Delta Risk Management Strategy
Status and Summary of Major Findings

1. Summary Status

The Delta Risk Management Strategy (DRMS) was originally called for in the 2000 CALFED Record of Decision. In May 2005, a steering committee was formed to guide the completion of DRMS and a scope of work was drafted. The Department of Water Resources (DWR) contracted with URS, Inc. to conduct the studies. The Phase 1 evaluations were initiated in March 2006 to better define the current risk and consequences of levee failure in both the Sacramento-San Joaquin Delta and in the Suisun Marsh. Thirteen technical memoranda (TM) consisting of over 3,000 pages were prepared which describe the development of evaluation modules (methods and software; a number of which did not exist at the start of the project), document various issues and parameters used in the risk analysis. The TMs, which were prepared in approximately 12 months, covered disciplines such as: floods, earthquakes, climate change, subsidence, wind-wave effects, geomorphology, levee vulnerability, emergency response of levees, hydrodynamics, water management, ecosystem impacts, infrastructure impacts, and economic impacts. A draft report for the Phase 1 risk analysis was released for review in June 2007. The report documented that Delta levees are subject to failure from a multitude of sources, including flood and seismic events, and that future stressors such as climate change would increase the risk over time.

As part of the completion of the Phase 1 studies, DWR contracted with several individuals, groups, and agencies to provide review comments on various portions of the studies. The DRMS Phase 1 studies are probably the most extensively reviewed evaluations of Delta levee issues ever completed. One of the reviews contracted by DWR was by an Independent Review Panel (IRP) that was put together by the CALFED Independent Science Board. The IRP review was very critical of the Phase 1 Draft report and how various aspects of the analyses, particularly with regard to uncertainties, were documented and carried through in the risk analyses. DWR has tasked URS to address all of the issues raised by the IRP review and to develop a revised report for a subsequent review by the IRP.

Following the release of the Phase 1 draft report, URS began work on the Phase 2 evaluations which are oriented towards identifying alternative risk reduction measures and what the costs and benefits would be associated with them. Approximately 20 individual measures, or “building blocks,” were identified (e.g. improved levees, development of a robust emergency preparedness/response, alternative water export conveyance, etc…). Many of these “building blocks” were compiled into three groupings, or trial scenarios which focused on alternative water conveyance options. Trial Scenario 1 used the existing water export conveyance system and approached risk reduction by improving most of the levees (~380 miles) to PL84-99 standards, and a few selected levee reaches (~100 miles) to be seismically resistant. Trial Scenario 2 approached risk reduction by creating an armored pathway for water conveyance through the middle of the Delta along Middle Creek. Trial Scenario 3 incorporated an isolated conveyance along the eastern edge of the Delta. All three trial scenarios also incorporated "building blocks" involving improved levee maintenance, raising or armoring Delta highways, and various ecosystem restoration strategies. Preliminary results of the Phase 2 evaluations were presented to the Delta Vision Blue Ribbon Task Force on August 30, 2007. Along with the Phase 1 study revisions, the Phase 2 studies are being reviewed and are planned to be revised as well.

2. Summary of Major Findings of DRMS Phase 1 Evaluations

Even though the DRMS Phase 1 studies will be revised to address the IRP comments, its major findings are not expected to change. These include:

1. Delta levees have been and will continue to be susceptible to failure by both flood events and unexplained sunny-day levee collapses. The chance of each individual island failing by a flood event in any single year is currently estimated to be between 3 and 7 percent (see Slide 2). Such annual risks will increase over time. Climate change is expected to bring more severe flood events (i.e., increase their frequency of occurrence) and increase sea level in the future. As has been our experience in the past (e.g. 1980, 1980, 1986, 1997), major floods are expected to result in multiple island inundations.

