall have spawned in the upper portions of the watershed where the temperatures of river and tributaries have remained within the requirements of these species. The report reviewed studies indicating that the majority of cold water habitat formerly used by salmon and steelhead are no longer accessible to these populations due to dam and reservoir construction. The report also reviewed studies that have shown that the provision of cold water habitat immediately below Sacramento River dams and tributary dams has been essential to the maintenance of populations of native chinook and steelhead populations. Active management of the storage of water in these reservoirs in spring, summer and autumn months and the installation and operation of cold water management devices within some of the reservoirs has enabled cold water releases from dams on the Sacramento River in summer and autumn months when water temperatures would otherwise be above salmon and steelhead preference ranges for spawning, holding and migration.

The adaptive management approach is also a requirement of cold water release manipulations. This approach appears to be entirely appropriate to introduce scientific accountability into the implementation of cold water management manipulations. The formulation of different hypotheses about the effectiveness of cold water management control effects on salmon population dynamics attributes, the setting up of cold water release experiments that could effectively test these hypotheses and the monitoring of (a) water flow and temperature outcomes of the manipulations and (b) the potential salmon population responses would be essential elements of a scientific-based adaptive management approach to cold water releases.

In summary, based on my review of relevant components of the scientific report, it is my view that the coordinated measures that provide cold water flows below Sacramento River and tributary dams in summer and fall months are based on sound scientific knowledge, methods and practices.

**Review Conclusion 7. Interior Delta flow requirements (Delta Cross Channel (DCC) gate closures, OMP reserves flow limits and export constraints) help protect resident and migratory species from entrainment and related effects in the southern Delta associated with CFP and SWP diversion activities.**

Chapter 2.4 characterizes the highly substantial modifications to the stream, river and tidal channels and natural floodplains over the course of industrial development of the Delta area, as well as to the upstream portion of the Sacramento and San Joaquin River basins. Chapter 2 also characterizes the features of the water extraction facilities, dikes, levees and developed water courses in the Delta. The alterations of the natural estuarine flow conditions were also characterized in detail. This included a major change in flow patterns from there being a relatively low frequency of net upstream directional flow to a much higher frequency and rates of reverse flow due to water export from the inner Delta to areas to the south.

The negative effects on resident and migratory fish species of higher frequency and higher rates of reverse flow especially into the waterways that lead to the water extraction facilities in the interior Delta are established through empirical tagging, other juvenile capture and fish salvage studies and also particle flow modeling. Studies cited in the report show that the survival rates of salmonids and other native fishes that use the Delta area for rearing, and that migrate through the area are reduced by higher reverse flow rates, entrainment into interior Delta and the pumping facilities and following salvage in the facilities. In my view the field scientific and analytical methods applied in these studies are appropriate and the findings are credible.

The field scientific and analytical methods that were applied to investigate the effect of different rates and directions of flow in the Delta are also in my view appropriate and the results credible. Data on flow rates and directions and survival and relative abundance for different fish species were available over numerous years and over a wide range of positive and reverse flow values. The plots showed marked increases in mortality rates for different fish species when the rates of reverse flow exceeded about negative 1200 cfs. The approach to identifying the set of months in the year in which higher reverse flows rates in the Delta had strongly negative effects on several of the native fishes that migrate through and reside in the Delta was in my view also appropriate and the findings obtained credible. The scientific analyses that established the limits set on water export rates for the Delta water pumping operations and regulations for the timing of closures of the DCC gates in my view were appropriate and credible. These correspond to the months in which the bulk of the juvenile salmon and two smelt species are migrating through and resident in the Delta area.

In my view, the scientific portion of the regulatory actions following from Review Conclusion 7 is based on sound scientific knowledge, methods and practices.

**Review Conclusion 8. Other aquatic ecosystem stressors have negative effects on fish and wildlife beneficial uses, and non-flow actions are also needed for ecosystem recovery.**

Chapter 4 of the scientific document reviews studies that have documented changes to the riparian, estuarine and flood plain habitat since pre-development times (early 1800s). These studies identify very substantial and extensive physical changes to the river and tributary channel structures through diking, channelization, channel deepening, dam and reservoir construction and agricultural and industrial development of land within the Sacramento – Juaquin River basin. The studies document very substantial reductions in the amount, diversity and quality of natural riparian vegetation and natural riparian habitat in the Sacramento River watershed. Studies that identify how natural riparian habitat are capable of fostering much higher native fish production than human-modified (e.g. rip-wrapped river banks, dikes and levees) are also cited. Studies are also cited that document very substantial reductions in the amount and quality of natural floodplain habitat for native fish species in the Delta. Studies are presented that indicate that floodplain habitats in the estuary and Delta generate far higher amounts of zooplankton and other natural food items for juvenile native fishes than open river channel habitats and thus demonstrate the importance of natural floodplain habitat in the Delta and estuary to native fish production. These studies are critical to supporting the several efforts aimed at restoring natural riparian habitat and vegetation in different parts of the Sacramento River watershed and restoring natural floodplain habitat in the Delta and estuary.

Studies that link the ability of the estuary to dilute, transform or flush human-sourced contaminants with Sacramento-San Juaquin River flows are cited also in Chapter 4. Studies documenting the differential effects of suspended contaminants and contaminants in sediments on different native organisms in the water column and also in the sediments are presented. In addition studies documenting negative relationships between pesticide concentrations (particularly pyrethroid pesticides) and native fish abundance indices and different negative effects (e.g., feeding behaviours, growth, neurological development, etc.) on different native fish species are also presented. Studies investigating the concentrations of several other different contaminant chemicals (e.g., endocrine disruptors, Ammonia, DDT, PCBs, etc.) and chemical nutrients to plant and algal growth in the river and tributary waters and in the sediments of different parts of the river system and contaminant concentrations in native fish, invertebrates, algae and plankton within the river system, Delta and estuary waters and benthos and their potential deleterious effects on these organisms were also reviewed in Chapter 4. The effect of different river system flow levels on water quality, contaminant concentrations, and the flushing of different contaminants from the system were also reviewed. In my view the scientific methods and practices in these studies were appropriate and the findings credible.

Studies documenting the regular occurrence of harmful cyanobacteria algal blooms (HABs) in the Delta since 1999 were reviewed in Chapter 4 also. Studies evaluating the presence of associated toxins in zooplankton, amphipods and fish in the Delta were also reviewed. Studies evaluating the potential effects of different levels of the biotoxins produced by HABs on different species of native zooplankton and a few fish species present in the Delta, e.g., Striped bass and Mississippi silversides were also reviewed. Factors potential responsible for setting off and suppressing HABs were reviewed.

Studies documenting the various natural and human-based sources , and concentrations and potential harmful effects of bioaccumulative substances such as methyl mercury in fishes within the Delta were also reviewed.

Studies on the harmful effects to native fishes from low DO and trends in DO in the river system and Delta were also reviewed in Chapter 4. Studies on changes to sediment and turbidity due to development of the River basin, changes in channel and bank structures and flow regimes show negative impacts triggering increases in the frequency of HABs and negative impacts on native fish production and growth. Studies were also reviewed that documented increased water temperatures in the Sacramento river, tributaries and Delta and negative effects on native fishes, especially salmonids. Non-native fish, bivalve and other invertebrate species introductions have been documented to have negative effects on the production of native fishes such as the two smelt species and starry flounder. Depending on the native fish species, this has been via predation, competition for limited spawning and rearing habitat and competition for food. The negative effects on native fishes of non-native aquatic plant invasions in the River system and Delta are also reviewed.

The positive and potential negative effects of hatchery production of salmon and steelhead on native salmon and steelhead populations were also reviewed.

Chapter 4 also points out that large uncertainty exists over the relative impacts of the different stressors to native fish population dynamics.

