Delta Risk Management Strategy Phase I
Technical Memorandum: Draft Impact to Infrastructure

Comment	Response
Reviewer: Goettel – U.S. Army Corps of Engineers	
General Comment: The use of "infrastructure" seems incomplete, since much of the discussion and much of the damages deal with buildings (residential, commercial, and public), as well as agricultural and marine facilities that are not commonly designated as "infrastructure". A more generic title such as Infrastructure and Building Stock would be more descriptive.	The term "infrastructure" has been used to designate all buildings and structures. Clarification is added to Section 2.2
1. Section 2 has a nice summary of inventory included. It could be improved by adding approximate quantities: miles of roads, miles of transmission/pipe lines, number of residential structures, number of commercial/public structures etc. Such numerical totals would give a better "picture" of the magnitude of at risk inventory. Similarly, an approximate replacement value for each category would be informative and emphasize the magnitude of at risk assets in the Delta.	Approximate quantities are included in Table 2-1 at the end of Section 2.2.1.
2. The Figures showing the various categories of inventory are VERY informative. Since there are only a few figures (10 or 12), the usefulness of the report would be enhanced by moving these to Section 2 so they are more visible to the reader.	To avoid splitting main sections of the TM, the figures need to be at the end of the TM.
3. Similarly, the Maps of the analysis zones are inexplicably buried in Appendix C. At a minimum, these should be with the other figures, but preferable these should be in the body of the report, for easy reference.	See response to Comment 2 regarding location of the figures in the TM. These figures are renumbered as Figures 3-2, 3-3, and 3-4, and are with the other figures.
4. Section 3.2. Means 2005 is two+ (since Means 2005 is generated in 2004) years out of date. Why not update to 2007 values? Should be simple tweaks to spreadsheet calcs.	Costs are kept at the 2005 values because the economic losses and evaluations are based on 2005; both costs need to be at the same base date.

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5. Section 3.2. Note that Google Earth had 30% more structures than HAZUS for 20 islands. 30% is a big difference. Which numbers were used? Note, however, that many of these structures may be storage etc, not residential.	The HAZUS numbers were used. "Google Earth" only applied to 20 islands, and as noted in comment, not all structures are residential. This check indicates a limitation of the data. See clarification in Section 3.2.
6. Section 4.1.1. MHHW should be clearly defined for non-technical readers.	There are two high tides and two low tides each lunar day (24 hours and 50 minutes) in the San Francisco Bay and Delta. The two tides are unequal, one of the high tides is higher than the other, and one of the low tides is lower than the other. The higher of the high tides each day is known as higher high water (HHW) and the lower of the low tides is known as lower low water (LLW). Mean Higher High Water (MHHW) is the mean value of all the higher high tides for each day over a 19-year period. (Mean Lower Low Water (MLLW) is the average of all the lower low waters during the same 19-year period.) Footnote added for clarification in Section 4.1.
7. Section 4.1.2. Using the 100-year flood is logical and representative of flood damages, but: a. The footnote states that FIRMs are under revision. Are drafts available? In any case, some qualitative estimate of the likely change would be very helpful, such as flood elevations may be one to two feet higher? b. For below-sea-level islands, there probably aren't big differences in damages for other floods smaller or larger than the 100-year flood. However, for urban areas, there will likely be much larger differences – some commentary on this should be added to the existing text.	a. FEMA is currently in the process of updating some of the 100-year flood maps in California including the Bay Area. We are not aware of drafts that are available. At this time we do not know how the new floodplains will differ from the existing floodplains. b. The largest differences between damages for the 100-year event and other events would be for infrastructure located near the edge of the floodplain or areas with topographic relief. Added clarification to Section 7.2