2. In 2003, the Working Group for California Earthquake Probability, convened by the United States Geological Survey, updated their estimate of the probability of a major earthquake in the Bay Area. They determined that the Bay-Delta area has been in a relatively quiet seismic period since the 1906 San Francisco Earthquake, but that strong earthquakes should be anticipated in the future (see Slide 3). Using the most recent information available on surface and hidden faults (previously not considered in prior studies), URS developed estimates of earthquake motions, known as peak ground accelerations, for the Delta region. The DRMS estimates are consistent with previous studies and show that moderate to strong earthquake motions should be expected in the western and central portions of the Delta (see Slide 4). Furthermore, the level of shaking along the eastern edge of the Delta is expected to be only about half of that along the western side. The level of earthquake shaking currently predicted for a 100-year earthquake also represents about 3 to 10 times greater motions than what the Delta has probably sustained for at least 100 years. Even higher earthquake motions are both possible and to be expected over the long term.

3. The DRMS Phase 1 studies gathered and evaluated available geotechnical data from previous geotechnical investigations in the Delta and estimated the seismic vulnerability (fragility) of levees across the Delta. The information from over 2,000 previous borings in the Delta were used in this effort, and represent the most extensive such review conducted to date (see Slide 5). The results showed that the levees are susceptible to liquefaction and could fail in moderate to strong earthquake shaking. This conclusion matches those of every known seismic evaluation completed for Delta levees over the last 25 years, including:

- Documentation Report, Sacramento-San Joaquin Delta, California, USACE, 1982
- Earthquake Damage in the Sacramento-San Joaquin Delta, California Geology, Mike Finch, 1985.
- McDonald Island Study, Levee Stability, Dames and Moore, 1985.
- Sacramento-San Joaquin Delta Levee Liquefaction Potential, USACE, 1987.
- "Estimated Performance of Twitchell Island Levee System," Mike Finch, 1988.
- Preliminary Seismic Risk Analysis, South Delta, U.S. Bureau of Reclamation, 1989.
- Seismic Design Criteria, Wilkenson Dam, Bouldin Island, Harding Lawson Associates, 1990
- General Seismic and Geotechnical Risk Assessment, Sacramento-San Joaquin, California, Dames and Moore, 1991.
- Preliminary Seismic Risk Analysis, North Delta, U. S. Bureau of Reclamation, 1991.
- Seismic Stability Evaluation of the Sacramento-San Joaquin Delta Levees, DWR, 1992.
- Seismic Vulnerability of the Sacramento-San Joaquin Delta, CALFED Bay-Delta Program, 2000.

Slide 5 presents current estimates of annual risk of island flooding induced by earthquake shaking. Most of the islands have annual risks on the order of 1 to 3 percent, and thus are expected to be less frequent than failures associated with flood events. While these particular numbers are being re-evaluated to address some of the comments by the IRP and can be expected to be revised, the conclusion that large numbers of islands could be flooded during a large earthquake will remain to be true. Furthermore, as determined by the USGS working group and considered in the DRMS analysis, the likelihood of a major earthquake (and thus the seismic risk) increases with time as years pass without earthquakes.

4. Large numbers of levee failures and island floodings are possible for both major flood and earthquake events. Even though it is calculated to be less frequent, a major seismic event would likely be more catastrophic:

   - A major seismic event leading to the simultaneous flooding of numerous islands occurring during the drier summer and fall months, would draw salt water into the Delta, halting water export and severely impacting the ecosystem. Such an event occurring during the dry season, even during a normal water year, could lead to over $60 billion in direct and indirect economic losses. Salt water intrusion is less likely during a flood event because there is so much fresh water flowing out to the Bay and ocean. However, long-term salt water intrusion could result if the flooded islands are not reclaimed and become part of the tidal prism.

   - A major seismic event could be more devastating to the levee system than a major flood event. This is because when a flood event induces a levee failure, usually only one levee breach is formed and the rest of the levee system remains more or less intact as the island fills with water. In a seismic event, earthquake experience demonstrates (Loma Prieta; Kobe, Japan) that, in addition to the potential for multiple levee breaches, there could also be miles of damaged levees many islands. The cost and time to repair miles of levee damage instead of only closing one levee breach is many times more time consuming and costly. In fact, some believe that a major earthquake causing miles of levee damage would make the levees so damaged that wave-wash erosion and other factors cause the damaged levees to deteriorate faster then they could be repaired.

