CDM Camp Dresser & McKee

In Association with The Bay Institute of San Francisco

San Pablo Bay Watershed Restoration Framework Program

November 2000

Prepared for:

Coastal Conservancy

US Army Corps of Engineers®

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Final Report

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Welcome and User's Guide to the San Pablo Bay Watershed Restoration Program

The San Pablo Bay Watershed Restoration Program is an innovative new effort to restore the ecological vitality of the San Pablo Bay watershed. There are many unique opportunities to revitalize streams, rivers and wetlands in this large, northern San Francisco Bay region, and the Watershed Restoration Program creates a framework to promote its rejuvenation.

Purpose

The purpose of the San Pablo Bay Watershed Restoration Program (WRP) is to facilitate the rejuvenation of streams, rivers, wetlands and upland areas within the area that drains to San Pablo Bay, which includes portions of five counties. The WRP provides technical and financial assistance to individuals, nonprofit organizations, and local agencies wishing to engage in ecological restoration projects. This is an assistance program, rather than a grant program. As the primary sponsors of the WRP, the U. S. Army Corps of Engineers and the California Coastal Conservancy will play active roles in any restoration project that qualifies under the program.

Contained in these pages is information about how to get involved in the WRP, as well as facts about the San Pablo Bay watershed. For more detailed information about any particular topic, please refer to the Table of Contents.

Who May Sponsor Watershed Restoration Projects?

Any individual, local government agency, or non-governmental organization may sponsor a project.

What Are the Obligations of Project Sponsors?

Anyone wishing to sponsor a restoration project must have legal authority over the site upon which the restoration is proposed to occur, or must demonstrate the support of the landowner. In addition, project sponsors must contribute matching funds and / or in-kind support to the project. The amount of money or in-kind support required will depend upon the type of project proposed and the specific funding sources secured. Finally, the sponsor or a partner with legal authority may need to serve as the permit holder for the project. [See Section 6 for additional information.]

Are There Legal Requirements That Must Be Met By Project Sponsors?

Ecological restoration projects typically involve construction in or near sensitive habitats. Because of their sensitive nature, a series of legal requirements must be met for most restoration projects before construction can begin. Those permits often require that an environmental assessment be performed to determine what the impact of the project will be. Fulfilling these permitting requirements may be the responsibility of project sponsors. However, part of the assistance package offered through this program includes help with the permit process. [See Section 6 for more information.]

How Will Projects Be Selected By Watershed Restoration Program Sponsors?

The Watershed Restoration Program is funded by federal and state programs. The amount of funding available for the WRP will vary from year to year depending on state and federal legislative actions. The program sponsors, the U. S. Army Corps of Engineers and the Coastal Conservancy, with the support of The Bay Institute, will review restoration project proposals several times each year. Proposals will be evaluated as to how well they meet the goals of the WRP, which are:

- Rehabilitate natural processes within the San Pablo Bay watershed system.
- Protect existing high quality habitat throughout the watershed.
- Restore degraded habitat to high quality ecological and hydrological function.
- Sustain a healthy community of native species.
- Improve and maintain water quality and in-stream flow.
- Prevent the establishment of new non-native species, and curb the expansion of existing non-native species.

Technical and Financial Assistance

Technical and financial assistance are available to qualifying project sponsors through this program. The U. S. Army Corps of Engineers (USACE) has several funding sources that may be tapped to finance a project, depending on the specific nature of the restoration proposal. [See Table 6-1 and Table C-2.] In addition, the USACE is qualified to perform many of the technical tasks associated with restoration projects. The Coastal Conservancy, co-sponsor of the WRP, also can assist qualifying projects with technical and financial assistance.

The Bay Institute (TBI), a regional nonprofit environmental organization, will offer project development assistance. TBI can assist project sponsors in advance of submission of a proposal, help assemble the proposal itself, and help determine whether a proposal has a reasonable chance of success.

Limited resources are available, so restoration project proposals will be considered on a competitive basis.

History of the Watershed Restoration Program

The San Pablo Bay Watershed Restoration Program was authorized by the United States Congress in 1996 under Section 503 of the Water Resources Development Act. In 1998, the San Francisco District of the U.S. Army Corps of Engineers began developing the WRP in collaboration with the Coastal Conservancy and The Bay Institute.

User's Guide to this Document

Where can I find the information I'm looking for?

For information on...	Look in....
Program Sponsors	Section 1
Project Goals	Section 1 and Section 6
The San Pablo Bay Watershed Restoration Program (what is it?)	Section 1; see Section 2 for watershed boundary
Habitat Descriptions	Section 3
Obtaining Funding	Section 6 and Appendix C
History of the Watershed	Section 2 for physical and land use **Section 4** for history of changes made by humans

Examples of Completed Projects	Interspersed throughout Section 5
Examples of Proposed Projects	Appendices D and E; summarized in Section 6
Lists of Species in the Watershed	Appendix B
Restoration Methods	Section 5
Problems in the Watershed	Section 4

What is in Each Section of the Restoration Program Report?

