FOREWORD

The Delta is a vital part of California's environmental and economic integrity, with over 20 million Californians depending on it for some portion of their daily water needs. The Delta supports a vibrant agricultural and recreational economy, with the Delta's agricultural economy totaling more than $2 billion in average annual gross value[1]. Commercial, recreational, and listed fish species use the Delta for at least a portion of their life-cycle. With this combination of factors, Californians have recognized the important role of a healthy Delta to the State and the need to reduce or eliminate the factors that threaten the Delta as we know it.

The Delta Risk Management Strategy (DRMS) Phase 2 report builds on the knowledge gained from the DRMS Phase 1 assessment to evaluate scenarios which could reduce the risks to our State economy. The methods include a selection of improvement strategies considered at the time of the study in 2009; however, today, there are more options in play. The information in the report provides insight to methods that may be used by the Department and others to manage risk.

Using existing data sets, DRMS Phase 2 provides the results of necessary work to establish risk reduction methods for consideration of the Department, the Delta Stewardship Council's Delta Plan, and the Bay-Delta Conservation Plan; and provides methods that add to the discussion of conveyance alternatives. From the perspective of statewide economic impacts addressed in the Phase 2 report, the reduction in risk to export freshwater flows has the most benefits. Moving forward, adding to our knowledge base, and additional study of the improvement strategies for the Delta, will help protect our vast State interests for future generations.

David Mraz, Chief
Delta Levees and Environmental Engineering Branch
FloodSAFE Environmental Stewardship and Statewide Resources Office
Department of Water Resources

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[1] (California Department of Food and Agriculture, Office of Agriculture and Environmental Stewardship)

Introduction

The overall purpose of the Delta Risk Management Strategy (DRMS) is to assess the performance of Delta and Suisun Marsh levees (under various stressors and hazards) and evaluate the economic, environmental, and public health and safety consequences of levee failures to California as a whole (Phase 1); and to develop and evaluate risk reduction strategies (Phase 2). DRMS was initiated in response to Assembly Bill 1200 (Laird, 2005), which required DWR to evaluate the potential impacts on water supplies derived from the Delta resulting from a variety of risks. The Phase 1 report presents the methodology and results that were used to develop Phase 2 of the project.

The focus of Phase 2 is to evaluate alternatives to reduce the risk to the Delta and the State from adverse consequences of levee failure. In the early stages, the DRMS consulting team reviewed prior studies and plans and interacted with the Governor's Delta Vision and the Bay-Delta Conservation Plan (BDCP) processes to understand their proposed solutions for managing the Delta in the future.

Study Objectives

The following objectives were developed for the DRMS Phase 2 work:

1. Evaluate the risks and consequences to the State (e.g., water export disruption and economic impact) and the Delta (e.g., levees, infrastructure, and ecosystem) associated with the failure of Delta levees considering their exposure to all hazards (seismic, flood, subsidence, seepage, sea-level rise) under present and foreseeable future conditions. The evaluation should assess the total risk and disaggregate the risk for the individual islands.

2. Propose risk criteria for consideration of alternative risk management strategies and for use in management of the Delta and the implementation of risk-informed policies.

3. Develop a DRMS, including a prioritized list of actions to reduce and manage the risks or consequences associated with Delta levee failures.

The DRMS consulting team used the knowledge gained from the Phase 1 Risk Analysis Report (URS/JBA 2008h) to develop improvement strategies that would increase the reliability of those systems that present the highest risks. The risk reductions to resources and assets of the Delta and Suisun Marsh are quantified under the alternative improvement strategies. The improvement strategies presented in the Phase 2 report are developed in sufficient detail to allow them to be considered in the risk model to quantify the risk reduction that may be associated with the improvement. The improvements require only enough engineering development to ensure that they are feasible and constructible and that they can be quantified in sufficient detail to allow development of a feasibility-level construction cost estimate.

Two sets of improvements are defined: building blocks and trial scenarios. The building blocks are individual improvements that cannot be further divided into sub-components and still

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maintain their functionality once they are built projects. Thus, each building block could be a project such as improved levees, a through-Delta conveyance, raised highways, increased subvention funding, and emergency planning and response preparedness. Trial scenarios, by contrast, are ensembles or combinations of building blocks. Trial scenarios aim to achieve multiple risk reduction objectives or benefits for the various assets and resources of State interest in the Delta and Suisun Marsh. Four trial scenarios were developed for this study, however more are possible as planners continue to investigate new improvements for the Delta. Table 2 summarizes the specific building blocks used in each of the trial scenarios. Detailed descriptions of the building blocks and the trial scenarios are included in DRMS Phase 2 main report.

Building Blocks

Building blocks were developed on the basis of the apparent and direct risk reduction value they offer to the flood control system in the Delta or to the resources and assets they would protect. Building blocks discussed in this report were developed along three main categories:

(1) Conveyance Improvements / Flood Risk Reduction and Life Safety

- Improved Delta Levee Maintenance
- Upgraded Delta Levees
- Enhanced Emergency Preparedness/Response
- Pre-Flooding of Selected Islands
- Land Use Changes to Reduce Island Subsidence
- Armored Pathway through Delta Conveyance (TDC)
- Isolated Conveyance Facility Alternatives (ICF)
- San Joaquin Bypass & San Joaquin River Widening

Although improved levee maintenance and enhanced emergency preparedness have low implementation costs, they provide a moderate reduction in risk. These building blocks do not provide a reduction in the seismic risk.

The highest overall reduction to the risk of water export disruption is the ICF, followed by the dual conveyance (DC), which is a combination of an ICF and armored pathway, then the through-Delta conveyance (TDC). Although the cost of implementation for each one of the conveyance improvement building blocks is high, benefits in terms of lower economic impacts are much higher than these costs. The ICF, DC and TDC building blocks would increase the reliability of water delivery and improve water quality.

(2) Infrastructure Risk Reduction

- Raising State Highways and Placing them on Piers, similar to I-80 across Yolo Bypass
- Construction of an Armored Infrastructure Corridor across Central Delta

The two building blocks considered in this category have a high overall risk reduction and high to very high cost. However, the combined contribution with other building blocks may make them attractive.

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(3) Environmental Risk Mitigation

- Suisun Marsh Tidal Wetland Restoration
- Tidal Marsh Cache Slough Restoration
- Install Fish Screens
- Setback Levees to Restore Shaded Riverine Habitat
- Reduce Water Exports from the Delta

The building blocks in this category provide benefits through enhanced and additional habitat and ecosystem restoration. Most of the building blocks have low to moderate implementation costs, particularly when combined with others (e.g., TDC, San Joaquin Bypass). The benefits to the ecosystem are estimated to be high to very high.

Trial Scenarios

Four distinct trial scenarios were developed to represent a range of possible risk reduction strategies.

Table 1 summarizes the costs and risk reduction benefits of the trial scenarios for 50-year and 100-year life cycles. The risk reduction benefits include reduced levee failure and in-Delta costs, reductions in ecosystem consequences, overall risk reduction, and the cost of implementation. The following provides a general description and findings for each trial scenario:

Trial Scenario 1: Improved Levees

The purpose of this trial scenario is to improve the reliability of Delta levees against flood-induced failures. In this trial scenario, central Delta island levees are upgraded to PL 84-99 standards and urban areas are upgraded to Federal flood control project levee standards. This upgrade improves the reliability of the levee system to provide up to 100-year flood protection, but offers no risk reduction benefits for seismic events.

Other major components of this trial scenario include improvements to transportation and utility corridors, consisting of raised highways and construction of an armored infrastructure corridor. These individual building block improvements provide both seismic and flood risk reductions.

Other highlights of this trial scenario include enhanced emergency preparedness and a number of environmental restoration actions.

Trial Scenario 1 Findings

The trial scenario results in a moderate reduction to the risk of flood-induced failures; however, it does not change the seismic risk of most levees.

- No risk reduction is apparent with regard to potential water export interruption.
- Improvements in levee maintenance and overall emergency preparedness have a positive but limited impact on risk reduction.

- A clear benefit results from restoration and improvement of the ecosystem in the Delta as part of this trial scenario.
- Land-use change to reduce subsidence does not have a direct benefit to current or near-term risk of levee failures; however, it is anticipated that a reduction in subsidence offers longer-term benefits by reducing the future accommodation space.

The cost of implementation for this trial scenario is about $10.5 billion, and the benefit for a 50-year life cycle is about $69 billion.

Trial Scenario 2: Armored Pathway (Through-Delta Conveyance)

The purpose of this Armored Pathway trial scenario is to improve the reliability of water conveyance by creating a route through the Delta that has high reliability and the ability to minimize the intrusion of saltwater into the south Delta. The armored pathway is created by seismically upgrading the levees along a pathway from the Sacramento River near Hood to the pumps in the south Delta, dredging channels to provide the required capacity, and installing channel barriers in the south Delta to limit saltwater intrusion during multiple island-flooding events. This trial scenario also provides for infrastructure improvement (raising highways, developing an armored infrastructure corridor), levee upgrade to PL 84-99 and urban levee standards, and environmental improvements and restoration.

Trial Scenario 2 Findings

The armored pathway reduces the likelihood of levee failures from flood events and earthquakes that could impact water exports. This upgrade, coupled with the installation of barrier gates in the southern Delta, has the joint benefit of significantly reducing the likelihood of export disruptions.

- This trial scenario provides a moderate reduction to the risk of levee failures due to flood events but provides no significant reduction to flooding of islands from seismic events because levees that do not define the armored pathway are not improved for seismic performance and remain as vulnerable as before.
- This trial scenario provides a substantial risk reduction to the costs and impacts associated with transportation and utility interruption due to both flood and seismic events.
- Improvements in levee maintenance and emergency preparedness overall have a positive, but limited impact in terms of risk reduction.
- A clear benefit results from restoration of and improvements to the ecosystem in the Delta.
- Land-use change as reflected in this trial scenario does not have a direct benefit to the current or near-term risk due to levee failures; however, it is anticipated a reduction in subsidence offers longer term benefits by reducing the future accommodation space.

The general cost of implementation of this trial scenario is about $15.6 billion, and the benefit for a 50-year life cycle is about $71 billion.

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Trial Scenario 3: Isolated Conveyance Facility

The purpose of this trial scenario to is to provide high reliability for export water conveyance (up to 15,000 cfs) by construction of an Isolated Conveyance Facility (ICF) on the eastern side of the Delta. The ICF avoids the vulnerability of water export disruptions associated with levee failures. This trial scenario also provides for infrastructure improvement (raising highways), improved maintenance and emergency planning, levee upgrades to PL 84-99 and urban levee standards, and environmental improvements and restoration.

Trial Scenario 3 Findings

The ICF avoids the vulnerability of water exports associated with Delta levee vulnerability and thus offers significant flood and seismic risk reduction over present conditions. The ICF, coupled with the installation of barrier gates in the south Delta, has the benefit of reducing the likelihood of significant export disruptions.

- The trial scenario provides a moderate reduction to the risk of levee failures due to flood events, but the trial scenario provides no reduction to the seismic risk of levee failure on islands that are not part of the ICF.
- A substantial risk reduction results because of significant reduction in impacts associated with transportation and utility interruption due to flood and seismic events.
- Improvements in levee maintenance and emergency preparedness have an overall positive, but limited impact in terms of risk reduction.
- A clear benefit results from the restoration of and improvement to the ecosystem in the Delta, and the substantial addition of habitat fosters bio-diversity.
- Land-use change to reduce subsidence does not have a direct benefit on the current or near-term risk due to levee failures; however, it is anticipated a reduction in subsidence offers longer term benefits by reducing the future accommodation space.