- Looking to the future, the current level of risk, which is already high, will be increasing. Sea level rise and subsidence will be adding pressure on the levee system (see Slide 7). Over the next 100 years, sea level rise is expected to rise at least 90 cm (~ 3 feet), with island subsidence also continuing. To simply attempt to maintain the current level of marginal performance over the next 100 years, it is estimated that it will require, on average, between $ 9 and $24 million per mile, depending on the availability of construction materials. Sea level rise and continuing island subsidence, if not completely mitigated, will increase the likelihood of levee failures from all future stressors (floods, earthquake, winds and sunny-day events). In addition, the probability of a major seismic event will continue to increase and much larger economic and ecological consequences are expected if "business-as-usual" processes are maintained in the Delta.

3. DRMS Phase 2 Risk Reduction Options under Consideration

The Phase 2 evaluations began by developing a list of individual risk reduction options, or "building blocks." These measures are shown in Slides 8 and 9 and below:

Levee Options

- Mitigation for Sea Level Rise, Island Subsidence: ~$ 9 to $ 24 million per mile
  (simply maintaining current levee performance over the next 100 years)
- Levee Improvements
  - PL84-99 Standard: ~$ 2 - 22 million per mile
  - Urban Levee Standards: ~$ 13 - 36 million per mile
  - Seismically repairable levees: ~$ 25 - 52 million per mile
- Increased funding for levee maintenance: ~$12 to 25 million per year
- Improved emergency preparedness/response: ~$100 million

Note: 1. Levee cost estimates depend upon availability of levee material on each island
2. Estimated costs are preliminary and developed for use in risk reduction evaluations

Water Export Conveyance Options

- Status Quo with Improved levees
- Armored Pathway along Middle River
- Isolated Conveyance Facility

Infrastructure Options

- Elevate State Highways (Highways, 4, 12, and 160) ~ $ 6 billion
- Armored Infrastructure Corridors (e.g. incorporate Highway 4, Mokelumne Aqueduct, and BNSF Railroad across Central Delta ~ $ 3 billion

Ecosystem Restoration Options

- Land Use Changes to Reduce/Reverse Island Subsidence
- San Joaquin Bypass ~ $2 billion
- Restoration of portions of Suisun Marsh to Tidal Wetlands ~ $ 170 million
- Cache Slough Restoration ~ $ 400 million
- Fish Screens on River/Island Diversions ~ $ 165 million
- Setback Levees used to provide Shaded Riverine Habitat ~ $35 million/mi.