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8. Page 16. The discussion (just above Section 4.2.2 should be amplified for clarity. Damage percentages were obtained from HAZUS depth-damage relationships for various types of infrastructure and buildings, for the average depths (if this was done) in each analysis zone.	This paragraph was deleted. See also response to Comment 10.
9. Scour damages. The draft has NO information about how scour damages were calculated. Per the modeling, scour is assumed to affect only 2000' x 2000' sections of a breached analysis area, but the location of the breach is random. Thus, the location and extent of scour damage will vary markedly from next to none (if there is nothing much in the scour zone) to a lot, if something big and vulnerable is in the scour zone. For critical infrastructure (Mokelumne Aqueduct, for example), scour damage may or may not occur. Thus, how scour is handled probabilistically is very important for interpreting the vulnerability of infrastructure to scour damages. Essential to include more details in this calculation. If (hopefully not), scour was assumed for the entire scour-prone zone of each analysis area, then scour damages in any flood would have been grossly overestimated. In any case, estimating scour damage is tricky and needs to be carefully explained.	Probability analysis is the subject of the Phase 1 Risk Analysis Report, not the technical memoranda; see Section 1.2. [The scour holes (2000' x 500') were handled probabilistically in the Phase 1 Risk Analysis Report.] Scour was not assumed for the entire scour-prone zone of each analysis area. Scour holes could occur anywhere within the island perimeters. Clarification was added in Section 4.2.2.

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10. Tables 4-1a and b. Urgently need explanation. These are stated as being for the MHHW or 100-year "event". "Event" for what analysis areas? One, several, all? Since which analysis areas flood in a given event is largely probabilistic, there is no such thing as a MHHW or 100-year event, rather there are MHHW or 100-year flood events which flood analysis area A, B, or C…. a. Also, the totals at the bottom of each table have almost no meaning – because they sum apples and oranges (gas wells, schools, cell towers etc.). I suggest removing the "grand" totals at the bottom of the tables.	Tables 4-1a and 4-1b were deleted.
11. Page 20. Cleanup costs for petroleum pipe breaks are estimated to be $10 million. Since such breaks are likely largely from scour, how is the probability of such breaks calculated?	Probability analysis is the subject of the Phase 1 Risk Analysis Report, not the technical memoranda.
12. Page 20. Omission of debris costs is puzzling. FEMA covers debris removal costs for all Federal disasters, so surely estimates of debris removal costs are available. Debris removal estimates should be added to other loss estimates.	Debris removal costs are included; the tables (in Section 7.1) were updated to include damage cost to contents. See Section 4.3.1.

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13. Section 4.3.2. The purported cost multipliers for repairs (and presumably replacement) are simply stated with little justification. For flooding "islands" which have relatively little inventory (compared to say, Sacramento), there is little or no justification for such cost multipliers. Flooding of 30 islands would surely increase the repair times, but it's hard to believe that total repair/replacement costs would be 2.0x those for flooding 5 islands. This is an important issue, since it affects the magnitude of losses and thus bears on public policy decisions. At a minimum, I'd like to see two sets of numbers: with and without the purported cost multipliers.	If there is a sudden increase in the demand for construction, it is expected that the construction costs would increase. With multiple levee failures scaling factors (multipliers) have been used to increase costs of repair due to the supply and demand for equipment, labor and, materials. In investigating the use of scaling factors, we have reviewed literature from post catastrophic events. The insurance industry refers to what we have termed "scaling factors" as "post event inflation" or "demand surge". The findings of this review support the scaling factors assumed in the draft TM. These findings are documented and assumptions clarified in Section 4.3.2. Tables referenced in Section 7.1 do not include the cost multipliers. Cost multipliers are used in the risk analysis for multiple island failures.
14. Page 22: Repair times vs. damage are an important element in the calculations. I'd like to see the algorithms be explicit rather than mentioned without any documentation of what values were used. The replacement times should be qualified as "typical" or "average". One difficult question, which should be addressed, is: if an island floods will homes be rebuilt at all? Or, if so, will it in fact take many years/decades before people choose to rebuild in an area that just had very deep, very long duration flooding? Important policy questions which should at least be acknowledged. As well documented by New Orleans, a really big flood changes the "picture" of rebuilding and future development in profound ways that will likely endure for decades	Algorithms are included in Section 4.4.1. The policy questions have been acknowledged in Section 4.4.2, first paragraph.

