LARGE-SCALE RESTORATION ALTERNATIVES FOR ELKHORN SLOUGH: SUMMARY OF INTERDISCIPLINARY EVALUATIONS AND RECOMMENDATIONS

Executive summary

Elkhorn Slough's estuarine habitats have been highly altered by human activities, including an artificially deep mouth to Monterey Bay that was created and maintained to accommodate Moss Landing Harbor. From 2006-2012, the Elkhorn Slough Tidal Wetland Project (TWP) characterized four large-scale alternatives designed to decrease tidal scour and associated negative impacts resulting from this artificial mouth. These four alternatives (as well as a No Action alternative) were evaluated according to multiple criteria using an interdisciplinary approach, with heavy involvement by many TWP participants.

The Strategic Planning Team, the decision-making body of TWP, charged the Elkhorn Slough National Estuarine Research Reserve (ESNERR) and Elkhorn Slough Foundation (ESF) with generating staff recommendations regarding the large-scale alternatives. The recommendations, drafted in September 2012, emphasize estuarine hydrology and marsh sustainability, which has been the focus of TWP thus far, and complement other conservation and restoration initiatives in the Elkhorn Slough watershed. The TWP Strategic Planning Team and advisory Science Panel were invited to score level of agreement with and provide comments on the staff recommendations in September-October 2012 through an electronic survey; the average scores from the 46 respondents demonstrated overall support for all the recommendations. A joint Science Panel / Strategic Planning Team meeting was held in November 2012, providing participants an opportunity to learn more about the recommendations and to express their perspectives about them. The majority of participants expressed satisfaction with the transparency and inclusivity of the evaluation process. In addition, they expressed support for the evolution of management strategies in response to results of new scientific investigations and socioeconomic analyses.

Informed by input from the Science Panel, the Strategic Planning Team then met alone to discuss and vote on the recommendations. After modifying three of them, the Strategic Planning Team voted to approve all of the recommendations. Of 16 possible votes, each received between 11-14 "yes" and between 14-16 "passing" (yes + neutral) votes. These recommendations have thus been adopted by the Tidal Wetland Program and will be implemented over the next decade.

The approved recommendations are briefly summarized below. The first two recommendations are directly related to the large-scale restoration alternatives that were originally developed and evaluated. The remaining five recommendations call for additional actions. These latter recommendations grew out of the evolving understanding of estuarine dynamics that resulted from the investigations of the original alternatives.

NO ACTION AT MOUTH: **We recommend that no management action currently be undertaken at the mouth of Elkhorn Slough**. Given current understanding of ecological and socioeconomic impacts and funding availability, we do not consider any of the mouth alternatives to be viable management options for Elkhorn Slough at this time. The Low and High Sills at the Highway 1 Bridge and the Mouth Re-route were evaluated as the first major focus of TWP because of the potential cost-effectiveness of implementing a single management action that could improve conditions in the entire estuary. These alternatives would reduce tidal scour, but it was not clear that they would support long-term marsh sustainability, and they involve a risk of water quality degradation which could negatively impact biodiversity. The ecosystem services most important to recreational visitors and commercial fishermen appear to be supported with the No Action alternative at the mouth. Sufficient

public and political support required for obtaining substantial funding cannot be mustered for a project that is not demonstrably superior for ecosystem health than No Action. It is important to note that while we recommend No Action at the mouth now, we recommend that the options investigated be reviewed periodically to see if conditions, or our level of understanding, have changed to the point where these might be viable solutions to tidal scour and habitat change in the estuary. It is our intention, however, to focus on other approaches for the next decade. While we began by considering large-scale alternatives, we now recommend investment in small- to medium-scale restoration projects, which involve lower risk to the ecology of the estuary and greater confidence of benefits to the ecosystem than any of the mouth alternatives.

PARSONS RESTORATION: **We recommend continued monitoring of the Parsons Sill Project, and potential future reduction of tidal prism in the Parsons complex.** The Parsons Sill Project was completed in 2011, decreasing tidal velocities within the Parsons complex and in the lower Elkhorn Slough channel. The effects of the sill will be thoroughly monitored for at least five years. This project focused on reduction of ebb-tide currents. Additional opportunities to decrease the tidal prism of the complex should be considered in the future.

MARSH RESTORATION THROUGH SEDIMENT ADDITION: **We recommend restoration of salt marsh through sediment addition to areas of Elkhorn Slough that have subsided due to earlier diking.** Sediment addition projects can achieve TWP objectives of restoring salt marsh and of decreasing tidal prism in the estuary. Such projects do not have as high risks or uncertainty about unintended negative ecological consequences as do water control structures that have been considered as mechanisms of improving salt marsh sustainability. We thus recommend pursuing sediment addition in accessible regions of the estuary where low quality, high elevation mudflats exist in areas of former salt marsh habitat. Such a project is already in the advanced planning stages for the Minhoto wetlands of ESNERR. Initial sediment addition projects should be thoughtfully designed and carefully monitored so that lessons learned can be applied to future larger-scale projects.

RESTORATION OF TIDALLY RESTRICTED HABITATS: **We recommend tidal exchange be increased to some wetlands where water quality and biodiversity are extremely degraded due to artificial tidal restriction, and where increased exchange would not significantly contribute to tidal scour or conflict with other management goals.** As a part of assessing the potential effects of tidal restriction as a mechanism for combating the negative effects of tidal scour in the estuary, various investigations were undertaken to examine water quality and ecological communities in Elkhorn Slough habitats with restricted tidal exchange. These investigations determined that most of the wetlands behind water control structures have impaired water quality and decreased biodiversity. This is significant because about 50% of the historic estuarine complex is behind water control structures. Some former estuarine wetlands are currently managed for zero or very limited tidal exchange in order to prevent flooding of farms or roads, to impound freshwater as an important resource in the region, or to allow for representation of brackish habitats and the distinctive species they support. But where landowners are supportive of increased tidal exchange, projects can be undertaken to enhance or remove water control structures. Such projects accomplish a stated TWP objective of improving conditions in restricted wetlands, but should be carefully designed not to conflict with another TWP objective of reducing tidal scour in the estuary. Examples of sites that would benefit from such projects include Whistlestop Lagoon, North Marsh, Estrada Marsh, and Strawberry Marsh on ESNERR.

EUTROPHICATION: **We recommend that efforts be taken to reduce nutrient-loading to the Elkhorn Slough estuary.** Water quality assessments and modeling undertaken as a part of the characterization of large scale alternatives led to a recognition that the estuary overall is moderately eutrophic, and that many of the more peripheral, and often tidally restricted, wetlands in the estuarine complex are highly eutrophic. TWP member organizations can support initiatives to decrease nutrient inputs, and foster further research on the sources, consequences, and potential mitigation of nutrient-loading to the estuary. Increased extent of salt marsh habitat through restoration projects and increased tidal exchange to sites with water control structures can also alleviate symptoms of eutrophication, while not directly addressing causes.

MARSH SUSTAINABILITY RESEARCH: **We recommend that further research be conducted to determine the causes of salt marsh dieback at Elkhorn Slough and to identify the factors most likely to contribute to future salt marsh sustainability.** When the assessment of large-scale alternatives began, the harbor mouth was assumed to be the main cause of salt marsh dieback. As a result of the investigations that have occurred in the past years, a more complex understanding of salt marsh dynamics has emerged. Multiple factors, including sediment starvation, marsh plain subsidence, and eutrophication may contribute significantly to recent marsh dieback, and accelerated sea level rise is likely to be very important in the future. In order to determine the most effective and sustainable management approaches for salt marsh conservation and restoration, we need a better understanding of the processes that lead to marsh loss vs. sustainability at Elkhorn Slough.

COLLABORATIVE GOAL-SETTING AND IMPLEMENTATION: **We recommend that TWP member organizations and other regional conservation partners explore the potential for jointly setting goals for habitats and conditions in the current and historical estuarine wetlands of the Elkhorn Slough watershed, so that multiple organizations can implement projects under a shared conservation plan.** In the course of evaluating the trade-offs associated with each of the large-scale restoration alternatives proposed for Elkhorn Slough, it became clear that there is no broadly agreed upon consensus for habitat goals or ecological conditions for the estuary. Currently, several conservation organizations are managing different portions of the current and historical estuarine wetlands of the Elkhorn Slough watershed, some with contrasting goals. We recommend that TWP facilitate a collaborative discussion among its member organizations and other regional partners to jointly decide whether it would be desirable and feasible to develop shared goals for habitats and conditions in the estuary. This could include maps indicating the desired mosaic of marine vs. brackish vs. freshwater habitats, and/or target areas for different valued biodiversity elements (e.g. salt marsh, intertidal mudflats, native oysters, snowy plovers) or ecosystem services (e.g. recreational activities, treatment wetlands). Also, potential agreements to address key nutrient sources and best management practices for water-adjacent properties could be explored. Through a shared vision and a mechanism for implementing it, partners can work together to collectively restore and conserve Elkhorn Slough's estuarine ecosystems.

Introduction

Elkhorn Slough: A rich but highly altered ecosystem

Elkhorn Slough is an exceptional ecosystem on the central California Coast, providing a key linkage between land and sea. The estuary harbors California's largest tract of tidal salt marsh outside San Francisco Bay. Elkhorn Slough tidal habitats encompass extraordinary biological diversity, providing critical habitat for hundreds of species of plants, algae, invertebrates, fish, birds and mammals (Caffrey et al. 2002).

The estuary has been highly impacted over the past century by human activities, especially by hydrological alterations (TWP 2007). Today about half of the original estuarine wetlands are behind water control structures, and there has been extensive loss of salt marsh and degradation of water quality in these areas. In contrast, the portion of the estuary that has not been diked has been subject to a dramatic increase in tidal energy following the 1946 creation and subsequent maintenance of the Moss Landing Harbor. The artificially deep mouth to the estuary increased tidal amplitude and current speeds in the estuary, leading to substantial tidal scour of the main channel and contributing to salt marsh loss (Oliver et al. 1988, PWA 1992, Malzone and Kvitek 1994, TWP 2007).

While hydrological alterations have greatly affected habitats at Elkhorn Slough, degraded water quality has strongly affected environmental conditions for organisms dwelling in the estuary. Elkhorn Slough is surrounded by some of the most intensely cultivated and productive farmlands in the nation. The estuary receives substantial agricultural run-off, and nitrate concentrations observed in the estuary often exceed values found in the nutrient-rich waters of Monterey Bay by nearly 20-fold (Johnson 2010). The aquatic biodiversity and ecosystem function of Elkhorn Slough depend both on intact habitats and on water quality. Decision-makers are faced with challenges in prioritizing these two cornerstones of ecosystem function, and in understanding how they interact to affect valued ecosystem services.

Elkhorn Slough Tidal Wetland Project: An ecosystem-based management initiative

In 2004, the Elkhorn Slough Tidal Wetland Project (TWP) was launched in order to implement an ecosystem-based management approach to coordinated, collaborative management in the estuary. Over a hundred coastal managers, including representatives from key regulatory and jurisdictional entities, leaders of conservation organizations, scientific experts and community members have participated in this effort (Appendix 1), united by a shared vision and objective (Appendix 2).

The Strategic Planning Team has decision-making authority for estuary-wide strategic planning by TWP, although specific authority for projects to be implemented as a part of this strategic vision rests with landowners and regulatory and permitting agencies. The Strategic Planning Team is supported by the Science Panel, which is tasked with providing expertise to support the process. Smaller working groups with joint planning team and science panel membership, as well as paid consultants, have been engaged as needed to provide targeted expertise. The local community has been engaged through numerous public meetings and recreational user surveys. In addition, 600 interested stakeholders receive the TWP electronic newsletter.