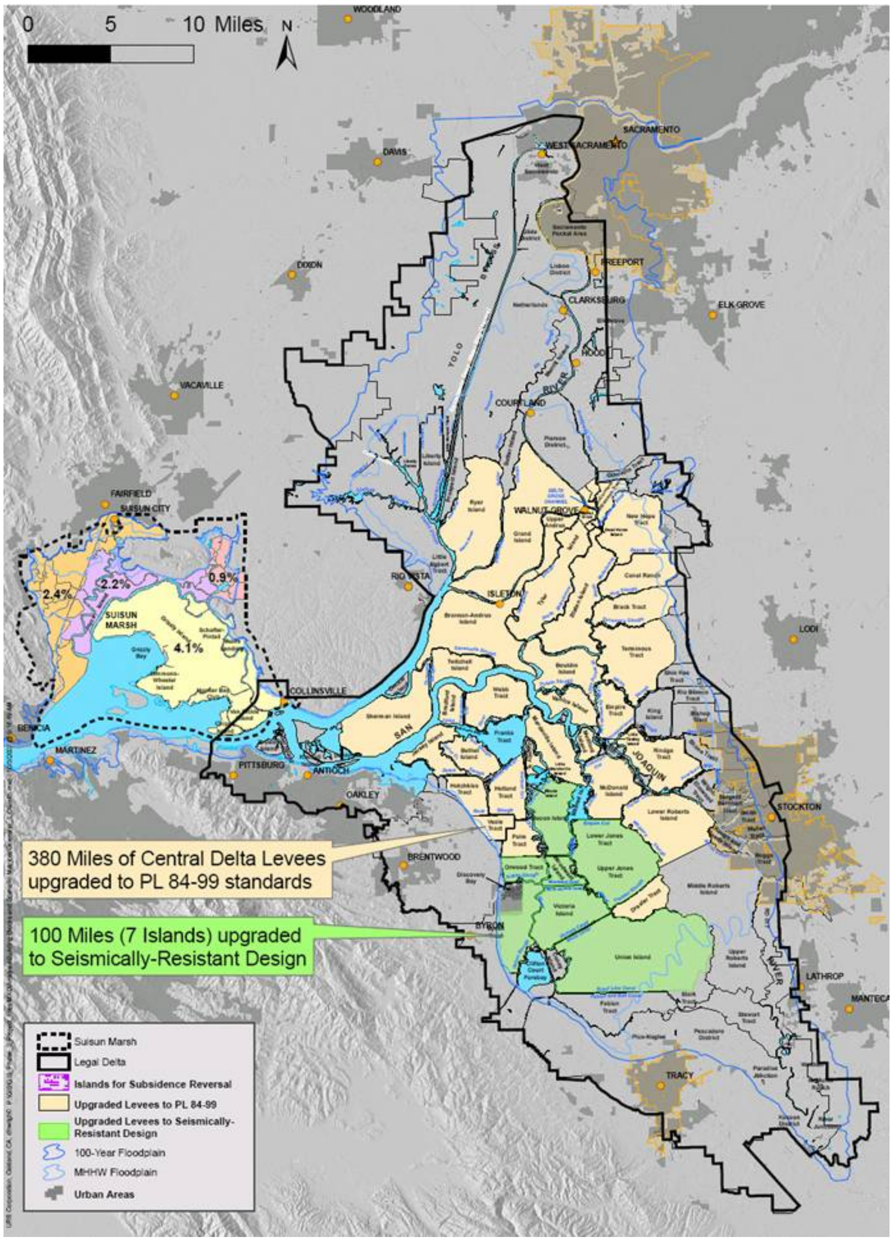
4. DRMS Phase 2 Initial Trial Scenarios

The three trial scenarios that were initially developed involved different combinations of "building blocks" and were focused on three different approaches for water conveyance. These water conveyance approaches were based on proposals from the 2007 PPIC report and conservation strategies developed by the steering committee for the Bay Delta Conservation Plan. As originally conceived, all three initial trial scenarios also included provisions for increased levee maintenance, emergency response, armoring/elevating infrastructure corridors, and ecosystem restoration. The initial evaluations were based on ***preliminary*** concepts and cost assessments. Further improved evaluations will process as:

- Preferences/priorities are identified
- Options are optimized (e.g. levee optimization work group)
- Costs are refined
- More detailed assessments are conducted

The building blocks and trial scenarios are currently being optimized and will be revised with input from the DRMS Steering Committee. To provide some information regarding the water conveyance portions of the trial scenarios, ***preliminary*** information is provided in Slides 10, 11, and 12, and below:

4.1 Trial Scenario 1 Water Conveyance Element: ***Improved Levees*** (see Slide 10)



"Improved Levees" Water Conveyance Element

Preliminary Design/Construction Costs:

- ~380 levee miles to PL84-99 ~ $ 1.7 Billion
- ~100 miles to Seismic Resistant Setback Levees ~ $ 3.8 Billion
- **Total Cost ~ $ 5 ½ Billion**