The cost of implementation of this trial scenario is about $14.8 billion and the benefit for a 50-year life cycle is about $83 billion.

Trial Scenario 4: Dual Conveyance

The purpose of this Dual Conveyance (DC) trial scenario to is to provide higher reliability and flexibility for export water conveyance (up to 10,000 cfs) by construction of an ICF on the eastern side of the Delta (similar to Trial Scenario 3) and a through-Delta conveyance (up to 5000 cfs) (similar to Trial Scenario 2). The trial scenario also provides levee improvements, enhanced maintenance and emergency planning, improvements to transportation and utility lines, environmental restorations similar to the previous trial scenarios.

Trial Scenario 4 Findings

The DC trial scenario avoids the vulnerability of water exports associated with Delta levee vulnerability and thus offers significant flood and seismic risk reduction over the present condition. The DC trial scenario also has the benefit of flexible water export from the Delta and/or from the ICF.

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- This trial scenario provides a moderate reduction to the risk of levee failures due to flood events but provides no reduction to the seismic risk of levee failure on those islands that are not part of the export conveyance system or the infrastructure pathway.
- This trial scenario provides substantial risk reduction to the potential costs and impacts associated with transportation and utility interruption due to both flood and seismic events.
- Improvements in levee maintenance and emergency preparedness have an overall positive, but limited impact in terms of risk reduction.
- A clear benefit results from restoration of and improvements to the ecosystem in the Delta.
- Land-use change to reduce subsidence does not have a direct benefit to the current or near-term risk due to levee failures; however, it is anticipated that a reduction in subsidence offers longer-term benefits by reducing the future accommodation space.

The cost of implementation of this trial scenario is about $17.1 billion, and the benefit for a 50-year life cycle is about $80 billion.

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Principal Conclusions

Three significant impacts are identified as a result of major flood or seismic events in the Delta. They are in-Delta losses, loss of transportation and utility services, and loss of water for export to out-of-Delta urban and agriculture users. From the perspective of the statewide economic impacts, the reduction in risk to export freshwater has the highest benefits. This fact is reflected in the calculation of benefits for all 4 trial scenarios and should be incorporated in the evaluation of how to move forward with the Delta. It should be noted that improving the flood protection system is an important part of all trial scenarios in this report.

Although the transportation and water conveyance losses are self-defined, the in-Delta impacts include developments, businesses, population at risk, and ecosystems.

The preliminary risk reduction evaluation conducted in this study indicates that the trial scenarios will rank in the following order when compared on benefit-versus-cost valuations:

1) Isolated Conveyance Facility: Lowest cost for the highest economic benefit

2) Dual Conveyance: second lowest cost for the second highest economic benefit

3) Through-Delta Conveyance: Third lowest cost for the third highest economic benefit

4) Improved levees: Fourth lowest cost for the fourth highest economic benefit

Table 1

Summary of Costs and Benefits of Trial Scenarios

Cost/Benefit Component ($billions in 2005)	**Scenario 1: Improved Levees**	**Scenario 2: Through Delta Conveyance (Armored Pathway)**	**Scenario 3: Isolated Conveyance Facility**	**Scenario 4: Dual Conveyance**
Capital cost	10.4	15.6	14.8	17.1
Reduction in expected economic losses from base case* during 2005 to 2050	69.0	70.9	83.3	79.9
Reduction in expected economic losses from base case* during 2005 to 2100	123.1	126.2	143.7	139.7
Reduction in expected value of lost output from base case* during 2005 to 2050	8.7	9.1	12.4	11.3
Reduction in expected value of lost output from base case* during 2005 to 2100	17.9	18.4	23.0	21.8

*Base case (Business-As-Usual) – includes current (2005) management practices and regulatory requirements.

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Table 2

Summary of Building Blocks and Scenarios

Categories	Building Block No. and Description		Option Identification and Description		Trial Scenario: Improved Levees	Trial Scenario: Armored Pathway	Trial Scenario: Isolated Conveyance Facility	Trial Scenario: Dual Conveyance
1 - Conveyance and Flood Risk Reduction	1.1	Improved Delta Levee Maintenance	a.	Delta levee subventions increased to ~$12 million/year (2 × current level)	●	●	●	●
			b.	Delta levee subventions increased to ~$25 million/year (4 × current level)				
	1.2	Upgraded Delta Levees	a.	Selected Delta levees (~764 miles) upgraded to PL 84-99 (Class 3) standards	●	●	●	●
			b.	Selected Delta Levees (~187 miles) upgraded to Urban Project Levee (Class 5) standards		●	●	●
	1.3	Enhanced Emergency Preparedness/ Response	a.	Spend ~$50 million for pre-positioning rock, sheet piles, and other emergency response materials	●	●	●	●
			b.	Spend ~$100 million for pre-positioning rock, sheet piles, and other emergency response materials				
	1.4	Pre-Flooding of Selected Islands	a.	Compares pre-flooding a group of western, eastern, and southern islands				
	1.5	Land Use Changes to Reduce Island Subsidence	a.	Change land use from farming to wetlands/carbon sequestration (e.g., rice growing, fish food farm) for all islands projected to have more than 3 feet of additional subsidence by 2100	●	●	●	●
	1.6	Armored Pathway Through Delta Conveyance (modified PPIC "Armored Island" Concept)	a.	Seismically (Class 8) upgraded levees along armored "pathway," channel dredging, operable barriers		●		●
	1.7	Isolated Conveyance Facility Alternatives	a.	Dual conveyance ICF (say 5,000 cfs capacity)				●
			b.	Intermediate ICF (say 10,000 cfs capacity)				●
			c.	Full Isolated Conveyance Facility (15,000 cfs capacity)			●	
	1.8	San Joaquin Bypass	a.	San Joaquin River detention and bypass				
		San Joaquin River Widening	b.	San Joaquin River widening				
2 - Infrastructure Risk Reduction	2.1	Raise State Highways and Place on Piers (similar to I-80 across Yolo Bypass)	a.	SR 4, SR 12, SR 160	(SR 12 and SR 160 only) ●	(SR 12 and SR 160 only) ●	●	●
	2.2	Construct Armored Infrastructure Corridor Across Central Delta	a.	Mokelumne Aqueduct, BNSF railroad, SR 4, gas pipeline (Class 7 setback levee)	●	●		
3 - Environmental Risk Mitigation	3.1	Suisun Marsh Tidal Wetland Restoration	a.	Suisun Marsh tidal wetland restoration	●	●	●	●
	3.2	Tidal Marsh Cache Slough Restoration	a.	Tidal marsh Cache Slough restoration (Yolo Bypass, upper and lower)	●	●	●	●
	3.3	Install Fish Screens	a.	River diversions	●	●	●	●
			b.	Armored pathway		●		●
			c.	ICF			●	●
	3.4	Setback Levees to Restore Shaded Riverine Habitat	a.	20 to 30 miles (Use BDCP, Sutter, Steamboat, and San Joaquin widening)	●	Included in Armored Pathway ●	●	Included in Armored Pathway ●
	3.5	Reduce water exports from the Delta	a.	2 to 3 percent				
			b.	4 to 5 percent				
			c.	6 to 7 percent				

Notes:
Colored circle indicates inclusion in respective scenario:
- (yellow) Scenario 1: Improved Levees
- (blue) Scenario 2: Armored Pathway
- (red) Scenario 3: Isolated Conveyance Facility
- (green) Scenario 4: Dual Conveyance

BDCP = Bay-Delta Conservation Plan
cfs = cubic feet per second
ICF = Isolated Conveyance Facility
PL = Public Law
PPIC = Public Policy Institute of California
SR = State Route

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8.1 INTRODUCTION

Analyses have shown that a significant seismic event could destabilize levees protecting islands in the Sacramento–San Joaquin River Delta (Delta). Levee failures could result in inundation of the islands, which could cause an intrusion of San Francisco Bay (bay) water (gulp) of higher salinity into the Delta. This higher-salinity water would replace, supplement, and mix with the freshwaters that flood the breached islands.

This discussion of Building Block 1.6, Armored "Pathway" (Through-Delta Conveyance), includes background information, describes conceptual development of the building block, and provides cost estimates, risk reductions, findings, and conclusions. An overview of the building block is presented on Figure 8-1.

8.1.1 Background

Through-Delta facilities were first studied in the late 1950s and were proposed by the Department of Water Resources (DWR) in 1960 as the single-purpose Delta Water Project (later referred to as the Waterway Control Plan). This alternative proposed such actions as enlarging Delta channels, closing channels, and constructing siphons, as well as moderate releases of water from upstream storage reservoirs for salinity control to improve movement of Sacramento River water to pumps in the South Delta. DWR formulated a similar concept in a plan proposed in 1983 under "Alternatives for Delta Water Transfer." Another through-Delta facility proposal was the North Delta Program, which addressed north Delta flooding issues in addition to improving conveyance capacity of north Delta channels to reduce reverse flow and salinity intrusion.

Previous forms of this building block were considered in the 1950s and 1960s as variants of the Biemond Plan, in the 1980s as the Orlob Plan, and in the 1990s by the California Bay-Delta Authority (CALFED) as various through-Delta alternatives.

8.1.2 Purpose and Scope of Building Block

The purpose of this building block is to evaluate the concept of a north-to-south freshwater corridor along Middle River that uses modifications of existing Delta infrastructure while reducing the potential for seismic disruptions of water supply.

The scope of this building block includes reviewing the geotechnical data, developing hydraulic analyses and system operation, developing construction methodologies, and estimating construction cost. A summary of the collected data and findings is presented in this section.

8.1.3 Objective and Approach

The objective is to confirm the engineering feasibility of this building block and develop the conceptual details, assess the risk reduction benefits, and make a preliminary cost estimate.

The approach is to review existing documentation, gather new information (i.e., current land uses, equipment), and present findings and conclusions.

8.2 CONCEPTUAL DEVELOPMENT OF IMPROVEMENT

8.2.1 Analysis Criteria and Basis of Design

The armored pathway (through-Delta conveyance) concept was developed to move freshwater from the Sacramento River to the State Water Project and Central Valley Project intake facilities located in the south Delta. A significant quantity of freshwater enters the Delta annually from the Sacramento River (approximately 21 million acre-feet [MAF], on average). Most Sacramento River flows are discharged to San Francisco Bay. The water that is used in the Delta and exported by the various larger diversions (including the state and federal water projects near Tracy) finds its way to the diversion sites through several complex routes using various Delta channels.

In this building block, it is desired to redirect a larger portion of the Sacramento River flows southward through Middle River (armored pathway). Note that no increase in the amount of exports is assumed. This building block focuses mainly on the armored pathway. In normal times (without levee breaches), the armored pathway being considered here will lower export salinity and should also improve water quality throughout the Delta.

However, the main objective behind the armored pathway is the ability to quickly reestablish freshwater conveyance to the project pumps in the advent of a major disruption to the Delta levees and the resulting salinity impacts that could result. The statewide impacts are the greatest in a prolonged disruption of the state's water supply. If the time required for reestablishing water exports can be significantly reduced, much of those impacts can be avoided.