Section 1 provides an overall introduction to watershed restoration and a brief introduction to the structure and goals of this Restoration Program. It includes a description of past restoration programs within the San Pablo Bay watershed.

Section 2 provides information about the physical setting of the San Pablo Bay watershed: topography, climate, land use, history of human habitation, and so on. A map and description of the watershed boundaries are included. **Appendix A** shows the relationship of this project area to other Army Corps of Engineers projects areas.

Section 3 describes the ecology of the watershed, including descriptions of the different types of habitats, the types of species that use each habitat, trends observed in each of the major taxa (fish, birds, etc.), and information about invasive exotic species. **Appendix B** provides lists of the species that can be found in the watershed.

Section 4 explains how humans have modified the San Pablo Bay watershed, thus necessitating current restoration efforts. As Section 4 emphasizes, it is critically important (but often challenging) to keep in mind the underlying problems facing the watershed: modified hydrology, land use, etc.

Section 5 is a technical manual for restoration. It includes advice about project planning, permitting, and monitoring. Most of the section is devoted to describing thirteen different restoration methods, ranging from levee modification to implementation of best management practices.

Section 6 provides information specific to this Restoration Program – the goals and objectives of the program, how to apply for funds, and what types of projects might be eligible for funding. **Appendix C** contains a sample application and more information on funding. **Appendix D** provides detailed information and conceptual restoration plans for three real "Pilot Projects," while **Appendix E** describes thirteen "Candidate Projects" that are still in early planning stages. Both **D** and **E** are meant to illustrate the types of projects that could be eligible for funding under this Program.

I'm already planning my project; all I need is funding. What part should I read?

Section 6 is the most important section for those already familiar with restoration techniques and the status of restoration in the San Pablo Bay watershed. **Section 1** also provides helpful background information, and the beginning of **Section 5** provides some regulatory context.

For More Information

Visit San Pablo Bay websites operated by the U. S. Army Corps of Engineers (www.spn.usace.mil/sanpablobay) and by The Bay Institute (www.bay.org). The websites include the entire contents of this report, an interactive reference library, and links to related sites.

Section 1
The New Watershed Restoration Approach

1.1 Introduction

This document describes an approachfor restoring the aquatic ecosystems of the San Pablo Bay Watershed, one of the major sub-watersheds of the larger San Francisco Estuary. The goals of this plan are the following:

- Rehabilitate natural processes within the San Pablo Bay watershed system.
- Protect existing high quality habitat throughout the watershed.
- Restore degraded habitat to high quality ecological and hydrological function.
- Sustain a healthy community of native species.
- Improve and maintain water quality and in-stream flow.
- Prevent the establishment of new non-native species, and curb the expansion of existing non-native species.

The ecological integrity of the San Francisco Estuary (hereinafter referred to as the Estuary) has deteriorated dramatically over the past several decades. Scientists and politicians alike have come to accept the fact that major changes must be made in the way the Estuary's resources are managed if they are to be saved.

Among the serious problems that have led to the deterioration of the Estuary's ecological resources are the following:

- *Destruction and modification of the Estuary's physical structure.* Approximately eighty-six percent of its tidal wetlands have been destroyed. An unknown large percentage of the riparian corridors of tributary rivers and streams has been destroyed. Large volumes of sediment have washed into the lower reaches of the Estuary, reducing its depth by as much as two meters. Fill, placed in extensive areas of shallow water, has reduced the Estuary's surface area and volume and eliminated valuable aquatic habitat. Extensive dredging and dredge spoil disposal has resulted in alteration of Estuary bathymetry.
- *Alteration of historic flow regimes.* Construction of dams on most of the major tributaries to the Estuary has enabled diversion of massive amounts of fresh water that once flowed to the sea. These diversions have altered the mix of fresh and salt water upon which the Estuary's ecosystem is based, consequently jeopardizing many species dependent upon unimpaired flow regimes, most notably, anadromous fish such as salmon. This altered flow regime also has caused phytoplankton productivity to plummet. Phytoplankton is the foundation of the Estuary's food chain.
- *Alteration of surface flows.* Hardening of the watershed's surface by roofs and paving and alteration of the surface by agricultural tilling and compacting have significantly altered the timing and volume of freshwater flows to the Estuary.
- *Discharge of pollutants into Estuary waters.* Discharge of pollutants from municipal, industrial, agricultural and other activities has contaminated many Estuary wildlife species, which poses a risk to them and other species up the food chain, including humans.
- *Introduction of non-native species.* Invasive, non-native species threaten to push many Estuary species to the brink of extinction. Some species, such as the red fox, prey directly on vulnerable wildlife, while others, such as the invasive reed, *Arundo donax*, can out-compete native plants and destroy vast areas of native vegetation, thus

eliminating both native plants and the native wildlife that depend upon them.