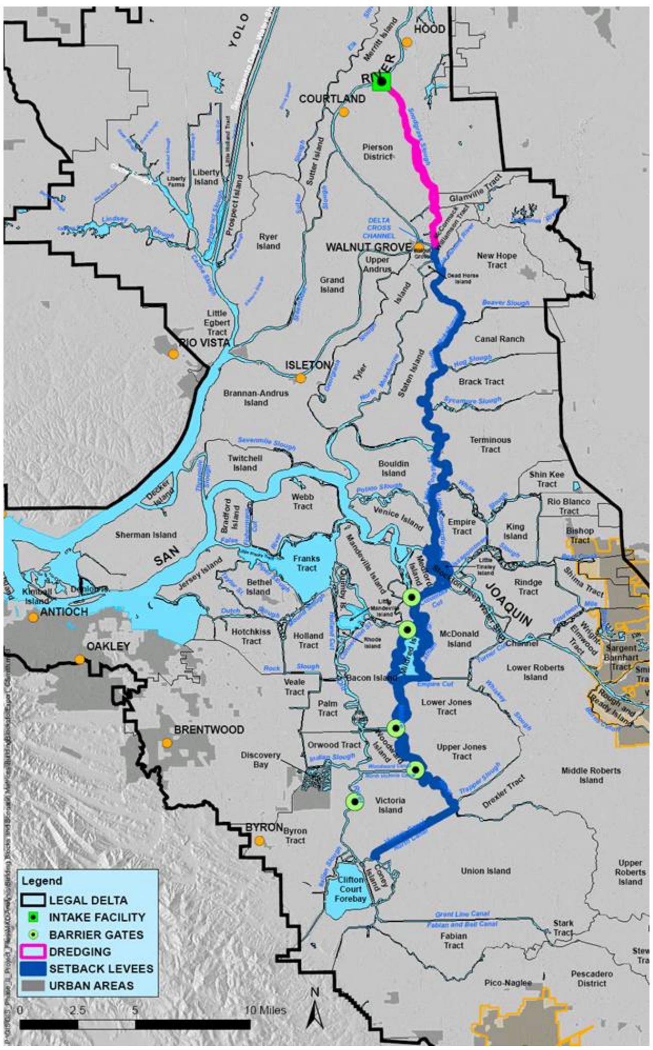
Potential Benefits Include:

- Reduced Risk of Salt Water Intrusion/Water Export Interruption
- Reduced Impact to Ecosystems
- Reduced Flood Risk Due to Overtopping and Seepage – helps protect agriculture, on-island ecosystem/habitat ,and legacy towns
- Improved Protection for Some Infrastructure (Highway 4, Mokeumne Aqueduct, BNSF Railroad)

Potential Limitations Include:

- Lower Reliability of Water Export due to Physical and Environmental Risks (compared to Armored Pathway or Isolated Conveyance Facility)
- Continues Current Impacts to Fisheries
- Costs do not include mitigation for sea level rise or continued island subsidence

4.2 Trial Scenario 2 Water Conveyance Element: ***Armored Pathway*** (see Slide 11)



"Armored Pathway" Water Conveyance Element

Preliminary Design/Construction Costs:

- 15,000 cfs Facility ~ $ 5 ½ - 9 Billion
- 10,000 cfs Facility ~ $ 4 ½ - 8 Billion
- 5,000 cfs Facility ~ $ 3 ½ - 6 Billion

Summary of Preliminary Design/Construction Cost Estimate Components for Armored Pathway Conveyance with 15,000 cfs Capacity

Intake Facility		~ $ 400 million
Dredging		~ $ 230 million
Bridge Modifications		~ $ 20 million
Setback Levees (Seismically Repairable/Resistant)		~ $ 2,300 – 4,370 million
Barrier Gates		~ $ 100 million
Old River Siphon		~ $ 65 million
Subtotal		~ $ 3,115 – 5,185 million
Mobilization/Demob.	@ 5 %	~ $ 155 – 260 million
Survey/Design/Admin./CM	@ 30 %	~ $ 980 – 1,635 million
Contingency	@ 30 %	~ $ 1,275 – 2,125 million
	Total	**~ $ 5.5 – 9.2 billion**

Potential Benefits Include:

- Significant Reduction in Risk of Water Export Interruption
- Significant Benefits to Fish by Isolating Old River from Middle River and constructing Setback Levees
- Operational Flexibility Using Barrier Gates

