ELKHORN SLOUGH TIDAL WETLAND STRATEGIC PLAN MARCH - 2007

Executive Summary

Elkhorn Slough, an estuary located on the Central California Coast, provides a rich ecosystem for over 780 aquatic bird, marine invertebrate, marine mammal, and fish species. Elkhorn Slough is an important nursery for commercially and recreationally harvested fish and a premier migratory stopover for birds. In the Elkhorn Slough watershed, there are over two dozen rare, threatened, or endangered species. The estuary provides many beneficial uses, including boating and kayaking, hiking, educational experiences, and research opportunities. The hundreds of acres of coastal wetlands also decrease shoreline erosion, reduce flooding, and filter polluted waters. Elkhorn Slough is recognized as a Globally Important Bird Area and Western Hemisphere Shorebird Reserve. The National Oceanic and Atmospheric Administration has designated areas of Elkhorn Slough as a National Estuarine Research Reserve and National Marine Sanctuary. Sections of Elkhorn Slough are also designated as a State Ecological Reserve and State Wildlife Management Area by the California Department of Fish and Game. The Elkhorn Slough Foundation and The Nature Conservancy have helped protect Elkhorn Slough's natural resources through strategic land acquisitions.

The Elkhorn Slough Tidal Wetland Project is a collaborative effort to develop and implement strategies to conserve and restore estuarine habitats in the Elkhorn Slough watershed. It involves over a hundred coastal resource managers, representatives from key regulatory and jurisdictional entities, leaders of conservation organizations, scientific experts and community members. The main goals of the Tidal Wetland Project are to: (1) conserve existing high quality estuarine habitats, (2) restore and enhance degraded estuarine habitats, and (3) restore the physical processes that support and sustain estuarine habitats. Particular emphasis in the restoration planning process has been placed on the first goal, which aims to stop the ongoing marsh loss and estuarine habitat erosion in Elkhorn Slough. The Tidal Wetland Project builds upon a number of past planning reports and efforts including the 1989 *Elkhorn Slough Wetland Management Plan*. The conservation and restoration of Elkhorn Slough's estuarine habitats are considered a priority to California due to the loss of approximately 80 percent of coastal marshes in the state alone.

Elkhorn Slough contains approximately 2,690 acres of distinct habitat types. This includes 293 acres of subtidal channels and tidal creeks, 1,605 acres of mudflats, and 796 acres of intertidal salt marshes and tidal creeks. These habitats provide a rich ecosystem for over 340 bird (135 aquatic species), 550 marine invertebrate, and 102 fish species. The climate, geomorphology, and tidal hydrology have gradually shaped the spatial distribution of Elkhorn Slough's estuarine habitats throughout the past 20,000 years.

Over the past 150 years, human actions have altered the tidal, freshwater, and sediment processes that are essential to support and sustain Elkhorn Slough's estuarine habitats. Approximately 50 percent, or 1000 acres, of the tidal marsh in Elkhorn Slough has been lost since 1870 due to human activities. Major physical modifications to the estuary have caused and are currently causing high rates of habitat loss and degradation in Elkhorn Slough. Human impacts have resulted in ongoing marsh loss and estuarine habitat erosion, degraded water quality conditions, increased levels of pollution, eutrophication, and increased numbers of invasive species. Almost 73,250 cubic yards of sediment are exported each year from Elkhorn Slough into Monterey Bay from habitat erosion. Bank erosion rates along the main channel of Elkhorn Slough range from 1 to 2 feet per year. These rapid changes not only affect the estuary's animals and plants, but also impact neighboring private lands, public access sites, and railroad and road infrastructure.

Broad restoration strategies have been developed by the Tidal Wetland Project teams to conserve and restore Elkhorn Slough's estuarine habitats. The first key restoration strategy aims to reduce interior marsh dieback and estuarine habitat erosion. The restoration alternatives included under this strategy propose to change the estuary's entrance to reduce the tidal influence and habitat erosion and restore or add sediment to promote marsh growth. The next step for this strategy will be to make a decision about whether to pursue a large-scale restoration project for Elkhorn Slough based on ongoing technical evaluations. The purpose of the second restoration strategy is to restore and enhance degraded estuarine habitats in Elkhorn Slough. These restoration alternatives include actions to restore marsh habitat in the Parsons Slough and North Marsh wetland complexes, enhance water quality conditions in degraded areas, and restore tidal brackish marsh habitats. The next steps will be to obtain funding for a Parsons Slough restoration project, priority research and monitoring activities, restoration planning for degraded wetland sites, and pilot restoration projects.

The implementation of restoration projects requires a thorough understanding of relevant regulations, technical and political feasibility, funding needs, stakeholder interests, and research gaps. Potential large-scale restoration projects to reduce interior marsh dieback and habitat erosion in Elkhorn Slough are being evaluated over the next few years using an ecosystem-based management approach. The analysis of options to modify the estuary's entrance and add sediments to rebuild marshes will include predictions about changes to tidal hydrodynamics, morphology, estuarine habitats and species, water quality, socioeconomic values, and political constraints. Restoration planning has been initiated for the Parsons Slough wetland complex. Funding is needed to support restoration projects, priority research and monitoring efforts, and community involvement activities.

PREFACE

Funding for the development of this plan has been provided by a grant from the National Oceanic and Atmospheric Administration's Coastal Impact Assistance Program to the California Department of Fish and Game in cooperation with the University of California Santa Cruz.

This report will be posted on the Elkhorn Slough Tidal Wetland Project web pages at http://www.elkhornslough.org/tidalwetlandproject.

Please cite this report as: Elkhorn Slough Tidal Wetland Project Team. 2007. *Elkhorn Slough Tidal Wetland Strategic Plan*. A report describing Elkhorn Slough's estuarine habitats, main impacts, and broad conservation and restoration recommendations. 100 pp.

PURPOSE

The purpose of the *Elkhorn Slough Tidal Wetland Strategic Plan* is to describe Elkhorn Slough's estuarine habitats, characterize the main human impacts causing loss and degradation of those habitats, and provide broad conservation and restoration recommendations. This document summarizes the results of many technical discussions, scientific evaluations, and resource management decisions made over the past few years by participants in the Elkhorn Slough Tidal Wetland Project, a large collaboration led by the Elkhorn Slough National Estuarine Research Reserve. The geographic scope of this plan includes both historic and current estuarine habitats in the Elkhorn Slough watershed. The *Elkhorn Slough Tidal Wetland Strategic Plan* is only the first critical step towards the conservation and restoration of Elkhorn Slough's estuarine habitats. Our intention is that the collaborative vision and goals within this document will provide guidance and momentum for a variety of restoration projects for many years to come.

PLAN CHAPTERS

Chapter 1 describes the location and watershed of the Elkhorn Slough estuary, relevant past management plans, and the goals of the Elkhorn Slough Tidal Wetland Project. Chapter 2 provides a brief introduction to Elkhorn Slough's estuarine habitats including the location, representative species, and key characteristics of each habitat type and selected wetland complex descriptions. Chapter 3 describes observed habitat changes and major human impacts to Elkhorn Slough estuarine habitats. Chapter 4 describes potential actions to conserve and restore Elkhorn Slough's estuarine habitats as recommended by the Tidal Wetland Project teams. Chapter 5 provides a framework to guide estuarine restoration projects in Elkhorn Slough, including relevant regulations and future funding needs to implement restoration projects, conduct priority research and monitoring efforts, and enhance community involvement activities.

ACKNOWLEDGMENTS

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Contributing Authors - Becky Christensen, Kerstin Wasson, Kim Merin, Elkhorn Slough National Estuarine Research Reserve, and numerous members of the Tidal Wetland Project's Strategic Planning Team and Science Panel

Past Efforts - We want to acknowledge all the past conservation and restoration planning efforts and scientific studies developed for Elkhorn Slough. These reports have built the necessary foundation for this plan and we hope our efforts can also provide guidance and momentum for future planning projects.

Maps - Although there are numerous methods to characterize estuarine habitats (Cowardin et al. 1979, Ferren et al. 1996), the acreages and maps presented in this plan are largely determined by vegetative cover from GIS interpretations of aerial photographs. Unless otherwise noted, maps have been created or provided by Eric Van Dyke, Elkhorn Slough National Estuarine Research Reserve.

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Participants - The *Elkhorn Slough Tidal Wetland Strategic Plan* has been a collaborative effort of hundreds of participants starting in 2004. Strategic Planning Team and Science Panel members contributed numerous hours in the creation of technical summary documents and the discussion of human impacts on tidal marsh loss and habitat degradation in Elkhorn Slough. This restoration planning effort has helped us all gain a better understanding of Elkhorn Slough in order to create sound restoration strategies for these estuarine habitats. The following pages list Strategic Planning Team and Science Panel participants. Elkhorn Slough National Estuarine Research Reserve docents have also contributed many hours to the Tidal Wetland Project by taking and summarizing meeting notes, copying project reports, and assisting with planning activities for wetland trainings. These docents included Jan Shriner, Linda Jordan, John Moir, Shirley Murphy, and Peggy Casper.

Dedication - To all the people who have contributed countless hours working to protect Elkhorn Slough

Strategic Planning Team

The primary role of the Strategic Planning Team (SPT) is to make decisions regarding the development and implementation of Elkhorn Slough estuarine restoration strategies. The SPT has created restoration goals and objectives, developed restoration strategies in collaboration with the Science Panel and provided input on background materials. The SPT will continue to evaluate and prioritize the development and implementation of restoration strategies.

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Science Panel

The primary role of the Science Panel is to provide technical advice to the SPT about restoration strategies based on the best available science. The Science Panel summarized relevant research studies and jointly developed preliminary restoration strategies with the SPT. The Science Panel will continue to provide technical reviews of restoration strategies, identify adaptive management efforts, and conduct research and monitoring activities.

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Chapter 1: Introduction to the Elkhorn Slough Estuary

Introduction

This chapter describes the location and watershed of the Elkhorn Slough estuary, relevant past management plans, and the goals of the Elkhorn Slough Tidal Wetland Project. The work conducted by the collaborative Tidal Wetland Project teams, made up of over a hundred coastal resource managers, representatives from key regulatory and jurisdictional entities, leaders of conservation organizations, scientific experts, and community members is summarized. This chapter also describes past restoration and conservation planning reports and efforts.

Site Description

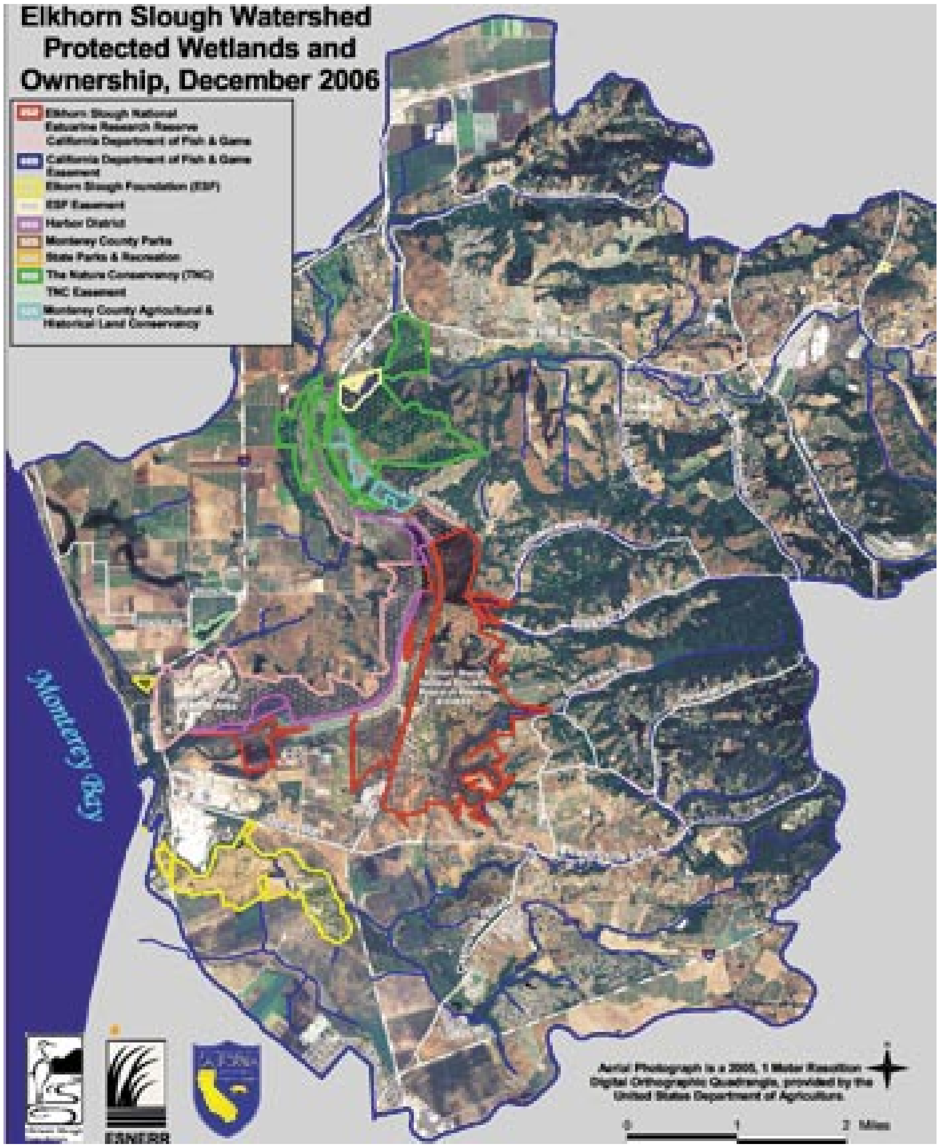
Elkhorn Slough, a seasonal estuary extending inland for seven miles (11 kilometers) from the midpoint of Monterey Bay in Central California (Figure 1), provides extraordinary biological diversity and recreational opportunities. The estuary contains approximately 2,690 acres (1,090 hectares) of distinctive habitat types including subtidal channels, tidal creeks, mudflats, salt marshes, and tidal brackish marshes (ESNERR, unpublished data). These habitats provide a rich ecosystem essential for over 340 bird (135 aquatic species), 550 marine invertebrate, and 102 fish species (Caffrey et al. 2002). Elkhorn Slough is an important nursery for commercial and recreational fish and a premier migratory stopover for birds. Estuaries like Elkhorn Slough are among the most threatened ecosystems in California, and as a result, a disproportionate number of rare, threatened, and endangered species reside in these areas. In the Elkhorn Slough watershed, two dozen species are included in these categories. The estuary also provides many beneficial human uses such as recreational boating, hiking, and bird watching. Moreover, the coastal wetlands minimize shoreline erosion and filter polluted waters.

Chapter Summary Points

- Elkhorn Slough, located at the midpoint of Monterey Bay in Central California, provides essential habitats for over 780 aquatic bird, marine invertebrate, marine mammal, and fish species.
- The Tidal Wetland Project was initiated in 2004 to conserve and restore estuarine habitats in the Elkhorn Slough watershed.

Figure 1. Maps show the location and surroundings of Elkhorn Slough (2005 NAIP Orthos).

The National Audubon Society designated Elkhorn Slough as a Globally Important Bird Area, and the Manomet Bird Observatory named the estuary a Western Hemisphere Shorebird Reserve. Significant conservation efforts to protect Elkhorn Slough's precious resources began in the 1980s. As a result, the National Oceanic and Atmospheric Administration has designated some of the southeastern areas within the estuary as the Elkhorn Slough National Estuarine Research Reserve (ESNERR) and designated the main channel as part of the Monterey Bay National Marine Sanctuary. The California Department of Fish and Game (CDFG) owns and manages ESNERR (which includes 980 acres of wetland and 583 acres of upland) and has designated this land as a State Ecological Reserve (Figure 2). CDFG also owns and manages 755 acres (not part of ESNERR) in Elkhorn Slough and the 688-acre Moss Landing Wildlife Management Area, which extends into Elkhorn Slough from the Highway 1 Bridge (Figure 2). The Nature Conservancy (TNC) and the Elkhorn Slough Foundation (ESF) have invested in protecting over 3,500 acres of the watershed lands. TNC owns or has easements on 345 acres of wetland (427 acres of upland) and the Elkhorn Slough Foundation owns or has easements on 134 acres of wetland (2,610 acres of upland) (Figure 2). These multiple designations and strategic land acquisitions recognize the importance of Elkhorn Slough as a vital ecosystem, protecting approximately a quarter of the estuary's habitats.



- Elkhorn Slough National Estuarine Research Reserve
- California Department of Fish & Game
- California Department of Fish & Game Easement
- Elkhorn Slough Foundation (ESF)
- ESF Easement
- Harbor District
- Monterey County Parks
- State Parks & Recreation
- The Nature Conservancy (TNC)
- TNC Easement
- Monterey County Agriculture & Historical Land Conservancy

Figure 2. Map showing public and private protected tidal wetlands in the Elkhorn Slough watershed. Please note that additional upland areas in the watershed are also protected, but not shown on this map.

The conservation and restoration of Elkhorn Slough estuarine habitats are a California priority because coastal salt marsh ecosystems are among the most threatened in the state. Approximately 91 percent (4.5 million acres) of California's wetlands have been lost since 1850, with an 80 percent loss of coastal marshes (Dennis and Marcus 1984, CDPR 1988, Dahl 1990). The restoration of Elkhorn Slough estuarine habitats also addresses the national conservation priority of "no net loss of wetlands" (EPA 1983).

Watershed

Estuaries such as Elkhorn Slough are defined as coastal embayments consisting of deepwater subtidal habitats with adjacent intertidal wetlands. These estuarine habitats are usually semi-enclosed by land with open access to ocean waters that enter with the tides and are diluted by freshwater (Cowardin et al. 1979, Ferren et al. 1996). Freshwater enters Elkhorn Slough from Carneros Creek and the Pajaro River (during flood events only) at the head of the estuary and the old Salinas River Channel draining the Tembladero watershed at the mouth of Elkhorn Slough (Figure 3). Intermittently during summer months, the water control structure between the Salinas River and Old Salinas River Channel is opened, and waters from the larger Salinas watershed may enter Elkhorn Slough (Figure 4). The Elkhorn Slough watershed is 30,292 acres

(12,260 hectares) (Figure 4). However, Elkhorn Slough is part of a larger interconnected network of estuarine habitats. Waters from the Moro Cojo watershed (13,349 acres/5400 hectares) and Gabilan/Tembladero (Alisal) watershed (101,026 acres/40,880 hectares) also drain into Elkhorn Slough (Figure 4). These waters enter Elkhorn Slough through the Old Salinas River Channel at the Moss Landing South Harbor, where flooding tides push these waters at least three-quarters of the way up the estuary (Figure 3, Johnson et al. in press).

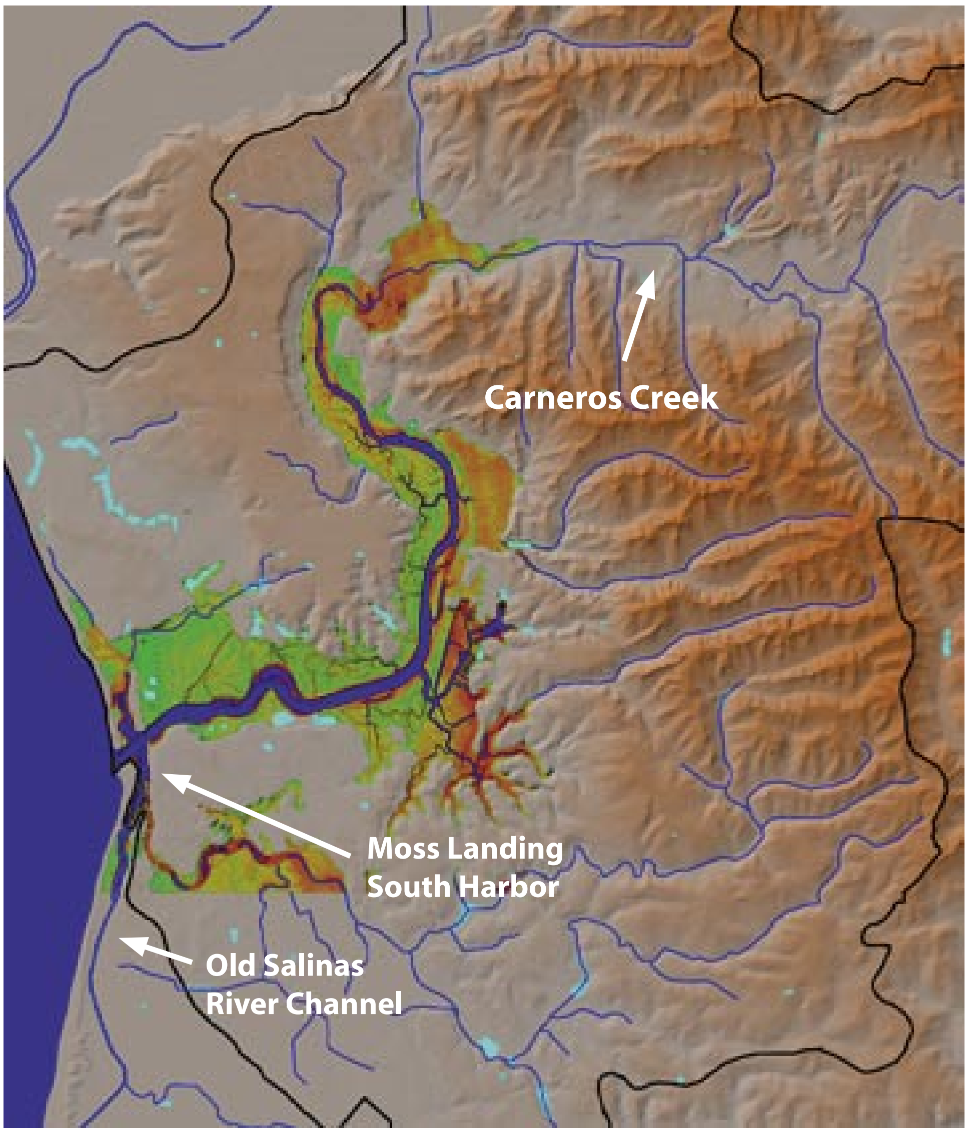


Figure 3. LIDAR map of Elkhorn Slough estuarine habitats superimposed on a DEM image showing the location of Carneros Creek, the Old Salinas River Channel, and the Moss Landing South Harbor.

Figure 4. Map of watersheds surrounding the Elkhorn Slough estuary (map adapted from CSUMB 2007). The white dot on the map indicates the area where Salinas River waters intermittently enter the Old Salinas River Channel and Elkhorn Slough.

Relevant Management Plans

The *Tidal Wetland Strategic Plan* not only synthesizes recent findings and decisions about Elkhorn Slough estuarine habitats, but also builds upon a number of past planning efforts and reports. ABA Consultants prepared the 1989 *Elkhorn Slough Wetland Management Plan* for the Monterey County Planning Department and the California State Coastal Conservancy. This document summarized information about habitat erosion, sedimentation, water quality, the natural history of Elkhorn Slough, and recommended wetland enhancement plans and implementation strategies. One focal point of the document was to identify long-term management problems. It stated: "The major environmental problem within the Elkhorn Slough is the erosion of marsh, mudflat, and upland habitat" (ABA Consultants 1989). The Tidal Wetland Project is now addressing this problem.

A number of water quality issues were also discussed in the 1989 Plan, including saltwater intrusion, high nutrient levels in groundwater, coliform bacteria contamination of waterways, impacts of persistent pesticides (chlorinated hydrocarbons and tributyltin), effects of less-persistent but more immediately toxic chemicals (such as chlorpyrifos and dacthal), and potential human health concerns from contaminated shellfish. Saltwater intrusion and contaminated groundwater are still problems. Use of persistent pesticides has been phased out, but high chemical concentrations are still present in the sediment. Although some agricultural land near waterways has been taken out of production, agriculture is still very chemical-intensive, and little is known about the potential movement of short-lived but acutely toxic chemicals off of farmland. High concentrations of chemicals are still found in local shellfish, generally associated with heavy runoff events, but shellfish harvesting appears to have decreased, reducing human health concerns (pers. comm. Jim Oakden). Marine non-native invasive species were not perceived as a problem in 1989, but have now been recognized as a significant issue. A number of conceptual wetland enhancement plans for specific sites were presented in the 1989 Plan. Most of the parcels have been acquired for conservation, but the implementation of enhancement and restoration activities has been slow. Although this current *Tidal Wetland Strategic Plan* addresses the most critical issue endangering Elkhorn Slough, marsh loss and the erosion of estuarine habitats, a number of other issues remain to be tackled in the future.

A number of additional plans and reports also support current restoration planning efforts in Elkhorn Slough. The *Elkhorn Slough Tidal Hydraulics Erosion Study* was prepared for the U.S. Army Corps of Engineers by Philip Williams and Associates, Ltd. and Moffatt & Nichol Engineers (PWA 1992). The purpose of the study was to determine if the creation of the Moss Landing Harbor has caused, or is causing, the erosion of the vegetated marshlands in Elkhorn Slough. The study also examined other possible causes that may have led to erosion and evaluated and recommended solutions to the habitat erosion problems in Elkhorn Slough. In 1996, Monterey County adopted the *Moro Cojo Slough Management and Enhancement Plan* that outlines management actions for those habitats. The *Elkhorn Slough Watershed Conservation Plan* has served as a guide for conservation activities in Elkhorn Slough by identifying important natural resources, the most significant impacts (stresses and sources of stress) to those resources, and strategies to protect them over time (Scharffenberger 1999). It identified coastal marsh as a vital resource in the Elkhorn Slough watershed and described one of the major impacts as the "loss and conversion of marsh habitat as a result of past human alterations of tidal influence and hydrology". The *Elkhorn Slough National Estuarine Research Reserve 2007 Management Plan* highlights key strategies to protect the five main habitat types in the watershed. The Reserve plan identifies major physical modifications to estuarine habitats resulting in habitat erosion, marsh loss, and reduced water quality as high priorities that need to be addressed through support of the Tidal Wetland Project. Most of these management plans can be found on the project web pages at http://www.elkhornslough.org/tidalwetlandproject.

Tidal Wetland Project Teams

The Tidal Wetland Project was initiated in April 2004 to develop and implement strategies to conserve and restore estuarine habitats in Elkhorn Slough. As with many restoration efforts, it was recognized early on that the scale and complexity of the estuarine habitat impacts required significant input from scientific experts, resource managers, and key stakeholders. Elkhorn Slough also contains multiple jurisdictional boundaries that are managed by different agencies and nonprofit organizations. The process of assembling a Strategic Planning Team, Science Panel, and community involvement activities to guide and support restoration planning and implementation efforts is detailed in Appendix A.

Strategic Planning Team
The Tidal Wetland Project's Strategic Planning Team (SPT) consists of over twenty coastal resource managers, representatives from key regulatory and jurisdictional entities, leaders of conservation organizations, and scientists with experience in tidal wetland restoration planning. The primary role of the SPT is to make decisions about Elkhorn Slough Tidal Wetland Project restoration strategies. The SPT created restoration goals and objectives, developed joint restoration strategies with the Science Panel, and provided input on background materials (Appendix B). The SPT will continue to evaluate and prioritize the development and implementation of restoration strategies.

Science Panel
Over thirty regional scientists and resource managers with local or regional expertise in estuarine ecology, hydrology, water quality, restoration, and geology were selected to be on a team designated as the Science Panel. The primary role of the Science Panel is to provide technical advice to the SPT about restoration strategies based on the best available science. The Science Panel summarized and reviewed relevant research studies and developed preliminary restoration strategies jointly with the SPT. The Science Panel will continue to provide reviews of restoration strategies and identify adaptive management and monitoring activities for restoration projects.

Community Involvement
Objectives of community involvement activities include increasing community awareness, participation, and stewardship of Elkhorn Slough's estuarine wetlands. Another goal is to provide and enhance ongoing opportunities for the public to educate resource managers and scientists about community needs that should be taken into consideration for restoration activities. Community input for the Tidal Wetland Project is encouraged and regarded as highly valuable for the success of future restoration efforts. Tidal Wetland Project efforts to facilitate and encourage community involvement include community forums and field tours, monthly community email bulletins, a web form for comments, contacts database, fact sheets, and presentations to individuals and community groups (Appendices A and B).

Tidal Wetland Project Purpose and Vision

Tidal Wetland Project Purpose and Scope
The purpose of the Elkhorn Slough Tidal Wetland Project is to develop and implement strategies to conserve and restore estuarine habitats in the Elkhorn Slough watershed. The geographic scope includes both historic and current estuarine habitats in the Elkhorn Slough watershed. Although there are multiple impacts to estuarine habitats, the Strategic Planning Team decided to prioritize restoration planning efforts due to funding limitations. Physical modifications were chosen as the focus because they have caused the greatest past alterations to habitats and are currently causing rapid marsh loss and habitat erosion.

