Review of the Delta Risk Management Strategy Phase 1 Report (Draft 4)

(URS Corporation/Jack R. Benjamin & Associates, Inc., July 16, 2008)

***Submitted to the CALFED Science Program* by the**

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EXECUTIVE SUMMARY

The CALFED Science Program's Independent Review Panel's (IRP) review of the revised Delta Risk Management Strategy (DRMS) Phase 1 Report concludes that the DRMS analysis is now appropriate for use in Phase 2, and is now acceptable for use as a tool for informing policymakers and others regarding potential resource allocations and strategies to address risk in the Delta region. This conclusion, however, is subject to some important caveats. First, the IRP cautions users of this revised DRMS Phase 1 Report that future estimates of consequences must be viewed as projections that can provide relative indicators of directions of effects, not predictions to be interpreted literally. Second, anyone using the results of the DRMS scenarios must be aware that ecosystem effects are not fully captured in the analysis, and that, in particular, the lack of ecosystem consequences reported does not imply small ecosystem impacts. Rather, the IRP notes that some scenarios could result in extremely large ecosystem disturbances, but these impacts will not be quantified because ecosystem consequences are inadequately accounted for in the current DRMS modeling framework. Finally, although the IRP found that most of the analyses were sound and the conceptual models used captured the likely risks to the Delta in the present and future, some questions still remained regarding the details of certain analyses. The most important of these are presented in the main body of the report below, while specific comments and analyses are presented in various Appendices. These must be considered for a full understanding of the IRP's review of the revised DRMS Phase 1 Report. The IRP believes that these caveats require users of the DRMS model framework to exercise due diligence to ensure scientifically credible interpretations of the results.

I. INTRODUCTION

A. Background

This report summarizes the findings and conclusions of the Independent Review Panel's (IRP or Panel) second review of the Delta Risk Management Strategy (DRMS) Phase I Report. The first review was completed by the IRP on August 23, 2007. In the first review, the IRP organized comments into Tier 1 and Tier 2 categories. The IRP identified several major Tier 1 concerns that influenced the primary results and conclusions listed in the first draft of the DRMS Phase 1 Report. The IRP also identified many Tier 2 concerns related to specific analyses in each report section.

In response to that review, the DRMS authors revised their original DRMS Phase 1 Report and submitted a revision of it (Draft 4, July 16, 2008) on July 17, 2008. That fourth draft of the revised DRMS Phase 1 Report is reviewed by the IRP in this document. Throughout this second IRP review, the IRP evaluates whether that revised DRMS Phase 1 Report addressed review comments from the earlier version. No subsequent review by the IRP is anticipated.

B. Review Process

The goals of this review, as detailed in the charge to the Panel (attached here as Appendix 1), were to assess the strengths and weaknesses of the revised DRMS Phase 1 Report, and to determine if the report provides a strong scientific and engineering foundation for further analyses that will lead to strategies for reducing risk in the Delta.

To complete this latest review, the IRP members read the latest (fourth) draft of the revised DRMS Phase 1 Report, with subgroups concentrating on assessing specific sections of the report. The IRP then held a conference call on August 19, 2008, to discuss each Panel member's assessment of the report. All members felt that there were some outstanding questions that would only be cleared up by direct questions to authors. Therefore, we set up a series of fact-finding calls to address four specific issues:

- Aquatic resources modeling
- Levee stability and seismic and flood forcing on levees

- Economics/valuation models
- Transparency and organization of the report

Notes were taken during calls and distributed to the IRP and DRMS authors. Written responses were provided by the DRMS authors to the IRP when additional clarification was needed. The call notes and written responses are presented here as Appendix 2.

The IRP met in Sacramento on September 4 and 5, 2008 to finalize the review and to develop this document. We also met with the DRMS authors and agency representatives to address any outstanding questions from our review and to present preliminary findings from the review process. The meeting was recorded, and the audio is available from the CALFED Science Program.

During the review process, IRP members made many detailed comments on the revised DRMS Phase 1 Report. Editorial comments, which identified inconsistencies, errors, problems of organization, repetitions, and omissions, were collated by CALFED Science Program staff and are provided in Appendix 3. Details on seismicity and seepage issues, in addition to those presented in the main body of the report below, are presented in Appendix 4.

An overview of the Panel's review and the contents of the Appendices were presented verbally to the DRMS authors and agency representatives on September 5, 2008. This present document is the final, written version of the IRP review.

C. Review Focus

The original IRP charge included three major categories and several questions (Appendix 1) that guided assessment of the revised DRMS Phase 1 Report, as follows:

- Information Gathering
- Information Analyses and Results
- Findings and Conclusions

The IRP combined these categories to better assess the revised and greatly expanded DRMS report, as follows. We begin by focusing on the overall adequacy of the DRMS scientific

information and on the overall technical adequacy of the analysis methods and information used for the components of the DRMS analysis related to *causes* of risk (Section II) and modeling of the *consequences* of risk (Section III). We then comment on the reasonableness of the findings and conclusions of the DRMS analysis (Section IV). A separate review of the Executive Summary to accompany the revised DRMS report (not provided to the IRP until late in the review process) is presented in Section V and Appendix 5. Finally, we summarize our main conclusions from the Review (Section VI).

D. General Statement of Review Findings

In the first review of the original DRMS Phase 1 Report (dated August 23, 2007), the IRP concluded that:

> "As written, many of the analyses are generally incomplete and therefore inadequate to serve as a foundation from which to make reasonable policy decisions about future resource allocations concerning strategies for the Delta region. In other words, the Panel believes strongly that the inadequacies in some of the analyses may lead policymakers and others to erroneous conclusions and inappropriate decisions. (Page 3)"

and

> "The Panel seriously questions the usefulness of any Phase 2 analyses that rely on results reported in a Phase 1 draft report that is not significantly revised to address the Panel's Tier 1 comments. (Page 7)"

In this second review, we find the revised DRMS Phase I Report (Draft 4) to be much improved. The DRMS authors successfully addressed many of the IRP's original questions and concerns, and substantially improved the exposition. The IRP has therefore concluded that the revised DRMS Phase 1 Report is acceptable for use as a tool for informing policymakers and others regarding potential resource allocations and strategies to address risk in the Delta region, provided that *some important caveats* (detailed below) are well understood.

The first caveat is common to any broad analysis that relies on a series of linked models. In such analyses, caution is imperative when interpreting scenarios that deviate substantially from baseline conditions. In the case of the DRMS analysis, baseline conditions are the 2005 base - year results. Predictions of conditions 20 to 30 years into the future are inherently highly

uncertain, and reliable predictions of conditions 50 to 100 years into the future are virtually impossible. We therefore caution that future estimates of consequences must be viewed as projections that can indicate potential directions of effects, not predictions to be interpreted literally. In a related issue, the IRP cautions readers and users of the DRMS report to avoid the common mistake of equating precision with accuracy. Precision is the exactness of the reported results. Accuracy is how close the predictions are to truth. The DRMS analysis involves many computer-based calculations that can be reported with very high precision, from which it is often tempting to infer great accuracy. In turn, this could lead to misinterpretation of the DRMS results, and thus to incorrect decisions.

The second caveat is specific to the DRMS analysis and is due to the minimal ecosystem consequences that are actually assessed in the revised DRMS Phase I Report. Estimates of the effect of island flooding on vegetation and wildlife were much reduced from what was described in the methods section of the first draft of the DRMS Phase I Report and in the Impact to Ecosystems Technical Memoranda (TM). Furthermore, there was no assessment of consequences for aquatic resources (i.e., fish). With ecosystem consequences minimally represented in the current DRMS models, and with fish absent from the predictions, the IRP believes this could easily lead to erroneous interpretations of DRMS model results. Thus, anyone using the results of the DRMS scenarios must be very aware that ecosystem effects are not fully captured in the analysis, and that, in particular, the lack of ecosystem consequences reported does not imply small ecosystem impacts. Rather, the IRP notes that some scenarios could result in extremely large ecosystem disturbances, but these impacts will not be quantified because ecosystem consequences are inadequately accounted for in the current DRMS modeling framework.

The IRP believes that these caveats require users of the DRMS model framework to exercise due diligence to ensure scientifically credible interpretations of the results.

II. REVIEW OF ANALYSIS METHODS AND INFORMATION—CAUSES OF RISK TO THE DELTA

A. Seismic Risk Analysis

The approach taken in the DRMS Phase I report to assess seismic risk has two key components: (1) an analysis to predict possible ground motions (seismic hazard), and (2) an analysis to predict levee response to ground motions (levee vulnerability).

Characterization of the seismic hazard used by the DRMS relies primarily on work done by the United States Geological Survey (USGS) and the California Geological Survey (CGS). We find the approach taken by the DRMS to be technically sound and defensible. In particular, the peak ground accelerations associated with return intervals of 100, 500 and 2,500 years at a range of locations across the Delta reported by the DRMS are comparable with published results from earlier studies.

The characterization by the DRMS of levee response to ground motions is also sound and similar to that used by other engineering organizations in the practice of geotechnical earthquake engineering. The predicted response of levees to historical earthquake events, such as the 1980 Livermore and 1906 San Francisco earthquakes, is consistent with available observations.

Therefore, the approach used by the DRMS to model seismic activity meets accepted standards of practice for modeling, and is based on currently available information. The methods and results are clearly presented in the revised DRMS Phase 1 Report, and an adequate description of the methods is provided in the associated Technical Memorandum.

The IRP notes that the predicted frequencies of island failures due to earthquakes in the base-case analysis are significantly higher than the historical record. The DRMS analysis predicts the following frequencies of island failures (Figure 13-2):

- one event per 10 years of having at least one island fail (flood) due to an earthquake;
- one event per 20 years of having at least ten islands fail due to an earthquake; and

- one event per 100 years of having at least 40 islands fail due to an earthquake.

Although there has potentially been seismically induced damage to Delta levees, there have been no known *failures* of islands due to earthquakes in at least the last 100 years. Even if the historical record of earthquakes were extended further back to include the relatively active seismic period between 1850 and 1906, before the modern Delta was developed, there would be at most several events where an earthquake may have caused hypothetical island failures if the Delta were in its present condition. Hence, the frequencies predicted by the DRMS for earthquakes causing one to ten island failures are significantly higher than the historical record suggests.

We recommend that the DRMS predictions of earthquake failures be better put into a historical and practical context in the revised DRMS Phase I Report. This context should include an expanded discussion and an acknowledgment of the potential limitations in the current standard of practice for seismic risk analysis (see Appendix 4 for a detailed discussion on this topic). This should also include widening the confidence bounds on the predicted frequencies (Figure 13-2 in the revised DRMS Phase I Report) to reflect that while the DRMS expects a higher frequency of seismic failures in the future, the *actual* frequency of failures could be similar to the available historical record. Providing readers with a realistic context for these results is particularly important because seismic-induced failures dominate the overall risk for high-consequence events.

B. Flood Risk Analysis

The DRMS report used the appropriate scientific information currently available for flood risk analysis. Data on stream-flow, levee elevation, and levee structure collected from the United States Geological Survey (USGS), the United States Army Corps of Engineers (USACE), the California Department of Water Resources (DWR), and other agencies were used to determine the potential flooding in the Delta. These are the most common and appropriate data used in such analyses. The methods used to collect this information are clearly presented and well-documented in the associated Technical Memorandum (Flood Hazard TM, March 4, 2008).

In general, the IRP identifies no major omissions or limitations to information gathering for the flood risk analysis. However, there is one potential issue related to characterization of levee foundation materials for failure analysis through seepage that may lead the DRMS analysis to under-estimate water seepage through levees. Available permeability values used to calculate seepage were derived from laboratory tests; apparently the field pumping test data was largely ignored (See Table 7 -12 for field data). The IRP believes that the laboratory test data are generally low (that is, on the impermeable side) for both peat and sand. Coupled with a peat permeability anisotropy value on the high side (e.g., Kh/Ky =100 for peat), this pushes up the factors of safety for levee stability when evaluating failure via through or under-seepage. More water is likely to seep through and/or under the levee than the DRMS models predict, but we are not certain how this would specifically affect their final analyses of failure of specific levee reaches.

C. Sunny Day Failures

The DRMS assessment of frequency of levee failures not directly caused by seismic or hydrologic events (that is, “sunny day” failures) is reasonable. It is based on the historical record where there has been approximately, on average, one failure every ten years.

The analysis did not include a potential future increase in sunny day failures owing to continual degradation of the levees, which hold back water 365 days a year. However, this potential limitation does not affect the overall results because single-island failures do not contribute substantially to the overall risks.

III. REVIEW OF ANALYSIS METHODS AND INFORMATION—MODELING OF RISK CONSEQUENCES

A. Life Safety

The IRP finds that the analysis of the effects of flooding events on human safety (fatalities) is performed in a technically competent fashion and clearly communicated. The model used by DRMS has been used by others to assess human risk from major dam failures, and was used recently in a risk analysis of the New Orleans levee system.

B. Economic Analysis

The data, models, and assumptions employed in the revised DRMS Phase I Report for the assessment of economic resources at risk are clearly defined. Given the complexities and large geographical scope of this assessment, the number of potential cost and impact factors contained within the region, and the short time-frame within which to conduct the assessment, the approach used by the DRMS authors, of necessity, relies on a wide array of secondary data and off-the-shelf models. This approach is an accepted procedure for performing the type of broad-scale assessment required for the DRMS effort. The scope of the analysis includes the economic costs and impacts estimated for both the "in-Delta" and "out-of-Delta" regions. A wide range of potential economic effects are quantified, including water quality (salinity) effects arising from levee failures and the consequent effects of these changes in salinity on water exports.

The economic assessment is based on a 2005 base case and employs a "business as usual" (BAU) assumption to predict future impacts. That is, trends in population and economic growth are presumed to continue as currently observed, and decision-makers (e.g., water managers, farmers, builders, regulators, etc.) continue to operate as if things are not changing. We believe this assumption likely overstates economic consequences. Evidence of this is the implicit assumption that after a significant flooding event, all infrastructure and residential dwellings will be rebuilt in exactly the same spatial arrangement as before the event. In some cases, the BAU scenario assumes rebuilding schedules that simply cannot occur within the simulated periodicity of flood events. For this reason, we believe that the economic analysis, while sound for present-year (base case) conditions, seriously overstates estimates of economic costs and impacts beyond 2020.

Although the underlying data and models used to assess the economic consequences of levee failure are subject to (and sometimes compound) errors and uncertainties, we believe the results are scientifically defensible overall for capturing the economic consequences of the base case scenario, as reported in Section 13. We do not feel, however, that the models and assumptions are capable of providing policy-relevant estimates of economic consequences

under any of the future scenarios discussed in Section 14 and in the Executive Summary, a concern to which we return in the discussion of findings.

C. Water Quality

The section of the revised DRMS Phase I Report that addresses Salinity Impacts (WAM – Water Analysis Module) satisfactorily addresses the comments of the first IRP review. In our opinion, it is a technically sound approach for simulating island flooding, water operations and exports, and salinity effects. Most of the IRP's comments from the first review related to the lack of consistency between the WAM TM and what was described in the original DRMS Phase 1 Report, and the general lack of clarity in this original report. As part of the first review, the IRP pieced together what had been done for the WAM component of the DRMS analysis from reports, the TM, and other sources, and had deemed the technical aspects of the WAM to be acceptable. The authors have now addressed the major IRP concerns stated in the first review by updating the report to better reflect the WAM analysis.

D. Flood Risk Analysis

Models used to analyze flooding are appropriate and well documented. The DRMS report and associated TM include adequate information on how the analyses and modeling were conducted. However, the results of these analyses relating to levee failure due to seepage and overtopping are difficult to interpret in some respects. Some levee vulnerability types have very steep fragility curves ("brittle" behavior) related to seepage driven by stage height. Therefore, the potential for failure becomes more sensitive to uncertainty or variability in the stage level. It appears from report figures that the standard deviation between measured and predicted values is not much over 1.5 feet, suggesting good agreement between modeled and measured stage. However, it is not clear from the report and the TM how this variability is accounted for between the model predictions and the actual flood levels; and if they do account for it, how they account for spatial correlations (e.g., if they under-predicted the stage at one island, they may be more likely to under-predict it at other nearby islands). This variability is not explicitly accounted for in the fragility curves—they theoretically represent the probability of failure for a given (known or actual) water surface elevation, not a predicted one. Although this error appears to be small (at Benson Ferry, for example, the 99th percentile value for the

peak annual value, or 100-year elevation, is a little under 1 foot greater due to this error), it could have a notable effect on the probability of failure since the fragility curves are steep for the most vulnerable levees.

Similarly, the fragility curves due to levee overtopping are also steep (Figure 7-75): At 2 feet over the crest, there is a mean probability of failure of 100%; at only 1 foot overtopping, there is a 60 to 90% chance of failure. Therefore, even a small range of uncertainty may make it difficult to predict failure due to overtopping. For the most vulnerable levee classes, this error could have a large effect on probability of failure due to both seepage and overtopping, manifested in future projections of levee failures due to flooding. Figures 13-13a and 13-13b show the mean annual frequency of present and projected future failure for islands from flooding. The highest predicted risk is in the Suisun Marsh, for islands that have never flooded. In contrast, the most commonly flooded islands historically correspond to a relatively low future risk of flooding. This implies that the DRMS models could be over-estimating failure in some areas, and under-estimating failure in other areas. It is not clear how this would affect the DRMS prediction of future risk of levee failure due to flooding under different climate scenarios. The very high increase (up to 10 times an increase) in expected failures of levees in 2100 under some future scenarios of climate change may be an outcome of this modeling uncertainty and the sensitivity of failure to small changes in predicted stage.

E. Ecosystems

The Ecosystem Consequences component of the revised DRMS Phase I Report was significantly reduced in scope relative to the first DRMS Phase I report reviewed by the IRP. In its current form, the revised DRMS Phase 1 Report does not address many of the major IRP review comments that were made on the first DRMS report regarding the ecosystems analysis. This stands in stark contrast to almost all of the other components of the revised DRMS Phase 1 Report, which made were amended significantly to satisfactorily address most IRP first-review comments.

Specifically, in the revised DRMS Phase 1 Report, the Impact to Ecosystem TM appeared to be only partially updated to describe a new aquatic resources analysis that was not implemented.

Furthermore, the description of the vegetation and wildlife impacts in the TM, as noted in the first review, does not match with what was reported in the revised DRMS Phase 1 Report. For example, there are several very large conceptual models shown as flowcharts, both in the TM (Figures 6-20a and 6-20b) and in the revised DRMS Phase 1 Report (Figures 12-14 and 12-15). All these appear to be outdated, identifying many quantitative analyses that are not reported in the results and creating the impression that more was done on ecosystem consequences in the Phase 1 analysis than actually took place.

The revised DRMS Phase I report *does* analyze consequences for wildlife and vegetation. However, only a small fraction of the results promised in the TM and the methods section of the revised report (Section 12) are actually reported in the 2005 Base Year Results section (Section 13) of the report. For example, the only results reported for vegetation are the percent of vegetation that spatially overlaps with the area impact by flooding. The suitability functions and time recovery described in the TM and revised DRMS Phase 1 Report are never actually computed and reported.

The revised TM and DRMS Phase 1 Report outline an entirely new method for analyzing the consequences for aquatic resources, but the method is not implemented. We understand that the impacts to aquatic resources will not be analyzed or included in Phase 2 of the DRMS project. This is an unfortunate choice, because the IRP finds that the completely revised approach to modeling aquatic resources described in the revised TM and DRMS Phase I Report appears to be a good effort to address our first-review concerns about the aquatic resources analysis. In the absence of a systematic modeling approach, the IRP concludes that reliance on a purely qualitative (narrative) approach for assessing risks to aquatic resources, as will likely be used during the Phase 2 work, allows for too much subjectivity, is difficult to peer review, and can be too easily dismissed when contrasted with quantitative results from the other consequences components (e.g., dollars from the economics analysis). Given the important role played by these key fish species in water management and ecosystem restoration, and given that they were targeted specifically for analysis in the DRMS study effort, the omission significantly weakens the usefulness of the revised Phase 1 DRMS Report.

The IRP also notes a pattern of reduction in both the breadth and scope related to the ecosystem consequences as the DRMS project progresses: only limited results for vegetation and wildlife were included in the revised Phase 1 report, and as noted, analyses for aquatic resources were completely omitted. The minimal evaluation of ecosystem consequences restricts the usefulness of the DRMS Phase 1 analysis, and limits the scenarios that can be examined in Phase 2 to those that can be identified from the start as having known or very small aquatic ecosystems impacts.

F. Climate Change Projections

The projections of potential climate change consequences for the Delta used in the revised DRMS Phase I Report are based on the most appropriate scientific information available. The methods used to collect this information are clearly presented and well documented in the associated TM. There are no obvious missing data-sets or information, and no serious limitations on the data used to generate future climate change projections.

If anything, the analysis may be biased toward under-estimating the range and/or magnitude of the potential effects of climate change, for three reasons. First, the “low end” sea-level rise projection, based on extrapolation of historical trends in sea-level rise over the past century, would be higher if derived from the accelerated trends that have been observed in recent decades. Second, for stream-flow and flooding projections, only four scenarios were examined, which truncated the range of possible effects. This is particularly a concern when assessing the effects of a higher emissions future, where nearly all winter precipitation could be expected to fall as rain rather than snow before the end of the century, increasing early season flood risk. Finally, there are multiple mechanisms by which climate can affect a given system. Although sea-level rise and changing stream-flow patterns are the most directly quantifiable, other impacts on atmospheric circulation systems, such as storm frequency and intensity, could also be important. The DRMS Phase I Report accurately notes that climate change may also affect storm frequency and severity, and correctly concludes that it is difficult to develop quantitative projections of this effect. When this effect is eventually quantified, however, the potential impacts of climate change on the Delta are more likely than not to be even more pronounced than currently stated in the report.

G. Model Linkages

The DRMS has constructed an approach to assess the human safety, economic, and ecosystem risks by linking together a series of models that characterize the hazard (e.g., earthquakes and floods), the performance of the levees in response to the hazard (e.g., overtopping and/or breaching), and the consequences to people, property, and the ecology resulting from levee performance. We believe this approach is logical and consistent. However, we do have some concerns.

First, this coupling of models is challenging and difficult to substantiate, due to the following factors:

- There is an extremely large (theoretically infinite) number of possible earthquake and flooding events that need to be considered;
- The levees and islands should be considered as an inter-connected system rather than treated as individual components; and
- The consequences depend not only on how many islands are flooded in an event, but which specific islands are flooded and at what time of year the flood occurs.

How the component models are linked in the DRMS analysis raises concerns about the transparency of the modeling framework. It would be nearly impossible to replicate the DRMS analysis by reading the DRMS Phase 1 Report and TMs alone. Detailed suggestions to improve the clarity of the report are provided in Appendix 3, but these are not sufficient for complete transparency. Because of the complexity of the individual models that have been linked together, ultimately the analysis takes on a “black box” approach, making it difficult to discern directly which input, models, and assumptions are important in the overall outcomes.

For this reason, the IRP recommends that additional sensitivity analyses would be valuable to define the influence of key variables on results and generally increase the transparency of the analysis. Such sensitivity analyses would also help in formulating and then interpreting the upcoming Phase 2 analyses.

IV. ASSESSMENT OF DRMS PHASE 1 FINDINGS AND CONCLUSIONS

A. Risk to Human Life and Safety

The total life safety risk, considering all causes of island failures, corresponds to events with more than ten fatalities occurring once every 10 years, events with more than 100 fatalities occurring once every 50 years, and events with more than 300 fatalities occurring once every 1,500 years. A presentation and discussion of the total life safety risk, in addition to the risk associated with individual causes of island failures, would be a helpful addition to the revised DRMS Phase I Report. For events with fewer than about 300 fatalities, the total life safety risk is governed by hydrologic causes. This conclusion should be stated clearly in the report. The estimated frequencies for fatalities are higher than the historical record; there are no known fatalities from the 166 failures in the Delta that have occurred over the past century. Discussion of this historical context, including how the size of the population at risk today and in the future compares to the past, should be included in the report. Finally, it would be valuable to compare the total life safety risk for this levee system with other similar levee systems (e.g., the New Orleans Hurricane Protection System) and with similar facilities, such as dams.

B. Economic Results

The economic costs and impacts reported in Section 13 of the revised DRMS Phase I Report are based on generating events within the seismic, flood, and sunny day analyses (e.g., see Figures 13-21a and Figure 13-21b). We have three concerns and suggestions to improve the reader's understanding of these results. First, it would be helpful if the estimates were given some context relative to other economic measures of similar events reported in the literature. For example, how does the upper-bound estimate of $40 billion compare with the overall value of economic activity within the region; and how does it compare with losses sustained from previous earthquakes in California?