8.2.1.1 Analysis Criteria

Solutions for the Delta typically revolve around three central issues: water quality and export reliability, in-Delta land and assets preservation, and ecosystem protection and enhancement. The armored pathway (through-Delta conveyance) building block is primarily a semi-isolated freshwater conveyance corridor; however, the project contains design elements that address all three central issues. This analysis will focus principally on the engineering feasibility of the water conveyance with additional discussion of related benefits.

8.2.1.2 Basis of Design

The design is based on a significant seismic event in Northern California that destabilizes multiple levees protecting islands in the Delta. The subsequent levee failures would result in inundation of some Delta islands, causing saltwater intrusion into the southern and eastern Delta, and displacing the freshwater that is normally in the Delta channel.

The design concept is to restore freshwater Delta conveyance through a semi-isolated corridor from the Sacramento River near the town of Hood to the Clifton Court Forebay in the south Delta. High-salinity waters in the channels and flooded islands after a seismic event would be separated from the conveyance route by seismic-resistant setback levees and by barrier gates located on specific sloughs crossing Middle River. Freshwater from the Sacramento River would be diverted to the new corridor to flush out any saline water that has intruded and to allow exports to resume. The building block includes an inlet structure located near the town of Hood, the seismic–resistant setback levees, and salinity control barriers on various channels across Middle River. The design elements addressed here include:

- Evaluating Delta water quality in the event of levee failure
- Evaluating Sacramento River water quantity
- Developing concepts for inlet facilities and fish protection
- Developing seismic- and flood-resistant setback levees
- Evaluating environmental impacts and benefits
- Evaluating barrier gate equipment and installation requirements
- Estimating preliminary costs

The conceptual alignment and facility locations are shown on Figure 8-1.

8.2.2 Analysis Results

The analysis results are presented in the following order: evaluation of Delta water quality after a significant seismic event, availability of Sacramento River water, and the specific features of the building block considered.

8.2.2.1 Delta Water Quality

As noted above, concern exists that a significant seismic event could destabilize multiple levees protecting islands in the Delta. The subsequent levee failures would result in inundation of the Delta islands and cause a gulp of bay water of high salinity content to intrude into the Delta, replacing and polluting the freshwater resource.

Studies have been conducted to examine the severity of the gulp caused by multiple island inundations and the methods that could be used to restore water quality. The Delta Risk Management Strategy (DRMS) Phase 1 Risk Analysis (URS/JBA 2008h) considered the full range of potential seismic and flood events and developed modeling capability to assess salinity impacts, repair operations, and time requirements to reestablish water supply operations, assuming present "business-as-usual" (BAU) conditions.

The DRMS model was developed from the Resource Management Associates (RMA) Bay-Delta Model, which simulates flow and water quality transport in the San Francisco Bay, Sacramento–San Joaquin River Delta (ranging from the tidal boundary at the Golden Gate to Freeport on the Sacramento River and Vernalis on the San Joaquin River). The RMA model uses finite-element computational methods and represents the embayments and major river sections. The DRMS analytical capabilities extended the model to address upstream reservoir operations in response to a Delta emergency, and streamlined the model structure so it could be used to analyze a large variety of events rapidly. The DRMS modeling capability includes assessments of statewide economic costs and impacts.

The Metropolitan Water District of Southern California (MWD) recently commissioned a study on Delta emergency preparedness (MWD 2007) to further evaluate salinity intrusion into the Delta as exacerbated by catastrophic levee failures and what could be done to improve recovery.

The MWD analysis uses one example of a major levee breach event and considers various new emergency response capabilities and procedures. The analysis was performed using the RMA Bay-Delta Model. The special accomplishment of the MWD study was to consider new uses of barriers and gates to manage the cross-Delta flows in the period after a major levee breach with salinity intrusion. The MWD study did not consider alterations to the Delta channels, such as widening cross sections or deepening channels to increase capacity.

Hydrodynamic modeling of multiple levee failures indicates significant salinity intrusion in the central and southern Delta soon after a seismic event. Also, the saltwater intrusion is difficult to displace with San Joaquin River flows, which average 4 MAF annually. An extended period of saltwater intrusion in the south Delta would significantly limit (or prohibit) the State Water Project (SWP) and Central Valley Project (CVP) from delivering freshwater to their customers.

The MWD study simulations included redirecting Sacramento River water through the eastern Delta (Middle River corridor) using the installation of barrier gates. The model indicated that the mitigation efforts, such as through-Delta conveyance facilities, would substantially improve performance over BAU conditions.

The CVP constructed the Delta Cross Channel in the early 1950s to improve water quality in the central and southern Delta. Water diverted through the Delta Cross Channel and Georgiana Slough aids in flushing salt out of the central Delta and re-establishing the “freshwater pool” at the San Joaquin River near the Mokelumne River and Potato Slough.

Setting up barriers to block the landward migration of higher-salinity waters was used during the 1976–1977 drought to limit the dispersion of salts due to tidal mixing. The same concept is used with the armored pathway by constructing salinity gates to block saline water from entering the channel and the south Delta during a potential collapse of multiple levees. This will also allow the channel to be flushed of saline water and used to reestablish exports more quickly. If non-potable water reaches the south Delta, within flooded islands, it can be very difficult to evacuate, and isolation becomes an important strategy. The problem was evident in the June 1972 failure of Brannan-Andrus Island. During that event, south Delta pumping continued during the initial intrusion of saline water into the central Delta, drawing further salt into the south Delta channels. The SWP shut down for a month while the CVP pumped an estimated 50,000 tons of salt into the San Joaquin Valley to clear the channels.

8.2.2.2 Sacramento River Water Availability

The available water to send into the armored pathway would be dictated by the seasonal flows available in the Sacramento River, as managed by the state and federal water projects using their upstream reservoirs. Figure 8-2 provides a chart showing flow variations between 2001 and 2006. The figure indicates that a minimum flow of approximately 10,000 cubic feet per second (cfs) is usually maintained in the river. Diversions into the armored pathway corridor would need to be regulated by flow control gates so as not to divert too much flow from the Sacramento River and not to flood the Mokelumne River, Middle River, and adjacent sloughs. It is anticipated that diverted amounts would simply reroute the waters needed to support the same amount of pumping that occurs under present conditions.

8.2.2.3 Alignment and Bathymetry

The alignment considered for the armored pathway building block is shown on Figure 8-1. The existing features along the alignment are presented in Table 8-1. The existing sloughs and rivers were evaluated to determine flow capacity and dredging requirements (if necessary). The bathymetry was evaluated to determine average depth along the alignment length for each slough and river. Alignment lengths and widths were scaled off of aerial photographs at the approximate mid-point. The slough and river measurements can vary greatly, but these measurements are sufficient for the present conceptual-level planning activities.

8.2.2.4 Operational Analysis

The operation of the armored pathway building block was evaluated to determine the potential corridor capacities and subsequent canal and levee cross sections. Three different canal capacities were evaluated. It is understood that the same total volume of water will be diverted under three different flow rates: 5,000, 10,000, and 15,000 cfs. The difference in operation is that normal diversion activities will occur for a longer period with a facility with a capacity of 5,000 cfs as compared to a facility with a capacity of 15,000 cfs. In case of a major levee breach event, diversions at capacity would likely be required for some period to flush intruded salinity from the pathway and reestablish exports. The ability to do this would depend on the availability of freshwater upstream.

8.2.2.5 Inlet Facilities and Fish Control

Diverting flows from the Sacramento River would require control of several factors, including debris, sedimentation, and fish. Debris and sedimentation can be controlled by incorporating maintenance features in the inlet facility. However, fish protection and control are important features of concern to many stakeholders.

Many effective design ideas are available for fish screening, and improvements in the science are continual. Applicable research and technology developments are monitored carefully by the local federal and state agencies and private consultants who would participate in further development of fish screen designs. Good initial resources for the fish screen design criteria include:

- National Marine Fisheries Service, Southwest Region, Fish Screening Criteria for Anadromous Salmonids, January 1997
- State of California, Department of Fish and Game, Fish Screening Criteria, June 19, 2000

Fish screens are addressed as a separate building block (Building Block 3.3, Install Fish Screens) in Section 15.

8.2.2.6 Levee Design

This building block envisions improved levees that are both flood resistant and seismic resistant. It is also desired that the new levees incorporate features to promote environmental habitat. Setback levees meet the critical design criteria for controlling foundation and embankment resistance to seismic forces, and providing habitat restoration as discussed below. The purpose of seismically upgrading the levees along Middle River is to ensure that the levees along the armored through-Delta conveyance channel will survive a seismic event and hence continue to allow freshwater to flow to the export pumps. Among the design criteria used to develop the upgraded cross sections are (1) the upgraded levee deformation goal is less than 1 foot when these levees are subjected to a 200-year earthquake and (2) the levees should not experience excessive damage or breach. Also, a static factor of safety of 1.4 is used on both the waterside and the landside.

Subsurface conditions under the levees in the Delta have been previously characterized (DRMS Phase 1) at 100-foot intervals in terms of the thickness of the organic soils and the liquefaction characteristics of the saturated loose sand immediately beneath the organic soil layer. A screening of the levees and foundation conditions by 100-foot increments was used to define the differing conditions along the armored pathway. After considering the above screening and the subsurface conditions in the Delta, 10 discrete improvement categories were developed (defined by foundation conditions), as shown in the list below. Based on these ten categories, ten seismic-resistant setback levee parametric cross sections were developed for the discrete conditions mapped along the armored pathway.

Organic Soil Thickness (feet)	Liquefiable Sand Layer with $(N_1)_{60\text{-}cs} < 20$	Non-Liquefiable Sand Layer with $(N_1)_{60\text{-}cs} > 20$
0	SL 0	SD 0
10	SL 10	SD 10
20	SL 20	SD 20
30	SL 30	SD 30
40	SL 40	SD 40

Notes: SL stands for loose sand, and SD stands for dense sand. The digits after the letters indicate the thickness of the organic deposits. $(N_1)_{60\text{-}cs}$ stands for the corrected standard penetration test (SPT) blow count for the sand deposits below the peat layer.

Based on these subsurface conditions within each reach, three seismic-resistant setback levee design concepts were developed. These three concepts cover the following cases: (1) the areas with no peat in the foundation, (2) the areas with 10 feet or less of peat thickness, and (3) the areas with more than 10 feet of peat thickness. The areas with 10 feet or less of peat can be over-excavated and replaced with engineered backfill. The areas with more than 10 feet of peat will be treated in place by soil improvement methods. For this last case, the cost of excavation and replacement becomes less competitive than foundation treatment. Foundation treatment could consist of deep soil mixing, jet grouting, stone columns, or other appropriate techniques to mitigate the potential liquefaction of the loose saturated sands. Conceptual designs for these three conditions are presented on Figure 8-3.

For the seismic-resistant setback levee upgrade, an allowance for essentially non-structural, planting fill between the original levee and the setback levee was included to create conditions suitable for various types of plantings. Planting and plant maintenance costs (based on the recent experience on the 2006/2007 DWR emergency levee repairs [see URS 2007a]) were used to develop these estimates. Appendix 8A discusses some of the features and benefits of the habitat restoration along the waterside bench of the seismic-resistant setback levee.