Vision for Elkhorn Slough Estuarine Habitats

The vision statement developed by the Strategic Planning Team for the Tidal Wetland Project is:

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.

Tidal Wetland Project Goals, Objectives, and Planning Principles

Goals and Objectives

The goals and objectives for Elkhorn Slough's estuarine habitats emphasize three main points: (1) conserve high quality habitats, (2) restore degraded sites, and (3) re-establish the physical processes. The objectives for Goal 1 focus on saving the highest quality habitats in the estuary by reducing the dramatic rates of salt marsh loss and the erosion of channel, mudflat, and tidal creek habitats. The degraded estuarine habitats indicated in Goal 2 were prioritized based on the habitat types that had experienced the highest rates of loss over time in Elkhorn Slough. The objectives for Goal 3 summarize the current understanding of natural processes that need to be restored to make restoration efforts successful and sustainable over time.

Goals and Objectives for Elkhorn Slough Estuarine Habitats

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 sediment 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 sediment in mudflat and subtidal channel habitats

Goal 3. Restore and enhance the natural processes (hydrologic and geomorphologic) 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 habitat erosion and salt marsh loss in other areas, and

C. re-establish or augment the supply of suitable sediment to increase the elevations and resiliency of subsided marsh areas.

The SPT, with agreement from the Science Panel, asserted that future restoration projects in Elkhorn Slough should fit within the guidelines of these goals and objectives. Although it is likely that projects may not meet all of the goals and objectives, priority will be given to those that meet multiple objectives and there will be a preference for restoring the specific habitat types that historically occurred in each location wherever possible.

Planning Principles

The SPT developed planning principles that are general considerations the team will incorporate during the planning and implementation of future restoration projects. These principles are intended to be used in coordination with the vision, goals, and objectives statements.

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 (i.e. sea-level rise) 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 to adaptively managing the resource.

- To the extent possible, find solutions that minimize the long-term cost of ongoing 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.
- Aim for more aesthetically-pleasing structures when large-scale projects are designed.

Describing Estuarine Habitats

The Science Panel developed documents that described the loss and degradation of Elkhorn Slough's estuarine habitats while also defining the pertinent causes. Final documents created during this process are listed below and available on the Tidal Wetland Project website (http://www.elkhornslough.org/tidalwetlandproject) along with a list of primary authors and major conclusions. Descriptions of estuarine habitats and historical changes are summarized in Chapter 2, and discussions about major human alterations and conceptual models of likely causes of habitat erosion and marsh loss are found in Chapter 3.

- *150 Years of Human Alterations and Tidal Habitat Change (1870-Present) in Elkhorn Slough*
- *Likely Major Mechanisms of Tidal Marsh Loss*
- *Key Physical Processes Causing Habitat Erosion in Elkhorn Slough*
- *Evolution of Elkhorn Slough and Associated Wetlands 20,000 years before present (ybp) to 1880 A.D.*
- *Elkhorn Slough: A Review of the Geology, Geomorphology, Hydrodynamics, and Inlet Stability*
- *Groundwater Information for Elkhorn Slough (DRAFT)*

Habitat Predictions

The Science Panel has created statements supported by scientific consensus that predict future estuarine habitat trends based on present trends and existing scientific knowledge. As explained below, these predictions clearly state that salt marsh, mudflat, tidal creek, and channel habitats will continue to deteriorate over time. Moreover, habitat erosion rates may accelerate in upper Elkhorn Slough areas.

50-Year Predictions of Elkhorn Slough Estuarine Habitat Trends[1]

The relationship between the cross-sectional area and tidal prism in the Elkhorn Slough system is not at equilibrium.

- The extent of salt marsh will continue to significantly decrease and convert to mudflat and tidal creeks.
- The extent and cross-sectional area of tidal creeks will continue to increase at the expense of smaller tidal creeks, salt marsh, and mudflat.
- Sediment in soft-bottom areas exposed to strong tidal currents will erode, leaving harder substrates with larger grain sizes and weight/volume ratios (bulk density).
- The cross-sectional area of the main channel will likely increase in the upper Elkhorn Slough.[2] The erosion rate in the upper Slough is currently less than the rate in the lower Slough, but will likely increase over time.
- Bank erosion will continue (and may accelerate in the upper Elkhorn Slough) causing significant marsh loss.
- The cross-sectional area will continue to increase significantly in the lower main channel of Elkhorn Slough.
- The extent of mudflat will continue to increase at the expense of salt marsh.

[1] *Predictions are only relevant for undiked estuarine habitats.*

[2] *The geographic break between the upper and lower Elkhorn Slough is Parsons Slough.*

Introduction

This chapter provides a brief introduction to Elkhorn Slough's estuarine habitats including subtidal channels, tidal creeks, mudflats, salt marshes, and tidal brackish marshes. It describes the key characteristics and a few representative species for each habitat type. The main factors that influence the distribution and extent of tidal wetlands are reviewed. Brief histories and site descriptions of selected wetland complexes in Elkhorn Slough are also provided.

Factors Controlling Estuarine Habitat Extent and Distribution

There are a number of factors that control tidal wetland composition, distribution, and function. The main controlling or forcing factors are climate and basin geomorphology as shown in Figure 5 (Mitsch and Gosselink 2000). The hydrology, physiochemical environment, and biota, however, are all factors that can be modified during restoration efforts. The linkages and feedback processes need to be clearly understood to predict restoration outcomes.

Chapter Summary Points

- Elkhorn Slough contains 293 acres of subtidal channels and tidal creeks, 1,605 acres of mudflats, and 796 acres of intertidal salt marshes and tidal creeks.
- Factors such as climate, geomorphology, and hydrology shape the distribution of the estuarine habitats in Elkhorn Slough.

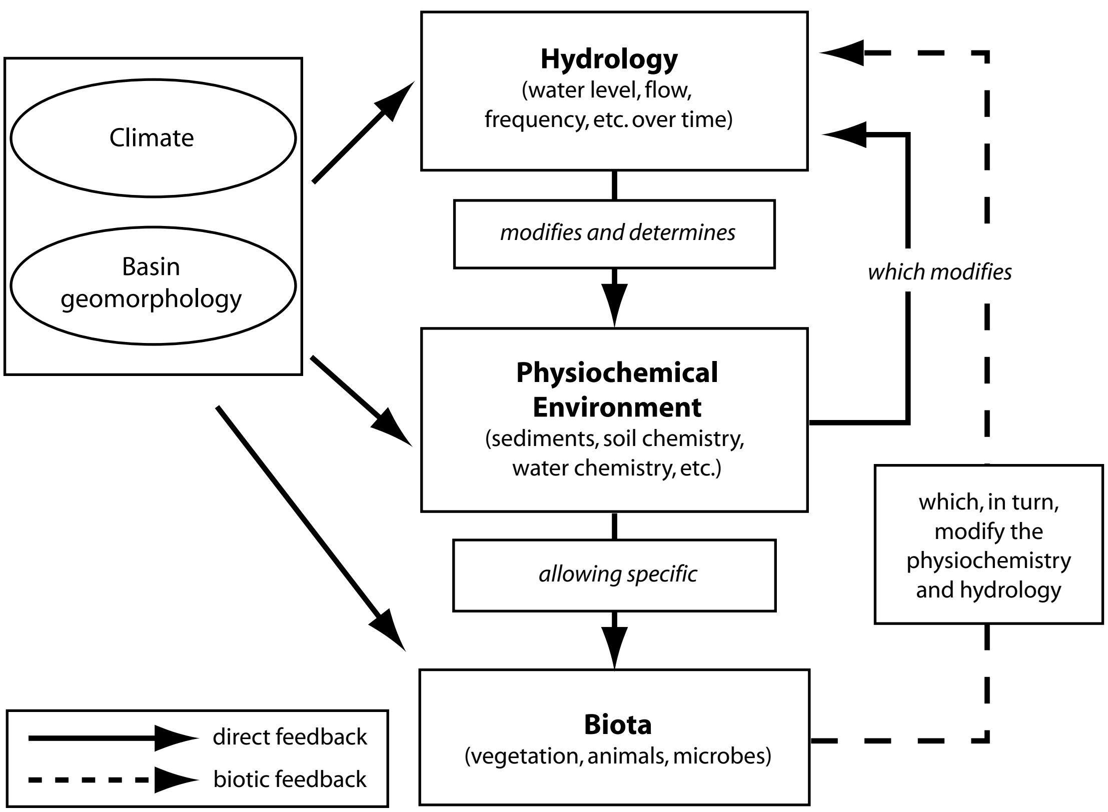


Figure 5. Conceptual model illustrating habitat controlling factors (climate, geomorphology) and the effects of hydrology on wetland function and the biotic feedbacks that affect wetland hydrology (Mitsch and Gosselink 2000).

Geomorphic Evolution

Elkhorn Slough was part of a larger regional estuarine network that has been closely linked to changes in sea level in the past 20,000 years. During the last glacial period, sea level was approximately 390 feet (120 meters) lower than it is today, and a freshwater river flowed through Elkhorn Valley to the modern shelf edge of the Monterey Bay (Schwartz 1986). About 18,000 years ago, the earth's glaciers began to melt, and sea level rose rapidly. Eventually, ocean water entered the mouths of Elkhorn and Moro Cojo Sloughs and converted these former streambeds into high-energy tidal inlets, which were then colonized by oysters and clams (Hornberger 1991, Schwartz 1986). As sea-level rise slowed 7,000 or 8,000 years ago, tidal energy decreased, sediment began to accumulate in local tidal wetlands, and mudflats and salt marshes developed (Hornberger 1991, Schwartz 1986, West 1988). As sediment deposition continued, mudflats became vegetated and salt marshes expanded.

Figure 6. Map (c. 1909) illustrating the interconnected estuarine network of Elkhorn Slough, Moro Cojo Slough, Tembladero Slough, and the Salinas River before the Salinas River was diverted.

Over the last 5,000 years, estuarine environments have existed in Elkhorn, Moro Cojo, Bennett, Tembladero, and McClusky Sloughs as well as the lower stretches of the Salinas and Pajaro Rivers (Figure 6, Hornberger 1991, Schwartz 1986, West 1988). Like most estuaries, these wetlands received variable amounts of oceanic and freshwater influence over time. Fluctuations have been based on the shifting Salinas River mouth (diverted c. 1909), the location of freshwater springs, seasonal rain inputs, and sandbars that formed on the shore. The majority of the estuarine system appears to have been dominated for thousands of years by tidally influenced salt marshes and mudflats along main channels and tidal creeks, while the upper margins have harbored brackish or freshwater marshes (Hornberger 1991, Schwartz 1986, Watson 2006, West 1988).

It is possible that during certain periods of time, the entrance to Elkhorn Slough closed seasonally. Although scientific evidence proving this point is lacking, other California estuaries with similar morphologies and lack of cordgrass have intermittent tidal connections. In addition, there is increasing evidence that Elkhorn Slough was dominated by brackish and freshwater wetlands for an extended period approximately 3,000 years ago. During this time it was possible that Elkhorn Slough was separated from tidal influence by a permanent sandbar (Watson 2006, West 1988). However, for the last 2,000 years, salt marsh vegetation and marine-influenced diatoms, invertebrates, and fish have dominated Elkhorn Slough and adjacent estuaries (Schwartz 1986, Hornberger 1991, Watson 2006). Local geologists hypothesize that the Pajaro River played an important and changing role in Elkhorn Slough's environment over time and provided freshwater and sediment inputs during episodic flood events like the 1995 Pajaro River flood. More detailed information and a timeline of known historic geological and hydrological events can be found on the Tidal Wetland Project web pages at http://www.elkhornslough.org/tidalwetlandproject.

The geomorphology, or shape and elevation of the landscape, can particularly be affected in California by long-term tectonic movements as well as seismic events. Three major earthquakes (magnitude 7.0 – 7.9) have occurred in the region in the past 150 years (USGS 2007). One took place in 1868 along the Hayward fault (7.0), and another in 1989 at Loma Prieta (7.1) (USGS 2007). The great earthquake of 1906 (8.25) resulted in many cracks in the mud at Moss Landing and eastward movement of the local sand-spit. Reportedly, subsidence at the Moss Landing pier changed the water depth from 6 feet (1.8 meters) deep before the earthquake to 18 or 20 feet (5.5 or 6.1 meters) after the earthquake, and caused nearby land subsidence of 2 feet (0.6 meters) (Lawson 1908). There has also been subsidence in Elkhorn Slough habitats, which could be due to a number of factors such as groundwater withdrawal, diking, and tectonic events. However, the relative importance of groundwater withdrawal compared with tectonic events in causing subsidence needs further research.

Climate

Elkhorn Slough typically has a mild and dry Mediterranean climate with monthly mean air temperatures ranging from 52-59°F. Rainfall is less than 0.2 inches per month (5 mm/month) between June and September, but the average rainfall at the Elkhorn Slough Reserve in December and January is 3 inches per month (76 mm/month) (Caffrey et al. 2002). Stronger winds occur in the afternoon between April and September, which can enhance mixing of tidal waters. Observed sea-level rise trends for California have ranged from 3.9 to 7.9 inches (10 to 20 cm) per century, and are predicted to increase over the next decade (Cayan et al. 2006). Sea-level rise predictions also include an increase in the occurrence of extreme tide events, which may increase the vulnerability of tidal marsh species to predation and exacerbate shoreline erosion.

Tidal Hydrology

Elkhorn Slough is a partially-mixed estuary, characterized by a weak stratification that is mixed during spring ebb tides. The tides in Elkhorn Slough are mixed semi-diurnal with a mean daily tide range of 5.6 feet (1.7 m) and a low-low tide that follows a high-high tide. The spring tide range is 8.2 feet (2.5 m) and the neap tide range is 3 feet (0.9 m) (Broenkow and Breaker 2005). The tide range is the difference in the level between successive high and low tides. It takes approximately 25 to 30 minutes for high tide to travel from the mouth to the upper sections of Elkhorn Slough (L. Breaker and N. Nidzieko, pers. comm.). Tidal currents in Elkhorn Slough are ebb-dominant, so ebb tides have stronger velocities and are shorter in duration than flood tides. The resulting potential for sediment erosion and transport is thus greater on ebb (outgoing) tides than flood (incoming) tides and partially contributes to the net export of sediment from the estuary. Maximum depth-averaged tidal currents in the lower portion of the main channel are approximately 2.9 mph (1.3 m/s) with RMS (root mean square) velocities of 0.7 mph (0.33 m/s) (pers. comm. Nick Nidzieko). Velocities near the Highway 1 Bridge can approach 3.4 mph (1.5 m/s) (Broenkow and Breaker 2005). Tidal current data from Acoustic Doppler Current Profilers (ADCP) from February 2005 to mid-May 2006 are available online at http://www.mbari.org/lobo.

Water Chemistry

The salinity in the main channel of Elkhorn Slough ranges from 0.5 to 37 parts per thousand (ppt) (Table 1). Evaporation exceeds the rate of freshwater input during the dry summer and fall, resulting in hypersaline conditions in the upper third of Elkhorn Slough until the first winter rainfall. Recent hydrodynamic and nutrient analyses demonstrate that waters from the Old Salinas River Channel can be carried up the estuary as far as Kirby Park by tidal currents (Johnson et al. in press, Monismith et al. 2005). Freshwater inputs also enter Elkhorn Slough from Carneros Creek at the head of the estuary with discharge rates between 7 and 1,300 cubic feet per second (0.2 and 38 cubic m/s) from December to April (Caffrey et al. 2002).

Table 1. Salinity data for the Elkhorn Slough channel (J. Needoba and J. Haskins, pers. comm.).

Channel Location	Salinity Average (Date)	Salinity Maximum (Date)	Salinity Minimum (Date)
Near Kirby Park	31 ppt (2005/2006)	37 ppt (July 2005/2006)	0.5 ppt (January 2005) 0.9 ppt (April 2006)
Just west of Seal Bend	32 ppt (2005/2006)	34-35 ppt (July 2005/2006)	5.4 ppt (March 2005) 9.5 ppt (April 2006)
Just east of the Highway 1 Bridge	32 ppt (2006)	36 ppt (2006)	19 ppt (2006)

Elkhorn Slough Estuarine Habitats

Estuarine habitats include subtidal areas that are covered by water even at low tide and intertidal areas that are covered with water during high tide, but are exposed during low tide. The main types of the 2,694 acres (1,090 hectares) of estuarine habitats found in Elkhorn Slough are listed below (Figures 7 and 8, Table 2). The distribution of these habitats is largely dependent on physical factors such as water depth, which depends on elevation.

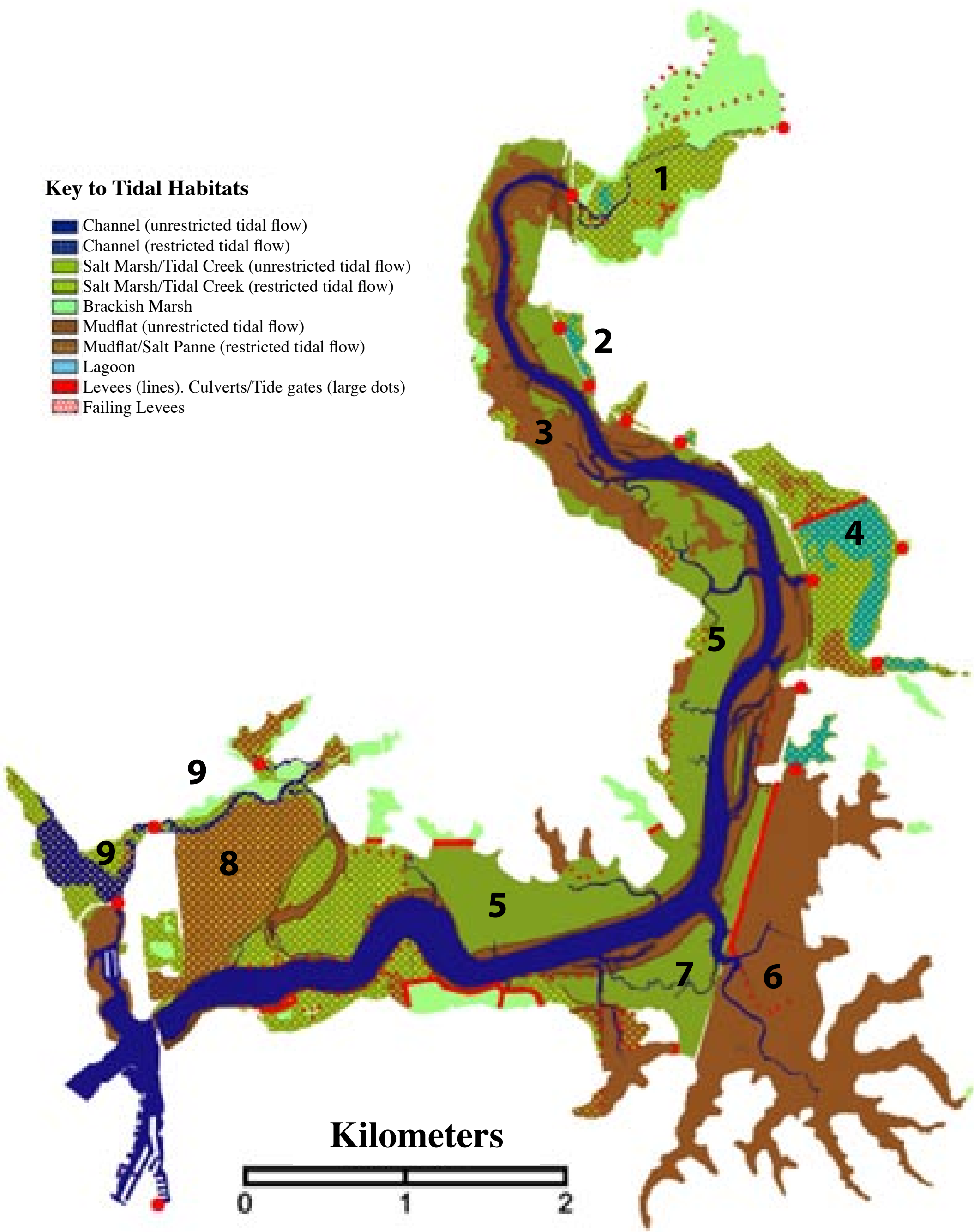


Figure 7. Spatial representation of Elkhorn Slough estuarine habitats based on GIS analysis of aerial photographs. The numbers refer to specific wetland complexes (Table 3, Page 20). The red dots indicate water control structures and red and white lines indicate levees.

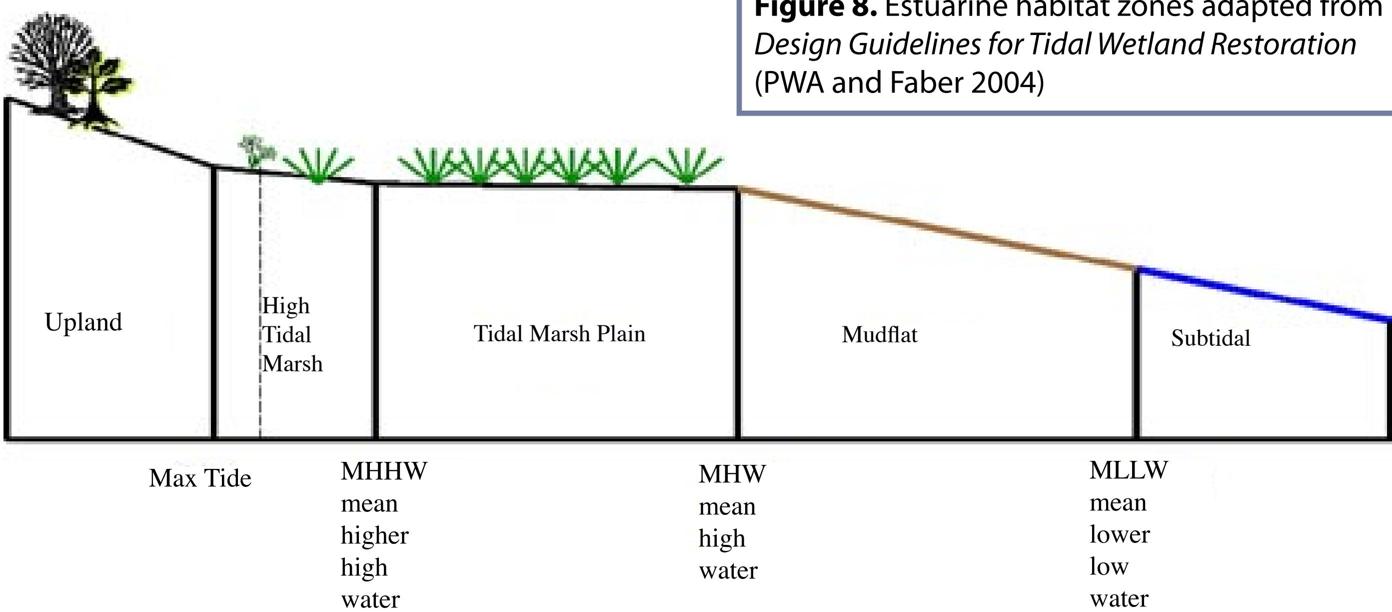


Figure 8. Estuarine habitat zones adapted from *Design Guidelines for Tidal Wetland Restoration* (PWA and Faber 2004)

Table 2. Acreage of Elkhorn Slough estuarine habitats (ESNERR, unpublished data).

ESTUARINE HABITAT TYPE	ACREAGE	PERCENT OF TOTAL
Salt Marsh and Tidal Creeks (intertidal)	796 acres (322 hectares)	29.5 %
Mudflats (intertidal)	1,605 acres (649 hectares)	59.6 %
Channels and Tidal Creeks (subtidal)	293 acres (119 hectares)	10.9 %

Subtidal Channel Habitat

Location: Subtidal channel habitats occur below the elevation of the low tidemark or Mean Lower Low Water (MLLW) where the substrate is continuously submerged.

Representative Species: Some areas are covered with submerged vegetation such as eelgrass (*Zostera marina*) and various algal species are widespread. Diverse invertebrates inhabit all subtidal areas. One large species found in greater abundance here than anywhere else in the world is the fat innkeeper worm (*Urechis caupo*). Numerous diving birds such as the brown pelican (*Pelecanus occidentalis*) and double-crested cormorant (*Phalacrocorax auritus*) use channel habitats. Among the many fish species inhabiting the channel, a few examples are the bat ray (*Myliobatis californica*) and shiner surfperch (*Cymatogaster aggregata*). Federally threatened southern sea otters (*Enhydra lutris nereis*) also commonly use channels as a sheltered area to rest and feed.

Key Characteristics: Elkhorn Slough channel habitats have substrates largely composed of material such as organic matter, mud, sand, and gravel. The fine-grained material in the Elkhorn Slough channel is often cohesive, particularly as a result of unconsolidated material eroding away in the past few decades. The channel depth averages about 9.8 feet (3 meters) but is as deep as 32.8 feet (10 meters) near the Highway 1 Bridge crossing and as shallow as 1.6 feet (0.5 meters) at the head of the estuary.

Mudflat Habitat

Location: Mudflat habitats are found between the elevations of Mean Lower Low Water (MLLW) and Mean High Water (MHW) and typically occur between channel habitats and marsh habitats. Because they are intertidal, mudflats are usually covered with water during high tide and exposed during low tide.

Representative Species: Lower mudflats support some eelgrass and algal species but are devoid of other vegetation. Similar to subtidal habitats, the soft sediment hosts a large variety of tiny invertebrates, as well as some large species such as gaper clams (*Tresus nuttallii*). Birds such as marbled godwits (*Limosa fedoa*), willets (*Catoptrophorus semipalmatus*), and sandpipers (*Calidris* spp.) are commonly seen feeding on these mudflat animals that are a key resource for migratory shorebirds. Fish species such as various gobies reside in the mudflats, and other species such as sharks, rays, and southern sea otters forage on large benthic invertebrates.

Key Characteristics: Mudflats serve an important function in estuarine chemical cycles. Currently mudflats are the most abundant habitat type in Elkhorn Slough.

Tidal Creek Habitat

Location: Tidal creeks form networks in salt and tidal brackish marsh complexes.

Representative Species: Tidal creeks provide habitat for estuarine fish such as the arrow goby (*Clevelandia ios*), a species that is also common in intertidal and subtidal mudflats.

Key Characteristics: Prior to high rates of eroding tidal creeks in Elkhorn Slough, these habitats served an important function of nursery grounds (i.e. food and shelter) for numerous species of juvenile fishes. Tidal creeks serve an important function of water conveyance and drainage onto and off of the marsh surface as well as the transfer of sediment and nutrients between marshes and the main estuarine channel.

Salt Marsh Habitat

Location: Salt marsh habitat occurs at elevations of approximately 4.6 feet (1.4 meters) above MLLW and high marsh is over 5.3 feet (1.6 meters) above MLLW. The majority of a salt marsh habitat is a flat plain, although some areas near tidal creeks, ponded areas, and upland transitions have more varied topography and greater plant diversity. Salt marshes characteristically contain persistent emergent plant species.

Representative Species: Low and middle elevation salt marshes are dominated by pickleweed (*Sarcocornia pacifica*, formerly *Salicornia virginica*) and are usually inundated during high tide and exposed during low tide. High salt marsh is flooded irregularly (usually exposed at least 10 continuous days) and vegetation consists of species such as salt grass *(Distichlis spicata* var. *stolonifera),* alkali heath *(Frankenia salina),* and jaumea *(Jaumea carnosa)*. In many areas, floating rafts of macroalgae (*Ulva* spp.*)* cover the salt marsh. The state listed California black rail (*Laterallus jamaicensis coturniculus*) is one of the few birds that exclusively uses tidal marsh habitat for resting, foraging, and breeding. The California black rail has not yet been observed in Elkhorn Slough, but is severely threatened by habitat loss. Most waterbirds, such as the great egret (*Casmerodius albus*) and long-billed curlew (*Numenius americanus*), utilize salt marshes as a roosting site during high tides.

Key Characteristics: Elkhorn Slough currently lacks cordgrass (*Spartina foliosa*), which dominates tidal creek and mudflat margins in many other California salt marshes. Vegetated marshes serve an important function in both the uptake of nutrients and to buffer shoreline erosion.

Salt Panne Habitat

Location: Another habitat that is mostly devoid of vegetation is salt panne habitat, which occurs as bare patches within high salt marshes. Salt pannes are typically flooded in the winter (with rain and extreme tides) and dry with a salty crust in the summer.

Representative Species: In the winter, salt pannes provide habitat for waterbirds and in the summer provide habitat for shorebirds such as the western snowy plover (*Charadrius alexandrinus nivosus*) and the American avocet (*Recurvirostra americana*).

Artificially Restricted Tidal Exchange Habitat

Location: A number of estuarine habitats in Elkhorn Slough currently have muted tidal hydrology due to levees or water control structures such as tide gates or culverts.