Second, while we accept that the general approach of using linked models is scientifically defensible, we believe that this communicates an inherent, upward bias to the resulting economic costs and impact curves. The upward bias results from the potential compounding of assumptions across the various linked models, as well as the assumption of "business as usual"

in the base case. Assumptions that err on the side of over-predicting effects may be reasonable for each model, but these assumptions are compounded as the output of one model is passed as input to the next model. At each step, the over-prediction gets amplified until it reaches the economics consequences. We do not feel, however, that this negates the utility of the economic consequences for use in policy decisions surrounding near-term consequences of levee failure (i.e., the base case results reported in Section 13).

Third, we have little trust in the economic consequences predicted for the future scenarios (years 2050, 2100, 2200), as reported in Section 14 and in the Executive Summary. While we understand that the DRMS authors were charged with performing such assessments, the magnitude of the uncertainty embedded in forecasting economic conditions beyond more than a few decades is too great to make these estimates useful for policy decisions.

C. Water Quality

Findings and conclusions regarding the effects of island failures on water quality reported in Section 13 of the revised DRMS Phase I Report and the Executive Summary are supported by the analyses. Most findings and conclusions about the WAM (Water Analysis Module) predictions of water quality effects are reported as they affect the economics. The accuracy of the statements about water quality is thus only as good as the economic calculations that use the WAM output as inputs. We also note that dissolved organic carbon and methylmercury are specifically discussed in the Executive Summary, but no actual analyses are provided in the narrative report or in a particular TM. Dissolved organic carbon and methylmercury are discussed in Section 11.7 of the revised DRMS Phase 1 Report entitled “Other Water Quality Impacts”, which states that they are not currently included in the WAM. Because only salinity is included in any comprehensive way, “water quality” should be defined very specifically, or the term should be replaced with “salinity” to better represent the actual analyses.

D. Ecosystems

The minimal ecosystem consequences reported in the revised DRMS Phase 1 report are reflected by the limited findings and conclusions presented in Section 13 and in the Executive Summary. No conclusions were reported for aquatic resources. The Executive Summary makes

the non-conclusive statement that “Levee failure and island flooding caused by earthquakes can have both adverse and beneficial impacts on the aquatic ecosystem.” The findings and conclusions for vegetation and wildlife accurately reflect the results of the analyses performed, but the scope of the analyses was extremely limited, and so the conclusions are too general for practical use. For example, the Executive Summary concludes that a multiple island failure could cause large losses of non-native vegetation and large losses of wildlife habitat, including several species of concern. Although we agree that these findings and conclusions concerning ecosystem consequences are accurate, they are accurate simply because the statements are very general. The IRP therefore concludes that the findings and conclusions about ecosystem consequences reported in the revised DRMS Phase1 Report fail to provide information useful for resource-allocation decisions and other related policy issues.

V. REVIEW OF THE DRMS EXECUTIVE SUMMARY

The executive summary is critically important, as it is the single document most likely to be read. For this reason the IRP conducted a detailed review of the executive summary (Appendix 5). The goal of the detailed comments presented in Appendix 5 are to ensure the summary accurately reflects the technical report; does not make any unsubstantiated statements; and is factual, precise, and accurate.

In general, the IRP feels that the executive summary approach is the right one. The summary is in the most part accurate (although we do caution against the use of language such as "can" and "will" that implies absolute certainty), and in general represents a major improvement over previous efforts. It is fairly concise, but could be made more so through eliminating repetitious text, and tightening up and increasing the precision of the language used. In light of the overwhelming importance of the executive summary, the IRP encourages the Department of Water Resources to seriously consider these comments and make the recommended changes to the executive summary.

VI. CONCLUSIONS

The IRP concludes that the revised DRMS Phase 1 report is acceptable for use in Phase 2 as a tool to inform policymakers and others about potential resource allocations and strategies to address risk in the Delta region.

In comparison to the initial draft of the DRMS Phase 1 Report, the current report is much improved. The DRMS authors should be commended for their efforts on the revised analyses and report. With the sole exception of ecosystem consequences, we find that the revised report adequately addresses both the Tier 1 and Tier 2 comments from the first IRP review.

This second IRP review, however, does highlight some major issues still outstanding. First is the reduced role of ecosystem consequences. The minimal vegetation and wildlife analyses and the complete lack of fish effects severely handicaps the ability of the DRMS analysis to estimate likely impacts on ecosystems. Second, because the final conclusions of the report rely on a series of linked models, caution is imperative when interpreting scenarios that deviate substantially from baseline conditions. Predictions of conditions far into the future are highly uncertain, and should be considered as indicators of effects, not precise predictions of future conditions. Finally, although the IRP found that most of the analyses were sound and the conceptual models used captured the likely risks to the Delta in the present and future, some questions still remained regarding the details of certain analyses.

These concerns must be considered by users of the DRMS model framework, as they exercise due diligence to ensure scientifically credible interpretations of the results to be obtained during the Phase 2 study effort and beyond.

Appendix 1: Charge to the Independent Review Panel
Review of the Delta Risk Management Strategy Report, Phase 1 (Draft 4)

The IRP will provide written reviews that focus on the strengths and weaknesses of the technical material in the DRMS Phase 1 and 2 Reports. The reviews will be conducted with consideration to the DRMS project scope of work, including the project timeline and budget, so that review comments will be reasonable, constructive and useful. Additionally, where appropriate, the IRP may recommend specific actions to enhance the value of the DRMS effort; these recommendations may fall within the existing scope of the DRMS project, or they may address areas beyond the original project scope that require additional effort.

The IRP will focus on the following subject areas and questions:

1. Information Gathering: Has the most appropriate scientific information been used in developing all technical areas? Are the methods of collecting information (existing or new) understandable, scientifically defensible, fully documented and the best available? What information (e.g. data, conceptual models, etc.) was not considered that should have been presented or addressed?
2. Information Analysis and Results: Have processes and methodologies (e.g. analyses of data) been used that are understandable, scientifically defensible, fully documented and appropriate? What results are missing that could reasonably be obtained? Are the modeling and risk analysis approaches employed defensible and consistent with other large scale projects elsewhere in the nation and internationally?
3. Findings and Conclusions: How well are the key findings and conclusions supported by the stated data, methodologies or conceptual models, and analysis results?

Appendix 2: Notes from fact-finding calls with the DRMS Authors
Review of the Delta Risk Management Strategy Report, Phase 1 (Draft 4)

The IRP held 4 conference calls with the DRMS authors prior to the September 4-5 panel meeting to obtain answers on outstanding questions on the following DRMS topics:

- Economics/valuation models.
- Aquatic resources modeling.
- Levee stability and seismic and flood forcing on levees.
- Transparency and organization of report

Notes were taken during the calls and distributed to the IRP and DRMS authors. Written responses were provided by the DRMS authors to the IRP when additional clarification was needed. The below notes summarize the IRP's impression of the more salient points.

1) Friday, August 22, 2pm (PDT): Economics/Valuation Models
Attendees: Richard Adams (IRP), Deb Niemeier (IRP), Ralph Svetich (DWR), Sean Bagheban (DWR), Richard Kranz (DWR), Said Salah-Mars (URS), Ram Kulkarni (URS), Marty McCann (JBA), Bill Betchart (JBA)

Richard Adams asked the DRMS authors to provide additional explanations and clarifications for estimating the economic costs charts shown in Section 13 given the economic data shown the tables of Section 12. The team agreed to provide a procedure explaining the process by no later then the end of next week. Said indicated that a good place to start would be from the charts of Section 13 showing the probability of island failures since those are clear to the IRP reviewers.

Rich also asked whether the authors have used scenarios in the calculations of the probability of islands flooding. Both Said and Marty indicated that in this round a full simulation of all possible sequences was used as opposed to the six scenarios evaluated in the previous draft. A discussion followed on the description of the sequences in the simulations, and how they were defined and evaluated. Deb Niemeier agreed that the memo explaining the steps leading to the economic charts of Section 13 will be helpful to clarify this particular point (sequences and simulation).

The resulting Action Items consisted of:

1) URS will prepare a memo explaining the implementation steps of the economic curves shown in Section 13. Explanation of how the Economic Exceedance curves in Section 13 were developed from the island failure probabilities and exceedance curves (Sections 4&12). Including a numeric example of the calculations.

2) Any additional specific comments or questions from Rich and Deb will be sent to our economists through Ladd and Sean at a later time.

The following appendix (Appendix A) was provided by the DRMS authors to the IRP to address action item 1 (above).

Appendix A

CALCULATION OF FREQUENCY OF EXCEEDING ECONOMIC CONSEQUENCES

This appendix illustrates the calculation of the frequency of exceeding different thresholds of economic costs and impacts. The exceedance frequency curves are shown in Figures 13-19a and 13-19b for seismic events and Figures 13-21a and 13-21b for hydrological (flood) events in the Risk Report.

An overview of the procedure to calculate the exceedance frequency is presented first. This is followed by a numerical example that shows a step-by-step derivation of the exceedance curves in Figure 13-21a.

Overview of Procedure

There are two basic inputs to the calculation of the frequency of exceeding different economic costs and impacts thresholds. These are the:

- frequency distribution on the number of flooded islands, and
- conditional probability distribution on the economic costs/impacts given the number of flooded islands.

Given the epistemic uncertainty in the frequency distribution on the number of flooded island, the frequency of exceeding economic costs (and impacts) also exhibits epistemic uncertainty and hence needs to be estimated at specified confidence levels. The frequency of exceeding economic costs at a specified confidence level was derived by combining the frequency of occurrence of island failures with the conditional probabilities of exceeding specified economic costs and impacts. The following equation was used:

$$f_P(C > c) = \sum_i f_P(n_i) \times p(C > c | n_i) \qquad \text{(A -1)}$$

in which

$f_P(C > c) =$ frequency of exceeding the cost, c at P% confidence,

$f_P(n_i) =$ frequency of flooding n_i islands at P% confidence, and

$p(C > c | n_i) =$ conditional probability of exceeding cost c given n_i islands are flooded.

The conditional probability, $p(C > c | n_i)$ was calculated by fitting a lognormal distribution to the cost distribution of simulated sequences of n_i flooded islands. (Note the sequences of different flooded islands (n_i) were obtained from the simulations of levee failure sequence as described in Section 4 in the Risk Report.) For example, consider a sequence of 10 flooded islands. Economic costs were calculated for a large number of simulated sequences of 10 flooded islands within the Delta (say there were k such combinations). A

lognormal distribution was fitted to the distribution of these *k* costs. This lognormal distribution, $p(C > c|n_i)$, was used in Equation A-1.

Numerical Example

The lower (16% confidence), median (50% confidence), and upper (84% confidence) estimates of the exceedance frequency for the total economic costs were shown in Figure 13-21a. A step-by-step derivation of these results is presented below.

Step1: Estimate the annual frequency of flooding different number of islands due to hydrological events.

Equation A-1 requires the frequency of flooding different number of islands at specified confidence levels. These frequencies were calculated by discretizing the frequency exceedance curves shown in Figure 13-10 in the Risk Report. This figure shows the annual frequency of exceeding different number of flooded islands due to hydrological events at 16%, 50%, and 84% confidence levels. The number of islands was divided into discrete intervals and the frequency of being in each interval was calculated as the difference in the exceedance frequency at the lower and upper values in the interval. Each interval was represented by its mid-point. Table A-1 shows the calculated annual frequencies of flooding different numbers of islands at the 16%, 50%, and 84% confidence levels.

Table A-1. Annual Frequency of Flooding Different Number of Islands due to Hydrological Events

# of Flooded Islands	Frequency at 16%%	Frequency at 50%	Frequency at 84%
1	0.0199	0.0297	0.0443
3	0.0361	0.0566	0.0888
5	0.0225	0.0372	0.0613
10	0.0173	0.0315	0.0574
20	0.0054	0.0119	0.0265
30	0.0032	0.0086	0.0234

Step 2: Generate simulated levee failure sequences and estimate costs of each sequence.

Levee failure sequences were simulated using the conditional levee failure probability (fragility curve) of each island under a given flood event. Each sequence identified the specific islands that are breached and therefore flooded. For each sequence, the economic

costs associated with the flooded islands was estimated using the models and data described in Section 12 of the Risk Report. The two main components of the cost are the In-Delta Costs and Statewide Costs. The sum of these two cost components is the Total Cost.

The main components of the In-Delta Costs are the levee emergency response and repair costs, infrastructure repair cost, lost use of structures and services, agricultural losses, losses due to the impact to oil and gas wells, loss due to the impact to wastewater facilities, agricultural losses, and the cost of lost recreation. These costs were estimated using the models/procedures described in Section 12 of the Risk Report.

The main components of Statewide Costs were losses due to the disruption to water supplies, lost use of statewide infrastructure, and agricultural losses outside the Delta due to water supply disruption. These costs were estimated using the models described in Section 12 of the Risk Report.

Table A-2 illustrates the estimation of various cost components and the total cost for one particular levee failure sequence. This sequence involved the flooding of 3 islands; namely, S-E Elk Grove (Zone 77), Brannan-Andrus Island, and Sherman Island. The total cost of this sequence was approximately equal to the median total cost among all simulated sequences involving the flooding of 3 islands. Table A-2 shows the main components of the In-Delta Cost and Statewide Cost. Note, in this case the infrastructure repair cost for Brannan-Andrus Island in Table A-2 is $ 91.7 million, which matches the repair cost shown in Table 12-7 in the Risk Report.

Table A-2. Main Cost Components for a Levee Failure Sequence Involving Flooding of 3 Islands

Island/Analysis Zone Flooded	Emergency Response & Repair Cost	Inundation Infrastructure Repair Cost	Lost Use of Structures & Services	Flooded Island Agricultural Loss	Loss due to Impact to Oil & Gas Wells and Wastewater Facilities	Total Flooded Island Cost	Cost of Lost Recreation in the Delta	Total In-Delta Cost	Lost Use of Staewide Highways	Total Statewide Cost	Total Cost for the Failure Sequence
S-E Elk Grove (Zone 77)	23.8	2.0	0.2	0.0	0.0	26.1					
Brannan-Andrus Island	165.2	91.7	75.6	27.2	5.4	365.1					
Sherman Island	125.8	16.4	3.0	8.3	0.2	153.6	27.1	571.8	149	149	720.8

Note: All costs are in millions of dollars.

Step 3. Fit a lognormal distribution to the total cost for each given number of flooded islands.

For each levee failure sequence, the In-Delta Cost, Statewide Cost, and Total Cost were estimated. The sequences were ranked from the lowest to highest total cost for each discrete number of flooded islands shown in Table A-1. A lognormal distribution was fit to the set of the total costs for each given number of flooded islands. Table A-3 shows the median and the logarithmic standard deviation of the total cost for each given number of flooded islands.

Table A-3. Parameters of Lognormal Cost Distribution for a Given Number of Flooded Islands

# of Flooded Islands	Median Total Cost ($ Million)	Logarithmic Standard Deviation
1	123.0	0.66
3	710.6	0.66
5	1,606.3	0.66
10	4,858.1	0.66
20	14,692.7	0.66
30	28,070.9	0.66

Step 4. Calculate the conditional probabilities of exceeding different cost thresholds for each given number of flooded islands.

For each number of flooded islands, the conditional probabilities of exceeding different cost thresholds were calculated for each number of flooded islands using the associated lognormal cost distribution. Table A-4 shows the probabilities of exceeding different cost thresholds for the number of flooded islands considered.

Table A-4. Probabilities of Exceeding Different Cost Thresholds for a Given Number of Flooded Islands				
Number of Flooded Islands	**$ 1 Billion**	**$ 10 Billion**	**$ 50 Billion**	**$ 100 Billion**
1	7.77E-04	1.56E-11	0.00E+00	0.00E+00
3	3.03E-01	3.27E-05	6.69E-11	4.03E-14
5	7.63E-01	2.88E-03	1.04E-07	2.22E-10
10	9.91E-01	1.38E-01	2.16E-04	2.48E-06
20	1.00E+00	7.19E-01	3.22E-02	1.89E-03
30	1.00E+00	9.40E-01	1.92E-01	2.75E-02

Step 5. Apply Equation A-1 to calculate the annual frequencies of exceeding different cost thresholds at specified confidence.

Results shown in Table A-1 and A-4 were combined using Equation A-1 to obtain the annual frequencies of exceeding different cost thresholds at the 16%, 50%, and 84% confidence levels. Table A-5 summarizes the results. Note, the results match those shown in Figure 13-21a.

Table A-5. Annual Frequencies of Exceeding Different Cost Thresholds							
				Conditional Probabilities of Exceeding Cost Thresholds			
# of Flooded Islands	**Frequency at 16%%**	**Frequency at 50%**	**Frequency at 84%**	**$ 1 Billion**	**$ 10 Billion**	**$ 50 Billion**	**$ 100 Billion**
1	0.0199	0.0297	0.0443	7.77E-04	1.56E-11	0.00E+00	0.00E+00
3	0.0361	0.0566	0.0888	3.03E-01	3.27E-05	6.69E-11	4.03E-14
5	0.0225	0.0372	0.0613	7.63E-01	2.88E-03	1.04E-07	2.22E-10
10	0.0173	0.0315	0.0574	9.91E-01	1.38E-01	2.16E-04	2.48E-06
20	0.0054	0.0119	0.0265	1.00E+00	7.19E-01	3.22E-02	1.89E-03
30	0.0032	0.0086	0.0234	1.00E+00	9.40E-01	1.92E-01	2.75E-02
				Annual Frequencies of Exceeding Cost Thresholds			
				$ 1 Billion	**$ 10 Billion**	**$ 50 Billion**	**$ 100 Billion**
			16% Confidence	5.38E-02	9.28E-03	7.83E-04	9.73E-05
			50% Confidence	9.73E-02	2.11E-02	2.04E-03	2.59E-04
			84% Confidence	1.80E-01	4.92E-02	5.35E-03	6.94E-04

Upon receiving Appendix A, the IRP had 7 follow-up questions to which the DRMS authors responded. These questions and answers are as follows:

Question 1. When the monte carlo simulations were conducted for events - were all events within an event type equally likely? Or were events within an event type generated with certain probabilities? For example, the authors state that flood events were simulated between 289k cfs and 2m cfs. First, was any flood event within the range equally likely? That is, was 500k cfs and 505k cfs flood (or, for example, a 500k and a 1m) equally likely to be used in generating the sequence of islands that failed? Or were the flood events discretized into combinations of water levels and then simulations occurred? If the latter, what was the prob distribution used to select floods to then run the sequences from?
Answer: The simulated events are not equally likely. The event probabilities are determined by the probabilistic model that was developed to estimate their likelihood of occurrence. The model for flood events is described in Section 7 of the risk report and the Flood Hazard technical memorandum.

Question 2. PG 13-4: Does each seismic event correspond to a seismic source when you run the Monte Carlo simulation? That is, for a given seismic event sequence from Monte Carlo, will the event correspond to one of the sources listed on Fig 13-3?
Answer: In estimating the frequency distribution on the number of flooded islands, all seismic sources are considered in the simulation.

Question 3. When the flood failure sequences were generated for the simultaneous flooding, did each island have equal chance of flooding? Or were different sets of islands assigned different probabilities.
Answer: The straightforward answer is the islands do not have an equal chance of flooding. For a given flood event, the chance of levees failing is defined by the levee fragility curves. The fragility curves define the conditional probability of failure as a function of water-surface elevation and they vary from 0.0 to 1.0 as water levels increase. The fragility of levees vary, depending on their characteristics and the levee crest elevation.

Question 4. When the MC simulation was run, were all possible permutations generated, or was it a very large sample? If it was a sample (i.e., not all permutations were performed), then did you resample with replacement or not?
Answer: All permutations are not generated, the number of permutations is too large. This is why we did simulations. The simulations are performed with replacement.

Question 5. For the flooding, the text seems to imply but not directly state that MC sequences were generated separately for MHHW and 100y - is this a correct interpretation?
Answer: Simulations were performed for seismic events and separate simulations were performed for flood events. The simulations for seismic events were performed assuming water-surface elevations were at the MHHW. Simulations for flood events were performed for a wide range of flood levels, as described above.

Question 6. When the sequences were generated using MC, were they generated by the bins (i.e., all the possible permutations of 3, then, 4, then 5 ... island failures) or were they generated where any number of islands could fail on any given sequence simulation?
Answer: The simulations were done for the 3, then for the 4, then for 5 etc.., separately.

Question 7. Does the process of calculating flood damages using the 100 year flood as the benchmark introduce an upward bias?
Answer: Estimating all flooding damages, initiated by flood events, likely introduces an upward bias.

2) Wednesday, August 27, 8 am (PDT) - Aquatic Resources Modeling
Confirmed Attendees: Ladd Lougee (CALFED), Terry Roscoe (CDFG), Kenny Rose (IRP), Richard Adams (IRP), Dave Mraz (DWR), Ralph Svetich (DWR), Richard Kranz (DWR), Jon Rosenfeld (Aquatic Restoration Consulting), Said Salah-Mars (URS)

The important information revealed by the call was that the DRMS team does not plan on actually doing the aquatics (fish) impacts analysis that is described in the report and the in the TM. It is not exactly clear the reason(s) but they seem to be related to scheduling problems with the outside set of 4 experts, coupled with DRMS people not wanting to proceed without the input of these outside experts, and perhaps budget issues with DWR. It is very disappointing because the proposed method is much clearer, simpler and is the right way to go than that proposed in the initial Phase 1 draft.

Conference call questions by the IRP and answers by the DRMS authors:
Question 1. When will the aquatic analysis be completed? Is it too late for the IRP to get suggestions incorporated, given the report says the aquatic analysis has not been completed yet.
Answer: Ralph explained that the process of convening the experts for the elicitation was very lengthy and time consuming to the point where it was not possible to meet the schedule of completing the phase 1 work. DWR instructed the DRMS authors to document the work done to date in the phase 1 report, and explain what was not done because of the inability of getting the experts together to participate in completing and testing the model that was developed as part of this process.
Said indicated that 2/3 of the work was done. 1) data collection, interpretation and 2) the development of the various pieces of the model with their uncertainties such as: fish entrainment, breach induced sediment modeling (temporal and special) into the breached islands, export interruption, loss/creation of habitat as a result of island flooding, island pump-out, etc.
Said also indicated the vegetation and terrestrial species models are complete and followed the same procedures outlined in the previous version of the risk report that the IRP reviewed.

Question 2: What will be included in phase 2 as far of the risk reduction on aquatic species?
Said indicated that the answer on the fish impacts and benefits in phase 2 will be qualitative since the phase 1 impacts results will not be available.

Dave indicated that there is a chance to complete the aquatic species impact analysis possibly through other programs (Delta Vision, BDCP, DRIRIP, etc.).

Question 3: How will the different survey data be combined to get a single, consistently-estimated, set of fish density estimates by time and spatial box? Is gear selectivity being taken into account?
Jon indicated that the various datasets provided by the experts were used to develop spatial and temporal fish population distributions throughout the Delta. The approach was based on estimating the percent mortality and hence the population numbers become less sensitive in the analyses. When data were incomplete and inconsistent, an averaging process was used.

Question 4. I will have to read the benefits of reduced pumping several more times. I can see the work of Kimmerer. I did not understand his paper that is the basis of this approach being used and it follows that I have trouble understanding this condensed version of the results of his paper. I also want to know about the expansion factors used to go from salvage and 20-mm data to numbers. But I expect the answer to these is to ask Wim. That is OK if that is the response.
Jon confirmed that this was based on Wim's paper.

Question 5. What data will be used to estimate the baseline Dennis model? Specifically, the characteristics of the time series used to estimate mean and variance parameters. Which time series, how long it is, what historical time period, etc? As you know, fish population abundances are far from in quasi-equilibrium (i.e., not stationary) in the system. How is this being accommodated in the parameter estimation of the Dennis model? Are you just going to use Bennett's estimates?
The model was to update the Bennett model and update mean and uncertainties and the slope of the mean curves based on the impact model results. He considered the Delta Smelt was the only specie covered in Bill Bennett analysis.

Question 6. How about the species besides delta smelt and salmon? You list other species but will you do the analysis on these other species?
We kept the model generalized enough so that we can accommodate the impact analysis to other species given the population statistics.

Disclosure by K. Rose (IRP): You should know that Kimmerer and Bennett and I work closely together on a CALFED-funded delta smelt population modeling project. So I know something about the datasets, and am familiar with many of the analyses by Kimmerer and Bennett; more than you might expect for someone from Louisiana.

3) Thursday, August 28th, 8:00 am (PDT) - Levee Stability and Seismic and Flood Forcing on Levees.
Attendees: Johnnie Moore, Bob Gilbert, Bill Marcuson, Ladd Lougee, Roy Shlemon, Said Salah-Mars, Marty McCann, Richard Kranz, Sean Baghebon and Ralph Svetich.

The IRP asked questions, most of which were given to the DRMS authors in

advance of the conference call. The major take home points by the IRP are encompassed in the following three bullets with details on the questions and answers following those.