The seismic-resistant setback levees would result in a significant reduction of seismic-induced deformations, in particular for levees composed of liquefiable materials or located over liquefiable materials. The reduction in the probability of failure under seismic loading was estimated by comparing the annual frequency of failure of the existing levees (3 to 5 percent mean annual frequency of failure; see results in the DRMS Phase 1 Risk Analysis Report [URS/JBA 2008h]) to that of the same levees after having been seismically upgraded to the 200-year earthquake (0.5 percent mean annual frequency of failure). The risk reduction of levee failure along the armored pathway would range from 80 to 90 percent. The level of reduction varies based on the seismic vulnerability of the existing levees.

8.2.3 Geometric Description of Improvement

The armored pathway building block has six main components:

- Inlet facility and fish screen on the Sacramento River near Hood
- Dredging of the alignment
- Seismic-resistant setback levees along the alignment
- Restoration of the 115 miles of riparian habitat on the levees
- Corridor and SRAH
- Barrier gates
- Two minor bridges over Snodgrass Slough

Each component is discussed below.

8.2.3.1 Intake Facility

An intake facility would be constructed on the Sacramento River south of the town of Hood and adjacent to Snodgrass Slough. The facility would have three main functions: controlled diversion of water, protection of fish, and control/removal of sediments. A location map of the intake facility under consideration is shown in Figure 8-4.

The facility would start with a debris boom and trash rack on the Sacramento River side, followed by the fish screens. For this building block, we anticipate vertical screens, with a fish bypass mechanism at the apex of each screen. In general, the fish are directed up the screens to a trough and then back out to the river. The water passes through the screens. An example of a vertical fish screen from Redlands Canal near Grand Junction, Colorado, is shown on Figures 8-5 and 8-6. A critical design consideration will be the maximum velocity of the water approaching the screens so that the fish can manage the planned avoidance route and be directed back to the river unharmed.

Flow from the Sacramento River and velocity in the slough would be regulated using radial arm gates similar to those at the Delta Cross Channel, as shown on Figure 8-7. The intake facility structure and gates would be designed to match Sacramento River high-flow stage and adjacent embankment elevations. This design feature would prevent uncontrolled flood waters from inundating Snodgrass Slough.

The intake facility would also house sedimentation control and removal components. The Sacramento River is naturally heavy with suspended solids, and provisions should be made at the intake facility to limit the amount of sediments entering Snodgrass Slough. This limitation can be accomplished through energy dissipation (stilling) of the waters entering the facility and incorporation of a sediment trap (sump). During low-flow periods in the summertime, the radial arm gates can be closed and sediments removed from the trap.

8.2.3.2 Dredging

Dredging activities are considered in Snodgrass Slough to provide a conduit from the Sacramento River to the main existing corridor near the Delta Cross Channel.

Additional dredging may be necessary in the downstream sloughs and rivers, depending on the capacity selected (5,000, 10,000, or 15,000 cfs).

A preliminary design for the corridor cross section is shown on Figure 8-8, and the dimensions are given in Table 8-2.

Corridor cross sections were determined from the continuity equation ($Q=V*A$, where Q = flow, V = velocity, and A = area). This relationship is important because it shows how the corridor cross section impacts velocity, which must be kept at less than 1.5 feet per second to minimize erosion. More detailed analyses of velocities under the influence of tidal flood and ebb flows will be needed and may require some enlargement of cross sections.

For this example, the corridor heights have all been set at 20 feet, which is reasonable for the existing corridor bathymetry and suitable for developing conceptual-level estimates. Further analysis should be conducted to best-fit the desired capacity to existing slough and river dimensions and thereby minimize dredging quantities and optimize the setback levee design concept. In the final design, it is likely the corridor cross section will change continuously along the corridor alignment.

8.2.3.3 Setback Levees

Levee improvements are anticipated from Snodgrass Slough to Clifton Court Forebay. The islands and tracts adjacent to the corridor being considered and the levee lengths and costs are identified in Table 8-3.

8.2.3.4 Riparian Benches

The armored pathway building block would reduce the risk of saltwater contamination of the Sacramento/San Joaquin Delta water exports in the event of a catastrophic levee failure. Strengthened setback levees are combined with salinity gates to control the flow of saltwater from intersecting sloughs in an approximately 50-mile-long north-south corridor from the Sacramento River to Clifton Court Forebay. Setback levees will increase riparian habitat in the Delta, and this habitat may be used by listed species. The salinity gate installation and operation might obstruct passage of listed species of anadromous fish, but operation procedures can be established to prevent a significant impact. A discussion of the ecological background for setback levees, riparian habitat, and fish passage is provided in Appendix 8A.

8.2.3.5 Barrier Gates

Barrier gates are considered in the southern Delta to isolate pathway freshwater from water with higher salinity content. Air-powered inflatable bladder–type gates were selected for this building block. Gates would be installed at slough crossings to create a continuous barrier along the armored pathway alignment. Gates are considered at seven locations adjacent to Staten Island, Bouldin Island, Venice Island, Bacon Island, Woodward Island, and Victoria Island. The gate locations are shown on Figure 8-1, and a section view of the inflatable barrier gate under consideration is shown on Figure 8-9.

8.2.3.6 Bridges at Snodgrass Slough

There are two road crossings of Snodgrass Slough with culverts: one at Lambert Road and the other at an unnamed unpaved farm access road. This building block anticipates their replacement with bridges over the armored pathway corridor.

8.2.4 Description of Benefits

Many benefits can be realized under the armored pathway building block. The primary benefit is available in the context of a major levee breach emergency—the ability to reestablish freshwater conveyance to the central and south Delta and to the state and federal project pumps near Tracy more rapidly than under current conditions. Other benefits include water quality and environmental habitat improvements, which are discussed below.

8.2.4.1 Reduced Disruption to Water Supplies

Presently, levee breaches on multiple islands within the Delta could disrupt CVP and SWP Delta pumping and might reduce south-of-Delta CVP and SWP deliveries. With the semi-isolated armored pathway, freshwater through the Delta can be reestablished more quickly and hence the consequences of such a disturbance will be decreased.

8.2.4.2 Reliable Water Supplies to Agriculture

In cases where south-of-Delta CVP and SWP deliveries are reduced, growers and districts will adjust operations to minimize income losses. In regions with developed groundwater pumping capacity, growers and districts will substitute groundwater subject to physical and economic limits. In some cases, groundwater substitution will eliminate the shortage. In other cases, the shortage will remain. In the latter type of cases, available water supply will be rationed. Rationing could take many forms and would be locally determined. However, it is reasonable to assume that within relatively confined geographic regions supplies will be directed, either by executive decision or through economic incentives, first to permanent crops, second to high-value row crops, and third to forage and pasture.

At the level of the individual farm, the farmer must decide at the time the project water delivery reduction is announced which crops already in the ground to continue producing and which crops not yet in the ground to move forward with. The farmer's choices will be guided by expected returns to production. For example, the farmer could choose to abandon crops in the ground to make water available for crops not yet planted if this would minimize the loss of farm income.

8.2.4.3 Reliable Water Supplies to Urban Users

The methodology used for DRMS to assess the economic consequences of a disruption to urban users consists of the following three-step process:

1. Determine the urban water agencies likely to be affected by levee failure in the Delta.
2. Collect the data necessary to estimate the level of shortage in affected agencies.
3. Estimate the cost of shortage for each agency.

The total risks estimated for urban water users represented one of the greatest risks assessed during the DRMS Phase 1 overall risk assessment.

8.2.4.4 Water Quality

The raw water quality of the Sacramento River is better than that of the San Joaquin River. In particular, the Sacramento River has lower total organic compounds and bromide levels. Also, the flushing action of Sacramento River water injected further east into the Delta will keep Delta salinity level lower and other quality measures higher. For potable water uses, this benefit is likely to be realized in both lower water treatment costs and higher consumer satisfaction.

8.2.4.5 Reduced Likelihood of Levee Breach

The seismic-resistant setback levees would reduce the likelihood of a breach along the armored pathway corridor alignment, but it should be noted that this building block does not include full levee replacement for any islands or tracts. The primary purpose of the improved levees is to protect and isolate the freshwater pathway.

8.2.4.6 Improved Biodiversity – Green Space

The seismic-resistant setback levees are designed to incorporate the existing levees, which will be modified to create environmental habitats. The existing levees will be breached at approximately 1,000-foot intervals to allow tidal flows to reach the inner areas between the new and old levees in places or graded as sloping beaches to create tidal and upper benches. The breach provides a corridor to the inner levee areas for aquatic species. The existing levees will also be vegetated to increase the riparian forests similar to those that once bordered the Delta waterways. A detailed discussion of the environmental impacts of this building block can be found in Appendix 8A.

8.2.4.7 Minimized Land Use Impact

The armored pathway building block uses the existing Delta configuration to meet the improvement goals. By using existing sloughs and rivers, less land is needed to accomplish freshwater conveyance, as opposed to other building blocks (e.g., the Isolated Conveyance Facility [see Section 9]). Although the setback levees may require a wider channel than presently exists, the loss of agricultural land is minimized and the new right-of-way requirement would be smaller.

8.2.4.8 Reduced Island Subsidence

A potential benefit associated with this building block is reduced island subsidence through the re-use of dredged materials recovered during canal construction.

8.3 COST ESTIMATE

8.3.1 Item Descriptions

This section briefly describes the key items in this building block:

- Intake Facility – The intake facility is sized for 15,000 cfs and contains debris booms, trash racks, fish screens radial arm gates, and a sedimentation basin. For this building block, the cost item does not include fish screens. Those costs are approximately $200 million and are considered in Section 15, as part of building block 3.3. The costs elements are combined in Scenario 2.
- Dredging - Dredging activities are assumed to be conducted from barges and the soils disposed on adjacent islands and tracts. The item is priced by the mile.
- Bridges – Two small, two-lane county roads crossing Snodgrass Slough are assumed. The preliminary size is 50 feet wide by 500 feet long.
- Setback Levees – Setback levees are designed to withstand significant seismic events and large floods. The work includes removal of peat soils or in situ improvement of the foundation under the new fill material, compacting or foundation improvements (e.g., deep soil mixing, jet grouting) of loose sands, and placing of levee fill material.
- Riparian Benches – The new setback levees and existing levees will be vegetated to restore riparian habitat along the alignment.
- Barrier Gates – The barrier gates considered for this building block are inflatable dam–style gates, manufactured by Obermeyer.

8.3.2 Cost Estimate Table

Table 8-4 shows the cost estimate for this building block.

8.3.3 Cost Resources

Costs were determined by analyzing other similar projects and manufacturer information, including:

- Building Block 1.7, Isolated Conveyance Facility Alternatives (discussed in Section 9)

- Value Engineering Study of a Through-Delta Facility, conducted by Strategic Value Solutions, Inc., for DWR in March 2007 (DWR 2007b)
- Projects implemented by Obermeyer Gates, Inc.

8.3.4 Operation Cost

Operation and maintenance activities at the intake facility include machine upkeep and removal/disposal of collected sediments. The fish screens will need to be evaluated for effectiveness and adjusted accordingly. The barrier gates will require regular maintenance to ensure that they are in good working condition when needed. A need will exist for maintenance and operations staffing, general support equipment, and electricity to operate screens and gates, including auxiliary power from emergency generators. The levees will also require regular inspection to evaluate their condition and occasional repairs to sections subjected to erosion or containing unwanted vegetation.