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15. Longer repair times for multiple island floodings appear more credible than the higher repair costs discussed above.	Noted.
16. Section 4.4.3. The technical terms used are not entirely self-explanatory and should be explained clearly. Otherwise, this section is less useful than it could be.	The technical terms are defined in Section 4.4.3
17. Page 20, fourth bullet: What scour zones were assumed for which analysis zones? As noted above, whether or a not a given breach results on scour damage to infrastructure depends enormously on where the breach is vis-à-vis at risk inventory. How was this modeled for the calcs?	See response to Comment 9. It is believed that this comment pertains to bullet 9 in Section 4.5, which pertains to scour.
18. Sections 5.1, 5.2 and 5.3. It would be informative to provide summary results for the ranges of changes in damages expected from 2007 to 2050, from the effects noted here. Is this a 1% change, a 10% change, a 100% change???	Such an overall summary is included in Section 7.2. (Section 5 discusses methodology.)
19 Section 6.2 Epistemic Uncertainty. Very unclear how the estimates in this section were applied to the calculations. Were the probability weighted damage functions used for the DRMS loss estimates? a. The stated weighting of expected values 50%, plus 30% values at 25%, and minus 15% values at 25% yields an adjusted value for repair costs which is slightly larger than the stated "expected value" (3.75% higher, from the asymmetry of the uncertainty). b. Why DRMS used an asymmetric distribution rather than the symmetric distribution used by the USACE is unclear. c. Also, there is no discussion of the magnitude of uncertainties assumed for DRMS vs. USACE (essential to provide this for reference).	This section describes the approach for addressing the epistemic uncertainty in cost estimation. The DRMS loss estimates use the expected repair costs based on the median depth-damage relationship. a. The approach defines three discrete depth-damage relationships with confidence values of 50%, 25% and 25%. The expected value from these three levels is not calculated. We agree with the comment that if the expected value were to be calculated, it would be slightly larger than the one associated with the 50% confidence level. b. An asymmetric distribution is used for cost because it is consistent with our experience with the accuracy of estimated repair costs and with typical engineering cost estimation procedures. It is based on the observation that we are more likely to underestimate than

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	overestimate the cost. c. In the USACE HEC-FDA, the percent standard deviation in the depth-damage function is a user input. No specific value for that measure of uncertainty is recommended. Furthermore, USACE HEC-FDA combines epistemic and aleatory uncertainties, while the DRMS approach treats them separately. We believe no direct comparison of the magnitude of the uncertainty between the two approaches is feasible.
20. Despite the above discussion of epistemic and aleatory uncertainties, the results Tables 7.1, 7.2 etc. contain only single values. Are these expected values using the HAZUS relationships or the "adjusted" expected values using the asymmetric DRMS epistemic uncertainty estimates? Where are the upper and lower bound results? (Certainly don't need full tables, but should at least have a discussion indicating the combination of epistemic and aleatory uncertainties vis-à-vis the expected values: that is, lower bound is X% below the shown values and upper bound is Y% above. Or, whatever is the appropriate statistical measure (if there is one) rather than "upper" and "lower" bounds.	The values shown are the expected values assuming the median depth-damage relationship. As noted in the TM, for a given depth-damage relationship, the repair cost is assumed to follow a lognormal distribution with the shown expected values and a coefficient of variation of 15%. Using the lognormal distribution, one can calculate different percentiles of the repair cost. For example, one standard-deviation upper- and lower-bound factors on the median cost would be 1.16 and 0.86, respectively. These are not shown to keep the tables relatively simple.
21. MHHW vs. 100-year flood. There are results for about 50% more study areas for the 100-year flood compared to the MHHW flood results. Presumably this is explained someplace in the DRMS report, but this is an IMPORTANT difference and really must be explained at the beginning of this TM, when the MHHW and 100-year flood are first introduced. Otherwise, just very confusing to the non-technical reader.	Clarification has been added to Sections 4.1 and 4.1.2.