Conference call take-home points.

- Concerning seismic risk ---- Their analysis indicates that the risk in the last 50 years should be similar to the risk in the next 50 years, yet their conclusion is that the levee failure rate will be an order of magnitude higher than historic failure rates. The IRP members believe the risk of levee failure from earthquakes is over-stated.

- Concerning permeability --- They have little field data and have relied on lab data to get horizontal permeability (Kh) and modeling and judgment to get Kh/Kv ratios. I think the results lead to unconservative conclusions regarding levee failure by under seepage. That is, more seepage is likely to actually occur than predicted. A key point here is that unlike levee failure by earthquake induced liquefaction, levee failure by under seepage is not sudden and usually gives a preview to the trained eye.

- Regarding failure by levee overtopping they have assumed in their analysis that time is a constant. They have done little analysis but relied on expert elicitation or engineering judgment for this mode of levee failure.

The following is the list of detailed IRP questions and a summary of the DRMS authors response.

1) Floods and overtopping -- How did they include the function of time that overtopping occurs in their analysis? To clarify, is not the probability of failure due to overtopping a also function of how long the water level is at elevation "x" above the crest. For example, if the water were 2' above the crest for 1 hr the levee might fail. Also if the water were 1' above the crest for 4 hours, the levee might fail with a similar probability. How was the time function considered?
Answer --- Time was not considered in this analysis.

2) You say --- "When expert elicitation is used, we will provide a detailed description ---- ." I believe expert elicitation was used for levee failure by overtopping (see Page 7 – 26 of your draft). Is this the case? If so, why was it is not mentioned.
Answer ---- Yes and we will add this.

3) With regard to levee under-seepage -- the issue concerns permeability values used for the peat and anisotropy of the peat permeability; that is, a) why did you ignore the field pumping test data to obtain horizontal permeability (see tables 7 - 12 and 7 - 13); and b) I assume you relied on the field pumping test data to get the vertical permeability to be 0.01 the of the horizontal permeability? (see page 7 - 20, Section 7.7.4.5, at the end

of the discussion of Grand Island of your draft). Near the bottom of this section you say that an anisotropy of the permeability of the peat will be 100 from now on. I'm ok with this; however, this leads to a vertical permeability of 1 x 10 to the minus - 7 cm/s for peat. I think this is too low. A permeability for the peat should be based primarily on your field pumping test data. I my opinion the result of one field pumping test is worth the results of several 10's of lab tests. See your tables 7-12 and 7-13.
Answer ---- Table 7 - 12 covers the permeability of sands and silts not peat. Table 7 - 11 covers permeability of the peats. These data are all lab test data but they are all the data we have. Yes we used expert elicitation and modeling to get the permeability anisotropy of 100 which we used. We worked closely with Ross Boulanger at U. C. Davis to get our peat properties. The DRMS team believes that the liquefaction potential of loose sand under the peat is independent of the overlying peat permeability. This is the case in their report because they use an empirical approach which relies on index parameters (such as, normalized SPT blow counts) and field data. Peat or sand permeability values are not parameters used in their approach/analysis.

4) Do you have data or calculations that show --- "The effects of the levee geometry on under seepage "is" ---- this word should be "are" ---- mostly controlled by levee crest elevation."? What about change in side slope? This will control the horizontal distance the water must travel between the slopes and under the toes. Is this not a significant parameter?
Answer ---- We held the land-side side slope constant but we evaluated 2 water-side side slopes. For the water-side slope of levees we evaluated both 1v/2.5h and 1v/1.5h.

5) With regard to the risk analysis in general, the issue is an absence of a sensitivity analysis. For example, they could hold all variables constant but one and let that one parameter vary and range from a high value to a low value and in this way show how sensitive your results are to variation of that one parameter. You could repeat this process for other significant variables.
Answer ---- The DRMS team indicated that they have run additional sensitivity studies and they promised to provide these to the IRP. These studies include one where time-dependent (that is Poisson) earthquake frequencies were used and one where island levees were modeled with a single reach instead of multiple reaches.

6) With regard to seismicity, the issue is the predicted failure with relatively small peak ground accelerations for fairly frequent earthquakes. See your Figure 6 - 10 then go to the top left hand corner. Is this realistic given we have good earthquake data for the last 30 or 40 years?
Answer --- Much discussion took place with little resolution. The IRP believes the seismic risk is over stated. Marty believes the concept of uniform risk is not well understood. We all agree on this!!! DRMS authors pointed to Figure 13 - 8 of their report showing historic earthquakes grouped between Mag 5 - 5.9; between Mag 6 and 6.5; and greater than Mag 6.5. Bob asked if they could simply run the analysis with and without energy build-up on the faults. They have done this and it shows a few percent difference in the Delta. Bob suggests this makes the case that the next 50 years might resemble the last 50 years according to their model. Their results do not show this but show that island

failures due to earthquakes will be at least 10 times more frequent in the next 50 years. The DRMS team considered the historic record since 1838 including six earthquakes of Mag 6.5 or greater. That is, they decided to use the entire earthquake record. They are concerned about the public communication issues but they think their analysis is correct. We think they understand our concerns and we understand their position. This said, we still don't understand how they use the long time interval for major seismic activity in this region to explain the results of their model (high chance of island failure due to seismic events) --- given that, their model produces the same results whether you predict what will happen in 1907 or 2007.

The DRMS team will discuss this more at our meeting in Sacramento.

7) Please refer to Chapter 14, page 14 - 30 your Section 14.3.3.6 on Potential Loss of Life. The paragraph that follows and the only paragraph in this section says absolutely nothing about this topic. Why not just delete this section or add some "meat" in it?
Answer ---- We agree and will delete.

8) Regarding levee vulnerability classes (see your figure 6-37a) – can they be consolidated (assuming we are okay with answers to the questions above) and better identified on the figure because this will likely be one of your most used figure in the report?
Answer --- All 24 vulnerability classes (VC) were evaluated. Each VC was analyzed separately and its response evaluated. For purposes of discussion they grouped the VC's into 2 broad groups; A VC's that would liquefy, and B VC's that would not liquefy. We asked if they could create an additional figure to better explain their conclusions. They are to expand their discussion and develop another figure.

Roy asked some general questions regarding ----
a) Do you have knowledge of Dick Meehan's blog?
Answer --- Yes.
B) Does DWR have a current drilling and sampling program in the Delta that is geared to understanding engineering properties of the subsurface, is DWR taking continuous cores and to what depth are you drilling.
Answer ---- Yes. DWR has a field investigation in the central valley. I do not have the details about how far it extends into the Delta but we'll find out and get back with you.
C) Are the DRMS authors familiar with the on-going studies and publications of the following; and have you incorporated these into your assessments:

1. Judith Drexler at the USGS in the Sacramento office?
2. Ken Verosub a Professor of Geology at UC at Davis?

Answer ---- We will ask our geomorphology and subsidence teams to verify this. From a geotechnical standpoint, we have worked with Ross Boulanger at U. C. Davis.

4) Thursday, August 28th, 9:30 am (PDT): Transparency and Organization of Report

Attendees: Ladd Lougee, Katharine Hayhoe, Johnnie Moore, Sean Bagheban, Ralph Svetich, Dave Mraz, Said Salah-Mars, Marty McCann, Ram Kulkarni

Katharine and Johnnie provided a set of specific suggestions aimed at increasing the consistency, coherence, and communicative power of the report. These consisted of: a good executive summary that draws directly from the conclusions made by each chapter; a set of summary points at the beginning of each chapter that serve as the basis for a conclusions chapter and the summary report; and improvements to the existing conclusions chapter so that the reader can easily understand the conclusions and findings of the report. They emphasized that no one will read the whole report, therefore it is essential that each chapter be cross-referenced (which would also help to reduce the length of the document by eliminating redundancies) and have its own summary.

Specific IRP Comments/Suggestions

- The scientific basis of the DRMS report has the potential to be a very useful product. However, the communication of the main results, findings, and conclusions can be improved.
- Include at the beginning of each chapter a summary of its purpose, methods of analysis, and main findings.
- Include at the end (or the beginning?) of each chapter a concise list of main conclusions.
- Prepare a summary report for the use of policy makers/ executives (DWR is preparing such a report and its draft will be sent to IRP next week).
- Check the entire report for consistency between different chapters and provide cross references to other chapters where relevant. Where such cross referencing is provided, shorten the current text and eliminate repetitive text, where feasible.
- These suggestions are meant to help DWR make their report as useful as possible by clearly presenting information. It is up to DWR to decide what to do with these suggestions.

Discussion

- DWR believes that the Executive Summary it is preparing should provide a good summary of the entire DRMS study, including main conclusions/ findings. DWR stated that they appreciated the comments, and have been talking about this issue for over a year. They understand the executive summary is key. This summary is specifically aimed at policy makers and executives. A draft will be sent to IRP next week.
- Said noted that Chapter 13 is a summary chapter that brings together the analysis and results from all other chapters for the current risks in the Delta. Similarly, he stated that Chapter 14 is a summary report for future risks. The IRP understands what these chapters are supposed to do but they feel the information could be presented in a manner that is easier to find and understand.

- Additional raw data/ detailed GIS data files etc. that are not included in the technical report will be maintained by DWR and will be available to the public.
- DWR will take the IRP suggestions/comments under consideration in light of time and other constraints.

Appendix 3: Editorial Comments
Review of the Delta Risk Management Strategy Report, Phase 1 (Draft 4)

During the review process, some IRP members made detailed editorial comments on the draft. These individual comments, which identified inconsistencies, errors, organization problems, repetitions, and omissions, were collated by CALFED Science Program staff and are provided below.

General Comments

Each section from 6 to 14 is in great need of a bolded summary up front that gives the reader the bottom line from the chapter. What are the main methods and findings in each area?

Section 1

This is a fairly clear explanation of what, who, and why. No major modifications needed.

A definition of risk would be useful in Section One.

Section 1.2 Last paragraph, last sentence: Please eliminate the "etc," which suggests that only selected management practices are being considered. [this is not a significant point, but one that needs to be addressed throughout the revised report].

1.2.2 Human safety should be added to the list of consequences.

1.2.2, 1.2.3, 1.2.4 Suggest that these introductory statements about report content specifically refer to the supporting reference; e.g., "see, for example, Chapters x and y." Such editorial notation will direct the interested reader to the specific chapter of interest, rather than requiring continual reference to the Table of Contents.

1.3.1 Recommend first spelling out the name of the agency, then immediately (in parentheses) provide the acronym; e.g., DWR. . .).

1.3.2 The topic sentence needs editorial revision. "Steering Committee members are policy advisors *who* [rather than "that"]. . . "

The word "Delta" appears three times in the same sentence. Please rewrite.

1.3.4 Third sentence: Suggest use of present tense: "The IRP *is* [rather than "was"] composed. . ."

1.3.5 Paragraph on PSHRP: Suggest referring to appendix or other technical document that provides the specific names of USGS and CGS "representatives" who provided the

PSHA comments. Presumably these names are provided in the PSHRP Technical Memorandum?

Page 1 – 8 I would prefer W. F. Marcuson III to Bill Marcuson and my affiliation is with W. F. Marcuson III and Associates not ASCE.

1.3.6 End of first paragraph: Now that Phase I work is still continuing, how about providing a new, estimated completion date?

Page 1 – 9 C. Allin Cornell is deceased. I suggest they add deceased behind his name. The same comment applies to Figure 1 - 3.

1.3.8 Topic sentence: Suggest rewrite to avoid using word "team" twice.

1.5 "Section 2 proves a general overview of the Delta and Suisun Marsh. It is based. . ." This suggested rewrite eliminates an unintended, but slight demeaning tone to the existing topic sentence.

Fig. 1-1 Please eliminate all the "etc" in the lowermost row of boxes. As is, the reader must guess what is included.

Section 2

The historical facts are good. Sea level rise is accurately reflected from climate change TM. Section 2.6 (summary of previous studies) seems out of place within Section 2.

2.1 The introductory descriptive sentences really need editing to reduce redundancy. An example for improvement is the topic sentence, which can be shortened to: "The Sacramento-San Joaquin Delta. . . basins, which drain about 40 percent of California."

Please rewrite the second sentence to eliminate three of the four "deltas" contained therein.

2.2 Technical memoranda say that late Pleistocene sea levels were ~350 ft below present, not the numbers given in the topic sentence. Probably not a significant issue, but is an example of inconsistency between some TM's and summary in Introductory sections.

2.4 Key observations: Changes in agriculture management . . . may [increase] Delta elevations. Is this true? Island elevations might rise? Not obviously apparent as to why. Please explain this, perhaps by citing an appropriate TM.

2.6 This section is a valuable addition to the report; it helps to provide context for this study and its results.

2.6.2 Suggest "about 40 percent" instead of "about 39.5 percent."

Section 3
The focus on sea level rise in this discussion is on the lower IPCC range rather than the more accurate range presented in the Climate Change TM. This should be remedied. Also section 3.6 does not appear to have been revised in response to our earlier comments.

Introduction: Suggest including some discussion about expressing risk as the expected consequence of failure, which includes the possible consequences and their respective probabilities. It would help for context here and when the results are presented to discuss the expected consequences since they are useful for decision making and relatively easy to understand for the general public.

Page 3 – 3 Under the Section entitled " Global Climate Change and Sea Level Rise " --- In the last sentence "seal" should be "sea".

3.4 Delta Improvements: Please update "2006" information in this section (page 3.5).

3.7 Suggest using "assessing" instead of estimating since risk (specifically probability) cannot be measured.

Section 4
This section is a valuable addition to the report in explaining how the analysis was conducted.

Section 4.0 (introduction): Please rewrite topic sentence to eliminate two of the three "risk" terms.

4.1.1 Last sentence: Please rewrite to eliminate the "fuzzy" and rather nebulous expression of "the environment and those who live and work there, *(etc.), include but are not limited to*: [really now, this is legal verbiage and has no place in, ostensibly, a technical document].

Meteor strikes: What is the probability of meteor strike causing a catastrophic failure in the Delta? Is it really worth listing?

4.2 Hazard Analysis, First paragraph: Suggest moving the last sentence to the first sentence of the paragraph.

4.3.1 First paragraph: Probability and frequency are used interchangeably here – suggest being careful to distinguish between these terms and to be clear and consistent in how they are used.

Equations 4-1 and 4-2 These are not equations – again, here it would help to start with the expected consequence of failure to show how consequence, frequency and probability are included in assessing risk. A simple illustrative example would be very helpful.

4.3.3 Fourth paragraph: Define “these issues” in the first sentence.

Equation 4-4 Suggest stating explicitly that this equation assumes that the occurrences of different hazards are statistically independent.

4.4.3 Fourth paragraph: Uncertainty in an estimated frequency from a historic record is typically modeled with a gamma distribution (assuming that the frequency is a Poisson process) – suggest explaining why a lognormal distribution was used.

Equation 4-9 Please indicate the subscript that is being summed. Also, the conditional symbol should be a vertical line, not a slanted line.

Page 4 – 19 Two sentences before equation 4 - 12 Is there a difference between levee failure and levee breach? If so, please explain the difference. If not, reword and delete one. They are the same to me.

Equations 4-11 and 4-12 The notation here is difficult to follow: suggest including parenthesis to make it clear which terms are included in each summation. Also, the result is a “frequency of failure” but the summation is of a probability of failure – please be consistent.

Equation 4-13 How is P(R1 intersect R2|ground motion) calculated?

4.4.7 Human safety consequences should be included here.

Page 4 – 23 Third line from the bottom mitigate should be mitigated.

Figure 4 – 4 The numbers on the vertical axis are too small and hard to read.

Section 5

Section 5 seems strangely out of place. There is a lot of overlap with Section 2. Strongly recommend the two be combined and placed up front.

Figure 5 – 6 Is the Mokelumne Aqueduct shown on this figure?? I can not find it.

Section 6

Introductory paragraphs: Please be consistent in use of adjectives to describe relative magnitude of earthquakes. For example, last sentence in first paragraph refers to a “severe” earthquake; then first sentence of next paragraph says “large” earthquakes. Check this throughout the section.

6.1.1 First bullet item, top of page 6.2: Presumably all seismic sources that *could* [reasonably or expected to] impact the Delta.

6.1.3 Last paragraph on page 6-3: “date of last rupture, *recent* seismicity rates. . . Does “recent” refer to historic, instrumental? Please clarify.

Page 6 – 19 Top of the Page I find no North arrow on Figures 6.61, 6.62, 6.63 so I do not know which way is south. Also is the deformation discussed in this paragraph horizontal or vertical.

Page 6 – 20 Table at the top of the page under Observations "pots" should be "post".

Page 6 – 21 The "water level in the slough and rivers" paragraph last word "deterministic" should be "deterministically" ---- same comment top of page 6 - 22.

Page 6 – 25 The 5th bullet under step 4 is not a bulleted item delete the bullet.

6.2.6.1, second paragraph: Where is the boundary between the stiff and dense deposits and the more recent alluvial deposits generally located?

Figure 6-58 Were drained conditions assumed for the peat? What is the relevance of phi and c (versus phi’ and c’) in the table?

6.2.6.7 The addition of this section is very helpful. It would be very helpful to analyze how the existing levee system would have responded to all of the relevant historical earthquakes back to 1850.

Page 6 – 27 Top of the page: I think Section 6.2.6 should be Section 6.2.7.

Section 6.2.7, 4th line from the top: "knows" should be "known".

Figures 65 thru 68 It would help to show the water surface on the up-stream sides.

Figure 6 – 69 In your title somewhere it would be helpful to tell the reader where the time history is located --- say under the center-line of the levee.

Figure 6 – 87 Please specify the displacement units (ft or m).

Figure 6 – 131 Are the displacements horizontal or vertical??

Sections 7-9. None of these chapters provide more than a very brief, cursory mention of how climate change is expected to affect flood, wind/wave, and sunny day risk, and some not even that. Only section 9 gives any kind of bottom line or summary.

Page 7 – 5, 3rd paragraph that starts with "Daily average flows ----. I suggest that you delete the word "that" between "and" and "most" in the 1st sentence.

Section 7.6 Last paragraph 1st sentence: The word "again" should be "against".

Section 7.7 First paragraph 3rd sentence: The word "variable" should be plural.

Page 7 – 10 Paragraph Aquifer Thickness: I can not see what you are discussing in the figure you site. I think you have the wrong figure numbers.

Page 7 – 11 Paragraph Drainage Ditches 5 lines from the bottom: "ffot" should be "foot".

Page 7 – 12 Paragraph Levee Geometry: Do you have data or calculations that show --- "The effects of the levee geometry on under seepage "is" ---- this word should be "are" --- mostly controlled by levee crest elevation."? What about change in side slope?? This will control the horizontal distance the water must travel. Is this not significant?

Page 7 - 19 Paragraph that starts "Table 7 - 14 and Figure 7 - 40 ----"the last sentence --- I like it !!! Could you not make a similar recommendation regarding either filling the ditches in with soil or moving the ditches away from the levee toes.

Page 7-19 First paragraph: The words “increase” and “decrease” need to be interchanged (the sentence says the opposite of what is in the Table and Figure).

Page 7 – 20 Section under Grand Island 3rd paragraph -- 3 sentences from the end -- The word "start" should be "starts".

Page 7 – 24 Second paragraph, 1st line: The word "a" should be "as".

Page 7 - 25 Section 7.8 The 1st word should be "Calculations".

Page 7 - 26 Section 7.9 Some explanation of how Figure 7 – 75 was developed is required.

Page 7 – 28 Equations (1) and (2): Please put a subscript to indicate which variable (i, j or k) is being summed. Also, it would help if the conditional probabilities were expressed using the conventional notation with a vertical line instead of subscripts. As discussed in our review for the first draft of the DRMS report, the basis for this approach is not strong. It essentially gives that the probability of at least one reach failing is a weighted average of the probability values for individual reaches. While this overall result is reasonable, particularly since it can be calibrated with all of the historical failure frequencies, the methodology to get to this result is not sound. For example, if the conditional

probabilities of two individual reaches failing in a particular flood event are 1 and 0.9, respectively, the total probability that at least one reach fails is 0.95 because there is only a 53 percent chance that the first reach (with a probability of failure of 1 for the flood event) is the weakest link. How can the probability that it is the weakest link be less than 1 if the reach is certain to fail in the flood event? I would prefer to see this approach developed by explicitly considering correlations between individual reach failures. However, the final results would likely not change even if a different approach were used.

Page 7 – 29 Equation (4): The paragraph following this equation is extremely confusing because it includes both what you wanted to do and what you actually did. I think it would help to just state how it was done.

Section 7.9 In the 2nd paragraph under this section 1st line the word "erode" should be "erodes".

Figure 7.2 The figure is too small to be meaningful and/or useful.

Figure 7 - 24 a and b should be Figure 7 - 25 a and b.

Section 12

On page 12-32, the authors introduce the term "consumer surplus" in explaining how they measured lost recreation values. This term will not be familiar to the average reader. I suggest they either 1) define the term or 2) simply say that the economic values (costs) they assign to lost recreational opportunities are borrowed from the economic literature. The latter approach seems simplest and is consistent with what the economic group did to get the cost numbers.

Section 13

Overall, this section is vastly improved from the first draft. Four suggestions in finalizing it:

1. It would be very helpful to calculate and discuss the expected consequences of failure, and also to discuss these results by providing some contextual information for comparison (such as other levee systems, dams, other impacts due to earthquakes, etc.).
2. The frequency for fatalities due to flood events seems high (Figure 13-22 in the DRMS report) based on the historical record. Specifically, frequency of having an event with at least 10 fatalities is estimated to be greater than once every ten years. In contrast, we are not aware of any flood events with fatalities that have occurred in the past 100 years in the Delta (our understanding is that the examples of fatalities due to flooding given in the report are not events that occurred in the Delta itself). Additional discussion and explanation of the estimated risk in the context of the historical performance is warranted here.
3. Due to the complexity of the components and the overall linked models that are used to assess the risk, additional sensitivity studies are warranted to

inform the user of these results about what is driving the risk. For example, if all of the Vulnerability Class 1 and 2 levees are removed from the analysis, what happens to the seismic risk?

Page 13 – 8 I find no figure 13 - 13a in my copy.

Section 14

Table 14-12 is a highly satisfactory response to our initial comments regarding the need to clearly assess the uncertainty involved in these estimates. However, the conclusions on p. 14-17 are unclear and downright confusing.

page 14 - 30 Section 14.3.3.6 Potential Loss of Life The paragraph that follows and the only paragraph in this Section says absolutely nothing about this topic.

Section 15

Vastly improved from previous draft.

Section 16

References (Section 16): Several incorrect or incomplete citations impact reader perception of quality control. This is particularly important should this document be treated as a "baseline reference." There are many problems here; and only a few representatives ones are specifically noted; e.g.:

Adam, P., 1990: Typically a complete reference includes the number of pages in the document; not so indicated here and for many others too.

Alameda Zone 7, 2005: Please provide a more complete reference so that an interested reader can find the original. If this document be on a web site, so indicate as such.

Atwater, B. F., 1982: Usually number of maps and scale are also given. See, for example, the citation for Jennings, C. W., 1994.

Baecher, G. B., and J. Christian, 2003: Publisher location (e.g., New York), and number of pages in book?

Gregor et al., 2007: (What is this? Incomplete citation?)

Grimaldo, L, 2000: Incomplete citation; needs volume and page numbers; see, for example, following Grimaldo and Hymanson citation).

Herbold et al., 1992: A more complete reference needed here. Where can the reference be obtained?

HTE, 2003: Is this a company report? If so, where is company located ?

R.S. Means, 2005: What is this? Surname is “R.S.”? I doubt it. Please provide complete reference.

Ramillien, G. et al, 2007: Who are the *et al*? Please provide complete and correct reference.

Schlemon (*sic*), R. J., and E. L. Begg, 1973: Misspelled citation and date. Correct one given in the Subsidence Technical Memorandum, viz:

Shlemon, R. J., and E. L. Begg, 1975, Late Quaternary evolution of the Sacramento-San Joaquin Delta, California: in Suggate, R. P., and Cresswell, M. M. (eds.), Quaternary Studies, Bulletin 13, The Royal Society of New Zealand, Wellington, New Zealand, p. 259-266.

Shelmon, R. J., and Begg, E. L., 1975: Here, too, misspelling of author’s name and incorrect citation. See above for correct one.

Stephens, J. C., et al, 1984: Incomplete citation. Please provide volume number and appropriate pages. Easy reference to find, and the editor, T. L. Holzer, is often cited.

Veliconga, I, and J. M. Wahr, 2005, 2006a, 2006b: How about some titles for these three papers? Complete reference properly.

Yahoo Maps: What kind of reference is this?

Zwally, H., J., et al, 2005: Need title, and complete list of the “et al.” authors.