Upstream reservoir operations may be used to enhance the flushing of salts out of the Delta. Changed reservoir operations will impact lake and stream recreational uses, but the exact nature of these changes has not been determined.

For this building block it is assumed that 10 staff members will be needed to maintain the facilities. The salary and overhead costs are combined and set at $100,000/year for a total of $1 million/year.

Supplies (e.g., vehicles, energy, tools, and other miscellaneous equipment) have not been considered. Losses and depreciation have also not been considered.

8.4 RISK REDUCTION ESTIMATE

The armored pathway building block will improve the reliability of the levee reaches that define it. These levee reaches, which will be seismically upgraded, will have a much lower probability of failure due to seismic events—perhaps lower by 80 percent or more than the present levees. This increase in the reliability of the levees that define the armored pathway, coupled with the installation of barriers across the identified sloughs, would significantly reduce the likelihood of long disruptions of water exports.

8.5 FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The armored pathway building block consists of six main components:

- Inlet facility on the Sacramento River near Hood
- Dredging of the alignment
- Seismic-resistant setback levees along the alignment
- Restoration of the riparian habitat on the levees
- Barrier gates
- Two minor bridges at Snodgrass Slough

The preliminary cost estimate is $5.7 billion in 2007 dollars for 15,000 cfs, $4.6 billion in 2007 dollars for 10,000 cfs, and $3.5 billion in 2007 dollars for 5,000 cfs.

The armored pathway (through-Delta conveyance) building block provides a reasonable way to maintain freshwater delivery in the south Delta. The design is feasible from an engineering perspective and minimally intrusive to the community. Many benefits would accrue, including improved recovery from major levee breaches, improved reliability of normal water delivery, improved water quality, and improved riparian habitat.

Additional evaluation is necessary in several areas:

- Determining the optimum location, design and fish screening requirements of the inlet facility on the Sacramento River
- Evaluating the organic soils and subsurface sands along the alignment to determine levee design parameters and better estimate costs
- Considering alternative levee designs to lower costs (e.g., a seismically damageable but repairable design that would still substantially accomplish the pathway isolation function)
- Identifying economical sources of levee material
- Conducting further hydrodynamic modeling of this alternative, both under normal (non-breach) conditions to evaluate the adequacy of the channel cross sections for conveying desired flows and under-levee breach conditions to evaluate the activities and time required to reestablish freshwater flow in the pathway for a wide variety of failure scenarios (Simulation of levee disruption scenarios may indicate that a bypass or tunnel under the San Joaquin River may be required.)
- Developing construction methods

Tables

Table 8-1 Existing Features Along Alignment

Alignment Description	Depth (feet)	Length[1] (miles)	Width (feet)
Snodgrass Slough	6	11	350
Dead Horse Cut	6	0.8	250
South Mokelumne River	16	10.3	300
Little Potato Slough	16	2.1	250
Little Connection Slough	20	4.5	600
Stockton Deep Water Ship Channel – Crossing	40+	-	-
Columbia Cut	9	1.6	500
Latham Slough	20	5.3	700
Middle River	20	7.9	400
Victoria Canal/North Canal	15	4.8	500
Clifton Court Forebay	6	-	-

[1] Reflects canal length along centerline; total length is approximately 50 miles.

Table 8-2 Preliminary Cross-Section Dimensions

Flow-Q (cfs)	Velocity-V (fps)	Area-A (sf)	Height-h(ft)	Base-b (ft)	Top-a (ft)
5,000	1.0	5,000	20	190	310
10,000	1.25	8,000	20	340	460
15,000	1.5	10,000	20	440	560

cfs = cubic feet per second
fps = feet per second
ft = foot (feet)
sf = square foot (feet)

Table 8-3 Improved Levee Locations and Lengths

Location	Length (Miles)
Staten Island	13
New Hope Tract	3.2
Canal Ranch	3
Brack Tract	2.5
Dead Horse Island	0.8
Tyler Island	9.5
Bouldin Island	4.7
Terminous Tract	5.9
Empire Tract	4.4
Venice Island	2.5
Medford Island	3.7
McDonald Tract	6.2
Mandeville Island	2.3
Bacon Island	7.8
Lower and Upper Jones Tract	8.8
Woodward Island	8.9
Orwood Tract	2.3
Victoria Island	15.1
Byron Tract	6
Union Island	4.3
Drexler Tract	1.3
Total	**115**

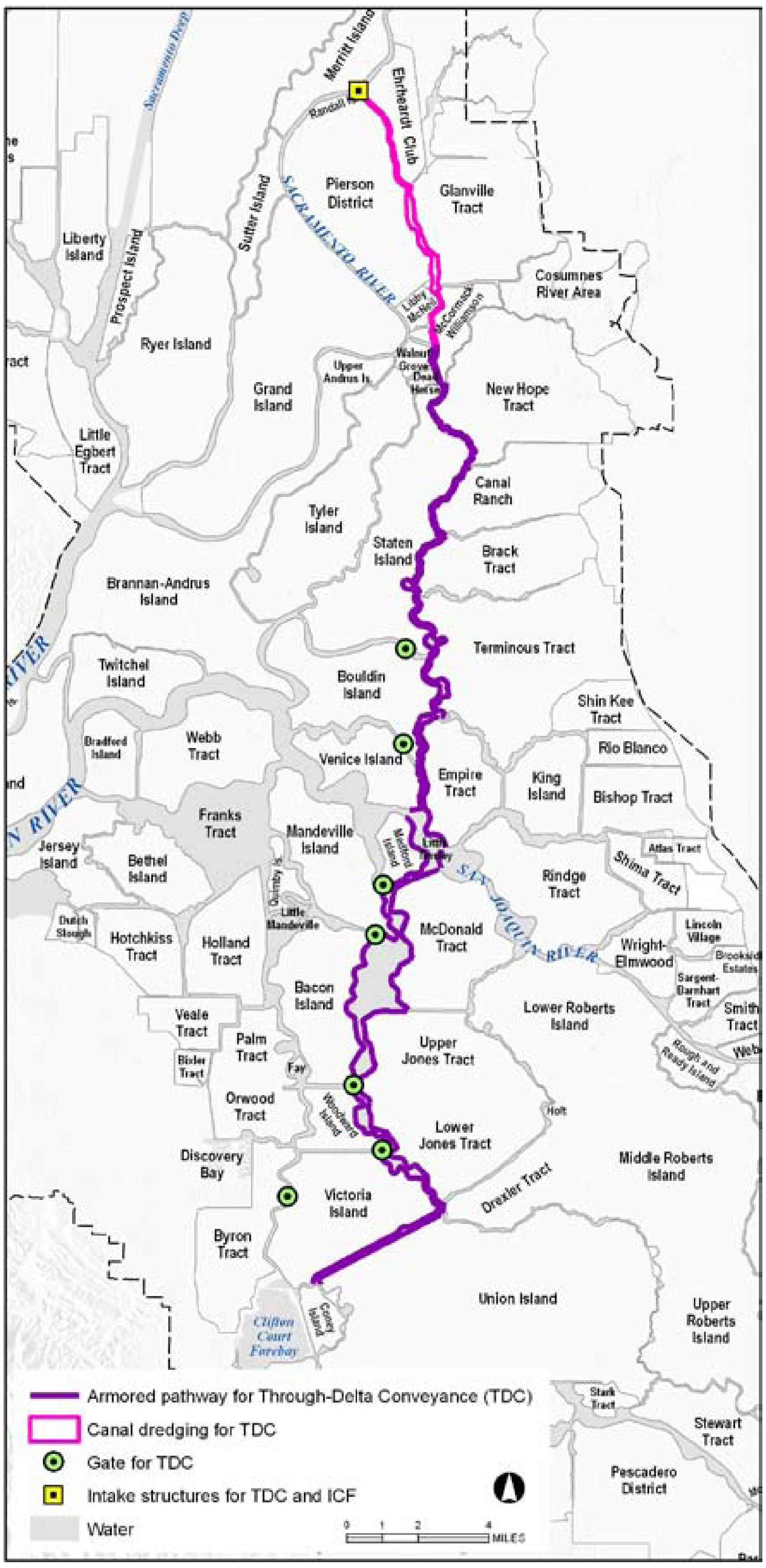
Table 8-4 Cost Estimate for Building Block 1.6, Armored "Pathway" (Through-Delta Conveyance), 15,000 cfs

Item	Description	Quantity	Unit	Unit Price	Total
1	Intake Facility	1	LS	$200M	$200M
2	Dredging	57.5	Mile	$4M	$230M
3	Bridges	2	EA	$10M	$20M
4	Setback Levees	115	Mile	$38M	$2.33B
5	Riparian Benches & Plantings	115	Mile	$5.0M	$324M
6	Barrier Gates	7	EA	$20M	$140M
				Subtotal	$3.24B
	Mobilization/Demobilization	5%			$162M
				Subtotal	$3.40B
	Eng., Admin., Legal, CM	30%			$1.02B
				Subtotal	$4.43B
	Contingency	30%			$1.33B
				Total[1]	**$5.76B**

[1] Approximately 90 percent of the cost is for seismic-resistant setback levees.

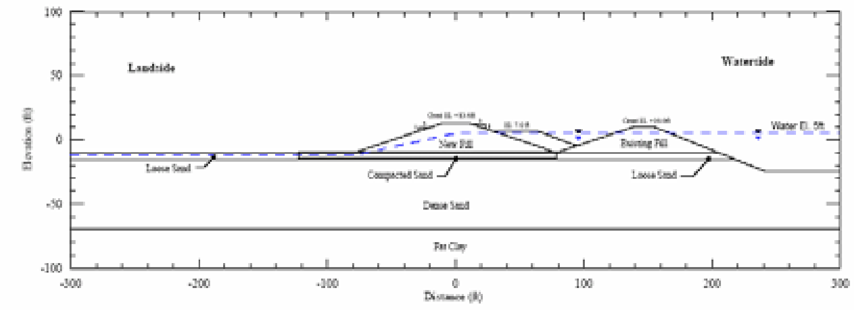
B = billion
cfs = cubic feet per second
CM = construction management
EA = each
LS = lump sum
M = million