Representative Species: In sites with moderate tidal exchange (e.g. 5-50 percent of full tidal range of 8.2 feet), animal species composition in the marshes, channels, creeks, and mudflats is broadly similar to habitats described above. In sites with very limited tidal exchange (e.g. <5 percent of full tidal range), animal species composition differs, with much lower representation by marine species (such as shorebirds, sharks, clams, etc.) and greater representation by brackish species such as the federally endangered tidewater goby (*Eucyclogobius newberryi*) and brackish water snail (*Tryonia imitator*). Plant communities in areas with very limited tidal exchange are very similar to those with full tidal exchange; areas with muted tidal exchange have significantly reduced plant diversity in the high marsh zone.

Key Characteristics: Historically, artificially restricted estuarine habitats did not occur in Elkhorn Slough. But while the water control structures are artificial, the brackish conditions found in some of these sites may be more representative of some historical estuarine conditions. Due to diking, many of these wetland areas have subsided and in many areas with muted tidal exchange, marshes have converted to open water lagoon or mudflat habitat.

Tidal Brackish Marsh Habitat

Location: Tidal brackish marsh occurs where saltwater is diluted by freshwater during much of year, salinity ranges between 0.5 to 18 ppt, and it floods extensively (or is in shallow water).

Representative Species: Tidal brackish marshes are characterized by a mix of persistent fresh and saline emergent plants such as bulrush (*Bolboschoenus maritimus* and *Schoenoplectus* spp. formerly *Scirpus* sp.), cattail (*Typha* sp.), and pickleweed. Pickleweed grows at higher elevations than bulrush and cattail in brackish marshes.

Key Characteristics: The plant and animal species are particularly adapted for a range of saltwater to freshwater conditions. In Elkhorn Slough, most of the tidal brackish habitat currently occurs in sites behind water control structures.

Tidal Marsh/Upland Ecotone Habitat

Location: Tidal Marsh/Upland ecotone habitats occur where tidal marsh transitions to upland vegetation. This transition zone may be inundated only on extreme high tide or flood events. This habitat is typically above the maximum tide elevation and functions as an important high tide refuge for tidal marsh species.

Representative Species: Tidal marsh/upland ecotone habitat usually contains high marsh plants and upland plants such as creeping wild rye (*Leymus triticoides*) and coyote brush (*Baccharis pilularis*), as well as dozens of non-native species. The California vole (*Microtus californicus*) and song sparrow (*Melospiza melodia*) commonly occur at this wetland-upland interface.

Site Descriptions for Selected Elkhorn Slough Wetland Complexes

Brief histories and site descriptions of selected wetland complexes in Elkhorn Slough are described below. Additional information about a number of these sites can be found in Appendix C. Although the conservation and restoration of estuarine habitats in lower Moro Cojo Slough is part of the Tidal Wetland Project scope, descriptions of this area are not included because it is the subject of other restoration planning efforts.

Table 3. Site names for selected Elkhorn Slough tidal wetland complexes. The site numbers refer to the locations in Figure 7 (Page 16).

Site Number	Site Name
1	Blohm-Porter Marsh Complex
2	Azevedo Ponds Wetland Complex
3	Upper Slough Marsh Complex
4	North Marsh Complex
5	Lower Slough Marsh Complex
6	Parsons Slough Wetland Complex
7	Yampah Marsh Complex
8	Salt Pond Wetland Complex
9	Bennett Slough/Struve Pond Wetland Complex

1. Blohm-Porter Marsh Complex

Figure 9. Photograph of the Blohm-Porter Marsh complex.

The Blohm-Porter Marsh complex, located at the head of Elkhorn Slough, is approximately 246 acres (100 hectares) between Elkhorn Road and Blohm Road (Figure 7). In the past, this area was dominated by tidal brackish marsh. A railroad embankment and bridge was built in 1872 between the Blohm-Porter Marsh complex and the main channel of Elkhorn Slough. Cattle have grazed parts of the Blohm-Porter Marsh complex since the mid 1800s. In the 1940s, a large earthen dam was constructed at the southern end of this area for the purpose of impounding freshwater and restricting tidal inundation to the northern areas. Around the same time, it was observed that water tables were being lowered by land use that reduced the flow and presence of freshwater springs and altered surface flows from Carneros Creek. The construction of the Harbor in 1947 increased tidal inundation to the Blohm-Porter Marsh complex. Around 1951, a linear section of the area was filled for the construction of Elkhorn Road, while culverts and tide gates were installed to allow one-way flow from the Blohm-Porter Marsh to Elkhorn Slough. The 1989 earthquake destroyed the tide gates and caused the road to subside. Consequently, from 1989 to 1995, tidal waters regularly flooded the Blohm-Porter Marsh complex. In 1996, Monterey County Public Works installed new culverts and tide gates (with flaps allowing one-way flow) under Elkhorn Road.

2. Azevedo Ponds Wetland Complex

Figure 10. Photograph of the Azevedo Ponds wetland complex.

The Azevedo Ponds wetland complex is located on the eastern side of Elkhorn Slough (Figure 7). The wetland areas are named Northern Azevedo Pond (12 acres/5 hectares), Middle Azevedo Pond (6 acres/3 hectares), and Southern Azevedo Pond (2 acres/1 hectare). In some reports, the Northern Azevedo Pond is further divided into north and south sections. The Azevedo Marshes are separated from the main channel system by a railroad embankment built in 1872 that has openings with wooden box culverts in the berm. Many of the wetland areas also have additional structures such as levees or culverts that restrict tidal exchange. The wetlands and surrounding upland areas were purchased in 1991 by the Monterey County Agricultural and Historic Lands Conservancy and The Nature Conservancy through a State Coastal Conservancy grant. Agricultural use was pulled back from the edges of these pocket marshes for the establishment of 100-ft wide vegetated buffers strips from 1994 to 1995. The Elkhorn Slough Foundation and The

Nature Conservancy are currently working on wetland enhancement projects for the Northern and Southern Azevedo Pond areas which should be completed by spring 2008.

3. Upper Slough Marsh Complex

Figure 11. Photograph of the Upper Slough Marsh complex.

The Upper Slough Marsh complex is located on the northwestern section of Elkhorn Slough north of the Big T Creek (Figure 7). A few small areas on the western edge of this complex were diked by 1956. After 1947, the tidal creeks started to deepen and widen through erosion and marsh areas started to deteriorate in interior areas due to increased tidal inundation. By 2005, hundreds of acres of marsh vegetation in the Upper Slough Marsh complex died converting these marshes to mudflats and open water areas.

4. North Marsh Complex

Figure 12. Photograph of the North Marsh wetland complex.

The North Marsh wetland complex is a 183-acre (74-hectare) area located on eastern side of Elkhorn Slough (Figure 7). This complex includes Estrada Marsh, Campagna Marsh, and North and South Strawberry Marshes. This area was historically dominated by salt marsh with a complex of tidal creeks. Between 1869 and 1872, Elkhorn Road was constructed on the east side and a railroad was built along the west side of the wetland complex reducing tidal exchange. A number of large, artificial freshwater ponds were created in the 1900s in the North Marsh wetland complex for waterfowl hunting. By 1956, the entire complex was removed from tidal exchange by a series of levees primarily for cattle grazing. The diking and draining of the tidal marsh areas during this time caused the marsh sediment to dry out, compact, decompose, and subside by approximately 1.9 feet (0.6 meters). The California Department of Fish and Game acquired North Marsh in 1980 and Estrada Marsh in 1993 as part of the Elkhorn Slough National Estuarine Research Reserve. Tidal action was returned to the North Marsh wetland complex in 1986 through four tide gates. North Marsh is currently dominated by a mix of open water, mudflat, and fringing salt marsh habitat and continues to be managed with tide gates due to the subsidence and the low-lying Elkhorn Road.

5. Lower Slough Marsh Complex

Figure 13. Photograph of the Lower Slough Marsh complex.

The Lower Slough Marsh complex extends from the marsh area north of Seal Bend to the Big T Creek in the northwestern section of Elkhorn Slough (Figure 7). This area includes the Rubis Creek marsh areas. A few small marsh areas on the western edge of this complex were diked by 1956 and converted to freshwater ponds. After 1947, the tidal creeks started to deepen and widen through erosion and marsh areas started to deteriorate in interior areas due to increased tidal inundation. By 1956, many areas of marsh vegetation in the Lower Slough Marsh complex had deteriorated, converting these marshes to mudflats and open water areas. There has been a brief recovery of marsh, but the tidal creeks are continuing to erode and interior marsh dieback is still occurring in these areas.

6. Parsons Slough Wetland Complex

Figure 14. Photograph of the Parsons Slough Marsh complex.

The Parsons Slough wetland complex is a 429-acre (174-hectare) area located in the southeastern section of Elkhorn Slough (Figure 7). This complex includes South Marsh and the Five Fingers area. In the past, the Parsons Slough wetland complex was dominated by tidal salt marsh and tidal creeks. Numerous levees and dikes were created in this area starting in 1872 with a railroad embankment that blocked off a number of tidal creek connections. In the 1900s, duck ponds were created converting tidal marsh habitat to artificial freshwater ponds. The entire Parsons Slough wetland complex was diked and drained by the 1960s, converting many acres to pastureland. As a result, this area has subsided and the average elevation is approximately 2.4 feet (0.7 meters) lower than what can support marsh vegetation. The main areas are dominated by mudflat areas with some subtidal creeks, fringing tidal marsh, and created tidal marsh islands. During the winter of 1982-1983, the levee at the Parsons mouth breached during a storm event, allowing tidal waters to enter. A 1980s restoration project in South Marsh created channels, habitat islands, and reconnected tidal waters. Since that time, bank erosion has significantly decreased the width and length of these habitat islands since they were first constructed.

7. Yampah Marsh Complex

Figure 15. Photograph of the Yampah Marsh complex.

The Yampah Marsh complex is a 98-acre (40-hectare) area located in the southeastern part of Elkhorn Slough (Figure 7). Yampah Marsh has never been diked, but the marsh is currently degrading at rapid rates. This complex may be suitable for pilot sediment addition or retention projects to restore degrading marsh habitat.

8. Salt Ponds Wetland Complex

Figure 16. Photograph of the Salt Ponds wetland complex.

The Salt Ponds wetland complex, located northeast of the Elkhorn Slough mouth, is a 153-acre (62-hectare) area (Figure 7). This area was historically dominated by salt marsh with a complex of tidal creeks. The Monterey Bay Salt Works company completely diked this tidal marsh area by 1931 for salt production. The California Department of Fish and Game acquired the former salt ponds as part of the Moss Landing Wildlife Area. The area is managed primarily as nesting and breeding habitat for the western snowy plover (*Charadrius alexandrinus nivosus)*, a federally threatened species. The numerous ponds also provide habitat for wintering waterfowl and shorebirds.

9. Bennett Slough/Struve Pond Wetland Complex

Figure 17. Photograph of the Bennett Slough/Struve Pond wetland complex.

The Bennett Slough/Struve Pond wetland complex, located northeast of the Elkhorn Slough mouth, is approximately 140 acres (57 hectares) (Figure 7). It includes the old Elkhorn Slough mouth area north of Jetty Road, the Bennett Slough channel (around the Salt Ponds), Bennett Ponds, and Struve Pond. The main areas are dominated by tidal mudflats, salt marsh, and tidal creeks, and also contain tidal brackish marsh and freshwater ponds. Prior to the 1850s, the Bennett Slough channel meandered around hundreds of acres of tidal marsh. Levees constructed by the Monterey Bay Salt Works company in 1931 blocked off the main eastern connection of the Bennett Slough channel. During the same time, levees were also constructed, blocking the tidal creek connections to create Bennett Ponds. The coast highway was reconfigured by 1931 and road embankments with culverts were built between Bennett Slough and Struve Pond. The creation of the Moss Landing Harbor in 1947 relocated the Elkhorn Slough mouth to the south and the construction of Jetty Road reduced tidal exchange to the Bennett Slough area. Before 1956, an earthen levee was constructed in Struve Pond by landowners to create a freshwater pond. The 1989 earthquake caused Jetty Road to collapse, which temporarily increased tidal exchange to Bennett Slough. California State Parks rebuilt Jetty Road in 1991 and replaced the single culvert with a six-culvert system, making the tidal exchange greater than the 1947-1989 conditions.

Chapter 3: Major Impacts to Elkhorn Slough Estuarine Habitats

Chapter Summary Points

- Approximately 50 percent (1,000 acres) of Elkhorn Slough's salt marshes have been lost since 1870.
- The tidal prism has almost tripled since 1956 causing habitat erosion.
- About 1/3 of estuarine habitats are behind water control structures and many have poor water quality.

Introduction

This chapter describes how major human impacts over the past 150 years have altered Elkhorn Slough estuarine habitats. It focuses on observed habitat changes and likely causes such as large, physical modifications to the estuary entrance and rivers. Significant human impacts have increased marsh loss and estuarine habitat erosion, degraded water quality conditions, increased levels of pollution and eutrophication, and introduced a number of invasive species to the estuary. This chapter outlines the observed habitat changes and then discusses the likely causes for each. While additional human alterations to the estuary are briefly described in this chapter, this discussion lies outside of the scope of this plan, and therefore, is not meant to be comprehensive.

Major Estuarine Habitat Changes and Likely Causes

Over the past 150 years, human actions have altered the tidal, freshwater, and sediment processes that are essential to support and sustain Elkhorn Slough's estuarine habitats (Appendix D). This has led to substantial changes in the extent and distribution of different estuarine habitat types. Approximately 50 percent or 1,000 acres (405 hectares) of salt marsh habitat has been lost in Elkhorn Slough from 1870 to 2003 due to human impacts (Figure 18, Van Dyke and Wasson 2005).

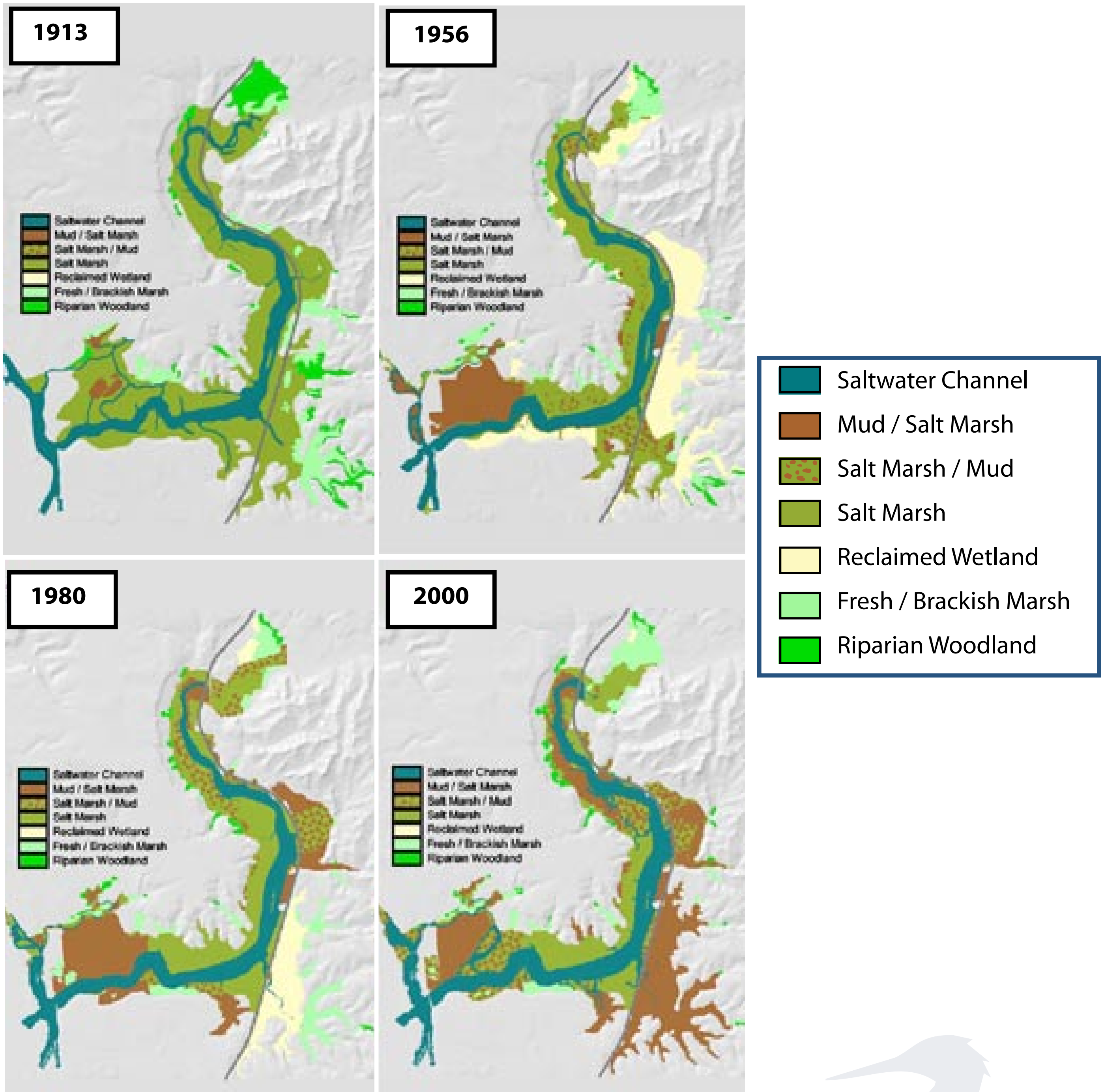


Figure 18. Aerial photograph interpretations of changes in estuarine habitat composition from 1913 to 2000.

Interior Marsh Dieback and Habitat Erosion due to Estuarine Mouth Modifications

Observed Changes – Interior Marsh Dieback and Habitat Erosion

Interior Marsh Dieback

Salt marsh is currently being lost at a rate of up to 3 acres (1.2 hectares) per year in Elkhorn Slough with more than 200 acres (81 hectares) being lost since 1931 in undiked areas (Figures 19 and 20, ESNERR, unpublished data). Researchers have observed a 50 percent loss of tidal marsh cover from 1931 to 2000 in Elkhorn Slough areas that have never been diked (Figure 21, Van Dyke and Wasson 2005). Although marshes are also being lost along the edges of channels, interior marsh dieback is occurring much more rapidly. Once marsh plants weaken or die, the roots can no longer hold the sediment in place and the sediment is easily eroded. Commonly, small open water areas appear first where marsh vegetation has died, and over time, these connect and create vast open water areas.

Figure 19. Examples of interior marsh dieback in Elkhorn Slough.

Figure 20. Aerial photograph showing an example of marsh loss in the northern section of Elkhorn Slough from 1931 (left image) to 2005 (right image). Along the channel, the darker gray areas in the left image indicate healthy marsh vegetation and the whitish areas in the right image indicate the loss of marsh vegetation.

Change in the Percent Cover of Marsh Vegetation in Elkhorn Slough from 1930 to 2003

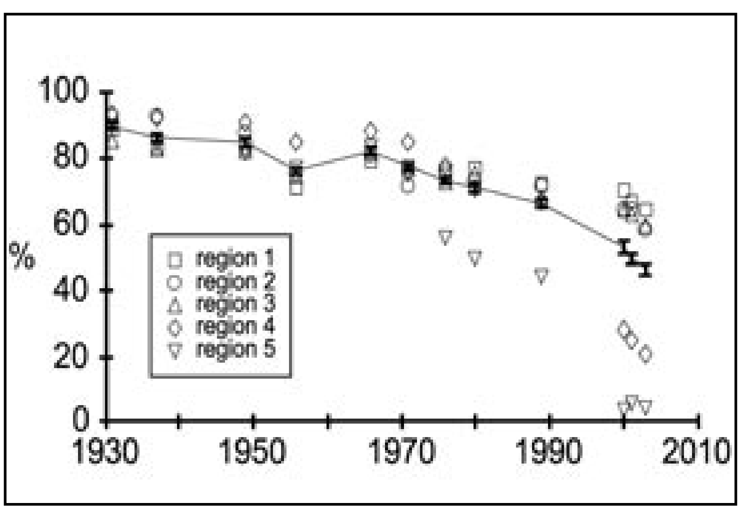


Figure 21. Decrease in the percent of marsh vegetation cover in Elkhorn Slough from 1930 to 2003 in 196 quadrats (100 x 100 meters) followed over time in undiked areas (Van Dyke and Wasson 2005). The shapes refer to different marsh study areas in the Slough (the greatest rate of marsh loss was found in the upper region).

Habitat Erosion

Elkhorn Slough channels and tidal creeks have deepened and widened through erosion at the expense of salt marshes and mudflats. Approximately 73,250 cubic yards (56,000 cubic meters) of sediment are exported each year from Elkhorn Slough into Monterey Bay (Sampey 2006). Bank erosion rates along the main channel of Elkhorn Slough are 1.3 to 2 feet (0.4 to 0.6 meters) per year in the upper slough and average 1 foot (0.3 meters) per year in the lower slough (Figure 22, Wasson et al., unpublished data). The mean cross-sectional area of the main channel has increased by approximately 16 percent in just 8 years (1993-2001) (Dean 2003, Malzone 1999). Areas near the mouth of Parsons Slough increased by almost 9.8 feet (3 meters) in depth during the same period (Dean 2003, Malzone 1999). Scientists have observed a decrease in fine unconsolidated sediment along the main channel of Elkhorn Slough since the 1970s (Kvitek et al. 1996). Fine sediment has scoured from the subtidal channel between Hummingbird Island and Kirby Park. This has exposed a harder, more consolidated, older substratum (i.e. hard polished clay and patchy coarse rubble) in portions of the channel, creating unsuitable conditions for a number of organisms (Kvitek et al. 1996).

Figure 22. Bank erosion of channel and tidal creeks in Elkhorn Slough causes marsh loss and threatens public access sites.

Tidal creeks in Elkhorn Slough have widened from an average of eight to 40 feet (2.4 to 12.2 meters) from 1930 to 2003, and are widening at a rate of up to 0.45 feet (14 centimeters) per year (Figure 23, Van Dyke and Wasson 2005). Bathymetric analyses have also revealed a deepening of tidal creeks since the first measurements were made in the 1970s (Kvitek, unpublished data). In many areas, tidal creeks have not only become larger, but the number and length of tidal creeks has greatly increased. The degraded tidal creeks have caused marsh loss, increased the conveyance of tidal waters on the marshes, and likely reduced the nursery function for some estuarine fish species.

Change in Tidal Creek Width (m) in Elkhorn Slough from 1930 to 2003

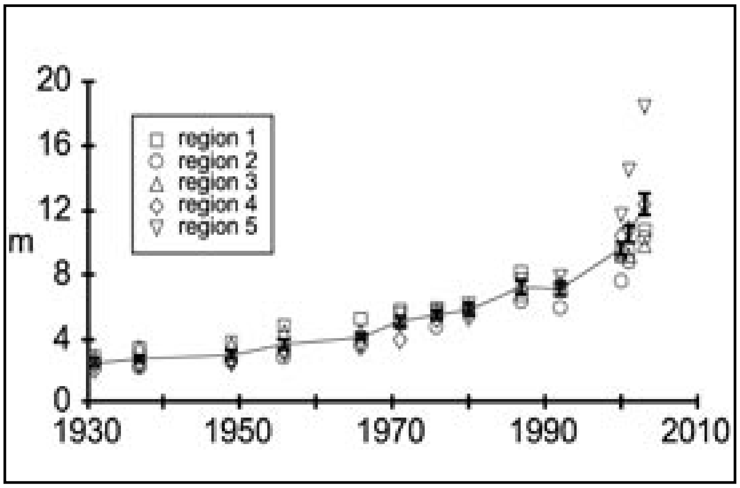


Figure 23. Increase in tidal creek width in Elkhorn Slough from 1930 to 2003 at 196 creeks followed over time in undiked areas (Van Dyke and Wasson 2005). The shapes refer to different study areas in the Slough.

Bank and channel erosion causes marsh plants to collapse into the channel, tidal creeks to deepen and widen, soft sediment in channel and mudflat habitats to be lost, and public access sites to crumble (Figure 22). Researchers have detected a shift in species composition in the intertidal invertebrate and fish communities. Lower abundances of many fish species (<30 percent lower than 1970s levels) in deep channel sites and an overall decline in diversity from the 1970s to 1990s has occurred in the main channel of Elkhorn Slough and has been attributed to changes in sediment size (Oxman 1995, Yoklavich et al. 1991). Tidal creeks do not support the same invertebrate assemblages they once did largely due to erosion, therefore the fish assemblages have changed and diminished the creeks' function as a nursery for estuarine fishes (Lindquist 1998). As tidal creeks deepened and widened over time, some fish species shifted from tidal creeks in the main Slough to mudflats in areas such as Parsons Slough (Carlisle 2006). A loss of fine sediment from various subtidal channels has caused a shift from gaper clams to boring clams in portions of the main channel between the 1970s and 1990s (Oliver et al., unpublished data). There has also been a decline of eelgrass beds near the mouth of Elkhorn Slough since the 1930s (MacGinitie 1935), likely causing a decreased abundance of animals dependent on eelgrass (Wasson et al. 2002).

Increasing Tidal Prism and Channel Velocities

The Elkhorn Slough mouth was deepened by more than five times when the Moss Landing Harbor was created in 1947 (Figure 24). The tidal connection between Elkhorn Slough and Monterey Bay is not only deeper, but is permanently open in a different location. The tidal prism of Elkhorn Slough has almost tripled since the first estimates were made in 1956 to 226 million cubic feet (6,400,000 cubic meters) (Broenkow and Breaker 2005, Sampey 2006). The tidal prism is defined as the volume of water covering an area between a low tide and the subsequent high tide. Maximum tidal velocities have increased from 1.4 to 3.4 mph (0.61 to 1.5 m/s) from the 1970s to 2005 in the main channel of Elkhorn Slough (pers. comm. N. Nidzieko). Near Seal Bend, the maximum velocity measured near the channel bed is 2.6 mph (1.15 m/s), which is important in understanding the erosion potential (pers. comm. N. Nidzieko).

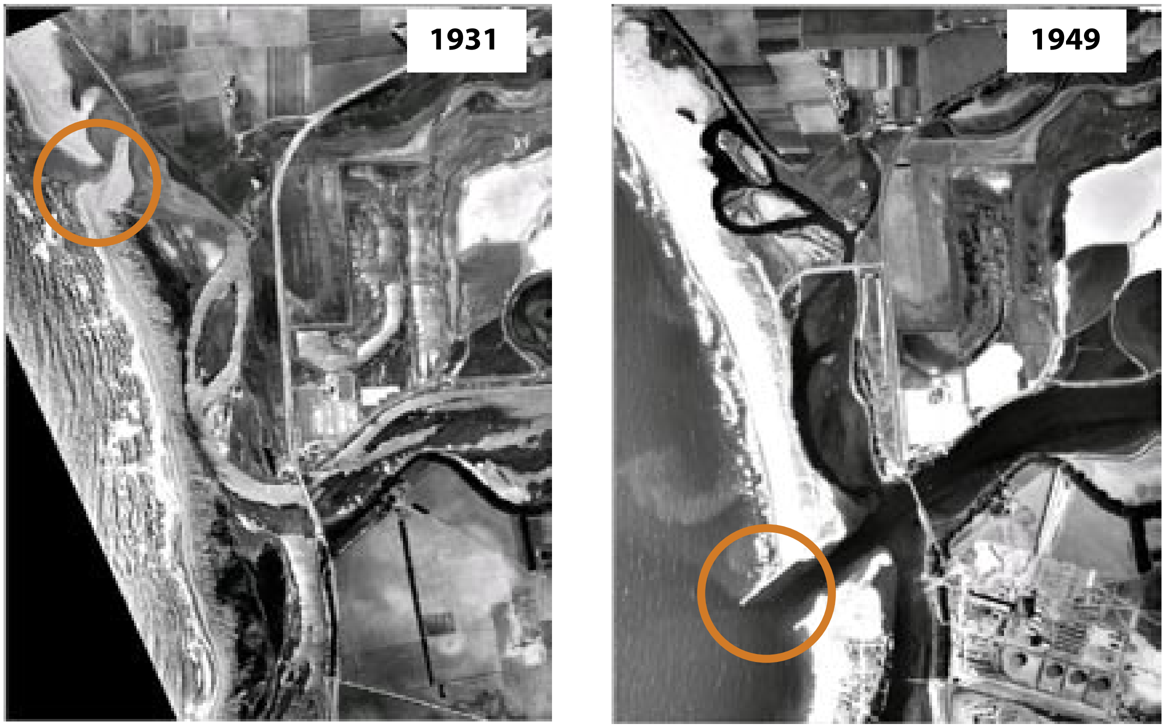


Figure 24. Aerial photographs comparing the mouth of Elkhorn Slough in 1931 (prior to the 1947 construction of the Moss Landing Harbor) and 1949. Monterey Bay is on the left side of the photographs. The orange circles indicate where the Elkhorn Slough estuary enters Monterey Bay.

