Bolinas Lagoon Ecosystem Restoration Feasibility Project

Final Public Reports

VI Peer Review and Public Comments on Previous Draft Reports with Responses

Philip Williams & Associates, Ltd.
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Peer review (TRG, PRAG and USACE) occurred on the administrative draft report (dated Dec 2005).

Review of the Draft Reports:

PWA and WRA, Protecting the Future Evolution of Bolinas Lagoon
Administrative Draft, 7 December 2005;

Roger A. Byrne, Recent (1850 - 2005) and Late Holocene (AD 400 – AD 1850)
Sedimentation Rates at Bolinas Lagoon, Marin County, California

For the Marin County Open Space District

by

Bolinas Ecosystem Restoration Project Technical Review Group

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Final Review
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I. Introduction to This Review

A concerned public is asking what Bolinas Lagoon will be like in 50 years, if nothing is done to manage or control its condition. The Marin County Open Space District (MCOSD) is sponsoring a study of the lagoon to address this question as part of the Bolinas Lagoon Restoration Project. Technical consultants for the study have used computer-based models to simulate how the lagoon mouth will respond to expected changes in lagoon depth and size that are based on empirical assessments of sedimentation inside the lagoon. Changes in lagoon depth and size are also interpreted as habitat changes to assess the ecological consequences. These forecasts of physical and ecological change are extended to the year 2050, which represents the outer limits of predictability in future conditions of the lagoon, given the current understanding of its natural variability over time. The study assumes there will be no change in how the lagoon and its watersheds are configured or managed.

The purpose of the Technical Review Group (TRG) is to help assure that the findings and recommendations of the technical consultants for the study are scientifically sound. Previous work by the TRG has focused on reviewing and advising the study's work plans and interim findings. The current focus of the TRG is on the conclusions and recommendations as represented in two draft reports for the study: "Protecting the Future Evolution of Bolinas Lagoon" and "Recent (1850 - 2005) and Late Holocene (AD 400 – AD 1850) Sedimentation Rates at Bolinas Lagoon, Marin County, California," dated December 7 and 14, 2005, respectively.

This review by the TRG incorporates commentary provided by its individual members into a single set of comments for the TRG as a whole. The commentary has been far-ranging and detailed. No subjects were intentionally avoided. While not every member of the TRG could provide authoritative commentary on all aspects of the technical work, each member provided essential expertise that the other members could not provide. Members were added to help address new technical topics as they arose. There was, however, overlapping expertise among the members for the general topics, such as the conceptual models of how the lagoon behaves as a physical system and as an ecosystem, the scientific framework for data collection and analysis, and the integrative interpretation of the findings.

This review is organized into general comments, specific comments, and a short summary of all comments. The general comments are further separated into five topics: Report Organization and Tone, Lagoon Sedimentation Rates, Forecasts of Physical Condition,

Forecasts of Ecological Condition, and Monitoring. The specific comments pertain to individual findings or recommendations either stated or implied in either report. Detailed comments regarding word choice, typographic errors, inconsistencies in terminology, and minor inconsistencies between text and graphics were provided by some TRG members to the authors on hardcopy versions of their reports, and are not included in this summary review. Such inconsistencies and errors, however small and apparently inconsequential, reduce the reader's confidence in both the data and their interpretation, and should be carefully corrected.

II. General Comments

A. Report Organization and Tone

The TRG recognizes that the consultants have acted upon many of its previous recommendations. The emphasis on the assessment of lagoon evolution in the absence of intercession was promoted by the TRG. The addition of an intensive investigation of historical and pre-historical sedimentation rates through coring of the lagoon was initiated by the TRG, as was the ongoing effort to establish tide gauges and a network of geodetic bench marks for the lagoon. A variety of adjustments in analytical methods and interpretive perspectives has already been suggested by the TRG and accepted by the consultants. We especially welcome the study's emphasis on gaining basic understanding about the relative roles of natural history and human history in shaping the lagoon's existing condition. The intensive, detailed, neutral assessments presented in these two reports provide a better foundation for managing the lagoon than previously existed.

The TRG recognizes that the primary purpose of this study is to assess how the lagoon will evolve over the newt 50 years if nothing is done to intercede in the evolutionary processes. We have concurred with the consultants that the assessment should focus on the likelihood that the lagoon mouth might close. Some of the stated goals and objectives for managing the lagoon depend on its mouth staying open. Closure of the lagoon would trigger major changes in its ecological, recreational, and commercial functions that could nullify existing management efforts. We also recognize that dredging the lagoon would be the main action to prevent its closure. In essence, the study will be used to help decide if large-scale dredging is needed. It therefore behooves the consultants, and the TRG, to consider the likely effects of large-scale dredging when weighing the costs and benefits of not interceding in the evolution of the lagoon. Otherwise, the relative benefits of the two management scenarios are difficult to determine.

The data from both reports indicate that two major conclusions can be drawn: the lagoon mouth is unlikely to close and the overall ecology of the lagoon is unlikely to change in significant ways during the foreseeable future. The consultants' reports provide three sets of evidence supporting these conclusions. First, there are empirical measurements of sedimentation patterns and sources of sediment by a number of authors, but done most comprehensively by Byrne et al., indicating that the shallow lagoon has not closed in the past, even when land use practices and earthquakes yielded sediment loads much greater than occur now. When these and other sedimentation data are utilized in the models run by

PWA, no lagoon closure is indicated for the future. Secondly, but perhaps equally important, is the discovery made multiple times that the bulk of the sediments in the major basins of the lagoon originate from the near-shore ocean (i.e., littoral) environment and from the bluffs just outside the lagoon, rather than from the local watersheds. The sediment coming down local creeks is mostly deposited near the creek mouths. Although the initial formation of the creek deltas substantially lessened the tidal prism, the ongoing build-up of the deltas and their gradual expansion contributes little to further prism loss because it occurs very high in the intertidal zone. From these findings we can infer that one major dredging event, which according to the models would increase tidal flood flow and thus bring more sediment into the estuary, could lead only to more dredging. We can also infer that watershed management is unlikely to affect the likelihood of lagoon closure, although it would affect the future of the deltas and the fringing intertidal habitats. The third and final set of critical evidence comes from the ecological analysis indicating that future habitat changes will be insignificant, and that shorebird habitat might even increase, for a net positive overall consequence of taking no management action on behalf of the lagoon mouth. While there is evidence that eelgrass beds are disappearing, that the population of ghost shrimp may be declining, and that invasive plants may increase, the cause of each of these trends is uncertain, and there is no evidence that the trends would be stopped or reversed by dredging or other actions taken to prevent lagoon closure.

It is also clear from these reports that the San Andreas Fault plays a very large role in the natural maintenance of the lagoon. The lagoon owes its existence to the fault, and the fact that the lagoon straddles the fault has major implications for all aspects of lagoon conditions. Major earthquakes along this reach of the fault cause the bottom of the lagoon east of the fault to drop, and this renews the ability of the lagoon to receive near-shore sediment without closing. The west side of the fault drops less (and might even rise slightly), and is therefore more likely to consist of tidal flats and marshes. In fact, the most visible recent changes in lagoon condition are the increases in tidal marshes and tidal flats on the west side of the fault line, near the town of Bolinas, its harbor, and its access road. These changes are locally important, but have had no measurable effect on the lagoon mouth or the tidal range inside the lagoon. Their effect has also been negligible on the distribution and abundance of most species of plants, fishes, and other wildlife that occur in the lagoon. However, the high visibility of these changes can nurture a public concern that exceeds what is warranted by their actual effect on the lagoon ecosystem as a whole.

We find quite reasonable the consultants' conclusion that, since the lagoon is unlikely to close in the foreseeable future, no intercession in the evolution of the lagoon to prevent its closure is warranted. Other actions might be considered to improve or maintain the conditions of local creeks, roadways, boat moorings, etc., but no action is warranted to prevent closure of the lagoon mouth. While it is true that the data are not complete and that they involve potential errors that should be addressed, we find that the basic conclusion is about as well supported as might ever be expected.

We think the Administrative Report should state this message more clearly, and we think the lack of clarity has three main correctible causes, as outlined below.

1. The Administrative Draft report is unduly complicated.

   - The figures must be integrated into the body of the report. The separation of text and figures invites confusion and frustration for the reader.
   - We think there is an interesting and informative narrative about the evolution of Bolinas Lagoon that could be developed based on this study. But the story gets lost in the details of the data and their analyses. The Administrative Draft report has expanded as the major parts have been refined and completed, and now exists as an accumulation of almost all the work done by PWA, WRA, and UCB for this study. The report, and its readers, would benefit greatly from a more integrated and succinct narrative to support the main message. For example, Sections 3-5 of the report could be integrated into a single, concise discussion about the natural and unnatural processes that account for the condition of Bolinas Lagoon, past, present, and future. This integration would reveal inconsistencies within and between the component reports that should be fixed, and would identify text and figures that can either be omitted or organized into a useful appendix for the Administrative Report.
   - The discussion of adaptive management (Section 7) should more clearly identify these essential steps: formulation of management questions; their translation into monitoring objectives; collection and management of cost-effective relevant data; interpretation of the data in the context of the management questions; translation of the results into management actions; and/or re-formulation of the management questions. It should be stated that the managers will need to identify who will collect the data, who will manage the data, who will interpret the data, and who will translate the findings into management actions. Unless these specifics are resolved early-on, adaptive management is unlikely to happen.
   - The list of findings (Section 2) can be useful (see Section III, Specific Comments, below) but a concise summary of them is needed. We suggest that the authors develop a short summary narrative of their essential findings with as little caveat and equivocation as possible. This summary should succinctly state that the lagoon is unlikely to close.

2. Findings of the sedimentary study by Byrne et al. are not well integrated into the Administrative Draft report.

   - We think the two reports should remain separate. However, the report by Byrne et al. on sedimentation is fundamental to the ecological assessment of the lagoon and should be more thoroughly integrated into the Administrative Report.
   - We strongly recommend that the authors of both reports achieve closer agreement about critical topics including average sedimentation rates, the concepts of equilibria and disequilibria as the intellectual framework for system analysis, the influence of seismicity and tectonics on the spatial and temporal variability in the channel network and sedimentation patterns within the lagoon, the ecological response to tidal prism changes, and the role of extreme but recurrent natural

events, such as earthquakes, tsunamis, and major storms in the natural maintenance of the lagoon. More collaboration among the authors would greatly help organize, streamline, and clarify the Administrative Report as the primary product of the study.

A significant step in the direction of integrating the two reports and resolving discrepancies between them could be achieved by developing a common base map of the lagoon that would be used in both reports. A common base map would make it easier to visualize the spatial and temporal relationships among key data and interpretations, as for example, the location of the coring sites with respect to the geomorphic units defined in the Administrative Draft report.

3. The concept of "dynamic equilibrium" is overly applied.

- The concept of dynamic equilibrium means different things to different people and it can change meaning between scientific disciplines. The consultants need to be clearer about how they use the term. We suggest that the concept pertains to systems that are controlled by the interplay between two or more opposing processes that vary but tend to be in balance with each other, such that the system as a whole does not change suddenly to a new state without a sudden change in external forcing.