Communities around the Estuary have built a highly engineered landscape of dams, levees and roads overlying the existing natural one. This approach has led to many unanticipated consequences, including the destruction of valuable natural habitats, along with a decline in the plant and wildlife species that reside in them. Moreover, it often has had additional consequences with more clear impacts on the region's human communities, such as erosion of agricultural topsoil, amplified flooding, and increased pollution of waterways.

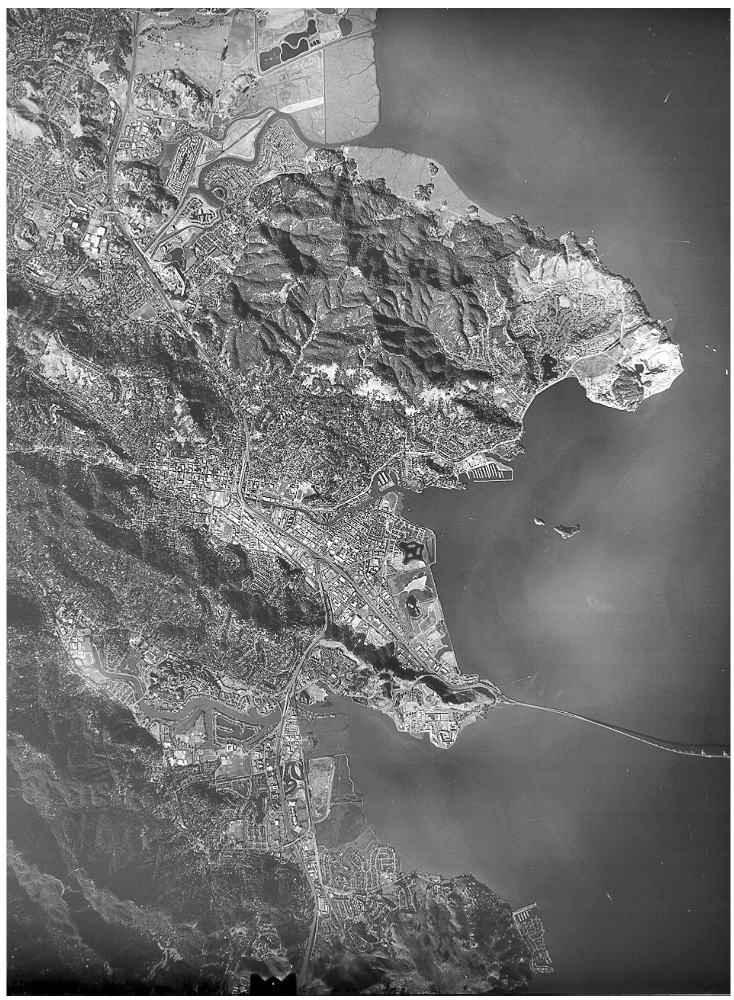
Today, planners are re-examining conventional approaches to managing problems as such as flooding and pollution. Out of this reconsideration has emerged the recognition that the most effective approach to planning for these important social and environmental needs is one that is based on a watershed scale. Increasing emphasis is being placed on restoring aquatic ecosystems on the watershed scale, in order to serve these multiple social needs most effectively.

Put generally, this means working with, rather than against, nature. The watershed restoration approach recognizes that a well-functioning aquatic ecosystem is an essential foundation upon which a healthy human community depends.

This program is based on the expanding scientific consensus that if the goals presented above are pursued within the context of the associated needs of the human community, it is likely that the declining condition of the underlying watershed ecosystem can be arrested and reversed. Moreover, it also is likely that the important needs of the human community, such as flood management and pollution control, can be met more effectively than they have been in the past.

The watershed restoration approach, if designed and implemented thoughtfully and skillfully, can revolutionize the relationship between human community and the environment. This plan outlines a way to redefine our relationship to the land, and in the process, make both human and wild communities healthier places. Part and parcel of that approach is a program of on-the-ground watershed restoration to be undertaken by forward-looking communities throughout the San Pablo Bay watershed. It is the hope of the authors that this program will serve as an effective model for broader application.

Included in this document are detailed descriptions of the ecological setting in the San Pablo Bay area and the specific challenges presented by San Pablo



Point San Pedro is the southern boundary of San Pablo Bay.

Bay's history of human habitation. This report describes techniques for watershed restoration and provides guidance for how to put a restoration project into action. Finally, example restoration plans, case studies and candidate project descriptions contained herein illustrate how real activities can be developed to meet the goals of this program.