Reduced Freshwater and Sediment Inputs
Sediment and freshwater inputs to Elkhorn Slough have been dramatically altered over time through river modifications (i.e. diversion, levee construction), groundwater overdraft, creek alterations, and modifications to the estuarine mouth.

Sediment inputs from Monterey Bay into Elkhorn Slough have likely decreased over time. Prior to 1947, the location of the estuarine entrance into Monterey Bay was north of the current configuration (Figure 24). Elkhorn Slough would have received greater inputs of littoral sediment (both sands and fine-grained material) in the past since the harbor jetties currently reduce these inputs and the entrance is now aligned with the Monterey Bay Canyon (Griggs et al. 2005).

The diversion of the Salinas River in c. 1909 and modifications to the Pajaro River (i.e. levee construction, channelization) likely led to a significant decrease in freshwater and sediment inputs to Elkhorn Slough. It is currently unknown to what extent either the Salinas or Pajaro River contributed to building and maintaining Elkhorn Slough marshes in the past. Currently, estimates of average sediment delivery from the Salinas River to Monterey Bay vary from 994,000 cubic yards (760,000 m^3) per year to 2.1 x 10^6 cubic yards (1.6 x 10^6 m^3) per year; finer material is hypothesized to be dispersed far into Monterey Bay (Farnsworth 2000 and McGrath 1987 *in* PWA 2007). However, preliminary research using sediment coring techniques suggest that for the Elkhorn Slough marshes studied, approximately three-quarters of the accumulated sediment is inorganic (mineral) which is indicative of riverine sources (Watson 2006).

Freshwater inputs to Elkhorn Slough were also likely greater in the past. In Blohm-Porter Marsh, analysis of marsh sediment cores and historical surveys suggest that this area was long dominated by brackish marsh (Herrmann 1898, Hornberger 1991). Modifications to Carneros Creek at the head of the estuary could also have reduced freshwater and sediment inputs to Elkhorn Slough, but not at the same scale as the Pajaro and Salinas Rivers.

Groundwater overdraft, first documented in the 1930s in the Monterey area, is largely due to an increase in the irrigation of agricultural lands (MCWRA 2005). Land survey maps from the early 1900s show freshwater artesian springs bubbling up in many tidal marsh areas of Elkhorn Slough. The overdraft is causing seawater intrusion and the loss of natural seeps and springs from the aquifer.

Many tidal brackish marshes have converted to other habitat types over time, but the exact acreage is unknown due to the limitations of aerial photograph interpretation. The reduced freshwater inputs to Elkhorn Slough likely contributed to the loss of tidal brackish habitats and natural saltwater/freshwater transition areas.

<u>Likely Causes - Interior Marsh Dieback and Habitat Erosion</u>

Habitat Erosion

The Elkhorn Slough estuary is currently facing unprecedented rates of tidal marsh loss and habitat degradation in areas that have never been diked. Based on current knowledge, the accelerated rates of marsh loss and habitat degradation are primarily due to previous modifications to the estuarine mouth to create the Moss Landing Harbor in 1947 (Figure 24). The larger entrance size of the Elkhorn Slough estuary, change in its location, erosion of intertidal habitats, and levee breaches have led to an increased tidal prism. The levee breaches were caused by winter storms, habitat erosion, and the restoration of the tidal flow to 160 acres (65 hectares) of previously diked South Marsh wetlands. The likely loss of significant inputs of riverine sediment from the Salinas River (diversion c. 1909) and/or Pajaro River and sediment entering the Elkhorn Slough from Monterey Bay due to the jetties is also considered to be significant in the imbalance of high erosion rates compared with low depositional rates.

The larger tidal prism has caused maximum tidal velocities to increase in the main channel of Elkhorn Slough, which in turn, has resulted in deeper and wider channels (including tidal creeks) to form through erosion. Larger channels convey larger volumes of water (e.g. tidal prism), which can lead to a positive feedback that results in further marsh loss and estuarine habitat degradation (Figures 22 and 25). The changing hydrodynamics of Elkhorn Slough are leading to shorter travel times for the incoming tides to reach the head of the estuary. Higher current velocities have caused habitat erosion, deepening and widening the channel and tidal creeks at the expense of salt marshes and mudflats. Bank and channel erosion causes marsh plants to collapse into the channel along the edges, tidal creeks to deepen and widen, and soft sediments to erode from channels and mudflats.

Additional factors that may be contributing to habitat erosion in Elkhorn Slough include the Monterey Canyon Head that acts as a sediment sink at the mouth of the estuary, increased wave action, sea-level rise, and levee breaching.

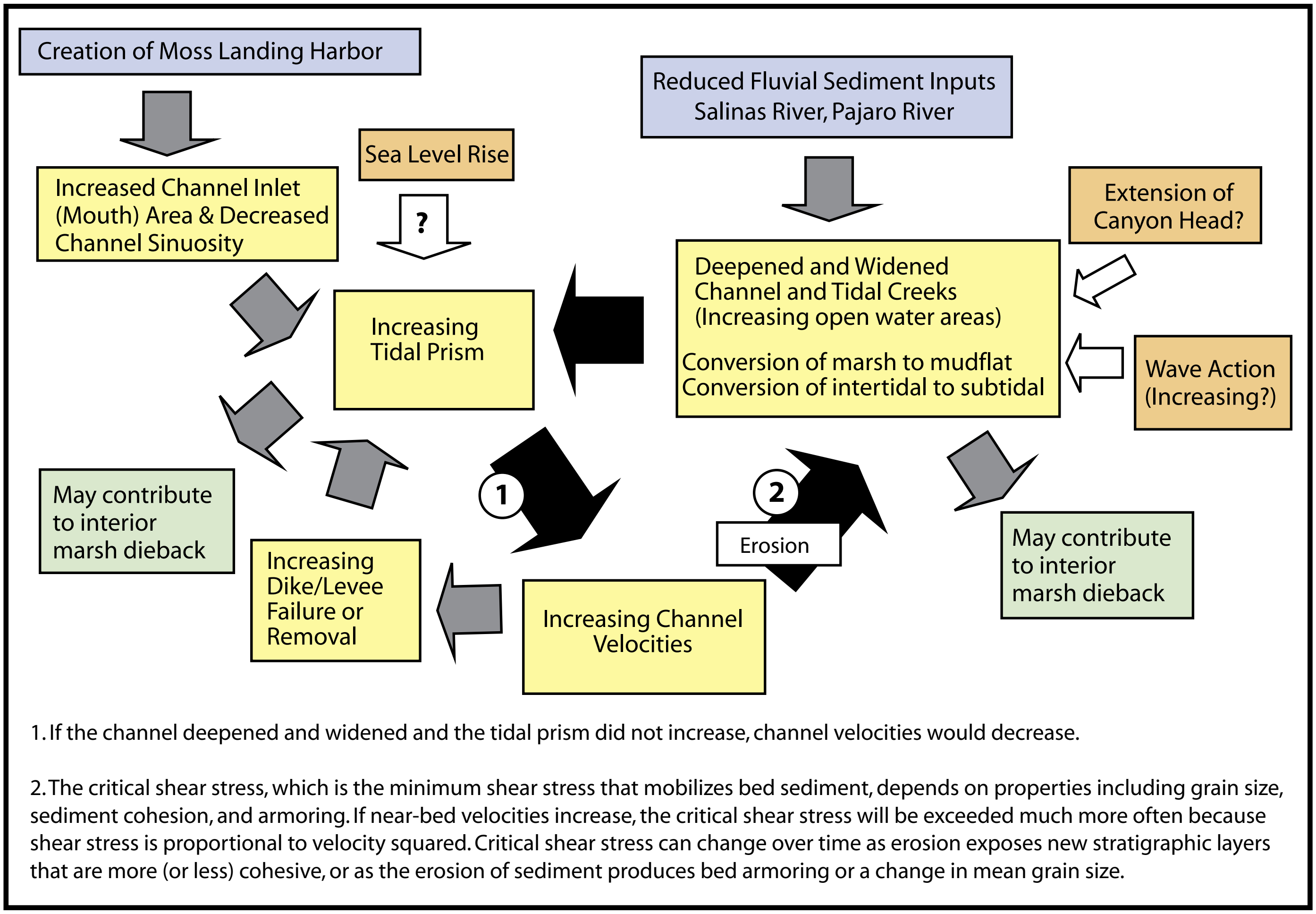


Figure 25. Conceptual model for the key physical factors causing habitat erosion in Elkhorn Slough.

Interior Marsh Dieback

Increased (prolonged or more frequent) inundation of tidal waters on marshes is likely causing interior marsh dieback (Figures 19, 20, and 26). If tidal inundation rates exceed the threshold that plants can adapt to, they will die. It is currently unknown how different factors contribute to marsh "drowning", but they could include changes in tidal volume, range, and velocities (i.e. harbor creation), reduced inputs of riverine sediment, decreased marsh elevations from tectonic or groundwater overdraft, sea-level rise, and elevated nutrient levels. Sediment inputs to Elkhorn Slough likely decreased due to the Salinas River diversion and Pajaro River modifications, but it is currently unknown to what extent either river contributed to building and maintaining Elkhorn Slough marshes in the past. Tidal marshes build their surface elevations both from organic matter supplied from decomposing plant roots and inorganic material supplied from rivers or tidal creeks (Friedrichs and Perry 2001). Studies conducted in Louisiana wetlands demonstrate that large infrequent flooding events might be very important in building and sustaining marshes over time (Day 2000). Excess nutrients in estuaries can also drive macroalgae blooms and the loss of marsh cover by reducing light availability (Valiela 1997). Tidal creeks that have become larger in size and increased in number and length may also impact the conveyance and drainage of tidal waters on the marsh plains.

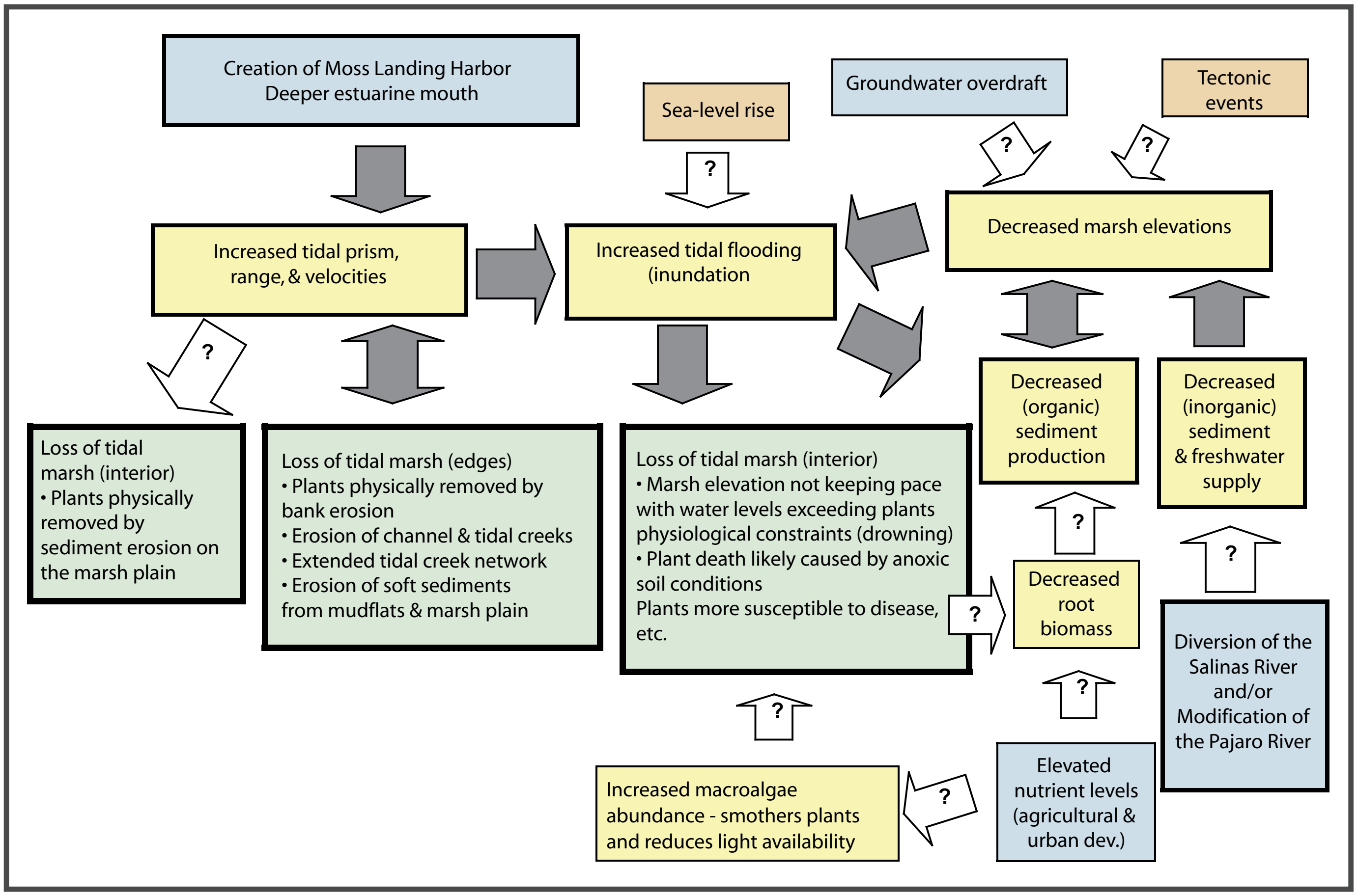


Figure 26. Conceptual model of likely major mechanisms of Elkhorn Slough marsh loss in interior and edge areas. Blue boxes are human impacts, yellow boxes are process changes, and green boxes signify the result (marsh loss).

Marsh Loss and Degraded Water Quality Conditions due to Diking

<u>Observed Changes – Marsh Loss and Degraded Water Quality Conditions</u>
The construction of dikes and the drying out of wetland soils resulted in subsidence of several feet in some areas. Processes contributing to subsidence include soil compaction, organic matter decomposition, loss of sediment imported with regular tidal flooding, and changes to water movement and storage (Cahoon et al. 1999). Levees not only converted wetlands to different habitat types, but also contributed to wetland degradation due to subsidence, loss of tidal connectivity, and decreased water quality. In areas where full or muted tidal flow has been returned to these subsided wetlands, mudflats and lagoons have replaced historic salt marsh habitat (Figure 27). Subsided elevations are a major constraint in restoring wetland habitat types.

Likely Causes – Marsh Loss and Degraded Water Quality Conditions
Since the 1870s, approximately 25 percent of Elkhorn Slough's salt marsh loss has been attributed to the conversion of wetlands to pasture, railroad and road construction, and the creation of freshwater impoundments for duck hunting (Van Dyke and Wasson 2005). Over 37 miles (60 kilometers) of levees and embankments were constructed between the 1870s and 1960s in Elkhorn Slough (Van Dyke and Wasson 2005).

In 1872, the Southern Pacific Railroad was extended through the estuary, creating a large levee separating marshes and tidal creeks on the east side of Elkhorn Slough. Local landowners built additional levees and dikes so that the impounded areas could be used for duck ponds (1930s), cattle grazing (1940s-1950s), and roads. By the 1960s, approximately 685 acres (277 hectares) or 31 percent of all estuarine habitats in Elkhorn Slough were isolated from the main channel and converted for human uses through diking and draining.

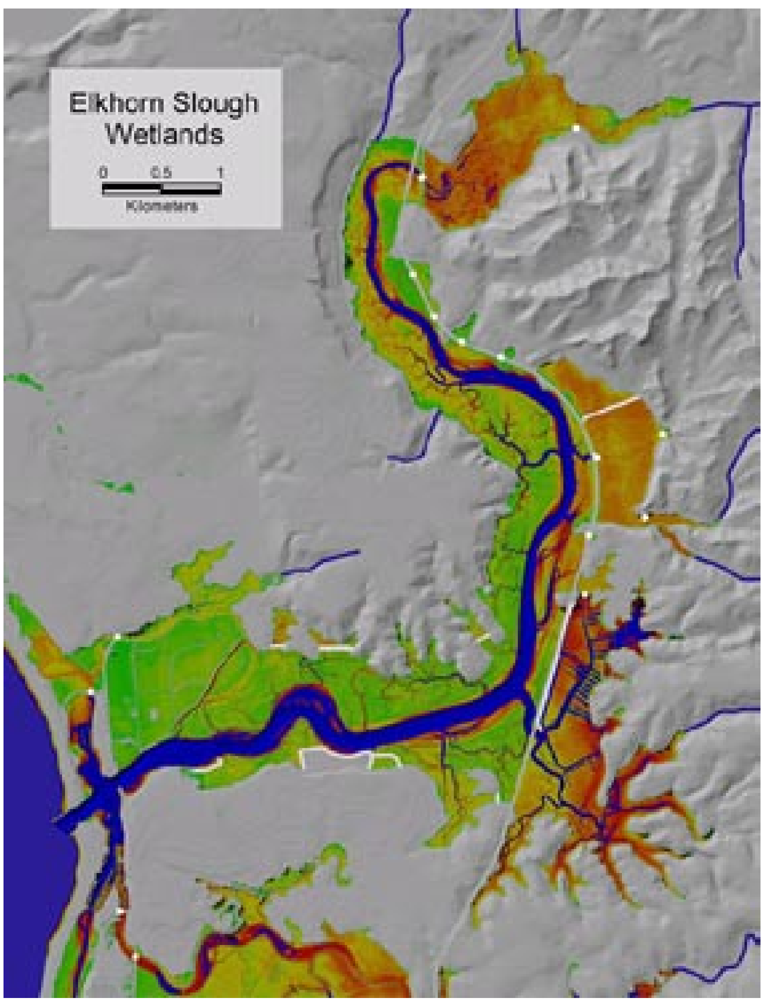


Figure 27. Map showing estuarine habitat elevations. The warmer colors (red) show subsided elevations, white dots illustrate water control structures, and white/gray lines indicate levees (2004 LIDAR data).

Approximately two dozen wetlands comprising approximately 637 acres (258 hectares) of estuarine habitats in the Elkhorn watershed are currently behind water control structures and levees. In all cases, this has resulted in an artificially abrupt transition in the tidal mixing zone, where formally, this transition would have occurred gradually. A recent study (Wasson et al. in review) found that species composition of fishes, invertebrates, and shorebirds differed significantly between sites at Elkhorn Slough with full versus very restricted tidal exchange (<5 percent of full tidal range). Furthermore, many sites with very restricted tidal exchange have water quality conditions that are poor, based on indicators such as dissolved oxygen (DO), organic matter accumulation (i.e. algae), and species richness (Appendix E). For example, studies of Azevedo Pond demonstrate that the site regularly experiences anoxia during the night (Beck and Bruland 2000, Chapin et al. 2004), and of two dozen wetland sites that receive muted tidal exchange, it has the highest tidal range (around 50 percent of the full tidal range). Many of the other tidal wetland sites with muted tidal exchange, which receive less than five percent of the full tidal range, experience even poorer water quality conditions.

Elevated Levels of Pollution and Eutrophication due to Non-Point Source Pollution

<u>Observed Changes – Elevated Levels of Pollution and Eutrophication</u>
An important and relatively poorly understood impact to Elkhorn Slough estuarine habitats is non-point source pollution which can result in the eutrophication of the estuary. Based on a survey in 1999, Elkhorn Slough is classified as a highly eutrophic environment due to the occurrence of low oxygen, high chlorophyll A, and high nitrate concentrations (NOAA 1998). Remarkably high nutrient and pesticide concentrations have been documented in the Slough's estuarine habitats (Caffrey et al. 2002). Up to 2000 μM (125 mg/L as nitrate, 28 mg/L as N) concentrations of nitrate have been recorded in the Old Salinas River Channel (Johnson et al. in press), which is almost three times higher than the water quality standard for municipal and domestic water supply use (45 mg/L as nitrate,10 mg/L as N).

The National Oceanic and Atmospheric Administration defines cultural eutrophication as the "enhanced accumulation of organic matter, particularly algae, that is caused by human related increases in the amount and composition of nutrients being discharged to the water body". This can lead to an array of harmful effects including reduction in water quality, fish death, and the loss of biodiversity (Cloern 2001), and has been identified by the Millennium Ecosystem Assessment as one of the largest and most dangerous threats to coastal ecosystems in the United States and globally. However, a scientific understanding of the processes that influence estuarine ecosystems such as Elkhorn Slough remains relatively primitive. Hobbie identified several reasons for the inability to characterize and quantify the important processes that affect biogeochemistry and ecological structure of estuaries including the inherent variability associated with estuarine mixing, tides, land runoff, and seasonality that creates tremendous observational challenges (2000). These challenges are compounded by the decadal (and greater) variability associated with global climate patterns.

Thus, while water quality research in Elkhorn Slough is relatively active (see Chapter 5), there remains a high level of uncertainty in assessing the effects of high nutrient concentrations in Elkhorn Slough. Few eutrophication studies have directly addressed the ecological impacts of pollution in Elkhorn Slough, but based on published studies elsewhere, it is possible that changes in water quality have increased the abundance of nutrient-limited producers (e.g., macroalgae) and pollution-tolerant animals, while decreasing the abundance of pollution-intolerant species.

Likely Causes – Elevated Levels of Pollution and Eutrophication

Non-point source pollution in Elkhorn Slough is likely from multiple sources. The high levels of nitrates in Elkhorn Slough suggest that pollutants that may be found in the runoff from some agricultural fields are a likely contributor. Use of persistent pesticides for agriculture in the area has been phased out, but high chemical concentrations are still present in the sediment. It will be important for agencies, the agricultural community, and scientists to work together in the future to both understand and reduce the impacts of non-point source pollution to Elkhorn Slough estuarine habitats.

Increased Numbers of Non-Native Invasive Species due to Aquaculture and Boating

Observed Changes – Increased Numbers of Non-Native Invasive Species

Another major impact to Elkhorn Slough's estuarine habitats includes the introduction and establishment of non-native species. Over 80 non-native species have been documented in the Slough's estuarine habitats. Some of the most commonly found non-native invasive species in Elkhorn Slough include the European green crab (*Carcinus maenas*) and the Japanese mud snail (*Batillaria attramentaria*) (Wasson et al. 2001). There are also algal, vascular plant, and fish invaders commonly found in Elkhorn Slough estuarine habitats. Marine and estuarine invasions have been shown to cause local extinction of native competitors and prey organisms, alteration of community composition and food webs, change in physical habitat structure, and even alteration of the flow of energy and materials through whole ecosystems (Grosholz 2002). In addition to estuarine invaders, non-native upland species have invaded Slough habitats. More than 30 terrestrial non-native plants have been found in the high marsh habitat in the watershed, and these account for about 15 percent of cover in this transition zone to the upland (K. Wasson and A. Woolfolk, unpublished data). In some places, non-native invasive species, such as poison hemlock and ice plant, form a virtual monoculture, dominating plant cover in the marsh-upland ecotone.

Likely Causes – Increased Numbers of Non-Native Invasive Species

The majority of the non-native aquatic invasive species in Elkhorn Slough are invertebrates, which were mostly transported to Elkhorn Slough through the aquaculture of non-native oysters and fouled boat hulls.

Entrainment of Organisms and Thermal Discharge due to the Power Plant

Observed Changes – Entrainment of Organisms and Thermal Discharge

Water intake pipes near the mouth of Elkhorn Slough entrain plankton and larval fish and impinge larger fishes, causing potential injury or death. In addition, large volumes of heated water, around a billion gallons, are discharged to Monterey Bay each day (MLML 2006). The U.S. Environmental Protection Agency is currently reviewing whether "once-through" cooling meets the "best technology available" standards mandated by the Clean Water Act. Generators may need to retrofit plants with cooling towers that recycle water which would either eliminate or dramatically reduce the marine life mortality and cumulative impacts on marine ecosystems from once-through cooling (Surfrider 2006). Proposed desalinization plants that would co-locate with the Moss Landing Power Plant could also have impacts such as entrainment of organisms and concentrated brine discharges (Pantell 1993).

Likely Causes – Entrainment of Organisms and Thermal Discharge

The Moss Landing Power Plant takes in large volumes of water from the Harbor for its cooling system and discharges heated water to Monterey Bay.

Introduction

This chapter describes broad strategies to conserve and restore Elkhorn Slough's estuarine habitats as recommended by the Tidal Wetland Project teams. The first main restoration strategy aims to reduce interior marsh dieback and estuarine habitat erosion. The restoration alternatives included under this strategy propose to change the estuary's entrance to reduce the tidal influence and habitat erosion and restore or add sediment to promote marsh growth. The purpose of the second main restoration strategy is to restore and enhance degraded estuarine habitats in Elkhorn Slough. These restoration alternatives include actions to restore subsided areas in the Parsons Slough and North Marsh Complexes, enhance water quality conditions in degraded habitats, and restore tidal brackish marsh habitats.

The level of detail for each restoration strategy varies and is based on the time allotted during the Tidal Wetland Project planning process. The scope of this project required that some strategies receive greater attention first due to current rates of habitat loss and degradation. The Strategic Planning Team decided that project efforts over the next five years should largely focus on evaluating and making decisions about restoration actions that address interior marsh dieback and habitat erosion.

Chapter Summary Points

- Changing the Elkhorn Slough entrance is one potential restoration strategy to reduce marsh loss and habitat erosion.

- Restoration strategies to enhance degraded wetland sites include adding sediment to rebuild marshes, restoring tidal creek networks, enhancing tidal exchange, or improving upland best management practices.

Restoration Strategy A: Reduce Habitat Erosion and Interior Marsh Dieback through Modifications to the Estuary Entrance and Sediment Additions

The goal of this strategy is to reduce the current dramatic rates of marsh loss and erosion of mudflat, channel, marsh, and tidal creek habitats in Elkhorn Slough. Erosion is due to changes in tidal volume, range, and velocities likely caused by the larger entrance size of the Elkhorn Slough estuary, change in its location, erosion of intertidal habitats, and levee breaches. Interior marsh dieback is attributed to the increased inundation of tidal waters that could be caused by factors such as changes in tidal volume, range, and velocities, reduced inputs of riverine sediment, decreased marsh elevations, and sea-level rise.

The following sections describe the potential restoration alternatives developed by Tidal Wetland Project teams to address interior marsh dieback and estuarine habitat erosion. These efforts focus on habitats in undiked areas of Elkhorn Slough. The alternatives listed below were prioritized from over 20 different alternatives initially developed by the joint SPT and SP teams as having the best potential to meet the goals. Given the likely causes of ongoing marsh loss and habitat erosion, the potential restoration alternatives differ vastly from those developed for other estuaries along the west coast. Again, restoration strategies for Elkhorn Slough aim to reduce the erosion of estuarine habitats, whereas strategies for most California estuaries are trying to reduce excess sediment depositing into their estuarine habitats. The potential restoration alternatives propose to modify the entrance of Elkhorn Slough and increase sediment supplies or add sediment to marsh habitats. Reducing Elkhorn Slough's tidal prism could decrease bank and channel erosion and may reduce the excessive tidal inundation of marsh plants. Decreased water velocities could increase the ability of the estuary to receive and retain sediment. This could reduce habitat erosion and preserve vegetated marsh areas. Increased retention of soft sediment in estuarine habitats could encourage the persistence of important benthic communities.

<u>Potential Restoration Alternative A1: Reroute the Elkhorn Slough Entrance</u>

Project Description

One of the potential alternatives is to restore or replicate the historic location, mouth size, and sinuosity of the Elkhorn Slough channel opening to Monterey Bay and block the current opening under the Highway 1 Bridge with a structure (Figure 28). The location of a potentially new entrance and channel has yet to be determined. Preliminary evaluations of this alternative suggest that it would reduce the tidal prism, water velocities, and channel erosion, increase sediment retention, and would likely reduce the ongoing marsh loss and habitat erosion. It may also create opportunities for greater inputs of littoral sediment (both sands and fine-grained material).

Figure 28. 2005 aerial photograph showing locations of potential large-scale changes to the opening of Elkhorn Slough as part of Restoration Alternative A. It shows the historic opening of Elkhorn Slough to Monterey Bay (yellow) and illustrates the Highway 1 Bridge crossing over Elkhorn Slough (orange).

Considerations
Although some Tidal Wetland Project participants regard this alternative as extreme, other members consider this option as a way to most closely replicate the "natural" historic conditions of the estuary. The level of uncertainty about the possible outcomes of this restoration alternative is very high. The political complexity, socioeconomic considerations, and construction costs to implement such a large-scale project would be substantial.

A newly constructed mouth and entrance channel may seasonally close without ongoing management so the movement of boats and pelagic animals (harbor seals, fish, etc.) between Monterey Bay and Elkhorn Slough and a working Moss Landing Harbor need to be considered during preliminary design phases. The fact that many species currently use Elkhorn Slough habitats necessitates a careful monitoring of existing conditions to compare with predicted conditions in order to balance the trade-offs of any large-scale restoration effort.