Large-scale restoration alternatives

As a part of pioneering research identifying the impacts of increased tidal energy associated with the artificial estuary mouth, proposals were made to reduce tidal energy by constructing submerged sills at the Highway 1 Bridge and the entrance to the Parsons Slough Complex (PWA 1992, Malzone and Kvitek 1994). These proposals could not be implemented without an understanding of the effects they would have on estuarine ecosystem function, and without strong support from decision-makers. The formation of TWP allowed these proposals to be vetted, along with other management alternatives. At a series of meetings in 2005, TWP members generated numerous potential management approaches. Of these, four large-scale restoration alternatives were selected and refined in 2006 to be thoroughly characterized and evaluated. From 2006-2012, the evaluation of the large-scale restoration alternatives was supported in part by substantial funding from the David and Lucille Packard and Resource Legacy Fund Foundations. The funding was used to obtain hydrodynamic and habitat modeling from Philip Williams and Associates, water quality assessments from MBARI's Land-Ocean Biogeochemical Observatory (LOBO), marsh sustainability and key species assessments overseen by scientists from the Elkhorn Slough National Estuarine Research Reserve (ESNERR), and socioeconomic characterization by the National Ocean Economics Program. A grant from the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) provided additional support for a multi-faceted, collaborative exploration of salt marsh sustainability. These investigations generated new data that changed perspectives about management of Elkhorn Slough (Appendix 3).

Evaluation of large-scale alternatives according to multiple criteria

Description of large scale alternatives

Large-scale alternatives comprised the initial focus for TWP strategic planning because if there were a single large project that could improve conditions in the entire estuary and achieve TWP objectives (Appendix 2), then this should be explored prior to consideration of small- or medium-scale projects. Four large-scale alternatives were developed as strategies to reduce the tidal prism and thereby slow current velocities and reduce tidal scour. The proposed changes to the mouth of Elkhorn Slough were also designed to reduce the height of high tide in the estuary in order to reduce the amount of time that the marsh plain is flooded, which would enhance salt marsh health and extent. A fifth alternative – taking no major estuary-wide action to address tidal scour – was also evaluated with the same rigor. Each alternative is briefly described below; the locations are shown in Figure 1. More extensive characterizations of the alternatives are provided in Philip Williams and Associates (PWA 2008).

<u>No Action</u>

This alternative consists of taking no major management action to reduce the tidal prism of the estuary as a whole. For evaluation purposes, this alternative was modeled as simply a continuation of current trends. Its primary function in this context was as a baseline for comparison with the other four alternatives. However, TWP decision-makers repeatedly made explicit that "no large-scale action" is not synonymous with no restoration action at all. The group has outlined and pursued investment in various small- to medium-scale projects consistent with TWP objectives (Appendix 2).

Mouth Re-route: new ocean inlet

The Mouth Re-route would entail closing the current connection between Elkhorn Slough and Moss Landing Harbor and the rest of the original, historical estuarine complex, including the old Salinas River channel, Moro Cojo, and Tembladero Slough. This alternative would create a new inlet to the north, at the location of an historic mouth of the slough. The flood shoals and long sinuous channel associated with the new inlet would slow the flow of water in and out of the slough, reducing tidal prism. Bennett Slough would be widened and deepened along the north and east sides of the Department of Fish and Game Wildlife Management Area, serving as the connecting channel between the new inlet and the rest of Elkhorn Slough. The inlet would require a new Highway 1 bridge. A pair of jetties was included in the description of this alternative because the inlet might close without them.

Low Sill and High Sill: tidal barriers at Highway 1

Both of these alternatives involve construction of a tidal barrier near the Highway 1 Bridge, consisting of a rock-armored sill shaped like a submerged dam. By constricting the channel at this point, the sill would produce a lag between tides in Elkhorn Slough and Monterey Bay, reducing tidal range and prism. The crest of the sill would be about 4.6 and 0.3 feet below mean lower low water, for the Low and High Sill, respectively. In the 1800s, the estuary mouth was about 2-4 feet below mean lower low water, so the low sill would more closely approximate the historical cross section of Elkhorn Slough’s inlet.

Parsons Restoration: strong reduction of tidal prism of Parsons Slough complex

This alternative consisted of a reduction of the tidal prism of the Parsons Slough complex by 80%, which would reduce the tidal prism of the entire Elkhorn Slough estuary by 25%. The reduction of the tidal prism of the Parsons complex could be accomplished by restoring the majority of the 450 acres of the Parsons complex to salt marsh. The Parsons complex was historically dominated by salt marsh, but subsided during decades in which it was diked; when tidal exchange was returned following acquisition of the property by ESNERR, extensive mudflats replaced the former marshes. For the purposes of modeling and characterizing this alternative, it was assumed that the salt marsh restoration would occur by sediment addition to raise the elevations within the complex sufficiently to support salt marsh. While the large-scale alternatives were still being evaluated, a complementary project was approved by TWP and implemented. A sill across the entrance channel of the Parsons complex was completed in 2011, serving to reduce tidal currents in Elkhorn Slough, without reducing the tidal prism of the Parsons complex. The interdisciplinary evaluations provided below do not apply to this completed project, but rather to the strong reduction of tidal prism of the Parsons Complex as originally modeled.

Hydrodynamic and geomorphic evaluation

TWP contracted with Philip Williams and Associates, Ltd. to lead a team of scientists and engineers in a hydrodynamic and geomorphic investigation of the large-scale alternatives. Team members included H.T. Harvey and Associates, 2nd Nature, Edward Thornton, and Stephen Monismith. The team developed a sophisticated tidal circulation model and used that to predict water levels and velocities in the slough and the erosion of the bed through time. The modeling was reviewed and refined with input from the Model Advisory Team and Geomorphology working groups. The results of this extensive study are presented in PWA (2008), reviewed in

Largay and McCarthy (2010), and very briefly summarized below. Overall, it is clear that the Mouth Re-route and High Sill do the most to decrease tidal scour (Table 1).

Tidal range: Tidal range would be reduced immediately by 15 percent by the Low Sill, 30 percent by the High Sill and 35 percent by the Mouth Re-route, relative to No Action. The Parsons Restoration would not affect tidal range.

Current velocities: Peak ebb tide currents, which erode the channel and export sediment from Elkhorn Slough, would slow immediately by 15 percent with the Parsons Restoration, 20 percent with the Low Sill, 40 percent with the High Sill and 50 percent with the Mouth Re-route, relative to No Action. By Year 50 in the model, peak current velocity was predicted to slow substantially under all alternatives, including No Action, as the main channel of the estuary grows larger and a new equilibrium is reached.

Tidal prism: The Low Sill would immediately reduce the tidal prism (the volume of water exchanged on each tidal cycle) by 10 percent; the High Sill, the Mouth Re-route and the Parsons Restoration would each reduce it by 25 percent relative to No Action.

Channel depth: By Year 10, the main channel (at a reference point near the center of the Slough) would deepen by 4 feet under the No Action scenario, by 1 foot under the Low Sill, and not at all under the High Sill or Mouth Re-route alternatives. The Parsons Restoration would deepen the channel in this area by 5 feet during this period, apparently by directing tidal energy, now dissipated in Parsons Slough, into upstream areas.

Sediment budget: Under the No Action, Parsons Restoration and Low Sill alternatives, no existing source of sediment to the watershed is sufficient to balance the sediment exported by tidal scour. When accounting for the sediment required to keep pace with accelerated sea level rise in future decades, the Mouth Re-route and the High Sill also result in a deficit of sediment and the continued conversion of salt marsh to mudflat and mudflat to subtidal habitat. The team (PWA 2008) found that restoration of marsh and mudflat habitats that are sustainable over many decades requires reestablishment of a perpetual sediment supply. Without this, the large-scale alternatives would only temporarily slow or reverse the rate of habitat conversion: rising sea level will submerge the remaining salt marsh, converting it to mudflats, which will likely give way eventually to subtidal habitats. The report also stated that subsided and eroded areas compete with salt marshes for sediment. It recommended the development of restoration strategies to add sediment to some of these areas.

Habitat predictions

The modeling team provided predictions of habitat extent under the five alternatives (PWA 2008). The habitats resulting from the various scenarios were determined solely by the duration of inundation. Areas inundated 1 to 12 percent of the time were classified as salt marsh, 12 to 99 percent of the time as intertidal mudflat and 100 percent of the time as subtidal habitat. The habitat analysis was limited to the estuarine habitats with full tidal exchange adjacent to the main channel of Elkhorn Slough; the other approximate 50% of former estuarine habitats in the watershed which are now behind water control structures (including Moro Cojo, Blohm-Porter

Marsh, and Bennett Slough) were not included in the analysis, because the assumption was made that their habitat distribution would not be significantly affected by the alternatives.

Because of effects on tidal range, proportions of different habitat types would be significantly affected by the five alternatives. The modeling suggested that salt marsh and subtidal habitat would be maximized under the Mouth Re-route and High Sill. Conversely, intertidal mudflats would be maximized under the No Action and Parsons Restoration alternatives (Table 1). Predictions for salt marsh are especially relevant, since the extensive loss of marsh over the past century at Elkhorn Slough was a major motivating factor for the initiation of the Tidal Wetland Project in general, and for development and exploration of the large-scale alternatives in particular.

A TWP Marsh Sustainability Working Group was convened to further explore and come to consensus on marsh sustainability issues (Callaway et al. 2012). They agreed that there have been multiple contributing factors to interior salt marsh loss in undiked portions of Elkhorn Slough, all of which have contributed to excessive inundation, also called “marsh drowning”. Increased tidal range following the 1946 opening of the harbor mouth led to initial losses, and has made marshes vulnerable to any subsequent stressor by decreasing their elevation relative to tidal waters. However the working group indicated that the role of the harbor mouth in more recent interior marsh dieback is unclear. In the future, accelerated global sea level rise is likely to become important. This consensus is based on monitoring and modeling of marsh dynamics conducted with CICEET funding (Van Dyke 2012, Wasson et al. 2012) and supports the conclusions of PWA (2008): that sea level rise will be the dominant driver of marsh loss 50 years into the future, and that extensive loss will occur under all of the large-scale alternatives.

The Marsh Sustainability Working Group also recognized subsidence of the marsh plain as an important factor. The marsh plain is currently not tracking sea level rise because it is sinking at almost the same rate as it is accreting sediment (Van Dyke 2012). This subsidence could be a result of eutrophication leading to lower below-ground investment by marsh plants or faster decomposition rates (Wasson et al. 2012). Eutrophication has been shown to lead to salt marsh die-back as well as channel widening and bank erosion (Deegan et al. 2012). If eutrophication increased under the large-scale alternatives that decrease tidal prism, then the potential gain in marsh predicted by PWA (2008) based solely on inundation time might be countered by increased subsidence rates. The working group indicated that reduction of nutrient levels and eutrophic conditions could support marsh health.

The importance of a sediment supply was also recognized by the Marsh Sustainability Working Group. Diversion of the Salinas River in the early 1900s may have resulted in decrease of an important sediment source. The Mouth Re-route alternative would further separate Elkhorn Slough from the freshwater and sediment inputs of the Salinas River and Tembladero Slough. The working group concluded that only through targeted sediment addition projects and/or restoration of a sediment supply to the entire estuary, can Elkhorn Slough marshes be sustained in the long-term.

Water quality assessment

Evaluation of water quality impacts of the large-scale alternatives designed to reduce tidal scour was critical to determining whether their net effect on the system would be positive or negative. Ken Johnson and his team at the Monterey Bay Aquarium Research Institute characterized water quality dynamics and predicted consequences of the alternatives. Johnson's Land-Ocean Biogeochemical Observatory network (www.mbari.org/lobo) of in-situ nitrate and water quality sensors revealed that the Old Salinas River Channel (that is fed in part by the Tembladero Slough system) is the primary source of nitrogen to the Elkhorn Slough estuary. Johnson noted that dissolved oxygen concentrations fluctuate much more widely in Elkhorn Slough than in most other estuaries with similar monitoring networks, and attributed this to the extremely high rates of primary productivity induced by external inputs of nitrogen. During the course of these investigations, Johnson was the first scientist to explicitly make the case to TWP audiences that even the well-flushed portions of Elkhorn Slough are eutrophic (showing indications of excessive nutrient enrichment). His analysis indicated that large portions of the slough are already at risk of dissolved oxygen concentrations low enough to kill invertebrates and cause avoidance behavior in fish. Under existing conditions, a two-week period of foggy and windless summer days could lead to low oxygen conditions lethal to fish. He cautioned that the estuary is "delicately poised" and that decreasing tidal exchange or the circulation of water could lead to substantially worse water quality.