Appendix A

Middle of page 3 - 3 of App. A entitled --- "I R P Comments on June 26, '07 , Draft on the Risk Analysis Report and the Response of the Consulting Team (Dated 11/2/07)" - IRP asks them to rephrase their 1st bullet to ---"Death and Injuries to Humans" so as to be consistent. In their reply in blue (same page 3 - 3) they say they will make the change. See page 3 -7 under Section 3.6 of their current Draft 4 Report and look at the 1st bullet – change not made. It says "Death or Injury of People."

On page 7 - 8 near the bottom of the page they claim they will add comparisons to Corps stage curves and historic data. Historic data I can find in their Draft 4. I can not find comparisons to Corps data.

On page 7 - 14 near the middle They say --- "When expert elicitation is used we will provide a detailed description --- ." I believe expert elicitation was used for levee failure by overtopping (see Page 7 - 26) but not mentioned.

Appendix 4: Seismicity and Seepage Review Details
Review of the Delta Risk Management Strategy Report, Phase 1 (Draft 4)

Seismic Risk Review Details

A. The estimated frequency for islands failing due to earthquakes seems high in comparison to the historical record. Figure 13-2 in the DRMS report shows the following annual frequencies of having events with different numbers of islands fail due to earthquakes:

- one per 10 years of having at least one island fail (flood) due to an earthquake;
- one per 20 years of having at least ten islands fail due to an earthquake; and
- one per 100 years of having at least 40 islands fail due to an earthquake.

In contrast to this estimate, the historical record indicates that there have been no known failures of islands due to earthquakes in at least the last 100 years. Even if the historical record of earthquakes were extended further back to include the relatively active seismic period between 1850 and 1906 before the modern Delta was developed, there would potentially be only a handful of events (at most) where an earthquake may have caused hypothetical island failures if the Delta were in its present condition. More discussion and explanation of the apparent discrepancy between the historical record (at return periods of 10 or 20 years) and the predicted results is warranted. The use of Figure 13-8 to justify the estimated high frequencies of island failures is not very compelling because:

- it shows the probability of a large earthquake in the Bay area (not necessarily the Delta), and
- it does not show that the annual frequency for small-magnitude but frequent events (several islands failing every 10 or 20 years on average) is substantially higher than the historical record going back to 1850 (that is, including the more active period in the late 1800s).

An analysis of how the existing Delta would have performed in all of the historical earthquakes would be very helpful in putting these results into context and possibly informing the estimated frequencies. Also, at a minimum, the uncertainty bounds on the estimated frequencies in Figure 13-2 should be expanded (specifically, the lower bound should be dropped by about at least an order of magnitude) to reflect that there is apparently substantial uncertainty in predicting both the frequency of small-magnitude ground motions as well as the possibility of liquefaction in these events.

B. The argument that the levees were lower in the 1906 earthquake and therefore not as susceptible to failure is debatable (e.g. section 6.2.1). If levee failures are driven by liquefaction, the panel is not sure that smaller levees necessarily reduce liquefaction potential: can you show this using your liquefaction model? Also, the sands would have been younger and potentially more susceptible to liquefaction 100 years ago. It would be helpful to provide more discussion here since it is an important reference point in interpreting and understanding your results.

C. Simplified Analysis of Sherman Island

The following simplified analysis of the risk of levee failure due to earthquakes was conducted for Sherman Island to shed some light onto what is driving the results and whether they are reasonable.

First, Figure 6-11 in the DRMS report was used to develop the annual frequency for different ground peak ground accelerations, as shown below on Figure 1. Discrete intervals of acceleration were used to simplify the calculations – for example, a value of 0.1 g in the figure represents an acceleration between 0.075 and 0.125 g.

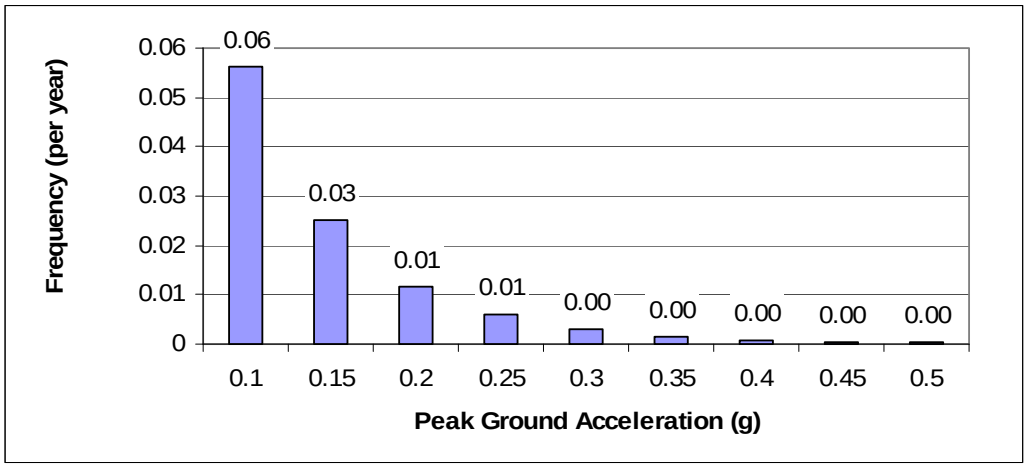


Figure 1

Next, we looked at Figure 6-37a to find that most of Sherman Island contains Vulnerability Class 4 with several small sections of Vulnerability Class 2. Then, we used Figure 6-137a to get the probability of failure as a function of the peak ground acceleration for these Vulnerability Classes, as shown below on Figure 2. For these Vulnerability Classes, the governing failure mode is liquefaction of the levee or its foundation.

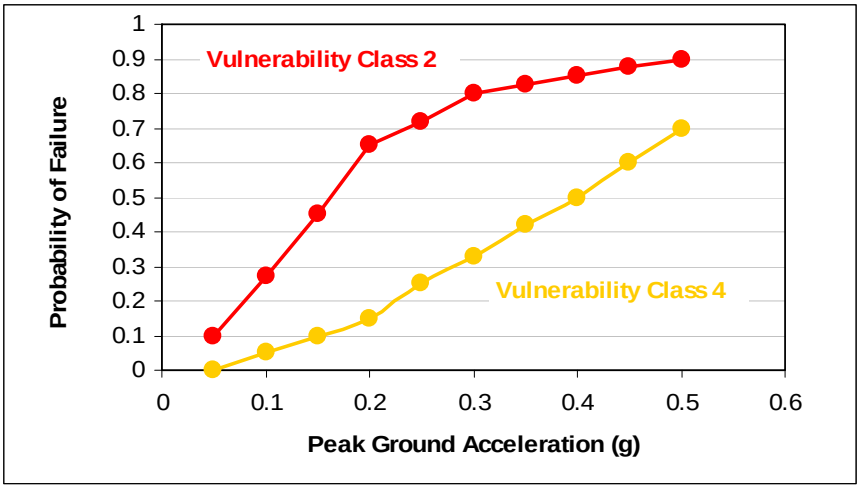


Figure 2

The use of Figure 6-37a in this simple analysis is an approximation because it corresponds to a magnitude 6.5 earthquake, which is a bit higher than the expected magnitude for an earthquake producing these ground motions at Sherman Island (Figure 6-26). If all of the possible magnitudes and distances were included explicitly in this calculation (as is done in the DRMS analysis), we suspect that the resulting probability of failure would be slightly lower than obtained in this simple analysis. Also, the information in Figure 6-37a corresponds to 2 feet of free board, which may be a bit lower (i.e., less freeboard) than the Mean Higher High Water level used in the DRMS analysis. Again, this approximation would potentially produce a slightly higher probability of failure with the simple analysis compared to the DRMS results.

Finally, we summed up the probability of failure for each Vulnerability Class as follows:

$$\begin{aligned} P(\text{Failure}) = {} & P(\text{Failure}|\text{pga} = 0.10\text{g})P(\text{pga} = 0.10\text{g}) \\ & + P(\text{Failure}|\text{pga} = 0.15\text{g})P(\text{pga} = 0.15\text{g}) \\ & + \ldots + P(\text{Failure}|\text{pga} = 0.50\text{g})P(\text{pga} = 0.50\text{g}) \end{aligned}$$

where $P(\text{Failure}|\text{pga} = \ldots)$ comes from Fig. 2 and $P(\text{pga} = \ldots)$ comes from Fig. 1. The results of these calculations are shown in the table below for Vulnerability Classes 2 and 4.

Table 1

		Class 2			Class 4		
pga	P(pga)	P(F|pga)	P(F|pga)*P(pga)	Contribution	P(F|pga)	P(F|pga)*P(pga)	Contribution
0.1	0.0563	0.27	0.0152	35%	0.05	0.0028	25%
0.15	0.0251	0.45	0.0113	26%	0.1	0.0025	22%
0.2	0.0118	0.65	0.0077	18%	0.15	0.0018	16%
0.25	0.0058	0.72	0.0042	10%	0.25	0.0015	13%
0.3	0.0030	0.8	0.0024	6%	0.33	0.0010	9%
0.35	0.0016	0.825	0.0013	3%	0.42	0.0007	6%
0.4	0.0009	0.85	0.0008	2%	0.5	0.0005	4%
0.45	0.0005	0.875	0.0005	1%	0.6	0.0003	3%
0.5	0.0003	0.9	0.0003	1%	0.7	0.0002	2%
		Total:	0.044		Total:	0.011	

The numbers in the boxes labeled “Total” are the annual probabilities of levee failure due to an earthquake for a reach with Vulnerability Class 2 or Class 4. The total probability of failure for the island is the probability that at least one reach fails. An approximation to obtain this probability is to assume that the event of failure is dominated by the single reach with the highest probability of failure (a reach with Vulnerability Class 2). Representing the entire island with the most vulnerable reach will produce a probability of failure for the island that is less than or equal to the value that would be obtained by accounting for all of the reaches that could fail. This approximation should be reasonable for Sherman Island since the number and length of reaches that are Vulnerability Class 2 is small and since the reaches that are Vulnerability Class 4 have a much smaller probability of failure (Table 1).

Therefore, the probability of failure due to earthquakes for Sherman Island obtained from this simplified analysis is 0.04. This result is similar to the DRMS result from the more complicated analysis, shown in Figure 13-7 (between 0.03 and 0.05 per year) and listed in Table 13-3 (0.037 per year).

In addition to providing a check on the DRMS results, this simple calculation is helpful because it highlights that the primary contribution to the probability of failure for Sherman Island is due to peak ground accelerations between 0.1 and 0.2 g (see columns labeled “Contribution” in Table 1). There are two significant aspects about this range of ground acceleration at Sherman Island:

1. The estimated frequencies for these ground motions are relatively high (return periods less than 100 years – see Figure 1 above or Figure 6-11 in the DRMS report), which is why they are driving the probability of failure. Such small return periods are not typically the focus in a Probabilistic Seismic Hazard Analysis (e.g., design return periods for structures and dams are typically on the order of 500 to 2,500 years). Also, there are historic data available to compare the actual ground motions that have occurred at Sherman Island that are relevant for such small high frequencies. For example, Figure 6-11 shows that the expected return period is 10 years for a peak ground acceleration exceeding 0.08 g. Based on over 50 years of records for a station at Antioch (close to Sherman Island), this ground motion has possibly (and not necessarily) been exceeded only once (in 1980).

Therefore, the estimated frequency of once per 10 years is higher than the historical record.

2. At these small accelerations, the potential for liquefaction is debatable. For example, using Appendix 6A as a guide, the cyclic stress ratios for peak ground accelerations of between 0.1 and 0.2 g would be between 0.05 and 0.1. If you look at the potential for liquefaction, which is obtained from Figure 6A-6 in the DRMS analysis and reproduced below as Figure 3), there are few actual data points where liquefaction occurred at a cyclic stress ratio of less than 0.1; it is an extrapolation to extend the curves showing the probability of liquefaction to these low stress ratios.

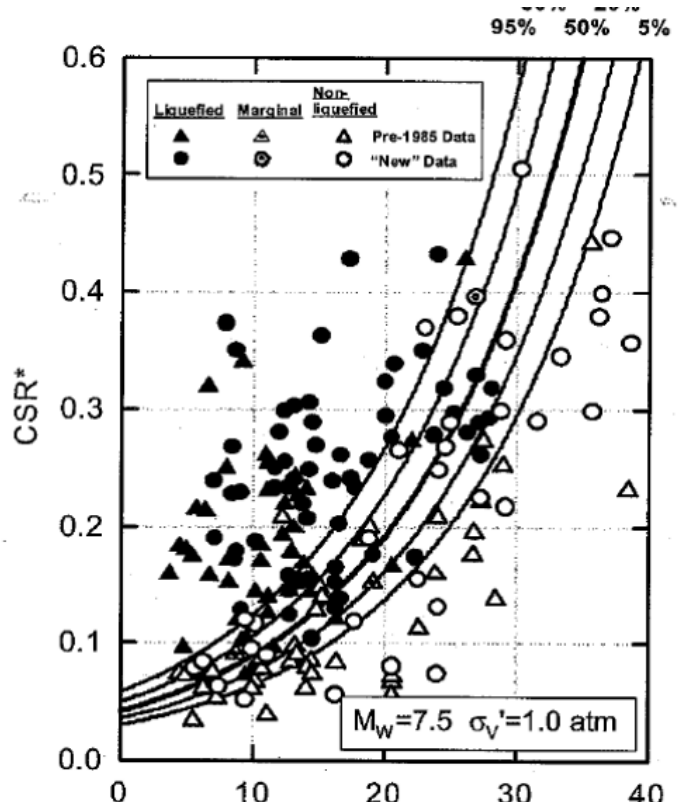


Figure 3 (taken from Figure 6A-6 in the DRMS Report)

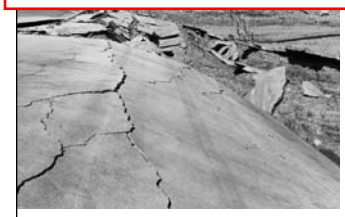
This simplified analysis also indicates that the probability of failure for the Island is apparently dominated by the small lengths of reach that are the most vulnerable to liquefaction (Vulnerability Class 2). In moving forward, this information could be useful in reducing the seismic risk. Measures to reduce the potential for liquefaction over relatively small lengths of the levee could have a large impact on the total risk for this island. Conversely, small undetected lengths of levee (due to relatively sparse geotechnical and geologic information) could also have a large impact on the total risk. So, efforts to target the most vulnerable reaches, by clearly identifying, delineating and upgrading them, could be valuable in managing the overall seismic risk.

In summary, the results from this simple analysis of Sherman Island indicate that the overall DRMS results can be replicated (at least approximately) and that the seismic risk is driven by liquefaction of the most vulnerable reaches at relatively small ground accelerations. Additional information about the frequency of small ground motions (say peak ground accelerations of less than 0.2 g) and the potential for liquefaction at these small motions would be valuable in the future to better assess the seismic risk for the Delta.

Seepage Risk Review Details

Section 7.7.4.5 As discussed in our first review, the use of the exit gradient as an indicator of seepage failure is a challenge because the calculated gradient depends strongly on the resolution of the finite element mesh and local variations in physical properties. We recommend considering the use of an average gradient across the peat as a more robust indicator. Also, if the unit weight of the peat is really only 70 pcf, then the critical gradient (the gradient at which the effective stress in the peat goes to zero) is much less than 1.0 (in fact, it would be 0.12). Therefore, the statement that “the calculated vertical exit gradient of 0.4 would be insufficient to initiate an under-seepage problem” is not necessarily correct. We recognize that the peat may have tensile strength and may be able to sustain vertical effective stresses of zero without piping or failing; we would prefer to see data for this tensile strength and to see it considered explicitly in the analysis, instead of seeing failure defined with a critical gradient that does not have a physical basis. Also, if a smaller critical gradient were used, then the initial assumptions about the permeability of the peat, which were based on measurements, may have been reasonable, and would not have required adjusting to explain the case histories. Given the large potential for this failure mode, future work to better understand and model seepage failures would be very helpful to better assess the risk of failure due to flood events.

Appendix 5: Comments by the IRP on the revised DRMS Phase 1 Executive Summary



Overview comments by the DRMS Phase 1 Independent Review Panel.

The executive summary is critically important, as this is the single document that most people will read.

The IRP feels that the approach taken here is the right one. This summary is in the most part accurate (although we do caution against the use of language such as "can" and "will" that implies absolute certainty), and in general represents a vast improvement over previous efforts. It is fairly concise, but could be made more so through eliminating repetitious text, and tightening up & increasing the precision of the language used.

The goal of the following comments is to ensure the summary accurately reflects the technical report; does not make any unsubstantiated statements; and is factual, precise, and accurate.

In light of the overwhelming importance of this executive summary, we encourage the DRMS to seriously consider these comments and make the recommended changes to the executive summary.

HASE 1

Delta
Risk
Manag
Strateg

SEPTEMBER 2008

[D A F T]

List of Documents Prepared by

URS Corporation/Jack R. Benjamin & Associates, Inc.,
for Phase 1 of the Delta Risk Management Strategy (DRMS) Project

Executive Summary

The following documents are available electronically on the DVD inserted at the back of this executive summary. They also are available online at www.drms.water.ca.gov.

Risk Analysis Report

should have 3 blue headers:
1. exec summary
2. risk report
3. technical memoranda
Then list the titles of the TMs below the blue "Technical Memoranda" header and remove the repeated "Technical Memorandum" from each item in the bulleted list

- Seismology Technical Memorandum
- Flood Hazard Technical Memorandum
- Climate Change Technical Memorandum
- Levee Vulnerability Technical Memorandum
- Wind-Wave Hazard Technical Memorandum
- Geomorphology Technical Memorandum
- Subsidence Technical Memorandum
- Emergency Response and Repair Technical Memorandum
- Water Analysis Module (WAM) Technical Memorandum
- Impact to Ecosystem Technical Memorandum
- Impact to Infrastructure Technical Memorandum
- Economic Consequences Technical Memorandum

[D R A F T]

Prepared by URS Corporation
for California Department of Water Resources

Pictured on cover:
Earthquake damage – Sylmar (February 9, 1971)
Source: DWR

Upper Jones Tract failure – Delta (June 4, 2004)
Source: DWR

Flood damage – Delta (June 7, 2004)
Source: DWR

Delta islands protected by levees from flooding
Source: DWR

What do "extremely" and "rapidly" mean?

KEY FINDINGS

The risks of levee failure in the Delta Region and their potential impacts on ~~the valuable resources of California~~ are extremely high.

change to: "California's valuable resources"

Re-arrange paragraph to begin with: "The risk due to Delta levee failures is increasing. This is due to future population growth ... " and then continue to list the items that currently begin the paragraph.

Considering future population growth both in the Delta Region and statewide and the increasing threat of earthquakes, sea level rise, floods, and continuing land subsidence, the risk ~~due to~~ of Delta levee failures is increasing rapidly. ~~Clearly,~~ under current practices, uses and configuration, the Delta and Suisun Marsh are not sustainable.

This is not yet clear to the reader - it's only the first page.

From which perspective are they not sustainable - economically? ecologically? other? all perspectives?

re protected by levees from flooding

DRAFT

KEY FINDINGS

The study shows that the single most catastrophic risk to the Delta Region (which includes the Delta and Suisun Marsh) is from a major earthquake along one of the many nearby faults. T[illegible] arthquake event becomes more likely with each passing year ~~without one~~. A major earthquake could cau[illegible] islands to flood simultaneously, which would have a ~~large~~ economic impact on California. The direct a[illegible] an earthquake are likely to exceed $40 billion.

"large" is very vague. There must be a better word.

change "is likely to" to "could be as high as" (use wording from second bullet)

PRESENT-DAY RISKS

~~Specifically,~~ under ~~a business-as-usual assumption~~, the present-day risk estimat~~ions~~ indicate:

Under present conditions, present-day risk estimates indicate:

SEISMIC HAZARD

- The Delta region is situated near a
- A major earthquake from a fault ne
magnitude 6.7 or greater has a 62 percent probability of occurring in the next 30 years.
- Earthquakes in the region of magnitude 6.7 or greater ~~can~~ may cause many levees to fail. For example, 20 islands could flood simultaneously with a 53 percent probability in the 25-year period between 2005 and 2030. Under these conditions, thousands of feet, if not tens of miles, of levees will experience extensive damage.
- Earthquake d possible vees in the Delta poses the most serious threat of catastrophic consequences.
- Although earthquakes are less frequent than floods, they could cause greater damage than floods, in any single event.

FLOOD HAZARD

- Flood hazard is the most common cause of levee failure in the Delta Region. Floods are more frequent than earthquakes ar
failures in the r
- Multiple and sir
flood hazard, t
extensive as those expected under a major earthquake.

from the technical report, it appears this increase is primarily due to increased flood risk from climate change, not inflation.

SUNNY DAY LEVEE FAILURES

- Sunny day nd are not cause occur at an aver cu of levee s t years. These failures/near failures will not have signif economic impacts; however, the total cost of damag repair of a single flooded island is estimated to be ab $100 million, which was the total repair and damage of the Jones Tract levee failure in 2004.

Need some context here. How many islands were involved in the Jones Tract Levee failure?

IMPACTS FROM LEVEE FAILURES

- The economic impact to the state ~~is likely to exceed~~ $40 billion from a major earthquake in the region.
- The economic impact to the state c
$25 billion from a major flood.
- Impacts to the ecosystem are likely difficult to quantify at this time.

This statement is not as straightforward as it should be. The truth is that the quantitative analysis was not done.

FUTURE RISKS

Under a business-as-usual future, risk estimates indicate:

al ~~assumption,~~ ~~the following future risk estimations indicate:~~

- By 2050, the frequency of island flooding from seismic events ~~will~~ increase by about 35 percent over 2005 conditions. "may" or "will probably"
- By 2100, the frequency of island flooding from seismic events ~~will~~ increase by about 93 percent over 2005 conditions.
- By 2050, the frequency of island flooding from flood events ~~will~~ increase by about 260 percent over 2005 conditions.
- By 2100, the frequency of island flooding from flood events ~~will~~ increase by about 800 percent over 2005 conditions.
- It is difficult to quantify future risks for the Delta Region's ecosystem from levee failures.
- The expected economic impacts to the state of a single event ~~will~~ increase in the future ~~with inflation~~. However, the frequency of these events ~~will~~ increase by the percentages above.

repetitive!

Again, this bullet is potentially misleading. The fact of the matter is that a reasonable approach for fish impacts has been proposed but not carried out, while terrestrial and vegetation analyses are cursory. This could therefore more accurately be stated as: "Future risks to the Delta Region's aquatic ecosystem from levee failures have not been assessed in this report." Lack of ecosystem impacts is an item of major concern to the IRP, as any potential user of the report should be aware that ecosystem impacts have not been quantified.

DRAFT

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DRAFT

OVERVIEW

This executive summary describes the key findings of Phase 1 of the Delta Risk Management Strategy Project (DRMS). Phase 1 of DRMS is an analysis of the risks California is facing due to levee failures in the Sacramento–San Joaquin Delta (referred to as the Delta) and Suisun Marsh (together referred to as the Delta Region). Phase 2 is the development of risk reduction strategies to minimize those consequences. The complete Phase 1 Risk Analysis Report is available on the DVD that accompanies this printed report and online at www.drms.water.ca.gov.

The DRMS Phase 1 analysis assesses the risks to Delta Region levees presented by earthquakes, floods, climate change, subsidence, and a combination of these hazards. This analysis estimates their potential impacts to the local and state economy, the environment, and public health and safety. These impacts are estimated for the current Delta (defined as year 2005) and the future Delta in years 2050 and 2100.

The Phase 1 analysis assumes that existing regulatory and management practices and current Delta Region services will continue in the future. This "business-as-usual" assumption (described in DRMS Risk Approach and Assumptions section) guides the analysis for modeling current ~~risk~~ and ~~for~~ projecting future risk.

[DRAFT]

Pictured above: Staten Island on the North Fork of the Mokelumne River. Source: DWR

Aerial View of Franks Tract from Connect Slough between Mandeville Island
Source: DWR

This sentence somewhat overstates what was done by the Technical Report. We recognize that this was certainly the *intent* of the Report to do this. But in our review we have identified areas where we don't feel this was actually accomplished.

The Delta Region **[FIGURE 1]** is a naturally dynamic, highly manipulated landscape. It is subject to major hazards ~~(earthquakes, floods, etc.)~~ whose probability of occurrence are increasing with time, ~~though at an uncertain rate.~~ The timing of these hazards and their impacts on the Delta Region are highly uncertain. The Risk Analysis Report identifies the estimated levels of risk using quantitative metrics ~~(with clear and understandable error margins)~~ or qualitative descriptions, where available data do not permit quantitative evaluation. The Risk Analysis Report also identifies what is not known now; what part of that uncertainty can be reduced through additional research, experimentation, and management choices; what level of uncertainty must be lived with; and the implications of doing so.

such as earthquakes and floods

this same concept is repeated in the next sentence.