This type of action would separate estuary and Harbor management activities and reduce freshwater and nutrient inputs from the Old Salinas River Channel (Moro Cojo and Gabilan/Tembladero watersheds) into the estuary. Any reduction in the tidal prism of Elkhorn Slough will greatly increase the chance of reduced water quality conditions. Reductions of nutrient loads from the Old Salinas River Channel may help negate these potential water quality impacts. However, the dominant nutrient inputs during summer months may be from internal sources (pers. comm. K. Johnson), so the balance between reducing the tidal prism without exacerbating water quality impacts needs a great deal of attention. More information about the sediment and pollutant loads from the Old Salinas River Channel needs to be collected to fully evaluate this alternative.

<u>Potential Restoration Alternative A2: Reduce the Elkhorn Slough Entrance Size</u>
Project Description
Another potential restoration alternative is to more closely approximate the historic entrance of the estuary by decreasing the opening size under or near the Highway 1 Bridge using a structure such as an underwater sill (Figure 28). Preliminary evaluations of this alternative suggest that it would also reduce the tidal prism, water velocities, and channel erosion, increase sediment retention, and would likely slow, stop, or reverse the loss and degradation of estuarine habitats. Initial assessments of this alternative indicate that it has a good potential to conserve estuarine habitats (Philip Williams & Associates 1992). As mentioned below, supplemental actions to add sediment and re-establish sediment supplies may also be required.

Considerations
The design and analysis of any new structures near the Highway 1 Bridge needs to take into account boat access into Elkhorn Slough, preservation of a working Moss Landing Harbor, the stability of existing highway infrastructure, the movement of the Monterey Canyon head, and the possible increase in nutrient concentrations if tidal flushing is reduced. The movement of pelagic animals (harbor seals, fish, etc.) across a structure such as a sill is also another concern that needs to be considered during preliminary design phases. As discussed above, an important concern is the probable result that reduced tidal flushing will increase the residence time (i.e. reduce mixing with Monterey Bay water) of nutrients and organic matter within Elkhorn Slough. This may result in decreased water quality conditions, such as extended hypoxic conditions, if concurrent action is not taken to control nutrient inputs.

Sediment additions are also likely needed as supplemental actions. A major requirement of a sill would be that it is high enough in the water to be effective, yet ensure safe boat passage.

Major Efforts in Progress for Restoration Alternatives A1 and A2
Technical evaluations of the potential restoration alternatives discussed above will occur over the next few years. The studies will evaluate the outcomes of the potential restoration alternatives compared with a "no action" alternative. Evaluations will include predictions about changes to habitat erosion and marsh loss rates, key plant and animal species abundances, relevant socioeconomic uses and political factors, and water quality impacts under each option (Appendix F). The predictions will also take into account sea-level rise estimates. The information from these analyses will result in a decision being made about whether to move forward with a large-scale project to reduce Elkhorn Slough marsh loss and habitat erosion. The selection of the best alternative for Elkhorn Slough by Tidal Wetland Project decision-makers will require increased input from technical experts and community members.

Next Steps and Future Recommendations for Restoration Alternatives A1 and A2
If a decision is made to pursue restoration alternatives that reduce the ongoing tidal marsh loss and habitat degradation in Elkhorn Slough, Tidal Wetland Project members would need to obtain additional grant funding for pre-implementation phases. These would include elements such as environmental review, monitoring, public outreach, and more detailed construction designs, project description, and cost estimates. A restoration project of this magnitude could cost millions of dollars to implement, so it is likely that multiple federal, state, and private funds would need to be secured in addition to permits. In addition, funding is needed for a thorough evaluation of historic and current sediment inputs into Elkhorn Slough to help create strategies to reestablish sediment supplies.

Pilot restoration projects that would add sediment to degrading marsh sites may help test the efficacy of this technique for restoring marsh vegetation. One 98-acre (40-hectare) wetland area, Yampah Marsh, is of particular interest because it is currently degrading at rapid rates while retaining enough vegetation to respond well to pilot sediment addition/retention projects (Figure 29). Additional pilot projects could include muting the tidal influence to other wetland sites.

A more detailed description of major efforts, next steps, and priority research and monitoring projects for all restoration strategies is provided in Chapter 5 and Appendix G.

<u>Potential Restoration Alternative A3: Add Sediment to Rebuild Marshes (Supplemental Action for A1 and A2)</u>
Project Description
Changing the entrance of Elkhorn Slough and muting the tidal prism alone may not allow marshes to reestablish. In regions of Elkhorn Slough that have never been diked, approximately 200 acres (81 hectares) of marsh vegetation has been lost (ESNERR, unpublished data). In many cases, the erosion of several inches of sediment has occurred in regions of Elkhorn Slough after the vegetation has died because the plant roots are important for holding sediment in place. The Northwestern Marsh complex of Elkhorn Slough is an example of this minor erosion (Figure 29). The addition of thin layers of sediment may need to be considered in combination with Alternatives A1 and A2 to encourage plant growth. The addition of sediment to the channel near new openings or structures could also create more gradual elevation changes and minimize scouring.

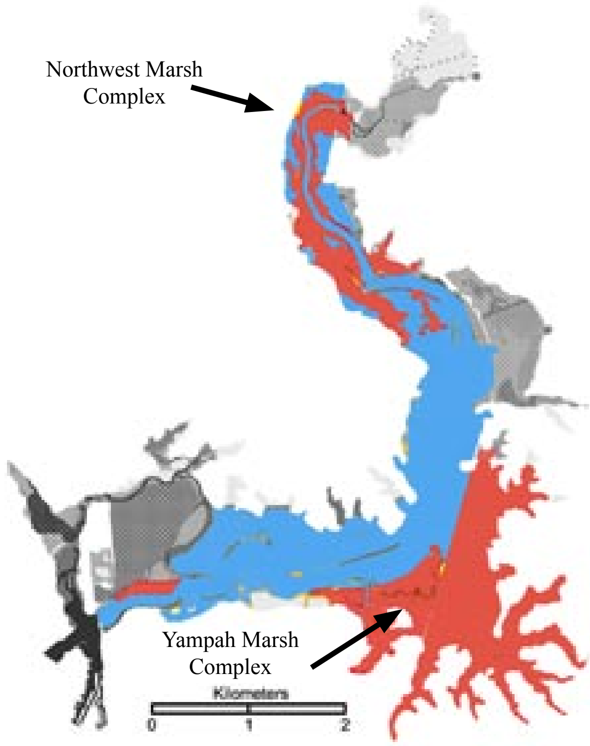


Figure 29. All map areas highlighted in color indicate sites in Elkhorn Slough that are suffering from ongoing marsh loss and erosion of habitats or high quality habitats critical to conserve. Some of the habitat areas shown in blue are in various states of degradation. Areas in red are former marsh areas that have already lost vegetation and could also benefit from restoration efforts.

Considerations
The application of thin layers of sediment to restore marsh vegetation has been successful in restoring estuarine marshes in areas such as Jamaica Bay, New York. Sediment from the Moss Landing or Santa Cruz Harbor dredging or the Pajaro River projects could be used to rebuild marsh areas if the characteristics (size, texture, non-polluted) were appropriate.

Next Steps and Future Recommendations
Meetings need to be held with regulatory agencies to discuss and develop sediment standards for restoration efforts to restore marshes in Elkhorn Slough. Currently, specific guidelines to permit sediment additions to estuarine sites in the Central Coast Region are lacking.

<u>Potential Restoration Alternative A4: Re-establish Sediment Supplies (Supplemental Action for A1 and A2)</u>
Project Description
The restoration of natural sediment supplies to Elkhorn Slough is also likely needed. It is currently unknown to what extent either the Salinas or Pajaro Rivers contributed to marsh building in the past. However, the diversion of the Salinas River in c. 1909 and modifications to the Pajaro River over the past decades could have reduced considerable sediment inputs to Elkhorn Slough. The restoration of riverine inputs should be considered for Elkhorn.

Considerations
Because the re-establishment of flooding waters from the Mississippi River that carry high sediment loads has proved essential in restoring Louisiana salt marshes, this strategy should be considered for Elkhorn Slough. Again, the sediment characteristics (size, texture, non-polluted) from the Pajaro or Salinas Rivers would need to be appropriate. Although in the short-term, more analysis needs to be done of both current and past sediment inputs, restoring episodic inputs from river flooding events needs to be considered in future restoration efforts. If large-scale restoration projects take place, every effort should be taken to

make sure the marshes can naturally sustain their elevations over time. This is particularly critical in light of projected rates of sea-level rise for the next century.

Next Steps and Future Recommendations
Meetings will need to be held with project managers and agencies overseeing Pajaro and Salinas River projects.

Meeting the Goals and Objectives for Restoration Strategy A
The potential restoration strategies listed above aim to conserve high quality estuarine habitats (Goal 1) by significantly reducing the rate of salt marsh habitat loss and degradation, subtidal channel erosion, the loss of soft sediment from mudflat and subtidal channel habitats, and tidal creek habitat loss and degradation. They could also restore and enhance degraded estuarine habitats (Goal 2) by increasing the extent of salt marsh habitats and high quality soft sediment in mudflat and subtidal channel habitats. The strategies aim to restore and enhance the natural processes (hydrologic and geomorphologic) to sustain a more stable and resilient estuarine system (Goal 3) by attaining a more appropriate tidal influence for undiked areas and reestablishing or augmenting the supply of suitable sediment.

Restoration Strategy B: Restore and Enhance Degraded Estuarine Habitats through Tidal Exchange and Creek Modifications, Sediment Additions, Upland Best Management Practices, and Freshwater Augmentations

More than 1,000 acres (405 hectares) of salt marsh habitat (including tidal creeks) have been lost in Elkhorn Slough from 1870 to 2003 mostly from the past diking and draining of wetlands (Figure 18, Van Dyke and Wasson 2005). At least some tidal influence has been returned to the majority of the formerly diked wetland areas, but they are severely subsided. In areas where full or muted tidal flow has been returned to these subsided wetlands, mudflats and lagoons have replaced vegetated salt marshes because of a decrease in several feet of elevation.

In addition, many tidal brackish marshes have converted to other habitat types over time, but the exact acreage is unknown due to the limitations of aerial photograph interpretation. Severe, chronic overdrafts of groundwater levels in the region, reduced riverine inputs, and diking of freshwater creeks have likely reduced freshwater inputs to Elkhorn Slough. This has contributed to the loss of tidal brackish habitats and natural transition areas. The restoration of salt and tidal brackish marsh habitats needs to include the re-establishment of the natural distribution and abundance of tidal creeks, pannes, vegetated plains, and wetland/upland transitional areas.

<u>Potential Restoration Alternative B1: Reduce the Tidal Influence and/or Add Sediment to Restore Parsons Slough Marsh Habitat</u>
Project Description
The Parsons Slough wetland complex, a 429-acre (174-hectare) area in the southeastern section of Elkhorn Slough, is the largest area of former marshlands that has subsided (Figures 30 and 31). The elevation is approximately 2.4 feet (0.7 meters) lower than what can support marsh vegetation. Although a number of subsided areas in Elkhorn Slough could benefit from restoration efforts, Parsons Slough was selected because of its large size, loss of hundreds of acres of marsh habitat, and the potential for these efforts to slow marsh loss and habitat erosion in the rest of the estuary.

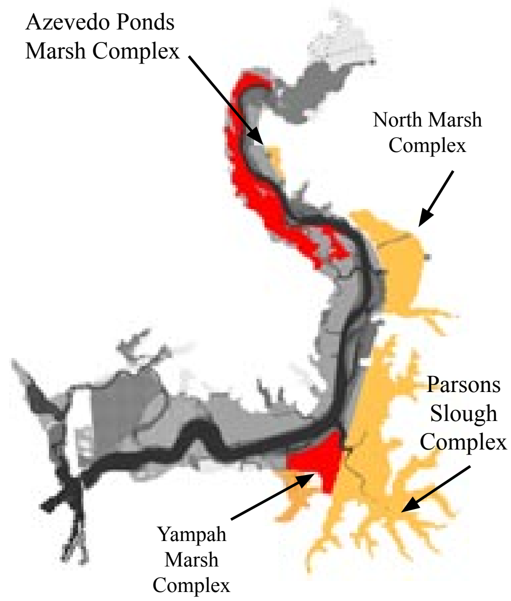


Figure 30. Aerial photograph showing the Parsons Slough Marsh complex. The comparison between 1931 and 2005 demonstrates marsh loss in Parsons Slough due to subsidence from past diking (darker areas in the 1931 photo indicate vegetated marshes). The potential reduction in the mouth opening of Parsons Slough would likely take place near the railroad crossing (orange circle).

Figure 31. Highlighted areas indicate potential restoration efforts (marsh habitat needs to be restored in currently or previously diked areas shown in orange and in areas that have never been diked in red).

The Parsons Slough wetland complex may benefit from the installation of a water control structure (i.e. culverts, tide gates, earthen or rock levees, or sill) to mute the tidal influence and sediment additions to restore marsh elevations and tidal creeks. A Parsons Slough project could restore the extensive tidal marsh and creek habitats historically present at the site. Preliminary evaluations of this alternative suggest that it could also slow marsh loss and habitat erosion in the rest of the estuary because Parsons Slough accounts for approximately 30 percent of the total Elkhorn Slough tidal volume.

Considerations

A Parsons Slough restoration project could be implemented whether or not a large-scale restoration alternative (A1 or A2) moves forward. Although structures are not a preferred restoration technique due to the high level of maintenance, options are limited in this high energy system. If large-scale restoration efforts (A1 or A2) take place that reduce the size of the Elkhorn Slough entrance and habitat erosion, long-term restoration activities for Parsons Slough should consider the removal of water control structures when no longer needed. Research has shown that non-restricted tidal inundation of wetland areas maximizes the amount of sediment imported from the main estuary (Cahoon et al. 1999), but too much tidal inundation may be harmful to plants.

Initial discussions of this alternative recognize that the design and analysis of any new structures near the mouth of Parsons Slough need to take into account the stability of the existing railroad infrastructure, access for sharks and rays, other fish, and marine mammals, and the possible increase in nutrient concentrations if tidal flushing is reduced. Care must be taken to ensure that the tidal exchange is not reduced so much that the estuarine habitats experience long-term harmful effects of reduced water quality conditions that may result from an increased residence time of water and nutrients behind the water control structure. In addition, due to the return of tidal hydrology to Parsons Slough, some of the mudflat and channel areas have become an important nursery for sharks and may be for other fishes as well (Carlisle 2006). Therefore, restoration plans for Parsons Slough also need to conserve existing high quality habitats within the site. A major SPT planning principle is to have restoration projects designed with the ability to adaptively manage them in order to maximize positive and minimize negative outcomes.

Major Efforts in Progress
A Parsons Slough restoration planning project has been initiated. The planning project will include a summary of existing conditions, evaluation of different restoration alternatives, and analysis of marsh sediment addition techniques. The main result of this project will be the development of a preferred wetland restoration alternative for Parsons Slough based on ecological indicators (e.g. salt marsh and eelgrass, water quality, fish), technical feasibility, long-term sustainability, and costs.

Next Steps and Future Recommendations
The most important next step is to obtain funding and permits for implementing a Parsons Slough restoration project. Pre-restoration monitoring of Parsons Slough habitat conditions is also considered vital to adequately restore these habitats. It will be important to anticipate any data gaps that should be filled before the project can move forward. Issues such as factors governing plant survival, patterns and timing of the establishment of biota, sediment grain size requirements for plant and invertebrate colonization, current sediment erosion/deposition rates, and the potential for invasion of newly restored habitat by non-native species may be important in planning the project, and may require advanced research. The filling of data gaps should proceed in parallel with the restoration planning process so that project implementation is not impeded by missing information. Pilot projects using sediment fences may also be beneficial to learn about the feasibility of adding sediment to rebuild marshes.

Meeting the Goals and Objectives
A restoration project in Parsons Slough would restore and enhance degraded estuarine habitats (Goal 2) by increasing the extent of salt marsh habitats including tidal creeks, pannes, vegetated plains, and wetland/upland transitional areas and high quality soft sediment in mudflat habitats. It may also conserve high quality estuarine habitats (Goal 1) by slowing the rate of marsh loss and habitat erosion in the main Slough. Restoration activities in Parsons Slough could also restore and enhance natural processes (Goal 3) by attaining a more appropriate tidal influence for undiked areas and re-establishing or augmenting the supply of suitable sediment.

Potential Restoration Alternative B2: Add Sediment and/or Improve Water Quality Conditions to Enhance North Marsh Habitats
Project Description
Tidal marsh could be restored in North Marsh, a 183-acre (74-hectare) wetland system on the eastern side of Elkhorn Slough (Figure 31). Similar to Parsons Slough, this area was historically diked and elevations within

this site have subsided by an average of 1.9 feet (0.6 meters). Because this wetland area is already managed behind a water control structure, sediment additions to restore the extent of marsh vegetation could be more straightforward than Parsons Slough. The degree to which sediment is naturally building up in this area is currently unknown, and monitoring needs to be part of a restoration planning effort. In addition, North Marsh has increased accumulations of organic matter (i.e. algae) which is indicative of eutrophication, high nitrate levels, and hypoxic events (Appendix E). Strategies to improve tidal circulation and water quality conditions in North Marsh could include restoring vegetated areas, enhancing tidal exchange, or restoring tidal creek networks and drainage.

Next Steps and Future Recommendations
More detailed restoration planning efforts for North Marsh are needed. Pilot restoration projects should be implemented to add or retain marsh sediment to promote vegetation growth. Funding is also needed for the maintenance and improvement of the outdated water control structure at North Marsh.

Meeting the Goals and Objectives
A restoration project in North Marsh would restore and enhance degraded estuarine habitats (Goal 2) by increasing the extent of salt marsh habitats including tidal creeks, pannes, vegetated plains, and wetland/upland transitional areas.

<u>Potential Restoration Alternative B3: Improve Degraded and Maintain Desirable Water Quality Conditions in Estuarine Habitats</u>
Project Description
Many estuarine wetlands in Elkhorn Slough currently behind water control structures and levees have hypoxic (low dissolved oxygen) and seasonal hypersaline conditions that reduce the quality of that habitat for many estuarine species. Wetland sites have varying levels and types of degradation, but the highest levels of nitrate have been measured in North Marsh, Blohm-Porter Marsh, Struve Pond, and South Azevedo Pond (Appendix E). Even though it is behind a water control structure, Whistlestop Lagoon is one area that includes important species such as southern sea otters and oysters, illustrating that if appropriate tidal conditions are provided, estuarine function can be retained.

Restoration options to enhance water quality conditions for these habitats could include strategies such as improving tidal circulation, enhancing tidal creek connections, implementing upland best management practices to reduce polluted inputs, or adding sediment to promote vegetation growth. Previous work in Southern California (Zedler et al. 1999) and in the San Francisco Bay (Sanderson et al. 2000) has shown that tidal creeks have a critical effect on distributions of many salt marsh plants, with greater diversity near creeks likely because of improved drainage. In addition to enhancing tidal creek connections to promote enhanced tidal circulation, some wetland sites (i.e. Estrada Marsh, Middle Azevedo Pond) that receive very minimal tidal ranges could receive enhanced tidal exchange (Appendix E). However, some wetland areas with low levels of tidal exchange (i.e. lower Moro Cojo and Struve Pond) have tidal brackish assemblages including the tidewater goby and tidal brackish snail not found anywhere else in Elkhorn Slough. Another potential strategy to improve water quality conditions is to filter polluted water through the creation of adequately sized vegetated areas between fields, irrigation canals, and estuaries. The Elkhorn Slough Foundation has partnered with Moss Landing Marine Laboratories and other local groups to implement the *Moro Cojo Management and Enhancement Plan* with the goal of restoring natural habitats and improving water quality. Projects over the last several years include decommissioning agricultural ditches, creating freshwater ponds and planting native species, and using these vegetated areas to filter agricultural runoff before the high-nutrient water flows into Monterey Bay. The specific restoration strategies applied at one site may not be applicable to other sites.

Considerations
If large-scale restoration efforts (A1 or A2) take place that reduce the overall tidal prism, long-term activities could include the removal of structures and levees that currently separate dozens of tidal wetland sites from the main estuary. Restoring the connection could be particularly important to sustain restored marshes because it would help increase sediment inputs from the main Slough during tidal flooding events. In the short-term, however, care should be taken for any significant increases in the Slough's tidal prism due to the potential acceleration of marsh loss and habitat erosion in the rest of estuary. In addition, some areas (i.e. Struve Pond, Moro Cojo) currently provide habitat for listed species such as tidewater gobies.

Major Efforts Completed
A recent ESNERR research project focused on evaluating indicators of estuarine health and diversity in sites behind water control structures. A few Tidal Wetland meetings of the Strategic Planning Team and Science Panel have been conducted to begin the discussion of potential restoration goals for these sites.

Next Steps and Future Recommendations
Meetings will be held to discuss the conditions of estuarine habitats behind water control structures and create restoration goals and strategies for some of these sites. In some cases, it may be decided that the site does not need restoration at all, particularly if the conditions provide habitat for listed species. It is critical that the conservation goals and potential restoration strategies be discussed to inform ongoing and future management activities. Potential restoration strategies will need to be identified by the Tidal Wetland Project teams with input by relevant agencies, organizations, and stakeholders. Continued monitoring of all estuarine habitat conditions is considered vital to the development of appropriate restoration strategies.

Meeting the Goals and Objectives
Restoration projects for wetland sites behind water control structures could enhance the quality of these estuarine habitats (Goal 2) and restore appropriate levels of tidal exchange to former tidal areas (Goal 3) that have no tidal connection or a very restricted tidal exchange (if it will not exacerbate erosion and marsh loss in other areas).

<u>Potential Restoration Alternative B4: Enhance Freshwater Inputs to Restore Tidal Brackish Marsh Habitats</u>

The extensive diking of tidal wetlands and the decrease of freshwater inputs, particularly from groundwater overdraft, has caused a reduction of natural transitional tidal brackish marsh habitats in Elkhorn Slough. Given Elkhorn Slough's reduced freshwater inputs and increased tidal influence, currently tidal brackish habitats are mostly represented in artificially diked areas with very low tidal exchange.

Project Description
Increasing appropriate levels of freshwater inputs to Elkhorn Slough from Carneros Creek and the Salinas and Pajaro Rivers should be considered. Because the loss of freshwater inputs includes large-scale, regional issues such as groundwater overdraft and river diversions, there are currently limited small-scale restoration strategies available to restore tidal brackish marsh transition areas. Initial ideas that have been presented

at Tidal Wetland Project meetings include altering the conveyance of surface flows to tidal wetlands to enhance the retention of freshwater without impounding these areas and periodically pulsing impounded areas with tidal waters. In some wetland areas with key tidal brackish species such as tidewater gobies, strategies should focus on preserving these habitat conditions in the short-term.

Considerations

Although a number of regional strategies consider restoring groundwater aquifer levels to make freshwater available for drinking water and irrigation, tidal brackish and freshwater wetlands in the Elkhorn Slough watershed also need these inputs restored to be fully functional.

Next Steps and Future Recommendations

In the future, a large-scale planning effort is needed to create goals and strategies to restore freshwater wetland and tidal brackish habitats in the Elkhorn Slough watershed. Restoration strategies need to take into consideration overarching Tidal Wetland Project goals, current conditions, and stakeholder concerns. Conservation planning for tidal brackish habitat areas may be combined with efforts to address estuarine habitats behind water control structures. Although this restoration planning is considered important, it is less urgent than strategies to address ongoing marsh loss and habitat erosion in the main Slough. Also, community members could become involved in regional efforts to restore groundwater levels for the benefit of tidal brackish and freshwater wetland habitats.

Meeting the Goals and Objectives

Restoration projects could increase the extent of tidal brackish marsh habitats and freshwater/saltwater natural transition gradients and connectivity (Goal 2).

Chapter 5: Next Steps for the Elkhorn Slough Tidal Wetland Project

Introduction

This chapter describes the relevant regulations, technical and political feasibility, costs, stakeholder interests, and research gaps required for the implementation of restoration projects. It provides a framework for evaluating these variables through its review of the relevant policies, partnerships, and future funding needs to guide wetland restoration projects. This chapter also discusses relevant ongoing efforts that are supporting the Tidal Wetland Project and strategies for the future development of this effort.

Chapter Summary Points

- Funding is needed for restoration, research and monitoring, and community involvement activities.
- Potential large-scale restoration projects are being evaluated using an ecosystem-based management approach.

Relevant Policies and Partnerships for Implementing Restoration Projects

Relevant Policies

Many federal, state, and local policies will guide the implementation of wetland restoration projects. These policies will vary greatly depending on the type of restoration project that is carried out. The relevant agencies who may be involved in permitting a restoration project include the California Coastal Commission, Regional Water Quality Control Board, Monterey County, Monterey Bay National Marine Sanctuary, Moss Landing Harbor District, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, and U.S. Fish and Wildlife Service. Appendix H describes the relevant regulations and permits required by a number of local, state, and federal agencies. Several representatives from regulatory agencies have already been involved in the Tidal Wetland Project so that regulations could be considered early on in the restoration planning stages. As more detailed restoration planning takes place for specific Elkhorn Slough projects, obtaining associated permits will greatly impact the time it takes to implement restoration projects.

Important Partnerships

Certain agencies and organizations will take the lead on future restoration efforts in Elkhorn Slough depending on the scale and location (jurisdiction and/or ownership) of the project. Several of the restoration projects will occur on public lands and may include agencies such as the California Coastal Conservancy, California Department of Fish and Game, California Wildlife Conservation Board, National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service and U.S. Geological Survey. Partnerships with scientific institutions, such as the Moss Landing Marine Laboratories, California State University Monterey Bay, University of California, Monterey Bay Aquarium Research Institute, University of San Francisco, Point Reyes Bird Observatory, San Francisco Estuary Institute, Stanford University and other institutions will continue to be important to support the research and monitoring of estuarine habitats and restoration projects. A number of nonprofit and private organizations will also be involved such as the Elkhorn Slough Foundation and The Nature Conservancy, and other private landowners and neighbors. Again, many of these key agencies and organizations have mission statements that substantially overlap with Tidal Wetland Project goals and some are already represented on the teams. Partners are needed who are committed to overseeing long-term restoration projects that require multiple funding and policy strategies, research and monitoring efforts, and ongoing adaptive management activities. Finally, continuing to build and maintain partnerships with local community members and business organizations will be needed to reach the long-term goals of the Tidal Wetland Project.

Ongoing Efforts Supporting Estuarine Restoration

Technical evaluations of potential restoration alternatives for Elkhorn Slough will occur over the next few years using an ecosystem-based management approach. The information from these analyses and the use of scientific research will result in a decision being made about whether to move forward with a large-scale restoration project to reduce marsh loss and habitat erosion. The selection of the best restoration alternative for Elkhorn Slough by Tidal Wetland Project decision-makers will require increased input from technical experts and community members.