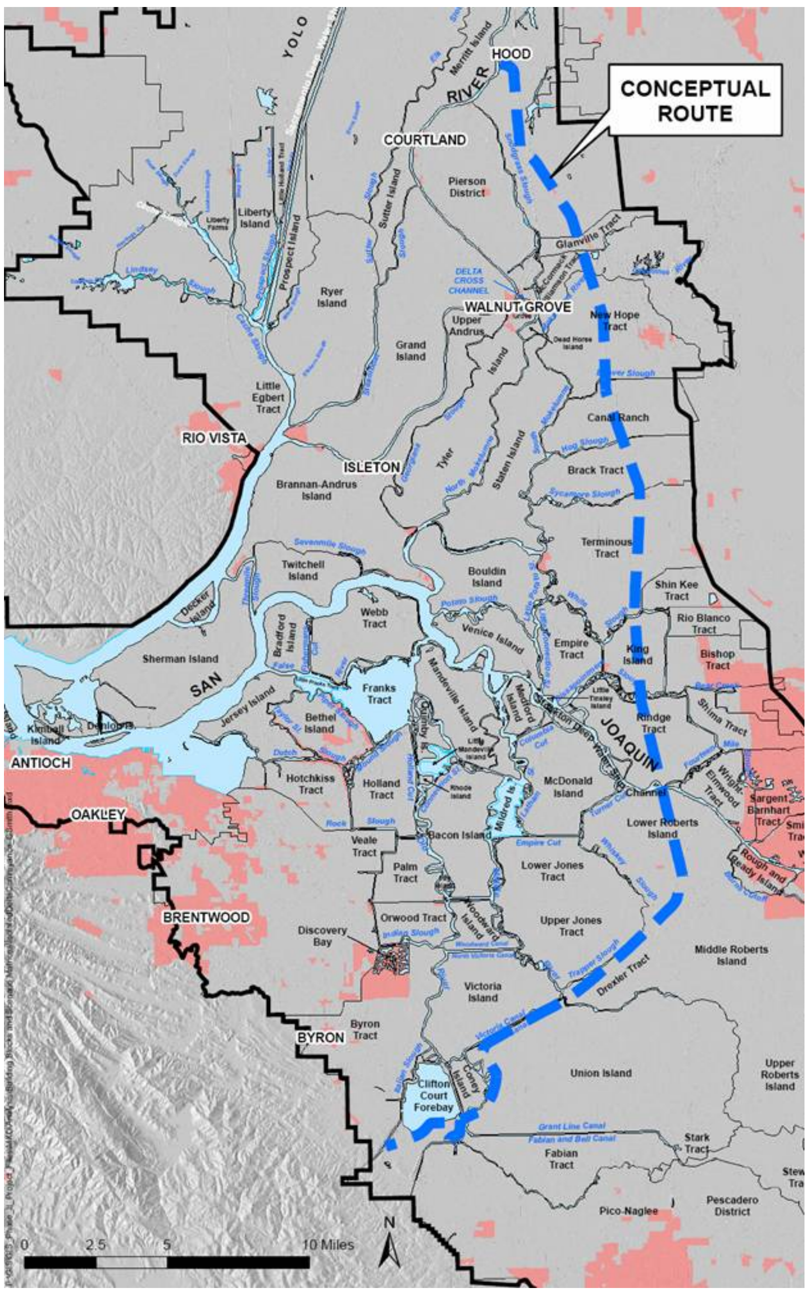
Potential Limitations Include:

- Operational Limitations to be Determined
- Lower Reliability of Water Export due to Physical and Environmental Risks (compared to Isolated Conveyance Facility)
- Costs do not include mitigation for sea level rise or continued island subsidence

<u>4.3 Trial Scenario 3 Water Conveyance Element: ***Isolated Conveyance Facility***</u>
<u>(see Slide 12)</u>

<u>Preliminary Costs:</u>

- 15,000 cfs Facility ~ $ 4.9 Billion
- 10,000 cfs Facility ~ $ 4.2 Billion
- 5,000 cfs Facility ~ $ 3.3 Billion



"Isolated Conveyance Facility" Water Conveyance Element

Summary of Preliminary Design/Construction Cost Estimate Components for Isolated Conveyance Facility with 15,000 cfs Capacity

Intake Facility		~ $ 400 million
Bridges and Culverts		~ $ 90 million
Pumping Plant		~ $ 230 million
Canal Excavation		~ $ 270 million
Canal Embankments		~ $ 380 million
Siphons and Controls		~ $ 1,105 million
Outlet Structures		~ $ 105 million
Right of Way		~ $ 140 million
Seeding/Roads/Fencing		~ $ 60 million
Miscellaneous		~ $ 10 million
Subtotal		~ $ 2,800 million
Mobilization/Demob.	@ 5 %	~ $ 140 million
Survey/Design/Admin./CM	@ 30 %	~ $ 880 million
Contingency	@ 30 %	~ $ 1,145 million
	Total	**~ $ 4,965 billion**