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22. Page 30 bottom paragraph. **"Assets within the scour zones are assumed to be completely destroyed."** If this was really done (hopefully not), the scour damages are grossly overestimated by factors of 10x or 100x because for any given study area, only a small fraction of the potential scour zone will actually be scoured in any given breach. That is, for any flood event, the most likely number of breaches per study area is probably 1.0 (or very slightly more than 1.0 – the entire perimeter of a study area cannot be breached (with scour) in a single flood event. **Clarification and revision (if this was really assumed) is CRITICAL. This appears to be a major computation blunder.**	See response to Comment 9. Concur: the entire perimeter of a study area cannot be breached (with scour) in a single flood event. Clarification was added in Section 7.1.
23. Section 7.3. The omission of values for the listed facilities is baffling. Surely reasonable estimates can be made for the value of such facilities on a unit cost per SF or unit cost per capacity. Such numbers are readily available for the listed "excluded" types of assets. Not a big impact on the overall results, but an unnecessary limitation for a study of this level of effort.	Section 7.3 was clarified. We consider damage to infrastructure assets that could result from levee breaching and island flooding (refer to Section 1.2). Infrastructure assets that would not be damaged by levee failure are beyond the scope of the TM.
24. Interpretation of results. **Given the massive amount of results data, it would be highly beneficial to provide a significant amount of commentary, analysis and summary tables.** For example, commentary on the ranges of damages for small and big islands, summary tables showing the 10 study areas/island with the largest damages, etc. etc. etc.	Commentary is in Section 7.2. Damage costs were handled probabilistically in the Phase 1 Risk Analysis Report.

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25. 2050 results area about 20% more damage. Is this from more inventory or from higher water depths (or, actually, how much from each?). I presume that all of the quoted damage values are in 2007 dollars? This is an important distinction and must be clearly stated in the text and in a footnote to the 2050 tables.	Clarification added in Section 7.2. Increased damage would result from more inventory and from greater water depths. 2005 dollars are used; see footnotes added to Table 7-8. See also response to Comment 4.
26. Are "building" damages really only for buildings or do they include contents? This is a very important difference and the basis for the building calcs needs to be explicitly stated in the text and footnotes. If indeed these are for buildings only, then the omission of contents is an inexplicable and major omission which should be corrected throughout by adding columns for contents damages. To omit such a major category of damages as "contents" is simply unacceptable.	Building damages have been revised to include both the structural damage to the building and damages to contents. The approach and percent values used to estimate these damages are based on FEMA's HAZUS-MH software. Costs are estimated as a percent of the structure replacement. With this revised data, the tables (in Section 7.1) were updated to include damage cost to contents. The draft TM was revised to include damage to contents and the assumptions used for estimating damages; see Section 4.3.1.

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Reviewer: Bedker – U.S. Army Corps of Engineers	
1. Page 13, last sentence on page: Discussion assumes that a breach occurred during the MHHW. How often does a MHHW occur? Daily? Weekly? Monthly?	As described in the response to Comment 6, above, MHHW is the average of the higher high waters that occur each lunar day. This means that for roughly half of the days the highest tide of the day would exceed MHHW and about half the days would have a highest tide that was less than MHHW. Most of the days with a highest tide that exceeded MHHW would be clustered together during a period known as a spring tide and most of the days with the highest tide less than MHHW would be clustered together during period known as a Neap Tide. There are usually two spring tide periods per month. See footnote to Section 4.1.
2. Page 14, first paragraph: In the middle of the paragraph there is a sentence that states "Where both exist, the value in the floodplain was used." What is the "value" that is used? What is the derivation of the value and what does it refer to?	On the FEMA FIRM maps for the Delta, elevations of the 100-year water surface (100-year flood elevation) provided for an island may differ from the value of the flood elevation given for the adjacent river. In these cases, the flood elevation provided for the island was used to generate the 100-year flood map since the flood map was meant to represent the case with flooded islands. See footnote to Section 4.1.2.
3. Page 14, paragraph referring to "Sour Zones": The scour zone is assumed to be 2,000 feet long. Please source the assumption. The cost to repair these sites is significant and there should be more information supporting this assumption.	See Section 4.2.2: The dimensions of scour holes were based on historical data from Delta levee failures as discussed in the Levee Vulnerability TM.
4. Page 15, first paragraph under "Point Assets": The last sentence in the paragraph refers to the total loss of the entire structure if 50 percent of the structure is damaged. Within Corps guidelines, this assumption is open to debate as well as the use of replacement cost assumptions.	Noted.