The ESNERR water quality team has monitored water quality in the estuary for over two decades. They conducted analyses that complemented Johnson's investigations, assessing causes and consequences of eutrophication at 18 sites throughout the estuary (Hughes et al. 2011). They evaluated conditions at each site and assigned each a eutrophication score based on rigorous, explicit criteria. Most of the main channel of Elkhorn Slough is moderately eutrophic, but more peripheral sites with restricted tidal exchange are highly or even "hypereutrophic". The best predictor of hypoxia (low oxygen) is tidal range; all sites in the estuary with extended low oxygen periods and "hypereutrophic" conditions are behind water control structures.

In June 2010, Johnson presented an evaluation of the water quality implications of each large-scale restoration alternative to TWP, integrating his investigations with those of the ESNERR team (Johnson 2010). No Action ranked highest for all water quality parameters assessed (dissolved oxygen, ammonium, hydrogen sulfide, primary productivity) except nitrate concentrations (Table 2). The Mouth Re-route alternative ranked highest for nitrate reduction, because it would separate Elkhorn Slough from the current major nitrate source. This would likely decrease eutrophication in the estuary in the long-term -- but not in the short-term, due to high existing organic enrichment. Johnson suggested that the Mouth Re-route as well as the Low and High Sills could lead to negative water quality consequences for the estuary, increasing the risk of extended periods of hypoxia by decreasing flushing and removal of algal mats. The TWP Water Quality Working Group (Haskins et al. 2010) concluded that predictions regarding water quality impacts of the large-scale restoration alternatives remain uncertain, but that it is important to proceed with great caution because of the high risk of dissolved oxygen crashes given the highly eutrophic conditions in the estuary. Both Johnson and the working group indicated that the ultimate solution to eutrophication in the estuary lies with decreased nutrient inputs. Johnson suggested that one possible solution would be creation of a new inlet between the Old Salinas River Channel and the ocean, so that the nutrient loads go directly into the larger

Monterey Bay where they will rapidly be diluted, rather than into the shallow and especially sensitive estuary.

Key species evaluation

In order to provide decision-makers with information on biological responses to the large-scale restoration alternatives, reports were prepared about a suite of key estuarine species (Griffith 2010, McCarthy 2010a and b, Nelson et al. 2010, Palacios 2010, Ruegg 2010, Wasson 2010a and b). Eight taxa (pickleweed, eelgrass, oysters, selected large benthic infaunal invertebrates, selected flatfish, selected shorebirds, harbor seals, and sea otters) were chosen as top priorities. They were chosen either because they have strong ecological effects on other species (e.g. by altering habitat structure or providing food resources) or because they have socioeconomic importance (e.g. recreational or commercial value). Each report was written by a local investigator, and was reviewed by a panel of 5-8 experts for that taxon (Appendix 1). Each begins with a review of the ecological and economic importance of the species, the species trends on this coast, and factors that affect its distribution and abundance in estuaries. The next section contains a synthesis of data from Elkhorn Slough, including spatial patterns of distribution and abundance, and temporal trends. Finally, each report contains predicted responses in estuary-wide abundance under the five large-scale alternatives.

Results of the key species predictions were summarized for TWP in June 2010 (Wasson 2010c). The rankings of the alternatives in terms of favorability for each taxon are shown in Table 3. No Action was found to be the best alternative for most of the large invertebrates and migratory shorebirds assessed, as well as for flatfish, sea otters, and harbor seals. These species all peak in abundance in the western, marine-influenced portion of the estuary and have co-existed with the harbor mouth without undergoing declines in the past decades. The Low Sill was ranked highest for some of the key species that were assessed (Olympia oysters, jackknife clams, and least sandpipers). These species peak in abundance in the mid-estuary, where marine influence is more moderate, and thus might expand in abundance in the western estuary if tidal energy were reduced and the marine influence was dampened. The High Sill ranked highest for pickleweed, due to reduction in tidal inundation time, and the Parson Restoration alternative ranked highest for eelgrass, due to decreased velocities in the western main channel while maintaining marine influence.

Economic, policy and feasibility assessment

Social science evaluations of the alternatives were conducted so that the decision-makers could choose an alternative that would be likely to garner political support, be broadly favored by regional stakeholders, and be feasible in terms of policy, permitting and funding. The National Ocean Economics Program (NOEP) was contracted to provide both economic and policy analyses of the proposed restoration alternatives. The economic portion was conducted by the Coastal Ocean Values Center under a subcontract led by Senior Fellow of the Ocean Foundation, Linwood Pendleton. The policy research was conducted by the NOEP research team, led by Judith Kildow. The results of the extensive investigation are provided in Kildow and Pendleton (2010a,b) and are summarized briefly here.

A first step in the economic analysis was to learn more about stakeholders who interact with the estuary. Randomized surveys revealed that most visitors to the area come to participate in some form of outdoor recreation. Of those interviewed, 72 percent said they hoped to see otters during their visit, and 41 percent listed birding as an activity that motivated their visit. While much of the focus of restoration at Elkhorn Slough is on salt marsh habitat, outdoor recreation in the estuary does not appear to be very affected by extent of salt marsh habitat. Recreation is concentrated in areas of greatest marine influence, including areas near the mouth of the estuary that lack extensive salt marsh. The Mouth Re-route or Sills would likely have negative impacts to kayaking by posing barriers to connectivity in navigation between kayak launching and wildlife viewing sites.

The analysis also characterized economically important activities around Elkhorn Slough, and sought potential linkages between them and environmental conditions in the estuary. The Moss Landing Power Plant has the greatest economic impact, followed by research/conservation by the various organizations located near the estuary (MBARI, Moss Landing Marine Laboratories, ESNERR, Elkhorn Slough Foundation). Commercial and recreational fishing, harbor activity, and recreational tourism comprise smaller but important components. Because the Elkhorn Slough/Moss Landing economy has developed around a strongly marine-influenced estuary, it is unlikely that current economic activity in the area will be affected detrimentally by the alternative of No Action. Other alternatives, however, could negatively impact the local economy. For instance, number of days of hypoxia might increase if tidal prism were decreased, and preliminary results indicated that there might be a negative relationship between days of hypoxia in the estuary and subsequent offshore commercial fishery catch of some species. However, such linkages between environmental changes resulting from the alternatives and local economic activity are currently not well understood and too uncertain to predict.

The economic analysis included consideration of the costs of the large-scale alternatives, which had been estimated by PWA (2008). No Action by definition has an implementation cost of zero. The cost estimate for the Mouth Re-route was about $100 million. The cost estimate for the Low Sill was about $27 million, with sediment addition behind the sill accounting for more than half of this cost. No cost estimate was provided for the High Sill (it would presumably be similar but somewhat higher than the Low Sill). The cost estimate for Parsons Restoration via extensive sediment addition was about $50 million (Moffatt and Nichol 2010). These estimates only include the costs associated with initial implementation of the alternatives; other costs such as loss of kayaking business or need for new boating access facilities are not included, but could be substantial for the mouth re-route and sill options. These latter options would also likely require regular adaptive management, the cost of which was estimated at $140,000 per year (Kildow et al. 2010).

The policy analysis revealed an array of about 25 federal, state, regional, and local agencies/programs that have some authority or interest in what happens to Elkhorn Slough, and about 30 applicable laws or regulations. No Action is clearly the most straightforward alternative from a policy perspective (Table 4). One of the most significant policy issues identified by the analysis was the absence of a single entity to coordinate legal oversight and accountability for the entire estuary, which would be required for the large-scale restoration alternatives at the mouth of the estuary. TWP facilitates coordinated strategic planning, but does not have legal authority over the estuary. Case studies examining restoration projects at other regional estuaries revealed that an incremental approach to implementation of restoration goals can be highly effective, and likewise, given the lack of single authority for the entire estuary, a patchwork of smaller scale projects implemented by different landowners could present productive options for Elkhorn Slough.

The policy analysis was augmented by a TWP Feasibility and Sustainability Working Group (Kildow et al. 2010). This group noted that pursuing a large-scale alternative at the mouth of Elkhorn Slough would require extensive federal, state, and local partnerships to meet the high costs of a project. Strong community support would be essential to generate the political will needed to generate this public investment. Currently, such broad support is lacking, partly because many stakeholders are pleased with the status quo, and partly because of stakeholder concerns about unmitigated impacts and risks of large-scale projects at the mouth. This workgroup also noted that in order for such a project to be considered eligible for the substantial state and federal funding necessary, it would have to demonstrate that it was cost effective relative to other alternatives, such as multiple smaller incremental projects, with regard to achieving restoration goals. Evidence would also be required that showed the project was resilient to predicted rates of sea level rise, such that the investment in the project would have long-term benefits for the system. Such evidence has not been provided to date for the large-scale alternatives at the mouth of the estuary.

Tidal Wetland Recommendations

Recommendation Process

In November 2010, the Strategic Planning Team charged staff from Elkhorn Slough National Estuarine Research Reserve (ESNERR) and Elkhorn Slough Foundation (ESF) with drafting recommendations regarding large-scale alternatives. Ten recommendations were completed in September 2012. TWP participants provided written feedback on and scored level of agreement with these recommendations during September and October 2012, as summarized in Appendix 4. The recommendations were discussed at a joint meeting of the TWP Science Panel and Strategic Planning Team in November 2012; additional perspectives shared at these meeting are included in Appendix 4. Overall, all the ten recommendations were supported by TWP participants as indicated by the average scores they received, with support ranging from weak support to very strong support for different recommendations (Appendix 4).

The TWP Strategic Planning Team met to vote on the ten recommendations in a session following the joint meeting with the Science Panel in November 2012. The ten recommendations were subject to an initial vote and all passed by the 2/3 majority required according to TWP decision-making guidelines agreed upon by the Strategic Planning Team in 2004. However, some members expressed concern about removing the Mouth Re-route alternative from future consideration, as indicated in the draft recommendation, because it might prove viable decades into the future, when concerns about water quality have diminished due to regulatory efforts and when funding might be available as a part of sea level rise adaptation of surrounding infrastructure. Other members expressed concern about investing TWP resources into further exploration and analysis of any mouth alternatives over the next decade, since such extensive analyses had been completed recently and resources could more effectively be devoted to small to medium scale projects in the near future. This was in contrast to the original staff recommendation regarding the Low Sill, which had suggested that the alternative be re-considered within the time horizon of this strategic planning effort (over the next decade). To address both of these concerns, during the November meeting the Strategic Planning Team drafted a modification to the recommendations regarding all three mouth alternatives (Low Sill, High Sill, Mouth Re-route) indicating that none of these alternatives are currently viable. This clarified that no TWP investment should be made in the near future to further explore these alternatives, but left the door open for consideration in the more distant future, if understanding of negative impacts or constraints were to change.

The Strategic Planning Team then voted on the 10 recommendations, following the modification to recommendations 3-5 about the mouth alternatives. The modification successfully increased the level of support for these recommendations. The final votes by each participating member and the total scores are shown in Appendix 5. Each recommendation received between 11-14 "yes" and 14-16 "passing" (yes + neutral) votes (from 16 voting members).

Recommendations 1-5 are evaluations of the four large-scale restoration alternatives that were originally developed for consideration by TWP, plus the No Action alternative. Recommendations 6-10 call for additional actions beyond these five alternatives. These latter recommendations grew out of the evolving understanding of estuarine dynamics that resulted from the investigations of the original alternatives (Appendix 3).

Since recommendations 3-5 are now all very similar, they can more briefly and clearly be presented jointly with recommendation 1 as a single recommendation indicating that none of the mouth alternatives are currently considered viable. This is how they have been synthesized in the Executive Summary of this document and will likely be presented in future synopses of large-scale decision-making. However, to avoid confusion, the same original numbering and order was retained below for consistency with the versions used for scoring and comments (Appendix 4) and voting (Appendix 5).

Approval of the recommendations has brought to a close this phase of evaluating selected large-scale restoration alternatives for the estuary. Ecosystem-based management of our natural resources is very important, and it is also challenging, time consuming, and costly because it offers a voice to all stakeholders and obtains information and insights from many different perspectives. Often there are divergent views; but working together through these differences, and ensuring stakeholders have a voice, results in a common vision and more successful projects with strong community support behind them.