Potential Benefits Include:

- Most Reliable Water Conveyance Approach - Major Reduction in Risk of Water Export Interruption
- Offers Most Flexibility for Water Quality in the Delta by Isolating Water Export from Delta Water
- Reduces Water Treatment Costs and Salt Accumulation in Agricultural Fields
- Decreases Impacts to Fisheries

Potential Limitations Include:

- By itself, Isolated Conveyance Facility provides the least protection to Delta Islands
- Will require additional environmental mitigation costs
- ICF only obtains water from Sacramento River; not able to use high winter flows in San Joaquin River
- Costs do not include mitigation for sea level rise or continued island subsidence

Any water conveyance element would have to be part of an overall package or solution in order to address the multitude of issues associated with the Delta. ***All water conveyance elements, by themselves, have the following potential limitations in common:***

- Significant risk of levee failure remains in most of the Delta, and potential flood impacts and fish entrainment remain unaddressed
- Requires additional maintenance costs over time to keep up with sea level rise and continued island subsidence
- Governance of Water Export and Water Quality need to be determined
- Long-Term Management Plan to be determined for maintaining Delta levees and for abandoning Delta islands, either before or after they flood

5. Schedule and Next Steps (Slides 14 and 15)

Phase 1

Currently URS is correcting the Phase 1 report to address the comments from the Independent Review Panel (IRP) appointed by the CALFED Independent Science Board. URS expects that it will take them from now through February 2008 to correct the Phase 1 documents. DWR and the DRMS Steering Committee will then review the documents in March 2008, so the final, corrected Phase 1 report can be provided to the IRP in April 2008. The IRP will be requested to perform another review of the report. The goal of the second review is to have the IRP acknowledge that all of their comments have been satisfactorily addressed.

However, while we agree with the need to have the report re-written to make it more readable, transparent, and document previous studies, we also believe the major risks to the Delta, as reported in the draft Phase 1 report, will not change substantially. As discussed above, the major concern to the Delta is still from a seismic event, and the final Phase 1 report will still reflect that same concern.

Phase 2

URS will be submitting a draft of the Phase 2 report to DWR in October 2007. This report will have the three initial trial scenarios previously presented to the Delta Vision Blue Ribbon Task Force at their August 2007 meeting. As discussed earlier, each of these scenarios contain many building blocks (individual actions/options). URS has determined costs for each of the building blocks, and they have also estimated the benefits derived from each of the building blocks. Each of the scenarios was then run through the risk model, developed in Phase 1, and the corresponding risk reduction for each scenario was determined.

Also, in October and November 2007, a subcommittee of the DRMS Steering Committee members will be meeting in an attempt to begin optimizing the levee upgrades for each of the scenarios. This subcommittee will report to the full Steering Committee at its November meeting with their recommendations. The Steering Committee will also provide recommendations to help address the comments and issues associated with the IRP review. It is expected that both the building blocks and trial scenarios will be revised to incorporate the initial results of the risk reduction evaluations and to optimize each option and trial scenario. The details of this latter effort are still in a state of flux and the schedule for Phase 2 may be revised depending on the outcome of the optimization process, and any input/requests from Delta Vision and the Blue Ribbon Task Force. It is anticipated that Delta Vision/BRTF may wish to have additional building blocks and scenarios evaluated in a Phase 3 set of evaluations.

6. Conclusion

The DRMS models and evaluations have provided valuable information and evaluations regarding Delta issues, risks, and potential risk reduction strategies. Over the next six months, the models, reports, and evaluations will be revised and improved and will represent the most reviewed and thorough set of risk management tools ever developed for the Delta. It will be an invaluable tool for use by Delta Vision and the Blue Ribbon Task Force in developing its Strategic Plan and in optimizing the elements of the plan. It will be fully available for this purpose in April 2008, but preliminary analyses can be made earlier.