- According to this definition, the lagoon mouth is apparently in dynamic equilibrium between (simply stated) the ongoing erosion and deposition of sand. The concept helps explain why the mouth is not likely to close in the foreseeable future, and it supports the finding that the lagoon can be monitored in a way that will give adequate warning and thus reduce the risk of unexpected change.

- We do not think the concept is usefully applied to the whole lagoon. While it is reasonable to state that the lagoon, as a physical system, exhibits "equilibrium-seeking behavior" (i.e., it *tends* toward a persistent average condition over time), it is not reasonable to imply that equilibrium will actually be achieved. While it is apparent that the lagoon has existed for millennia, and that the mouth of the lagoon has not changed size in historical times, it is also apparent that the overall abundance of each geomorphic unit continues to either decrease or increase, without a "leveling-off" or asymptote being achieved. That the lagoon is a physical system tending toward an overall equilibrium between erosive and sedimentary forces does not mean that the equilibrium exists or will ever be achieved. The data show that no balance between sediment supply and demand has ever been achieved for the lagoon as a whole before some major perturbation, such as a major earthquake, tsunami, change in the rate of sea level rise, or change in land use interrupts the sedimentary processes.

  We understand that some local habitat features, such as some tidal flats and the vegetated marsh plain of some tidal marshes, also exhibit dynamic equilibria.

But, unlike the lagoon mouth, these features do not comprise integral geomorphic units and in the aggregate they do not exhibit equilibrium.

Furthermore, while one can always average processes across any spatial or temporal gradient, such averaging tends to hide the variability that illustrates physical cause-and-effect relationships, and that drives a lot of ecological change. For example, the data help explain variations in sedimentation at different time scales. There is a shorter scale of days to years for variations in sedimentation driven by winds, tides, and land use. There is a longer time scale of decades to centuries that reveals the effects of sea level rise, changes in climate, and tectonic events, each of which can profoundly influence shorter term sedimentation patterns within the lagoon. Climate change is an important driver of sea level change that, in turn, can drastically alter wave energy and tides, which can alter sedimentation rates, especially within the near-shore (littoral) environment. Tectonic events are inherently unpredictable at the shorter time scales, yet can lead to dramatic and sudden alteration of short-term sedimentation patterns and rates. Long term effects of major tectonic events on the San Andreas Fault are large enough to be the major determinants of sedimentation rates, but they are predictable only in a general and probabilistic way.

- The concept of dynamic equilibrium is least applicable to the lagoon as an ecosystem. While there might be indicators for tracking "equilibrium-seeking behavior" for the physical system (i.e., the rate of change for the lagoon mouth or for total tidal prism), comparable indicators for the ecosystem are not obvious. One might consider total primary or secondary production, but the calculations would be fraught with huge uncertainties. Furthermore, the ecology of the lagoon is only partially attributable to the temporal and spatial variability in physical processes. At any given time in the evolutionary trajectory of the lagoon as a physical system, disease, biological invasions, and chance interactions among populations will help shape the communities of plants and animals. The well-documented plant invasions that affect the elevation and extent of Kent Island comprise one example of unpredictable ecological phenomena that prevent equilibrium for the ecosystem.
- The over-use and perhaps misuse of equilibrium concepts for the lagoon system as a whole affects the overall tone of the Administrative Draft report, which in turn can foster unrealistic public expectations. There is a psychological element associated with equilibrium and restoring equilibrium; equilibrium is easily interpreted as the natural state threatened by human activity. Acknowledging that the system is naturally variable, even if it expresses "equilibrium-seeking behavior" in the long-term, promotes a more realistic intellectual framework in which even occasional short-term closure is part of a natural range of conditions that the public might accept. The relationship of the lagoon to the San Andreas Fault demands and encourages this perspective; the public seems to generally accept the idea that in time lands on the west side of the lagoon will move far north of their present location; the equally well supported concept that the lagoon

is ever evolving within a broad range of natural conditions should be equally acceptable. The scientific evidence points to Bolinas Lagoon being a variable system, well adapted ecologically to respond to changes in sediment accumulation or erosion. By contrast, the equilibrium concept suggests a management or governance responsibility to reduce this variability by fighting nature: e.g., if the estuary is filling-in because of human actions, then we should be prepared to restore it to its natural state to compensate for our activities. To do so would ignore the evidence that human actions have had rather minor effects on the lagoon as a whole, and could cause ignorance of the negative consequences of the "restorative" actions themselves. We think it is more appropriate to characterize the Bolinas Lagoon system as being in "dynamic evolution" than in "dynamic equilibrium," and that the rate of evolution for the system slows after a major perturbation. For example, it ought to be stated that the expansion of tidal flats and marshes will continue to slow until the next major earthquake, which will, at once, destroy some of them and jump-start their re-formation.

B. *Lagoon Sedimentation Rates*

The analysis of sedimentation rates is central to the entire study and warrants special attention in this review.

The Administrative Draft report states that the average rate of sedimentation can be calculated by comparing bathymetric surveys supervised by the USACE from 1968-1998. It's not clear, however, to what level of International Hydrographic Organization (IHO) accuracy standards these surveys were held. One might assume that they at least followed the USACE Hydrographic Surveying manual EM 1110-2-1003, which expects a resultant depth-sounding accuracy of +/- 0.5 ft for survey depths of 15 ft or less. This error would need to be figured into the possible range of bathymetric change, and this would mean that the error exceeds the estimate in at least some cases. Another factor that should be considered in determining survey accuracies is the USACE practice of establishing tidal datum control through the geodetic vertical network. This procedure must rely on computing the correct NGVD 29-MLLW offset for the survey area and establishing staff gauges in the vicinity that are leveled to geodetic bench marks, correcting for spatial time and range differences (tidal zoning) and adjusting for changes in Tidal Epochs. There is no evidence that this procedure was followed. Most importantly, there is no evidence in these reports that the elevations of the bench marks to which the surveys were related were valid, that is, still accurate. The lagoon and its environment are seismically active, and the integrity of any bench mark is therefore suspect. Finally, the analysis of shallow cores by Byrne et al. provides evidence that the bathymetric surveys for the north basin of the lagoon are not reliable.

The TRG previously asserted that the historical bathymetric surveys of Bolinas Lagoon should not be compared because they lack adequate vertical control. Unless the consultants can provide evidence that the aggregate error of the bathymetric surveys used to calculate sedimentation rates was less than the reported differences between the surveys, or unless

the survey data can be calibrated against an independent data set, then the surveys should not comprise the primary source of data about sedimentation rates.

The report by Byrne et al. provides a major and essential contribution to the understanding of the functioning of the Bolinas Lagoon sedimentary basin. Their report provides the strongest data on sedimentation rates. If the historical bathymetric surveys are valid, then they should yield results that are comparable to those reported by Byrne et al. It should be possible, for example, to use the survey data to back-calculate a mid-19th century rate of sedimentation that is comparable to the corresponding rate reported by Byrne et al.

Since Byrne at al. gathered data primarily in the North Basin, using their data to model overall changes in tidal prism requires a major assumption that their data pertain to the whole lagoon. This assumption might or might not be supported by future cores. If the data from Byrne et al. are used in this way, then a map should be prepared of the entire lagoon showing all the geological sampling locations in the context of the current geomorphic units identified in the Administrative Draft report. The authors of both reports might then consider adding caveats regarding the modeling of the lagoon based on these geographically limited sedimentation rates.

The report by Byrne et al. contains inconsistencies between text and figures that must be corrected. There are also concerns about their estimates of bioturbation depths, estimates of down-dropping during earthquakes, and the scant chronological control for the stratigraphic analyses among the many shallow cores based on their profiles of magnetic susceptibility. In each case, however, the methods of analysis seem appropriate and well-executed, and the adjustments in interpretation are unlikely to change the overall conclusions. In fact, the recommended adjustments, as previously provided by the TRG to the authors, would decrease the estimates of sedimentation rates, and thus bolster the conclusion that the lagoon in unlikely to close.

The conclusion that sedimentation rates are not adequate to cause the lagoon to close may have reduced the importance of knowing the sediment sources. However, knowing the sources and their relative contribution to the lagoon is essential to forecast how their management might affect the lagoon in the future. The knowledge of these sources gained by this study should influence any future decisions about land use around Bolinas Lagoon. The overall conclusion of the Administrative Draft report that watershed sources contribute less than half of the total input of sediment to the lagoon seems substantiated by the independent study of Holocene sediment sources by Byrne et al. However, the results in the Administrative Draft report could be better supported by further explanation of the methods and related assumptions for the watershed studies. It would be helpful to have a clearer image of how the watershed sources were assessed. Including a simple table of estimated sediment sources would assist the reader in this effort.

Additional explanation is needed for the analysis of watershed yields of sediment to support the findings presented in the Administrative Draft report. The description of the numerical modeling approach is too general for us to comment on its applicability to this system. The hydraulic modeling as described apparently does not take the size of material

into account, and it should, since this will determine the distribution of the sediment within various storage places from the creek channels to their deltas and the lagoon. Furthermore, there is scant evidence that the modeling was verified by field work. In short, the findings seem to depend heavily on modeling, but the models are not explained in enough detail to judge their efficacy. Perhaps these short comings are tolerable because the effect of watershed inputs on overall lagoon condition seem minor, but any future analysis of watershed yield, and any plans for creek restoration will need to be more comprehensive in approach and more thoroughly documented.

C. *Forecasts of Physical Condition*

The effort to forecast changes in the average physical condition of the lagoon assumes that they would be caused mainly by changes in the lagoon mouth. We think this is a reasonable assumption based on multiple lines of evidence indicating that most of the sediment comes from outside the inlet, and given its obvious role in maintaining the tidal regime of the lagoon.

A relatively simple scoping model, the O'Brien model, has been used to predict how the lagoon mouth would respond to changes in the interplay between the tidal prism of the lagoon, which tends to keep the mouth open, and wave energy in the ocean, which tends to deposit sands in the lagoon mouth. This is essentially an application of the dynamic equilibrium concept that we agree pertains to the lagoon mouth. The only assumed change is a gradual decrease in the tidal prism due to further sedimentation in the lagoon, as evidenced in the reports by Byrne et al. and others. According to the model, if the tidal prism gets small enough, the lagoon will close.

We think the O'Brien model is appropriately used in this case. Implementing a more complex simulation model would cost much more, take longer, and would probably not yield any more credible predictions. The critical threshold value for the wave:tide stability parameter that indicates lagoon closure has been derived from studies of two other lagoons, the seasonal lagoon at the mouth of the Russian River and the restored lagoon at Crissy Field in San Francisco. The use of these data seems appropriate if issues of wave period and sediment type can be clarified (see second point in the paragraph immediately below). Confidence in the applicability of the O'Brien model to Bolinas Lagoon would be much increased by showing that changes in cross-sectional area of the mouth respond to changes in tide and wave conditions.