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5. Page 15, third bullet: The narrative indicates that a levee failure would affect water quality and thus the pump station's ability to deliver water. Are there restrictions on pumping through the pumps based on water quality? If so, please indicate the assumed restrictions and indicate the regulations impacting these deliveries.	As noted in Section 4.2.1, a levee failure would affect water quality and thus the pump station's ability to deliver water. The pumps would not be operated if salinity were excessive. This portion of comment is beyond the TM's scope.
6. Page 15: Are there any damage estimates noted for gas or water wells? Ports? Bridges?	There are damage estimates for bridges (both rail and road) and ports. Gas/water wells are not considered in the repair cost estimates.
7. Page 15, first paragraph under "Linear Assets": The first paragraph indicates that repair costs were either obtained from historical records by asset owners or by appropriate cost estimates. Can you elaborate on the "appropriate cost estimate" base used to determine the cost estimates?	The wording used is *approximate* cost estimation, not *appropriate* cost estimation. Nonetheless, clarification has been added in Section 4.2.1; used the term conceptual level cost estimation.
8. Page 20, last paragraph: Can you give an example of the type and quantity of cleanup that has historically taken place. Please provide examples.	Suisun Marsh is cited in Section 4.3.1. The type and quantity of clean up is cited. Cost of clean up is not available.
9. Page 20, last paragraph: Is there a reason that disposal of debris is not included in the cost estimates?	See response to Comment 12. above.
10. Page 21, Multiple Island Failure: What is the basis for these scaling factors? Have they been used in other studies in the past? Please identify these other studies and the methodology around the scales.	See response to Comment 13, above.
11. Page 21, first paragraph under General Methodology: The last sentence of the paragraph indicates that "judgment was used to estimate repair times." Please indicate whose judgment was used and the experience or thought process in arriving at the repair times.	Clarification was added to Sections 4.4.1 and 4.4.2.

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12. Page 21, under General Methodology: The infrastructure is lost from the time the levee breaks until the island is pumped out and dried and fixtures are fixed. How much time is estimated for this and what is the approach you use to compute this?	Pump out time is the subject of the Emergency Response and Repair Tech Memo. Repair times in the Infrastructure Tech Memo are from the time that island pump out has been completed. See Section 4.4.1.
13. Page 22, fifth bullet point: Assuming that it takes less than a month to fix the highways and roads, how long does it take to pump-out the islands? Assume breach of levee until the water pumping is completed. Wouldn't the repair time be based somewhat on the use of the road or highway and the economic cost incurred due to its' downtime? The assumption conflicts with the repair times noted at the bottom of page 23 for Interstate 5 and 205, state highways and other roads.	See response to Comment 12, below. Concur. The repair times would be based on the use of the road or highway, as noted in Section 4.4.2 (see bullets under Linear Assets). Clarified in Section 4.4.1, last paragraph.
14. Page 31: Is there an accepted published approach using the scaling factors cited?	See responses to Comments 13 (previous set of responses) and 11 (this set of responses). See also Section 4.4.3 for comparison with reconstruction activities following Hurricane Katrina.
15. General comment: It is hoped that the data indicated in the tables are available for use electronically. The citation by Kates was extremely helpful in the documentation of infrastructural damages.	The data in the tables presented in Section 7 are available electronically.