Adaptive management approaches and scientific monitoring programs are in place and proposed to monitor and where appropriate contribute to the design of new regulatory, new biological control and technical interventions and modifications to existing practice, e.g., salmon hatchery operations, to address the interannual changes in stressors on native fish and other native organisms of concern.

In my view the scientific methodologies and practices documented to evaluate the different aquatic ecosystem stressors and formulate new monitoring and new “non-flow” regulatory and management actions to address the different aquatic ecosystem stressors are appropriate and the findings obtained credible.

Thomas Meixner  
Professor  
Department of Hydrology and Atmospheric Sciences  
University of Arizona

May 26, 2017

I have been asked to review “*Scientific Basis Report in Support of New and Modified Requirements for Inflows from the Sacramento River and its Tributaries and Eastside Tributaries to the Delta, Delta Outflow, Cold Water Habitat, and Interior Delta Flows*”

And specifically this first conclusion of the report-

**“1. Significant changes have occurred to the hydrology and hydrodynamics of the Sacramento River and its tributaries, Delta eastside tributaries, and the Delta.**

The Science Report focuses on the flow characteristics of the main stem Sacramento River, its tributaries, the three eastside tributaries to the Delta and the interior Delta. These flows are critical to supporting ecological processes and the species that depend on those processes, including native anadromous and estuarine species. The magnitude, duration, timing and frequency of flow in all these waterbodies were evaluated to assess the types of change in the flow regime that have occurred over time. This information is provided as background and supporting information for subsequent chapters. Diversions and exports have reduced average annual outflow, reduced winter and spring outflow and reduced seasonal variability (Figures 2.4-7 and 8 and Table 2.4-3) over time. Water development in regulated tributaries, such as the Sacramento River at Freeport, has resulted in reduced annual flows, a reduction and shift in spring inflow, an increase in summer inflow, and a decrease in hydraulic variability (Figure 2.2-5 and Table 2.2-2). Tributaries without large reservoirs generally have lower flows in summer and part or all of the fall. Project pumping in the south Delta has increased (Figures 2.4-4 and -5) and this has resulted in an increase in the magnitude and frequency of reverse (upstream) flows on Old and Middle rivers (Figure 2.4-5). This information is included in Chapter 2 of the Science Report.”

The structure of my review will provide an overall brief summary of the report to communicate what lessons evidence and conclusions I drew from reading the report. Next I will assess each of the factual claims of the conclusion and then assess whether the overall conclusion is supported by the document and relevant science. Following that I will make general and specific comments about aspects of the report that the writers can take into account at their discretion.

#### **General description of what I read in the report-**

The scale of work involved in putting together this report as a whole and the Chapter 2 on hydrologic changes is truly impressive. The diverse systems represented and the author’s careful explication of the hydrologic variety of the system is very well done (Pages 2-3-2-12)

I very much appreciate the careful distinction the authors make between natural and unimpaired flows. As they note knowing what the natural flows in this system would be without human influence is a

difficult if not unknowable system attribute. The authors thus rightly, in my opinion, focus on unimpaired flows to investigate the impact of human water resources management on the hydrology of the Delta and its tributary rivers.

The authors then proceed to show that the differences between natural and unimpaired flows are small and then proceed to investigate the departure of actual flows from the unimpaired flows over time. Showing that the hydrology of inflows and outflows of the Delta has continued to become more strongly differentiated from the unimpaired flows (Figures 2.1-1-2.1-3).

Figure 2.1-10 starts building the evidence to support this conclusion and shows the profound changes in river system hydrology in the historical record compared to un-impaired flow estimates. Importantly the results also show differential river system responses to wet and dry years. The authors also provide the well prepared Table 2.1-1 to permit an easy view of how their assumptions and the SAC-WAM model might influence the results displayed in Figure 2.1-10. The SAC-WAM model is key to the estimates of unimpaired flows and while all modelling comes with uncertainty SAC-WAM is assigned a fairly basic task here to simulate the unimpaired flows of the system as compared to the observed flows. Additionally SAC-WAM is built upon the foundation of the established and well regarded WEAP model.

The authors then step through a discussion of the hydrology of the Sacramento and other major tributary rivers. In each system the authors carefully walk through the shift in hydrology due to water resources management in the system and show a typical shift of decreased spring streamflow and increased summer streamflow in response to management. Some tributaries to the Sacramento have little shift in hydrology due to few dams and reservoirs or other diversions in their watersheds. As might be suspected rivers with large reservoirs and significant water diversions have the greatest difference between observed and unimpaired flows.

After discussing the impacts of hydrologic alterations on inflows to the Delta the authors shift focus to the flood basins with the River systems as these can influence the water flow through the coupled river-Delta system. Of note in this section the authors do not provide a figure showing the locations and scales of these basins. Such a figure would assist the reader in understanding the nature and importance of the systems and where they fit in the overall hydrologic system. These flood basins are important since they can impact the magnitude timing and duration of flood flows in the tributary river systems to the Delta. Changes in these hydrograph characteristics then have an effect on the ultimate hydrologic flows in, within, and out of the Delta.

The authors finally move in section 2.4 to the Delta itself and show that the cumulative change in inflows to the Delta from the various tributaries results in a much drier system overall particularly during the spring snowmelt season and to a lesser degree an increase in observed inflow compared to unimpaired flows during the late summer.

Flow in the Delta is of course further complicated by the human infrastructure that is used to wheel water through the Delta to the Bay Area, the southern Central Valley, and the urban centers of southern California. This pumping further interacts with tidal processes to make for a very complicated set of hydrodynamics. The authors clearly show that change in management can result in significant shifts in hydrology in the Delta (evidenced by changes in south Delta exports in figure 2.4-4). Figure 2.4-5 also

documents a significant shift in Delta flows with the OMR region seeing significant upstream flow much of the time compared to the unimpaired and pre-1968 series which show much less frequent upstream flows.

The authors compile a compelling set of graphs comparing both unimpaired and current conditions of Delta inflow and outflow as well as historical changes in outflow (Figures 2.4-5, 2.4-7 and 2.4-8) that clearly demonstrate the hydrologic changes that water resources development and management has exerted on the inflow and outflow of water from the Delta. They further this argument in showing the X2 distance increasing for current conditions compared to unimpaired and also showing its movement upstream in more recent periods versus earlier observed periods (Figures 2.4-10, 2.4-11 and 2.4-12).

*Part 1 – “Diversions and exports have reduced average annual outflow, reduced winter and spring outflow and reduced seasonal variability (Figures 2.4-7 and 8 and Table 2.4-3) over time.”*

The authors clearly demonstrate through the use of historical data and the SAC-WAM model that inflows and outflows from the Delta have changed significantly through the impact of water resources management on the Delta system. The authors further show clearly that the changes in hydrology in this system are focused on reduced seasonal variability that has resulted in reduced winter and spring inflows and outflows from the Delta and increased summer inflows and outflows. These changes have resulted in the salinity boundary called X2 moving farther up the Delta system.

*Part 2 - “Water development in regulated tributaries, such as the Sacramento River at Freeport, has resulted in reduced annual flows, a reduction and shift in spring inflow, an increase in summer inflow, and a decrease in hydraulic variability (Figure 2.2-5 and Table 2.2-2).”*

This result showing the shifting of spring snowmelt flows into the summer period is evident repeatedly on the river systems contributing to Delta inflows. The figure and table cited are certainly appropriate pointers to this large body of evidence. However I might use an e.g. in the parenthetical figure call so that readers understand this is not the only figure supporting the conclusion.

*Part 3- “Tributaries without large reservoirs generally have lower flows in summer and part or all of the fall.”*

This conclusion is supported by the current condition versus unimpaired flows descriptions of several of the Sacramento River’s tributaries (e.g. Figure 2.2-9). However the nature of the monthly flow figures and the arithmetic y-axis that the authors have chosen makes it somewhat difficult for a reader to assess how much low flow summer conditions have changed in these non-impounded tributary streams. While the decreased summer and fall flows is seen on a number of streams an alternative data presentation either focused on this season, using cumulative flow duration curves, or logarithmic y-axes would help the reader observe the evidence for this conclusion more clearly.