Figures

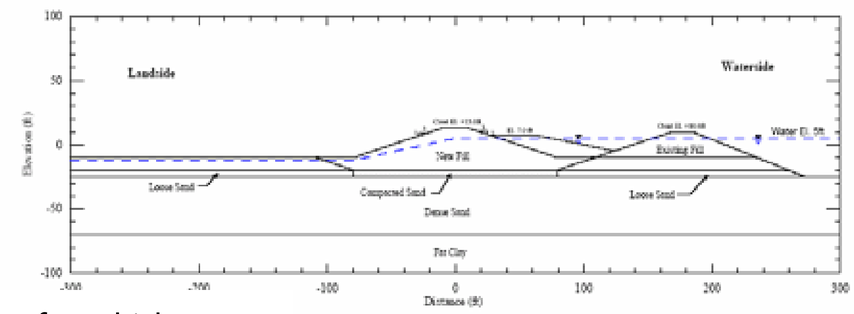


Typical Cross Sections

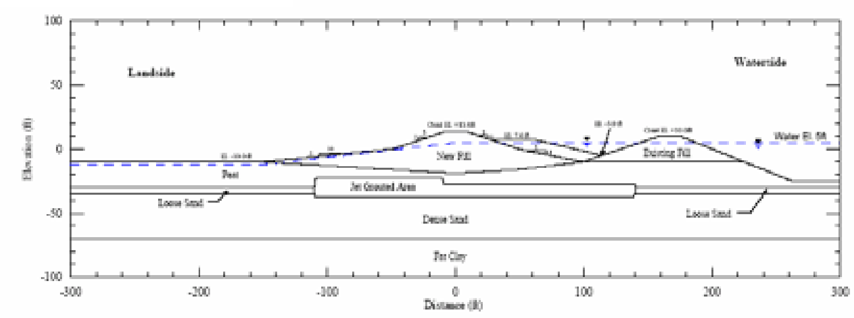
(1) No peat

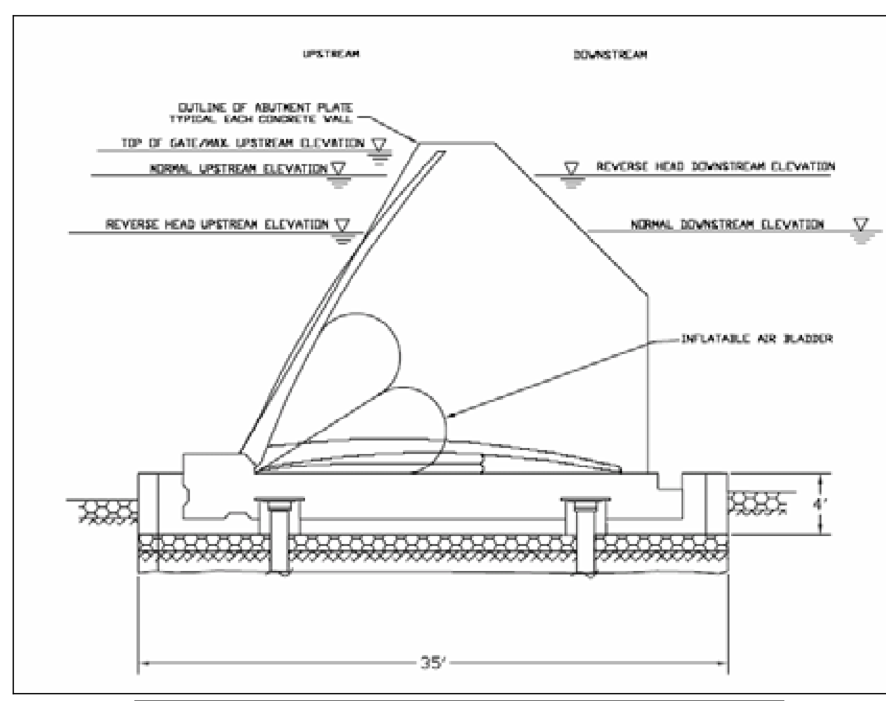


(2) 10-foot-thick peat



(3) 20-foot-thick peat





Typical Barrier Gate

PROJECT INFORMATION
- Capacity = 15,000 cfs
- Corridor Length = 48 miles
- Seismic-Resistant Setback Levees = 115 miles
- Barrier Gates = 7
- Siphon at Old River
- Intake and Fish Screen at Sacramento River

PROJECT BENEFITS
- Keeps Salinity Levels Low After Major Disruption to Delta Levees
- Maintains Water Quality
- Reduces Risk of Export Interruption Somewhat; May Require a Tunnel under San Joaquin River or a Large Flow Control Structure
- Protects Agricultural Areas Adjacent to Improved Levees
- Fish Screens Protect Fish at Intake
- Increases Habitat Area in Riparian Zones (115 miles)
- Seismic-Resistant Levees
- Barrier Gates Could be Used for Improving Water Quality

PROJECT LIMITATIONS
- Dredging Required
- Land Acquisition for Larger Conveyances
- Reduced Flow in the Sacramento River
- No Risk Reduction for Fish Entrainment
- Larger Fish Screen Costs
- Not Very Efficient During Periods of Major Damage to Delta Levees
- Saltwater Intrusion Through San Joaquin River, Particularly During the Dry Season
- Construction Impacts
- Additional Maintenance Cost to Keep up with Sea-Level Rise (115 miles of levees)

PROJECT COSTS
- 15,000 cfs Facility = $5.7 billion
- 10,000 cfs Facility = $4.6 billion
- 5,000 cfs Facility = $3.5 billion

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As described in Section 2, Building Blocks and Scenarios, two types or levels of improvements are considered for the Sacramento–San Joaquin River Delta (Delta): “building blocks” and “trial scenarios.” The building blocks are defined as individual components of improvement that cannot be further subdivided into sub-components and still be fully functional projects. The trial scenarios represent ensembles of building blocks that offer risk reduction benefits to more than one asset or resource in the Delta and Suisun Marsh.

The building blocks were developed on the basis of the apparent and direct mitigation value they offer to the flood control system or to the resources and assets they would protect. The building blocks discussed in this report were developed along four main categories: (1) conveyance improvements, (2) protection of infrastructure systems, (3) environmental protection, and (4) flood risk reduction and life safety.

The first part of this section summarizes the key findings of the building block evaluations in terms of their risk reduction potential and costs of implementation. The second part of this section summaries the findings from the evaluation of the trial scenarios.

19.1 SUMMARY OF KEY FINDINGS OF BUILDING BLOCKS

Building Block 1.1: Improved Delta Levee Maintenance

The focus of this building block is to provide a higher level of state support for the Delta Levees Maintenance Subvention Program. The purpose is to enhance levee maintenance through more program continuity, programmatic mitigation, and an improved level of maintenance and repair of Delta levees. The primary contribution of increased Subvention Program funding would be to decrease the rate of occurrence of levee breaches from sunny-day events and at least some floods (small- and medium-sized floods).

Building Block 1.2: Upgraded Delta Levees

This building block was developed to reduce the likelihood of levee failures. The building block consists of the following sub-building blocks:

- Selected Delta levees (about 764 miles of levees) upgraded to Public Law 84-99 (PL 84-99) standards
- Selected Delta levees (about 187 miles of levees) upgraded to Urban Project Levee (UPL) standards

Most of the Delta levees already meet the Hazard Mitigation Plan standards. Some of the levees in the central Delta (called project levees) already meet the PL 84-99 standards. Upgrading levees to meet the PL 84-99 and UPL standards would reduce the flood risk and provide 100-year flood protection.

Building Block 1.3: Enhanced Emergency Preparedness/Response

The purpose of this building block is to identify potentially useful planning, organizational, and action items (e.g., stockpiling of materials, facilities construction) that can facilitate a betterorganized, more efficient, and more effective Department of Water Resources response to major flood and storm events and levee breaches in the Delta.

Enhanced emergency preparedness/response can help reduce adverse impacts from levee breach incidents. Preliminary hydrodynamic calculations and the level of stockpiling indicate that improvements in response and a reduction in export disruptions are expected. Should significant stockpiles be implemented, additional questions would be raised, such as the adequacy of equipment (e.g., barges, cranes,) to support high rates of rock placement at multiple locations during a major event.

Building Block 1.4: Pre-Flooding of Selected Islands

The purpose of pre-flooding selected islands is to reduce the risk of flooding that may cause excessive salt intrusion. Possible options for pre-flooded islands might include the following:

- After a controlled breach, allow surrounding levees to naturally degrade with wind-wave action, similar to what occurred on Franks Tract.
- Carefully design and construct breaches and armored levee interiors to preserve the levees and control tidal flow in and around the flooded islands.
- Armor and preserve the surrounding levees and use the flooded islands as in-Delta reservoirs, similar to the proposed Delta wetlands project.

In all three cases, the islands would be filled during periods of high runoff to minimize potential salinity intrusion impacts.

Pre-flooding sets of Delta islands would reduce the disruption of Delta water exports and the resulting export deficit with large-scale levee failure events. The most promising option appears to be selecting sets of islands in the south Delta and leaving those islands closed to tidal exchange. Key findings include:

- The western Delta islands should not be breached and left open to tidal exchange due to the resulting increase in dispersive salt flux into the central Delta.
- Pre-flooding eastern Delta islands and leaving them open to tidal exchange does not appear to have a negative salinity impact. This result is likely to be true for north Delta islands as well.
- Hardening Delta islands against failure or pre-flooding and leaving the islands closed to tidal exchange may in general be a more robust solution because breached islands may accumulate salt if the period following a failure event is very dry.

Pre-flooding and closing the islands may require management that could include levee maintenance.

Building Block 1.5: Land Use Changes to Reduce Island Subsidence

This building block considers constructing wetlands on Delta peat islands. Carbon sequestration has been shown to successfully reverse subsidence and result in a net accretion of organic carbon over time. However, little is known about how this accretion would change the indirect risks associated with catastrophic levee breach over time. Key findings include the following:

- Wetlands can be used to reverse subsidence on Delta peat islands where ponding depth and plant species are optimized.
- U.S. Geological Survey work suggests that optimal water depths are 1 to 2 feet to maximize carbon sequestration and accumulation of organic matter. The elevation of Delta islands typically varies by considerably more than 2 feet. Therefore, a substantial amount of grading would be required to reduce this variability across an entire island's surface.
- Construction costs can be reduced by changing land use practices and allowing islands to naturally level over time or alternatively by using natural island contours to achieve optimal ponding depths on separate island segments.
- The benefits of carbon sequestration include improved biodiversity, subsidence reversal, and reduction in greenhouse gases.
- The constraints to carbon sequestration include the loss of agricultural production on islands and increased costs to protect infrastructure.
- Reductions in the direct and indirect risks associated with a catastrophic levee breach include reduced on-island economic consequences in the event of levee failure, and reduced salinity intrusion due to a reduced island volume in the future. Given that the benefits of carbon sequestration would be increasingly realized through time, the temporal elements of this risk reduction need to be quantified. Available data indicate that the overall rate of accretion can be estimated at 2.6 inches per year or nearly 11 feet in 50 years. Considerable social and transaction costs are likely to be involved with any carbon sequestration project. These costs, whether compensation for lost agricultural production or capital costs to purchase land, have not been assessed as part of this cost estimate.

Building Block 1.6: Armored "Pathway" (Through-Delta Conveyance)

A significant quantity of freshwater enters the Delta annually from the Sacramento River (approximately 21 million acre-feet). Currently, most Sacramento River flows are discharged to San Francisco Bay. The armored pathway (Through-Delta Conveyance) building block was developed to move freshwater from the Sacramento River to the State Water Project and Central Valley Project intake facilities located in the south Delta in case of a major disruption to water quality due to multiple island failures. The armored pathway building block consists of six main components:

- Intake facilities and fish screens on the Sacramento River near Hood
- Dredging of the alignment
- Two minor bridges
- Seismic-resistant setback levees along the alignment
- Restoration of riparian corridor and shaded riverine aquatic habitat along about 110 miles of the water's edge in the through-Delta conveyance
- Salinity barrier gates to control flow during major disruption caused by multiple levee failures, to allow freshwater conveyance to the export pumps

The through-Delta conveyance would provide a relatively more reliable water export system than present conditions and would add more habitat along about 110 miles water's edge.