This is a noble goal, but we cannot find where this was actually DONE in the Technical Report. If it was not done, you should not say it was done.

missing verb: "and what are the implications..."

DRAFT

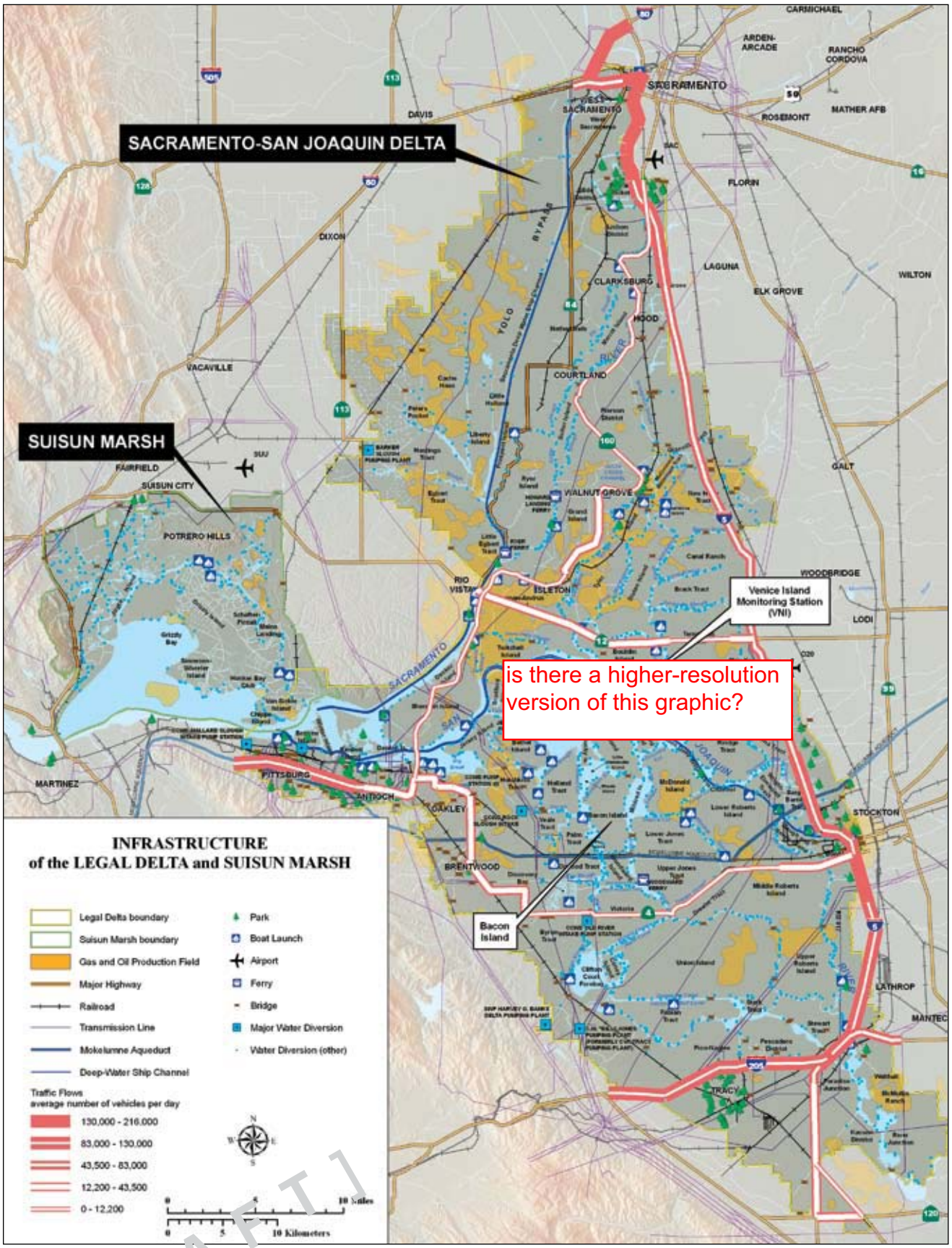
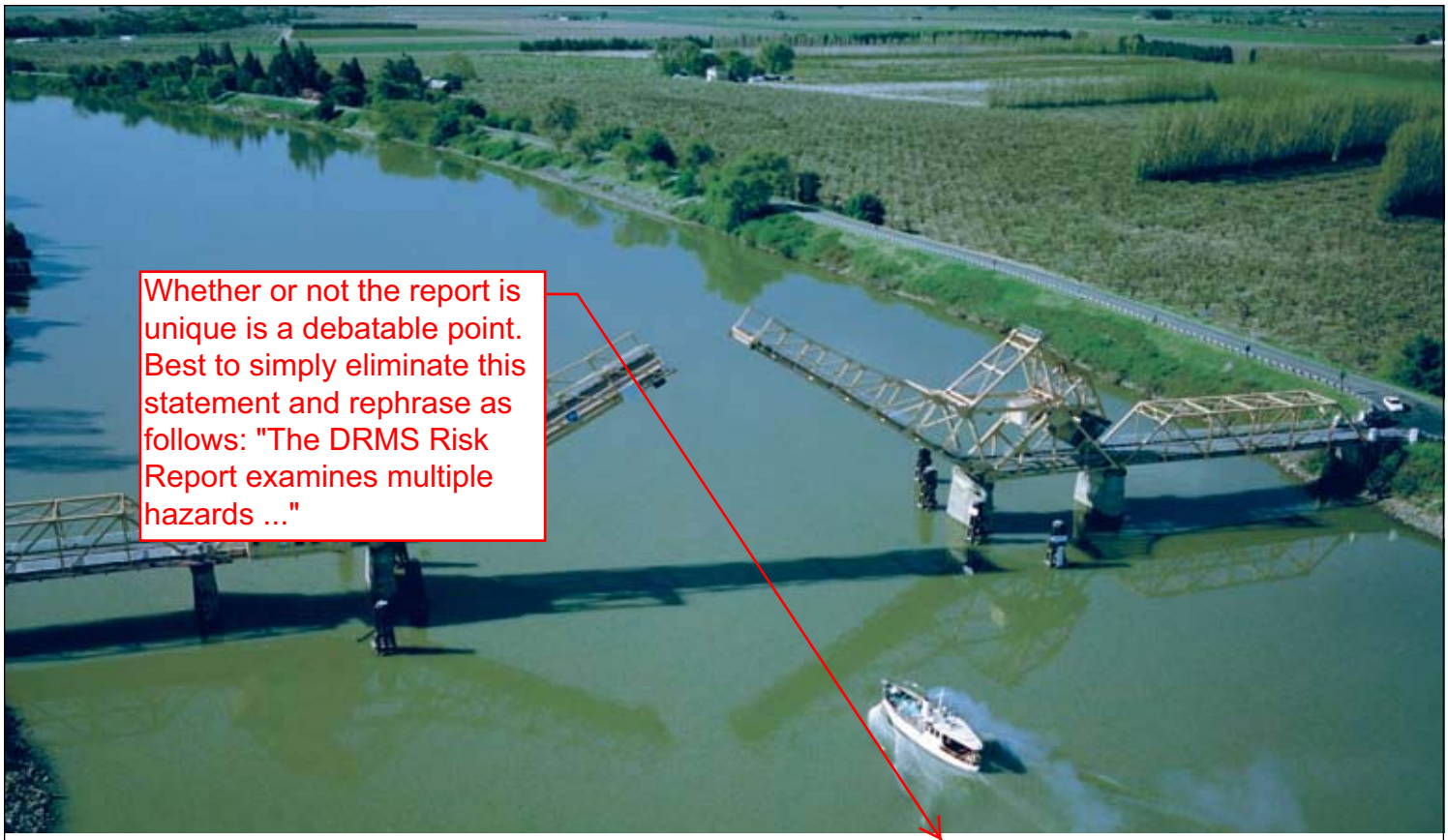


FIGURE 1 **The Sacramento–San Joaquin River Delta and Suisun Marsh (the Delta Region)**

Source: Figure developed by URS for use in Status and Trends Report (URS 2007)

[D R A F T]



Whether or not the report is unique is a debatable point. Best to simply eliminate this statement and rephrase as follows: "The DRMS Risk Report examines multiple hazards ..."

APPROACH

The DRMS ~~framework is unique because it~~ examines multiple hazards and their effects on the Delta Region's levee system ~~and the impact of levee failures on a number of~~ resources and assets.

Need a more accessible word here. "Framework" under the picture of a bridge implies a physical structure.

Language should be precise - "key"or "several" - "number" is too vague.

Run-on sentence. "It also evaluates ...

ssumptions

The DRMS risk analysis evaluates major threats to the Delta Region's levee system that ~~will~~ lead to increased levee failures. The impacts those failures can have on the Delta Region, life safety, its habitat, the state's water delivery system, and those who rely on the Delta for exports of fresh water are evaluated in this report. The DRMS framework ~~is unique because it~~ examines multiple hazards and their effects on the levee system and the impact of levee failures on many resources and assets.

flood and seismic

"can" or "may"

What is "life safety" and "its habitat"? The Delta is not alive, it does not have a habitat. Moreover the ecosystem impacts were not really evaluated by this report.

can you be more specific (many?)

Need to change the wording of this last sentence a little. It is still a run-on sentence, and is exactly the same as the pull-out item at the top.

DRAFT

Pictured above: Bridge on the Sa

The objectives of the DRMS project are to answer the following questions:

fuzzy wording

- **What is the frequency or rate of occurrence of hazard s ~~events~~ of varying magnitudes that can compromise the integrity of Delta Region levees?**
- **How vulnerable are individual levee sections to various hazards?** this question is not really answered by the technical report
- **How do the hazards and levee vulnerabilities interact to produce levee failures?**
- **What are the water quality, economic, ecosystem, and public safety impacts of levee failures?**
- **How will risk change in the future?**

The DRMS Phase 1 Risk Analysis Report identifies the characteristics and problems of the Delta Region with its current practices and uses. This approach, which ~~allows for cor~~ and ~~tion of~~ current policies, funded projects, and practices, is referred to as the "business-as-usual" scenario. Defining a business-as-usual Delta Region is necessary because one ~~of the~~ objectives of DRMS Phase 1 is to estimate whether the current practices of managing the Delta Region are sustainable over the next 100 years. Proposals for Delta Region improvements to reduce these risks are ~~considered~~ in Phase 2 of DRMS.

considers

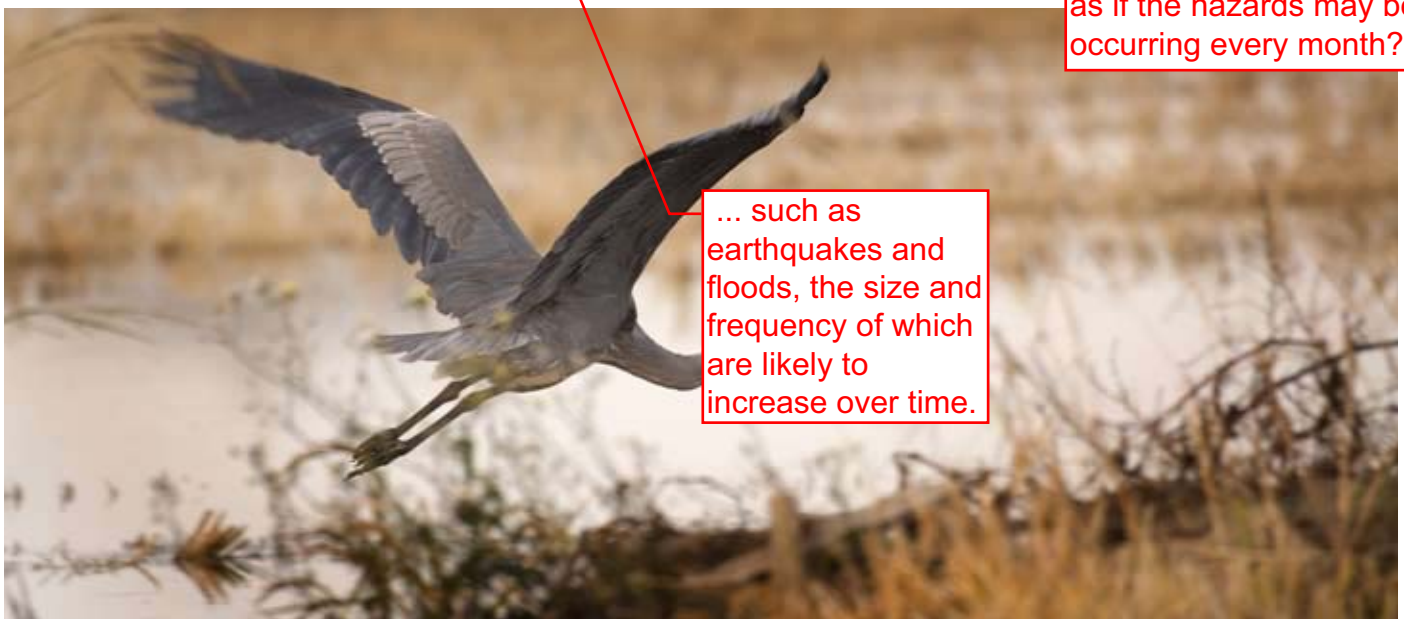
"presented" or "evaluated"

why is water quality first on this list?

This bullet sounds more mechanistically insightful than the technical report actually is.

The Delta Region is a naturally dynamic, highly manipulated landscape. It is subject to major hazards ~~(earthquakes, floods, etc.) whose~~ sizes and frequencies of occurrence are increasing with time...

can this be quantified further, so it doesn't sound as if the hazards may be occurring every month?



... such as earthquakes and floods, the size and frequency of which are likely to increase over time.

Source: DWR

yet ecosystem impacts are not adequately addressed in the technical report

THE DELTA REGION

Although the Sacramento-San Joaquin Delta and Suisun Marsh cover only about 1 percent of California's land area, the region is ~~at the center of many resource issues~~.

"at the center of resource issues" is pure jargon - it means nothing to the average reader. Need to replace this clause with something clearer (i.e., it is the source of drinking water for 2/3 of California's population).

It provides ..

It also houses ...

This is a run-on sentence.

Sacramento-San Joaquin Delta and Suisun Marsh

The Delta and Suisun Marsh are vital to California's economy and environment. The region has highly fertile agricultural land ~~and~~ provides a unique estuarine habitat for many resident and migratory fish and birds, some listed as threatened or endangered species, ~~and~~ houses critical infrastructure for the state's dynamic economy. The Delta is ~~also~~ the hub of the state's water system. About two-thirds of Californians get some portion of their drinking water from the Delta and approximately 3 million acres of agricultural land receive a portion of their irrigation water from the Delta.

Pictured above: Overlooking the Delta at dusk. Source: DWR

[DRAFT]

What is the difference between an engineered vs. a non-engineered levee?

Much of the land in the Delta Region is below sea level and protected by a non-engineered and fragile system of levees. A ~~unique~~ feature of the Delta Region is that much of its land is made up of highly organic soils ~~overlying loose sands~~. These organic soils are fertile and pr[illegible]e an abundant agricultural harvest. However, the process of tilling ~~the soils~~ has caused the land surface to subside at an alarming rate. Over the past 100 years, subsidence has lowered land surface to as much as 25 feet below sea level. The land that is below sea level requires an extensive system of levees to prevent the land from flooding [FIGURE 2].

soil

very subjective. What is "an alarming rate"?

About 1,830 miles of levees protect lands and waterways in the Delta and Suisun Marsh. The levees play a vital role in protecting the various assets, resources, uses, and services that ~~California obtains~~ from the ~~Delta Region~~.

Californians obtain

Better to say "characteristic feature". Most other upper estuarine plains have the same characteristic. So not unique.

This is a good introductory statement but should be moved to a more appropriate place earlier in the document.

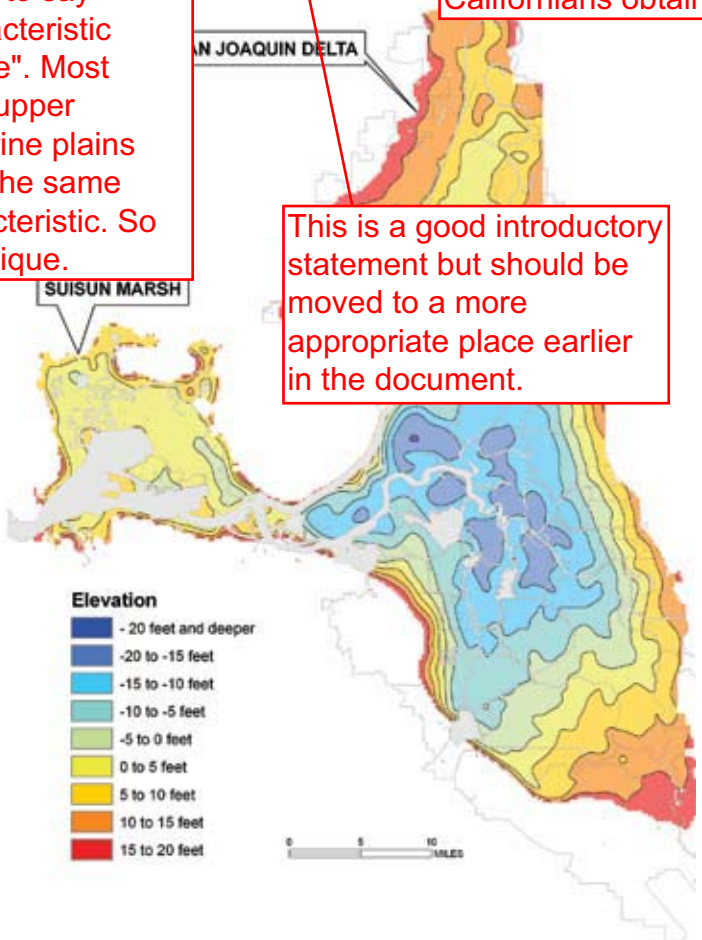


FIGURE 2 **Surface elevation map of Sacramento-San Joaquin River Delta and Suisun Marsh**
Source: DRMS Risk Report (URS/JBA 2008c), Fig. 5-14

Most Delt
Source: D

The most important characteristics of and services provided by the Delta include:

~~Some of the key attributes of the Delta Region are as follows~~:

- Agriculture is the main land use in the Delta.
- Managed conservation land is the main land use in the Suisun Marsh.
- Urban areas are rapidly developing around portions of the Delta Region periphery and within the Delta Region at its margins.
- Over 75 percent of the Sierra Nevada's western watershed in California drains through the [illegible]
- The ecological importance of t[illegible] beyond its boundaries.

By itself, this bullet says nothing concrete. Maybe it should be merged with the next bullet?

- Part of the largest estuary on the west coast of North and South America, the Delta Region supports a unique estuarine habitat. The Delta Region ~~provides for~~ more than 750 resident and migratory aquatic and terrestrial species, some of which are listed as threatened or endangered.

harbors

- About one-quarter of the urban water used in California is diverted from the Delta.
- About two-thirds of Californians get some portion of their drinking water from the Delta.
- Approximately 3 million acres of agricultural land receive a portion of their irrigation water from the Delta.
- Major transportation and utility corridors pass through the Delta Region to other regions of California.
- Wide expanses of open land, interlaced waterways, historic towns, and the feeling of a slower pace of life make the Delta Region attractive for recreation, tourism, and as a place to live.

[DRAFT]

LEVEE CONDITION

Earthquakes, floods, continued land subsidence, and climate change ~~pose threats to the levee system.~~

threaten the levee system.

Condition of the Levee System

Since 1900, levee failures have flooded islands 166 times, some flooded islands have never been recovered. Several Delta islands and tracts have flooded multiple times. Vast land areas lie many ? feet below sea level, and these areas will flood whenever a levee fails. Historically, levee failures have occurred during both flood and non-flood (sunny day) conditions.

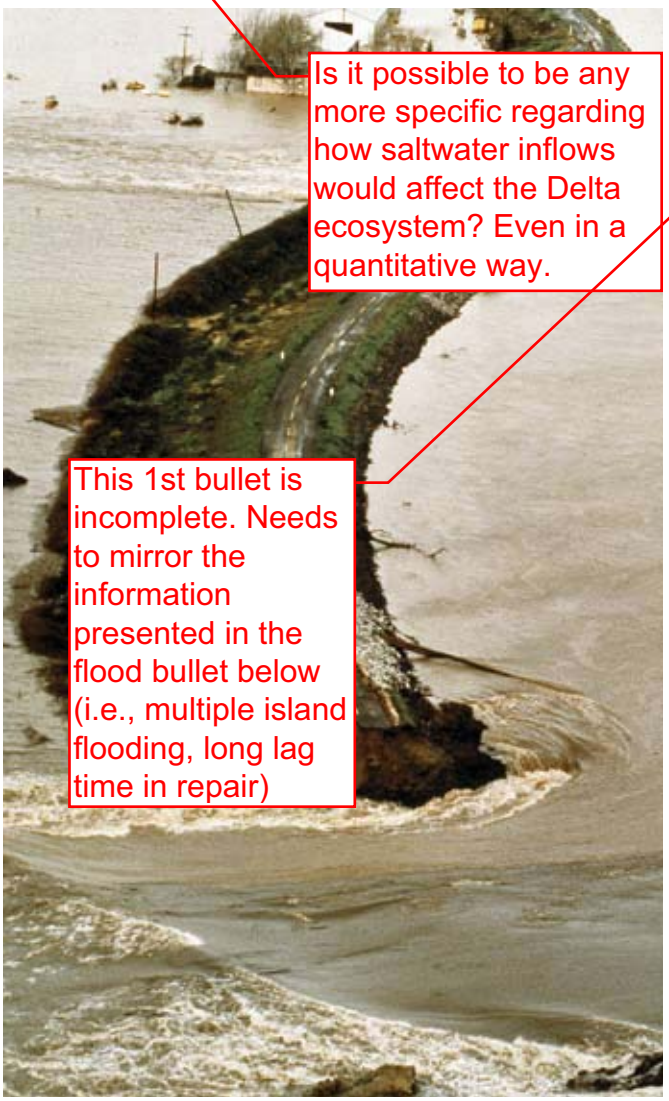
The report doesn't actually talk about island recovery - the flooded islands are now used for recreation and aquatic habitat, and in fact some of them were not recovered intentionally.

[DRAFT]

Pictured above: Protecting the landside of a levee on a flooded island [Jones Tract, 2004].
Source: DWR

The current Delta Region levees have not experienced a damaging earthquake yet. Nonetheless, the risk of widespread damage from a major earthquake is high. An earthquake could cause multiple levee failures and several islands to flood simultaneously. If the disaster occurs during a time of low or moderate Delta inflow, saline water would flow into the Delta from Suisun Bay. This saline water would subsequently fill the islands and cause the Delta waters to become highly salty. Delta waters then could not be used for in-Delta irrigation supplies, local urban supplies (for example, use by the Contra Costa Water District), or state and federal water project exports. Impacts would also occur to the Delta ecosystem.

Key hazards ...



Is it possible to be any more specific regarding how saltwater inflows would affect the Delta ecosystem? Even in a quantitative way.

This 1st bullet is incomplete. Needs to mirror the information presented in the flood bullet below (i.e., multiple island flooding, long lag time in repair)

Levee breaches at Tyler Island (1986). Source: DWR

Delta levees are susceptible to seismic-induced liquefaction. Seismic-induced levee failures in the Delta ~~will~~ be similar to those that occurred in Kobe in 1994. Source: Professor Ray Seed.

would/could/may

~~The~~ hazards and their effects on levee integrity include:

- Earthquakes which ~~can~~ cause damage to many miles of levees.
- Floods (defined as high storm runoff into the Delta Region) combined with high tides can cause water to rise above the tops of the levees or increase pressure on the levees and foundations, causing instability and seepage through and under the levees. These flood-related effects can lead to levee failures and can cause several islands to flood in a single storm. However, because damage typically occurs at discrete points, repairs can typically be made quickly compared to seismic levee damage.
- Subsidence increases the landside height of a levee, intensifying the water pressure on the levee. Greater water pressure increases the risk of seepage through and under the levee. (See **FIGURE 3** for more on subsidence and Delta farmed land.)

It's not clear that this statement is supported by the technical report.