1.2 Regulatory Framework

In 1996 Congress enacted Section 503 of the Water Resources Development Act. Section 503 called for the U. S. Army Corps of Engineers to develop and implement watershed restoration plans for thirteen watersheds identified by name, including the San Pablo Bay watershed in the northern San Francisco Bay area. Section 503 was enacted specifically to promote the pursuit of broad, ecological restoration of the watershed, as opposed to more limited objectives, such as flood control or pollution abatement.

Impetus for the enactment of Section 503 came from growing recognition of the toll that traditional water and land management practices had taken on important aquatic resources. Construction of reservoirs and flood control systems, dredging of navigation channels, clear-cutting of riparian forests along rivers and streams, and reclamation of large areas of wetlands, among other things, had caused extensive damage to fish and other wildlife species inhabiting the aquatic environment. In many cases, the native habitat of these species had been modified so significantly that some species became extinct, while others were brought to the edge of extinction. The populations of many other species spared from the threat of extinction nevertheless suffered dramatic declines.

In addition, those same practices also often failed in their attempts to achieve their primary objectives, such as flood control or pollution abatement. In many cases, for instance, a flood control project on one portion of a waterway would simply cause the flooding problem to shift to another location. Similarly, regulation of pollution discharges from a limited number of stationary sources failed to address the significant pollutants being introduced into waterways by other unregulated sources.

In short, a number of land use and land management practices that were once thought to have no deleterious impact on the quality of our nation's waters are now recognized to have serious potential impacts, indeed. Growing consensus has emerged that the only effective way to protect the Nation's waters is to manage virtually all significant activities within the geographic units known as watersheds.

Section 503 is one of the most recent in a long history of legislative initiatives intended to address problems within the Nation's aquatic ecosystems. It is one of the first in which Congress calls explicitly for the ecological restoration of watersheds as a means to achieve other important social objectives. As such, it is a significant public policy landmark.

1.3 Overview of the History of National Water Protection Efforts

Until the passage of WRDA Section 503, Congress had attempted to protect the nation's waters through technological means. The first federal legislation passed to promote preservation of the Nation's water resources came in 1948. Basically, this legislation recognized the need to protect the integrity of the nation's waterways for certain benefits that they provided to the human community. Those benefits included drinking water, recreation and waste transport. In general, they did not include benefits that were not considered to be of significant value to the human community, such as protecting the needs of fish and other aquatic wildlife. The 1948 law deferred entirely to the states to determine what level of protection was to be afforded to waterways.

By 1972, growing public concern regarding the deterioration of the nation's waters prompted Congress to enact national standards for water quality. Over the objections of most states, Congress required those who discharged pollutants into waters of the United States to meet newly-established water quality criteria. The criteria were to be technologically based, using the best available methods to ensure that pollutant loading would be reduced significantly.

It was expected by many at the time that, if this program were implemented and enforced, the quality of the nation's waters would improve dramatically. Twenty-eight years after the passage of that groundbreaking federal legislation, however, many believe that the nation's waters are still not clean. Moreover, there is growing perception that the country's lakes, rivers and other waters are more polluted than they were almost three decades ago.

Hindsight has taught us that the 1972 program addressed only a limited range of pollutants, and a limited number of pollutant discharges. The program didn't address habitat loss, which has had a significant adverse impact on aquatic resources. The program developed in response to the 1972 Clean Water Act regulated only stationary sources of pollution, such as municipal wastewater plants and factories. It failed to recognize that significant amounts of pollution were being generated by sources without a central "pipe" from which discharges flowed. These "non-point sources" include activities such as animal feed lots, dairy farms and suburban gardens, among others. As it turns out, pollution from non-point sources comprises more than fifty percent of the discharges to the nation's waters.

Ironically, while cities and industries were making major reductions in their contribution to aquatic pollution, explosive population growth and unregulated agriculture and forestry practices were drowning these advances in a sea of non-point source pollution.

1.4 The Benefits of Aquatic Habitat Restoration

By the 1980s, it became clear that any approach to protect the quality of the nation's waters must include a strategy to effectively manage the pollution contribution of non-point sources within watersheds. New attention was placed on methods by which non-point source pollution could be reduced.

For instance, one pollutant from non-point sources is the sediment that erodes from agricultural fields or clear-cut slopes during rain and runoff events. When this sediment, along with attached herbicides and pesticides, is carried into the receiving streams, it can bury bottom habitat and fish spawning gravels. Two methods that can be applied to prevent these problems are to plant soil-holding vegetation on exposed croplands to reduce the amount of erosion and to maintain natural vegetated buffer margins along rivers and streams to filter out sediment prior to the runoff entering the stream. This latter approach is recognized to have the additional benefits of providing habitat for native species, which would otherwise be

Cullinan Ranch, Napa River watershed.

driven out by the removal of vegetation right up to the stream bank.