For the purpose of clarity and completeness, there are four aspects of this simple modeling approach that need to be better addressed in the Administrative Report. First, the model assumes that all waves are the same. The role of waves is actually a function of their period, or rather steepness. Short-period wind-waves tend to be erosive, while long-period ocean swells tend to deposit sand in the mouth, build beaches, etc. Second, the mouths of Bolinas Lagoon, Crissy Field and Russian River are exposed to very different directional wave spectra. Third, the uncertainty of the O'Brien model increases near the threshold values of tidal prism or mouth size that correspond to significant frictional energy loss,

which is ignored by the model. As closure begins, friction reduces the tidal prism, allowing for more sedimentation in the mouth that in turn increases friction and further reduces the tidal prism. This positive feedback can cause a tidal inlet to close rapidly once it crosses the threshold in size where the effects of friction can't be ignored. While it is unlikely that this threshold will be crossed in Bolinas Lagoon, it should be noted that the predictive abilities of the model decrease as the threshold is approached. The consultants should indicate that if the mouth starts to get smaller, the rate at which it decreases in size can increase, such that significant change may happen quickly. The system must therefore be monitored for early warning signs. Fourth, the stability criterion of the model depends on the mouth material. The coarseness of the sands in the mouth, and the presence of larger materials will affect how the mouth behaves. Again, the mouths of Crissy Field, Russian River, and Bolinas Lagoon have different sediments and one can expect different hydraulic radii leading to different critical values of the stability parameter.

We suggest that the models should be re-run using the sedimentation rates developed in collaboration with Byrne et al., following this review. We expect that the rates will be revised downward, such that the estimated likelihood of lagoon closure is further reduced, the existing conclusions will stand, and the figures and graphs of the report that are based on the unrevised sedimentation rates will still be appropriate.

No matter how precise the data or accurate the modeling, they cannot remove the inherent uncertainty of the Bolinas Lagoon system. The modeling results, as illustrated in the forecasts and snapshots of future conditions, either as graphs or maps, tend to imply more certainty in the future than exists. Sea level rise alone presents a very uncertain future for the lagoon. We therefore suggest that the authors plainly state in the beginning of the final reports, and repeat as necessary in later sections of the reports, that the illustrations are approximations of likely conditions, not exact indications.

We agree that all elevations of habitats should be referenced to both the local tidal datum and to NAVD88. However, there was no discussion in either report of how the NAVD88 or tidal elevations were determined. The final report must include a description of the method used to determine these elevations, and the accuracy of the determinations.

D. *Forecasts of Ecological Condition*

The ecosystem analysis does not contribute substantially to the explanation of sedimentation rates or their relationship to the likelihood of lagoon closure. There is too little agreement between these central issues and either the type of ecological analysis carried out or the data collected. The TRG previously recommended that the ecological data and analyses should emphasize the interactions among plants, animals, and lagoon morphology, in terms of sediment entrapment, wave energy reduction, sediment re-suspension, etc. Instead, the ecological work has focused on the possible effects of physical habitat changes on the distribution and abundance of selected populations of plants and animals.

Study plans called for using data about sediment quantity and grain size as causal variables to predict changes in the distribution and abundance of habitat types and communities. While the extensive tables and figures reporting species lists and distribution data could be useful as part of a baseline data set for monitoring future change, none of this information is explicitly linked to sediment characteristics. Such linkage could be made, and would help relate the ecological forecasts to the physical change forecasts.

The inclusion of special-status species in the ecological analysis is an example of considerable effort expended for limited results. Special status species apparently have not been a dominant determinant of management actions for the lagoon.

There are simply not enough data to address the possible effects of large-scale dredging on plant invasions and the recovery of eelgrass and Brant (a small coastal goose). These are speculative matters that cannot be resolved in the Administrative Report.

The most important results are the baseline map and the year 2050 projections, plus the maps of marsh expansion in the main text. Comparing Year 0 to Year 50 reveals some expansion of tidal marsh and low tidal flat. These results are not unreasonable, given the well-known natural histories of the plant and benthic animal populations involved.

In the final analysis, the contribution of the ecological analysis remains limited but clear. The habitat units are widely recognized and accepted, but the projected changes in them aren't large enough to be clearly detrimental, and no clearly beneficial changes would result from any action, such as large-scale dredging, to prevent lagoon closure. Because of its dependence on the forecast of physical changes, the ecological analysis cannot predict different consequences other than what physical changes are expected to cause. This does not mean that ecological changes due to other causes, including density-dependent and density-independent actions within and among populations, won't occur. In all likelihood they are occurring now and will continue to occur, but they are disregarded in this analysis of ecological response to physical habitat change. Future management of the lagoon would benefit greatly from ecological studies that reveal thresholds of habitat change that trigger measurable changes in key populations that, in turn, trigger management actions. But such studies would require much more time and funding than was available.

The greatest strength of the study is that all of its reports support the conclusion, to a greater or lesser degree, that the lagoon is unlikely to close and that dredging or any other action to prevent closure is not justified at this time. There is an absence of ecological problems that would be mitigated by such apparently unnecessary preventive actions. However, it is interesting to speculate on what might happen if the analysis were to be expanded to include the impacts of such actions, especially dredging. Manifold short-term negative impacts, such as the likely reduction in shore bird populations and disruption of the recently renewed Coho run in Pine Gulch Creek, and the disruption of current creek flows with their impacts on sediment deposition and removal would seem to strengthen the case against large-scale dredging. Presenting an assessment of the likely impacts of dredging or other actions should be considered for it would provide a broader framework within which to make decisions regarding monitoring and managing the lagoon.

E. *Monitoring*

We strongly agree that a program of empirical observation is needed to warn of any unexpected changes in the lagoon, and we generally agree with the monitoring recommendations included in the Administrative Draft report. We caution against collecting any data that aren't essential to track trends in tidal prism of the lagoon and volume of the lagoon entrance, however. Monitoring is expensive, and there must be clear and anticipated value for any monitoring data gathered in the future.

We think that tidal range inside the lagoon is the single most important factor to monitor. It is the most cost-effective indicator of an overall change in the physical condition of the lagoon. In theory, changes in cross-section of the lagoon mouth might provide an earlier warning of potential problems. But cross-sections of lagoon entrances can be highly variable over short periods and thus many surveys may be needed to discern evolutionary trends from natural variability. We therefore suggest that the monitoring program start by installing long-term tide gauges, one at the lagoon entrance and one inside the lagoon, referenced to a basic geodetic network of bench marks whose NAVD88 elevations are published by the National Geodetic Survey. Once these are in place, periodic LIDAR or standard ground-based surveys should be able to accurately detect significant topographic changes and concomitant changes in tidal prism. We are aware that the MCOSD has been pursuing the establishment of the geodetic bench mark network and tide gauges. We are also aware that the observations made of the network of geodetic bench marks established earlier this year did not meet federal standards. It is essential that the bench marks be re-occupied with better quality GPS equipment to correct this deficiency, and that the tide gauges be installed according to federal standards.

The modeling effort suggests that some hydrological measurements should be made concurrently inside and outside the lagoon. If tidal levels in the lagoon and wind-waves outside the lagoon are monitored together, then a change in the stability index for the lagoon mouth could be detected. This warning could precede a change in tidal prism. Data on ocean swells are already available from the Coastal Data Information Program (CDIP), but local observation of wind-waves would have to be initiated. If tide heights are monitored inside and outside the lagoon, then the tidal ranges that bracket the lagoon mouth could be compared to obtain indices of sill heights at the mouth and, more importantly, to assess frictional loss of energy at the mouth (providing a warning if the no-friction assumption of the O'Brien model is violated).

A critical aspect of monitoring that was not addressed in either report is the interpretation of the monitoring data. We strongly recommend that the managers of the lagoon identify a neutral party to collect and interpret the data in the context of the managers' questions and objectives. We caution against any liberal interpretation of the monitoring results as triggers for dredging. The interpretation must be conservative and based on a number of consecutive years of clear indications of a developing problem. Local stewardship of the program should be considered.

III. Specific Comments

The following comments pertain to the statements of conclusions in Section II of the Administrative draft report. The comments are referenced by number to the statements.

1. Add tectonics and land use.
2. Remove reference to dynamic equilibrium (see general comments above).
3. Replace "punctuated" with "reset."

4,5. Indicate more clearly that hydrology affects morphology, which in turn affects hydrology, and that plants and animals invade, colonize, inhabit and influence the resulting landforms.

6. Remove reference to dynamic equilibrium (see general comments above) and simply state that the system has been persistently fully tidal since the previous great earthquake.
7. Add land development (housing, harbors, hardening of the spit, etc.).
8. Rectify these values against those provided by Byrne et al.
9. De-emphasize the notion of environmental or system "balance."
10. Rectify these values against those provided by Byrne et al., and report ranges that reflect the uncertainty of the estimates.
11. Rectify these values against those provided by Byrne et al., report ranges that reflect the uncertainty of the estimates, but note that a future decrease in sedimentation rate is expected.
12. Note that the various sediment sources vary in importance around the system, with watershed sources contributing mostly to peripheral changes.
13. Note that aggradation of the deltas do not contribute much to prism change.
14. Be consistent with #12; sediments from the bluff can at least sometimes dominate beach sands.
15. Remove reference to dynamic equilibrium (see general comments above).
16. Note that Bolinas Channel may have enlarged during the 1906 earthquake.
17. Omit reference to equilibrium. Consider that strong winds that occur from SE during major storms can reduce the value of the Delta as protection against waves; Kent Island may provide more protection at these times.
18. Remove reference to dynamic equilibrium (see general comments above).
19. See # 14 and #12 above.

20, 21. Consider the perspective that most of watershed yield is trapped on the delta and thus contributes little to prism change.

22. See # 17 above.

23. See #16 above. Consider that Bolinas Channel has progressively shifted south since the 1906 earthquake, while it has shoaled and narrowed, but that another earthquake might re-open the channel.
24. Remove reference to dynamic equilibrium (see general comments above), and consider importance of lesser or no subsidence on west side of lagoon.
25. Consider that the data on land use suggest that the sediment supply from local watersheds will decrease as they recovers from logging, intensive grazing, etc.
26. Note that this is a moderate estimate for the future rate of sea level rise.
27. State clearly that it is unlikely that the lagoon mouth will close.
28. This usage of the equilibrium concept is appropriate.
29. Consider stating "probably will occur" – the existing statement seems too certain given that the supply of sediment might decrease (see # 25 above).
30. No comment.
31. State that the decline in eel grass is not explained by the data collected for this study.
32. Consider that the sediment supply from Bolinas bluffs and from the local watersheds may decrease while sea level rises, and report prism estimates in ranges that reflect their uncertainty.
33. Data do not clearly support this statement. Consider that overall species diversity might actually increase during habitat evolution because of succession, invasion, plus persistence of refugial populations.

IV. Summary of TRG Major Conclusions and Recommendations

The following summaries are derived directly from the text of Sections 1 and II above.

A. The TRG finds reasonable the approach and conclusions of this study - specifically that the lagoon mouth is unlikely to close and that the overall ecology of the lagoon is unlikely to change in the foreseeable future. The final study report should plainly state these findings.

