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.

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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

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.

(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.

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.

- 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.

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.

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:
- ● Scenario 1: Improved Levees
- ● Scenario 2: Armored Pathway
- ● Scenario 3: Isolated Conveyance Facility
- ● 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