For instance, one non-point source of pollution was sediment that eroded from agricultural fields or clear-cut slopes. This sediment could bury fish spawning gravels within streams, or carry pesticides and herbicides into waterways. Two methods that were developed to prevent these problems. These erosion-prevention weremethods were to plant soil-holding vegetation on exposed croplands and to maintain natural vegetated buffer margins along rivers and streams. This latter approach was recognized to have additional benefits, such as providing habitat for native species that may have been driven out when agricultural operations had removed all natural vegetation right up to the stream bank..

Expanded investigation into the benefits of aquatic habitat began to reveal that the protection and restoration of natural systems could facilitate the attainment of clean water and other associated social objectives. Gradually, it was recognized that the value of environmentally friendly, non-structural approaches to watershed management could play a major role, not only in cleaning up the nation's waters, but in providing important additional benefits.

The scientific community and the federal government recognize the many benefits provided to the human community by a healthy aquatic ecosystem. The National Research Council's Committee on Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy declares:

> *Aquatic ecosystems perform numerous valuable environmental functions. They recycle nutrients, purify water, attenuate floods, augment and maintain streamflow, recharge ground water, and provide habitat for wildlife and recreation for people.* (National Research Council 1992)

1.5 The Watershed Approach

This awareness of alternate approaches has caused the fundamental goal of water management to be called into question. Rather than the historic goal of management to protect a narrow range of purposes, such as drinking water quality and waste transport, the emerging goal is management of the entire watershed through protection and restoration of the underlying aquatic ecosystem. Watershed management provides multiple benefits while minimizing unintended harmful consequences.

Since 1991, the U. S. Environmental Protection Agency has been promoted the watershed protection approach as a framework for restoring the health and integrity of aquatic ecosystems. The EPA defines this approach as:

> *A holistic strategy for more effectively restoring and protecting aquatic resources. This approach focuses on hydrologically defined draining basins-watersheds - rather than on areas arbitrarily defined by political boundaries. Thus, for a given watershed, the approach encompasses not only the water resources, such as a stream, river, lake, estuary, or aquifer, but all the land from which water drains to the resource. To protect water resources, it is increasingly important to address the conditions of land areas within the watershed because as water drains off the land or leaches to the ground water it carries with it the effect of human activities throughout the watershed.* (USEPA Office of Water 1994)

The approach is consistent with the advice of the National Research Council, which recommends:

> *That a national aquatic ecosystem restoration strategy be developed for the United States. This comprehensive program should set specific national restoration goals and wetlands, rivers, streams, and lakes, and it should provide a national assessment process to monitor achievement of those goals.* (National Research Council 1992)

This program embraces the watershed approach, and attempts to describe a program of watershed restoration and management that will result in more healthy natural and human communities within the San Pablo Bay watershed.

1.6 The Science of Aquatic Restoration

Several successful restoration projects undertaken around the country have demonstrated the potential for success of the watershed restoration approach. These successes, however, have resulted largely from the initiative of government agencies or private organizations pursuing independent or uncoordinated projects. Little exists in the way of comprehensive standards to guide restoration efforts. In addition, many restoration projects have failed. Most noteworthy among these failures are those projects that are developed as mitigation for the loss of aquatic resources permitted by government agencies.

Restoration can be successful, but that success depends heavily on the effectiveness and comprehensiveness of the planning and implementation measures initiated as part of a well-conceived restoration effort. It now is generally accepted in the scientific community that success may only be assured by planning the restoration project in the context of the entire watershed. A watershed based effort is considered to be the best approach to protect the many beneficial purposes served by our water resources.

The National Research Council identifies several deficiencies in past and current efforts to restore aquatic ecosystems. Primary among them are the following:

- Restoration planners fail to integrate restoration projects into the larger watershed context.
- Restoration projects are often not planned with long-term horizons in mind.
- Planners often do not include adequate monitoring and maintenance provisions in restoration projects.
- Current federal and state environmental programs and policies are fragmented, and do not adequately emphasize restoration based on management of large, interconnected aquatic ecosystems.

The National Research Council describes the prospects for repairing the nation’s damaged aquatic ecosystems as “excellent.” In order to address the problems described above, the Council recommends the development and establishment of a coordinated, comprehensive national program. It proposes the adoption of specific goals and restoration criteria, including long-term monitoring and management programs to inform and improve restoration efforts.

Among other objectives, the San Pablo Bay Watershed Restoration Program strives to develop a program on a watershed scale that includes all the components necessary to maximize the chances of restoration success. This program will be described in greater detail in the Project Sponsorship section.

1.7 An Overview of Restoration Efforts to Date in the San Pablo Bay Watershed

The San Pablo Bay watershed is a significant feature of the San Francisco Bay and Delta Estuary. The Estuary is one of the most important ecological units on the west coast of North America, and certainly the most ecologically valuable estuary in California.