B. The differences in system behavior between the east and west sides of the San Andreas Fault should be discussed more fully, since they help explain why the tidal inlet in unlikely to close despite the visible sedimentation on the west side.

C. The final reports from the different consultants must agree with each other on the details about the relative roles of natural history and human history on shaping the lagoon, on sediment sources and net sedimentation rates, on the role of extreme events, and on the applicability of equilibrium concepts. The report by Byrne et al. provides the most credible data about sedimentation rates.

D. While the concept of dynamic equilibrium pertains to the lagoon mouth, it does not pertain to the entire lagoon as a physical system or as an ecosystem. For the lagoon as a whole, a term such as "dynamic evolution" is more appropriate than the term dynamic equilibrium.

E. The methods of modeling and analyzing watershed processes including especially sediment yield should be explained well enough to support the argument that local watersheds are not a very important source of sediment for the lagoon.

F. While the modeling effort to predict behavior of the lagoon mouth is reasonable and appropriate, the assumptions of the model and its basic limitations should be further explained.

G. To be relevant to the central topic of sedimentation in the lagoon, the ecological forecasts should focus more on the expected interactions between sedimentation, vegetation, and tidal regime. Vegetation should be regarded as a component of the physical structure of the lagoon as well as habitat.

H. The findings of the reports should be further summarized into a short narrative that tell the story of lagoon evolution and culminates with the basic finding that the lagoon is unlikely to close in the foreseeable future.

I. Monitoring should emphasize early detection of net changes in the size of the lagoon mouth. The essential data are tide heights inside and outside the lagoon, referenced to geodetic bench marks, according to federal standards.

J. The essential steps in adaptive management that lead from formulating management objectives, though collecting and interpreting data, to management actions and refining the objectives should be outlined. The consultants should state the need to identify who will collect and manage the monitoring data, who will interpret them in the context of the management goals and objectives, and who will be responsible for any needed management actions.

Response to TRG Comments dated 10 JAN 2006 on Administrative Draft (7 DEC 2005)

The thoughtful insight and review by the Bolinas Lagoon Technical Review Group (TRG) is greatly appreciated. Their comments have led to several revisions, as described below, and improved the quality of the report.

TRG comments were provided in detail and summarized in Section IV of their 10 January 2006 document. The paragraphs below are our response to the central issues outlined in their General Comments (Section II).

1. T*he Administrative Draft is unduly complicated.*

   We have acted on several TRG suggestions in order to clarify the central messages of the report. Specific changes included the following:
   - Inserting figures into the main body of the report.
   - Adding a concise summary of essential findings before the list of specific conclusions.
   - The list of specific comments was slightly edited to increase the clarity of the bullets. However, as mentioned below, we have retained the use of punctuated dynamic equilibrium as a useful intellectual framework.

2. *Findings from Byrne et al. are not well integrated.*

   The Administrative Draft report did not integrate all of the UCB findings, mostly because the Byrne et al. report was not finalized until after 7 Dec. We have now reviewed the complete UCB report and made the following changes:
   - Added a section on the role of large earthquakes
   - Created a figure showing UCB core locations on top of our Year 0 geomorphic units.
   - Cited the late Holocene sedimentation rates report from the two long-cores.
   - Cited the mineralogy of the North Basin sediments & their likely origin (bluff-eroded silt)
   - Cited the evidence of Cerithidea californica shells as evidence of intertidal habitats in the mid 19th century. (This generally confirms our interpretation of the 1854 T-sheet.)
   - Cited apparent evidence of the 1700 tsunami (or Little Ice Age?).

   There appears to have been confusion regarding how we used the Byrne et al. sedimentation rates, and those based on the 1968-98 surface models. This is described in more detail below. Generally, our projections of future morphology in the North Basin were already established by applying the post-1906 sedimentation rates derived by Byrne et al. (As discussed below, the use of the 1968-98 surface models in establishing future change was limited to the Pine Gulch Creek delta – an area note covered by the UCB cores.)

3. The concept of dynamic equilibrium is overly applied.

   We have edited the report to emphasize geomorphic evolutionary trajectories and the role of major earthquakes in resetting the lagoons evolution. We agree that 'equilibrium seeking behavior' describes the evolution of individual geomorphic units and key attributes of the whole lagoon. However, use of this terminology inevitably poses the question in the publics mind –"what equilibrium?" We have therefore continued to describe 'dynamic equilibrium' as a conceptual end

state while acknowledging that because of re-adjustment after major tectonic events the lagoon may have never achieved it.

We believe this discussion of the appropriateness of defining dynamic equilibrium to be very important in interpreting the future of the lagoon. Our conceptual model of the lagoon is that it is a self-organizing sedimentary estuarine form that persists due to the balance between sedimentation, and the creation of 'accommodation space', both from continual sea level rise and from infrequent episodic tectonic subsidence events. In projecting an equilibrium form we have evaluated how the lagoon morphology would adjust over the next few centuries in response only to projected sea level rise. We find that this projected morphology and associated tidal prism–the asymptote of the evolutionary trajectory, does equilibrate as a fully tidal system. In other words, the lagoon does not require another major earthquake within the next few centuries to persist as a tidal system. The role of these earthquakes is to punctuate the dynamic equilibrium state, reinitiating evolutionary trajectories that converge on a particular estuarine morphology, which is in turn changing over time.

We did not intend to imply that the ecosystem is in dynamic equilibrium. Our discussion above, and the use of dynamic equilibrium in the report, is restricted to physical morphology.

4. *Lagoon sedimentation rates.*

There appears to have been confusion regarding our use of net sedimentation rates derived from recent core analysis (Byrne et al, 2005) and that from the 1968-98 bathymetric surveys. In general, we projected future morphology by: (1) assessing planform changes to each geomorphic unit; (2) modifying specific points along the hypsometric curve based on these planimetric changes; and (3) graphically integrating the difference between the Year 0 and Year 50 hypsometric curves. Note, that we did *not* apply one gross sedimentation rate to project future lagoon morphology or tidal prism.

The TRG recommends we apply the recently developed net sedimentation rates from Byrne et al. in our models of future morphologic change. This was done to our approach in the North Basin to project changes in the subtidal shallows and mudflats. (The post-1906 Byrne rate was adjusted for accelerated sea level rise and multiplied by mudflat slopes to determine lateral changes to high/low mudflats.) The sedimentation rate applied to subtidal shallows and mudflats in the South Arm (from Macdonald and Byrne) is very similar to the post-1906 rate in the North Basin (6 mm/yr vs. 6.8 mm/yr).

We have revised the report such that the post-1906 rate of sediment accumulation is now based solely on extrapolating the average rate from Byrne et al (6.8 mm/yr). This leads to an average sediment accumulation rate of 43,000 CY/yr (as opposed to 45, 000 CY/yr in the draft report – a median value between the rates derived from extrapolating the UCB data and applying the surface models).

We have used the 1850-1906 and post-1906 rates from Byrne et al. to estimate late-19th century tidal prism changes and explain 20th century tidal prism losses, respectively. Since Byrne measured net sedimentation, these rates cannot be applied to compute tidal prism changes (subtidal deposition does not affect tidal prism). However, as noted in the report, the extrapolated Byrne rates are consistent with the 20th century tidal prism losses established from inspecting the 1929 T-sheet and 1968-98 GIS models (ie., our estimate of 20th century tidal prism loss is ~80% of sediment accumulation).

Specifically, the use of the 1968-98 GIS models were limited to:

- Help explain the late-20th century rate of tidal prism loss. (Specifically, we plotted the 1998 and 1968 tidal prism values based on the surface models. The rates of tidal prism loss are in

general agreement with the 1929 T-sheet and what would be expected from extrapolating the UCB data. We've added an appendix summarizing these computations.) As noted above, this hindcast derived from the surface models was *not* applied to project future tidal prism change.

- Confirm that the rate of watershed delivery from Pine Gulch Creek with values computed from rating curves, bedload transport modeling, and watershed yield.
- Project radial extension of the Pine Gulch Creek. We applied the volumetric accumulation rate, established from the 1968-98 TINS, to half-cone equations in order to assess radial progradation. This is the only instance in which results from the 1968-98 surveys were used to project future change.

Although use of the data from the 1968-98 TINS was limited, we have added a short description of the benchmark re-surveys to address potential errors in their reported elevations (Appendix B). In addition to the re-survey of the NOS benchmark on Wharf Road, PWA performed a level loop to Caltrans benchmark along Highway 1. Once the original NGVD elevations of both benchmarks were compared to the revised NAVD elevations (VERTCON was used for NGVD/NAVD datum conversions), we observed only a 0.07-0.08 ft change in elevation. These changes were well below the +/- 0.25 ft range used to assign probably error bars to the 1968 and 1998 tidal prism values.

5. *Forecast of physical conditions*

   a. Inlet closure. At the suggestion of the TRG, we have qualified the O'Brien analysis by stating its limitations more clearly. We have also included a short discussion of how closure could occur rapidly if the inlet enters a 'friction-dominated' regime.

   b. Lagoon morphology. As noted above, the use of the 1968-98 GIS models in our future projections of lagoon morphology were limited to Pine Gulch Creek. We believe this is valid because: (1) the 1968-98 rate of volume accumulation on the delta matches our estimate of watershed delivery from this creek; (2) data in Byrne et al. are derived from cores taken outside of the Pine Gulch Creek delta and do not account for the fluvial processes that form this feature.

6. *Monitoring*

   Given the significance of an open inlet on the lagoon's ecology, and the uncertainties associated with the inlet stability analysis, we believe it is prudent to monitoring for change in closure potential. We agree that the most obvious indicator would be tidal monitoring. (Long-term tidal monitoring would also help establish more precise tidal datums.)

   In addition to tidal monitoring, we believe that monitoring along select mudflat transects is also prudent. This would confirm our hypothesis that locally generated wind waves will keep mudflat elevations below colonization elevation in exposed areas. We believe the balance between erosive wind waves and depositional processes are important in determining mudflat elevation between earthquakes.

   Based on comments from the PRAG, we have added more elements to the biological monitoring program.

NOTE: In the process of working to increase consistency with the Byrne et al. data, we revised our estimates of 1854 & 1929 tidal prism. The revised values are based on an equation we feel is more appropriate (the volume between two conic sections) and are summarized in Appendix B. These revisions have led to smaller historic values, and are more consistent with the (generally) similar distribution of mudflat/marsh in 1854 and Year 0.

Response to PRAG Comments

Gary Page (PRAG member)
Comments on Administrative Draft: Bolinas Lagoon Ecosystem Restoration Project

Three areas where the draft report could be improved are the summarization of information on potential human effects to the lagoon's current and future status, more detailed information on the invertebrates, fish and birds likely to be affected by the habitat changes, and a clearer rational for the proposed adaptive management plan.

Summarization of information on potential human affects on the lagoon's current and future conditions.

The summary is not clear as to the potential affects of human activities on changes in lagoon morphology and tidal prism. This information should be summarized carefully to enable the public to understand the human impact. Here are some suggestions for the Conclusions based on points presented throughout the report.