*Part 4 – “Project pumping in the south Delta has increased (Figures 2.4-4 and -5) and this has resulted in an increase in the magnitude and frequency of reverse (upstream) flows on Old and Middle rivers (Figure 2.4-5).”*

Figure 2.4-5 and the description of the Delta hydraulics clearly demonstrates that reverse (upstream) flow conditions now occur a greater fraction of the time than historically. The authors also provide convincing evidence that these hydrodynamic changes are due to increased pumping in the south Delta. It seems recent pumping has decreased and several scientific approaches to understanding the effect of this reduction on Delta flows and upstream flows have commenced. It would be nice to see some data showing what the effect of the reduced pumping has been on X2 or on Delta Outflow. I understand the impacts of the recent drought may confound such an analysis but the changes in pumping provide a useful real world test of the system and it would be valuable to see the impacts of those changes on Delta conditions.

### **Overall conclusion**

Conclusion 1 of the report – **“1. Significant changes have occurred to the hydrology and hydrodynamics of the Sacramento River and its tributaries, Delta eastside tributaries, and the Delta.”** Is supported by the evidence included in this report. The evidence for this conclusion is built up brick by brick by the authors. First they show that the tributaries have shifted significantly in their flow particularly in shift of spring snowmelt to summer flows on rivers with impoundments. This shift in river flows integrated across the Delta tributaries leads to overall decreases in inflow to the Delta particularly during the spring snowmelt season. These decreases in inflow combine with the exports from the Delta and the managed flow architecture of the Delta to reduce outflows. This reduction in outflows has in turn caused an eastward movement of the fresh saline water boundary and has caused reversed or upstream flows to become more common than downstream flows in portions of the Delta. Combined this evidence points to significant changes in the hydrology of the tributary rivers to the Delta and the hydraulic flows of the Delta itself. As noted above there are a few places where clarification or additional data and analysis might be helpful in further increasing confidence in this conclusion but these slight changes would likely strengthen the evidence supporting this conclusion.

### **Minor Comments**

Table 2.4-3 describes the unimpaired contributions to total Delta outflow from various locations. It is unclear why the percentages in each column sum to be greater than 100%. It could be either due to double counting on some reaches (both upstream and downstream locations are included) or it could be due to the hydrologic changes. The authors should explain the problem of sums greater than 100% in a footnote to the table or in the text of the document.

University), **Post-doc.** W. C. Leggett (McGill, now Emeritus Prof. Queens Univ. Ontario)



**DR. THOMAS J. MILLER**  
Director

University of Maryland  
CENTER FOR ENVIRONMENTAL SCIENCE  
CHESAPEAKE BIOLOGICAL LABORATORY

P.O. Box 38  
146 Williams Street  
Solomons, MD 20688  
Voice: (410) 326-7276  
Fax: (410) 326-7264  
Email: miller@cbl.umces.edu  
WWW: hjort.cbl.umces.edu

May 25, 2017

Gerald W. Bowes, Ph.D.  
Manager  
Cal/EPA Scientific Review Program  
Office of Research, Planning and Performance  
State Water Resources Control Board  
1001 "I" Street, 16<sup>th</sup> Floor  
Sacramento, CA 95814

Dear Dr. Bowes

Re: Review of the Scientific Basis for New and Revised Water Quality Objectives for the  
Phase II Update of the Bay-Delta Plan

This letter accompanies my review of the scientific basis for the new and revised water quality objectives for the Phase II update of the Bay-Delta Plan as requested by you in your letter of April 25, 2017. Attachment 2 of that letter identified eight broad conclusions on which your office sought evaluation. As you are aware from our discussions prior to my commitment to undertake the review, my area of expertise in the ecology of fishes limits the number of broad conclusions on which I feel qualified to comment. Additionally, I had not read one specific conclusion related to the application of "holistic" models to develop flow characteristics with sufficient specificity. I naively believed that holistic was being used in its colloquial sense rather than in its technical sense. As a result, my review only addresses six of the eight broad conclusions: I do not comment on Conclusion 1 or Conclusion 3.

I would be happy to elaborate or clarify any comments I have made in the attached review if it would assist the review process.

Sincerely,

Thomas J. Miller, Ph.D.

**REVIEW OF THE SCIENTIFIC BASIS FOR NEW AND REVISED WATER QUALITY OBJECTIVES FOR  
THE PHASE II UPDATE OF THE BAY-DELTA PLAN**

**Thomas J. Miller, Ph.D.  
Chesapeake Biological Laboratory  
University of Maryland Center for Environmental Science  
146 Williams Street // 0038  
Solomons, MD 20688**

**May 25, 2017**

## Description of Review Activities

I was provided with access to a range of documents related to the development of water quality objectives for the Phase II update of the Bay-Delta Plan (BDP) including:

Attachment 1: Summary of the Phase II Update

Attachment 2: Scientific Issues to be addressed by Peer Reviewers

Attachment 3: Individuals involved in the development of the Science Report

Attachment 4: Folder containing electronic Reprints of all Citations

Attachment 5: Science Report, dated April 2017

As a part of my review, I read Attachments 1, 2 and 5 in detail. I confirmed a lack of significant conflicts of interest by evaluating the scientists listed in Attachment 3 who worked on the Phase II update of the BDP. Where necessary I reviewed the relevant supporting peer-reviewed publications and government reports referenced in Attachment 4.

My review did not involve accessing or verifying raw data presented in the Scientific Basis report (Attachment 5).

## Review Findings

The Scientific Basis Report summarizes a vast array of primary data, scientific reports and peer-review literature to evaluate flow requirements to support the coequal goals of providing a more reliable water supply for California and protecting, restoring and enhancing the Delta ecosystem. The Scientific Basis Report has been a mammoth undertaking and has been completed to a high professional standard. It combines analysis of primary data, development of statistical relationships and mathematical population models to infer flow standards to protect the Delta ecosystem. I wish to commend and thank all those involved in preparing the Scientific Basis Report for their thorough and well-documented analysis.

The flow standards recommended in the Scientific Basis Report are based on analyses of the dynamics of eight native fish species, and two invertebrate groups. The selection of the 10 taxa examined in detail is appropriate and well justified. For each species, the Scientific Basis Report provides summaries of empirical and quantitative habitat modeling that were conducted to define relationships between some characteristic of flow (usually seasonal average flow) and the resilience of the population, variously defined by life stage or by overall population growth rate.

**Review Finding 1:** The review provides limited consideration of the broader ecosystem context of Bay-Delta ecosystem. Fundamentally, the analyses focus on habitat suitability as measured by flow, temperature and DO, and largely ignore ecological mechanisms that may constrain the expression of flow-dependent, temperature-dependent or DO-dependent relationships with population abundance. Stated simply, the review assumes that if the flow, temperature and DO conditions are appropriate, all other components of the ecosystem will naturally follow. In

reality the flow, temperature and dissolved oxygen criteria established are necessary, but not necessarily sufficient conditions for the long term survival of the 10 taxa considered and the Bay-Delta ecosystem of which they are emblematic.

It might be argued that since the statistical relationships are phenomenological, and most do not prescribe a mechanistic relationship, the flow, temperature and dissolved oxygen criteria may reflect both necessary and sufficient conditions for the entire ecosystem. However, it should be noted that this makes the assumption that all ecosystem components, or at least the critical ecosystem components demonstrate the same phenomenology. It may be that for salmonids in particular, flow is the critical habitat resource and the relationship is indeed mechanistic. But regardless of such explanations, the lack of an ecosystem context in many of the analyses remains. For example, prey abundances are rarely considered. There is only limited consideration of limits to overall system productivity or of low frequency drivers of ocean-estuarine productivity, such as the PDO.