The Estuary contains four basic geographic sub-regions (excluding the Sacramento-San Joaquin Rivers Delta): San Pablo Bay; Central Bay; South Bay; and Suisun Bay. In the past thirty years, there has been considerable restoration activity throughout the Estuary. In order to understand current restoration activities in the San Pablo Bay watershed, it is necessary to provide a history of human habitation of the larger Estuary, and of restoration efforts Estuary-wide. Most of the landmark events presented here pertain to tidal wetlands, because their destruction and partial restoration offers one of the most dramatic views of the Estuary's history. Restoration of riparian zones and uplands habitats is equally important to overall watershed health, but such efforts are more recent and smaller in scale. Please refer to Section 5 for case studies about riparian restoration and best management practices in upland areas.

The burst of immigration that marks the start of the contemporary era of settlement of the Estuary began with the 1849 California Gold Rush. San Francisco grew from a remote western outpost of the continent to a burgeoning United States commercial center almost overnight. One of the consequences of this explosive growth was the commencement of diking and draining of the estuary's marshes to create farm and pasture lands. That practice continued into the 1960s, and was augmented by development of the diked lands as commercial and residential centers.

By 1999, the extent of tidal marshes around the Bay had been reduced from approximately 190,000 acres to 40,000 acres. This occurrence dramatically impaired the ecological functioning of the estuary, and was compounded by other impacts caused by large increase in human habitation. By 1965, public concern rose to such a significant level that a law was passed that effectively brought an end to the practices of diking, draining and filling.

Also emerging at that time was an interest in safeguarding the remaining wildlife habitat in the Estuary. In 1972, the San Francisco Bay National Wildlife Refuge was established in South Bay. Originally established on diked tidal marsh converted to salt evaporation ponds, the Refuge eventually was expanded to include other wetland types, and into other sub-regions of the Estuary, including the San Pablo Bay watershed.

In 1983, a citizen organization was established in the South Bay to promote expansion of the boundaries of the San Francisco Bay National Wildlife Refuge. Soon, other voices joined the chorus, and by the mid-1980s there was significant public demand for restoration of tidal marshes and associated wetlands lost to diking and draining.

Taking the initiative to carry out their mission to protect waterfowl and endangered species, refuge managers began to pursue wetland restoration projects in the 1980s. Among the first efforts to restore tidal marsh in the San Pablo Bay watershed was the acquisition of Cullinan Ranch, a 1,500-acre hay ranch established on diked and drained tidal marsh. The property was purchased in 1990, and plans are in the works to breach the dikes and restore tidal flow to the property. In the meantime, a very productive fresh water seasonal wetland has established itself on the site, as a result of winter rainfall that inundates the diked basin.

Prior to this, tidal marsh restoration projects had occurred in various locations around the bay; these projects were undertaken as mitigation for the loss of wetlands due to public works projects. As mitigation for the impacts of constructing the Dumbarton Bridge across South Bay, the California Department of Transportation breached the dikes on a 200-acres of former tidal marsh in Hayward. Similarly, the Golden Gate Transit District restored a diked tidal marsh in Corte Madera as a requirement of its construction of a ferry terminal nearby. Finally, a tidal restoration project was undertaken on Lower Tubbs Island in southern Sonoma County as mitigation for construction of a lagoon community on diked marshes in the city of Novato.

In addition, the California Department of Fish and Game acquired some properties for the purpose of restoring wildlife habitat, especially for dabbling ducks. These early acquisitions were intended to replace lost seasonal, fresh water marshes rather than tidal marshes.

In 1987, San Francisco Bay was added to the National Estuary Program (NEP), a federal initiative aimed at restoring the ecological health of vital estuaries throughout the nation. The NEP focused unprecedented attention on San Francisco Bay, and culminated in the adoption of a Management Plan that placed great emphasis on the need for ecological restoration of the Estuary. Diked tidal marshes were identified as prime candidates for restoration.

At the same time the NEP was underway, a unique initiative promoted the use of dredged spoils from channel deepening projects in tidal restoration projects. Local environmental groups were pressing the Port of Oakland, the region's largest port authority, to halt the practice of dumping dredge spoils in the bay. The groups proposed that the Port place the material on diked wetlands to facilitate restoration instead. This innovative initiative resulted in the completion in 1995 of the Sonoma Baylands project, a tidal restoration encompassing 360 acres. Today, several similar restoration projects are being planned.

In 1994, an extremely important milestone in efforts to restore the San Pablo Bay watershed was reached–the State of California purchased approximately 9,000 acres of salt evaporation ponds adjacent to the Napa River for the purpose of restoring them as wetlands.