Building Block 1.7: Isolated Conveyance Facility Alternatives

The Isolated Conveyance Facility (ICF) would provide a north-to-south freshwater corridor through the construction of an isolated canal around the eastern periphery of the Delta. The ICF would include the following components:

- Intake structures and fish screens near Hood
- Canal excavation and embankment construction to the elevation of mean higher high water plus 3 feet
- Road and railroad bridge crossings
- Siphons under sloughs and flow-control structures
- Pumping station at Disappointment Slough

The ICF would significantly reduce the vulnerability of water export to Delta levee failure and flooding. The ICF could also be operated to improve water quality during major failures of the Delta levees.

The canal embankments are conceived to resist a 200-year earthquake. The canal embankments would be constructed with 3 feet of freeboard above MHH. Although the canal would be overtopped by large flood events (e.g., a 100-year flood), such flooding would result in freshwater entering the canal and thus would not pose water quality issues. After such a large flood event, the canal embankments would need to be repaired.

Building Block 1.8: San Joaquin Bypass

The purpose of this building block is to evaluate two alternative flood bypasses or equivalent plans for Stewart Tract and Roberts Island. The objectives are twofold: (1) protect lives and property in Lathrop, Mossdale, Stockton, and adjacent communities during flood events, and (2) create more habitat for fish, waterfowl, and wildlife, and improved aquatic food-web production and water quality, as described in the Bay-Delta Ecosystem Restoration Program Plan (CALFED ERP 2007).

Two alternatives were considered under this building block:

- Alternative 1: Construct weirs to divert San Joaquin River floodflows through Stewart Tract and Roberts Island and thereby lower water surface elevations adjacent to populated areas on the east river bank.
- Alternative 2: Widen the San Joaquin River flood channel by removing the west bank levee and constructing a new setback levee along the eastern edge of Stewart Tract and Roberts Island. Create permanent floodplain habitat in the 22-mile-long, half-mile-wide area between the river and new setback levee.

Construction of either Alternative 1 or Alternative 2 would result in a decrease in the water-surface elevations in San Joaquin River between Lathrop and Stockton. The decrease for a large storm event could be on the order of 10 feet in the vicinity of Mossdale and 3 to 5 feet along the western edge of Rough and Ready Island.

A reduction in the peak water surface elevations of the order predicted in this analysis corresponds to a factor of 10 or more reduction in the frequency of levee failures along San Joaquin River between the south end of Stewart Tract and Rough and Ready Island. Besides providing increased flood protection to towns along the San Joaquin, a significant risk reduction would occur for islands in the Delta.

Both alternatives would provide substantial flood control to the populated areas east of San Joaquin River. Alternative 2 provides more benefits and fewer adverse effects to social systems, agricultural land use, infrastructure, land value, and habitat than Alternative 1. Alternative 2 also provides improved flood protection to the majority of Stewart Tract and Roberts Island.

Building Block 2.1: Raise State Highways

Raising State Route (SR) 4, SR 12, and SR 160 above the Federal Emergency Management Agency (FEMA) 100-year flood elevation and constructing them on piers with a seismically resistant design could reduce the risk of damage and failure for those highways. Also, this building block has the benefit of having the roads in service in the event of a seismic- or flood-induce levee failures.

Raising SR 4, SR 12, and SR 160 would require significant capital cost, and would outweigh the direct risk reduction benefits. However, if a significant portion of the levees were breached, the state highways would be an access route for emergency repairs and normal uses. The loss of these highways during the emergency period would result in delays in repairing damaged levees and increase economic costs.

Building Block 2.2: Construct Armored Infrastructure Corridor Across Central Delta

To reduce the risk of the loss of essential infrastructure due to flooding or seismic activity, this building block evaluates the construction of an armored corridor with new levees. The new levees would be seismically resistant and have elevations 3 feet above the 100-year FEMA flood elevation. Two options for the placement of the relocated infrastructure were considered:

- Option 1: Construct two east-west levees, a northern and southern levee, across the central Delta. Construct SR 4 on the new southern levee and the BNSF railroad on the new northern levee. The existing Mokelumne Aqueduct system and the Kinder Morgan pipeline would be unaffected but protected against flood or seismic failure of the Delta levees.
- Option 2: Construct a single, larger levee to the south of the Mokelumne Aqueduct system. This new levee would carry the new SR 4, the BNSF railroad, the Mokelumne Aqueduct system, and the Kinder Morgan pipeline.

The main risk-reduction benefit of this building block would be the improved reliability of the transportation system, the railroad, water supply delivery via the Mokelumne Aqueduct system, and product delivery via the Kinder Morgan pipeline. The risk-reduction benefits appear to outweigh the cost. It is noted that this building block is similar to strategy that the East Bay Municipal Utility District (EBMUD) is employing to protect the aqueduct system.

Building Block 3.1: Suisun Marsh Tidal Wetland Restoration and Managed Wetland Enhancements

The purpose of this building block is habitat enhancement and protection of existing wetland and wildlife resources, values, and functions. Its main purpose is not risk reduction, though some risk is mitigated. This building block evaluates the benefits associated with tidal marsh restoration and managed wetland enhancement as well as the conceptual-level costs and reduction of risks. The key finding of the analysis of restoring tidal wetlands in Suisun Marsh is that there are island complexes where restoration is most cost-effective.

Considerable potential exists to enhance and diversify Suisun Marsh habitats and contribute to the recovery of special-status species. However, this opportunity may be accompanied by the loss of diked managed wetland habitats, wildlife populations, hunting areas, and significant impact to water quality from increased mixing of salts. Levees that are breached and lands that are restored to tidal action reduce the risk of catastrophic levee failure and repair costs.

Building Block 3.2: Tidal Marsh Cache Slough Restoration

The purpose of this building block is to create a conceptual preservation, restoration, and implementation plan for the Cache Slough Complex to restore the ecology of the region. This plan is based on a conceptual analysis of proposed general and specific habitat restoration goals presented in a collection of plans by various agencies (Solano Land Trust, Bay-Delta Conservation Plan, Public Policy Institute of California, North Delta National Wildlife Refuge, Pacific Flyway and Central Valley Joint Venture, and Office of the Governor of California).

The study area includes the Cache Slough Complex below the 100-year floodplain that is bordered in the northeast by the Yolo Bypass, including some portion of the bypass area, and Prospect Island on the west. The analysis presents a rough estimate of the acreage of habitat and listed species that would benefit from the hypothetical removal of the barriers separating wetland and upland habitat.

Conservation and restoration of 32,900 acres would connect with 12,000 acres of currently conserved or restored areas, increasing contiguous habitat by 37 percent to 44,900 acres. Conservation groups with similar goals may be interested in coordinating efforts to protect and restore the area. This area would protect sensitive habitats supporting high levels of biodiversity, including riparian and vernal pool habitat, which support over 80 listed species. Tidal restoration of this area would initially re-establish 23,600 acres of floodplain, 7,100 acres of rapidly establishing tidal marsh, 3,900 acres of tidal marsh that would establish slowly over time, and 10,300 acres of open water habitat. Restoration would connect wetland and upland habitats over this large area, which is critical to several listed species. Some of the restoration actions proposed here may also benefit exotic fish species. The habitat value of restored floodplain is directly connected with the operations of the Yolo Bypass, and in particular the frequency of flooding.

Analysis of fish surveys indicates that little is known about preferred Delta smelt spawning microhabitat or locations. Several lines of data suggest that they may spawn in shallow water gravel areas near deep water and may use the Sacramento Deep Water Ship Channel and benefit from restored areas of deep water near tidal marsh. Further data collection would be required to determine actions that would increase Delta smelt spawning and rearing habitat.

Building Block 3.3: Install Fish Screens

The purpose of this building block is to provide a conceptual overview of possible fish screens in the Delta and to provide a general assessment of their function based on our current understanding of how they may be designed. Fish screens were reviewed for the ICF, the Tracy Pumping Plant, the Banks Pumping Plant, and small agricultural withdrawals. The following are the key findings of this building block:

- No effective, proven means exist to physically screen eggs and larval life stages of fish from intakes.
- Screens that operate in the Delta to the current criteria for Delta smelt are effective at excluding larval life stages (fish smaller than 25 millimeters in length) from small intakes. However, at the large Tracy and the Banks Pumping Plant intakes, the fish survival benefits of collecting, transporting, and releasing these small fish is uncertain.
- The intakes at the Isolated Conveyance Facility, Tracy Pumping Plant, and Banks Pumping Plant require large facilities to screen flows from 4,000 cubic feet per second (cfs) to 15,000 cfs. These large flows can be successfully screened using multiple in-canal vee-type screens of about 2,500 cfs capacity in each module. Screens of this size have been used successfully at other installations, such as the Skinner Fish Facility.
- The possible biological benefits of screening intakes in the Delta are not clearly known because many factors can influence the overall benefit. Reductions in direct fish losses could be significant because fish entrainment and impingement losses at the screens would approach zero for fish over 20 millimeters.
- The south Delta fish screens will not be as effective at protecting fish as those located in the north Delta or at an Isolated Conveyance Facility intake for several reasons. First, a greater amount of debris must be removed by mechanical means in the south Delta, which will affect fish survival. Second, the fish bypassed in the screening facility must be transported to another location in the Delta. This operation increases the stress on and the mortality of the fish. Third, facilities in the south Delta is more likely to entrain smaller fish that cannot be effectively screened. Fourth, the poor water circulation in the south Delta makes the intake more vulnerable to extended outages due to fish being trapped in a dead-end area.
- The south Delta screening facility will cost more than similarly sized facilities in the north Delta for at least four reasons. First, poor subsurface soil conditions will require more costly foundations. Second, additional structure and mechanical devices will be required to remove the additional accumulated debris from the water. Third, the bypassed fish require holding facilities and it will be necessary to provide a means to transfer fish to release sites throughout the Delta. Fourth, the tidal influences and shallow water depths could require a larger facility than is required in the north Delta.
- Over 2,000 agricultural withdrawal sites are present in the Delta, and only 1 percent of them are currently screened.

The Delta is a complex and unique environment with multiple competing interests and resources. These relationships and balances have been studied for some time, but it is still unclear what the benefits or impacts are for the actions discussed under this building block. Despite this uncertainty, fish screening does reduce some risk of fish loss for a given diversion and is therefore likely to be a part of any future Delta actions.

Building Block 3.4: Setback Levee to Restore Shaded Riverine Habitat

The setback levee building block was developed to restore shaded riverine habitat and to reduce the likelihood of levee failures due to seismic events. This building block consists of sub-blocks for 20 or 30 miles of setback levees to withstand a 200-year earthquake.

Seismically upgrading Delta islands to the setback design may reduce the frequency of individual island failure. Also, setback levees would create riparian corridors and shaded riverine aquatic habitat.

Building Block 3.6: Reduce Water Exports from the Delta

The purpose of this building block is to begin exploring changes that would be involved in reducing Delta water exports. The objective is to provide an initial understanding of what it would mean if Delta water exports were decreased. Three alternative levels of decreased water exports were considered: 10 percent, 25 percent, and 40 percent.