The lack of the broader ecosystem context in setting flow standards increases the uncertainty with which any recommendation is made.

**Review Finding 2:** The Scientific Basis report presents analyses of several fishery-independent surveys, such as the Fall Midwater Trawl. These data are presented as index values. Few details are provided over the development and analyses of these survey data (but see CDFW 2016). But there is little evidence of evidence to standardize the survey data or to adjust for the occurrence of true “0” hauls in which a target species was not caught. There is a large and detailed literature that presents options for standardizing and analyzing such data in marine fisheries. These methods include the application of zero-inflated models, with both single and two stage approaches having been developed (Stefansson 1996, Jensen et al. 2005). In addition, these approaches can often be used to evaluate and adjust for the effect of survey design factors such as strata and month. There was little evidence that such analyses had been conducted and the lack of such analyses may reduce the ability to detect significant impacts of flow, temperature and dissolved oxygen on abundance of the 10 targeted taxa. I note that the application of such approaches to data from the Bay-Delta system has been demonstrated (Latour 2016).

**Review Finding 3.** The Scientific Basis report analyzes empirical measurements of bulk flow in the Bay-Delta system. These flows are often presented as seasonal average flows, e.g., spring flows or summer flows. These seasonal flow data are then used directly in a number of analyses (See Review Finding 4 below). However, in all cases I evaluated the flow was used as a direct covariate without any temporal lag – that is the abundance in year  $t$  was regressed against flow in year  $t$ . There was very limited exploration of the potential for lagged effects of flow, such that the abundance in year  $t$  could be influenced by the flow in year  $(t-C)$ . There are some specific examples in which flow in some species has been shown to have a lagged relationship with subsequent abundance, particularly in salmonids. Consideration of such lagged effects may have improved the confidence with which flow criteria may have been developed.

**Review Finding 4:** The Scientific Basis report relies on direct laboratory and field measurements of flow as the foundation for some criteria; others are developed through statistical modeling. Three broad categories of statistical models are commonly employed for the flow-abundance relationships. Two of the three categories were associated with significant statistical concerns.

- 1) Flow abundance relationships are developed using the methodologies in two peer-reviewed articles. The first, by Kimmerer (2002) regresses  $\log(x+C)$  abundance against the position of the X2 isohaline. The position of the X2 isohaline is strongly correlated with the log of annual average January-June flow. The use of  $\log(x+C)$  transformations was once common in the ecological literature to address the occurrence of true “0” values in a dataset. Different values of C were used by different authors, but C=1 is a commonly used value, although Kimmerer (2002) and other authors have used other values (e.g., C=10). However, application of this transformation is now known to produce bias in results, possibly altering conclusions about the significance of different covariates (O’Hara and Kotze 2010). In particular, the value of C is either arbitrary or set “by-tradition.” Yet, its value can influence the likelihood that statistical relationships with covariables will be found. The second approach (e.g., Jassby et al. 1995) employed modern generalized linear models that can be easily fit to the zero-inflated count data that are inevitable in fish survey work. Importantly, these more modern generalized linear modeling approaches for count data are not associated with concerns over potential statistical bias. Reliance on the Kimmerer approach increases the uncertainty associated with flow criteria.
- 2) Flow abundance relationships were developed from cumulative frequency distributions of flow for periods when staff could identify periods when the abundance goal was obtained or exceeded.
- 3) Flow abundance relationships were developed using a logistic regression approach in which estimates of the finite rates of population growth ( $\lambda$ ) were converted to a binary scale (0,1) in which  $\lambda < 1 = 0$  and  $\lambda \geq 1 = 1$ . The binary (0,1) variable was then regressed against the log of average seasonal outflow and the flow that is associated with a probability,  $p=0.5$  of being associated with stable or growing populations was estimated from the logistic regression. This approach was used in particular for longfin and delta smelts. There was limited clarity over which flow year was used in these inherently lagged analyses, nor whether any consideration was given of autocorrelation among individual  $\lambda$  values which would alter the interpretation of the analyses. For example Figure 3.5-3 presents the results of the application of the logistic regression methodology for longfin smelt for which the finite growth rate was calculated assuming an age of maturity =2. It is unclear whether for flow for year 0, year 1 or year 2 was used in the regression – or whether the effect of this lag was examined.

In general the statistical analyses presented were less sophisticated than would be anticipated for a document supporting a policy of this importance. This is particularly the case given the examples set by Latour (2016), Maunder and Deriso (2011) and Maunder et al (2015). These papers present state of the art statistical methods, both generalized linear models within an

information theoretic framework and state space modeling which allows for evaluation of random effects and both observation and process errors. The effort to assess the reliability of conclusions regarding a definitive role of flow, temperature and dissolved oxygen in meeting the two coequal goals would be stronger if statistical frameworks such as those used by Latour and by Maunder and co-authors were used more broadly. These comments should not be seen to denigrate the efforts of earlier studies (e.g., Kimmerer (2002), Jassby et al (1995)), but rather to reflect the rapid development and broad availability of new statistical tools which would be more appropriate for assessing and quantifying the role of flow, temperature and dissolved oxygen in determining flow levels that protect, restore and enhance the abundances of emblematic species within the Bay-Delta ecosystem.

### **Validity of Scientific Conclusions**

#### **1. Significant changes have occurred to the hydrology and hydrodynamics of the Sacramento River and its tributaries, Delta eastside tributaries, and the Delta.**

Not reviewed

#### **2. Changes to the flow regime of the Sacramento River and its tributaries and the eastside tributaries to the Delta, Delta outflows, cold water habitat, and interior Delta flow conditions have contributed to the impairment of the ecosystem and native fish and wildlife beneficial uses and could contribute to future impairments without additional regulations.**

There is clear evidence for the decline of many of the 10 emblematic taxa examined in the Scientific Basis report. For each of the species, I provide an assessment of the confidence with which the scientific “conclusion” is supported.

With high confidence, the current flow regime within the Bay-Delta ecosystem has impaired the population diversity and abundance of Chinook salmon (*Oncorhynchus tshawytscha*, all runs) and of Central Valley steelhead (*O. mykiss*). Evidence for this conclusion reflects the combination of direct reductions in habitat resulting from damming and restrictions on flow, results from aquaculture studies on the temperature and flow requirements of both species, and historical patterns of abundance (often measured as escapement in salmonids). The confidence of this conclusion would be further strengthened by the development of stock assessment models which derive abundance estimates from the integrated statistical analysis of fishery-independent survey data and fishery dependent harvest levels for historical data when harvests may have been substantial.

With high confidence, the current flow regime within the Bay-Delta ecosystem has impaired the population abundance of longfin smelt (*Spirinchus thaleichthys*). The most reliable evidence for

this decline, and the role of flow in causing the decline is derived from state-space modeling conducted by Maunder et al. (2015). Similar robust support is derived from Latour's (2016) application of generalized linear models. The evidence from the simple linear regression of  $\log(\text{Fall Midwater trawl abundance})$  against time is less compelling because of shortcomings in the regression model with respect to the distribution of errors and possible autocorrelation among years caused by low frequency environmental forcing. However, despite the shortcoming of the statistical model, the fivefold decline longfin smelt in the Fall Midwater Trawl survey between 1970 and present cannot be easily ignored. The step change regression model presented in the Scientific Basis report, following methods described by Kimmerer (2002) provides additional support for the positive exponential relationship between flow and abundance of longfin smelt, but the lack of a full information theoretic approach in these analyses weakens the strength of the inference.

With moderate confidence, the abundances of white and green sturgeon have been negatively impacted by the flow regime in the Bay-Delta ecosystem. These impacts are likely due to reductions in suitable spawning habitats (defined by access to areas of suitable temperature, flow and substrates) that result directly from changes in flow. Knowledge of these species requirements come from both direct empirical measurements of current spawning and the results of aquaculture studies. However, the lack of integrated statistical models, either similar to the Maunder et al. state-space model, or a more formal statistical catch-at-age or statistical catch-at-length model prevents a full understanding of the role of commercial and recreational harvests on the abundance of these two species.