The Cargill Salt Company owned diked wetlands on which it manufactured salt via the solar evaporation process. The holdings included these solar evaporation ponds that had been constructed in the 1950s and used to manufacture salt. In 1992, Cargill lost the primary customer for its salt, and after two years decided to sell all of these ponds to the State of California. The State's declared objective in purchasing the ponds was to restore the wetland ecosystem of this major sub-region within the San Pablo Bay watershed.

Finally, although not an on-the-ground restoration project, major impetus was given to the cause of restoration of diked wetlands throughout the Estuary by the 1999 publication of the *Baylands Ecosystem Habitat Goals*, a scientific treatise describing the restoration needs of estuary wildlife. The report was produced by a team of more than one hundred scientists from government and academia. It recommends that major restoration of tidal marshes occur in the San Pablo Bay watershed in order to reverse the decline of endangered and declining species, as well as to enhance other important functions, such as water quality protection, flood control and maintenance of navigation channels.

Today, of the original expanse of approximately 53,000 acres of tidal marshes, approximately 20,000 acres are publicly held and slated for restoration. Other diked tide lands are in public hands and being used for waste-water reclamation. Most of the remaining diked wetlands of San Pablo Bay are privately held and managed as hay farms. A significant threat still exists that these restorable wetlands will be lost to urban and suburban development. In 1998, a developer received final approval to construct a golf course on restorable diked wetlands in the city of Novato.

1.8 Summary

The San Pablo Bay Watershed Restoration Program is based on the emerging scientific consensus that ecosystem management occurs most effectively on a watershed scale, and that the benefits of this approach to human communities within the watershed can equal or exceed the application of traditional approaches.

This document provides an overview of the historic activities within the watershed that have resulted in the land use patterns and practices existing today, as well as the impact of those practices on the watershed's aquatic resources. It concludes with a recommended program to restore those resources in order to recapture a level of ecosystem vitality sustainable for generations to come.

Section 2
The San Pablo Bay Watershed: Physical Setting

2.1 Overview

The San Pablo Bay watershed includes those lands in the northern reaches of the San Francisco Bay area whose streams flow into San Pablo Bay. This watershed is a component of the much larger San Francisco Bay-Delta Estuary, which includes the Sacramento and San Joaquin Rivers. The San Pablo Bay watershed lies between the Suisun Bay to the east and the San Francisco Bay to the south.

This section includes a physical description of the San Pablo watershed, as well as a history of the human habitation that has altered it.

2.2 Physical Description

Figure 2-1 shows the location of San Pablo Bay watershed (watershed) in relation to the San Francisco Bay Estuary.[1] The watershed is approximately 900 square miles in area. The drainage areas of the major stream and creeks that flow into San Pablo Bay have established the boundary of the watershed shown in Figure 2-1. The watershed's furthest upstream point to the north is Mount St. Helena. To the east, the boundary includes the Howell Mountains in Napa and Solano Counties, the Carquinez Strait, and the Franklin Ridge, the Briones Hills, and the Berkeley Hills in Contra Costa County. The western border is defined by a series of small mountain and hilltops including: Loma Alta and Red Hill in Marin County; Meacham Hill, Sonoma Mountain, Bennet Mountain, and Mt. Hood in Sonoma County; and the Mayacmas Mountains along the northern border of Napa and Sonoma Counties. San Pablo Bay flows into the central portion of San Francisco Bay (Central Bay) at Point San Pedro in Marin County and Point San Pablo in Contra Costa County.

Figure 2-1
Location of San Pablo Bay Watershed

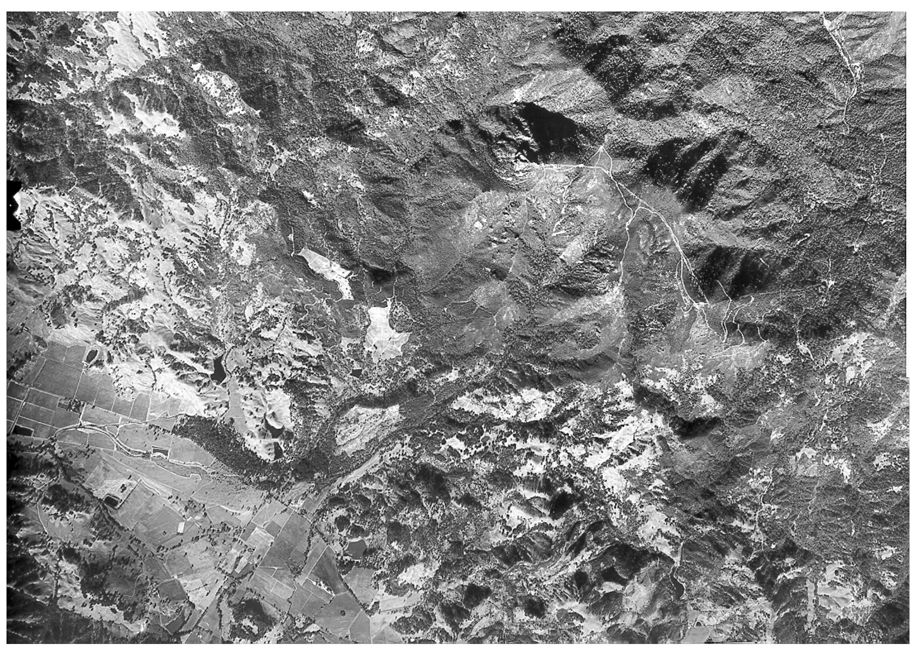
[1] Appendix A shows the project area for the Restoration Plan in relation to other U.S. Army Corps of Engineers projects in the watershed.