The key findings of the exploratory analysis are the following:

- Responses and impacts to stipulated reductions in Delta water exports are complex and uncertain. Even preliminary characterizations require more detailed and intensive analyses than have been possible within the Delta Risk Management Strategy (DRMS) Phase 2 schedule.
- Responses and impacts in the context of normal conditions (no levee breaches) are expected to be nonlinear; they will increase more dramatically, especially in capital and operating cost, as the size of the export reduction is increased. Exported water will transfer from agriculture to urban agencies, groundwater will be increasingly developed and overdrafted and agricultural land fallowing will occur. To the extent that fish are now adversely impacted by diversion of Delta waters and entrainment in the south Delta pumps, they should be less impacted, and the surviving species should be more viable.
- Risk reductions are extremely uncertain and are likely to be variable.
    - For urban agencies, to the extent that a percentage of their supply comes from Delta exports, one might expect them to be impacted by the disruption due to a major levee breach event. The impacts to urban agencies could be greater, depending on their conservation efforts, the availability of emergency supplies, and the type of water years (drought years versus wet years).
    - For agricultural water users, a Delta levee breach event is likely to have much more dramatic effects, even though substantial acreage has been fallowed. Groundwater basins are likely to be severely overdrawn in agricultural areas and unavailable as significant emergency supplies. More acres of high-value, permanent crops are likely to be lost.
    - For aquatic organisms, the only chance for reduced Delta exports to provide an improved outcome to a major levee breach event is to have a more viable aquatic ecosystem when the event occurs. Entrainment onto flooding islands and other adverse mechanisms are

still likely to produce very high mortalities. Only the advantage of having a larger and stronger population at the beginning of the event might lead to a larger number of survivors. This strength may give the species an ability to regenerate a sustainable population. In contrast, some species populations may be so marginal that they could be lost under "business as usual".

The choices, relationships, and interactions necessary to characterize the results of decreases in Delta exports are complex. Assessment of risk reduction benefits (in the face of Delta levee breaches) requires another step to extend the analyses beyond "normal conditions," which are already uncertain and have received limited study. More intensive analysis is required if quantitative estimates of the results are desired.

19.2 EVALUATION OF BUILDING BLOCKS

As stated above, the building blocks discussed in this report were developed along four main categories consisting of: (1) conveyance improvement, (2) protection of infrastructure systems, (3) environmental protection, and (4) flood risk reduction and life safety. The evaluation of the building blocks is discussed along these four main categories. For each of the building blocks, a summary of the relative risk reduction benefits, overall risk reduction (in-Delta, ecosystem, and economic) and cost to implement are discussed. In the evaluation of building blocks that follows, we consider the relative overall risk reduction and the cost of implementation.

Flood Risk Reduction and Life Safety (Building Blocks 1.1 to 1.5 and 1.8)

Although improved levee maintenance and enhanced emergency preparedness have low implementation costs, they provide moderate reduction in risk. For improving Delta levees to PL 84-99 and UPL standards, the costs of implementation are high to very high, but they afford a low to moderate risk reduction against flood hazards. These building blocks do not provide a reduction in the seismic risk.

Conveyance (Building Blocks 1.6 and 1.7)

The highest overall reduction to the risk of water export disruption is the ICF, followed by the dual conveyance (DC) (ICF and armored pathway), then the through-Delta conveyance (TDC). Although the costs of implementation are high, the loss reductions (benefits) are much higher than the cost of implementation (costs). The ICF, DC and TDC building blocks would increase the reliability of water delivery and improve water quality in that order.

Infrastructure Risk Reduction (Building Blocks 2.1 and 2.2)

The two building blocks considered in this category have a high overall risk reduction and high to very high relative cost. However, the combined contribution with other building blocks may make them attractive.

Environmental Risk Mitigation (Building Blocks 3.1 to 3.5)

The building blocks in this category provide benefits through enhanced and additional habitat and ecosystem restoration. Most of the building blocks have low to moderate implementation costs, particularly when combined with others (e.g., TDC, San Joaquin Bypass). The benefits are estimated to by high to very high.

19.3 SUMMARY OF KEY FINDINGS OF THE TRIAL SCENARIOS

The following discussion summarizes the key findings for each of the trial scenarios evaluated. A qualitative summary of the trial scenarios in terms of the relative risk-reduction benefits (levee failure and in-Delta costs, ecosystem consequences, and economic consequences), overall risk reduction, and the cost of implementation follows.

Trial Scenario 1: Improved Levees

The purpose of this scenario is to improve the reliability of Delta levees against flood-induced failures. In this scenario, central Delta island levees are upgraded to PL 84-99 standards and urban areas are upgraded to UPL standards. This upgrade improves the reliability of the levee system up to 100-year flood protection, but offers no risk reduction benefits for seismic events.

Other major components of this trial scenario include improvements to transportation and utility corridors, consisting of raised highways and construction of an armored infrastructure corridor. These improvements provide both seismic and flood risk reductions.

Other highlights of this scenario include enhanced emergency preparedness and a number of environmental restoration actions.

The findings of the evaluation of this scenario include:

- The scenario results in a moderate reduction to the risk of flood-induced failures and does not change the seismic risk of levee failure.
- A moderate reduction in the risk of levee failures due to flood events occurs in this scenario, but the scenario does not provide any reduction to the seismic risk of levee failure.
- No risk reduction is apparent with regard to potential water export interruption.
- Improvements in levee maintenance and overall emergency preparedness have a positive but limited impact on risk reduction.
- A clear benefit results from restoration and improvement of the ecosystem in the Delta; a substantial addition of habitat space fosters bio-diversity.
- Land-use change does not have a direct benefit to current or near-term risk of levee failures; however, it is anticipated that a reduction in subsidence offers longer-term benefits by reducing the future accommodation space.
- The general cost of implementation for this trial scenario is about $10.5 billion, and the cost benefit for a 50-year life cycle is about $69 billion (see Table 18-6 for other life-cycle cost benefits and impacts).

Scenario 2: Armored Pathway(Through-Delta Conveyance)

The purpose of this scenario is to improve the reliability of water conveyance by creating a route through the Delta that has high reliability and the ability to mitigate the intrusion of saltwater into the south Delta. The armored pathway is created by seismically upgrading the levees along a pathway from the Sacramento River near Hood to the pumps in the south Delta (see the description of Building Block 1.6), dredging channels to provide the required capacity, and installing channel barriers in the south Delta to limit saltwater intrusion during multiple island-flooding events. This scenario also provides for infrastructure improvement (raising highways, developing an armored infrastructure corridor), levee upgrade to PL 84-99 and urban levee standards, and environmental improvements and restoration.

The findings of the evaluation of this scenario include:

- The armored pathway reduces the likelihood of levee failures that could impact water exports. This upgrade, coupled with the installation of barrier gates in the southern Delta, has the joint benefit of significantly reducing the likelihood of export disruptions.
- The scenario provides a moderate reduction to the risk of levee failures due to flood events but provides no reduction to the seismic risk of levee failure.
- The scenario provides a substantial risk reduction to the potential costs and impacts associated with transportation and utility interruption due to both flood and seismic events.
- Improvements in levee maintenance and emergency preparedness overall have a positive, but limited impact in terms of risk reduction.
- A clear benefit results from restoration of and improvements to the ecosystem in the Delta, and the substantial addition of habitat spaces fosters bio-diversity.
- Land-use change does not have a direct benefit to the current or near-term risk due to levee failures; however, it is anticipated a reduction in subsidence offers longer term benefits by reducing the future accommodation space.
- The general cost of implementation of this scenario is about $15.6 billion, and the cost benefit for a 50-year life cycle is about $71 billion (see Table 18-6 for other life-cycle cost benefits and impacts).

Scenario 3: Isolated Conveyance Facility

The purpose of this scenario to is to provide high reliability for water conveyance (up to 15,000 cfs) by construction of an ICF on the eastern side of the Delta (see the description of Building Block 1.7). The ICF avoids the vulnerability of water export disruptions associated with levee failures. This scenario also provides for infrastructure improvement (raising highways), improved maintenance and emergency planning, levee upgrades to PL 84-99 and urban levee standards, and environmental improvements and restoration.

The findings of the evaluation of this scenario include:

- The ICF avoids the vulnerability of water exports associated with Delta levee vulnerability and thus offers significant flood and seismic risk reduction over present conditions. The ICF, coupled with the installation of barrier gates in the south Delta, has the benefit of reducing the likelihood of significant export disruptions.
- The scenario provides a moderate reduction to the risk of levee failures due to flood events, but the scenario provides no reduction to the seismic risk of levee failure.

- A substantial risk reduction results because of the potential costs and impacts associated with transportation and utility interruption due to both flood and seismic events.
- Improvements in levee maintenance and emergency preparedness have an overall positive, but limited impact in terms of risk reduction.
- A clear benefit results from the restoration of and improvement to the ecosystem in the Delta, and the substantial addition of habitat space fosters bio-diversity.
- Land-use change does not have a direct benefit on the current or near-term risk due to levee failures; however, it is anticipated a reduction in subsidence offers longer term benefits by reducing the future accommodation space.
- The general cost of implementation this scenario is about $14.8 billion, and the cost benefit for a 50-year life cycle is about $83 billion (see Table 18-6 for other life-cycle cost benefits and impacts).

Scenario 4: Dual Conveyance

The purpose of this scenario to is to provide higher reliability and flexibility for water conveyance by construction of an ICF on the eastern side of the Delta (similar to Trial Scenario 3) and a through-Delta conveyance (similar to Trial Scenario 2). The scenario also provides levee improvements, enhanced maintenance and emergency planning, improvements to transportation and utility lines, environmental restorations similar to the previous scenarios.

The findings of the evaluation of this scenario include:

- The DC scenario avoids the vulnerability of water exports associated with Delta levee vulnerability and thus offers significant flood and seismic risk reduction over the present condition. The DC also has the benefit of flexible water export from the Delta and/or from the ICF.
- The scenario provides a moderate reduction to the risk of levee failures due to flood events but provides no reduction to the seismic risk of levee failure.
- The scenario provides substantial risk reduction to the potential costs and impacts associated with transportation and utility interruption due to both flood and seismic events.
- Improvements in levee maintenance and emergency preparedness have an overall positive, but limited impact in terms of risk reduction.
- A clear benefit results from restoration of and improvements to the ecosystem in the Delta, and the substantial addition of habitat spaces fosters bio-diversity.
- Land-use change does not have a direct benefit to the current or near-term risk due to levee failures; however, it is anticipated that a reduction in subsidence offers longer-term benefits by reducing the future accommodation space.
- The general cost of implementation of this scenario is about $17.1 billion, and the cost benefit for a 50-year life cycle is about $80 billion (see Table 18-6 for other life-cycle cost benefits and impacts).

19.4 CONCLUSION

Three significant and equivalent impacts are identified as a result of major flood or seismic events in the Delta. They are in-Delta losses, loss of transportation and utility services, and loss of water for export to out-of-Delta urban and agriculture users.

Although the transportation and water conveyance losses are self-defined, the in-Delta impacts include developments, businesses, population at risk, and bio-diverse habitats.

The preliminary risk reduction evaluation conducted in this study indicates that the trial scenarios will rank in the following order when compared on benefit-versus-cost valuations:

1) Isolated Conveyance Facility: Lowest cost for the highest benefit

2) Dual Conveyance: second lowest cost for the second highest benefit

3) Through-Delta Conveyance: Third lowest cost for the third highest benefit

4) Improved levees: Fourth lowest cost for the fourth highest benefit

A final observation of the initial trial scenario results suggests that more detailed evaluations should be made to assess the benefits and the costs. These evaluations seem important in light of the considerable expense required to achieve meaningful risk-reduction benefits.