Levee failures flooded islands

166 times since 1900

DRAFT

This is the wrong title for the plot

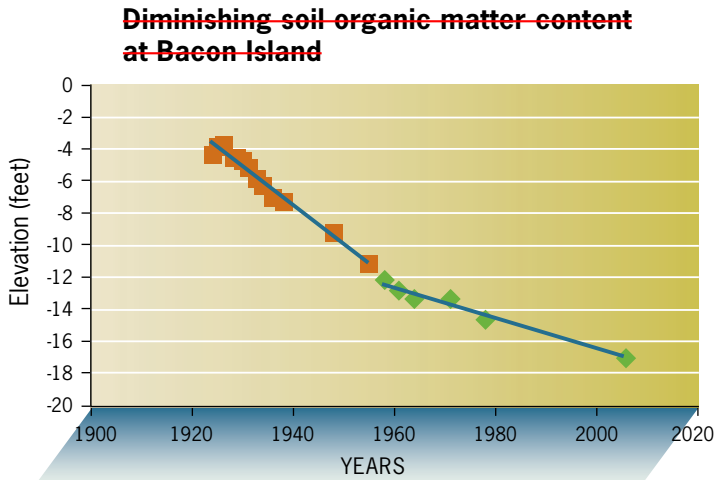


FIGURE 3 *Source: DRMS Subsidence TM (URS/JBA 2007a), Fig. 8*

Figure 3 shows the average change in elevation *for Bacon Island from 1922 to 2006. From 1924 to 1955, the subsidence rate was estimated to be 7.2 centimeters/year (2.83 inches/year). The subsidence rate from 1958 to 2006 was estimated to be 2.9 centimeters/year (1.16 inches/year), which is 40 percent less than the 1924–1955 rate.*

The organic content of the farmed land in the Delta is decreasing exponentially, which combined with improved land-management practices is resulting in a slower rate of subsidence. The change in the rate of subsidence from the pre-1955 period to the present [Figure 3] was in large part due to changing land-management practices.

Ultimately, the depletion of organic matter will result in no further subsidence. Currently, a large portion of the farmed land in the Delta has low to no organic content.

is likely to have

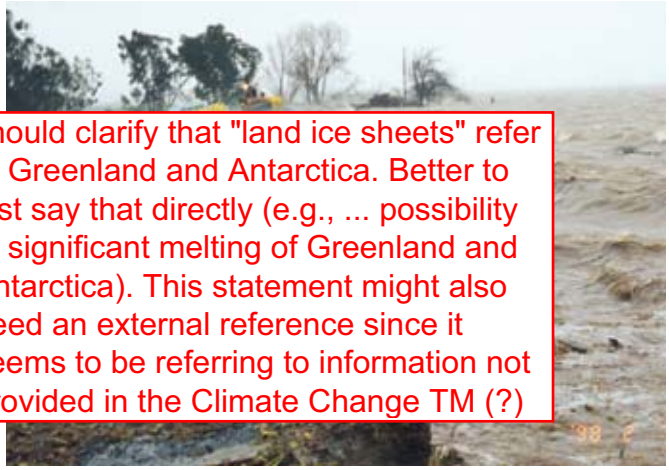
What are the rest? Either say "The primary impact is sea level rise" and just talk about it, or must mention other possible impacts here as well.

- Climate change ~~has~~ multiple impacts. One of the primary impacts on the Delta Region is sea level rise. Sea level rise projections are shown in **TABLE 1**. These projections are based on results from several sources and were developed for the DRMS Phase 1 analysis. Sea level rise will directly affect levee stability and ~~will~~ cause salt intrusion, as shown in **FIGURE 4**. Salt intrusion can affect species dependent on a freshwater environment. The sea level rise projections do not include the possibility of significant melting of land ice sheets, which could further impact the Delta Region.

can

- Sunny day events refer to levee failures that occur during normal, non-flood conditions, typically between the end of the Sierra Nevada snowmelt and the beginning of the rainy season. Sunny day failures are caused by undetected defects, such as burrowing animal activities, pre-existing weaknesses, or high seepage caused by unusually high tides. These events are typically single-island events and historically have been repaired in a matter of weeks.

aken levees but are opes of levees when islands are flooded. Damage to the interior slopes on one island could result in secondary levee failures on adjacent islands if not repaired.

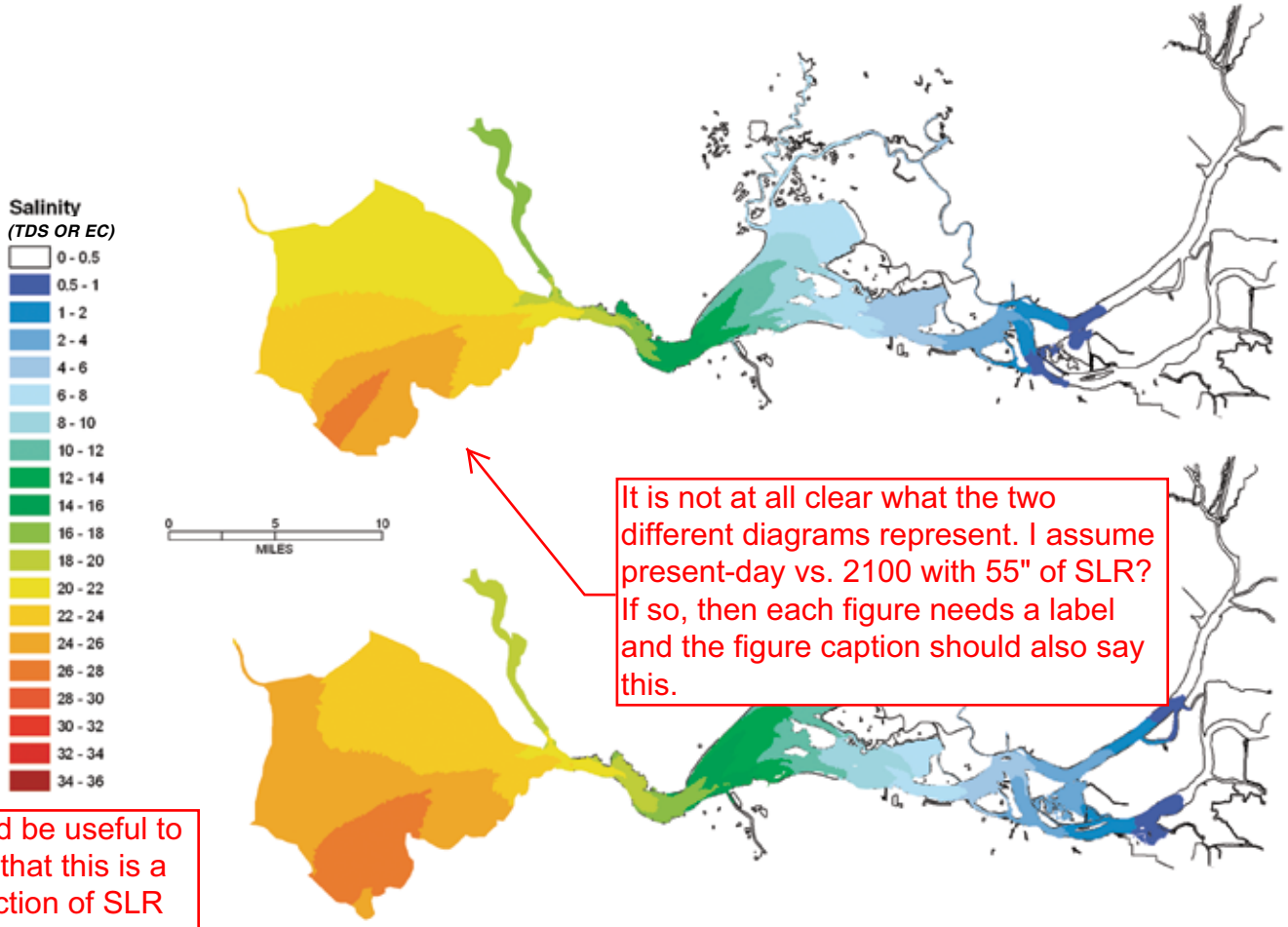


Erosion of a Delta levee during a storm and high tide.
Source: DWR

should clarify that "land ice sheets" refer to Greenland and Antarctica. Better to just say that directly (e.g., ... possibility of significant melting of Greenland and Antarctica). This statement might also need an external reference since it seems to be referring to information not provided in the Climate Change TM (?)

as well as other coastal lowlands.

[D R A F T]



It is not at all clear what the two different diagrams represent. I assume present-day vs. 2100 with 55" of SLR? If so, then each figure needs a label and the figure caption should also say this.

Would be useful to state that this is a prediction of SLR at 2100 (based on Table below)

FIGURE 4 **Estimated saltwater intrusion as a result of 140 centimeters (55 inches) of the sea level rise expected in 2100**

Source: DRMS Water Analysis Module TM (URS/JBA 2007b), Appendix H3, Fig. H3.5-6

Recommended seems like the wrong word here: estimated, or predicted...

RECOMMENDED VALUES FOR GLOBA at the Golden Gate relative to 1990 value (in			
Date	**Range of Sea Level Rise**	**Sea Level Ir (centime**	**ement**
2050	High[1]	41	16
	Mid[2]	30	12
	Low[3]	20	8
	Llinear extrapolation[4]	11	4
2100	High[1]	140	55
	Mid[2]	[illegible]	[illegible]
	Low[3]	[illegible]	[illegible]
	Llinear extrapolation[4]	[illegible]	[illegible]

[1] *Based on Rahmstorf 2006 high estimate.*
[2] *Based on Rahmstorf 2006 mid estimate and IPCC 2001 high estimate.*
[3] *Based on Rahmstorf 2006 low estimate and IPCC 2001 mid estimate.*
[4] *Based on linear extrapolation from observed increases during twentieth century.*

TABLE 1 *Source: URS/JBA 2008a, Table 2*

2 "LL"s in "Llinear"

what does "during 20th C" mean -- 1900 to 1999? SLR rate doubled over > the last half of the century. Therefore would be more accurate to use a shorter time period to base the linear extrapolation on (e.g., the length of the TOPEX record). Otherwise the linear extrapolation method significantly under-estimates even present-day rates of SLR.

RISKS TO THE DELTA REGION

With its current uses and practices, the Delta Region is not sustainable.

... over what time frame? Next 100 yrs?

less dramatic wording - "major"?

A massive failure of the Delta Region's levee system would have ~~staggering~~ effects on California's economy. The risks to the Delta Region are continuously increasing ~~and will increase manyfold over today's risks~~. The risks analyzed in DRMS include seismic, flood, and sunny day levee failures.

Change the order of this paragraph as follows:
"... are continuously increasing. The risks analyzed in DRMS ... failures. Over the coming century, they are likely to increase many times relative to today's risks."

Pictured above: Upper Jones Tract Failure [June 4, 2004].
Source: DWR

DRAFT

The U.S. Geological Survey estimates that ...

SEISMIC RISKS

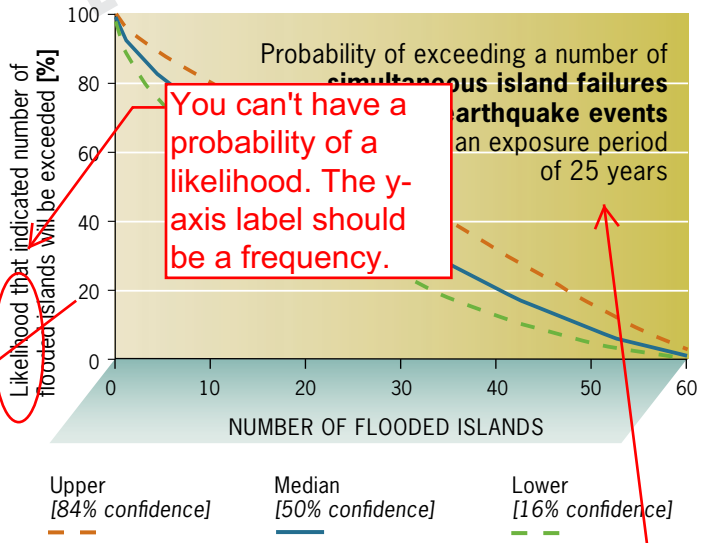
Seismic activity in the Delta region is characterized as moderate to high, as shown in **FIGURE 6**. ~~Experts estimate~~ that an earthquake of magnitude 6.7 or greater has a 62 percent probability of occurring in the San Francisco Bay Area during the next 30 years [**FIGURE 7** – *see next page*]. Such an earthquake ~~is~~ may be capable of causing multiple failures of Delta Region levees and severely affecting export water deliveries for an extended period. The highest potential for seismic levee failures ~~will~~ would come from an earthquake on the Hayward, ~~Midland,~~ Calaveras, ~~or~~ San Andreas faults.

Midland is a buried fault; no historical seismicity, hence not comparable to other faults listed here.

Probability of Multiple Island Failures

Earthquakes can cause extensive damage to thousands of feet, if not tens of miles, of levees. As a result, many islands could flood simultaneously. **FIGURE 5** displays the likelihood of multiple islands flooding as a result of earthquakes in the Delta Region during a 25-year period under current practices. For example, there is about a 53 percent chance that 20 or more islands in the Delta Region will be flooded by a major earthquake in the next 25 years (2005 to 2030).

... during a major earthquake.



You can't have a probability of a likelihood. The y-axis label should be a frequency.

FIGURE 5 *Source: DRMS Risk Report (URS/JBA 2008c), Fig. 13-4*

This text needs to be moved to the figure caption and simplified. The figure title should simply state something like: "Probability of multiple island flooding"

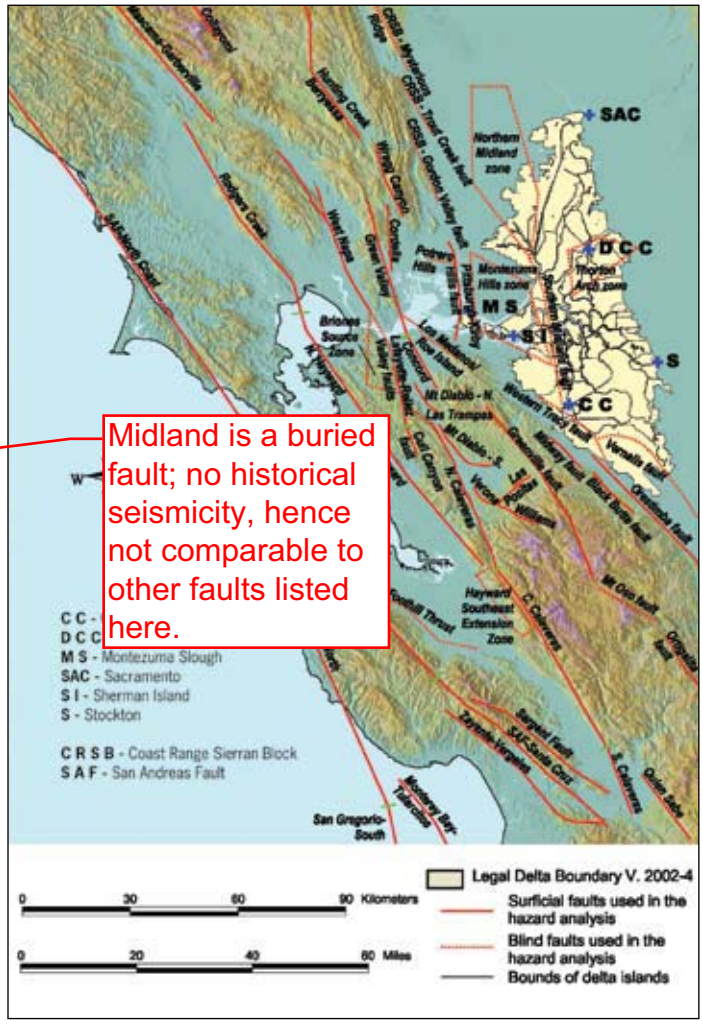


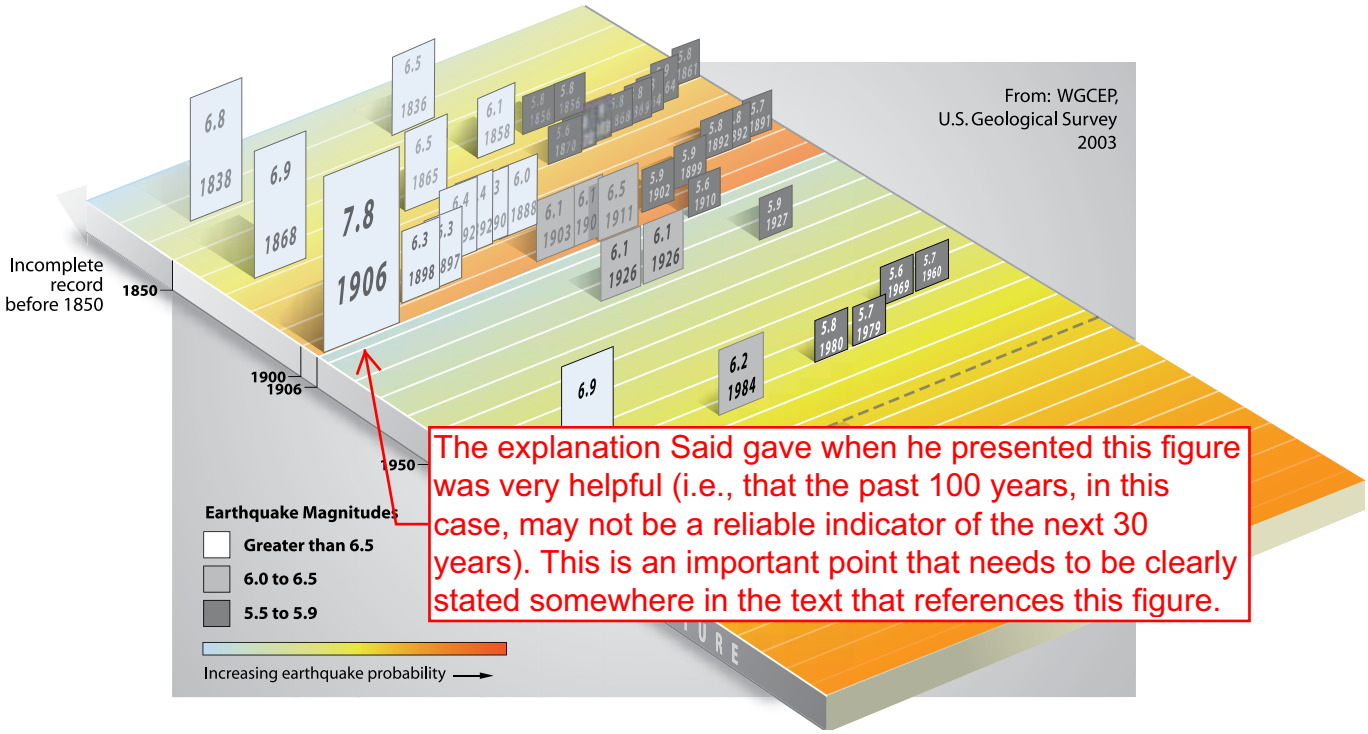
FIGURE 6 **Faults and seismic sources in the regional vicinity of the Delta**

Source: DRMS Risk Report (URS/JBA 2008c), Fig. 6-1

Failure Probability of Individual Islands

The expected annual frequency of failure from earthquakes for each island is shown in **FIGURE 8** *[page 15]*. The map is color coded to show groups of islands with similar ranges of annual seismic failure rates. The areas with lower seismic failure rates tend to be in the western Suisun Marsh and the eastern and northern portions of the Delta. The areas with higher seismic failure rates are in the central and south-western Delta and eastern Suisun Marsh.

[DRAFT]



The explanation Said gave when he presented this figure was very helpful (i.e., that the past 100 years, in this case, may not be a reliable indicator of the next 30 years). This is an important point that needs to be clearly stated somewhere in the text that references this figure.

FIGURE 7 **Past and future earthquakes in the Bay and Delta regions**

Source: DRMS Risk Report (URS/JBA 2008c), Fig. 13-8

DURATION AND COST OF REPAIRS for Earthquake-Induced Levee Failures		
Number of Flooded Islands	Estimated Range of Cost of Repair and Dewatering [$million]	Estimated Range of Time to Repair Breaches and Dewater [days]
1	43 – 240	136 – 276
3	204 – 490	270 – 466
10	620 – 1,260	460 – 700
20	1,400 – 2,300	750 – 1,020
30	3,000 – 4,200	1,240 – 1,660

TABLE 2 *Source: DRMS Risk Report (URS/JBA 2008c), Table 13-9*

EXPORT DISRUPTION from Earthquake-Induced Levee Failures		
Number of Flooded Islands	Duration of Export Disruption [days]	Amount of Water Not Exported [millions of acre-feet]
1	0 – 138	0 – 1.1
3	1 – 197	0 – 2
10	1 – 320	0 – 3.1
20	2 – 481	0.01 – 8.2
30	3 – 624	0.1 – 10.6

TABLE 3 *Source: DRMS Risk Report (URS/JBA 2008c), Figures 13-17 and 13-18; William Betchart, personal communication, July 2008.*

These tables need captions. Also, would be helpful to change "days" to "weeks". No one has a good concept of how many weeks 1,200 days is.

Emergency Response and Lev

This is not only due to the number of ...

The duration and cost of levee repairs rise with the number of islands flooded in an earthquake [TABLE 2]. not only from the number of repairs required but also due to availability of labor and materials to make repairs. For example, it ~~will~~ take 750 to 1,020 days (about 2 to 3 years) and $1.4 to $2.3 billion to repair damaged and breached levees and dewate 20 flooded islands. As noted in the previous section there is about a 53 percent chance that ~~such~~ an earthquake will strike the Delta Region in the next 25 years (2005- 2030).

would

capable of causing such damage

Export Disruption

Earthquake damage to the levees and the islands they protect could take years to repair. The largest and most

...emergency repair could cost up to

$2.3 billion

and take about 3 years to repair 20 flooded islands.

in 2005 dollars?

significant impacts from levee failures are to the state's water supplies. For example, for 20 flooded islands the export of Delta fresh water could be disrupted for about a year and a half, with a loss of up to 8.2 million acre-feet of water to state and federal water contractors and local water districts [TABLE 3]. Again as noted in the probability section there is a 53 percent chance that such an event will occur in the next 25 years (2005- 2030). Contra Costa Water District, an urban agency in Northern California, is likely to be at the greatest economic risk from disruption, particularly in dry years, ~~because~~ this district relies heavily on Delta water.

when

onomic Consequences

The total economic costs and impacts from multiple levee failures in the Delta could be tens of billions of dollars to the state. FIGURES 9A AND 9B show the probability of economic losses from potential earthquakes during the 25-year period 2005 through 2030. For example, there is about 40 percent chance of incurring $22 billion or more in costs [FIGURE 9A] and about $3 billion or more in impacts [FIGURE 9B].

[D R A F T]

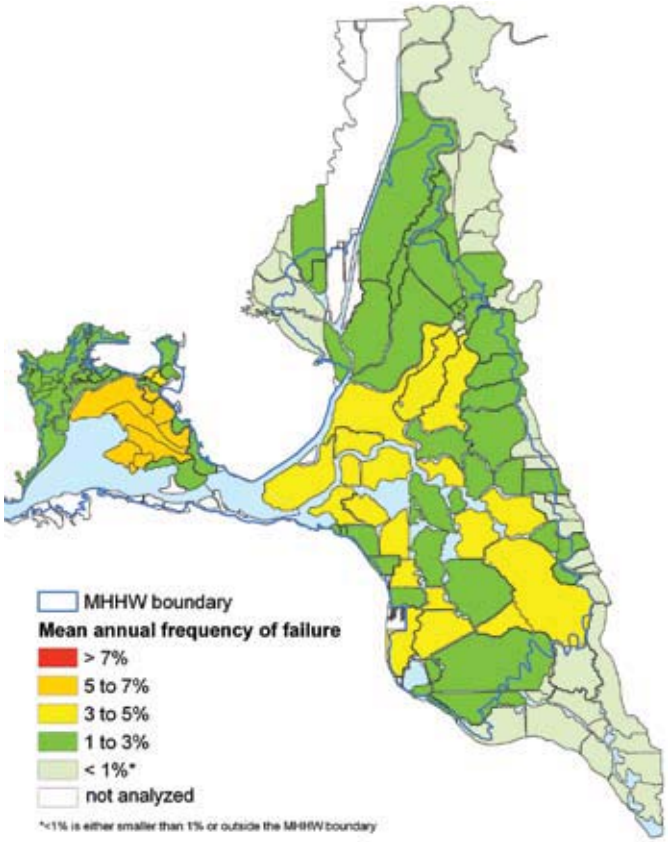
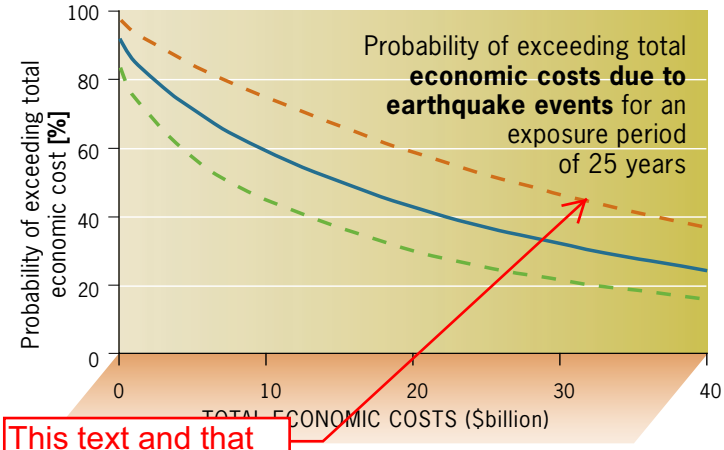
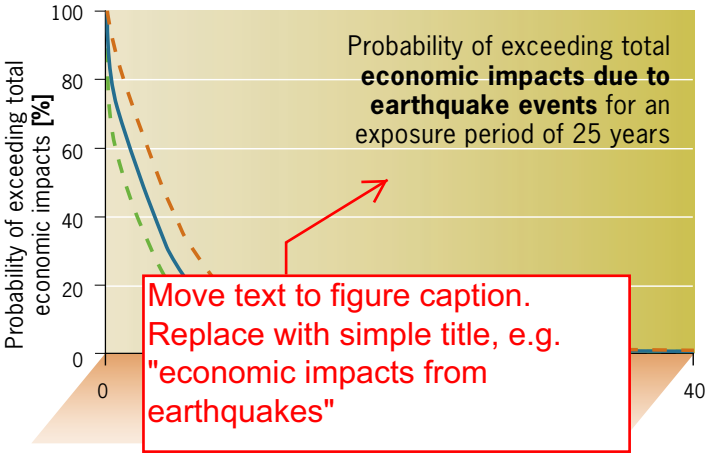


FIGURE 8 Annual frequency of failure of individual islands as a result of earthquakes

Source: DRMS Risk Report (URS/JBA 2008c), Fig. 13-7





Move text to figure caption. Replace with simple title, e.g. "economic impacts from earthquakes"

This text and that on figure 9b should be moved to the beginning of the figure caption. All you need here is a simple title (e.g. economic costs from earthquakes). Also "exposure period" is jargon. Use time period instead.

r *[84% confidence]* — Median *[50% confidence]* — Lower *[16% confidence]*

the direct economic losses associated
racts, islands, and infrastructure; the
and the payment of living expenses for
tural losses; and the lost water supply to
ntractors and local water districts.