Recommendations regarding originally proposed large-scale alternatives

1) NO ACTION AT MOUTH: **We recommend that no management action currently be undertaken at the mouth of Elkhorn Slough**. The large-scale alternatives were evaluated as the first major focus of TWP because of the potential cost-effectiveness of implementing a single management action that could improve conditions in the entire estuary. However, the interdisciplinary approach to characterizing the large-scale alternatives revealed clear trade-offs between different components of ecosystem function (Tables 1-4). Thus, no single alternative was identified that could optimize all desired management targets. The Mouth Re-route and Sill alternatives would reduce tidal scour, but it was not clear that they would support long-term marsh sustainability, and they involve a risk of water quality degradation which could negatively

impact biodiversity. Biological analyses revealed that many key species (such as various shorebirds, large clams, and marine mammals) have coexisted well with the harbor mouth, undergoing no declines or even increasing over the past 50 years. The ecosystem services most important to recreational visitors and commercial fishermen appear to be optimized under the No Action alternative. Given the high expense and policy hurdles that would need to be overcome, a large-scale project at the mouth could only be pursued with strong public and political support. This cannot be mustered for a project that is not demonstrably superior for ecosystem health than No Action. It is important to note that while we recommend No Action at the mouth now, we recommend that the options investigated be reviewed periodically to see if conditions, or our level of understanding, have changed to the point where these might be viable solutions to tidal scour and habitat change in the estuary. It is our intention, however, to focus on other approaches for the next decade. While we began by considering large-scale alternatives, we now recommend investment in small- to medium-scale restoration projects such as sediment addition, which involve lower risk to the ecology of the estuary and greater confidence of benefits to the ecosystem than any of the mouth alternatives.

2) PARSONS RESTORATION: **We recommend continued monitoring of the Parsons Sill Project, and potential future reduction of tidal prism in the Parsons complex.** The Parsons Sill Project was completed in 2011, decreasing tidal velocities within the Parsons complex and in the lower Elkhorn Slough channel. The effects of the sill will be thoroughly monitored for at least five years, and lessons learned will be shared with TWP stakeholders. This project focused on reduction of ebb-tide currents. Additional opportunities to decrease the tidal prism of the complex should be considered in the future. This could be accomplished by adding adjustable elements such as flashboards to the existing Parsons Sill, if a wing wall were constructed to avoid differential water levels across the railroad tracks. Or the tidal prism could be further reduced through sediment addition to restore former marshes in the complex. Bringing all of the subsided wetlands back to an elevation sufficient to sustain marsh would be extremely costly, but sediment addition could be conducted with a phased approach, taking advantage of inexpensive sediment when it becomes available.

3) LOW SILL AT HIGHWAY 1 BRIDGE: **Given current understanding of ecological and socioeconomic impacts and funding availability, we do not consider the Low Sill a viable management alternative for Elkhorn Slough at this time.** While a Low Sill would be likely to reduce subtidal scour of the lower main channel, there is currently significant uncertainty and lack of broad consensus about a Low Sill's potential benefits for salt marsh sustainability and potential negative impacts on water quality, wildlife, recreational use of the estuary (due to a standing wave), and associated economic benefits. If more data become available on these issues, the Low Sill could be further explored as a restoration alternative. Continued monitoring of the Parsons Sill will help to inform an understanding of the likely costs and benefits of a sill at Highway 1. Continued monitoring of subtidal bathymetry and intertidal mudflat deposition/erosion is critical to determine whether rates of tidal scour are decreasing over time, continuing, or even increasing. We also recommend continued monitoring of benthic invertebrate communities to determine how they are being affected by tidal scour as well as other anthropogenic disturbances (pollution, invasions). The Low Sill as currently designed would pose a significant barrier to navigation, likely hampering access from Moss Landing Harbor into Elkhorn Slough. Given the popularity of boating (especially kayaking) in the estuary, a sill

should only be considered in the future if safe, continuous boating access to Elkhorn Slough can be accomplished. Future consideration of this option could include exploration of alternative sill designs, heights and locations, and the possibility of multiple sills rather than a single structure.

4) HIGH SILL AT HIGHWAY 1 BRIDGE: **Given current understanding of ecological and socioeconomic impacts and funding availability, we do not consider the High Sill a viable management alternative for Elkhorn Slough at this time.** While this alternative would decrease tidal scour, it involves a high likelihood of major negative impacts to water quality, wildlife, animal movement and recreation.

5) RE-ROUTE OF MOUTH OF ELKHORN SLOUGH: **Given current understanding of ecological and socioeconomic impacts and funding availability, we do not consider the Mouth Re-route a viable management alternative for Elkhorn Slough at this time.** This alternative would decrease tidal scour, but is very costly due to the need for a new Highway 1 bridge, major construction to create a new channel between Elkhorn Slough and the ocean, and a dam under the existing Highway 1 bridge. The Mouth Re-route would involve decreased nutrient and contaminant loading to Elkhorn Slough, but deprives the already sediment-starved estuary of its major source of suspended sediment and freshwater. It bisects the estuarine network that Elkhorn Slough was historically a part of, effectively creating two separate estuarine systems with their own separate inlets, which would hamper future restoration efforts of the integrated estuarine complex. It also involves a high likelihood of major negative impacts to water quality, wildlife, and navigation. This alternative could be reconsidered at some future time if symptoms of eutrophication and constraints to implementation have diminished, perhaps with funding and partnerships available as a part of broader sea level adaptation efforts in the region.

Recommendations for other conservation actions

6) MARSH RESTORATION THROUGH SEDIMENT ADDITION: **We recommend restoration of salt marsh through sediment addition to areas of Elkhorn Slough that have subsided due to earlier diking.** Sediment addition projects can achieve TWP objectives of restoring salt marsh and of decreasing tidal prism in the estuary. Such projects do not have as high risks or uncertainty about unintended negative ecological consequences as do water control structures that have been considered as mechanisms of improving salt marsh sustainability. Sediment addition was included in the original consideration of large-scale alternatives as the mechanism for achieving a major reduction of tidal prism in the Parsons complex. However, filling the entire Parsons complex appears too costly to be feasible in the near future. Also, access to many portions of the Parsons complex is difficult with current transport options. We thus recommend pursuing sediment addition in accessible regions of the estuary where low quality, high elevation mudflats exist in areas of former salt marsh habitat. Such a project is already in the advanced planning stages for the Minhoto wetlands of ESNERR. Initial sediment addition projects should be thoughtfully designed and carefully monitored so that lessons learned can be applied to future larger-scale projects. Monitoring will also be critical to determine whether such newly restored marshes can be designed such as to be sustainable in the face of sea level rise. Sediment addition projects should seek to provide representation of all components of the salt marsh ecosystem, including tidal creeks, low marsh, high marsh, and marsh-upland ecotone.

7) RESTORATION OF TIDALLY RESTRICTED HABITATS: **We recommend tidal exchange be increased to some wetlands where water quality and biodiversity are extremely degraded due to artificial tidal restriction, and where increased exchange would not significantly contribute to tidal scour or conflict with other management goals.** As a part of assessing the potential effects of tidal restriction as a mechanism for combating the negative effects of tidal scour in the estuary, various investigations were undertaken to examine water quality and ecological communities in Elkhorn Slough habitats with full, muted, or minimal tidal exchange. These investigations determined that most of the wetlands in the estuary behind water control structures have impaired water quality (Hughes et al. 2011) and decreased biodiversity (Ritter et al. 2007), including of estuarine endemic species. This is significant because about 50% of the historic estuarine complex is behind water control structures. Some former estuarine wetlands are currently managed for zero or very limited tidal exchange in order to prevent flooding of farms or roads, to impound freshwater as an important resource in the region, or to allow for representation of brackish habitats and the distinctive species they support. But where landowners are supportive of increased tidal exchange, projects can be undertaken to enhance or remove water control structures. Such projects accomplish a stated TWP objective of improving conditions in restricted wetlands, but should be carefully designed not to conflict with another TWP objective of reducing tidal scour in the estuary. Examples of sites that would benefit from such projects include Whistlestop Lagoon, North Marsh, Estrada Marsh and Strawberry Marsh on ESNERR.

8) EUTROPHICATION: **We recommend that efforts be taken to reduce nutrient-loading to the Elkhorn Slough estuary.** Water quality assessments and modeling undertaken as a part of the characterization of large scale alternatives led to a recognition that the estuary overall is moderately eutrophic (Johnson 2010, Hughes et al. 2011), and that many of the more peripheral wetlands in the estuarine complex are highly eutrophic. TWP member organizations can support initiatives to decrease nutrient inputs, and foster further research on the sources, consequences, and potential mitigation of nutrient-loading to the estuary. Increased extent of salt marsh habitat through restoration projects (Recommendation 6) and increased tidal exchange to sites with water control structures (Recommendation 7) can also alleviate symptoms of eutrophication, while not directly addressing causes. A recent study revealed that both reduction in nutrient-loading through habitat restoration and water control structure management have measurable effects on local water quality at wetlands in the Elkhorn Slough estuary (Gee et al. 2010).

Recommendations for continued science-based collaborative strategic planning

9) MARSH SUSTAINABILITY RESEARCH: **We recommend that further research be conducted to determine the causes of salt marsh dieback at Elkhorn Slough and to identify the factors most likely to contribute to future salt marsh sustainability.** When the assessment of large-scale alternatives began, the artificial harbor mouth was assumed to be the main cause of salt marsh dieback, both in earlier decades and recent ones. As a result of the investigations that have occurred in the past years, a more complex understanding of salt marsh dynamics has emerged (Watson et al. 2011, Callaway et al. 2012, Van Dyke 2012, Wasson et al. 2012). Multiple factors, including sediment starvation, marsh plain subsidence, and eutrophication (Deegan et al. 2012) may contribute significantly to recent marsh dieback, and accelerated sea

level rise is likely to be very important in the future. In order to determine the most effective and sustainable management approaches for salt marsh conservation and restoration, we need a better understanding of the processes that lead to marsh loss vs. sustainability at Elkhorn Slough. We should explore whether introduction of native cordgrass (*Spartina foliosa*) might be an effective mechanism for increasing salt marsh habitat and decreasing sediment export in the estuary. We should also consider future options for increasing marsh sustainability by increasing the sediment supply to the estuary's salt marshes, for instance through a connection to the Pajaro River.

10) COLLABORATIVE GOAL-SETTING AND IMPLEMENTATION: **We recommend that TWP member organizations and other regional conservation partners explore the potential for jointly setting goals for habitats and conditions in the current and historical estuarine wetlands of the Elkhorn Slough watershed, so that multiple organizations can implement projects under a shared conservation plan.** In the course of evaluating the trade-offs associated with each of the large-scale restoration alternatives proposed for Elkhorn Slough, it became clear that there is no broadly agreed upon consensus for habitat goals or ecological conditions for the estuary. Stakeholders broadly agree that marsh should be conserved and restored, and water quality improved. But it is not clear which goal should take precedence when there are trade-offs between these goals. Stakeholders also broadly agree that the estuarine wetlands should include a mosaic of different habitat types and different degrees of marine vs. freshwater influence, but not how much of each habitat type should be represented, and where. Currently, several conservation organizations are managing different portions of the current and historical estuarine wetlands (and adjacent uplands) of the Elkhorn Slough watershed, some with contrasting goals. We recommend that TWP facilitate a collaborative discussion among its member organizations and other regional partners to jointly decide whether it would be desirable and feasible to develop shared goals for habitats and conditions in the estuary. This could include maps indicating the desired mosaic of marine vs. brackish vs. freshwater habitats, and/or target areas for different valued biodiversity elements (e.g. salt marsh, native oysters, snowy plovers) or ecosystem services (e.g. recreational activities, treatment wetlands). Also, potential agreements to address key nutrient sources and best management practices for water-adjacent properties could be explored. Through a shared vision and a mechanism for implementing it, partners can work together to collectively restore and conserve Elkhorn Slough's estuarine ecosystems.