RESPONSE: We have re-written many of the specific conclusions to make the message more clear. Also, we have added a concise (1-page) summary of key findings at the very beginning of Section 2.

Making Points 8-10 more specific:

1854-1906

8. At the time of the first bathometric surveys in 1854 the morphology of Bolinas Lagoon appears to have been in dynamic equilibrium with sea level rise offsetting sedimentation. The tidal prism (definition) of approximately 4.2 million cubic yards (MCY) was sufficient to keep the inlet open under the most extreme wave and tidal conditions. Subsequently, logging, grazing and other landscape changes increased sediment delivery to the North Basin reducing tidal prism by 0.5 MCY to about 3.7 MCY at the time of the large earthquake on the San Andreas Fault in 1906.

RESPONSE: We have revised the estimates of tidal prism based on the 1854 and 1929 T-sheets, by using an equation we think is more accurate (see Appendix B). This has reduced the 1854 estimated tidal prism to 3.7.

9. The 1906 earthquake was responsible for a sudden 3.7 MCY increase in tidal prism to 7.2 MCY through subsidence of the rock underlying the lagoon. Would it have been 7.7 MCY if there had been no anthropogenic affect between 1854 and 1906?

RESPONSE: We believe the amount of tidal prism increase is mostly related to the magnitude and nature of individual earthquakes. The sediment texture (grain size) and depth is also likely important in that dynamic compaction occurs along with vertical displacement. In general, we do not believe the 1906 down-drop, and hence tidal prism increase, would have been substantially different without 1854-1906 anthropogenic effects.

It would further help to summarize points 11-24 very succinctly to enable the public to easily understand how natural and human factors may have altered the lagoon from 1906 to present.

RESPONSE: Some of these have been re-worded. As noted above, we have also included a concise narrative before the list of specific comments.

Here are the main points I got from your report:

1906 to Present

Since 1906, natural process and human activities have resulted in net sedimentation in the lagoon and a reduction in tidal prism of about 3.7 MCY to about 3.5 MCY today. Can this 3.7 MCY loss be partitioned between anthropogenic and natural forces? Can you estimate what the tidal prism would be today had there been no anthropogenic affect between 1854 and 1906?

RESPONSE: As noted above, we have revised our estimates of historic tidal prism based on re-computing the values derived from T-sheets.

It is not possible to say precisely what the 'natural' form of the lagoon should be today, since large earthquakes like the 1906 event significantly alter the lagoon form and channel network, particularly near the inlet. However, we have developed estimates of how much tidal prism has been lost due to the two most direct anthropogenic modifications: Seadrift Lagoon and channelization of Pine Gulch Creek.

10a. The sudden down drop of the lagoon floor during the 1906 earthquake greatly increased the tidal prism and the amount of sandy sediment swept in through the lagoon mouth and deposited in the interior.

RESPONSE: As noted by Byrne, much of the littoral sediment is bluff-eroded silt. Coarser beach sands mostly deposit on flood-tide shoals and islands closer to the inlet.

10b. Human actions in the watershed and channelization of Pine Gulch Creek caused the Pine Gulch delta to extend into Bolinas Lagoon. Creek bed channelization eliminated flood plain sedimentation which in turn increased the rate at which gravel and course sand from the Pine Gulch Creek watershed deposited in Bolinas Lagoon. Similar deltas formed near the mouths of steep creeks that drain Bolinas Ridge but their effect on lagoon tidal prism and habitats was much less than those of the Pine Gulch Creek watershed.

10c. The growth of Pine Gulch Creek delta into the lagoon and its colonization by tall dense riparian vegetation altered wind patterns. The result was the development of an

area sheltered from turbulent waves between Pine Gulch delta and Kent Island which in turn allowed mudflats there to be colonized by salt marsh.

10d. The sedimentation between Kent Island and Pine Gulch also filled in the head of Bolinas Channel, thereby reducing the ability of tidal scour to maintain a large channel. The connection between Bolinas Channel and Pine Gulch Creek was eliminated as the head of the Kent Island Channel filled in and the mouth of Pine Gulch Creek migrated north. Doesn't this result in decreased ability of the lagoon to flush sediment coming in from Pine Gulch Creek? If so, in the future would the relative balance of sediment accumulation between fluvial and littoral sources shift toward the fluvial?

RESPONSE: Much of the coarse watershed is deposited on the fluvial deltas near the mouth of Pine Gulch Creek. This sediment would not of been transported out of the lagoon even if the head of Bolinas Channel had not filled with material. It is difficult to say if the smaller Bolinas Channel means less alluvium is removed. However, it is clear that segregating Bolinas Channel from other portions of the lagoon will reduce its cross-sectional area and depth, since the tidal scour will diminish.

10e. Fill was placed in the lagoon, particularly during the development of the Seadrift sandspit.

2000-2005

In 50 years we project a further loss of 1.2 MCY of tidal prism to 2.5 MCY compared with the estimated 4.2 MCY in 1854. Since sedimentation will still be outpacing sea level rise, the lagoon will still be filling in but the lagoon inlet will only be subject to closure under extreme combinations of strong El Nino storms and weak neep tides. The net loss of 1.7 MCY of tidal prism from 1854-2005 can be attributed to human activities directly and indirectly as follows (see Table 6.3):

- 0.30 MCY -- fill associated with the Seadrift development.
- 0.10 MCY -- fill placed elsewhere in the lagoon, especially along Highway 1.
- 0.25 MCY -- increased creek bed load delivery.
- 0.25 MCY -- reduced wind wave action between Pine Gulch Creek and Kent Island
- 0.80 MCY -- affect on wind fetch and resulting waves from Pine Gulch Delta protrusion and construction of Seadrift Seawall

Note: The last two bullet points are difficult to understand. These bullet points are derived from table 6.3.

RESPONSE: Project 50-yr tidal prism loss is ~ 1MCY. Note: We have revised our estimates of 1854 tidal prism, and this has affected the findings presented in Table 6.3 of the administrative draft. See new table. Also, note that the 0.3 MCY associated with Seadrift Lagoon is the long-term loss. Approximately half of this was temporarily offset

by dredging a 'borrow' channel along the outboard side of the newly constructed dike (portions of this borrow channel are still present).

Associated with loss of tidal prism will come changes in the composition of subtidal, intertidal and super tidal habitats over the next 50 years. Apparently the eelgrass beds in subtidal habitat of the Bolinas Channel have already disappeared. Future habitat changes in are listed in table 6.1 and summarized below:

- No change in extent of flood tide shoals inside the lagoon entrance.
- No change in the size of the flood tide island (Kent Island).
- Loss of 2 acres of the current 171 acres of subtidal channel.
- Loss of all 27 acres of current subtidal shallow ponded habitat.
- Loss of 106 acres of the current 399 acres of frequently submerged mudflat.
- Increase of 63 acres to the current 264 acres of frequently emerged unvegetated mudflat.
- Net loss of 43 acres of mudflat (combining frequently and infrequently submerged).
- Increase of 44 acres to 244 acres of salt marsh.
- Increase from 3 to 5 acres of brackish marsh.
- Increase from 30 to 54 acres of creek delta.
- Increase from 5 to 6 acres of transitional habitat.

The numbers of acres lost do not tell the whole story with regard to level of impact. There should be some way to rate habitat as to importance to estuarine dependent fish and for marine fish.

RESPONSE: See TRG comments regarding importance of projected morphologic change on ecology.

Is there any way to calculate the habitat changes from 1854-2050? The tidal prism changes are related to 1854 but the habitat changes are related to 2000.

RESPONSE: Fewer habitat types are listed in the 1854 T-sheet (e.g, intertidal flats are not differentiated by "typically submerged" or "typically exposed"). However, we have listed the acres of marsh, intertidal flats, and subtidal channel in the 1854 T-sheet (see Appendix B).

Need more specific information on the invertebrates, fish and birds likely to be affected by the potential habitat changes

Compared to the detail presented on tidal prism changes and habitat changes summarized above, there is only very general information on the organisms likely to be affected by the habitat changes. More detail should be presented.

Invertebrates

Table 5.1 lists 99 invertebrates documented for Bolinas Lagoon. The tidal zone in which they occur is also listed. It is probably reasonable to expect the 34 species (includes Washington Clam) identified as using the mid and low tide habitats or just low tide habitats as losing habitat over the next 50 years. This is a third of the listed invertebrates. Notable among these species are Fat Innkeeper worm, Rock Crab, Blue Mud Shrimp, Soft shelled Clam, Geoduck, Washington Clam, and Gaper. The Washington Clam is probably already gone and the beds of Gaper Clams greatly reduced in extent.

RESPONSE: We agree that many invertebrates will lose habitat over the next 50 years; however, species-specific impacts were not discussed due to the large-scale focus of the document. The report was modified to reflect the fact that the species mentioned in the comment will lose habitat.

Fish

Table 5.2 lists 38 species of fish identified in the lagoon. Tom Moore of Dept. of Fish and Game has done the most recent sampling of fish in the lagoon. Here are his comments on fish in the lagoon.

"I went back to our fish survey data to try and pull out more gear–specific species composition. I looked at our trawl data as basically sampling the subtidal channel habitat. Our catch data from the beach seine and stick seine represented the subtidal shallow and frequently submerged habitat species composition.

There is an amount of crossover of species captured by all the gears and thus utilizing all the habitats, such as schooling plantivores like topsmelt and jack smelt. We typically did our survey work on days with tides in the mid-range (3-4 ft) which meant that subtidal-shallow and freq. submerged mudflats were flooded and species that utilized these habitats should have been present (just not enough time and too much current to effectively sample a number of areas on just the high). If I had the time and personnel, I would focus on just high tide collection in shallower habitats for a more representative sample.

Most fish captured in the subtidal shallow and frequently submerged mudflats were small benthic oriented fishes, both small fish and small (juvenile) fish utilizing this area as nursery grounds (have to discount the large bat rays and leopard sharks that forage here on high tides but that is another aspect/use of these habitats). I see this as particularly insidious loss because this is the largest area of loss in all the coastal areas from development and sedimentation.

One of the things about Bolinas Lagoon subtidal channel habitat is the lack of fringing eelgrass and any subtidal eelgrass that would afford cover for fish in higher habitats as tide drops. So, as their habitat diminishes in Bolinas lagoon, unlike other more typical coastal areas, their mortality rate will increase due to this lack of cover/complex habitat (that's why I am pushing for native oyster restoration or eelgrass restoration).

Species that will be impacted the greatest belong to benthic-oriented (eco guild) fish, typically juvenile life stages but not always. They would include:

Flatfishes- speckled sanddab, English sole, starry flounder, California Halibut

Roundfishes- Pacific staghorn sculpin (dominant by number) and others; arrow goby, yellowfin goby (exotic), and others; cabezon; shiner, walleye, dwarf, and barred surfperch, juvenile rockfish spp.

Sharks and rays- leopard shark and bat ray, bottom feeders on inverts in those habitats.

Invertebrates- shrimps, *Crangon* spp. and *Heptacarpus* spp. are important prey items for fishes and others that utilize these habitats. Crabs- Dungeness, red rock, slender, Oregon cancer crab, and green crab (exotic); usually small juvenile sizes in these habitats.