Evaluation of Potential Large-Scale Restoration Alternatives to Reduce Habitat Erosion and Marsh Loss

- A consulting team will make quantitative predictions about changes to the tidal hydrology, geomorphology, and estuarine habitats under different restoration alternatives. Preliminary designs and rough estimates for the costs of restoration strategies will also be developed. *Target Completion Date - March 2008*
- Monterey Bay Aquarium Research Institute (MBARI) scientists will lead efforts to examine interactions of nitrogen dynamics for different restoration scenarios. Restoration strategies will have to carefully balance reductions in tidal influence to conserve and restore estuarine habitats without further degrading water quality conditions. *Target Completion Date – January 2009*
- ESNERR researchers and collaborators will predict the responses of key species to the various restoration alternatives using the predicted changes to estuarine habitats and nutrient conditions. *Target Completion Date – January 2009*
- MBARI social scientists and collaborators will analyze the socioeconomic values of Elkhorn Slough and evaluate how restoration alternatives will affect human uses. The team will also conduct an analysis of the political feasibility of selected options based on case studies and the analysis of relevant laws and regulations. *Target Completion Date – January 2009*

Restoration Planning to Restore Marsh Habitat to Parsons Slough

- The Parsons Slough restoration planning project will include a summary of existing conditions, evaluation of different restoration alternatives, and analysis of marsh sediment addition techniques. *Target Completion Date – August 2008*
- The main result of the planning project will be the development of a preferred wetland restoration alternative for Parsons Slough based on ecological indicators (e.g. salt marsh and eelgrass, water quality, fish), technical feasibility, long-term sustainability, and costs. *Target Completion Date – December 2008*

Research, Monitoring, and Pilot Restoration Projects

- ESNERR staff are working with NOAA to install secondary tide stations in Elkhorn Slough to evaluate tide levels to better understand the mechanisms of marsh loss and guide future restoration efforts. *Target Completion Date – 2007*
- A consultant and ESNERR staff are using sediment elevation tables to evaluate spatial differences in marsh loss. *Ongoing*
- ESNERR has long-term monitoring programs for water quality, habitat change, and biotic indicators and maintains a database of Elkhorn Slough research activities (http://www.elkhornslough.org/research.htm). *Ongoing*
- MBARI (http://www.mbari/.org/lobo) researchers monitor real-time and long-term water quality conditions in Elkhorn Slough. *Ongoing*
- Monterey Bay National Marine Sanctuary's Sanctuary Integrated Monitoring Network funds numerous

research and monitoring projects in Elkhorn Slough (http://www.mbnms-simon.org). *Ongoing*
- California State University Monterey Bay's Seafloor Mapping Laboratory (http://seafloor.csumb.edu) provides bathymetric maps of Elkhorn Slough. *Ongoing*
- Moss Landing Marine Laboratories (http://www.mlml.calstate.edu) scientists and students study Elkhorn Slough marine mammals, plankton, benthic invertebrates, fishes, and geologic processes. *Ongoing*
- ESNERR is collaborating with partners to conduct a pilot sediment fence project to test the feasibility of sediment additions to restore marsh elevations and promote plant growth. *Target Completion Date – 2007*
- A UC Berkeley researcher is taking limited marsh sediment cores to determine the age of marshes and sedimentation rates in various regions of Elkhorn Slough. *Ongoing*
- Stanford University constructed and is refining a 3-D hydrodynamic model of Elkhorn Slough (http://www.stanford.edu/group/efml). *Ongoing*
- ESNERR staff are evaluating indicators of estuarine health and diversity in sites behind water control structures. *Target Completion Date - 2007*

Community Involvement and Partnerships
- Community forums and field tours are being hosted to bring Tidal Wetland Project-related information directly to the community and for community members to provide input on potential restoration strategies. *Ongoing*
- Print materials and email updates about the Tidal Wetland Project are being provided to over 850 people including landowners, scientists, members of community organizations, and agency representatives interested in the conservation and restoration of Elkhorn Slough's estuarine habitats. Almost 300 of those contacts now receive monthly email updates about Tidal Wetland Project activities, and each month several new individuals request to be added to the email list. *Ongoing*
- Several community forums and walking tours are being held to receive public input about potential restoration activities and approximately 120 attendees have been involved to date. *Ongoing*

Priority Funding Needs to Support Elkhorn Slough Restoration Efforts

Potential restoration projects in Elkhorn Slough will require different levels of funding. Costs could be in the tens of millions of dollars for large-scale restoration projects. As mentioned in Chapter 4, the decision to proceed with efforts at this scale is yet to be made and will depend on the results of analysis of different alternatives currently being undertaken. Some of the pilot and smaller-scale restoration projects and research efforts could be funded earlier. Much effort over the next five years will be focused on obtaining both public and private sources of funding for restoration actions listed in the previous chapter, for community involvement activities, and to support staff to manage the projects. The list below provides priority funding needs for the next stages of restoration projects, research and monitoring activities, and community involvement and partnership actions. A list of additional priority research and monitoring projects to help guide Elkhorn Slough estuarine restoration efforts is listed in Appendix G.

Restoration Projects
1. Secure funding for the implementation, permitting, and monitoring of a Parsons Slough restoration project.
2. Obtain funding and hire consulting teams to conduct pre-restoration phases for large-scale restoration projects to reduce marsh loss and habitat erosion. This could include activities such as an environmental

review, research and monitoring efforts, detailed construction designs and project descriptions, and cost estimates for implementation.

3. If a decision is made to proceed with a large-scale restoration project, obtain funding. Since these projects could cost millions of dollars to implement, a tremendous effort and various strategies are needed to secure multiple sources of federal, state, and private funds.
4. Acquire funding to develop detailed restoration plans for the North Marsh complex.

<u>Tidal Wetland Project Planning and Project Development Efforts</u>

5. Decide whether to proceed with a large-scale restoration project to reduce marsh loss and habitat erosion in Elkhorn Slough.
6. Hold meetings with regulatory agencies to discuss and develop sediment standards for restoration efforts to restore marshes in Elkhorn Slough.
7. Convene smaller working group meetings of the Tidal Wetland Project's Strategic Planning Team and Science Panel at least quarterly to guide restoration projects.
8. Discuss degraded estuarine habitats behind water control structures and create restoration goals for these sites.
9. Work with partners to develop a strategic planning effort to restore freshwater wetland and tidal brackish habitats in the Elkhorn Slough watershed. Share resources and lessons learned from other restoration projects that have been implemented.
10. Create strategies to secure long-term funding for the Tidal Wetland Project to both continue its efforts and expand the scope of the program. Currently, the entire project is completely dependent on grant funding.

<u>Priority Research, Monitoring, and Pilot Restoration Projects</u>

11. Evaluate marsh tidal inundation to find out if the tidal range, duration, and inundation frequencies are the primary mechanism for the spatial patterns of marsh loss. Studies are needed to determine if increased tidal inundation and/or poor drainage is causing anoxic conditions in subsurface marsh sediment resulting in plant dieback.
12. Expand sediment elevation table monitoring to include potential restoration sites and wetlands that receive muted tidal flows to understand sediment sources and if restoration projects involving sediment additions will be sustainable.
13. Quantify current sediment sources and quantities to determine if marsh restoration projects would be sustainable in the long-term. Field samples need to be collected to quantify suspended sediment loads in tidal waters and identify inputs from marine, terrestrial, and fluvial sources and lab analysis is required to characterize the source (Old Salinas River channel, Carneros Creek, Pajaro River, littoral drift).
14. Quantify historic sedimentation rates, sources, and vegetation patterns to determine the role of sediment and current patterns of marsh degradation and to better understand past habitat characteristics for Elkhorn Slough. Sediment coring and lab analysis is required to characterize the past sediment supply (episodic events, Salinas River, Pajaro River) and pollen analysis is needed to understand historic vegetation communities.
15. Expand the numeric model to include ecosystem components such as wetland and biogeochemical processes (i.e. also include the role of plants and infauna). Improve modeling of likely effects of predicted (maximum and minimum) sea-level rise to inform restoration strategies.

16. Use a hydrodynamic model to compare pre- and post-harbor conditions to inform large-scale restoration alternatives such as the potential for reducing habitat erosion and understanding past tidal range conditions.
17. Conduct pilot restoration experiments to test the feasibility of adding or retaining sediment behind temporary structures (earthen levees, sediment fences, etc.) as a method of restoring estuarine habitats.
18. Perform comprehensive research and monitoring studies of Elkhorn Slough's ecological communities over time (i.e. before, during, and after restoration projects).

<u>Community Involvement and Partnership Activities</u>

19. Develop additional opportunities for community members to learn about how human actions over time have affected Elkhorn Slough habitats and what is currently being done to address these problems.
20. Create opportunities for the public to educate decision-makers about community values and needs that should be taken into consideration for restoration decisions. An example of this type of activity could be stakeholder presentations to resource managers, agency staff, and scientists so they could learn more about Elkhorn community organizations and businesses.
21. Empower individuals to advocate on behalf of wetlands and to live, work and recreate in a manner that takes wetland conservation into consideration.

Future Development of the Elkhorn Slough Tidal Wetland Project

The coordination of the Tidal Wetland Project has always relied on grant funding, so future efforts should be focused on creating a more permanent institution with stable funding to oversee activities that will be ongoing for years to come. Currently, the Elkhorn Slough National Estuarine Research Reserve has led the Tidal Wetland Project initiative. In the future, this project would be strengthened by multi-institutional leadership, long-term funding, and oversight. Tidal Wetland Project members also need to discuss if the scope of their activities should expand over time to encompass issues beyond estuarine restoration projects, such as pollution, invasive species, and freshwater wetland restoration.

Maintaining and expanding partnerships and project teams are critical to implement and monitor estuarine habitat restoration projects in Elkhorn Slough. However, the structure and participation of Elkhorn Slough Tidal Wetland Project teams will change over time to adapt to restoration project needs. For example, as a Parsons Slough restoration project moves forward, an advisory group consisting of Strategic Planning Team and Science Panel members will be formed to guide restoration efforts conducted by consulting groups. Smaller working groups and project managers will continue to rely on the larger Strategic Planning Team to make major decisions and on the full Science Panel to offer technical recommendations and reviews of restoration components. It is expected that members of the project teams will likely change over time as the scope of activities shift to involve additional agencies that would grant permits or implement restoration activities. Community members will need to be more closely involved with the Tidal Wetland Project as specific restoration projects proceed.

Community involvement has been a major component of Tidal Wetland Project efforts to date (Appendices A and B). Increased input from community members will be needed so that human uses of the estuary can be represented in the restoration planning process. The input of these collaborative teams of scientists, resource managers, agency representatives, and key stakeholder groups will be extremely important during the implementation of restoration projects.

Chapter 5: Next Steps for the Elkhorn Slough Tidal Wetland Project

Although this plan summarizes past restoration planning decisions, broad restoration goals and strategies, current efforts, and recommendations about next steps, strategic planning for the Elkhorn Slough Tidal Wetland Project is ongoing. Future meeting results and products for the Tidal Wetland Project will be posted on the website to make this plan a "living" document.

APPENDICES

Appendix A. Description of the Tidal Wetland Project Planning Process

An organizational framework was developed for the Tidal Wetland Project teams including the Strategic Planning Team, Science Panel, Working Groups, and for Community Input (Figure 32).

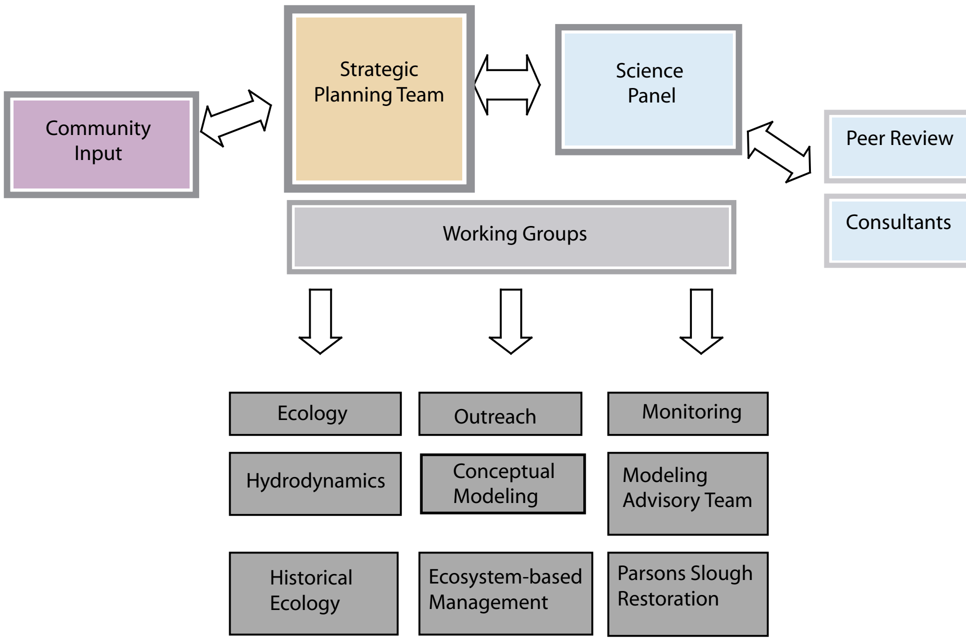


Figure 32. Diagram of Elkhorn Slough Tidal Wetland Project teams.

<u>Community Involvement</u>

Either a community forum or field tour has been hosted every six months of the planning process to bring Tidal Wetland Project-related information directly to the community and provide a venue for community members to share their observations about estuarine habitats. A contacts database has been created and updated that includes more than 850 people such as landowners, scientists, members of community organizations, and agency representatives interested in the conservation and restoration of Elkhorn Slough's estuarine habitats. Almost 300 of those contacts now receive monthly email updates about Tidal Wetland Project activities, and each month several new individuals request to be added to our email list. An additional 400 contacts receive mailed notifications of our upcoming forums and events. Several community forums and walking tours have been held to receive public input about potential restoration activities with approximately 120 attendees. Over 50 web pages accessible to the public have been developed about the Tidal Wetland Project with some outreach materials created for technical experts and others aimed at lay audiences. In addition, web forms are available for any members of the public to send in comments or questions at any time about the project.

<u>Key Project Milestones</u>

Twenty-four meetings of the collaborative Strategic Planning Team and Science Panel teams and community members have been held since 2004 involving hundreds of participants. Meeting agendas, summaries, and presentations are posted on the publicly accessible project website at http://www.elkhornslough.org/tidalwetlandproject as a record of discussions and decisions. A synopsis of the purpose and main outcomes of Tidal Wetland Project meetings can be found in Appendix B.

<u>Restoration Planning Framework</u>

The first step with any wetland restoration effort is to conduct a planning phase. The framework for the planning process was largely based on similar restoration planning efforts and National Oceanic and

Atmospheric Administration's guidance on approaches to coastal restoration (Diefenderfer et al. 2003). The framework for the planning phase consisted of four main steps with the final outcome being a plan that would guide the implementation of restoration projects in Elkhorn Slough. The Strategic Planning Team provided revisions to draft planning frameworks and adopted the process shown in Figure 33.

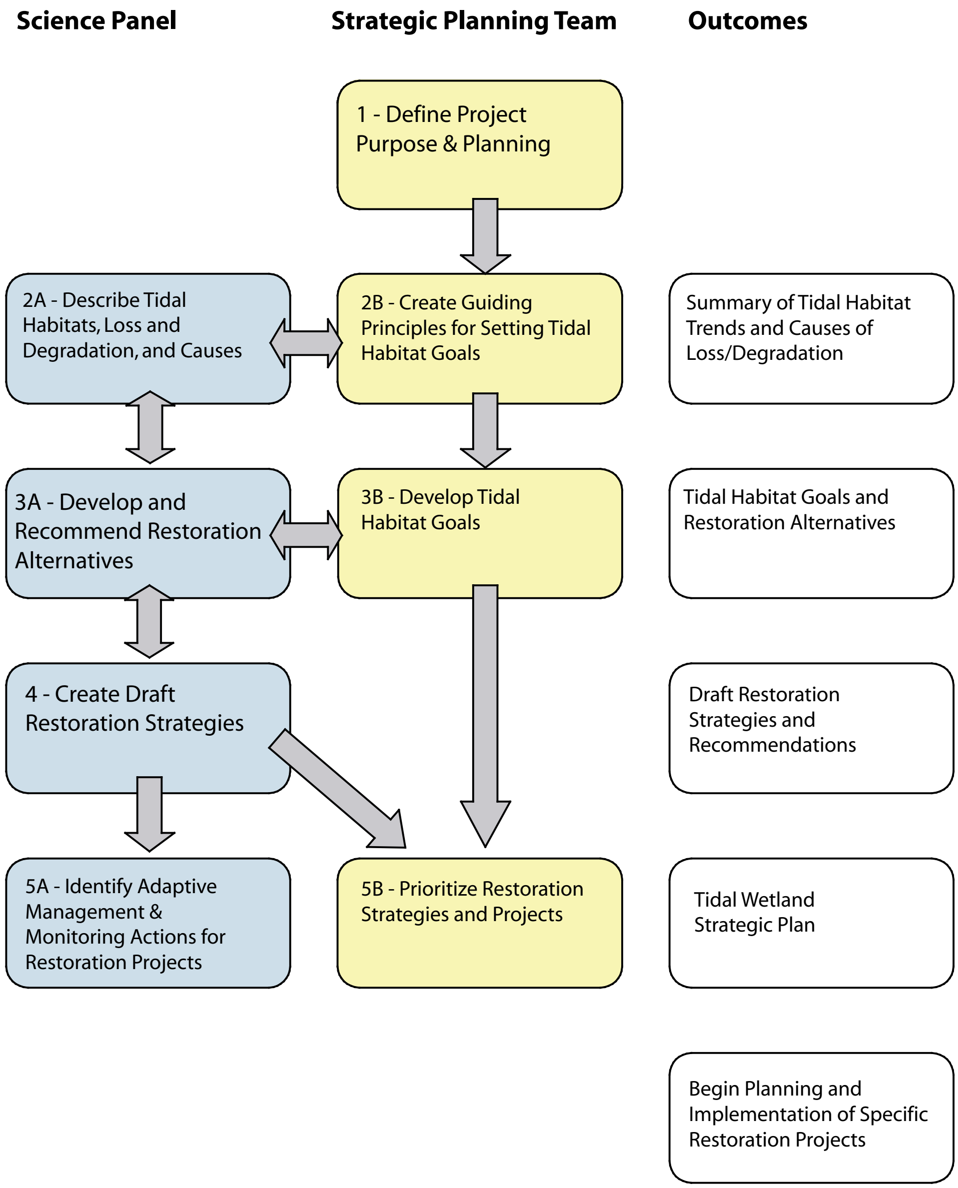


Figure 33. Elkhorn Slough Tidal Wetland Project restoration planning framework (2004).

<u>Developing the Vision, Goals, and Objectives for Estuarine Habitats and Planning Principles</u>
The main responsibility of the Strategic Planning Team (SPT) was to develop the vision, goals, and objectives for Elkhorn Slough estuarine habitats (See Chapter 1). The SPT has used consensus decision-making to find agreement during the restoration planning process. A document was created to outline the decision-making guidelines and provide alternatives to consensus if needed. Consensus agreement on a broad vision statement was a relatively straightforward process even with the diverse interests and agency missions of the SPT members. The vision statement placed importance on native estuarine communities because of the recognition that these ecosystems are ancient, rare, and historically and ecologically significant. The SPT also recognized that if the physical processes that support estuarine habitats were not in place, conservation and restoration efforts would not be successful. The third key component of the vision statement was the acknowledgment that healthy, sustainable estuarine habitats are valuable for people.

The SPT spent numerous hours deliberating the format of estuarine habitat goals and objectives. Many restoration planning efforts create maps or use percentages of habitats restored as goals. But unlike other systems, Elkhorn Slough is facing ongoing and rapid loss and degradation of estuarine habitats. Several team members compared what the estuary goals should be to an emergency triage situation – that the priority should be to investigate how to stop the hemorrhaging (continuing loss and degradation), implement those strategies, and then focus on other restoration efforts. Therefore, the idea of conserving existing habitats is a priority for Elkhorn Slough. The SPT decided that the goals and objectives should not be measurable at this time because it is currently unknown to what extent restoration efforts could stop or slow ongoing marsh loss and habitat erosion. Without further studies and analysis, setting quantified or spatial estuarine habitat goals was considered arbitrary.

During Tidal Wetland Project meetings, the SPT also discussed what time period could be used as a baseline for restoration efforts. The best maps and aerial photographs that show habitat type and extent dates back to 1870 and 1931, but neither date is considered a pristine condition for Elkhorn Slough because there were already many intensive human land uses in the watershed at that time. Also, researchers are just now embarking on more detailed investigations of historical habitat characterizations based on sediment core analysis. It is important to note that where the goals use the word "natural", the intention of the SPT is to aim for an estuarine habitat composition before major alterations by European colonists. The SPT recognized, however, that because the entire estuary has been altered so drastically and large-scale processes have changed so much, it is unlikely that future efforts can fully return Elkhorn to historic conditions.

The Science Panel also participated in the development of goals for Elkhorn Slough estuarine habitats. The discussions mostly focused on whether it would be better to develop habitat goals or physical process goals. Many restoration projects use habitat goals, but because the processes that support estuarine habitats have been so altered, the Science Panel and SPT agreed that both types of goals were needed.

The SPT had a number of additional questions while developing the goals and objectives. For example, how will restoration efforts in Elkhorn Slough take into consideration listed (rare, threatened, endangered) species, human uses, or sea-level rise? To address these topics, the SPT created planning principles that members would keep in mind during the planning and implementation of future restoration projects. The planning principles are intended to be used in coordination with the vision, goals, and objectives statements.

<u>Final Steps in the Planning Framework</u>

The final tasks in the planning framework (Figure 33) were to; (1) develop and make recommendations about restoration alternatives and strategies, (2) identify adaptive management and monitoring actions for restoration projects, and (3) prioritize restoration strategies and projects. These items have been discussed in greater depth previously in this plan. The majority of planning efforts during 2005 centered on developing and evaluating potential large-scale restoration alternatives for estuarine habitats with ongoing marsh loss and habitat erosion. In 2006, significant project time was devoted to following up on SPT and Science Panel recommendations to secure funding for a technical analysis of potential large-scale restoration alternatives and detailed restoration planning for Parsons Slough. It was decided that projects would be designed to be adaptively managed and specific monitoring activities would be developed for each project to maximize the positive outcomes. Monitoring activities would also assess each project's ability to meet overarching goals and objectives in addition to project specific outcomes. The final outcome of the planning phase is this *Tidal Wetland Strategic Plan* that will be used to guide the development and implementation of estuarine habitat restoration projects in Elkhorn Slough.

Appendix B. Key Project Milestones for the Tidal Wetland Project (2003-2006)

2003

Funding, National Oceanic and Atmospheric Administration's Coastal Impact Assistance Program grant to the California Department of Fish and Game and University of California-Santa Cruz, October 2003

Amount Awarded: $300,000
Grant Duration: October 2003 - February 2007
Grant Activities: Project activities focused on the hiring of a Tidal Wetland Project Coordinator, creation of management and technical project teams to guide restoration planning efforts, development of research summaries to assist wetland planning efforts, identification of and meeting with key stakeholders, and setting of restoration goals.

2004

Personnel, Hiring of Tidal Wetland Project Coordinator, April 2004

Teams, Creation of Strategic Planning Team and Science Panel, July 2004

Meeting, Strategic Planning Team, September 17, 2004
Purpose: Understand Elkhorn Slough habitat changes and discuss restoration planning.
Outcomes: Amended and adopted the structure of the decision-making team, planning process, and began discussing the overall project vision.

Meeting, Community, October 13, 2004 (morning)
Purpose: Launch the Elkhorn Slough Tidal Wetland Planning Process through a series of presentations.
Outcome: Awareness of Elkhorn Slough estuarine habitat loss and degradation over time and the new planning process that will help address the major impacts.

Meeting, Science Panel, October 13, 2004 (afternoon)
Purpose: Provide a critical review of the potential causes behind estuarine habitat and hydrological trends in Elkhorn Slough.
Outcomes: Creation of several Working Groups (Hydrodynamics, Historical Ecology, Ecological Characterization and Changes, Human Use and Socioeconomic Patterns, Conceptual Model, Groundwater, and Public Information) and tasks (i.e. summary documents) that each group could accomplish.

Meeting, Science Panel (Hydrodynamic Working Group), November 12, 2004
Purpose: Discuss how hydrodynamic models could help predict hydrological changes of potential restoration alternatives based on existing data.
Outcomes: Recommendations about strategies to incorporate bathymetric, sediment, and watershed data into a hydrodynamic model.

Meeting, Strategic Planning Team, November 18, 2004
Purpose: Revise the planning framework and select guiding principles to prioritize habitat goals.
Outcomes: Agreement on a consensus decision-making strategy, planning process framework, and public involvement.

Meeting, Science Panel (Historical Ecology Working Group), November 22, 2004
Purpose: Come to a shared understanding of past historical changes (interpretation of sediment cores and historical maps) in order to create a 1-5 page summary.
Outcomes: Evaluation of concepts for the historical ecology document.

Meeting, Science Panel (Ecological Characterization and Changes), November 22, 2004
Purpose: Create, revise, and review a document that characterizes key estuarine habitats and species (including threatened and endangered) and biological trends in Elkhorn Slough.
Outcomes: Revised estuarine habitat document.

2005
Meeting, Science Panel, January 6, 2005
Purpose: Come to an understanding of the key physical processes causing current changes to estuarine habitats (with an emphasis on habitat erosion in the main channel of Elkhorn Slough).
Outcomes: Agreement on key mechanisms of habitat erosion, decision about external review needs and strategies, list of recent causes of estuarine habitat change, and discussion about the range of options to predict outcomes of no-action scenarios.

Meeting, Strategic Planning Team, January 26, 2005
Purpose: Reach agreement on guiding principles and strategic planning tenets and discuss the next stages of the planning process.
Outcomes: Understanding of Science Panel draft summaries, agreement on guiding principles and planning tenets, and creation of draft habitat goals and large-scale alternatives.

Meeting, Joint Science Panel and Strategic Planning Team (Field Trip), March 4, 2005
Purpose: Discuss the major changes to biological communities and alterations at each site and potential opportunities to restore or enhance both natural processes and habitat functions.
Outcomes: Shared understanding of past changes and recent estuarine habitat trends and ideas about possible conservation and restoration actions.

Meeting, Community (Friends of Moss Landing Public Seminar), March 9, 2005
Purpose: Provide information about historic changes and research of Elkhorn Slough tidal wetlands through a series of presentations.
Outcome: Enhanced public awareness about Elkhorn Slough estuarine habitat loss and degradation over time and how past changes and current research are vital in guiding conservation and restoration efforts.

Meeting, Joint Science Panel and Strategic Planning Team, April 13, 2005
Purpose: Characterize the likely future trends for habitats (unrestricted tidal flow) in the Elkhorn Slough watershed for a no action management alternative and discuss potential large-scale alternatives to reverse undesirable trends.
Outcomes: Consensus statements predicting likely future trends for channel, mudflat, and salt marsh/tidal creek habitats, discussion that justifies the need to reverse the current trends, and a list of potential large-scale alternatives to reverse undesirable trends.

Meeting, Strategic Planning Team, May 5, 2005
Purpose: Come to consensus on a vision statement and create a draft list of broad goals for estuarine habitats in the Elkhorn Slough watershed.
Outcomes: Consensus agreement on a vision statement, draft list of project goals, and statement that the 50-year habitat trends are not acceptable and therefore a no-action alternative is not an acceptable course of action.

Major Decision, Strategic Planning Team Consensus Statement that the 50-year habitat trends are not acceptable and therefore a no-action alternative is not an acceptable course of action for Elkhorn Slough, May 5, 2005

Major Decision, Joint Science Panel and Strategic Planning Team Consensus Statement on 50-year Estuarine Habitat Predictions, May 16, 2005

Meeting, Joint Science Panel and Strategic Planning Team, June 8, 2005
Purpose: Discuss the feasibility of potential large-scale restoration alternatives to reverse undesirable estuarine habitat trends.
Outcomes: Refined list of potential large-scale restoration alternatives that would reduce estuarine habitat loss and degradation and preliminary evaluation of how each potential alternative could slow, stop, or reverse each estuarine habitat trend.

Meeting, Strategic Planning Team, July 18, 2005
Purpose: Come to consensus on vision, goals, and guiding principles statements for estuarine habitats in the Elkhorn Slough watershed.
Outcomes: Consensus agreement on vision, goals, and guiding principles statements.

Major Decision, Strategic Planning Team Consensus Statement on Tidal Wetland Project Vision, Goals, Objectives, and Strategic Planning Principles, July 29, 2005

Meeting, Joint Science Panel and Strategic Planning Team, August 9, 2005
Purpose: Predict water quality trends and discuss potential restoration alternatives.
Outcomes: Draft statements predicting likely water quality trends for selected potential management alternatives (including no action) and identification of potential restoration projects that could be initiated soon.

Meeting, Joint Science Panel and Strategic Planning Team, September 28, 2005
Purpose: Discuss and narrow down the list of potential restoration alternatives based on technical evaluations and items needed to further evaluate combinations.
Outcomes: Revised list of combinations of potential restoration alternatives, identification of what is needed to evaluate selected combinations, and prioritization of project funding needs.

2006
Funding, David and Lucile Packard Foundation and Resources Legacy Fund Foundation, January 2006
Amount Awarded: $1,200,000
Grant Activities: Project activities center on the evaluation of large-scale restoration alternatives using an ecosystem-based management (EBM) approach. The analysis of options to conserve and restore Elkhorn Slough estuarine habitats will include predictions about changes to tidal hydrodynamics, morphology, estuarine habitats and species, water quality, socioeconomic values, and political constraints. The main result of this project will be agreement by Tidal Wetland Project teams about preferred restoration strategies that are science-based, politically and economically feasible, and supported by the community in the long-term.
Grant Duration: January 2006 – January 2009

Meeting, Strategic Planning Team, January 23, 2006
Purpose: Make decisions to guide the next three years of strategic planning for Elkhorn Slough tidal wetland restoration and conservation activities.
Outcomes: Agreement about whether to proceed with Parsons Slough restoration planning, discussion about long-term strategies to evaluate large-scale restoration and conservation alternatives, and draft timeline of project efforts for 2006-2011.