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Figure 1. Map of Elkhorn Slough. A: The Low Sill and High Sill alternatives would be constructed near the Highway 1 Bridge at the entrance to Elkhorn Slough. B: The Mouth Re-route alternative would open a new inlet between the ocean and the main channel of Elkhorn Slough; the current entrance channel would be dammed under the Highway 1 Bridge. C: The Parsons Restoration alternative would substantially reduce the tidal prism of the entire Parsons Slough Complex. D: The majority of nitrate inputs to the estuary arrive in Elkhorn Slough via the Old Salinas River Channel, which receives input from Tembladero Slough. Colors correspond to elevations: green areas are above Mean High Water, of sufficient elevation to sustain salt marsh. Red and yellow elevations support intertidal mudflats. Blue areas are subtidal (channels that are permanently submerged).

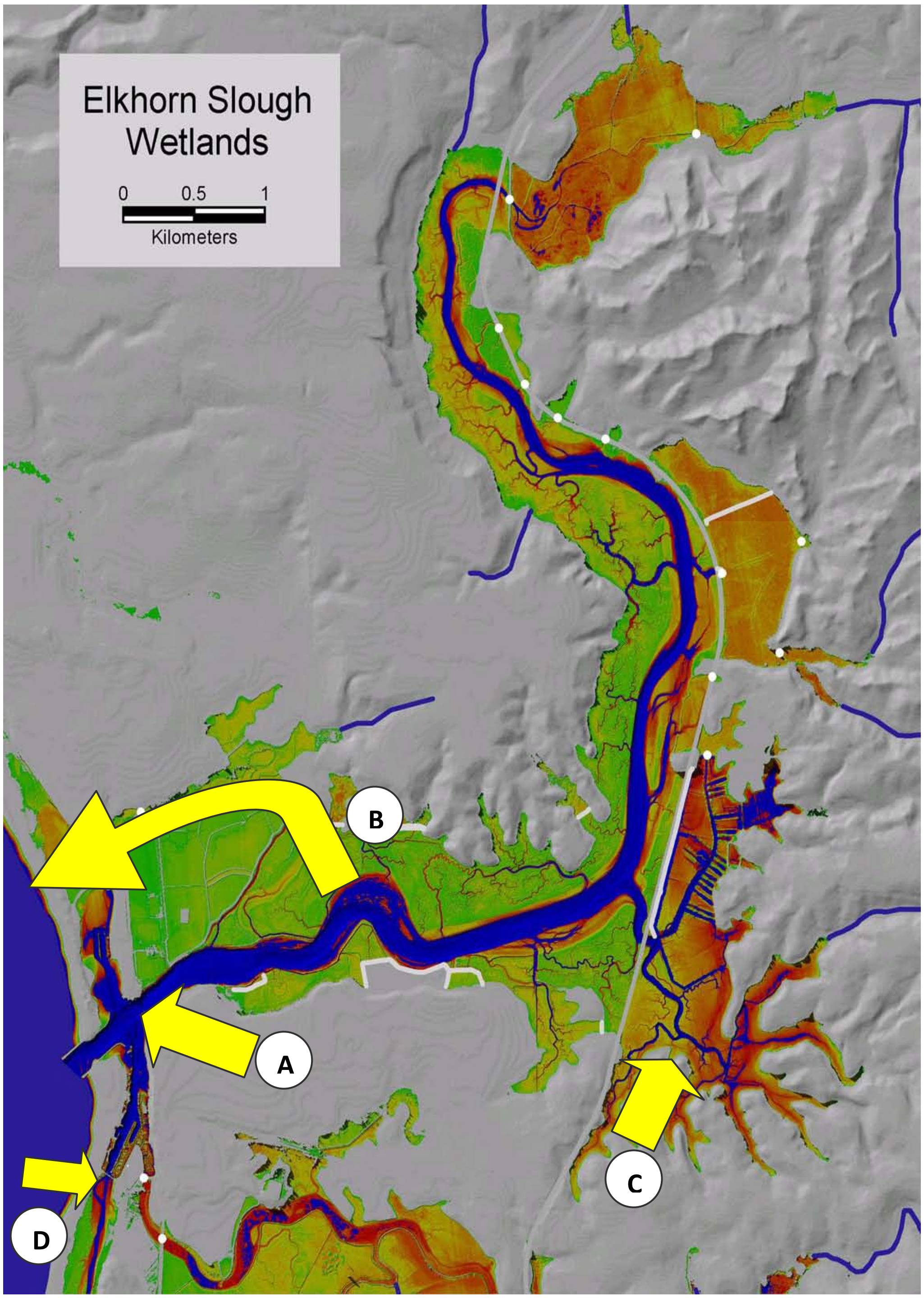

TABLE 1. RANKING OF ALTERNATIVES BASED ON TIDAL SCOUR AND HABITAT EXTENT.

Assessment is from PWA (2008), for Year 0 of modeling.

PARAMETERS RELATED TO TIDAL SCOUR	IMPORTANCE	RANKING OF ALTERNATIVES				
		No mouth action	Parsons	Low Sill	High Sill	Mouth Re-route
Tidal range reduction	lower tidal range leads to less inundation of marshes	4	4	3	2	1
Current velocity reduction	peak ebb currents result in much of the tidal scour and sediment export	5	4	3	2	1
Tidal prism reduction	decrease in the amount of water exchanged on each tide reduces tidal energy and scour	3	1	2	1	1
Channel depth stability	slowing or stopping the trend of increasing channel depth is a key part of reducing tidal scour	3	4	2	1	1

HABITAT EXTENT	IMPORTANCE	RANKING OF ALTERNATIVES				
		No mouth action	Parsons	Low Sill	High Sill	Mouth Re-route
Salt marsh extent	vegetated estuarine wetlands support rare plant communities and provide habitat for birds and invertebrates	4	5	3	1	2
Intertidal mudflat extent	mudflats support rich invertebrate communities which provide food for migratory shorebirds, fish and marine mammals	1	1	2	3	4
Subtidal habitat extent	subtidal channels provide habitat for invertebrates, fish, and marine mammals	5	4	3	2	1

TABLE 2. RANKING OF ALTERNATIVES BASED ON WATER QUALITY PARAMETERS.

Assessment is from Johnson (2010).

PARAMETERS RELATED TO TIDAL SCOUR	IMPORTANCE	RANKING OF ALTERNATIVES				
		No mouth action	Parsons	Low Sill	High Sill	Mouth Re-route
Nitrate	extremely high concentrations of these nutrients, which can fuel excessive production, are found in the estuary, so decreases are desirable	2	3	4	5	1
Ammonium		1	2	3	4	5
Eutrophication	excessive primary production can lead to hypoxia; eutrophication can also be harmful to marshes	1	2	4	5	3
Hypoxia	low oxygen can lead to fish and invertebrate diebacks and sublethal negative effects	1	2	4	5	3
Hydrogen sulfide	sulfide is toxic to many animals and can contribute to marsh dieback	1	2	4	5	3

TABLE 3. RANKING OF ALTERNATIVES BASED ON FAVORABILTY TO KEY SPECIES IN ESTUARY.

Assessment is from reports on each taxon available on the Elkhorn Slough technical report webpage and summarized by Wasson (2010c).

SPECIES or GROUP	IMPORTANCE	RANKING OF ALTERNATIVES				
		No mouth action	Parsons	Low Sill	High Sill	Mouth Re-route
Eelgrass	increases fish and invertebrate biodiversity, traps sediment	2	1	3	5	4
Pickleweed	traps sediment; supports food webs through detritus; may improve water quality	5	4	3	1	2
Olympia oyster	increases fish and invert diversity; may increase water quality	5	4	1	2	3
Fat innkeeper, ghost shrimp, gaper, butter and littleneck clam	harvested by humans, eaten by sharks, rays, flatfish	1	2	3	4	5
Jackknife clam		5	4	1	2	3
Flatfish	harvested commercially and recreationally; affect estuarine food webs	1	2	3	5	4
Willet, Long-billed Curlew, Marbled Godwit	popular with birdwatchers; affect estuarine food webs	1	2	3	4	5
Least Sandpiper		5	4	1	2	3
Harbor seal	popular with recreational visitors; affect estuarine food webs	1	2	3	5	4
Sea otter		1	2	3	5	4

TABLE 4. RANKING OF ALTERNATIVES BASED ON COST, PERMITTING, AND POLICY ISSUES

Assessment is from Kildow & Pendleton (2010b).

PARAMETER	IMPORTANCE	RANKING OF ALTERNATIVES				
		No mouth action	Parsons	Low Sill	High Sill	Mouth Re-route
Cost of project	the higher the costs the need for stronger justification for expenditures and the more difficult to put funds in place in a timely fashion	1	2	3	4	5
Number of landowners/abutters	increases the number of legal approvals and potential owners impacted	1	2	3	4	5
Number and type of agencies involved	The greater the number of permissions and approvals needed, the more time-consuming and costly the project	1	2	3	4	5
Complexity and uncertainty of outcome	raises stakeholder/ agency concerns and probability of unintended events	1	2	3	4	5
Timing and time frame	delays and time to get underway could compromise outcomes	1	2	3	4	5
Types and number of permissions	permitting is a difficult part of project implementation, and some permits are difficult to obtain	1	2	3	4	5

Appendix 1. Participants in the evaluation of large-scale restoration alternatives for Elkhorn Slough 2006-2012. Those Strategic Planning Team and Science Panel Members who filled out the survey scoring level of agreement with recommendations and providing comments are marked with an asterisk (*).

Tidal Wetland Project (TWP) Staff

Current TWP staff are employed through a collaboration between the Elkhorn Slough Foundation and the California Department of Fish and Game's Elkhorn Slough National Estuarine Research Reserve

Barb Peichel	TWP Director, 2004-2007
Bryan Largay	TWP Director, 2007-2012
Monique Fountain	TWP Director, 2012- present
Nina D'Amore	TWP Adaptive Management Lead
Amy Brookes	TWP Assistant
Erin McCarthy	TWP Specialist
Kevin Fisher	Wetland Scientist
Gui Lessa	Estuarine Scientist

Additional Staff Support for TWP

Elkhorn Slough National Estuarine Research Reserve (ESNERR) and Elkhorn Slough Foundation (ESF) staff with significant responsibilities for TWP and the evaluation of large-scale alternatives

Becky Suarez	TWP Supervisor (as ESNERR Manager), 2004-2010
Dave Feliz	TWP Supervisor (as ESNERR Manager), 2011-present
Mark Silberstein	Lead from ESF (as ESF Executive Director)
Kerstin Wasson	TWP Science Lead (as ESNERR Research Coordinator)
Andrea Woolfolk	TWP Stewardship Lead (as ESNERR Stewardship Coordinator)

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<u>Harbor seal</u>

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Maldini, Daniela	Okeanis
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<u>Sea otter</u>

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Reviewers of this document

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Appendix 2. Vision, Goals, Objectives, and Strategic Planning Principles of the Elkhorn Slough Tidal Wetland Project

Vision

"We envision a mosaic of estuarine communities of historic precedence that are sustained by natural tidal, fluvial, sedimentary, and biological processes in the Elkhorn Slough Watershed as a legacy for future generations."

Goal 1. Conserve the existing highest quality estuarine habitats and native biodiversity by aiming for a more natural rate of habitat change.

Objectives. Significantly reduce the rate of: (A) salt marsh conversion to other habitat types, (B) subtidal channel erosion, (C) loss of soft sediments from mudflat and subtidal channel habitats, and (D) tidal creek conversion to other habitat types.

Goal 2. Restore and enhance the estuarine habitats of Elkhorn Slough. Aim for the natural distribution, extent, and quality of Elkhorn Slough habitats with special emphasis on habitats with the highest loss rates.

Objectives. Strive to increase the extent of: (A) salt marsh habitats, including the natural distribution and abundance of tidal creeks, pannes, vegetated plains, and wetland/upland transitional areas, (B) tidal brackish marsh habitats, including the natural distribution and abundance of tidal creeks, pannes, vegetated plains, and wetland/upland transitional areas, (C) freshwater/saltwater natural transition gradients and connectivity, and (D) high quality soft sediments in mudflat and subtidal channel habitats.

Goal 3. Restore and enhance the natural processes (hydrology and geomorphology) of Elkhorn Slough and its watershed to sustain a more stable and resilient estuarine system. Emphasize the roles of natural sources, transport, circulation, filtration, and storage of water and sediment.