Schooling plantivores (eco guild) not as impacted as benthic-oriented fishes but will suffer with loss of access to this habitat- jacksmelt, topsmelt, and surfsmelt. Pacific herring, PWA report mentions Pacific herring with more emphasis than warranted since I believe they are substrate-limited in Bolinas Lagoon with regard to spawning habitat but I believe the juveniles (most likely entrained into Bolinas Lagoon similar to Bodega Bay) utilize these habitats.

RESPONSE: We agree that many fish species, which use habitats within the lagoon at various life stages, will lose habitat over the next 50 years; however, species-specific impacts were not discussed due to the large-scale focus of the document. Text was added to the report to address the fact that fish will likely be impacted by changes in the lagoon's habitats.

Birds

Habitat changes will affect the habitat potential for many bird species.

Birds Facing Potential Habitat Losses

1. Diving fish-eating birds: examples are Common Loon, Double-crested Cormorant, Brown Pelican, Western Grebe, Osprey, Red-breasted Merganser, Elegant Tern, Caspian Tern, and Forsters Tern.
2. Diving benthos feeders: examples are Horned Grebe, Greater Scaup, Ruddy Duck, Common Goldeneye, Bufflehead, and Surf Scoter
3. Dabbling benthos feeders exploiting frequently submerged tidal flat: examples are Northern Pintail, American Wigeon, Northern Shoveler, and Gadwall.

4. Long-legged shorebirds exploiting frequently submerged tidal flats: examples are Marbled Godwit and American Avocet

Species Facing Potential Habitat Trade-offs.

1. Loss of frequently submerged habitat may be offset by increase in frequently emerged tidal flat and/or salt marsh: examples are Long-billed Curlew, Whimbrel and Green-winged Teal.

Species Facing Potential Habitat Gains

1. Shorebirds using frequently exposed intertidal habitat: examples are Black-bellied Plover, Least Sandpiper, Western Sandpiper, Dunlin, Sanderling, Black Turnstone, and Willet.
2. Species relying on salt marsh: examples are Savannah Sparrow.
3. Species relying on brackish marsh: examples are Black Rail, Common Yellow throat and Marsh Wren.

RESPONSE: Like other groups and guilds, there will be gradual shifts in bird community structure as habitat gains and losses occur. To address large scale changes, we did not address all species in the report. In response to the comment, some of the species mentioned were added to the text to illustrate impacts of gradual habitat change on feeding guilds.

Proposed adaptive management plan

The proposed adaptive management plan will appear to most people as the main conclusion drawn from the report. It will be viewed negatively by some as just more study.

The function of the proposed adaptive management study is not clear. Some monitoring is proposed to see if the future hydrological and sedimentation projection rates are correct. Since no decision as been made on whether the changes projected in this report are acceptable and require some intervention, proposing studies to measure the accuracy of the projections, does not answer the key question of when intervention is warranted.

RESPONSE: We agree that open-ended monitoring is not appropriate. Instead, we have recommended (and prioritized) monitoring focused at managing key uncertainties. The first is inlet closure. Based the limitations of the O'Brien analysis and the potential ecological consequences of closure, we think it is prudent to track inlet closure potential. Also, as stated in the report, the exact balance between erosive and depositional processes over the mudflats is unclear. Collected elevation information at selected transects would provide useful information regarding how stable mudflat platforms are in wind-swept portions of Bolinas Lagoon.

What actions, if any, should be taken now to arrest the rate of some of the predicted changes to the functioning and habitat composition of the lagoon? If some actions are proposed and implemented then monitoring should be conducted to measure their effectiveness. If no actions are taken future monitoring will not be adaptive unless triggers are set for actions based on some criteria. Right now we don't now if the current study should trigger actions.

RESPONSE: We agree that this monitoring will not lead to adaptive management decisions unless triggers are established. We suggest that the new findings from the UC Berkeley study and this report be used to revisit, and possibly revise, the goals and objectives that would be the basis for indicators and triggers.

The biological section on monitoring argues for certain indicator species and emphasizes locally nesting herons and egrets over migratory birds indicating factors outside the lagoon can affect local migratory bird abundance. While this is true, it is also true that factors such as predation can affect colony nesting birds such as heron and egret rookeries causing them to move. I would argue that biological monitoring should look at communities of invertebrates, fish and birds.

RESPONSE: Based on this comment and those received from DFG, we recommend monitoring be conducted for invertebrates, fish, and birds.

Tom Moore (PRAG member)
Comments on Administrative Draft: Bolinas Lagoon Ecosystem Restoration Project

The PWA report is first and foremost a technical document dealing with the physical aspects, the geomorphology and hydrology, and secondly, the ecological aspects in a 50-year projection. The quantity and quality of physical data are impressive, especially compared to the biological data. In trying to stay in my realm (fish and their habitats) I felt that I didn't have a lot of real data to work with. Many of my questions, such as those on eelgrass, probably can't be answered by this report.

What is clear to me is that Bolinas Lagoon is quite different than other local coastal embayments in a number of respects. I was struck by the lack of complex intertidal and subtidal habitat. By this I mean, there was (1992) very little subtidal vegetation (eelgrass or algae) and other rocky intertidal or subtidal habitat. In our fish surveys in the lagoon we used otter trawl, beach seine, stick seine and crab traps to survey the lagoon habitat types. Two distinct areas had the highest species numbers of species, the Bolinas Channel (Kent Island Channel?) and the intertidal/subtidal area on inside of the east side of the inlet. Bolinas Channel had eelgrass beds and the area inside the inlet had a rocky bottom with some algal cover. The unvegetated mudflats and sandy channels did not support this type of species diversity.

- Why did Bolinas only have a very small amount of eelgrass when other local estuaries have relatively large and healthy eelgrass resources?

RESPONSE: Not known. It may have been absent in the late 1850s when the lagoon was primarily shallow mudflat with subtidal channels similar to today. The 1906 opened up the tidal prism and there was significantly more deep water habitat. Eelgrass may have colonized the lagoon, but as sedimentation has decreased tidal prism and the amount of deeper water habitat, the eel grass no longer occurs.

- And why only in the Bolinas Channel? I don't mean to fixate on the Bolinas Channel but it supported the only eelgrass bed in the lagoon and had the highest fish species diversity also, and now the eelgrass is almost gone and it seems, so is Bolinas Channel.

RESPONSE: Not known.

- I may have missed it, but I really couldn't find any information on how important the Bolinas Channel is to the tidal prism and lagoon functioning and what will it look like in the future. Ecologically, I know it was a unique and valuable habitat in the lagoon and supported a diverse assemblage of fish in a number of life-stages.

RESPONSE: See top of page 72. It will continue to decrease in size as tidal marsh expansion between Kent Island and the Delta limits the daily flow of ebb and flood tides.

To me, the rapid erosion of the eelgrass beds and the simultaneous filling of the channel in just 10 years or so, bring home the message that change can be quick in the Lagoon.

- What was the threshold or key environmental event that led to this?
- Was this a redistribution of Lagoon sediments or input from outside?

RESPONSE: The expansion of Pine Gulch Creek delta and the expansion of tidal marsh between Kent Island and the Delta has constricted the channel. Rather than a major connection to the northern part of the lagoon, the channel is constricted and will drain the tidal marsh resulting in less tidal scour with subsequent sedimentation and decline in size and function.

In Section 6.9.1 of the Draft, Expected Shifts in Habitat Dist. And Abundance,

Subtidal Channel- Subtidal channel is said to represent about 15% of the total area of the lagoon and will have a very small decrease of only about 2 acres over 50 years.

- In many other local bays, a small change such as this would be OK since most subtidal channels are fringed with eelgrass. In Bolinas Lagoon, the loss of the highest-value subtidal channel habitat with fringing eelgrass just happened in Bolinas Channel and is still occurring.

RESPONSE: Noted.

Subtidal Shallow- The text states that this is a small area (2.3%) of the total area and is used as a nursery area (as is subtidal channel). Text states that there will be loss of habitat to benthic flatfish species and invertebrates and that small fish utilizing it as a nursery area will move into other areas

- While small in area, this is another valuable habitat loss that will impact multiple species, at different life stages, and an important prey-base. There is a reason all the animals are using this habitat.
- Not all habitats are equal, and just adding-up the total areas, doesn't really estimate the impact of its loss (ecological function as stated in the text).

RESPONSE: Noted and report modified.

Frequently Submerged Mudflat- While the text doesn't calculate the expected decrease in the next 50 years (27%) this is a habitat with a large expected decrease in area and with expected impacts to fish populations. This is also an area where data have been collected for quite a while on fish eating birds. Text suggests using bird abundance and diversity as an indicator of adverse changes in fish abundance associated with habitat type decline.

- I would suggest rather that monitoring through direct surveys of fish populations

be done in this and the other habitats.

RESPONSE: Done

Fish

Table 5.2 lists 38 species of fish identified in the lagoon. Many of these are likely to be affected by loss of subtidal ponded habitat and frequently submerged habitat. How many of the 38 species may be present in lower numbers in the future because of loss of flooded habitat: Species in the following families looked susceptible to me: Atherinidae 2 spp; Bothidae 2 spp; Clupeidae 1 spp; Cottidae 3 spp; Embiotocidae 8 spp; Engaulidae 1 spp; Hexigrammidae 1spp; Myliobatidae 1spp; Osmeridae 1spp; Perichthyidae 1spp; Pleuronectidae 3 spp; Scorpaenidae 1 spp; and Trakididae 1 spp.

RESPONSE: We agree that many fish species, which use habitats within the lagoon at various life stages, will lose habitat over the next 50 years; however, species-specific impacts were not discussed due to the large-scale focus of the document. Text was added to the report to address the fact that fish will likely be impacted by changes in the lagoon's habitats.

Section 7.2- states that "As expressed in these goals, the over-arching strategy is to allow for natural geomorphic and hydrologic processes to maintain the resources of the lagoon (Goal 1, Objective 3). This is a recognition that development of habitats (Goal 1, Objective 2) and biological uses (Goal 1,Objective 1) rely on natural processes that drive the geomorphic evolution of the lagoon".

- Does this mean we sit back and watch to see if we need to jump-in and do something or can we try to enhance the existing system as it currently is.?

RESPONSE: This is a question that will be addressed in the next steps of the planning process with public input. The MCOSD and the State and Federal partners are obligated to complete the Feasibility Study and EIR/S (a draft Feasibility and DEIR/S were completed in 2002). Whether and what type of restoration/intervention measures will be considered then.

Stuck in Goal 1, Objective 2, is the word "enhance". It is not in the description of Goal 1.

- I have to admit, I am confused as to whether enhancement is a proposed activity or something that will occur by itself?

RESPONSE: The list of Goals and Objectives listed in the report are those developed for the 1996 Bolinas Lagoon Management Update. Considering our significantly improved understanding of how the lagoon functions and changes over time, we

recommend revisiting these Goals and Objectives as part of the next steps in the planning process.