Major Decision, Strategic Planning Team Consensus Statement, January 23, 2006
Consensus decision to obtain funding for Parsons Slough restoration planning. Decision about project priorities (time/funding allocation) for the next few years - creating detailed descriptions and evaluating large-scale conservation and restoration alternatives (45% effort), planning a Parsons Slough restoration project (45% effort), and conducting restoration experiments and research and monitoring (10% effort).

Meeting, Joint Science Panel and Strategic Planning Team, February 22, 2006
Purpose: Understand the characteristics of estuarine habitat areas that receive varying levels of tidal exchange and identify areas of certainty and uncertainty regarding mechanisms of tidal marsh loss.
Outcomes: Enhanced knowledge about the characteristics of estuarine habitats behind water control structures, reviewed summaries of wetland management histories, and revised conceptual model of tidal marsh loss in Elkhorn Slough.

Meeting, Joint Science Panel and Strategic Planning Team, April 4, 2006
Purpose: Expert review of interior marsh loss mechanisms and potential estuarine habitat conservation and restoration alternatives and identification of priority research and monitoring projects that would help with tidal wetland restoration planning and implementation efforts.
Outcomes: Better understanding of tidal marsh dynamics, international marsh restoration efforts, and interior marsh loss mechanisms. Prioritized list of research and monitoring projects to inform tidal wetland planning and/or restoration efforts.

Major Decision, Joint Science Panel and Strategic Planning Team Document, Priority Projects to Inform Restoration Planning and Implementation, April 4, 2006

Meeting, Community (Forum), April 26, 2006
Purpose: Provide information through presentations about the major impacts to Elkhorn Slough estuarine habitats and discuss potential efforts to conserve and restore these habitats.

Outcome: Enhanced public awareness about estuarine habitats, loss and degradation of these habitats, the Elkhorn Slough Tidal Wetland Project, and the role of community input in future efforts.

Meeting, Joint Science Panel and Strategic Planning Team, August 2, 2006
Purpose: Discuss and recommend potential restoration strategies for tidal wetlands behind water control structures.
Outcomes: Shared understanding of the management history and characteristics of tidal wetlands behind water control structures and revised draft restoration strategies for specific tidal wetland areas behind water control structures.

Meeting, Community (Walking Tour), December 2, 2006
Purpose: Observe and learn about marsh loss and bank erosion in Elkhorn Slough.
Outcome: Enhanced public awareness about estuarine habitat loss and degradation and the Elkhorn Slough Tidal Wetland Project which is striving to conserve and restore these habitats.

Funding, Environmental Protection Agency's Wetlands Protection Development Grant and State Coastal Conservancy Grant, November 2006
Amount Awarded: $250,000
Grant Duration: November 1, 2006 - March 31, 2009
Grant Activities: The main project purpose is the development of a *Parsons Slough Wetland Restoration Plan*. Project activities will include the evaluation of tidal marsh restoration alternatives for Parsons Slough including actions to reduce the tidal prism and/or add sediment to rebuild marsh elevations.

Meeting, Science Panel and Strategic Planning Team, December 8, 2006
Purpose: Understand project progress on the evaluation of potential outcomes of several large-scale restoration alternatives compared with the outcome of a "no action" alternative and meet newly hired consultant team.
Outcome: Knowledge about the evaluations of restoration alternatives that will be accomplished over the next few years that will result in a Science Panel recommendation and Strategic Planning Team decision about whether to move forward with system-wide conservation strategies for Elkhorn Slough.

Appendix C. Past and Current Management of Selected Tidal Wetland Sites

Maps and photographs of wetland sites can be found at http://www.elkhornslough.org/tidalwetlandproject.

Site 1. Parsons Slough/South Marsh Complex

Acreage/Location

The Parsons Slough/South Marsh Complex (including Five Fingers) is located on the southeastern area of Elkhorn Slough. The entire complex is approximately 429 acres (174 hectares) in size and the main areas are dominated by mudflat areas with some subtidal creeks, fringing tidal marsh, and created tidal marsh islands.

Past Human Activities (Modifications/Restoration/Management)

In the past, the Parsons Slough/South Marsh Complex was dominated by tidal salt marsh and tidal creeks. In 1872, a railroad was built along the western side of this area and this railroad embankment blocked off the connections of about half a dozen tidal creeks. Railroad bridges were constructed over two of the main tidal creeks (mouth of Parsons Slough and just south of Hummingbird Island) allowing these connections to remain open. In 1902, a group of San Francisco businessmen purchased the land of South Marsh and started the Empire Gun Club. By 1913, this group created a number of large, artificial freshwater ponds (converted from tidal marsh) in the South Marsh area using earthen dams to enclose the areas and pipes to convey water from freshwater springs for the purpose of encouraging waterfowl prized for hunting. A few large, artificial freshwater ponds had also been created in Parsons Slough for duck hunting by 1913. One of these large ponds was created by blocking off four of the six fingers of Parsons Slough with an earthen dam.

In the 1920s, J. Henry Meyer purchased the South Marsh property and the Elkhorn Dairy was established. By 1956, the entirety of South Marsh was enclosed with large levees, cleared, leveled, and drained, converting the tidal marsh and duck ponds to pastureland for dairy cattle. This diking blocked one of the two remaining tidal creeks to South Marsh just south of Hummingbird Island and separated South Marsh from Parsons Slough (except for 1-2 areas in the levees that look like they may have had some sort of water control structures that could have been used as drainage during heavy rain events). Another levee, constructed across the mouth of Parsons Slough between 1949 and 1956, completely removed the remaining major tidal creek and marsh areas from tidal exchange. This levee may also have contained some sort of water control structure such as a flap gate that could have been used to facilitate drainage of water out to the main slough during this time. The draining of the tidal marsh areas in the Parsons Slough/South Marsh Complex between 1931 and 1956 caused the marsh sediment to dry out, compact, decompose, and subside by several feet. Between 1956 and 1980, a levee breach opened four of the six fingers of Parsons Slough and allowed flood waters to drain into Parsons and the main slough.

In 1980, part of Elkhorn Slough (including the majority of the Parsons Slough/South Marsh Complex) was purchased and designated as a National Estuarine Sanctuary. The Elkhorn Slough National Estuarine Research Reserve (Reserve), as it is now known, is one of a network of 27 protected areas nationwide that were established for long-term research, education and stewardship through federal-state partnerships. The Reserve is owned and managed by the California Department of Fish and Game (CA DFG) in partnership with the National Oceanic and Atmospheric Administration (NOAA).

Soon after the Reserve was designated, planning efforts were started with the purpose of returning the grazing land of South Marsh to wetland. The proposed plan consisted of creating four experimental tidal salt marsh (including tidal creeks, mudflats, and islands) areas at two different scales behind levees and dams (that could be manipulated), two smaller freshwater wetlands, and causeways for public access on 50 acres. Sediment would have to be excavated to create the tidal creeks and built up (with gradual slopes) to create vegetated, tidal marsh. In order to restore tidal exchange to the salt marsh areas, it was proposed that the Parsons Slough-South Marsh levee (just north of the Parsons Mouth levee) would be breached. This wetland plan was submitted for permit approval in 1981.

During winter of 1982-1983, the Parsons Mouth levee breached during a storm event allowing tidal waters to enter both South Marsh and Parsons Slough. There was an attempt to curb the flooding, but the currents were too strong. Even though some of the earthwork had already started in the South Marsh project site, the preparations had to be delayed and eventually when conditions allowed, water was pumped out to finish construction work. During this time, the proposed project plans were changed to a series of straight channels and habitat islands (as we see today) that would receive tidal exchange (changing the focus of this project from more of a replicated experimental approach to a wetland enhancement approach). During the spring and summer of 1983, these new proposed plans were resubmitted for permit approval (as amendments), went out for bid, and channel and island construction began. In the fall of 1983, the Parsons Slough-South Marsh levee was breached restoring tidal exchange to this area. Since that time, pickleweed established on the tops of the islands and small-scale plantings were done in the high marsh areas of South Marsh. Bank erosion has significantly decreased the width and length of these habitat islands since they were first constructed.

Because of severe land subsidence that occurred during the years that the wetland was drained and used as pasture, the average land elevation in the Parsons Slough/South Marsh Complex is now approximately 2.4 feet (0.7 meters) below what can support marsh vegetation. Apart from a few constructed tidal marsh islands and fringes of tidal marsh adjacent to upland areas, this land elevation currently supports mudflat habitat.

Current Management/Ownership

The majority of the Parsons Slough/South Marsh Complex (except for a few tips of Five Fingers) is owned and managed by the California Department of Fish and Game as part of the Elkhorn Slough National Estuarine Research Reserve in partnership with NOAA.

Site 2. North/Estrada Marsh Complex

Acreage/Location

The North/Estrada Marsh Complex is located on eastern side of Elkhorn Slough. This marsh complex is separated from the main system by a railroad embankment and tide gates. North Marsh, approximately 124 acres (50 hectares), is dominated by a mix of open water, mudflat, and fringing salt marsh habitat that is currently managed with a muted tidal range through the use of tide gates. Estrada Marsh, approximately 46 acres (19 hectares), is covered mostly with pickleweed and open mud pannes. North Strawberry Marsh is approximately 8 acres (3 hectares) and South Strawberry Marsh is approximately 5 acres (2 hectares).

Past Human Activities (Modifications/Restoration/Management)

In 1869, Elkhorn Road was constructed on the east side of North/Estrada Marsh Complex, and it, at least minimally, reduced tidal exchange into Campagna and Strawberry Marshes.
A railroad, built in 1872 along the west side of North/Estrada Marsh Complex, blocked three of the four tidal creek connections (one to Estrada Marsh, three to North Marsh) from the main channel of Elkhorn Slough. The remaining tidal creek opening is under a railroad bridge with an open trestle.

In 1902, the Empire Gun Club purchased the land of the North/Estrada Marsh Complex. By 1913, this group created a number of large, artificial freshwater ponds (converted from tidal marsh) in the North/Estrada Marsh Complex using earthen dams to enclose areas and pipes to convey water from freshwater springs for the purpose of encouraging waterfowl prized for hunting. Between 1913 and 1931, landowners removed the southern half of North Marsh from tidal exchange by enclosing it with large levees so it could be drained. A levee was built separating Estrada Marsh from North Marsh between 1937 and 1949. By 1956, the entire North/Estrada Marsh Complex (including North and South Strawberry and Campagna Marshes) was removed from tidal exchange by a series of levees. One of these levees (with a horseshoeshape) blocked off the remaining large tidal creek connection from the main Elkhorn Slough system. This levee may have contained a water control structure such as a flap gate that allowed freshwater to enter Elkhorn Slough during flood events, but did not allow tidal waters to enter this area. The draining of the tidal marsh areas during this time caused the marsh sediment to dry out, compact, decompose, and subside by, on average, 1.9 feet (0.6 meters).

The California Department of Fish and Game acquired North Marsh in 1980 and Estrada Marsh in 1993 as part of the Elkhorn Slough National Estuarine Research Reserve. Soon after the Reserve was designated, CDFG managers began discussing the possibility of restoring tidal flow to 124 acres (50 hectares) of reclaimed North Marsh lands to enhance habitat by excavating tidal creeks, creating habitat islands, and grading to add topographic features. The plan was to have the maximum tidal inundation possible without flooding Elkhorn Road to the east by adding tide gates to the previously blocked culverts in the horseshoe-shaped levee by the railroad bridge. During major storms in December of 1982, the horseshoe-shaped levee failed causing Elkhorn Road to flood. Monterey County then raised the road in 1985 to mitigate the effects of flooding. That same year, contractors were hired to replace the failing water control structures. Once this work was completed, tidal action was returned in the summer of 1986, through four new tide gates.

Like many structures used in marsh management, the North Marsh levee and tide gates have required a great deal of maintenance, repair, and continued, intensive management over the years. Repairs have included the rebuilding of the main levee after a washout in the early 1990s; the replacement of several rusted tide gate stems; and repair to gate hinges. Maintenance has included the annual placement of several tons of sandbags on top of the levee to prevent overtopping by extreme high tides; the building up of levee elevation using dirt and large riprap; annual cleaning of gate flaps and removal of fallen riprap by SCUBA divers; and monthly maintenance of all tide gate stems. Ongoing management involves the opening and closing of tide gates to adjust water levels.

The earthen levee separating North Marsh and Estrada Marsh partially eroded in the summer of 2003, resulting in a narrow creek (approximately 1 m wide) between the two wetlands. This creek has restored a minimal amount of tidal flow to Estrada, but it is currently too small to allow for full tidal exchange. Currently, tidal flow enters Estrada, but does not appear to drain. Instead, ponded tidal water evaporates over the summer months, resulting in seasonally hypersaline conditions throughout much of the Estrada marsh.

Current Management/Ownership

North Marsh is owned and managed by the California Department of Fish and Game as part of the Elkhorn Slough National Estuarine Research Reserve in partnership with NOAA. Estrada Marsh is also owned and managed by the California Department of Fish and Game, but is not part of the Reserve system.

Site 3. Azevedo Marsh Complex

Acreage/Location

The Azevedo Marsh Complex is located on the eastern side of Elkhorn Slough, approximately 4.5 miles from the mouth. These marshes are named Northern Azevedo Pond (12.2 acres), Middle Azevedo Pond (6.3 acres), and Southern Azevedo Pond (2.3 acres). In some reports, the Northern Azevedo Pond (NAP) is further divided into north and south sections.

Past Human Activities (Modifications/Restoration/Management)

The Azevedo Marshes are separated from the main system by a railroad embankment (built in 1872). There are openings under the railroad embankment that contain four wooden box culverts (three contain 8-15 inch diameter pipes) located in Northern Azevedo Pond-North site, Northern Azevedo Pond-South site, Middle Azevedo Pond, and Southern Azevedo Pond.

There is also an earthen, horseshoe-shaped levee on the east side of the railroad culverts at the NAP North site (which seems ready to fail and is definitely overtopped at high tide). It is likely that the levees were built to prevent tidal inundation to farmland after the Harbor mouth was constructed and to provide greater control of freshwater drainage.

The 135-acre (55-hectare) Azevedo Agriculture and Natural Resource Site was purchased in 1991 by the Monterey County Agricultural and Historic Lands Conservancy (MCAHLC) and The Nature Conservancy (TNC) through a State Coastal Conservancy (SCC) grant (included both wetlands and uplands). The reason for this acquisition was to protect agricultural and natural resources on the site by developing a working farm and research site to evaluate methods to reduce impacts from agriculture on resources areas in a cost effective and practical manner. Agricultural use was pulled back from the edges of these pocket marshes for the establishment of 100-ft wide vegetated buffers strips from 1994 to 1995. Since the 1990's, sediment basins and other erosion control improvements have been installed at the Azevedo sites and continue to be installed as needed. In 1993 an *Enhancement Plan for the Azevedo Marshes: Hydrologic Elements* report was prepared by Robert Coats of Philip Williams & Associates, Ltd. for The Nature Conservancy. Then, in February 2000, an *Azevedo Agricultural and Natural Resource Site Management Plan* for the MCAHLC and SCC (in cooperation with TNC and the Elkhorn Slough Foundation) was prepared by Laurel Marcus and Associates. These plans recommended wetland enhancement activities for Northern and Southern Azevedo Ponds, and that a plan for these activities would be developed.

<u>Current Management/Ownership</u>

TNC owns the Azevedo Marsh Complex (21 acres/9 hectares). TNC and MCAHLC jointly own the adjacent upland areas (114 acres/45 hectares). TNC's lands are managed by ESF.

ESF, with approval from TNC, is currently funded (by the State Coastal Conservancy from Port of Santa Cruz Mitigation and Proposition 50 funds) to restore and enhance Azevedo North and South Azevedo Marshes. The wetland enhancement project aims to reduce tidal erosion and conserve/create marsh habitat. The project plans have been permitted and the implementation of the proposed wetland enhancement and restoration activities will likely be completed by spring 2008.

Site 4. Blohm-Porter Marsh Complex

<u>Acreage/Location</u>

The Blohm-Porter Marsh Complex, located at the head of Elkhorn Slough, is approximately 246 acres (100 hectares) between Elkhorn Road and Blohm Road.

<u>Past Human Activities (Modifications/Restoration/Management)</u>

A railroad embankment and bridge was built in 1872 between the Blohm-Porter Marsh Complex and the main channel of Elkhorn Slough. A wooden bridge, constructed in the past to permit passage over the Blohm-Porter Marsh Complex, allowed tidal and freshwater exchange.

Cattle have grazed parts of the Blohm-Porter Marsh Complex since the mid 1800's. In the 1940s, a large earthen dam was constructed at the southern end of this area for the purpose of impounding freshwater and restricting tidal inundation to the northern areas. Around the same time, it was observed that water tables were being lowered by land use which reduced the flow and presence of freshwater springs and altered surface flows from Carneros Creek.

The construction of the Harbor in 1947 increased tidal inundation to the Blohm-Porter Marsh Complex. Around 1951, a linear section of Blohm-Porter Marsh was filled for the construction of Elkhorn Road for its present-day alignment creating a permanent berm that obstructed tidal water exchange. Culverts and flap gates were purchased by the Moss Landing Harbor District Commission and installed by Monterey County under the road to allow one-way flow from Blohm-Porter Marsh to Elkhorn Slough. In the early 1980s, Monterey County performed maintenance work on this berm to build up the road and also likely repaired the water control structure. The 1989 earthquake destroyed the flap gates and caused the road to subside. From 1989 to 1995, tidal waters regularly flooded the Blohm-Porter Marsh Complex (beyond the extent that received tidal inundation just prior to the Harbor construction in 1947). In 1996, Monterey County Public Works installed new culverts and flap gates under Elkhorn Road with state and federal funding.

Current Management/Ownership

Monterey County is responsible for maintaining Elkhorn Road and associated culverts. The Nature Conservancy owns and the Elkhorn Slough Foundation (ESF) manages the majority, 159 acres (64 hectares), of the Blohm-Porter Marsh Complex. ESF also holds a conservation easement on 35 acres (14 hectares) in this area. Fifty-two acres (21 hectares) of Blohm-Porter Marsh are not under any conservation protection. In the past few years, Mosquito Abatement has periodically cleared the flap gates of debris and non-native tubeworm reefs to keep the flap gates functional to reduce mosquito populations.

Site 5. Bennett Slough/Struve Pond Marsh Complex

Acreage/Location

The Bennett Slough/Struve Pond Marsh Complex is located northeast of the mouth of Elkhorn Slough. The entire complex is approximately 140 acres (57 hectares) in size and includes the old Elkhorn Slough mouth area north of Jetty Road, Bennett Slough (around the Salt Ponds), Bennett Ponds, and Struve Pond. The main areas are dominated by tidal mudflats, salt marsh, and tidal creeks and also contain tidal brackish marsh and freshwater ponds.

Past Human Activities (Modifications/Restoration/Management)

Prior to the 1850s, the Bennett Slough channel meandered around 216 acres (87 hectares) of tidal wetlands (today's western Salt Ponds) connecting to the main Elkhorn Slough channel near the old mouth and about a half mile east of the coast highway crossing. Before the 1860s, the coast highway crossed northwest Bennett Slough with a bridge. Around 1890, a narrow gauge railroad embankment and bridge was constructed between Bennett Slough and the old Elkhorn Slough mouth and was used until 1929. By 1914, an access road was constructed through the salt marsh in today's western Salt Ponds. The Monterey Bay Salt Works company constructed earthen levees to dike and drain hundreds of acres of tidal marsh by 1931. These levees blocked off the main eastern connection of the Bennett Slough channel. During the same time, levees were also constructed blocking the tidal creek and marshes in Bennett Slough's northeastern edges (currently referred to as Bennett Ponds) and northern channel, and to north of Bennett Slough (creating ponds). The coast highway was also reconfigured by 1931 and road embankments with culverts were built between Bennett Slough and Struve Pond and on the western edge of Bennett Slough which decreased the tidal influence to these areas.

The construction of the Moss Landing Harbor in 1947 rerouted the Elkhorn Slough mouth to the south causing the old mouth connection to Monterey Bay to close by 1956. The construction of the Jetty Road embankment and culvert, built during this same time, also reduced tidal flow to Bennett Slough. Before 1956, an earthen levee was constructed in Struve Pond by landowners to convert this area to a freshwater pond for hunting purposes. This levee reduced tidal exchange to the northern section of Struve Pond. The endangered Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*) probably started to breed in Struve Pond and the northern section of Bennett Slough in the 1950s and consisted of hundreds of individuals in the 1970s (U.S. Fish and Wildlife Service 1999). In addition, during a survey at Struve Pond in March 2006, staff at the National Estuarine Research Reserve observed salinity levels of 5-6 ppt in the main pond, and salinity levels of 1-3 ppt in small shallow areas at the edge of the main pond (Wasson and D'Amore, unpublished data). The endangered tidewater goby has now been found in Struve Pond. Increased salinity levels in Struve Pond were found in mid-1980s which could have been caused by levee breaches during winter storms near the Salt Ponds (Rainey 1985).

The 1989 earthquake caused Jetty Road to collapse which temporarily increased tidal exchange to Bennett Slough. In 1990 a *Restoration Plan for Gibson's Landing Marsh and Lower Bennett Slough* was prepared by Robert Coats of Philip Williams & Associates, Ltd. recommending a four-culvert design under Jetty Road and a flap gate in the culvert under Highway 1. California State Parks applied for permits with a project proposal to repair the road and install four culverts with two tide gates (to reduce inundation time of vegetated areas) under Jetty Road to replace the single culvert in order to reestablish public access and enhance tidal action in Gibson's Landing Marsh (area north of Jetty Road) and Bennett Slough. The California Coastal Commission required a six-culvert design as part of the permit conditions (3-90-104) and California State Parks completed the project in the fall of 1991 and replaced the single culvert with a six-culvert system to make the tidal exchange greater than the 1947-1989 conditions.

Due to this change, Struve Pond is currently converting back to tidal brackish habitat rather than the freshwater conditions that existed there from the 1940s to 1980s. According to the 1999 *Santa Cruz Long-Toed Salamander Draft Revised Recovery Plan*, this endangered species has not been found in these lower Bennett Slough areas since 1985 likely due to increased salinity levels. The endangered tidewater goby has now been found in Struve Pond in recent research activities by staff at the National Estuarine Research Reserve. The wetland area north of Jetty road may be currently experiencing marsh loss from increased inundation and tidal erosion since 1991.

Current Management/Ownership

Jetty Road and the associated culverts are owned and managed by California State Parks. The area north of Jetty Road is owned primarily by the Moss Landing Harbor District and also by State Parks and private landowners. Most of the Bennett Slough area is owned and managed by California Department of Fish and Game as part of the Moss Landing Wildlife Area. Struve and Bennett Ponds are privately owned and managed. The Nature Conservancy has an easement on a portion of Struve Pond because of the endangered Santa Cruz long-toed salamander. The culverts under Highway 1 are maintained by the California Transportation Department (Caltrans).

Appendix D. Major Human Impacts to Estuarine Habitats in Elkhorn Slough

Year(s)	Selected Major Human Modifications
1860s and 1870s	Beginning of railroad and road construction (levees and bridges built in marshlands) reducing tidal connections
	Land clearing increasing sediment inputs
1900s	Significant wetland diking/draining for agriculture causing estuarine habitat loss and subsidence
	Dams and levees built for waterfowl hunting causing habitat conversion
c. 1909	Salinas River diverted likely reducing significant sediment and freshwater inputs into Elkhorn Slough
1930s	Groundwater overdraft/seawater intrusion first documented in the region reducing freshwater inputs into Elkhorn Slough
	Dams, culverts, tide gates constructed causing habitat loss and fragmentation
1940s	Agricultural changes decreasing groundwater inputs to estuarine habitats
1947	Moss Landing Harbor constructed creating a much deeper and permanently open tidal connection between Elkhorn Slough and Monterey Bay in a different location contributing to estuarine habitat loss and degradation
1980s	Conservation efforts to change land use practices decreasing polluted runoff to estuarine habitats
1981-1983	Levee breaches from wetland restoration efforts (South Marsh), winter storms (Parsons Slough), and habitat erosion (ongoing) accelerating marsh loss and estuarine habitat degradation

Appendix E. Summary of Biological Indicators and Water Quality Conditions for Tidal Wetland Sites behind Water Control Structures (K. Wasson, unpublished data). The numbers in bold indicate potential opportunities to improve the conditions of these estuarine habitats.

Summary of Ecological Indicators of Tidal Restriction (August 1, 2006)								
site	**tidal range**	**salinity max** (ppt)	**nitrate max** (mg/L as NO3)	**number of native species**			**species of concern**	percent of 1931 **marsh** extent
				birds	**fish**	**inverts**		
North Marsh	4.5	**59**	**13**	10	5	6	Brown pelican	53
Estrada Marsh	**0.5**				4			72
Strawberry North Lagoon	**1.5**				4			37
Whistlestop Lagoon	16	36	6	4	8	7	Sea otter, Olympia oyster	
Hidden Pond	22.5			0	5	3		
South Azevedo	**0**	**55**	**12**	1	5	3	Tryonia snail	83
Middle Azevedo	**0**	**85**	8	3	4	1		65
North Azevedo	46	37	5	2		9	Olympia oyster	61
Porter Marsh	**0.5**	35	**90**	4	2	4	Tryonia snail	
Lower Moro Cojo	6	34	**37**	5	4	3	Tidewater goby, Tryonia snail	
Moro Cojo Railroad	**0**			1		0		
Struve Pond	**1**	**56**	**18**	3	4	2	Tidewater goby, Tryonia snail	29
Old Mouth (lower Bennett)	44	35	10	4	6	7	Sea otter, Brown pelican	
Packard Pond	**0**				4			
Average from adjacent full exchange sites	*100*	*35*	*30*	*6.2*	*4.6*	*8.6*	*Sea otter, Brown pelican, Olympia oyster, Tryonia snail*	
	potential concern if <2%	potential concern if >50 ppt	potential concern if >10 mg/L					
tidal range: as measured by ESNERR staff at various sites on Dec 12, 2005, a spring tide (true range is likely to vary somewhat from this value); expressed as % of full exchange (obtained from SWMP & LOBO data)								
salinity and nitrate max: annual maximum averaged over past 5 years from ESNERR monthly volunteer monitoring program								
marsh: % of 1931 marsh aerial extent (salt, brackish and freshwater marsh with >25% cover combined), present in 2003								
number of species: from survey by ESNERR staff in 2005; numbers are result of rapid assessment, not comprehensive site surveys; search effort was consistent across these sites and adjacent, shallow full exchange sites								
blanks in all cases mean no data were available for this parameter								

Appendix F. Evaluating Large-Scale Restoration Alternatives using Ecosystem-based Management

The Tidal Wetland Project is supported by multiple grants, however funding from the David and Lucile Packard Foundation and Resources Legacy Fund Foundation in January 2006 is targeted at the evaluation of large-scale restoration alternatives using an ecosystem-based management approach. The analysis of options to conserve and restore Elkhorn Slough estuarine habitats will include predictions about changes to estuarine hydrodynamics, morphology, habitats and species, water quality, socioeconomic values, and political constraints. The final outcome of this project will be the selection by Tidal Wetland Project teams of preferred restoration strategies that are science-based, politically and economically feasible, and supported by the community in the long-term. The specific project activities are highlighted below.

Development of Strategies to Predict Tidal Hydrodynamics and Sediment Changes
A consulting team, headed by Philip Williams and Associates, Ltd., will make quantitative predictions about changes to the tidal hydrodynamics, geomorphology, and estuarine habitats for the different restoration alternatives. Preliminary designs and rough estimates of the costs of restoration strategies will also be developed.

Interactions of Nutrient Dynamics
Monterey Bay Aquarium Research Institute (MBARI) senior scientist Ken Johnson will lead efforts to examine interactions of nitrogen dynamics with changes to tidal hydrology predicted for different restoration scenarios.

Responses of Biological Indicators
Elkhorn Slough National Estuarine Research Reserve (ESNERR) research coordinator Kerstin Wasson and collaborators will predict the responses of key species to the various restoration alternatives using the predicted changes to estuarine habitats and nutrient conditions.

Estimates of Economic Values and Analysis of Legal and Political Context
MBARI social scientist Judith Kildow and collaborators will analyze the socioeconomic values of Elkhorn Slough and evaluate how restoration alternatives will affect human uses. Kildow and her team will also conduct an analysis of the political feasibility of selected options based on case studies and the analysis of relevant laws and regulations.

Interactions of Wetland Elevation, Tidal Hydrology, and Sediment on Marsh Habitats
ESNERR geographical ecologist Eric Van Dyke and consultants will examine marsh sustainability and degradation by studying the role of elevation, tidal hydrology, and sediment. Tide stations and sediment elevation tables will be installed and monitored.

Continuation and Expansion of the Tidal Wetland Planning Process
The Tidal Wetland Project planning process will continue to bring together over a hundred resource managers, community members, and scientific experts to address habitat erosion and marsh loss. It will be expanded to incorporate new findings into its decision-making framework. Tidal Wetland Project staff will also create an organizational structure that sustains a collaborative group to oversee restoration projects and enhance the involvement of key stakeholders.