Objectives. Take actions to: (A) attain a more appropriate tidal influence by reducing the tidal prism in undiked areas, (B) restore appropriate levels of tidal exchange to former tidal areas that have no tidal connection or a very restricted tidal exchange if it will not exacerbate tidal erosion and salt marsh loss in other areas, and (C) re-establish or augment the supply of suitable sediments to increase the elevations and resiliency of subsided marsh areas.

Strategic Planning Principles

- Consider the broadest range of possible approaches to achieve the goals and objectives.
- Accommodate boating, farming, transportation, recreation, and other human uses necessary to support people in the region.
- Incorporate the needs of special estuarine conservation targets such as estuarine-dependent species, state- and federally-listed species, migratory species, and formerly dominant species.
- Give priority to actions that focus on protecting estuarine habitats most rapidly being lost both locally and in the region.
- Mitigate or avoid the negative impacts and consider the positive impacts of management strategies to neighboring landowners.
- Support projects that improve water quality for estuarine habitats and humans.
- Take into account present natural and cultural constraints and future geomorphological and climatic conditions in selecting restoration strategies.
- Consider how restoration and management strategies might be tested and implemented through pilot projects and reversible steps.
- Take advantage of opportunities for short-term pilot and demonstration projects that answer research questions most relevant in adaptively managing the resource.
- To the extent possible, find solutions that minimize the long-term cost of on-going maintenance required to sustain ecological services of habitats or the natural processes that control them.
- Maintain flexibility so that the planning process and potential strategies can be adaptively managed in the future.
- Recognize that the geographic scope is variable depending on estuarine processes so different scales need to be considered.
- Keep a watershed perspective. Consider the conservation and management efforts of adjoining upland and stream habitats.
- Document the major assumptions of all restoration designs and determine if the project seems reasonable to accomplish the goals.
- Learn from the successes and failures of similar projects that have been implemented and favor management strategies with high rates of success.
- Collaborate and stay informed about other planning processes in the area without disrupting those efforts.

Appendix 3. Recent scientific advances with implications for Elkhorn Slough management.

From 2006-2012, investigations of estuarine dynamics at Elkhorn Slough took place as a part of the evaluation of the large scale-restoration alternatives. The understanding that scientists had of estuarine processes has evolved in unexpected directions as a result of these studies, with consequences for management. The following is a synthesis by K. Wasson (ESNERR Research Coordinator) of how the views of ESNERR and ESF staff have changed in response to new data.

Salt marsh dieback has complex causes, of which harbor mouth is just one contributing factor. Previous understanding: harbor mouth was considered main cause of interior marsh dieback in undiked Slough regions. Update: A number of factors have reduced the ability of Elkhorn Slough marshes to recover from increased inundation associated with the construction of a deep inlet. Elkhorn Slough wetlands had low initial elevation capital, currently lack an abundant sediment supply, lack cordgrass which promotes channel stabilization, and marsh platforms are subsiding at a rate approximately equal to that of sediment deposition (perhaps linked to eutrophication). Sources: Callaway et al. 2012, Watson et al. 2011, Van Dyke 2012, Wasson et al. 2012. Management implication: decreasing the estuary mouth size alone will not save the estuary's salt marshes, and might even worsen problems related to sediment starvation and eutrophication.

Accelerated global sea level rise will be a main driver of future marsh loss. Previous understanding: local sea level rise due to the harbor mouth had been considered an important driver, but the role of global sea level rise had not been explored. Update: sea level rise is likely to become the major driver of salt marsh dieback within a few decades, and play a much stronger role in affecting marsh than the harbor mouth. Sources: PWA 2008, Callaway et al. 2012, Watson et al. 2012. Management implication: none of the restoration alternatives originally considered will result in long-term sustainability of Elkhorn Slough's salt marshes; a reliable sediment source or sediment addition is needed to allow marshes to maintain sufficient elevation in the face of sea level rise.

Tidal scour and marsh dieback may be slowing. Previous understanding: due to a negative feedback loop, rates of scour and marsh dieback are increasing over time. Update: The most recent analysis (by E. Van Dyke) of marsh extent in undiked Slough regions suggests that rate of loss has slowed in the past years. Bathymetric data shows that rates of erosion along the thalweg of the main channel have decreased throughout the Slough since 2001. The majority of erosion today exists along the mud banks of the channels. Between 2005 and 2012 the areas with the highest rates of annual erosion persisted along the north bank of the main channel between Parson's Slough and the Highway 1 bridge and within the channel to Parson's Slough. This suggests that while rates of channel deepening have slowed, rates of channel widening and down cutting along the banks continue (R. Kvitek and C. Marks, pers. com.). The decrease in marsh loss and thalweg erosion is recent and may not represent long-term trends, and other aspects of erosion continue. However the earlier model of accelerating losses due to a feedback loop may be incorrect. Sources: Kvitek and Marks (report in progress); Van Dyke 2012. Management implication: gradual decrease in tidal scour and a new equilibrium may be approached without management intervention.

Salt marsh extent today is within natural range for the estuary. Previous understanding: Half of the salt marshes of the Elkhorn watershed were lost in past 150 years and this has brought us to an unnaturally low extent of salt marsh. Update: Wetland extent at Elkhorn Slough for the last 500-3,000 years has been relatively stable. Today's salt marsh extent is well within this range. However, between about 400 years ago and the earliest Coast Surveys, wetlands expanded rapidly - approximately doubled, perhaps as a consequence of European-American settlement. So, human actions appear to have first increased, then decreased the areal extent of wetlands existing at Elkhorn Slough. Source: Watson et al. 2011, Wasson et al. 2012. Management implication: It may not be feasible, or even desirable, to restore all the recently lost marshes, since today's extent falls within the natural range and the higher extent may have been associated with high sedimentation levels that are not possible now. However, management is still necessary to prevent or mitigate extensive future losses that would put salt marsh extent outside the natural range of variation.

Tidal restriction has strong negative consequences at Elkhorn Slough. Previous understanding: the ecological communities and water quality of tidally restricted parts of the estuary had not been carefully examined, so we simply didn't know what was there. We guessed that muted tidal sites like Whistlestop Lagoon or Bennett Slough with intermediate tidal exchange might represent a "Goldlilocks" choice, with better estuarine diversity than the sites with full tidal range (and scour) and lower diversity than the minimal exchange sites. Update: An investigation of ecological communities revealed that the highest diversity and abundance of estuarine species is found in full tidal exchange, not muted. A study of eutrophication showed that even muted tidal sites have thicker subtidal algal mats, more sediment anoxia, and stronger daily dissolved oxygen fluctuations than do fully tidal sites. There was a highly significant regression between hours of hypoxia and tidal range of sites, and all "hypereutrophic" wetlands in the estuary had minimal tidal exchange. Highly impaired water quality more strongly affects estuarine biodiversity than does tidal scour. Sources: Ritter et al. 2008, Hughes et al. 2011. Management implication: alternatives such as the High Sill or Mouth Re-route which strongly decrease tidal range are likely to result in decreased biodiversity and water quality. Increase of tidal exchange to some sites currently behind water control structures would improve water quality and increase biodiversity.

Fully tidal parts of Elkhorn Slough exhibit clear symptoms of eutrophication and may be delicately poised. Previous understanding: consulting experts were cautious about even referring to the restricted parts of the Slough as eutrophic, and suggested the main channel of Elkhorn Slough had good water quality due to strong flushing. Update: placing Elkhorn's data in the context of other estuaries suggests that the fully tidal parts of Elkhorn Slough are moderately eutrophic. Benthic microbial processes related to hypoxia are sensitive to minor changes such as a few weeks of fog. The Old Salinas River is the major source of nutrient-loading and nitrate peaks near Potrero tide gates in south Moss Landing harbor are extreme, as detected by the LOBO network of in-situ sensors. According to a recent National Coastal Condition Report, water quality near the Potrero tide gates is the most impaired with respect to nitrogen of any coastal monitoring station on the Pacific Coast of the United States. Sources: Hughes 2009, Caffrey et al. 2010, Johnson 2010, Hughes et al. 2011, US EPA 2012. Management implications: eutrophication may pose a threat to Slough ecosystems of comparable or even greater magnitude than does the harbor mouth. Causes of eutrophication (nutrient loading) should be addressed, and care should be taken to avoid any actions that might increase symptoms of eutrophication.

Many of the Slough's species appear to have coexisted well for the past 60 years with the current mouth configuration. Previous understanding: attention had focused on species which underwent declines in the period since the harbor mouth opened, especially pickleweed and benthic infauna requiring fine sediments. This led to the impression that the harbor mouth negatively affected the majority of estuarine biodiversity at Elkhorn Slough. Update: While it is clear that many species and biological communities have changed over the past 60 years, it is less clear that there is a simple cause and effect relationship between the harbor mouth and species decline. Some species have certainly declined, but the causes of decline are often complex and multifactorial, for instance involving pollution or invasive species as well as hydrology. Many species appear to have had stable populations in the estuary over the past 60 years, and still others have increased in abundance or distribution. Source: Key species reports available on the ESNERR Technical Report Series webpage. Management implications: many populations of estuarine species are sustainable without management action at the estuary mouth.

Appendix 4. Feedback from TWP participants on recommendations.

The following provides a synthesis of comments on the draft recommendations received by the Science Panel and Strategic Planning Team members who filled out a survey form and/or participated in discussions at the TWP meeting in November 2012 (whose names are marked with an asterisk in Appendix 1).

Respondents to the survey scored their level of agreement with each recommendation. Agreement scores fall on a scale of 1-5: 1=strongly disagree, 2=agree, 3=neutral, 4=agree, 5=strongly agree. The average score for the 31 Science Panel and 15 Strategic Planning Team members who filled out the survey are shown below. These scores were important in providing advisory input to the decision-making by the Strategic Planning Team (see Appendix 5).

All major issues that were raised are summarized below. In some cases, clarifications by staff to the comments are also provided.

Note that the scores and comments are in response to the draft recommendations proposed by ESNERR staff. The Strategic Planning Team subsequently modified these to indicate the Low Sill, High Sill, and Mouth-Reroute are not currently considered viable options due to ecological and socioeconomic impacts and funding limitations. The average scores for recommendations 3-5 would likely have increased somewhat if they had been re-scored after this modification, since concerns of many respondents are now addressed.

1) NO ACTION AT MOUTH: **We recommend that no management action currently be undertaken at the mouth of Elkhorn Slough**.

Science Panel Score: *3.9*
Strategic Planning Team Score: *3.8*

Agreement with rationale: Various people submitted comments supporting the rationale for this recommendation provided in the summary document. Respondents indicated that they thought mouth actions might create more problems than they solve, and that the system might stabilize without intervention. One respondent highlighted that there is fundamental uncertainty about causes of marsh loss, and indicated that mouth action would not be helpful if nutrient-loading is determined to be main cause, as demonstrated in a paper that was published while this survey was open (Deegan et al. 2012).

Delay / caution: Various respondents indicated that they might still support action at the mouth later, but supported a cautious approach of further study without immediate action. One mentioned wanting to observe the Parsons Sill for a few years. One respondent indicated that sediment transport and water quality implications of mouth action needed to be better characterized before it could be considered. Another said mouth actions could be re-considered after nutrient-loading problems have been addressed.

Sediment supply: One respondent suggested that if no action is taken at the mouth to help support salt marshes, then a sediment supply such as the Pajaro or Salinas River should be seriously considered, if water quality concerns associated with these rivers can be addressed.

Concern about removing low sill from consideration: A few respondents indicated that did not agree with this recommendation because they would not like to see the low sill removed from consideration.

> *ESNERR Clarification: Recommendation 1 (No Action at mouth NOW) was meant to be fully compatible with and complementary to Recommendation 3 (keep low sill under consideration for the future).*

Concern about continued erosion under No Action alternative: One respondent indicated that taking no action at the mouth will not accomplish the original goal of maintaining salt marsh and other habitats. Another noted that erosion has damaged structures such as the Kirby Park parking lot and has increased marine influence and representation of marine species all the way up the main channel. Another respondent indicated that the system is out of equilibrium due to the harbor mouth, and only action at the mouth can address this problem. One respondent noted that climate change will worsen conditions under no action in the future.