A number of pilot projects are being done in SF Bay using native oyster restoration to provide habitat complexity, along with other benefits such as increased water clarity, in subtidal shallow and frequently submerged habitat types. Additionally, small-scale eelgrass seeding projects using buoyed floats to scatter eelgrass seed are being evaluated. Recent work by Merkel and Associates developing a model for predicting suitability of areas for eelgrass growth and restoration may be useful in identifying potential areas for eelgrass establishment.

The reason I mention these small restoration projects is because it seems the document is focused, and maybe we are still, on big projects (intervention) involving dredging large areas and potentially having big impacts. Also, it seems that the process will take a long time to determine if we will do anything. Recent changes to CEQA allow small scale (< 5 acre) restoration projects to be implemented in a very short time. The two projects, oyster restoration and eelgrass seeding, deal directly with looses we have seen in Bolinas Lagoon and will continue to experience at some level in the future.

RESPONSE: The TRG strongly recommended that the report focus only on the 50-year projection and not on restoration/intervention alternatives. One figure (Fig. 6-1) originally mentioned "a large scale project"—this was inadvertent and has been changed. If purpose and need is determined, a range of restoration/intervention alternatives, large and small, should be considered.

Section 7.4.2 – I would suggest adding Fish as a species to be monitored.

RESPONSE: Done.

With regard to the Figures and Tables- as they exist now, they pretty much stand alone and are not referred to in the text.

RESPONSE: The figures and tables have been integrated into the text.

In Figures 7.1-7.3 restoration action/experiments is on a large-scale.

- No small scale enhancement experiments allowed?

RESPONSE: This has been changed. The next steps of the planning process (completing the Feasibility Study and EIR/S), with public input, will determine purpose and need for intervention. A range of restoration alternatives—not just a single large project--- may be evaluated.

- Are all actions to be interventions to protect birds or mammals? Reality may be at the project level that certain ESA fish species (coho and steelhead) will drive the activity permitted. The Lagoon is Essential Fish Habitat and a consultation with NOAA Fisheries will be needed to obtain a COE permit.

RESPONSE: Consultation and permits from numerous agencies will be required before any activity occurs in the lagoon. As noted above, the Feasibility and EIR/S must be completed as part of the planning process. The TRG strongly recommended that the report focus only on the 50-year projection and not on restoration/intervention alternatives.

- Need to update text on page A-14 in Appendix A as to status of coho and steelhead.

RESPONSE: Report modified.

In summary, I found it quite difficult to evaluate the PWA report trying to focus on fish or fish habitat. I found myself in agreement with the studies that dredging is probably not justified at this time. As to fish and fish habitat, I think a significant loss of habitat has already occurred in the Bolinas Channel. The monitoring and management section needs to be more clear and should include enhancement as a goal on a smaller scale now rather to wait until sometime later for possible large scale intervention to restore.

RESPONSE: Again, the Report focuses on the 50-year projection. Restoration or intervention alternatives were specifically not discussed in the report. The section on adaptive management was to present in outline what an adaptive management plan involves. As noted above, the inadvertent allusion to a large-scale project was modified.

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Comments on Administrative Draft: Bolinas Lagoon Ecosystem Restoration Project

Overall the report needs reorganization, editorial review, and a clarification of terms used or coined in the report.

I recommend:
-Historic evolution of the lagoon is presented first so that the public learns first what the lagoon is and what brought it to its present state.
-The key physical and biological processes of the lagoon
-Existing lagoon conditions
-Future evolution of the lagoon.
-The conclusions and recommendations
-Monitoring and adaptive management recommendations.

This might present a more coherent succession of information and recommendations.

RESPONSE: Sections 3 & 4 have been combined, and we have included a concise summary of key findings before the list of specific conclusions.

There is no mention of the effects of the ebb tides into and out of the lagoon. They too have the ability to transport sediment. This needs to be addressed.
Tidal prism was increased with the 1906 event; this shift in dynamic equilibrium should have gone on the side of increased tidal prism. What the report says is that since the shift we have decreased the tidal prism by .2 MCY in 92 years. Is this the result of anthropogenic effects on the sedimentation patterns in the lagoon? If so, then why shouldn't there be some sort of moratorium on any development or changes to the surrounding water shed, if, in fact, the sedimentation is due to human induced changes.

RESPONSE: Tidal dispersion and tidal asymmetry are discussed in length in the report. Tidal dispersion in particular is noted as a key processes related to the sediment dynamics of the lagoon.

The report states that the 1906 down-drop *increased* the lagoon by 3.5 MCY.

Almost all of the watershed is already protected by public and private (Audubon Canyon Ranch).

It would further help to summarize points 11-24 very succinctly to enable the public to easily understand how natural and human factors may have altered the lagoon from 1906 to present.

RESPONSE: Done.

The tidal prism increased to 7.2 MCY between 1854 to 1906, 52 years. From 1906 to 1998 the shift was from 7.2MCY to 3.5 MCY a .2 MCY in 92 years in spite of the unchecked development around the lagoon. Could this .2 MCY been avoided if development hadn't taken place? Not mentioned in the report.

RESPONSE: We have revised our estimate of tidal prism derived from the 1854 T-sheet, based on an equation we feel is more accurate (see Appendix B). This has significantly reduced the difference between 1854 & 1998 (Year 0) tidal prism.

The mouth of the lagoon has remained open in spite of the development that has taken place within the lagoons watershed. The sediment deposited in the interior of the lagoon wasn't only material moved into the mouth alone much of this material came from the watershed.

RESPONSE: As discussed in Byrne et al. (2005), most of the sediment accumulated since 1906 originate from littoral sources.

Some mention needs to be made that the differences in the amounts of sediment delivered to the lagoon is reflected on where human induced changes have occurred in the water shed.

RESPONSE: The report does properly note that the most significant anthropogenic-induced changes have occurred at the fluvial delta near the mouth of Pine Gulch Creek and Seadrift Lagoon.

How does the unmanaged watershed and the continuing runoff derived sediment contribute to the sediment sources?

RESPONSE: The most significant increases are to bedload delivery.

The fill placed in the lagoon, particularly during the development of the Seadrift sandspit, is not much emphasized. The public needs to be made aware of how development such as this is detrimental to the life of the lagoon.

RESPONSE: We have provided an estimate of the long-term loss of tidal prism due to Seadrift Lagoon – approximately 0.3 MCY.

We need to ask the question of how the unchecked development has had adverse effects on the lagoon. How can this be controlled in the future to slow the decrease in tidal prism?

RESPONSE: Most of the watershed is already protected. See comment above.

Fish

Table 5.2 lists 38 species of fish identified in the lagoon. Many of these are likely to be affected by loss of subtidal ponded habitat and frequently submerged habitat. How many of the 38 species may be present in lower numbers in the future because of loss of flooded habitat: Species in the following families looked susceptible to me: Atherinidae 2 spp; Bothidae 2 spp; Clupeidae 1 spp; Cottidae 3 spp; Embiotocidae 8 spp; Engaulidae 1 spp; Hexigrammidae 1spp; Myliobatidae 1spp; Osmeridae 1spp; Perichthyidae 1spp; Pleuronectidae 3 spp; Scorpaenidae 1 spp; and Trakididae 1 spp.

RESPONSE: Report modified.

Response to USACE Comments

Cindy Tejeda
Senior Project Planner
US Army Corps of Engineers
San Francisco District

Technical

1. The concept of dynamic equilibrium is difficult to fully comprehend from the text. It is unclear whether the dynamic equilibrium the lagoon will reach in the near future is different from the dynamic equilibrium that it would have (and did) reach under natural conditions. In the past, under natural conditions, did the lagoon reach its dynamic equilibrium X # of years after a given earthquake and then stay in that dynamic equilibrium until the next earthquake? And if so, does that mean that the logging & grazing (etc.) that occurred in the 1850's accelerated this process, causing the lagoon to reach its dynamic equilibrium sooner? Or is the lagoon progressing towards a new (different) equilibrium?

   Response: We have attempted to clarify the use of punctuated dynamic equilibrium in the report and emphasized that lagoon may not reach dynamic equilibrium between the few hundred years between earthquakes. However, we do believe it is correct to state that the lagoon tends towards an equilibrium form that balances erosive and depositional processes. Anthropogenic changes that modify important sediment dynamics generally results in an evolutionary trajectory towards a *different* equilibrium form.

2. Your report emphasizes the significance of the contribution of littoral sediments to the lagoon's net sedimentation rate (saying that the bottom drop caused by earthquakes creates sediment sinks), and this would have happened (did happen) under natural conditions. The contribution of watershed sediment is de-emphasized in your report because, it is stated, the overall contribution of watershed sediments is comparatively low. The significance of those mid-nineteenth century watershed practices (and current practices, especially at Pine Gulch Creek), and the impact they had on the shape of the lagoon, cannot be denied, however. In another draft of something I read earlier, you stated that "sea level rise will overtake PGC delta accretion in approximately 177 years, at which point the delta will have grown radially by 530 feet." Has this (human-induced) increased rate of sedimentation *not* affected the future shape/formation of Bolinas Lagoon? Especially when you consider that sedimentation rates are higher in that area due to the presence of vegetation & the lack of wind-wave erosion. Getting back to my first comment, has Bolinas Lagoon been put on "fast forward" towards its natural dynamic equilibrium, or is it approaching an altered dynamic equilibrium? The answer to this question could determine the future of Corps activities on this project…

   Response: We believe the lagoon is approaching a different equilibrium form. This is primarily due to: development of Seadrift Lagoon, which impounded a portion of the tidally active Bolinas Lagoon; and increased delivery of watershed sediments (especially bedload), which has formed a delta at the mouth of Pine Gulch Creek. However, as the Byrne data reveal, most of the sediment accumulated in the intertidal and subtidal portions of the North Basin since 1906 originates from littoral sources.

Editorial

1. Pg 25, last paragraph. I think Pickleweed Island no longer exists. Please check with someone from BLTAC or Ron Miska.

Response: Text revised

2. Pg 25, first paragraph. After "rock cod," the following appears: (, I think the species name is missing.

Response: Text revised

3. Pg 28, second paragraph. After "the great blue heron," it should read *is* a permanent resident of the area (not *are permanent residents*).

Response: Text revised

4. Fig 5-4: at the top of the figure, a noun is missing in this sentence: Majority of watershed delivery occurs during infrequent periods of intense ---*what?*

Response: Text revised

5. Fig 3-6. While it might be obvious to most, I think Bolinas Lagoon should be added to one of the categories listed on this figure. Also, as Bill Brostoff mentions in his comments (he requested a definition of "lagoon"), I think there may need to be a short paragraph on the difference between lagoons and estuaries as this was certainly a matter of debate when we released the draft reports in 2002. If it is really a spectrum, where open estuary lies on one end of the spectrum and hyper saline or freshwater lagoon lies on the other, we need to determine where the "natural" state of Bolinas Lagoon lies on that spectrum (and where it currently lies, if its condition has changed). For example, some commenters made the statement that since "natural" lagoons filled in "naturally" anyway, why should anything be done in Bolinas Lagoon? I guess this was based on the strict definition of lagoon, which is a body of water that is often (always?) closed to the ocean, whereas most of us can agree that Bolinas Lagoon is not a lagoon (by definition) but an estuary, and since it lies on an active fault line, perhaps it defies the standard definitions?