Appendix G. Priority Projects to Inform Restoration Planning and Implementation

The main criteria used by the Science Panel and Strategic Planning Team for prioritizing projects was how much the project would help with decision-making about estuarine habitat restoration planning and/or implementation efforts. The top 10 priority projects are underlined below.

A. Are increases in tidal inundation the primary cause of interior marsh loss and degradation?
Project: Evaluate marsh tidal hydrology and inundation. *Purpose:* Find out if the tidal range, duration, and inundation frequencies are the primary mechanism for the spatial patterns of marsh loss. *Funded:* ESNERR will install secondary tide stations. *Unfunded:* Studies to determine if (a) Marsh surface drainage is inhibited in some areas causing marsh plant die-back; (b) If tidal inundation increases upstream such that marsh loss rates are higher in the upper Slough, (c) Increased tidal inundation and/or poor drainage is causing anoxic conditions in subsurface marsh sediment resulting in plant die-back; (d) Groundwater overdraft is/has caused subsidence leading to increased tidal inundation; (e) If increases in sea-level rise in recent decades have resulted in increased inundation, and (f) Compile a document to explain the likely roles of regional sea-level rise, local groundwater extraction, locally increased tidal range, and tectonics on increased tidal inundation.

B. Can changes to sediment supply help explain estuarine habitat loss and degradation? Will restored marshes be sustainable?
Project: Evaluate marsh sediment sources, distribution, and fate. *Purpose:* Understand marsh sedimentation rates and characteristics so that restoration projects can address as many of the driving factors as possible. *Funded:* ESNERR plans to hire a consultant to install sediment elevation table (SET) stations in a small number of areas to compare marsh sediment accretion rates in degrading versus reference areas. *Unfunded:* (a) Measurements of organic/inorganic marsh sediment characteristics; (b) Expansion of SET location monitoring to include potential restoration sites and existing muted tidal flow sites and analysis of SET data with aerial photos to use inundation levels to determine elevation contours; (c) Measurements of marsh sediment cohesion differences.

Project: Create a sediment budget for Elkhorn Slough to understand the current and historical sources of sediment. *Purpose:* Quantify existing and historic sediment sources to determine if marsh restoration (particularly sediment addition) projects would be sustainable in the long-term. *Unfunded:* (a) Collect field samples to quantify suspended sediment loads in tidal waters (*requested*); (b) Quantify inputs from marine, terrestrial, and fluvial sources; (c) Characterize the current (Old Salinas River channel, Carneros Creek, littoral drift) and past supply (episodic events, Salinas River, Pajaro River) of sediment (field sampling, coring, lab analysis); (d) Report on possible contributions of sediment during episodic events; (e) analyze turbidity data from the LOBO water quality buoys; (f) quantify the sediment plume.

C. Does pollution contribute to estuarine habitat loss and degradation?
Project: Evaluate chemical (i.e. pesticides) and nutrient (i.e. nitrate) pollution. *Purpose:* Understand the role of chemical and nutrient pollution in marsh loss so that restoration projects can address as many of the factors as possible. *Funded:* MBARI and ESNERR monitor real-time and long-term water quality conditions of channel waters. *Unfunded:* (a) Measurements of belowground biomass of marsh vegetation to determine if plant roots are weakened by high nutrient loads; (b) Literature review of vegetation and organism tolerances of chemicals and nutrients; (c) Monitoring levels of chemical pollutants in Elkhorn Slough and field studies with controlled nutrient and herbicide treatments; (d) Literature review of nutrients effects on *Ulva* and smothering effects of *Ulva* on salt marsh.

Project: Analyze benefits of wetland buffers. *Purpose:* Use wetlands as buffers to improve water quality for the estuary. *Funded:* RCD, MLML, and CSUMB. *Unfunded:* (a) Evaluate what ecological and water quality benefits would be improved by using different levels of created/restored wetlands as buffers.

D. What medium and large-scale potential alternatives to conserve, enhance, and restore estuarine habitats are feasible?

Project: Create designs for and predict how muting the tidal prism at the Parsons Slough mouth and/or sediment additions in the project area would impact estuarine habitats in the project area and system-wide. *Purpose:* Build support for a preferred tidal wetland restoration project for Parsons Slough. *Unfunded:* (a) Assessment of current site conditions; (b) Preliminary designs of water control structures; (c) Detailed description of sediment addition strategies to restore marsh elevations; (d) Predictions about changes to the tidal hydrology, estuarine habitats, and water quality both system-wide and for the project area comparing different water control structures and sediment addition strategies (includes no action); (e) Understanding of permitting requirements for sediment additions (*a-e requested*); (f) Study where the productivity is coming from that results in hypoxia in Parsons Slough to understand the effects of muting tidal exchange; (g) Understand how water control structures can be designed to maximize fish access.

Project: Create designs for large-scale restoration alternatives (including no action) and predict how different options would change the tidal hydrology, geomorphology, estuarine habitats, ecology, water quality, and human use. Numeric modeling efforts need to predict geomorphic change to estuarine habitats. *Purpose:* Understand if large-scale restoration alternatives are technically feasible and if the habitat benefits are better than the no action alternative so decisions can be made to pursue them or not. *Funded:* Stanford University constructed and is refining (will be adding tidal velocities from Old Salinas River channel) a 3-D hydrodynamic model for Elkhorn Slough; and ESNERR plans to hire consultants for numeric modeling and cost estimates of potential alternatives, MBARI will predict water quality changes, CSUMB will predict human use changes, ESNERR/TWP SP will predict habitat and ecological changes. *Unfunded:* (a) Expand numeric model to include ecosystem components such as wetland and biogeochemical processes (i.e. also include the role of plants and infauna in trapping and making sediment and increased friction); (b) Literature review of similar projects so that we can learn from the successes and failures of similar estuarine restoration project around the world; (c) Use of hydrodynamic model to predict the 1945 conditions before opening and then after the new harbor to see if it can predict today's bathymetry to verify model and for future predictions about areas of erosion and deposition and velocity under different potential restoration alternatives (including no action); (d) Study if a newly constructed mouth and channel for Elkhorn Slough would seasonally close, and if so, how for how long; (e) Study of changes to sediment loads in the harbor of different restoration options; (f) Understand how wide the mouth of Elkhorn Slough would have to be to slow the velocities, (g) Understand what alternatives would be most adaptable to a future rise in sea level, (h) Consider the unintended consequences of different restoration projects.

Project: Understand the permitting structure for wetland restoration projects that reuse sediment. *Purpose:* Look for opportunities to streamline permitting process to make wetland restoration projects that involve aspects such as sediment additions more feasible. *Funded:* CSUMB will create report on wetland permitting for Elkhorn restoration projects. *Unfunded:* (a) Create report of possible sources and characteristics of sediment that could be used to rebuild marsh elevations perhaps using SF Bay LTMS as a model (*requested*).

Project: Quantify how the head of the Monterey Canyon is changing over time. *Purpose:* Understand the sustainability of large-scale projects at the mouth of Elkhorn Slough. *Funded:* CSUMB

E. What small-scale potential alternatives to conserve, enhance, and restore estuarine habitats are feasible?

Project: Evaluate methods to enhance the functions and long-term sustainability of marsh complexes behind water control structures. *Purpose:* Identify areas and methods where improved tidal flushing could minimize hypersalinity issues or sustain marsh vegetation, tidal erosion and marsh loss could be reduced, and subsided marsh elevations could be built up through sediment additions (so if the system in the long-term becomes less erosive, the water control structures could be removed). *Unfunded:* (a) Measure subsurface salinity levels to understand if salt marsh vegetation in marshes with no tidal exchange will persist; (b) Describe and prioritize wetland enhancement projects that include the alteration water control structures including Bennett Slough, the Old Salinas River Channel, North Marsh, Estrada Marsh, and Blohm-Porter Marsh (portions east and west of Blohm Road); (c) Describe and prioritize wetland enhancement projects that include sediment additions to build up marsh elevations.

Project: Evaluate methods and conduct restoration experiments to explore the feasibility of adding or retaining sediment behind temporary structures (earthen levees, sediment fences, etc.). Projects could be in areas such as marshes along the main channel in the upper Slough or in the fingers within Parsons Slough. *Purpose:* Find out the feasibility of raising the elevation of marshes through sediment addition or retention methods to reduce marsh degradation and loss in the short and/or long-term. *Unfunded:* (a) Project description and analysis for small-scale sediment additions and/or retention projects; (b) Pilot restoration projects to retain or add sediment to build marsh elevations.

Project: Spartina analysis. *Purpose:* Explore the feasibility of use of *Spartina foliosa* plantings to decrease impacts of tidal erosion. *Unfunded:* (a) Literature surveys and expert analysis to determine 1) whether *Spartina* would be likely to survey if planted at the Slough, and in what sorts of locations/elevations; 2) feasibility of introducing only the native species, without contamination by invasive species or hybrid, 3) predictions of the consequences for depositional processes and habitat extents (would extensive mudflats be lost?).

F. Can historical conditions give us guidance on the types and extent of estuarine habitats to conserve and restore?

Project: Characterize historical estuarine habitat types and salinity conditions (150-5000 years before present). *Purpose:* Inform decisions about which restoration and conservation alternatives to pursue. *Funded:* NERR fellow has taken limited marsh sediment cores to determine the age of marsh in various regions. *Unfunded:* (a) More thorough coring effort to determine the range of past habitat types (150-5000 years before present) which could include a comparison of marsh age and distance from the channel through carbon or pollen dating; (b) Coring efforts to determine if cordgrass was historically present; (c) Studies to determine if the Elkhorn Slough mouth seasonally closed historically; (d) Conceptual model of estuarine geomorphology.

Project: Characterize regional estuarine habitat trends to determine the relative loss rates of different estuarine marsh habitat types for the Central Coast. *Purpose:* Inform decisions about which restoration and conservation alternatives to pursue. *Funded:* State Wetlands Program Demonstration Project. *Unfunded:* (a) Literature review and discussions with regional experts about past and current status of regional estuarine habitats; (b) Field trips for Elkhorn Slough folks to learn about other estuarine systems and restoration projects, (c) Locate and characterize control sites for Elkhorn restoration projects, (d) Finalize National Wetland Inventories for the Elkhorn Slough Watershed.

G. How can characterizing current conditions and past trends of estuarine habitats help predict future ecological changes?

Project: Understand ongoing changes to Elkhorn Slough bathymetry. *Purpose:* Quantify rates of tidal erosion and deepening and widening of main Elkhorn Slough channel to build support for possible restoration actions and help predict future changes under different restoration scenarios. *Funded:* CSUMB to measure bathymetric changes. *Unfunded:* (a) Analyze the spatial patterns of deepening and widening of the tidal channel and creeks to create a five-year projection of bathymetric changes and/or 50-year range of projections.

Project: Quantify changes to invertebrate and macroalgae communities over time. *Purpose:* Understand ecological changes over time and possible causes of those trends and help predict future ecological change under similar conditions. *Funded:* MLML characterizing the benthic and planktonic communities of Elkhorn Slough. *Unfunded:* (a) Quantify the extent of intertidal mudflat along the main channel that has been lost to predict changes from tidal erosion; (b) Describe the effects eroded subtidal habitats have on the amount of prey for southern sea otters and fish species.

Project: Compare functions of different habitat types. Purpose: Describe how the conversion of salt marsh to mudflat or channel habitats effects estuarine indicators. *Funded:* ESNERR GIS habitat analysis, water quality, and ecological research. *Unfunded:* (a) Examine ecosystem services of vegetated versus unvegetated habitats through literature reviews, field studies of particular guilds, or use of isotopes to determine relative contribution of marsh or eelgrass C and N versus algal sources; (b) Compare habitat use of degraded versus healthy estuarine habitats (i.e. sparsely vegetated marshes versus dense marshes, scoured versus less scoured tidal channels); (c) Comprehensive studies and monitoring of Elkhorn Slough's ecological communities over time (both before, during, and after restoration/conservation projects).

Acronyms

ESNERR - Elkhorn Slough National Estuarine Research Reserve, MLML - Moss Landing Marine Laboratories, CSUMB - California State University at Monterey Bay, MBARI - Monterey Bay Aquarium Research Institute, TWP SP – Tidal Wetland Plan Science Panel, RCD-Resource Conservation District

Appendix H. Relevant Regulations for Estuarine Habitat Restoration Projects

Key Agencies and Regulations

Geographic Scope	Agency Name	Policies Overseen	Relevant Permits and Scope of Work
Local	Elkhorn Slough National Estuarine Research Reserve (ESNERR) - managed by the California DFG in partnership with NOAA	ESNERR Management Plan	Permits (distributed by the California DFG) are required for any research activities conducted within the Reserve.
	Moss Landing Harbor District	California Harbors and Navigation Code, Moss Landing Harbor District Ordinance Code	Requires permits for various activities within the harbor's jurisdiction including wetlands development and restoration activities and construction projects.
	Watsonville City in Santa Cruz County and unincorporated Moss Landing, Elkhorn, and Castroville areas in Monterey County	Misc.	Monterey County
Regional	Central Coast Regional Water Quality Board (under the authority of CalEPA)	California Code of Regulations Section 3831(k), Section 401	Ensures water quality through certification for adding large amounts of silt and reducing tidal flow.
	Pacific Fishery Management Council	Magnuson Fishery Conservation and Management Act	Enforces fishery management plans.
	Monterey County	North Monterey County Land Use Plan includes policies and recommendations for Elkhorn Slough.	In order to obtain permits for restoration activities in the Monterey County coastal zone, the actions taken must demonstrate a parallel vision with the North County Land Use Plan.
	Monterey County Local Coastal Program	The California Coastal Act	Oversees Local Coastal Plan and provides permits for certain types of development in specified areas of the coastal zone.
	Monterey County Planning and Building Inspection Department	Misc.	Requires permits.
	Monterey County Public Works	Misc.	Requires permits. Permits for culverts in Blohm-Porter Marsh still needed.
	Neighboring counties, including Santa Cruz and San Benito	Misc.	Misc.
	Water Quality Control Boards	Clean Water Act Title III, Section 03	Submits basin plans to the State Water Quality Control Board.
	Other potential key regional agencies could include the Monterey County Parks System, the Monterey Peninsula Water Management District, the Northern Salinas Valley Mosquito Abatement District and the Pajaro Valley Water Management Agency.	Misc.	Misc.

California Coastal Commission (CCC)	California Coastal Zone Management Act (CZMA), Sections 30230, 30231, 30233, 30236, and 30240	Manages use and development of the coastal zone. Reviews certification of compliance with the California Coastal Management Program, which is a prerequisite for applicants of ACOE Section 404 and Section 10 permits. Requires permits for the development or alteration of California's coastal wetlands.
California Department of Fish and Game (DFG)	California Coastal Act	Obligated to comment on ACOE permit decisions regarding this Act
	California Environmental Quality Act (CEQA)	Obligated to comment on ACOE permit decisions regarding these Acts
	Clean Water Act, Section 404(b)	
	Magnuson-Stevens Fishery Conservation Management Act	
	Marine Life Management Act and the Marine Life Protection Act	
	River and Harbors Act, Section 10	
	California Endangered Species Act	Has primary responsibility for implementation of this Act.
	California's Public Resources Code	Regulates or comments on activities in wetland and riparian areas.
	California's Wetlands Conservation Policy	Ensures no net loss of wetlands and a long-term net gain in the quantity, quality, and permanence of wetland acreage and values.
	Fish and Wildlife Coordination Act	Regulates or comments on activities in wetland and riparian areas.
		Oversees activities and operations throughout the Elkhorn Slough Reserve. Issues permits for any research conducted within the Reserve.

California Department of Transportation (Caltrans)		
California Environmental Protection Agency	CEQA	Approves Environmental Impact Reports (EIR).
California Resources Agency		The Resources Agency is just beginning to implement a statewide wetlands policy to define the State's goals and objectives with regard to the preservation of remaining wetlands and set priorities and guidelines for restoration.
California State Coastal Conservancy (SCC)	N/a	Resolves coastal land use conflicts not amenable to regulatory solutions in order to protect coastal resources and expedite environmentally sound development. This agency has no regulatory function.
California State Lands Commission		Has jurisdiction of state tidal and submerged lands, and over the beds of naturally navigable lakes and rivers, swamp and overflow lands and school lands. Management responsibilities include activities within submerged land and those within three nautical miles of shore.
Coastal Sediment Management Workgroup		
State Regional Water Quality Control Boards, part of Cal EPA	Clean Water Act, 401(a)(1), Sections 301, 302, 303, 206, 307	Has regulatory authority over development activities affecting the water quality of navigable water and wetlands.
State Water Resources Control Board (SWRCB)	Statewide water quality control plans/policies include the Ocean Plan, the Thermal Plan, and the State Implementation Policy.	Oversees water quality.
Other potential key state agencies could include the California Department of Boating and Waterways (DBW), California Ocean Protection Council, California State Parks and Recreation and the California Wildlife Conservation Board.	Misc.	Misc.

Federal	Monterey Bay National Marine Sanctuary (MBNMS)	National Marine Sanctuaries Act	The main channels of the Elkhorn Slough fall under the Monterey Bay National Marine Sanctuary jurisdiction. Requires permits for construction, sea wall maintenance, operation of equipment on beaches, discharges, impacts to water flow and quality.
		MBNMS Joint Management Plan	
	National Marine Fisheries Service (NMFS)	Magnuson-Stevens Fishery Conservation Management Act	
		The Marine Mammal Protection Act	Protects cetaceans and pinnipeds.
		The Endangered Species Act	Protects endangered bird and fish species.
		Clean Water Act, Section 404(b)	Can review applications for CWA 404 permits.
	National Marine Protected Areas Center		
	National Oceanic and Atmospheric Administration (NOAA)	Coastal Zone Management Act of 1972	Oversees the National Estuarine Research Reserve System (NERRS).
	Office of Ocean and Coastal Resource Management (OCRM)	Coastal Zone Management Act of 1972	Applicants for ACOE Section 404 and Section 10 permits must include in their application a certification of consistency with the California Coastal Management Program.
	Soil Conservation Service	Clean Water Act, Section 404(b)	Can review applications for CWA 404 permits.
	U.S. Army Corps of Engineers (ACOE)	NEPA	
		River and Harbors Act, Section 10	Regulates the diking, filling, and placement of structures in navigable waterways for local and regional interests such as navigability, land use, economics, flood control, fish and wildlife, ecology, pollution, as well as traditional navigability. Administers nationwide permits #18 or #27.

U.S. Coast Guard	Clean Water Act	Prevents pollution caused by hazardous substances, discharges from vessels of oil or other pollutants.
U.S. Environmental Protection Agency (EPA)	NEPA	Approves Environmental Impact Statements (EIS)
	Clean Water Act Section 404	Can review applications for CWA 404 permits.
U.S. Fish and Wildlife Service (FWS)	Marine Mammal Protection Act	Protects all marine mammal species other than whales, porpoises and pinnipeds.
	Endangered Species Act	Protect and recover listed species of plants and animals native to the United States and territories. Relevant permits are under the authorities of sections 7 and 10 of the Endangered Species Act. In addition, the U.S. Fish and Wildlife Service also oversees the Migratory Bird Treaty Act for protection of migratory birds.
	Clean Water Act Section 404	Can review applications for CWA 404 permits.
Other potential key federal agencies could include the Bureau of Land Management, U.S. Dept. of the Interior, U.S. Dept. of Transportation, U.S. Forest Service, the U.S. Geological Survey	Misc.	Misc.
Elkhorn Slough Foundation	Elkhorn Slough Watershed Conservation Plan	Misc.
Monterey County Agricultural and Historical Land Conservancy	N/a	Private, non-profit organization that is a landowner near the Slough.
Misc. Parties	Clean Water Act, Section 404(b)	Regulates the disposal of dredge and fill materials in waters, including all streams to their headwaters, lakes over 10 acres, and contiguous wetlands, including those above the ordinary high water mark in non-tidal waters and mean high tide in tidal water. All saline, brackish, and freshwater wetlands adjacent to (and in some circumstances, isolated from) navigable waters are subject to ACOE jurisdiction. Has guidelines to control discharges of dredged or fill material into U.S. waters. Can review applications for CWA 404 permits. Administers nationwide permits #18 or #27.

National Estuarine Research Reserve Association (NERRA)	N/a	Works with Congress, NOAA, and public and private partners to increase support for research, monitoring, education, and stewardship within the NERR system.
The Nature Conservancy	Elkhorn Slough Watershed Conservation Plan	Misc.
Union Pacific Railroad	N/a	Requires permits.
Pajaro Sunny Mesa Water District		
Private Landowners	N/a	Provide public input for CEQA and NEPA processes (EIR and EIS will also be required). Participate in overall process.
North County Fire Department		

Glossary

Tidal Wetland Project Planning Process Terms

Consensus decision-making: a process used to find the highest level of agreement where everyone in the group supports, agrees to, or can accept a particular decision

Goals: the purpose towards which a management alternative is directed

Objective: a specific, measurable step to accomplish a goal

Strategic Planning Principles: general considerations that will be used to guide strategic planning. Ideally, the strategic planning principles would all be maximized, but there is recognition that some of these principles are incompatible and that there will inevitably be tradeoffs.

Vision: a short, compelling statement describing a desired future state.

Tidal Wetland Project Scientific Terms

Anoxia: absence of dissolved oxygen in water or soil

Benthic: of or relating to or happening at the bottom of a body of water

Benthos: the collection of organisms living on or in sea or lake bottoms; the bottom of a sea or lake

Brackish: slightly salty; salinity of 0.5-18 parts per thousand (ppt); for example, water that is a mixture of freshwater and saltwater is often considered brackish (ocean water is typically 35 ppt, freshwater is less than 0.5 ppt)

Coliform: Of or relating to the bacilli that commonly inhabit the intestines of humans and other vertebrates, especially the colon bacillus

Colluvium: mixed deposits of rock fragments and soil material that accumulate near the base of steep slopes as a result of landslides or local surface runoff

Cordgrass: any of several grasses of the genus *Spartina,* of coastal regions

Culvert: a drainage conduit that crosses under a road or embankment

DEM (digital elevation model): digital representation of ground surface topography or terrain

Deposition: the act of depositing, especially the laying down of matter by a natural process, such as rock fragments being deposited at the bottom of a river

Diurnal (tides): relating to or occurring in a 24-hour period; daily

Ebb tide: the receding or outgoing tide; the period between high water and the succeeding low water

Ecotone: the boundary or transitional zone between two adjacent ecosystems, such as between land and wetlands

Edaphic: of or relating to soil, especially as it affects living organisms; influenced by the soil rather than by the climate

Effluent: something that flows out or forth, especially a stream flowing out of a body of water or a discharge into a body of water

Embayment: an indentation in a shoreline forming an open bay (larger than a cove but smaller than a gulf)

Estuary: a coastal embayment consisting of deepwater subtidal habitats and adjacent intertidal wetlands that are usually semi-enclosed by land but have open access to ocean waters that enter with the tides and are usually diluted by freshwater

Estuarine habitats: include subtidal areas (channel, tidal creeks) covered by water even at low tide and intertidal areas (mudflat, salt marsh) that are covered with water during high tide and exposed during low tide

Eutrophication: over-enrichment of a water body with nutrients, resulting in excessive growth of organisms and depletion of oxygen concentrations

Flood tide: the incoming or rising tide; the period between low water and the succeeding high water

Fluvial: pertaining to rivers and river action

Geomorphology: the study of the origins and development of landform, including the major forms of the earth's surface

Groundwater: the water that has percolated through the surface soil and has accumulated in the ground, saturating and completely filling all spaces and pores in rock and/or soil

Habitat: the local environment or physical location in which an organism or biological population (plants, animals, microbes, etc.) lives or occurs

Headwaters: the source of a river

Hummus: organic material derived from partial decay of plant and animal matter

Hydric soil: a soil that is saturated, flooded or ponded long enough during the growing season to develop conditions where oxygen is absent (anaerobic). Wetland soils are hydric.

Hydrology: the scientific study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere

Hydrophytic vegetation: any plant growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content; vegetation typically adapted for life in saturated soil conditions. Wetland plants are hydrophytic.

Hypersaline: water with a salinity that is greater than 40 parts per thousand (ppt). This is in contrast to freshwater which has a salinity of less than 0.5 ppt and ocean water that is typically 35 ppt

Hypoxia: typically waters with dissolved oxygen less than 2 mg/L in water (some regulatory agencies consider waters impaired with dissolved oxygen less than 5 mg/L in water)

Intertidal: of or being the region between the high tide mark and the low tide mark

Marsh: a wetland area with emergent plants that occurs in areas subjected to extended periods of flooding or in shallow water

Mudflat: an intertidal habitat that is usually covered with water during high tide and exposed during low tide, typically found below marsh habitats, and usually devoid of vegetation. There are approximately 1,605 acres of mudflat habitats in Elkhorn Slough.

Nutrient Cycle: pathway of a nutrient or element through its ecosystem, starting from uptake by organisms to release through decomposition

LIDAR (laser imaging detection and ranging): optical remote sensing technology which measures properties of scattered light to find range and/or other information of a distant target

Organic compounds: all living things and products that are produced solely by other living things. Examples are sugar and leather.

Persistent emergent: emergent hydrophytes (plants) that normally remain standing at least until the beginning of the next growing season

Photosynthesis: the chemical process conducted by green plants through which light energy is used to produce glucose from carbon dioxide and water. Oxygen is released as a byproduct. This process enables green plants to produce plant tissues that lead to growth.

Primary Producer: in an ecosystem, those organisms, including green plants and organisms such as algae and diatoms in the water, that use light energy to construct their organic constituents from inorganic compounds

Salinity: salt content of water, typically reported in parts per thousand (ppt). The salinity of ocean water is 32-35 ppt.

Salt marsh: <u>Low salt marsh</u> is usually covered with water during high tide and exposed during low tide and the vegetation is primarily pickleweed (*Sarcocornia pacifica*, formerly *Salicornia virginica*). <u>High salt marsh</u> is flooded irregularly (usually exposed at least 10 continuous days) and the most common vegetation is salt grass *(Distichlis spicata* var. *stolonifera),* alkali heath *(Frankenia salina),* jaumea *(Jaumea carnosa), Atriplex* species, and parasitic dodder *(Cuscuta salina).* The macroalgae that looks like lettuce leaves and covers the salt marsh in some areas is called *Ulva* (various species). There are approximately 796 acres of salt marsh (includes tidal creeks) in Elkhorn Slough.

Sediment: unconsolidated inorganic and/or organic mineral and rock particles, usually sand, silt or clay that are transported and deposited by flowing water

Slough: a depression or hollow, usually filled with deep mud or mire; a swamp, marsh, bog, or pond, especially as part of a bayou, inlet, or backwater marked by meandering channels bordered by marsh

Subsidence: to sink to a low or lower level (i.e. land elevation)

Substrate: a surface on which an organism grows or is attached

Subtidal (channel): areas covered with water even at low tide and include channels and tidal creeks

Tidal creeks: creeks that form a network in salt marshes and serve an important function of transferring sediment and nutrients between salt marshes and the main estuarine channel. They also serve as a primary habitat for estuarine fish.

Tidal prism: the volume of water covering an area between a low tide and the subsequent high tide; the tidal prism of Elkhorn Slough was estimated to be 6,400,000 cubic meters in 2005

Tidal/tide range: the difference in the level between successive high and low tides

Tidal scour/erosion: erosion along the bank or bottom of a tidal channel or tidal creek

Tidal wetland: areas along coasts and in estuaries where the ground is covered by high tides but drained at low tide

Tide gate: a water control structure that either allows water to flow freely when the tide sets in one direction, but which closes automatically and prevents the water from flowing in the other direction (i.e. flap gate under Elkhorn Road between Blohm-Porter Marsh and Hudsons Landing) or a water control structure that restricts the total amount of water exchanged through a sliding mechanism that usually reduces the height of the tide level (i.e. slide gates are found under the levee in North Marsh)

Turbidity: a measure of the murkiness or cloudiness from sediment, organic material, or plankton suspended in the water

Water table: the upper surface of groundwater that rises and falls depending on the amount of groundwater

Watershed: the area of land that catches precipitation such as rain and drains into an estuary, river, lake, or other body of water

Wetland: an area, such as marsh, that usually supports hydrophytic vegetation, hydric soils, and is usually saturated or inundated by surface or groundwater sometime during the growing season of each year

Wrack: any marine vegetation cast up on the shore

Glossary sources are from Cowardin 1979, Ferren et al. 1996, Mitsch et al. 2000, Nebel et al. 1998, Smith 1996 and web sources including Biology Online (http://www.biology-online.org/dictionary.asp), Dictionary.com (http://www.dictionary.com), NOAA Tidal Terminology, and Word Web Online (http://www.wordwebonline.com)

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