At the meeting, three participants indicated that they were concerned about the paradigm shift that has taken place over the past years, with focus shifting from tidal scour to eutrophication as the greatest threat to estuarine organisms and processes. These participants expressed that they still consider tidal scour to be the most significant threat requiring attention. One recommended consideration of the cost of sediment exported from the estuary annually, and suggested that the estuary would lose much of its soft sediment environments and associated fauna in coming decades if no mouth action were undertaken.

2) PARSONS RESTORATION: **We recommend continued monitoring of the Parsons Sill Project, and potential future reduction of tidal prism in the Parsons complex.**

Science Panel Score: *4.6*
Strategic Planning Team Score: *4.7*

Importance: Various respondents indicated that they consider monitoring the Parsons Sill to be the most important continuing effort, because it is the largest estuarine restoration project TWP has undertaken to date and because it will provide important information about the pros/cons of a future low sill at the Highway 1 bridge.

Monitoring: There was strong support in the comments for continued monitoring. Two respondents noted that the commitment to monitoring must be in the long-term, beyond five years, because effects on currents, sediment deposition, and infauna could take a long time to be detectable. Various respondents indicated a desire to learn more about monitoring programs and results to date. One respondent noted that monitoring should be question-driven and cost-effective. Another stated that s/he would rather see monitoring efforts spread over the entire estuary rather than concentrated on the Parsons complex.

> *ESNERR Clarification: ESNERR's current long-term monitoring programs include sites within and outside the Parsons complex, which will allow detection of trends resulting from the Sill project.*

Future decreases of tidal prism: Various respondents raised concerns about future reduction of tidal prism in the Parsons complex. One indicated that such considerations are premature and should await at least a decade of monitoring results. Another stated that such prism reduction should only proceed if initial monitoring shows large positive benefits for salt marsh, eelgrass, or benthic habitats without negative impacts to water quality or fish populations. Three respondents indicated support for tidal prism reduction via sediment addition. One respondent was concerned about achieving tidal prism reduction through water control structure management (such as increasing the sill's height).

3) LOW SILL AT HIGHWAY 1 BRIDGE: **We recommend that a Low Sill or comparable structure(s) remain under consideration for the future**.

Science Panel Score: *3.8*
Strategic Planning Team Score: *3.5*

Note: the average scores for this recommendation are harder to interpret than for the other recommendations. The comments reveal that some participants scored this recommendation low because they prefer that the low sill be pursued more actively and rapidly, while others prefer that it not be considered at all in the future. However, all those who gave a score of "strongly disagree" or "disagree" with this option indicated in the comments that they would like the low sill to be removed from future consideration.

<u>Benefits to low sill</u>: Various respondents noted that a low sill would help address tidal scour issues. One respondent indicated that slowing erosion will protect habitats and private property. Another respondent stated that there appears to be uncertainty about whether there would be a clear, lasting benefit of a sill to salt marshes or other key aspects of estuarine biodiversity. Another respondent suggested that a low sill would provide rationale for pursuing sediment addition projects. One respondent suggested that the benefits of a low sill appear to be limited given projected sea level rise.

<u>Concerns with low sill</u>: One respondent noted that the issues identified for the high sill are applicable to some extent to the low sill as well. Numerous respondents highlighted the importance of avoiding barriers to boat and marine mammal movement. One indicated s/he had a concern for public safety after observing the high flow rates of the Parsons Sill. One respondent was concerned about any decreases to tidal prism. One respondent expressed concern about disproportionately more nutrient-rich lower salinity water flowing over the sill vs. denser, saltier, less nutrient-laden Monterey Bay water. Various respondents indicated that the high cost did not seem merited given the modest benefits and potential environmental impacts. One respondent was concerned that such a structure would require on-going maintenance and adaptive management, which is difficult to fund.

At the meeting, concern about the sill was raised from the perspective of the Harbor Commission, which is committed to ensuring safe navigation.

<u>Predictability of outcomes</u>: One respondent indicated that it is very difficult to predict exact outcomes of sills, even with extensive monitoring and modeling. She pointed to the example of the extensive erosion observed southwest of the Parsons Sill. This person recommended that in the absence of robust predictions, the best pathway is to proceed with the low sill and observe the outcome. Another respondent also pointed to lack of predictability, mentioning the surprisingly high velocities observed over the Parsons Sill, but reached the opposite conclusion, opposing a low sill at the mouth because of concern about unintended consequences to Elkhorn Slough and infrastructure.

> *<u>ESNERR Clarification</u>: The high velocities over the Parsons Sill and the resultant nearby bank erosion were anticipated in advance through modeling.*

<u>Design issues</u>: Various participants noted the importance of refined design options for future consideration. One indicated that the sill at Highway 1 should be adjustable, similar to the original design for the Parsons Sill. One respondent noted that one configuration to consider might involve little more than armoring of the bottom. Another respondent indicated that it doesn't really make sense to distinguish between low vs. high sill at this stage, since they fall on a continuum and optimal height would need to be determined by further modeling.

<u>Postponement of consideration</u>: Various respondents suggested waiting until the Parsons Sill has been examined for a longer time period before re-opening consideration of this alternative. One respondent suggested that the sill could be pursued after nutrient loading from the Old Salinas River channel and Tembladero Slough has been decreased.

4) HIGH SILL AT HIGHWAY 1 BRIDGE: **We recommend that a High Sill no longer be considered as a viable management option for the estuary.**

Science Panel Score: *4.2*
Strategic Planning Team Score: *4.1*

Concerns with high sill: Most comments on this recommendation consisted of concerns about the consequences of a high sill. These concerns included water quality, public safety and boating. Respondents described this option as “way too risky ecologically” and as having more negative impacts than taking no action. At the meeting, concern about the sill was raised from the perspective of the Harbor Commission, which is committed to ensuring safe navigation.

Design issue: One person noted that the distinction between low vs. high sill is arbitrary and that an intermediate height between the low and high sill that were modeled could be considered.

5) RE-ROUTE OF MOUTH OF ELKHORN SLOUGH: **We recommend that the re-route of the estuary mouth no longer be considered as a viable management option for the estuary.**

Science Panel Score: *4.1*
Strategic Planning Team Score: *4.0*

Concerns with re-route: Various respondents agreed with the rationale for removing this alternative from consideration, citing the extremely high cost, difficulty with permitting, and concern about lack of sufficient flushing to prevent oxygen problems. One respondent noted that lagoon management for a desired degree of “openness” is challenging and requires on-going maintenance. Another respondent mentioned that this alternative would threaten the levees of the Moss Landing Wildlife Area and thus could be harmful to the Snowy Plover population there. At the meeting, one participant with hydrological expertise indicated that there was a high degree of uncertainty about hydrodynamic outcomes of this alternative.

Retaining this alternative: Various respondents disagreed with the recommendation to cease consideration of this alternative, preferring to see it remain under consideration for the future. Three respondents suggested re-considering it a few decades from now, if eutrophication concerns are decreased or funding is available due to sea level rise adaptation. At the meeting, one participant suggested that this alternative would be compatible with marine mammal use of the estuary; based on his extensive experience he did not anticipate that a smaller, shallower entrance would hamper entry. Another participant indicated that this alternative is useful conceptually as the basis for comparison with No Action and other alternatives, and should be retained at least as a hypothetical option.

Benefits: Respondents mentioned the potentially dramatic water quality benefits of this option (due to diverting inputs from the Tembladero and Old Salinas River Channel from Elkhorn Slough), and potential benefits to reducing the impacts of sea level rise.

Cost reduction: Two respondents suggested that the cost of the new Highway 1 Bridge might be offset by partnering with Caltrans and/or the Army Corps as a part of sea level rise adaptation.

Naturalness: Various respondents indicated in the comments that they found this alternative conceptually appealing because it appears to them to be the most historically natural of all the alternatives.

> *ESNERR Clarification: While various respondents assumed that this alternative was more natural/historical than others, ESNERR’s historical ecology research, summarized below,*

suggests this alternative deviates significantly from natural baselines for the estuary. Maps and historical accounts from the late 1700s and 1800s indicate that the Slough's mouth migrated over time, and that the location targeted in this alternative is not any more "natural" than several other possible locations varying from Tembladero Slough to north of Moss Landing. Historical data from the late 1800s also indicate that the tidal prism of the Elkhorn Slough estuarine complex was relatively large, due to the interconnected network of channels including Moro Cojo and Tembladero Sloughs and the Salinas river channel. That tidal prism was substantial enough to keep the estuary's mouth open most of the year, at elevations a few feet below mean lower low water, except when storm wave energy temporarily exceeded tidal prism or river flow energy. When this occurred, in winter months, the mouth could close at or above the high intertidal for up to a few weeks, before opening again, and apparently remaining open through the other seasons. PWA's analysis of this alternative found that a new ocean inlet might be "susceptible to periodic or permanent closure. . .and require mechanical intervention (breaching) since no significant source of freshwater discharge is available to naturally re-open the inlet as occurred historically with the Salinas River" . Damming the current mouth of Elkhorn Slough would artificially divide one arm of the estuary from the rest of the historical estuarine network, not only removing an important historical source of freshwater, but also depriving the estuary of an important historical source of sediments (the Salinas River). While Moro Cojo, Tembladero, and the Old Salinas River Channel are currently highly degraded relative to their historic condition, future restoration of the historic, integrated estuarine complex should not be ruled out by creating a dam between different components. (Note that none of the large-scale alternatives considered included restoration of natural baseline conditions of a relatively small estuarine mouth but a large interconnected estuarine network with large tidal prism. Recreating a more natural mouth size without bisecting the estuary with a dam to maintain the artificial mouth was considered incompatible with the harbor and boat traffic.)

6) MARSH RESTORATION THROUGH SEDIMENT ADDITION: **We recommend restoration of salt marsh through sediment addition to areas of Elkhorn Slough that have subsided due to earlier diking.**

Science Panel Score:	*4.2*
Strategic Planning Team Score:	*4.4*

<u>Effectiveness</u>: Various respondents indicated that they consider sediment addition a viable tool for marsh restoration, and the best hope to address Elkhorn Slough’s marsh drowning. Some respondents noted the additional benefit of reduction of tidal prism. One respondent raised the question of whether this can be done at a large enough scale to make a significant difference. One respondent noted that the hope is that sediment addition promotes self-sustaining elevation gain, but another expressed concern whether continued sediment addition would be necessary in the face of accelerated sea level rise.

<u>Experimental design and monitoring</u>: Numerous respondents indicated the importance of conducting pilot sediment addition projects to test different treatments and examine outcomes, so that adaptive management can improve success of future salt marsh restoration projects. One respondent emphasized that pre-project experimental and statistical design is critical. Respondents suggested tracking subsequent marsh elevation after adding varying thicknesses of sediment. One respondent noted the importance of monitoring how much sediment remains in place vs. moves to other areas. Various respondents highlighted the importance of monitoring potential unintended consequences, such as smothering existing infauna and epifauna, tracking recolonization by these species, and examining impacts of the sediment to adjacent eelgrass habitats.

Cost: One respondent expressed concern that sediment addition costs are so high that it seems unlikely that many projects will be funded. Another respondent described sediment addition as a cost-effective strategy if it can be done in partnership with "dirt brokers". Another respondent suggested EPA support for using dredged material from Moss Landing and Santa Cruz harbors.

7) RESTORATION OF TIDALLY RESTRICTED HABITATS: **We recommend tidal exchange be increased to some wetlands where water quality and biodiversity are extremely degraded due to artificial tidal restriction, and where increased exchange would not significantly contribute to tidal scour or conflict with other management goals.**

Science Panel Score: *4.4*
Strategic Planning Team Score: *4.2*

Water quality benefits: Two respondents noted that this recommendation would help address the water quality impacts associated with restricted tidal circulation combined with nutrient inputs. Another indicated that it would lead to beneficial increases in oxygen concentration. Another respondent expressed concern that increased tidal exchange might not improve water quality, citing the example of Bennett Slough, where tidal exchange increased following the Loma Prieta earthquake, but many portions of the wetland have extensive anoxia. This respondent suggested that increasing clean freshwater inputs might prove a better flushing and water quality benefits than increased tidal exchange.