S/JBA 2008c), Fig. 13-19a (costs) and 13-19b (impacts)

FIGURE 9b

Economic Impacts *include the indirect economic losses associated with the loss of potential revenues because of services not provided. These include the loss of revenue that customers of Pacific Gas and Electric Company, Metropolitan Water District of Southern California, railroads and other service providers suffer because they lose the services these companies provide, combined with lost wages and jobs that result because consumers lose these services.*

two periods

Impacts to Water Quality

how much?

DISSOLVED ORGANIC CARBON: If subsided Delta islands flood due to a levee breach, significant amounts of dissolved organic carbon (DOC) would be released from the high organic-matter soils. Depending on several factors, these elevated levels of DOC could adversely affect the drinking water supply from the Delta. DOC reacts with disinfectants during the drinking water treatment process to produce disinfection byproducts, many of which can cause cancer ~~at elevated~~ levels.

If they occur at sufficiently high

After the suspended sediments have cleared from Delta island flooding, algae may increase and bloom, which would produce another source of DOC and disinfection byproducts. These [illegible] could challenge water treatment facilities and require ~~costly~~ treatment and could e[illegible]s that supply drinking water to many urban areas for an unspecified period. These events could also increase food supply to the ecological food web, though the food would not necessarily support native species.

expensive

run-on sentence

METHYLATION OF MERCURY: Some soils in the Delta Region ~~have moderate levels of mercury~~ due, among other things, to historical inputs from gold mining activities during the Gold Rush. When islands are flooded, some mercury in the soils can change from a non-toxic element to the toxic methylated form under some circumstances.. Methylated mercury can be absorbed by an organism at a rate quicker than the organism can lose it, allowing the Methylated mercury to move up the food chain to fish and humans. Of particular concern is the availability of Methylated mercury during algal blooms, which provides a pathway up the food chain.

of what - levee failure?

Ecosystem Consequences

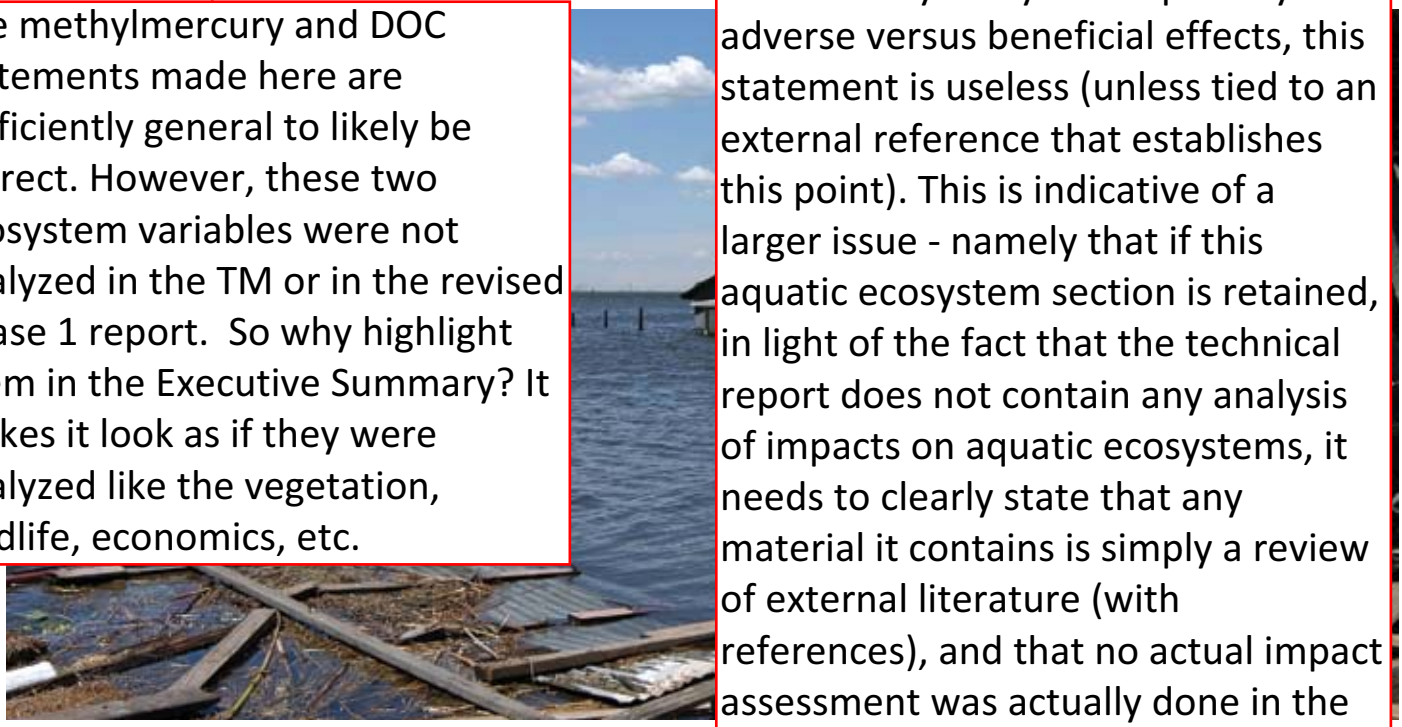
Ecosystem impacts and consequences are similar, whether they result from seismic, flood or sunny day failures. The key factors are time of year, water conditions, location and number of breaches.

Can't state this. Ecosystem impacts were not adequately quantified in the technical report.

IMPACTS TO AQUATIC [illegible] flooding caused by earthquakes can have both adverse and beneficial impacts on the aquatic ecosystem. Aquatic species ~~can die as a result of entrainment~~ (i.e., inflow of water through a breach in a levee that transports fish into a flooding island) combined with the ensuing murky waters during and

The methylmercury and DOC statements made here are sufficiently general to likely be correct. However, these two ecosystem variables were not analyzed in the TM or in the revised Phase 1 report. So why highlight them in the Executive Summary? It makes it look as if they were analyzed like the vegetation, wildlife, economics, etc.

Without any analyses to quantify the adverse versus beneficial effects, this statement is useless (unless tied to an external reference that establishes this point). This is indicative of a larger issue - namely that if this aquatic ecosystem section is retained, in light of the fact that the technical report does not contain any analysis of impacts on aquatic ecosystems, it needs to clearly state that any material it contains is simply a review of external literature (with references), and that no actual impact assessment was actually done in the DRMS Phase I report.



Flood damage – Delta (June 7, 2004). Source: DWR

DRAFT

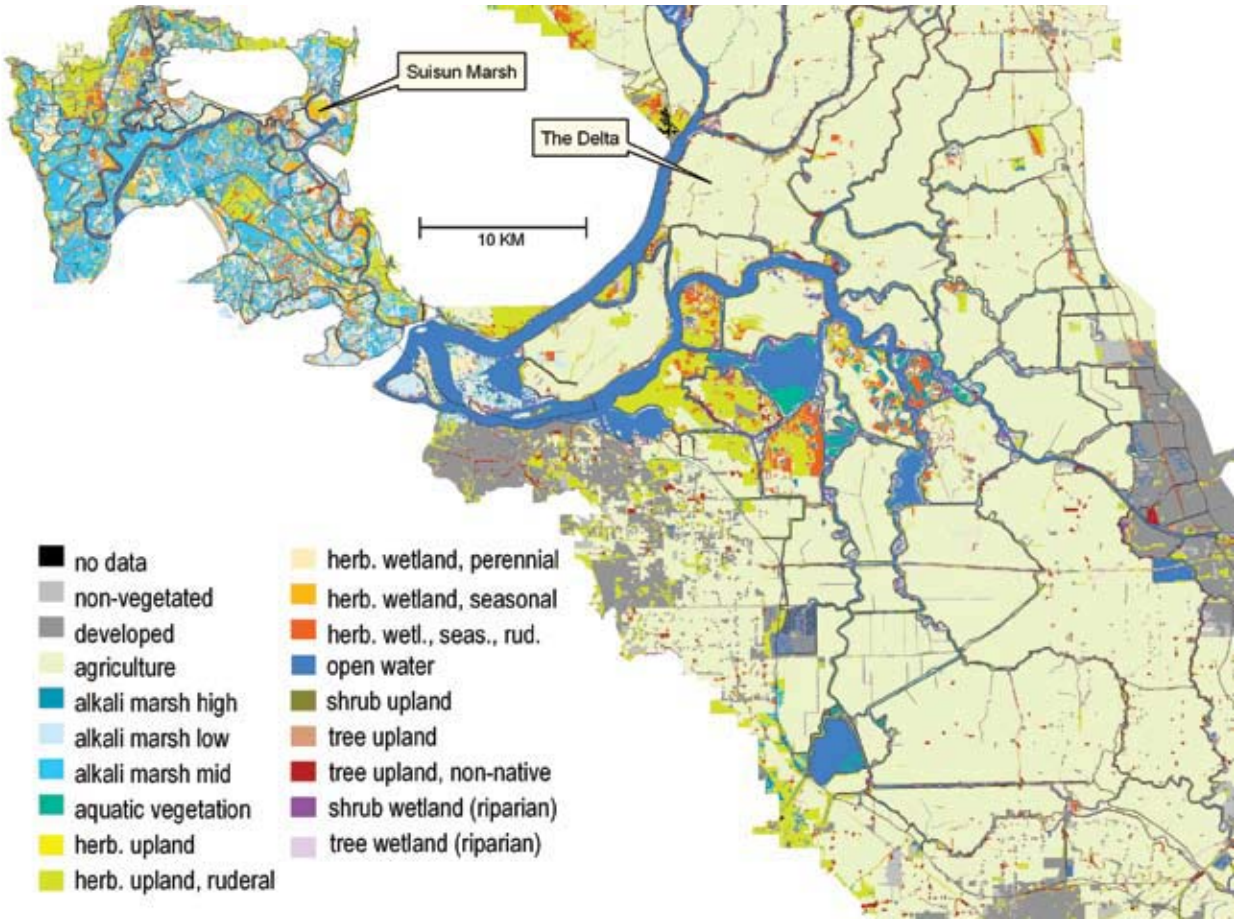


FIGURE 10

Needs a figure caption

Vegetation of the Delta and Suisun Marsh

Source: DRMS Risk Report (URS/JBA 2008c), Fig. 12-13a, 12-13b, and 12-13c

immediately after islands flood. Pumping flooded islands after breach repair will also kill aquatic species that inadvertently colonized island habitat. On the other hand, the temporary stoppage of water export operations and the creation of new aquatic habitat present potential ecosystem benefits. The magnitude of each of these impacts varies by specie, number and location of flooded islands, time of year that flooding occurs and the time that elapses between levee failure and breach repair.

missing comma

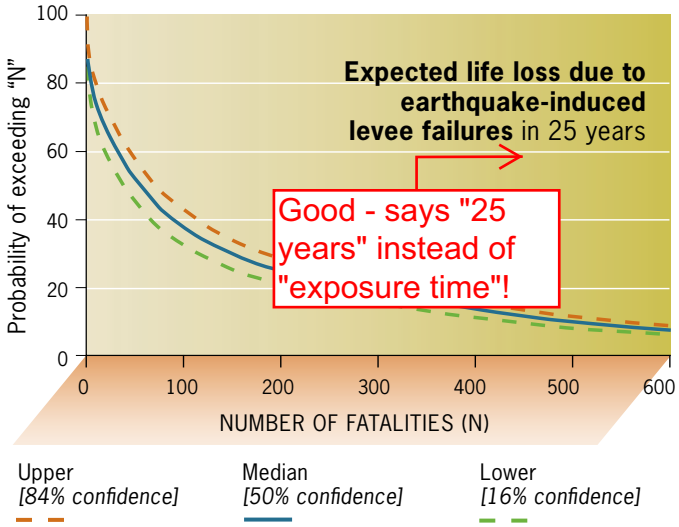
IMPACTS TO NATURAL VEGETATION: FIGURE 10 shows the natural vegetation of the Delta and Suisun Marsh. In all seismic levee failure scenarios, the vegetation area that is damaged increases with the area flooded, but the degree of impact depends on the vegetation type. Results indicate losses of up to 39 percent of herbaceous wetland, seasonal ruderal vegetation; 29 percent of non-native trees; and 24 percent of shrub wetland in the Delta and Suisun Marsh. (Agricultural vegetation is not discussed here.) Of the critical vegetation types that include native vegetation and rare species of vegetation, native herbaceous upland vegetation (which comprises a small total area of the Delta [less than 500 acres]) is not impacted by flooding in any of the cases. Also, less than 12 percent of critical intertidal and aquatic habitat is impacted in any scenario. However, a considerable amount of critica habitat including alkali high marsh, shrub wetland and ripar trees are reduced by 10-24 percent in the Delta and Suisun Marsh. Overall, these results, though not incorporating the impacts of levee breaches on sensitive species, suggest that the primary impacts of flooding are on non-native vegetation types.

how much?

IMPACTS TO TERRESTRIAL SPECIES: The breaching of levees in Suisun Marsh would potentially result in impacts on several terrestrial wildlife species of concern, including

POTENTIAL losses

DRAFT



Good - says "25 years" instead of "exposure time"!

FIGURE 11 *Source: DRMS Risk Report (URS/JBA 2008c), Fig. 13-20*

Needs a caption.

the federally endangered saltmarsh harvest mouse and the California clapper rail, and saltmarsh common yellowthroat and Suisun ornate shrew. The results suggest that large-scale levee breaches cause substantial losses of available habitat, food shortages, and displacement of birds and other terrestrial species. However, other environmental benefits could result due to the increase in tidal water habitat.

Public Health and Safety Consequences

The Delta island levees most likely to fail are generally located in the central-west area of the Delta. Their failure ~~will~~ cause rapid flooding of the affected islands, leaving little time for evacuation.

would

The most immediate public safety concern is for the people on flooded islands. The estimated loss of life resulting from an earthquake in the region is shown on FIGURE 11. For example, there is a 40 percent probability of 90 fatalities or more in the region from earthquake-induced levee failures in 25 years (2005-2030). The expected life loss from earthquake-induced island flooding is higher because of the reduced warning time during major earthquake events.

Future Seismic Risk

Assuming an earthquake does not happen before years 2050 and 2100, all factors considered in developing an estimate of seismic risk are expected to increase. These factors include the likelihood of future earthquakes, the seismic vulnerability of levees, and the consequences of levee failures. TABLE 4 provides a range of low, medium, and high estimates of the increase in these factors for 2050 and 2100 relative to the 2005 business-as-usual assumption. Due to an increase in seismic hazard and levee fragility in the future, the risk of levee failure in the Delta Region increases on average by 35 percent over the next 50 years and 93 percent over the next 100 years. The more significant increases in risk are expected for impacts to in-Delta resources (potential life loss and expected economic losses). These risks increase because of the impact of salinity intrusion and the growing statewide population and economy. The potential loss of life is expected to increase on average by about 250 percent from 2005 to 2050. The expected economic losses are anticipated to increase on average by about 200 percent for 2050 and by about 500 percent for 2100.

DRAFT

EXPECTED FUTURE INCREASE IN EARTHQUAKE HAZARD AND ITS CONSEQUENCES

Risk Factor	2050			2100		
	Low	Medium	High	Low	Medium	High
Seismic Hazard	10%	10%	10%	20%	20%	20%
Frequency of Island Flooding[a]	28%	35%	49%	68%	93%	140%
Potential Loss of Life	229%	249%	283%	N/A	N/A	N/A
Expected Economic Losses	160%	202%	260%	291%	500%	831%

TABLE 4 [a] *Increased frequency in island flooding reflects increased hazard and fragility. N/A = not available.*
Source: URS/JBA 2008c, Table 14-23

Table needs a caption.

FLOOD RISKS

Although earthquakes pose the greatest single risk to the Delta Region, flooding is also a serious hazard. High water during large floodflows into the Delta Region can overtop levees or increase hydrostatic pressure on levees and their foundations, causing instability. High water can also cause through-levee seepage and under-levee seepage failures. Most levee failures in the Delta Region have occurred during floods, often in conjunction with high tides, storm surges, or other storm-related phenomena. FIGURE 12 shows measured and predicted water surface elevation and ranges as a function of return periods at the Venice Island monitoring station (VNI). See FIGURE 1.

What is Fig 1? Need reminder - it's been a long time.

Probability of Multiple Levee Failures

Levee breaches from high floodflows into the Delta are the most common type of failure. Considering the probability of all flood-related levee breaches under current conditions, about 140 failures ~~will~~ occur in the Delta during the next 100-year period (compared to 166 in the past 100 years). This number corresponds to an average rate of 1.4 failures per year.

are likely to (not will)

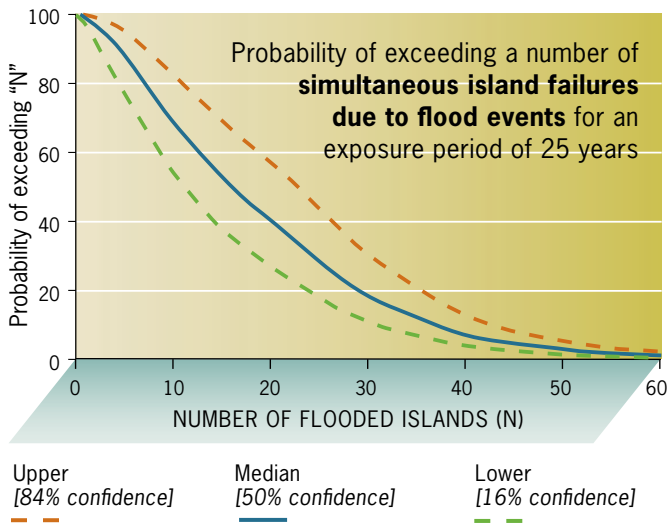
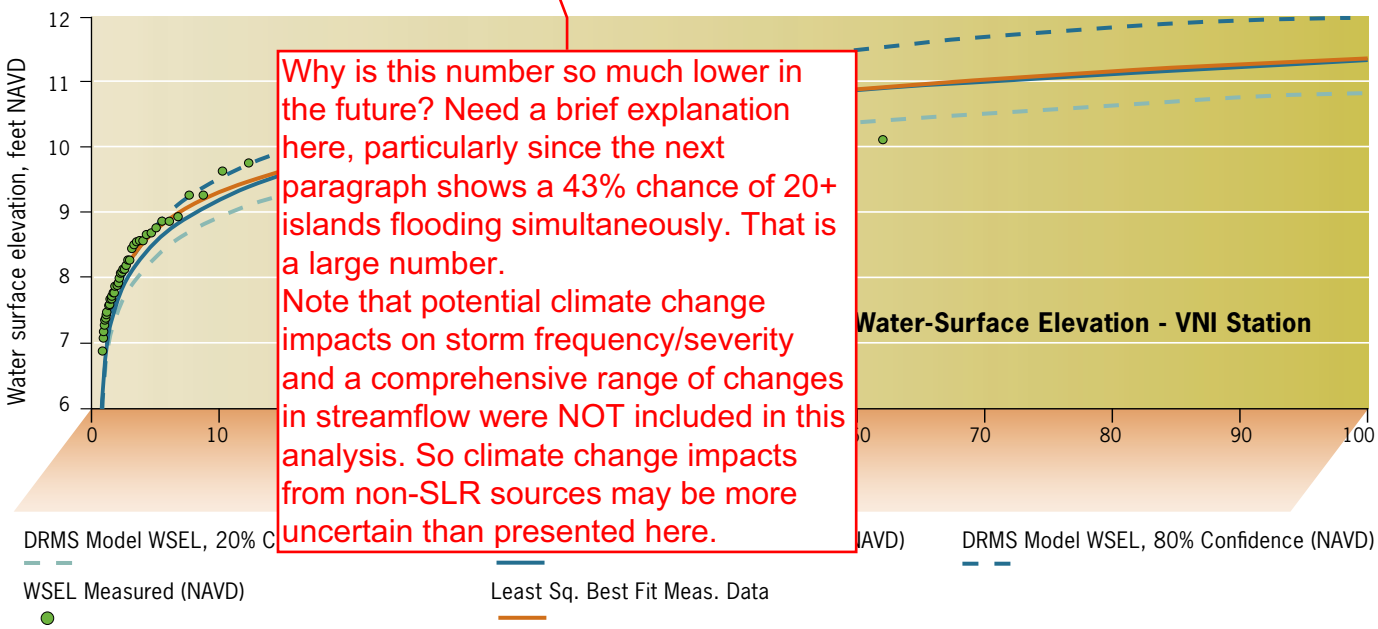


FIGURE 13 *Source: DRMS Risk Report (URS/JBA 2008c), Fig. 13-11*

Need to simplify figure title (probability of multiple island floods) and add figure caption.

Depending on the severity of the in-Delta storm-induced flows, multiple islands could fail during a single storm event. FIGURE 13 illustrates the probability of multiple islands flooding for the 25-year period 2005 through 2030 under business-as-usual conditions. For example, there is a 43 percent chance on average that 20 islands or more will flood in the Delta region during a flood event in 25 years (2005-2030).



Why is this number so much lower in the future? Need a brief explanation here, particularly since the next paragraph shows a 43% chance of 20+ islands flooding simultaneously. That is a large number.
Note that potential climate change impacts on storm frequency/severity and a comprehensive range of changes in streamflow were NOT included in this analysis. So climate change impacts from non-SLR sources may be more uncertain than presented here.

FIGURE 12 *Source: DRMS Flood Hazard TM (URS/JBA 2008a), Figure 7.1*

Needs caption.