Response: We have added "lagoon" and "estuary" to the glossary. Figure 3-6 from the Admin Draft has been removed, as part of the re-organizing suggested by the TRG.

We do not believe that all lagoons naturally "fill in". This depends on the sediment budget of any particular lagoon. Evidence from the recent UCB study reveals that in the case of Bolinas Lagoon, large earthquakes along the San Andreas Fault have a major role in the maintenance of Bolinas Lagoon.

6. Page 1. Last sentence of 2nd paragraph. It states that MCOSD decided to reformulate the ERP in order to develop a "cost effective" and scientifically sound plan…. I don't see anything in this document that discusses the costs (or benefits) of any plan or part thereof. I'm not sure where that statement came from or why it is in the text.

Response: Text revised to omit cost-effectiveness.

22 December 2005
"PWreportDec05_commentsCSC.doc"

Comments on "Projecting The Future Evolution Of Bolinas Lagoon"
Administrative Draft (PWA Ref. # 1686.02)
Prepared by PWA and WRA, 7 December 2005
By Craig Conner
Water Resources Section, San Francisco District
US Army Corps of Engineers (CESPN-ET-EW)

Editorial Comments

- The Conclusions and Recommendations section should be moved to the end of the report; an Executive Summary section can be added to the beginning of the report.

RESPONSE: We have kept this section at the beginning in order to provide a summary of key findings. Also, at the request of the TRG, we have added a concise narrative before the numbered list of specific conclusions.

- In the final version of the report the figures should be integrated within the text and placed as close as practical to where they are first cited in the report.

RESPONSE: Done.

- Some paragraphs are not formatted properly (see page 42 for an example). Please check the formatting of all paragraphs before submitting the final version of this report.

RESPONSE: This was a problem with the PDF processes. Problem corrected.

- Some references cited in this report are not included in the References section; please check all references and update the References section in the final version of this report.

RESPONSE: Done.

General Comments

- This report provides information and analyses on the historical, present, and future without project conditions of Bolinas Lagoon. The information, results, and conclusions presented in this report are similar to those given in the Corps draft Feasibility Study report (USAED-SF 2002a) and as such provide greater assurance about our understanding of without project conditions at Bolinas Lagoon.

- The report contains one appendix on the biological field studies. The report does not contain an engineering appendix documenting the data sources and their accuracies, more detailed description of methods used in their analyses and their associated assumptions and limitations, independent data checks, and quality control certification. An engineering appendix is needed to corroborate the information, analyses, and conclusions given in this report. Without an engineering appendix the results and conclusions given in this report should be considered speculative at best.

RESPONSE: The Bolinas Lagoon TRG has provided comments on the general approach and findings. Also, many of the essential findings are based on results from the recent UCB sediment core study – which does describe details of the pollen dating and other analyses.

- This report relies heavily on the assumption that if you create new similar physical conditions as exits for certain present habitats, that these habitats will populate in a similar manner in the new physical environment. Previous work (Zedler & Callaway 1999) has indicated that this assumption may not be true for all restoration projects. Further explanation is needed in this report on why the authors feel this is a good assumption for this project site. References to where this assumption has been successfully applied to other restoration projects would be helpful.

RESPONSE: No habitat creation or restoration actions are described in this document. Instead, the purpose of this study is to evaluate the No Action alternative.

Specific Comments

Sediment Budget, Sediment Dynamics And Equilibrium Form (Page 8): A table should be added to this section summarizing the Sediment Budget results. The table should include all sources and sinks of sediment, their volume amounts along with the uncertainties in the estimates, and should sum to zero. A schematic containing this same information (possibly overlain on a photograph of the area) may also be helpful to the reader.

RESPONSE: Since the values of the sediment budget have varied over the Holocene and historic record, we have not added numbers to specific tables/figs. Instead, the quantities of 20th century alluvial and littoral accumulation are spelled out in the text (including succinct bullet points).

Intertidal Mudflats (Page 26): A definition, table, and schematic should be given for Local Mean Sea Level (LMSL) as it relates to other important vertical datums. The difference in elevation between LMSL, MSL, MLLW, MHW, NGVD29, and NAVD88 should be specifically given as these datums are important for engineering and regulatory purposes for the project.

RESPONSE: We have included a table of the published NOAA tidal datums for Bolinas Lagoon, as well as the conversion between NGVD and NAVD (based on VERTCON), in an appendix.

Sea Level Rise (Pages 36 & 37): The authors should consider a range of sea level values, including using curve 3 from the National Research Council Report (NRC 1987), and show the sensitivity of sediment budget results to the various assumed values of sea level rise. The authors should then select one value for sea level rise and provide an explanation as to why they feel the chosen value best represents what will happen at Bolinas Lagoon over the next 50 years.

RESPONSE: We have established estimates of future sea level at Bolinas Lagoon by applying a *projected acceleration* to the *observed rate* of 20th century sea level rise. Specifically, we have applied the median projected acceleration due to eustatic effects (1 mm/yr^2) established by IPPC (2001) to the observed 20th century rate from the Presidio gage (NOAA web site). We have reported an error bar on the effects of future sea level rise on tidal prism by doubling the acceleration to 2 mm/yr^2. More discussion of future sea level rise is included in our response to TRG comments.

Changes In Tidal Prism And Inlet Stability (Page 41-42): A common engineering method for determining tidal inlet stability is Escoffier's analysis (van de Kreeke 1992; Escoffier 1940). This method was applied to Bolinas Lagoon by the Corps and the results indicated that the tidal inlet is unstable (USAED-SF 2002b). The authors of this report did not conduct an Escoffier analysis, nor comment on the past analysis, in their assessment of tidal inlet stability. The authors should provide further explanation as to why they feel an Escoffier analysis was not needed for their assessment.

RESPONSE: Several conventional methods provide information on inlet stability, but the time-varying O'Brien method is the only analysis that quantifies the *frequency* of possible inlet closures. The Escoffier analysis in particular does not include the effects of incident waves – a critical driver that influences inlet closure.

Trends In Lagoon Evolution Beyond 50 Years (Page 44, Figure 6-12): This section and Figure 6-12 conflict with results given on pages 41 and 42 of this report and other previous work (USAED-SF 2002b). Further explanation is needed to account for these differences and on what is meant by a long-term equilibrium condition.

RESPONSE: The methods used by PWA and USACE-SF differ significantly, and it is not surprising that the two projections of future conditions differ. For example, the USACE-SF analysis did not consider the effects of sea level rise or the influence of locally generated and erosive wind-waves. Additionally, the present analysis relies heavily on findings from the recent UCB study (Byrne et al., 2005). Our defination of long-term means beyond Year 50 but before the next large earthquake along the San Andreas Fault.

Suggested Monitoring At Bolinas Lagoon (Pages 54-57): This monitoring plan emphasizes more physical processes monitoring of Bolinas Lagoon than biological monitoring (which would be done on five year intervals). This monitoring plan presumes a direct connection between physical processes and biological/ecological responses at Bolinas Lagoon. Further explanation, information, and data are needed to justify this

presumption. It appears from the text that a simple monitoring program consisting of a topographic and biological survey every 5 years may be sufficient for adaptive management needs.

RESPONSE: We have proposed monitoring elements that are tied to key uncertainties. Monitoring of the inlet and lagoon tides is particularly important since the potential ecological consequences of closure are significant.

References

Escoffier, F.F. (1940). **The stability of tidal inlets**, *Shore & Beach*, 8(4): 114-115.

NRC (1987). **Responding To Changes In Sea Level: Engineering Implications**, *National Research Council, National Academy Press*, Washington, DC, 148 pp.

USAED-SF (2002a). **Draft Feasibility Report Bolinas Lagoon Ecosystem Restoration Project**, *US Army Engineer District San Francisco and Marin County Open Space District*, San Francisco, CA, June 2002.

USAED-SF (2002b). **Bolinas Lagoon Ecosystem Restoration Water Resources Appendix**, *US Army Engineer District San Francisco*, San Francisco, CA, 11 June 2002.

van de Kreeke, J. (1992). **Stability of tidal inlets; Escoffier's analysis**, *Shore & Beach*, 60(1): 9-12.

Zedler, J.B. and J.C. Callaway (1999). **Tracking wetland restoration: do mitigation sites follow desired trajectories?**, *Restoration Ecology*, 7(1): 69-73.

Interim Review of Administrative Draft of Bolinas documents – 12/23/05
by William N. Brostoff, Ph.D. SPN ACOE

1. The current draft appears to be substantially improved over the previous one and I appreciate the attention given to the comments I provided on the previous draft.

2. There appear to be no major technical problems in the current version. However, there are several items of concern which should be addressed before the draft is finalized for public distribution. These include clarifying the use of some technical terminology, revising one figure, and some minor editing.

3. The addition of the "Glossary" is a major improvement and will greatly contribute to public understanding of the document. Several terms should be added:

a. Evolution (I am uncomfortable with the way this term is used throughout the document and in particular how it relates to "dynamic equilibrium."

Response: See TRG comments.

b. Dynamic equilibrium (especially in the context of item 15 on p 4 where it is stated that the 1906 earthquake disturbed the dynamic equilibrium, is this different from 'constant state of flux' on p 11 when talking about the inlet?).

Response: See TRG comments

c. Lagoon (this was brought up at one public meeting; also "intertidal lagoon" as used on p.2; a classic definition of a lagoon includes periods of closure so maybe this needs to be addressed).

Response: done.

d. Siltation.

Response: done.

4. While I appreciate the increasing attention to the causal relationship between earthquakes (other than the 1906) and increased tidal prism, it would be helpful to tighten the linkage (e.g., p 2).

Response: Text added to reflect findings from recent UCB study.

6. Item 30 on p 5 (…major changes … not expected…) should be more detailed.

Response: We wanted to keep the bullets brief. More detail is in the main body of the report.

7. Under ecological functions (item 4.2, p 14-15) it is stated "… habitat types…influence the species that dominated the system…" This seems to be circular reasoning since habitat types are often defined by the species present. Please reword.

Response: As stated in our previous conceptual models, and in this report, we believe that bed elevation relative to tidal datums is a major driver in determining habitat type.

8. Examples of editing that needs tidying up: p 24, 2nd to last line alga = singular, algae = plural; p 15, 4.3, 2nd paragraph subject very agreement impact …were.

Response: the text has been edited for typos / grammar in several places.

9. Figure 3-6 is excellent in concept and synthesizes a lot of information, however, it needs to be tidied up since the hypersaline lagoon is shown as having a lower salinity than the open estuary.

Response: At the request of the TRG, we have re-organized this section. This reorganization has led to the removal of this figure.

10. It would be helpful to standardize measurements. Siltation is reported in mm, depths in ft.

Response: Since sea level rise and estuarine sedimentation are often referenced in SI units, we have used both English and SI in certain places. This allows for better linkage with UCB report.