Tidal erosion: One respondent noted concerns about potential increases to tidal erosion, describing scour upstream of culverts at Bennett Slough and Moro Cojo Slough. Another respondent questioned whether mimicking the "unnatural" high tidal exchange of the main channel is a positive action. Another respondent indicated that opening weirs and tide gates was critical for estuarine function. This respondent suggested that while opening tidally restricted areas would increase erosion in the short term, it would speed the geomorphic process towards a new stable equilibrium. This respondent also noted that in some cases, sediment addition could be conducted at the same time as increased tidal exchange, off-setting increases to tidal prism.

Site selection: One respondent indicated that their level of support depends on which wetlands are considered. One respondent indicated that Whistlestop is a high priority site for such action. Another respondent indicated that historical estuarine sites currently managed as freshwater should be excluded. Another indicated that the Moss Landing Wildlife Area has low oxygen but excellent brine flies and habitat that supports Snowy Plovers, so limited tidal exchange is an effective management strategy there. One respondent suggested a map of target areas for increase of tidal exchange be prepared. At the meeting, one participant noted heavy bird use of North Marsh and suggested that perhaps no increase in tidal exchange was needed there.

Unintended consequences: Various respondents noted that care would have to be taken to avoid (and monitor for) unintended consequences. For instance, consequences to listed species and migratory birds should be carefully considered. One respondent noted that Salt Marsh Harvest Mouse habitat should not be inundated.

> *ESNERR Clarification: The salt marsh harvest mouse (*Reithrodontomys raviventris*) does not occur at Elkhorn Slough. This species is restricted to the San Francisco Bay area (USFWS 2010. Salt marsh harvest mouse 5-year review: summary and evaluation. http://ecos.fws.gov/docs/five_year_review/doc3221.pdf). The Salinas or Monterey Bay harvest mouse (*Reithrodontomys megalotis distichilis*) does occur in our watershed, and while not threatened or endangered, it does appear on the Department of Fish and Game's Watch List. DFG finds this animal's status as a subspecies of* R. megalotis *to be "questionable" and mammal*

surveys on ESNERR found this mouse in many habitats, including marsh, grasslands, scrub, poison hemlock, and oak woodlands. It does not appear to be dependent on Elkhorn Slough marsh habitat.

Sea level rise: One respondent requested more information on how tidally restricted habitats would be affected by sea level rise and how this would change under different levels of tidal restriction.

8) EUTROPHICATION: **We recommend that efforts be taken to reduce nutrient-loading to the Elkhorn Slough estuary.**

Science Panel Score: *4.7*
Strategic Planning Team Score: *4.8*

Importance of addressing eutrophication: All survey participants who commented on this recommendation indicated support for this recommendation. One respondent indicated this should be a top priority for immediate action, given the degradation of water quality observed in the estuary. Another stated it was the most sustainable action that could be undertaken. One noted that addressing eutrophication will become especially important if tidal exchange becomes more managed in the future. One respondent noted that salt marshes appear to be saturated in their ability to take up additional nutrients. Similarly, another respondent indicated that the proximal cause of marsh loss may be nutrients, as demonstrated recently for another marsh system (Deegan et al. 2012). One respondent noted how relevant this is to TWP's original focus, because investigations elsewhere have indicated strong links between nutrient-loading, erosion, and salt marsh sustainability. One respondent suggested that TWP could play an important role supporting the determination of TMDLs and other regulatory efforts by the regional water quality control board. At the meeting, numerous participants noted that developing an action plan for addressing eutrophication together with partners would be critical for success implementing this recommendation. The enormity of this task was noted by various participants, but others were optimistic, with one advocating for the strength of an incremental approach: "if you take it one bite at a time, you can eat an elephant."

Treatment wetland: One respondent suggested that maybe creating a meandering treatment wetland between Potrero and Sandholdt Roads could reduce nutrient loading to Elkhorn Slough.

9) MARSH SUSTAINABILITY RESEARCH: **We recommend that further research be conducted to determine the causes of salt marsh dieback at Elkhorn Slough and to identify the factors most likely to contribute to future salt marsh sustainability.**

Science Panel Score: *4.6*
Strategic Planning Team Score: *4.3*

Importance of marsh research: Various respondents expressed support for marsh research, describing it as a fundamental goal. One respondent noted that marsh restoration projects will be more likely to succeed if causes of recent marsh die-back are better understood. Another respondent emphasized that marsh sustainability research and monitoring are central to ESNERR's charter. In contrast, two respondents expressed doubt about the importance of marsh research, since extensive loss is projected due to sea level rise under all alternatives. Another respondent expressed concern that results would be difficult to interpret and might not prove useful in guiding management. At the meeting, one participant suggested that the possibility of capturing flood sediments be explored.

Research complexity: One respondent noted that past, current, and future causes of marsh dieback are not necessarily the same, and thus responses may not be the same. She recommended slough-wide spatial/spectral monitoring and continuous water datasets to help dictate directions for research.

Linkages to eutrophication recommendation: At the meeting, various participants noted the importance of better understanding how eutrophication may be affecting salt marshes. If negative effects are documented, this could be important for shaping the regulatory process and public support for it.

Need for similar research for other habitat types: One meeting participant advocated for the importance of a similar research program to examine threats to and strategies to increase resiliency of other estuarine habitat types, especially mudflats.

10) COLLABORATIVE GOAL-SETTING AND IMPLEMENTATION: **We recommend that TWP member organizations and other regional conservation partners explore the potential for jointly setting goals for habitats and conditions in the current and historical estuarine wetlands of the Elkhorn Slough watershed, so that multiple organizations can implement projects under a shared conservation plan.**

Science Panel Score: *4.7*
Strategic Planning Team Score: *4.2*

Support for concept: Various respondents provided comments in favor of this recommendation. For instance, one wrote "Hopefully all interested parties can come to an agreement on goals for habitats to implement projects together or with each others' support." Another wrote "Absolutely. There must be general agreement on management goals in an interconnected system." At the meeting, one participant mentioned a potential opportunity for combining this effort with the NOAA Habitat Blueprint initiative. Another participant noted the importance of habitat heterogeneity, suggesting that TWP had overemphasized salt marsh habitat and should consider all wetland habitat types together.

Linkages to eutrophication: At the meeting, various participants noted that a collaborative regional approach would be needed for addressing eutrophication. However, one participant noted that TWP meetings would likely involve much more conflict if agricultural partners were included, and expressed skepticism about whether TWP was the right organization to lead such discussions.

Not worth effort: One respondent thought such expanded regional collaboration is probably not worth the effort. She indicated that the TWP process to date has gotten most folks on the same page. Trying to get other agencies to adopt goals would take a lot of staff effort without much benefit beyond what TWP currently has.

Caveats: One respondent noted that it is important to remember ultimate decisions for many agencies are made by Boards, Commissions, etc., not the staff participating in strategic planning efforts such as these. One respondent was in favor of this regional collaboration only if ESNERR were organizing the effort. Another respondent indicated that participating organizations would need to be able to pursue existing and near-term projects while working on such overarching goals. Another respondent indicated that there are already separate planning processes in neighboring drainages. This respondent also emphasized that addressing land use conflicts and hydrological alterations is more important than setting habitat goals. One respondent suggested that a broader regional scope to include wetlands outside the Elkhorn Slough watershed (such as Watsonville wetlands or Pajaro and Salinas river mouths) would be more appropriate. At the meeting, one participant cautioned that TWP should approach regional partners with sensitivity, taking care not to "steamroll" existing planning efforts for adjacent ecological areas. Another meeting participant suggested a very broad regional approach to setting habitat goals, for instance noting that marsh has increased at Morro Bay while it has decreased at Elkhorn Slough, so perhaps these processes balance each other at a broad scale.

TWP review of future projects: One respondent noted that it would be helpful to have a review process by which new projects could be approved by TWP prior to acquiring funding and permits. Such a process would enable projects conducted by organizations other than ESNERR to be considered TWP projects.

ADDITIONAL CONSIDERATIONS

In the final section of the survey, respondents had the option to provide additional comments not related to any specific recommendation. Two respondents provided additional suggestions for future focus. One meeting respondent also raised an additional point.

Agricultural toxins: One respondent indicated that emphasis should be placed on other agricultural contaminants besides nutrients.

Marsh migration: One respondent noted the importance of acquisition of upland transition areas where salt marshes could migrate following sea level rise.

Ecosystem services: One participant at the meeting indicated the importance of continuing to link TWP with regional economics, for instance examining the ecosystem services that the estuary may provide to the Moss Landing Harbor.

OVERALL SATISFACTION WITH EVALUATION AND RECOMMENDATION PROCESS

The overwhelming majority of TWP participants who commented on the evaluation and recommendation process, both in the survey and at the meeting, expressed satisfaction with the transparency, thoroughness, and inclusiveness of this process. Many commented on the wisdom of a strongly science-based approach. A minority of participants expressed concern that large-scale actions to address tidal scour are not currently recommended, and discomfort with increased attention being focused on eutrophication relative to tidal scour. However the majority of participants indicated they were impressed that there had been thoughtful evolution of management strategies in response to new scientific investigations and socioeconomic analyses.

NEXT STEPS

Various TWP participants indicated that the vital next step is for ESNERR to propose a concrete action plan, specifying a timeline and key partners, for implementation of each of the recommendations. These action plans can then be vetted and further developed at a future TWP meeting.

Appendix 5. Results of votes on recommendations by Strategic Planning Team

The following chart summarizes the votes of the 16 participating Strategic Planning Team (SPT) members with regard to the recommendations, following revision of recommendations 3-5 to indicate that these are not currently considered viable. These votes represent the perspectives of the SPT members as individuals participating in strategic planning. They do not necessarily represent official positions by the organizations they represent, nor do votes have any regulatory or permitting implications. Any concrete projects to be undertaken to implement the recommendations would require separate evaluation by the appropriate authorities.

Last Name	First Name	Organization	1	2	3	4	5	6	7	8	9	10
Callaway	John	University of San Francisco	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Cann	Jeff	California Department of Fish and Game, Monterey	neutral	yes	yes	yes	yes	yes	neutral	yes	yes	neutral
Chapman	Trish	California Coastal Conservancy	yes	yes	yes	yes	yes	yes	yes	yes	yes	neutral
Clark	Ross	Central Coast Wetlands Group	neutral	yes	yes	no	no	yes	neutral	yes	yes	yes
Collins	Josh	San Francisco Estuary Institute	yes	yes	no	yes	no	yes	yes	yes	no	yes
Cuffe	Kelly	California Coastal Commission, Central Coast District Office	yes	neutral	yes	yes	yes	neutral	yes	yes	yes	yes
DeVogelaere	Andrew	Monterey Bay National Marine Sanctuary	yes	yes	yes	yes	neutral	yes	neutral	yes	yes	yes
Feliz	Dave	Elkhorn Slough National Estuarine Research Reserve	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Harvey	Jim	Moss Landing Marine Laboratories	yes	yes	yes	yes	yes	yes	yes	neutral	yes	yes
Hennessy	Scott	Monterey County Planning and Building Inspection (retired)	yes	yes	neutral	yes	yes	neutral	yes	yes	yes	yes
Leonardini	Tony	Moss Landing Harbor District	neutral	neutral	neutral	neutral	neutral	neutral	neutral	neutral	neutral	neutral
Martin	Jacob	US Fish & Wildlife Service	yes	yes	yes	yes	yes	yes	yes	yes	yes	neutral
Newkirk	Sarah	The Nature Conservancy	yes	yes	yes	yes	yes	neutral	yes	yes	yes	yes
Scianni	Melissa Apodaca	EPA Wetlands Regulatory Office	neutral	yes	neutral	neutral	neutral	yes	yes	yes	yes	yes
Silberstein	Mark	Elkhorn Slough Foundation	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
von Langen	Peter	Central Coast Regional Water Quality Control Board	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
TOTAL YES			12	14	12	13	11	12	12	14	14	12
TOTAL NEUTRAL			4	2	3	2	3	4	4	2	1	4
TOTAL PASSING			16	16	15	15	14	16	16	16	15	16
TOTAL NO			0	0	1	1	2	0	0	0	1	0