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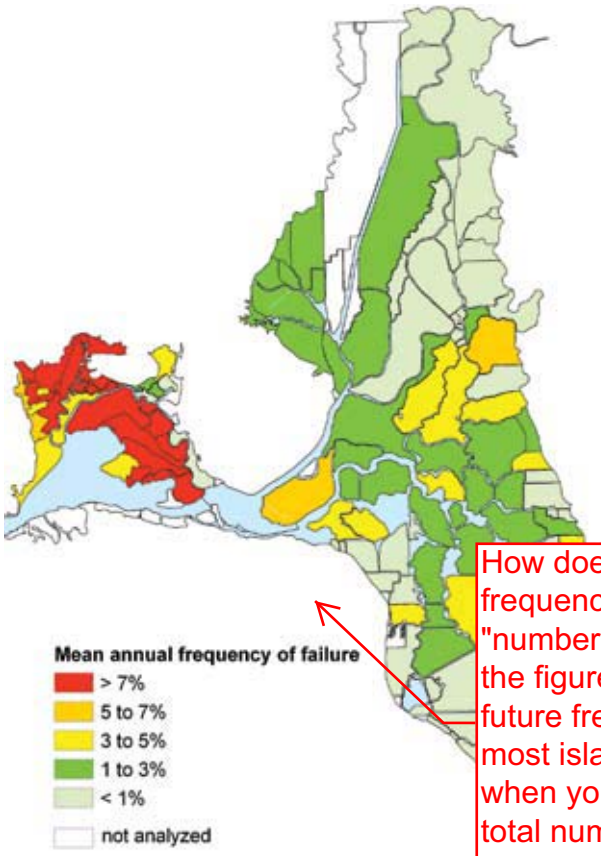

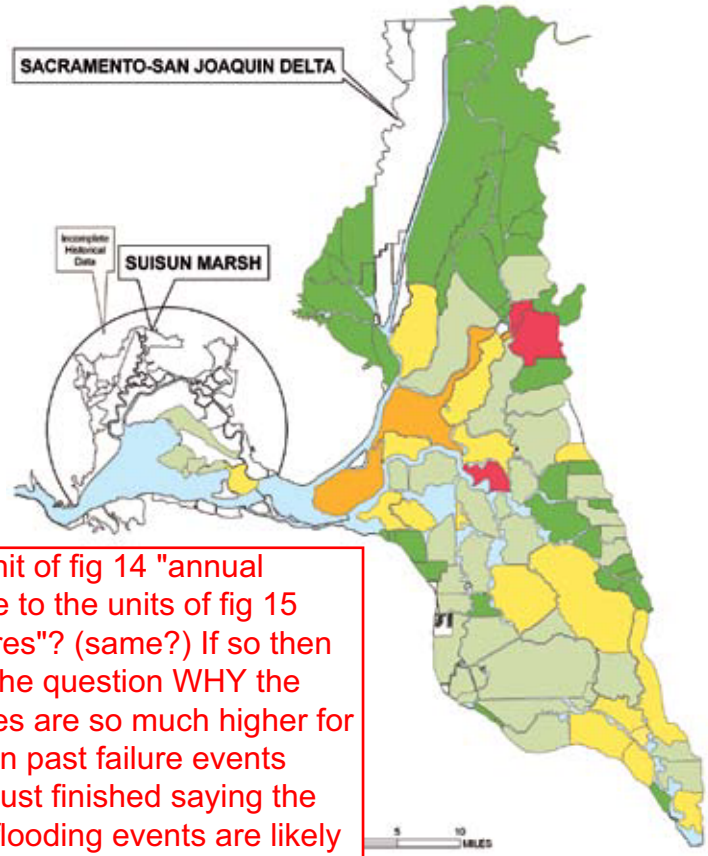

How does the unit of fig 14 "annual frequency" relate to the units of fig 15 "number of failures"? (same?) If so then the figures beg the question WHY the future frequencies are so much higher for most islands than past failure events when you have just finished saying the total number of flooding events are likely to be less in the 2000s than the 1900s.

FIGURE 14 **Expected future mean annual frequency of failure of individual islands as a result of floods**

Source: DRMS Risk Report (URS/JBA 2008c), Fig. 13-13a

FIGURE 15 **Number of failures in the last 100 years for individual islands as a result of floods**

Source: DRMS Risk Report (URS/JBA 2008c), Fig. 13-13b

Failure Probability of Individual Islands

The expected annual frequency of flood-related failure for each island is shown in **FIGURE 14** as fitting into one of five bands (less than 1 percent, between 1 percent and 3 percent, etc.). The areas with higher failure rates tend to be in Suisun Marsh and to a lesser extent in the central and western parts of the Sacramento-San Joaquin River Delta, but overall the patterns appear to be more variable for floods than for earthquakes. **FIGURE 15** shows the actual annualized numb After of levee failures since 1900.

Emergency Response and Levee Repair

In general the cost of levee repairs are less for floods than for earthquakes because flood-related breaches tend to be more localized and much smaller than seismic-induced levee breaches. The duration of repair and dewatering are generally similar for a given number of flooded islands.

is estimated to take

As shown in **TABLE 5**, for example, it ~~will~~ take about 930 to 1,110 days (about 2½ to 3 years) and $990 million to $1.2 billion to repair damaged and breached levees and dewater 20 flooded islands.

Export Disruption

~~Under~~ flood-induced levee failures, no significant export disruptions are expected at the time of the failure. The Delta would be flooded with fresh water; the size and number of levee breaches would be smaller (compared to earthquake-induced breaches); and with fewer breaches the repairs would take less time. Due to these factors the Economic costs and impacts would generally not be as high as ~~with the~~ earthquake-induced failures.

remove "E"

[DRAFT]

Run-on sentence. Change to: "... disrupted. High fresh water flows will dilute ..."

primarily due to

Economic Consequences

Unlike Seismic events, the majority of the total economic costs and impacts from multiple island failures in the Delta and Suisun Marsh from floods, would be in-Delta costs. This is due primarily to the fact that water exports are not expected to be disrupted with the high fresh water flow to dilute any contaminants resulting from flooded islands. **FIGURES 16A AND 16B** show the probability of economic losses from floods over the next 25 years (2005-2030). For example, there is on average a 40 percent chance of incurring about $10 billion or more in costs **[FIGURE 16A]** and about $4 billion or more in impacts **[FIGURE 16B]**.

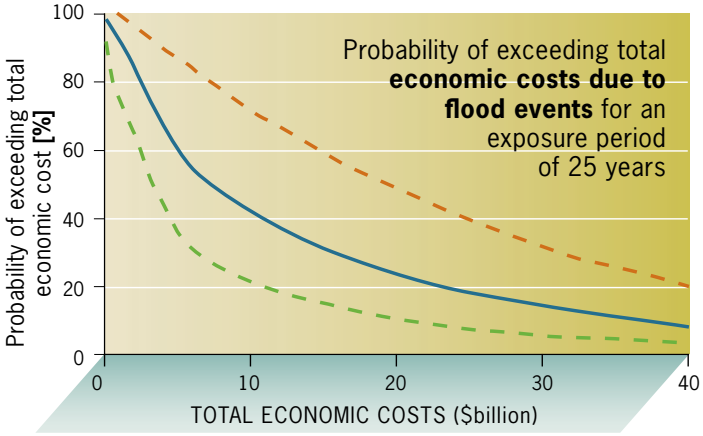

FIGURE 16a

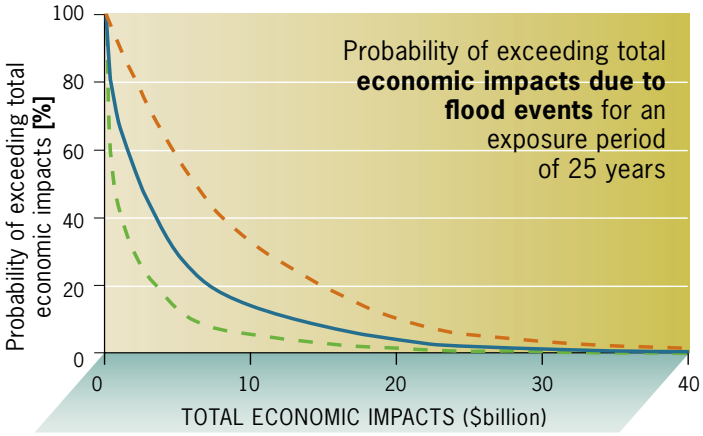

FIGURE 16b

Upper [84% confidence] Median [50 Lower nfidence]

Source: DRMS Risk Report (URS and 13-21b (impacts)

Shorten figure titles and add longer captions.

DURATION AND COST OF REPAIRS for Flood-Induced Levee Failures		
Number of Flooded Islands	Estimated Range of Cost of Repair and Dewatering [$million]	Estimated Range of Time to Repair Breaches and Dewater [days]
1	30 – 110	47 – 170
3	140 – 260	240 – 450
10	490 – 680	590 – 1,060
20	990 – 1,200	930 – 1,110
30	1,500 – 1,800	1,380 – 1,580

TABLE 5 *Source: DRMS Risk Report (URS/JBA 2008c), Table 13-26.*

Table needs caption. Dollars need year attached. Time should be in weeks not days.

Impacts to Water Quality

Although flood-induced impacts to water quality are similar to those following a major earthquake, DOC and Methylated mercury concentrations during and after a flood are expected be lower because of high freshwater inflows during storm events.

DISSOLVED ORGANIC CARBON: If subsided Delta islands flood due to a levee breach, significant amounts of DOC would be released from inside the islands. Depending on several factors, these elevated levels of DOC could adversely affect the drinking water supply from the Delta. DOC reacts with disinfectants during the drinking water treatment process to produce disinfection byproducts, many of which can cause cancer at elevated levels. After the suspended sediments have cleared, algae may increase and bloom, which would produce another source of DOC and disinfection byproducts.

METHYLATION OF MERCURY: When islands are flooded, mercury in the soils can change from a non-toxic element to the toxic methylated form. Methylated mercury can be absorbed by an organism at a rate quicker than the organism can lose it, allowing it to move up the food chain to fish and humans. Of particular concern is the availability of Methylated mercury during algal blooms, which provides a pathway up the food chain.

All of this material is a DIRECT repeat from earlier. Best to condense and refer reader back to previous section.

[DRAFT]

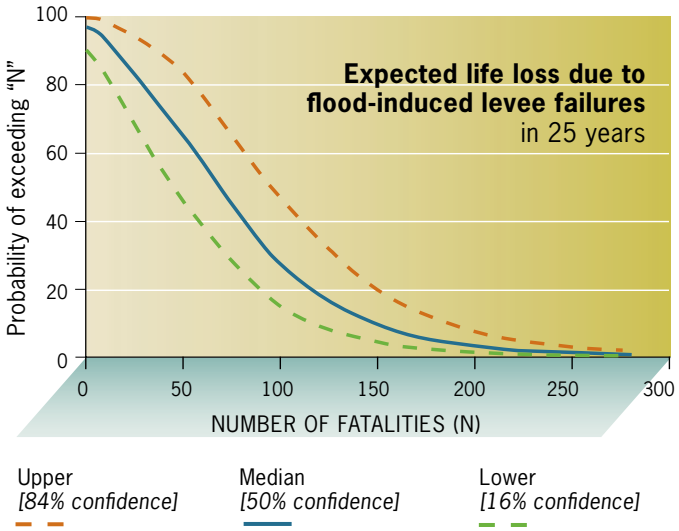

FIGURE 17 *Source: DRMS Risk Report (URS/JBA 2008c), Fig. 13-22*

Add figure caption.

Ecosystem Consequences

IMPACTS TO AQUATIC SPECIES: Levee failure and island flooding caused by floods, like those caused by seismic events, can have both adverse and beneficial impacts on the aquatic ecosystem. Aquatic species can die as a result of entrainment (i.e., inflow of water through a breach in a levee that transports fish into a flooding island) combined with the ensuing murky waters during and immediately after islands flood. Pumping flooded islands after breach repair also kills aquatic species that colonize island habitat. The magnitude of each of these impacts varies by specie, number and location of flooded islands, time of year that flooding occurs and the time that elapses between levee failure and breach repair.

IMPACTS TO VEGETATION: Flooding harms areas of vegetation, but the degree of impact depends on the vegetation type. (See FIGURE 10 Vegetation of the Sacramento-San Joaquin River Delta and Suisun Marsh.) Of the critical vegetation types that include native vegetation and rare species of vegetation, native herbaceous upland vegetation (which comprises a small total area of the Delta Region [less than 500 acres]) was not impacted by flooding in all scenarios. Overall, results, though not incorporating the impacts of levee breaches on sensitive species, suggest that the primary impacts of flooding are on non-native vegetation types.

IMPACTS TO TERRESTRIAL SPECIES: The breaching of levees in Suisun Marsh would potentially result in impacts on several terrestrial wildlife species of concern, including the federally endangered saltmarsh harvest mouse and the California clapper rail, and saltmarsh common yellowthroat and Suisun ornate shrew. The results suggest that large-scale levee breaches cause substantial losses of available habitat, food shortages, and displacement of birds and other terrestrial species.

DRAFT

All of this material is also a direct repeat from earlier. It should be shortened and re-phrased to avoid repetition.

EXPECTED FUTURE INCREASE IN FLOOD HAZARD AND ITS CONSEQUENCES

Risk Factor	2050			2100		
	Low	Medium	High	Low	Medium	High
Flood Hazard	35%	194%	500%	130%	458%	1,140%
Frequency of Island Flooding[a]	241%	261%	297%	681%	798%	1,016%
Potential Loss of Life	676%	723%	803%	N/A	N/A	N/A
Expected Economic Losses	676%	723%	803%	N/A	N/A	N/A

TABLE 6 [a] *Increased frequency in island flooding reflects increased hazard and fragility. N/A = not available.*
Source: URS/JBA 2008c, Table 14-23.

Add table caption.

would

need a time frame here - is already causing SLR? is projected to cause future SLR?

Public Health and Safety Consequences

The primary public safety concern after a flood-induced levee failure is for the people on flooded islands. FIGURE 17 shows estimates of the population at risk. For example, there is on average a 40 percent probability of 80 fatalities or more in the region from flood-induced levee failures in 25 years (2005-2030). The population at risk is high during a flood-induced levee failure because larger areas are at risk to flood (more islands and tracts), such as the Sacramento Pocket Area and the City of West Sacramento.

... as compared to?

This first part of the paragraph needs to be better organized. It alternates between streamflow and SLR impacts in a confusing way. Also second half of paragraph should be separated.

Future Flood Risks

Climate change will cause sea level rise and more frequent floods due to a change in hydrograph to more rain and less snow, which ~~will~~ increase the future flood hazard in the Delta Region. Also, sea level rise will increase the possibility of overtopping during floods. The freshwater inflow from the floodflows will generally prevent immediate salinity intrusion, but long periods to repair levees may present problems in subsequent periods of low flow. Large in-Delta impacts from additional flooding are expected, due especially to increased population and development, as well as increased pressure on the ecosystem. The potential loss of life in the Delta is expected to increase on average by 723 percent from 2005 to 2050. The expected economic losses are also anticipated to increase on average by 723 percent from 2005 to 2050 [TABLE 6].

Are these additional impacts due to climate change alone? Not clear.

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SUNNY DAY LEVEE FAILURE RISKS

Sunny day failures occur occasionally during non-flood conditions. Such failures are attributed to many factors: rodent activities, pre-existing weaknesses in the levee fill and foundation (given the non-engineered construction of the levees), slow deterioration with time, and other circumstances ~~(subsidence, ditches, etc.).~~ Often, high tides, low barometric pressure, or sea level surges worsen conditions and lead to failures. The most recent example of a sunny day failure is the June 2004 failure of the Upper Jones Tract levee. The total cost of the damage and island recovery was nearly $100 million.

how many islands flooded in this event?

including subsidence and ditches.

Historical levee failures were used as the model to estimate the rate of sunny day levee failures. Under 2005 business-as-usual conditions, the Sacramento-San Joaquin River Delta is expected to have about ~~ten~~ sunny day breaches and the Suisun Marsh will have about ~~four~~ sunny day breaches in a 100-year period.

10, 4

[DRAFT]

Sandbags temporarily control a sand boil on Staten Island on June 18, 2007. The muddy water indicates that material in the levee or its foundation is being washed away. Unnoticed, sand boils can lead to a failure of the levee.
Source: DWR

COMBINED RISK OF ISLAND INUNDATION FROM MULTIPLE HAZARDS

likelihood or probability - NOT frequency.

The probability that an individual island will flood due to any cause can be estimated from the expected annual ~~frequency~~ of failures due to earthquakes, floodflows, and sunny day events.

Considering the probability of levee breaches from all hazards for the 2005 business-as-usual conditions, the annual ~~frequency~~ of individual islands flooding due to these hazards (earthquake, floodflows, and sunny day) is illustrated in FIGURE 18. This figure indicates that islands in Suisun Marsh and the central-southern Sacramento-San Joaquin River Delta are the most vulnerable with a mean annual ~~frequency~~ of failure greater than 5 percent.

Where is the same map for future conditions?? There should be a side-by-side comparison here.

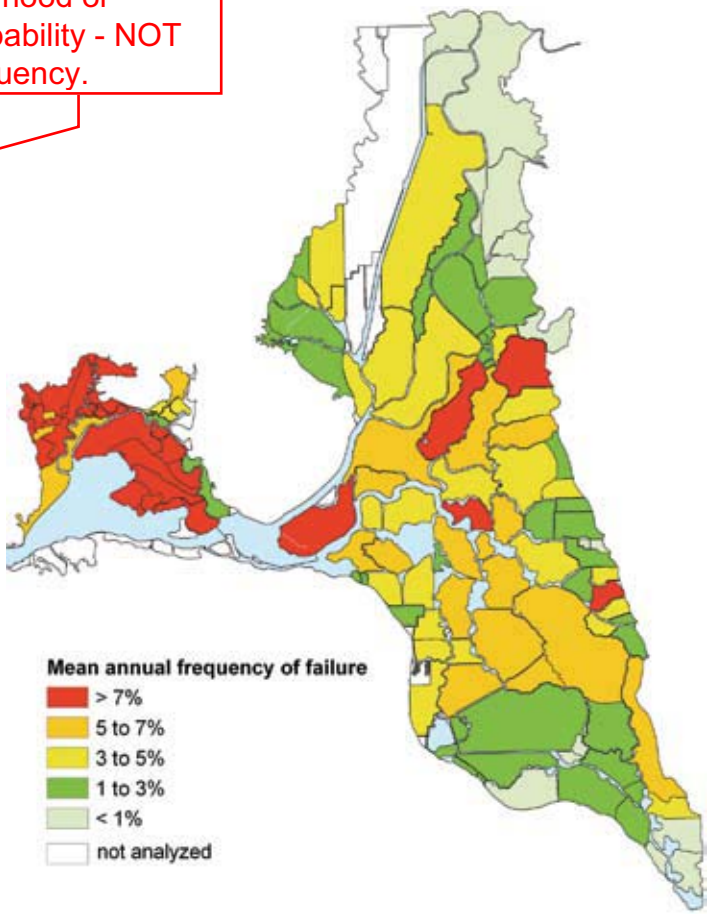

FIGURE 18 **Mean annual frequency of failure for individual islands under combined earthquake and flood risks**

Source: DRMS Risk Report (URS/JBA 2008c), Fig. 13-16

[D R A F T]

This doesn't seem to fit what URS stated to the IRP. i.e., that Phase 2 would be considering 3 scenarios.

NEXT STEP

Source: DWR

Phase 2 of DRMS will evaluate risk-reduction options for long-term management of the Delta and Suisun Marsh levees. It will not propose a new plan for the Delta Region; rather, Phase 2 will describe a set of actions that can be taken to reduce risks to the economy and the ecosystem from levee failures resulting from earthquakes, floodflows, sunny day failures and the effects of ongoing subsidence and climate change. Phase 2 is expected to be available for public review in December 2008.

More information on the DRMS Risk Report and its supporting Technical Memoranda can be found on the DRMS portal, http://www.drms.water.ca.gov/, part of the Web site of the California Department of Water Resources.

General comment on references: For statements made in the executive summary that are not supported directly by the DRMS Phase 1 report, an external reference should be provided.

SELECTED REFERENCES

CALFED. 2000. Record of Decision.

California Department of Water Resources. 2007. Delta Risk Management Strategy. Web site: http://www.drms.water.ca.gov/.

IPCC (Intergovernmental Panel on Climate Change). 2001. Climate Change, 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the IPCC. Cambridge, England: Cambridge University Press, 2001. Also available at http://www.grida.no/climate/ipcc_tar/.

Rahmstorf, Stefan. 2006. *A Semi-Empirical Approach to Projecting Future Sea-Level Rise, Sciencexpress*, www.sciencexpress.org, 14 December 2006. Science 19 January 2007 315(5810): 368–370. DOI: 10.1126/science.1135456.

URS (URS Corporation). 2007. *Status and Trends of Delta-Suisun Services*. Prepared for California Department of Water Resources. May.

URS/JBA (URS Corporation/Jack R. Benjamin & Associates, Inc.). 2007a. *Delta Risk Management Strategy, Phase 1, Subsidence Technical Memorandum*. Prepared for California Department of Water Resources.

URS/JBA (URS Corporation/Jack R. Benjamin & Associates, Inc.). 2007b. *Delta Risk Management Strategy, Phase 1, Water Analysis Module Technical Memorandum*. Prepared for California Department of Water Resources.

URS/JBA (URS Corporation/Jack R. Benjamin & Associates, Inc.). 2008a. *Delta Risk Management Strategy, Phase 1, Climate Change Technical Memorandum*. Prepared for California Department of Water Resources.

URS/JBA (URS Corporation/Jack R. Benjamin & Associates, Inc.). 2008b. *Delta Risk Management Strategy, Phase 1, Flood Hazard Technical Memorandum*. Prepared for California Department of Water Resources.

URS/JBA (URS Corporation/Jack R. Benjamin & Associates, Inc.). 2008c. *Delta Risk Management Strategy, Phase 1, Risk Analysis Report*. Prepared for California Department of Water Resources, July.

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RM Econ: Economic Analysis

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M-Cubed: Economic Analysis

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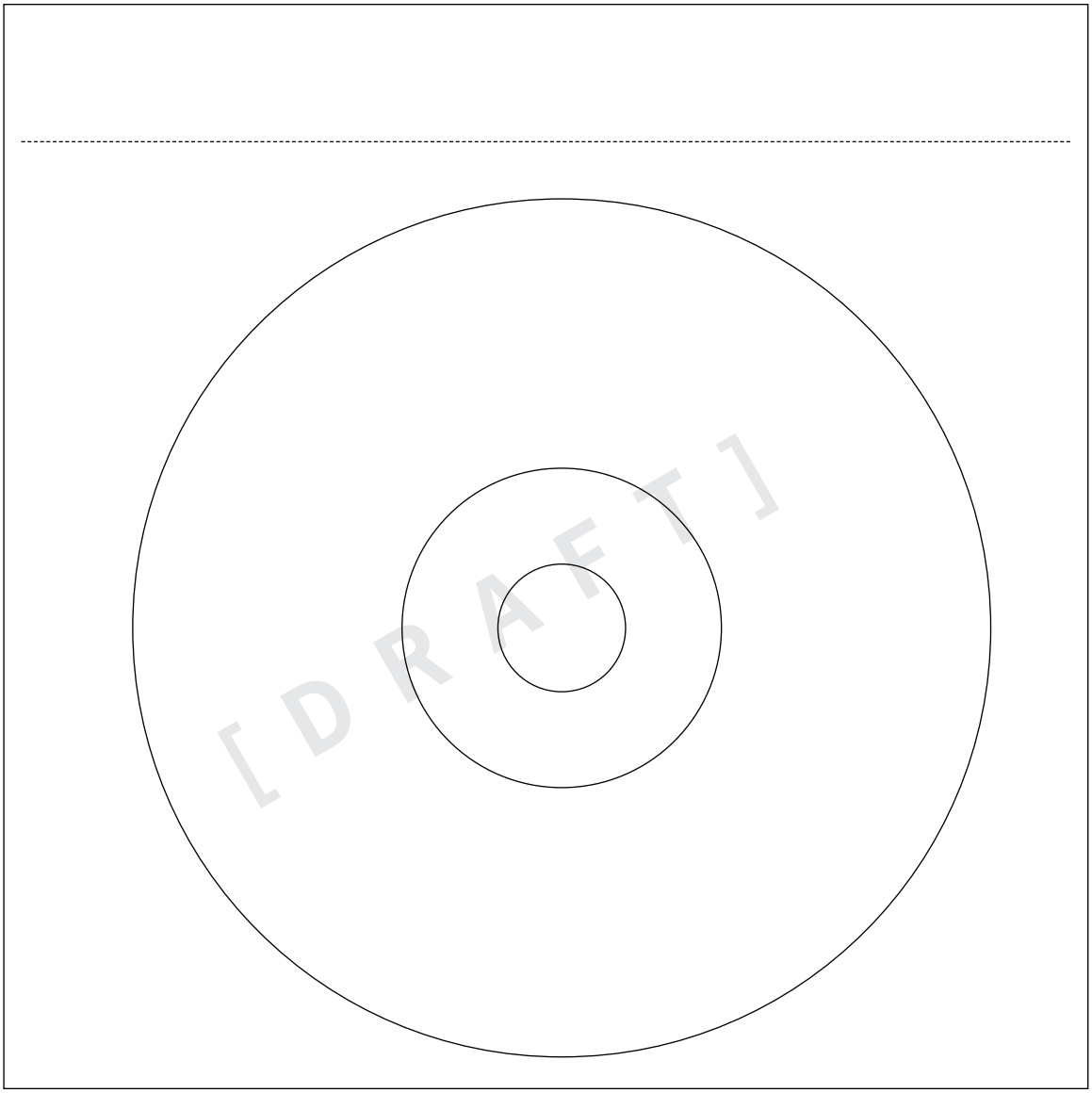
[D R A F T]

[D R A F T]