With moderate confidence, the abundance of Sacramento splittail (*Pogonichthys macrolepidotus*) has been negatively affected by changes in the Bay-Delta flow regime. The fall midwater trawl index for splittail has declined by a factor of 20-50 since 1970. However the pattern of decline in this species is less consistent than that observed for other species. Direct modeling of the relationship between flow and  $\log(x+1)$  abundance of splittail in the fall midwater trawl survey supports a role for flow, but the variance explained by the relationship, although significant, is only moderate ( $r^2=0.31$ ).

Delta smelt (*Hypomesus transpacificus*) has been the subject of considerable sampling and analysis. With high confidence the abundance of Delta smelt has declined since 1970. Overall the abundance of Delta smelt in the fall midwater trawl survey has declined approximately 50-fold. The application of a state-space model to Delta smelt abundance data provides strong evidence of the decline (Maunder and Deriso 2011). However, because much of the evidence for the impact of flow alterations on Delta smelt relate to the position of the isohaline X2, there are multiple alternative (and potentially competing) hypotheses that may help explain this relationship and the definitive role for flow is yet to be conclusively made (e.g., Rose et al. 2013a, b).

With low confidence, the abundance of starry flounder (*Platichthys stellatus*) has declined since 1980. The role of flow in this decline is uncertain as it requires a multistage model that includes

impacts of gravitational circulation on selective tidal stream transport of young flounder into the Bay-Delta.

With low confidence, the abundance of California Bay shrimp (*Crangon franciscorum*) has varied without significant trend over the last 30+ years. The lack of an integrated statistical model that accounts for commercial harvest and survey uncertainty on the abundance of shrimp challenges the ability to draw conclusions regarding abundance. As a result relationships between flow and abundance are associated with considerable uncertainty.

Trends in the abundance of zooplankton (two key species – *Neomysis mercedis*, *Eurytemora affinis*) are highly uncertain because of the high degree of spatial variability in both of these species and the resultant low sampling intensity.

**3. To expeditiously address the impairments to native fish and wildlife beneficial uses in a very large, highly complex, and heavily-modified system such as the Bay-Delta, an approach based on the holistic method to the development of environmental flows that provides for flows of a more natural pattern that can then be further managed to maximize flow-related functions for the benefit of fish and wildlife beneficial uses is feasible and scientifically justified.**

Until I read the Scientific Basis document, I was unaware of the technical definition of the “holistic method” to developing flow criteria and do not feel qualified to comment on its application to the Bay-Delta ecosystem.

**4. Inflows that more closely mimic the natural flow and water quality conditions to which native migratory fish are adapted are needed in the Sacramento River basin and Delta eastside tributaries to provide spawning and rearing habitat and connectivity with the Delta.**

This conclusion is supported with a high degree of confidence. The Scientific Basis report provides detailed descriptions of the life history and timing of the 8 fish species and shrimp. These life history descriptions provide clear indications of the flow, temperature and dissolved oxygen requirements of these species in space and time. Together these environmental requirements provide compelling evidence that the native migratory species were adapted to the natural hydrograph of the Sacramento River Basin and eastside tributaries. There remains, however, considerable uncertainty as to whether the pattern AND the scale of the natural flows are required or whether the pattern is a necessary and sufficient condition provided that adequate flows are provided. I find there is moderate confidence in the analyses reported in the Scientific Basis report that it is likely that the flow pattern with adequate levels of flow will protect, restore and enhance emblematic fish and invertebrate species. I find there is moderate certainty that the analyses presented in the Scientific Basis report provide reliable estimates for appropriate flows for native migratory fish species in the Sacramento River Basin.

However, I note that I believe the Scientific Basis report underestimates the extent, nature and importance of intra-population life history diversity, particularly as it relates to migration behavior (Secor 2015). The recommended flows will likely support the typical or average

migratory behavior, but there is increasing evidence that migratory pathways demonstrated by minority contingents are what provides population resilience (Kraus and Secor 2004, Kerr and Secor 2012). Therefore, the extent to which the conditions that favor the migratory behavior of the majority contingent, thereby disadvantaging minority behavior, may serve to weaken overall population resilience over that expected.

**5. Delta outflows that more closely mimic the natural flow and water quality conditions to which native migratory fish are adapted are needed year round to support the migration, spawning and rearing of native estuarine and anadromous species.**

I find this conclusion to be supported with a high degree of confidence. The Scientific Basis report presents detailed description of the life history of native migratory species that provide a justification of the spatial and temporal distribution of habitat use during migrations – of both returning adults and emigrating juveniles. The Scientific Basis report supports, with high confidence, the conclusion that the pattern of Delta outflows is a necessary condition for the protection, restoration and enhancement of native migratory species. I find that the report also provides clear justification that the recommended flows would provide the pattern of flow and afford a level that would, with high likelihood, afford appropriate conditions for native estuarine and anadromous species.

I re-emphasize the comments about intra-population life history diversity made relative to natural flows in Sacramento River Basin above in supporting population resilience with respect to Delta outflows.

**6. Cold water habitat is needed below reservoirs to compensate for natural cold water salmonid habitat lost by reservoir construction above dams.**

I find this conclusion to be supported with a high degree of confidence. The Scientific Basis report presents compelling evidence that the level, timing and temperature of flows in the Sacramento River Basin and in other regions of the Bay-Delta supported Chinook salmon and steelhead. This evidence is derived from direct measurements of temperature and flow in the field, results from experience gained from aquaculture and from releases of aquaculture-raised individuals as a part of stock enhancement activities. With moderate confidence, the Scientific Basis report provides evidence that the loss of this flow-, temperature- and dissolved oxygen specific habitat can be replaced by equivalent habitats below existing dams if releases from the dams are managed to replicate the environmental conditions required by specific life history stages.

**7. Interior Delta flow requirements (Delta Cross Channel (DCC) gate closures, OMR reserves flow limits and export constraints) help protect resident and migratory species from entrainment and related effects in the southern Delta associated with CVP and SWP diversion activities.**

The complexity of the flows associated with the DCC gate closures, OMR reserve flows and export constraints make assessment of this conclusion with a high degree of confidence difficult. It is clear that the flows do mitigate against entrainment in the CVP and SWP

diversions, but the lack of holistic integrated models that allow assessment of alternative hypotheses regarding sources of mortality make assessment of this conclusion highly uncertain.

**8. Other aquatic ecosystem stressors have negative effects on fish and wildlife beneficial uses, and non-flow actions are also needed for ecosystem recovery.**

I find this conclusion supported with a high degree of certainty. However, the lack of holistic whole population models for many of the species considered in the Scientific Basis report make comparing the impacts of the individual external stressors (whether they are contaminants, fisheries management or climate change) difficult. Thus the degree and magnitude of the individual negative effects can be quantified with only low precision.

The section on fisheries management in Chapter 4 draws attention to the unquantified impact of the harvest of adults of several species (salmonids, sturgeons, and flounder) in the marine environment. The recognition of the potential impact of harvest in this section of the report is at odds with its lack of consideration in Chapter 3, making the case for integrated assessment models stronger to fully understand factors leading to declines.

Similarly, the section on climate change (Section 4.6) introduces uncertainties into the time frame over which recommended flows are applicable. The section on climate change also strengthens Review Finding 1 (above) which highlighted the lack of an ecosystem context for the understanding of the impacts of population stressors.

## LITERATURE CITED

- California Department of Fish and Wildlife 2016. Monthly Abundance Indices (Downloaded from Attachment 4, available at <http://www.dfg.ca.gov/delta/data/fmwt/indices.asp>)
- Jassby, A. D., W. J. Kimmerer, S. G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J. R. Schubel, and T. J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. *Ecological Applications* **5**:272-289.
- Jensen, O. P., R. Seppelt, and T. J. Miller. 2005. Winter distribution of blue crab (*Callinectes sapidus*) in Chesapeake Bay: application of a two-stage generalized additive model (GAM). *Marine Ecology - Progress Series* **299**:239-255.
- Kerr, L. A. and D. H. Secor. 2012. Partial Migration Across Populations of White Perch (*Morone americana*): A Flexible Life History Strategy in a Variable Estuarine Environment. *Estuaries and Coasts* **35**:227-236.
- Kimmerer, W. J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? *Marine Ecology Progress Series* **243**:39-55.
- Kraus, R. T. and D. H. Secor. 2004. Dynamics of white perch *Morone americana* population contingents in the Patuxent River estuary, Maryland, USA. *Marine Ecology-Progress Series* **279**:247-259.
- Latour, R. J. 2016. Explaining Patterns of Pelagic Fish Abundance in the Sacramento-San Joaquin Delta. *Estuaries and Coasts* **39**:233-247.

- Maunder, M. N. and R. B. Deriso. 2011. A state-space multistage life cycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt (*Hyposmesus transpacificus*). *Canadian Journal of Fisheries and Aquatic Sciences* **68**:1285-1306.
- Maunder, M. N., R. B. Deriso, and C. H. Hanson. 2015. Use of state-space population dynamics models in hypothesis testing: advantages over simple log-linear regressions for modeling survival, illustrated with application to longfin smelt (*Spirinchus thaleichthys*). *Fisheries Research* **164**:102-111.
- O'Hara, R. B. and D. J. Kotze. 2010. Do not log-transform count data. *Methods in Ecology and Evolution* **1**:118-122.
- Rose, K. A., W. J. Kimmerer, K. P. Edwards, and W. A. Bennett. 2013a. Individual-Based Modeling of Delta Smelt Population Dynamics in the Upper San Francisco Estuary: I. Model Description and Baseline Results. *Transactions of the American Fisheries Society* **142**:1238-1259.
- Rose, K. A., W. J. Kimmerer, K. P. Edwards, and W. A. Bennett. 2013b. Individual-Based Modeling of Delta Smelt Population Dynamics in the Upper San Francisco Estuary: II. Alternative Baselines and Good versus Bad Years. *Transactions of the American Fisheries Society* **142**:1260-1272.
- Secor, D. H. 2015. *Migration Ecology of Marine Fishes*. The Johns Hopkins University Press, Baltimore, MD.
- Stefansson, G. 1996. Analysis of groundfish survey abundance data: Combining the GLM and delta approaches. *ICES Journal of Marine Science* **53**:577-588.

**To:** State Water Resources Control Board of California, c/o Gerald W. Bowes, Ph.D.

**From:** N. LeRoy Poff, Ph.D. and Professor, Department of Biology, Colorado State University, Fort Collins, CO 80523

**Subject:** Scientific review and comments on Conclusions 2, 3, 4, 5, 6, and 7 of “Working Draft Scientific Basis Report for New and Revised Flow Requirements on the Sacramento River and Tributaries, Eastside Tributaries to the Delta, Delta Outflow, and Interior Delta Operations”

**Submitted:** May 24, 2017

---

**CONCLUSION 2. Changes to the flow regime of the Sacramento River and its tributaries and the eastside tributaries to the Delta, Delta outflows, cold water habitat, and interior Delta flow conditions have contributed to the impairment of the ecosystem and native fish and wildlife beneficial uses and could contribute to future impairments without additional regulations.**

**Hydrologic impairment:**

The alteration of flow regimes is extensive throughout the Bay-Delta Watershed (BDW) both in terms of annual depletions of flow (Fig. 2.1-10) and of monthly and seasonal deviations in the timing of unimpaired (“natural”, pre-settlement) flows (e.g., Fig. 2.2-2). Flow “impairment” is framed in terms of the natural flow regime paradigm, which posits that flows of varying magnitude, frequency, timing and duration both shape species adaptations and determine contemporary community/ecosystem structure and function. Accordingly, human-caused deviations in these flows lead to biological and ecosystem impairment. This framework is scientifically well-accepted and it is widely applied globally in ecological water resources management. The Report provides ample citation of appropriate literature that documents the scientific validity of the approach.

The key features of unimpaired flow regimes in the BDW consist variably of (depending on geographic location) spring peak flows driven by snowmelt or rain-on-snow events, winter storm flows, fall storm flow pulses, and summer base flows. These features are observed on remaining free-flowing tributaries (Fig. 2.2-19, Fig. 2.2-22). Numerous dams and diversion structures of different sizes and operational modes occur throughout the BDW, and they strongly modify the quantities and timing of freshwater delivered from tributaries and flows through the basin and into the Delta by capturing runoff and reducing spring/summer peak flows and elevating late season base flows (Fig. 2.2-2, Fig. 2.2-13), or by decreasing late season base flows under heavy diversion (Fig. 2.2-25). Flow inputs to the Delta are further impaired (Fig. 2.4-2) by trans-basin pumping structures (the Projects) that diminish total and seasonal flow outputs from the Delta (Fig. 2.4-7) and that cause large flow reversals.

**Biological and ecosystem impairment:**

The Report aims to demonstrate that flow impairment leads to biological (species) and ecological (whole ecosystem) impairment throughout the BDW. A “holistic” (whole ecosystem based) approach is adopted, consistent with a natural flows paradigm, i.e., flow variability promotes dynamic processes, habitat variability, genetic and life history diversity of migratory fish species and populations (“runs”), lateral connectivity, and minimization of thermal distortions by impoundment. At the whole watershed scale, hydrologic impairment of quantity and timing of outflows contributes to reductions in habitat quality and quantity and to reduced connectivity among habitats that is essential for many migratory fish species.

For individual species, the accepted scientific approach of “flow-ecology” relationships is used. These are statistical (correlational) relationships between degree of flow impairment and level of reduction in

biological performance or ecological condition. The flow-ecology relationships are grounded in the “functional” flow needs of individual species, i.e., quantity and timing of flows needed to complete habitat-specific life cycles, to promote growth, and to persist and thrive for both freshwater (e.g., Figs. 3.4-12) and estuarine species (see Conclusion 6 below). For these species, flow “functions” to provide suitable habitat quantity (e.g., habitat extent, floodplain inundation) and/or quality (e.g., salinity levels). The focus on “functional flows” in the context of hydrologic impairment allows for a biologically-informed (“mechanistic”) interpretation and can, therefore, directly inform management interventions that aim to restore biological performance or ecosystem attributes at local, tributary and whole watershed scales.

Summary: The Report presents ample species-specific data on “functional” flow-ecology relationships for key freshwater and estuarine species. These analyses provide evidence showing that flow impairment (deviations in magnitude and timing of flows) is strongly associated with biological impairment and ecosystem conditions at local to watershed scales. The empirical associations demonstrated in the flow-ecology relationships provide scientific support for the expectation that downward trends in populations of species of concern throughout the BDW will continue to decline under present levels of flow impairment. Reductions in flow impairment will likely contribute to some degree of biological restoration.

**CONCLUSION 3. To expeditiously address the impairments to native fish and wildlife beneficial uses in a very large, highly complex, and heavily-modified system such as the Bay-Delta, an approach based on the holistic method to the development of environmental flows that provides for flows of a more natural pattern that can then be further managed to maximize flow-related functions for the benefit of fish and wildlife beneficial uses is feasible and scientifically justified.**

The “holistic” method is one that recognizes that species are imbedded in an ecosystem context, and therefore successful management of species is much more likely achieved when broader ecosystem impairment is treated. Since the “needs” of the entire, complex BDW “ecosystem” cannot be precisely specified, a first-principles argument is made that a natural range of flow variability (quantity and timing) supports the widest range of species and historically prevailing ecosystem processes by providing a wide variety of habitat types (and connectivity between them) to which native have adapted their life cycles. Accordingly, flow restoration toward a more natural pattern of flow will promote better ecosystem conditions in general. This is a widely-accepted scientific principle (as expressed in the natural flow regime paradigm) that is extensively applied in the practice environmental flows management and supported by published literature (as indicated by citations in the Report).

Because other factors (temperature, sediment, salinity) are also variably contributing to biological impairment across the BDW, a more focused, site-specific tailoring or “sculpting” of flow management is argued as necessary to feasibly achieve specific management goals (e.g., targeting key species at specific locations). This is particularly the case for cold-water species that no longer have access to headwater spawning streams (e.g., winter-run Chinook). Such local-scale “designer” flows that may deviate from the unimpaired seasonal patterns can be flexibly integrated with flow management from other tributaries to attain the basin-wide aim of increasing inflows in the bay-delta.

Summary: This approach is well-reasoned scientifically in accordance to well-accepted principles of environmental flow science and management.

**CONCLUSION 4. Inflows that more closely mimic the natural flow and water quality conditions to which native migratory fish are adapted are needed in the Sacramento River basin and Delta eastside tributaries to provide spawning and rearing habitat and connectivity with the Delta.**

Many BDW species are migratory and thus require qualitatively different habitat types at different stages of their life cycles, including native salmon (section 3.4), nonnative game fishes (section 3.12) and native plus nonnative estuarine species (section 3.6). This requires suitable conditions in the different kinds of habitat (e.g., for salmon: cool, gravel-bedded streams for salmonids, slack water habitats such as inundated floodplains for growth of out-migrating smolts, and access to the ocean for growth to maturity). Connectivity between these habitats is critically important. Therefore, flow management across the entire basin is necessary to maximize the survival and abundance of migratory species. A mimicking of the natural flow regime by reducing hydrologic impairment will support habitat conditions (quantity and timing of water, salinity conditions in the Bay-Delta) and their connectivity across the BDW.

Summary: This is a scientifically sound inference supported by empirical data. (Also see comments to Conclusions 2 and 3 above.)

**CONCLUSION 5. Delta outflows that more closely mimic the natural flow and water quality conditions to which native migratory fish are adapted are needed year round to support the migration, spawning and rearing of native estuarine and anadromous species.**

More natural outflows from freshwater habitats into the Delta and Bay support native (and nonnative) species (Figs. 3.6-2, 3.6-3, 3.7-2, 3.9-2, 3.10-2, 3.11-1, 3.11-2). The salinity gradient in the Bay-Delta is largely controlled by the quantity of freshwater into the Delta (Fig. 3.2-1) and can also be a determinant of species success (Fig. 3.5-6).

Summary: Many species benefit from a more natural magnitude and timing of Delta outflow (summarized in Table 3.13-2), providing strong evidence that reduction in flow impairment in the BDW that results in increased Delta outflow will enhance native (and some nonnative) species.

**CONCLUSION 6. Cold water habitat is needed below reservoirs to compensate for natural cold water salmonid habitat lost by reservoir construction above dams.**

In a complex and highly modified BDW, a “return to natural” is not necessarily the best path to meet all socially desired ecological outcomes. Dams and reservoirs block many migration pathways for anadromous salmonids, such that some cannot ascend to cooler headwater streams to spawn. Cold water stored in reservoirs can be released to promote species persistence downstream. The timing of such releases may be inconsistent with natural timing but may serve the priority management goal of sustaining targeted species that are as limited by thermal conditions as they are by flow conditions.

Summary: This Conclusion is well supported. Long-term sustainability of species dependent on temperature-impaired habitats (e.g., winter-run Chinook) will require both thermal management (local) and flow continuity (whole basin).

**CONCLUSION 7. Interior Delta flow requirements (Delta Cross Channel (DCC) gate closures, OMR reserves flow limits and export constraints) help protect resident and migratory species from entrainment and related effects in the southern Delta associated with CVP and SWP diversion activities.**

Extensive incoming freshwater flows from BDW rivers is exported out of basin, reducing Delta outflows. The infrastructure in place to pump water results in flow reversals that entrain and kill juvenile (Figs. 3.4-15, 3.4-16, 3.5-5) and adult fishes (Fig. 3.8-7).

Summary: Data presented clearly demonstrate that reducing flow reversals is likely to diminish mortality (salvage) of affected fish species.

**CONCLUSIONS 2-7 Summary**

Final Summary: The Report uses extensive and comprehensive data on many aquatic species (mostly fish) for the BDW. The performance of these species (survival, growth, abundance) is related to recent historical flow conditions (hydrologic impairment) within and across habitats in the BDW to demonstrate biological impairment. This impairment approach is supported by the natural flows context (magnitude, timing) widely adopted in environmental flows methods. Empirical flow-ecology relationships are presented that clearly show reduced biological performance in response to flow impairment. These relationships demonstrate the “functional” role that impairment of flow magnitude and timing play in biological impairment, and they are used to recommend narrative flow targets at the tributary and whole basin scales. These narrative targets are well justified by the scientific analyses presented in the Report. These scientific methods and practices are appropriately and adequately cited in the Report. Further, these simple flow-ecology relationships can be viewed as generally robust, in that other limiting factors (considered elsewhere in the Report) are not captured in these empirical flow-ecology relationships.

A review submitted on May 24, 2017 by Dr. Elowyn Yager, Department of Civil Engineering, Center for Ecohydraulics Research, University of Idaho.

I have read the Science Report and have evaluated it primarily with respect to Conclusion One. I outline my comments below following a restatement of Conclusion One.

**Conclusion 1. Significant changes have occurred to the hydrology and hydrodynamics of the Sacramento River and its tributaries, Delta eastside tributaries, and the Delta.**

**The Science Report focuses on the flow characteristics of the main stem Sacramento River, its tributaries, the three eastside tributaries to the Delta and the interior Delta. These flows are critical to supporting ecological processes and the species that depend on those processes, including native anadromous and estuarine species. The magnitude, duration, timing and frequency of flow in all these waterbodies were evaluated to assess the types of change in the flow regime that have occurred over time. This information is provided as background and supporting information for subsequent chapters. Diversions and exports have reduced average annual outflow, reduced winter and spring outflow and reduced seasonal variability (Figures 2.4-7 and 8 and Table 2.4-3) over time. Water development in regulated tributaries, such as the Sacramento River at Freeport, has resulted in reduced annual flows, a reduction and shift in spring inflow, an increase in summer inflow, and a decrease in hydraulic variability (Figure 2.2-5 and Table 2.2-2). Tributaries without large reservoirs generally have lower flows in summer and part or all of the fall. Project pumping in the south Delta has increased (Figures 2.4-4 and -5) and this has resulted in an increase in the magnitude and frequency of reverse (upstream) flows on Old and Middle rivers (Figure 2.4-5). This information is included in Chapter 2 of the Science Report.**

- 1) In the first step of my review, I have read the Science Report in detail to assess whether Conclusion One is supported by the presented data on the basin hydrology and whether the use of unimpaired flow is justified. The assessment of changes in annual outflow and specific seasonal flows are based on a comparison of modeled unimpaired and current flow conditions in 23 tributaries of the Sacramento River/Bay-Delta. These calculations are provided on a monthly basis for water years 1921-2015. For a given tributary and the entire drainage basin, all outflows for a given scenario (unimpaired vs. current flow) are combined for the simulation period to create an outflow distribution for each month. Then the distributions of unimpaired and current outflows are compared to estimate the impacts of flow regulation/diversions on the river/bay/delta system. Unimpaired flows are used instead of natural flows because most watersheds have been substantially altered by human activities and therefore the natural hydrology is very difficult to simulate/calibrate. Unimpaired flow is the outflow that would be available for all uses if no flow regulations or diversions occurred. The justification for using the unimpaired flows is reasonable and scientifically sound.

In many watersheds, particularly those with dams or diversions, the unimpaired flow distributions are very different from the current flows. In particular, many tributaries and the bay/delta have lower outflows currently than would occur for unimpaired flows in the winter/spring. Outflows are often higher in current than unimpaired conditions in summer months for regulated rivers. These monthly changes contribute to the reduced

seasonal variability that is mentioned as part of Conclusion One. The data presented show that there have been significant changes in the Sacramento River, many of its main tributaries and eastside tributaries to the Delta. The Science Report also shows that many of the hydrodynamics of the delta have changed over time, in particular the location of X2, the inflows and outflows of the delta, and the net flow directions (e.g. reverse flows in Old River and Middle River channels). Based on a detailed reading of the Science Report, I conclude that the modeled/measured data presented support Conclusion One. The hydrologic data presented outlined here are also used for the basis of many of the following conclusions (2-8), which is scientifically sound.

- 2) I have two minor points of clarifications that do not affect the overall Conclusion One.
  - a) In Section 2.1.1 natural, unimpaired and historical flows are discussed to motivate using unimpaired flows for the Science Report. Why are the historical flows changing through time in Figures 2.1.-2 and 2.1.-3, what is the definition of historical flow here? Why are natural and unimpaired flows different from historical flows because of “water development”? I thought the impact of water development (e.g. regulations, diversions) was removed from both natural and unimpaired flows? Can you please provide some additional details that explains these results?
  - b) It is stated that variability in X2 has decreased over time and although this is evident in Figures 2.4.-12 and 2.4-11, I do not see this pattern in Figure 2.4-10, which generally show the same width of the X2 distributions through time. Why are the results different between studies? There is also relatively low variability in X2 in 1970 in Figure 2.4.-12, what would be causing this?
- 3) Although I found Conclusion One compelling, very little information was provided in the Science Report about the flow model (SacWAM) used to obtain many of the data that support this conclusion. In particular, details about the model validation, calibration, and input data were not provided. Unfortunately, a full and extensive review of the model itself was beyond the scope of the review of the Science Report. However, I found a recent and detailed (Dec 2016) peer-review of the model entitled “Independent Peer Review of the Sacramento Water Allocation Model (SacWAM)” (hereafter referred to SacWAM Review, 2016), which I used to help further evaluate the application of SacWAM for the Science Report. Given that a panel of experts spent considerable time reviewing SacWAM, I assume that their review is accurate and I outline below how some of their comments may be relevant to Conclusion One in the Science Report.
  - a) SacWAM unimpaired flows cannot be directly calibrated and validated because of a lack of flow data on many tributaries prior to flow regulation/diversion. It is therefore compared to CalSIM II (another model for the basin) to show that it is performing adequately (SacWAM review, 2016). It was unclear to me in reading the SacWAM Review (2016) and Appendix A of the Science Report whether any SacWAM estimated current flow conditions are calibrated and validated using existing flow data. I assume that this must be the case but some additional information would be helpful on this in the Science Report as well as the uncertainties involved in this calibration.

- b) An error in the flow allocation in SacWAM for a specific watershed (Kellogg Creek) was mentioned in the c Review (2016). Although Kellogg Creek was not one of the specific major tributaries analyzed in the Science Report, if other such errors are present in the SacWAM code, some comparisons between current and unimpaired conditions may include large uncertainties. I cannot comment further on this given that it would require a detailed evaluation of the entire SacWAM code for each tributary basin. However, it does imply that a thorough review of the model results is needed to ensure that the results are physically realistic in each basin. I assume that this is has already occurred in the watersheds modeled as part of the Science Report though?
- c) It is stated in SacWAM review (2016) that “there are additional concerns and limitations to SacWAM. To date, there has been no sensitivity analysis performed or effort to quantify SacWAM model uncertainty....While the corroboration was incomplete (as acknowledged by the SacWAM developers at the October 19, 2016, public workshop), the need for additional corroboration is not acknowledged in the documentation or the model itself.” I concur with this assessment in the context of the current Science Report, some estimate of uncertainty (see my comment 3a) in the comparison of the unimpaired and current flow conditions is needed. Is the level of uncertainty in the model much less than the differences between these two scenarios, and therefore the main part of Conclusion One (and specific conclusions for each tributary) is likely not significantly impacted by model uncertainty? Are there tributaries where the model has a higher level of uncertainty, which would imply that some of the unimpaired and current flow conditions may not be as different as suggested by the model output in the Science Report? I realize that placing uncertainty values on the model would be somewhat difficult given the lack of ability to calibrate the model for unimpaired flows. However, if there are uncertainties in the inputs of unimpaired flows that are not also present in the current flow scenario inputs, these uncertainties should likely be propagated through the model to provide some sort of sensitivity analysis as proposed in the SacWAM review. Is such a sensitivity analysis possible in at least a few of the tributaries?
- d) It is also stated in the SacWAM Review (2016) that “At the public workshop, SacWAM developers acknowledged that the corroboration and/or calibration of upper watershed catchments would need to be refined before it is ready for use. The upper watershed catchments can be corroborated from unimpaired streamflow data from other hydrologic models (DWR 2017) or by using time series data publicly available of naturalized and unimpaired streamflow data (Lane *et al.* 2017). State Water Board staff indicated that the upper watershed catchments are not intended for use in the Bay-Delta Phase II update; instead, the State Water Board is relying upon pre-processed hydrology time series. The upper watershed catchment corroboration and calibration deficiencies need to be clearly stated in the documentation, and if possible, this functionality should be disabled within the model until it is sufficiently corroborated and verified...” Are these upper watersheds the same as those used in the Science Report? If so, this implies that there may be considerable uncertainties in the modeled outflow values, but such uncertainties are never mentioned. If these are not the same upper watersheds as in the Science Report, then please ignore my comment. Finally, other uncertainties are also mentioned in the SacWAM review (2016) (specifically under “Required Prior to Phase II use”) that I will

not repeat here. The relevance of these uncertainties to the Science Report was difficult for me to determine without a more detailed understanding of the exact SacWAM implementation (assumptions, input data etc.) for the Science Report.

- 4) It is stated in the Appendix A of the Science Report: “The “key assumption” called “Constrain GW Pumping” limits the maximum flow through each transmission link from a groundwater source to a demand site.... For this unimpaired flow study, the maximum groundwater pumping for each transmission link was set equal to the result from the Existing Conditions simulation. This ensured that groundwater pumping would not increase in response to a reduced surface water supply. The only effect this assumption has on stream flow is to prevent the relatively small amount of return flows associated with groundwater pumping from increasing.” This seems to imply that ground water pumping is allowed in the unimpaired scenario. I am unclear why this would be the case because this ignores how ground water removal could impact surface water availability, and therefore could lead to under-estimates of the actual unimpaired flows available for all uses. Or does this statement mean that groundwater pumping has very little impact on stream discharges and therefore does not impact unimpaired flows? Or does it mean that any ground-water rights and pumping are not part of the future flow regulations proposed in Phase II?

In summary, I think that Conclusion One is valid overall and is based on sound science. The model uncertainties mentioned above may be unlikely to change the broad conclusion that regulation/diversions have significantly altered annual and seasonal inflows to the delta and within individual tributaries. However, the uncertainties could change some of the exact conclusions in a given tributary (e.g. current flow is a certain percent of unimpaired flow in a given water year) or in a given water year for total delta inflow/outflow. Given that these data will be used to help make regulatory decisions (meeting certain percentages of unimpaired outflows may be proposed; outlined in Chapter 5 of the Science Report and part of Conclusion Three), the uncertainties in the model predictions that I have mentioned above could become important. Such uncertainties may need to be quantified or if they are impossible to quantify (which I know will be the case for some of the uncertainties), at least mentioned qualitatively in the context of setting specific flow guidelines.