Geologic History

The formation of the San Pablo Bay watershed began approximately 25 million years ago (Schoenherr 1992). The watershed is located within the northern Coastal Range. The formation of the Coastal Range is generally attributed to the effects of plate tectonics, specifically, the Pacific plate sliding beneath the border of North America as the continent moved west. This movement caused uplifting, folding and faulting of both the Pacific plate and the leading edge of the continent, with the most important episode of mountain building occurring roughly 3 million years ago. This process eventually formed the parallel series of ridges and valleys that make up the present Coastal Range.

As the western edge of North America met the Pacific plate, a series of parallel faults were also formed. The primary fault in this series is the San Andreas Fault, which lies west of San Pablo Bay watershed. Known faults located within the boundaries of the watershed include the Northern Hayward, Rogers Creek and West Napa. The Concord / Green Valley Fault is located just east of the eastern border of the watershed.

Approximately 15,000 years ago, the San-Francisco Bay had not yet formed. Most of the earth's water was frozen in glaciers, which meant that sea level was 400 feet lower, and the Pacific coastline was 20 miles west of its current location (just past the present-day Farallon Islands). As the glaciers melted, the sea level rose, and the ocean moved continually eastward. The ocean passed through the Golden Gate approximately 10,000 years ago, first forming the San Francisco Bay. In more recent years, most of the glaciers had melted and the sea level rise slowed. Stabilizing the sea level allowed suspended sediments to deposit, which formed the vast system of mudflats and marshes around the perimeter of San Pablo Bay (Association of Bay Area Governments 1992).



Mount St. Helena is the northern boundary of the San Pablo Bay watershed and is the headwaters of the Napa River (Pacific Aerial Surveys).

Topography

The San Pablo Bay watershed comprises a series of parallel ridges and narrow valleys that run in a northwestern to southeastern direction, as shown in Figure 2-2. The main ridges include the Sonoma, Mayacmas and Howell Mountains, as well as the Berkeley Hills. The major valleys include the Novato, Petaluma, Sonoma, Napa and San Pablo. The valleys are very narrow in upper ends, and open into flat wide plains that merge into the San Pablo Bay.

The erosion of the Coastal Range created various physiographic regions as sediments were removed from the mountains and deposited in the valleys and into San Pablo Bay. Physiographic regions of San Pablo watershed include:

- Small mountains with elevations from 1,000 to over 4,000 feet.
- Terraces and rolling hills with elevations ranging from 400 feet to 1,000 feet.

Link to Figure 2-2
San Pablo Bay Watershed Topography (1.35 MB)

- Intermountain valleys that run into the Bay and include nearly level alluvial fans, alluvial plains, and flood plains with elevations that range from sea level to 400 feet.

- Mudflats and tidal marshes that are located along the edges of San Pablo Bay. The elevations of these areas range from below sea level to 10 feet above.

Geology

Like most of the Coastal Range, the geologic picture of San Pablo Bay watershed is very complex. Most of the watershed is composed of a melange of rock units from different sources and different ages (Schoenherr 1992). The diversity of rocks is due to the area's long history as a continental borderland. As the Pacific plate slid beneath the continent, ocean sediments and volcanic rocks lifted to form the Coastal Range. Today the San Pablo Bay watershed is underlain by a variety of rock units including shale, sandstone, consolidated sedimentary and metamorphic rock, deposits of clay(marine to brackish water), lava flows interlayed with tuff and volcanic sedimentary deposits, and fine-grained silt.

The entire San Pablo Bay and near-shore area is covered by Bay mud. Bay mud is a soft, compressible deposit of silt, clay, and peat interspersed with fine-grained sand and gravel lenses. "Older Bay mud" covers the bedrock base and was probably deposited during an interglacial period, and "younger Bay mud" began deposition about 10,000 years ago and continues today with the majority of sediment loads coming from the Sacramento-San Joaquin River system.

The great varieties of rock materials have degraded to form a corresponding variety of soils. Soils in the tidal flats, basins and basin rims comprise primarily silty clay loams that are poorly drained, strongly acidic, saline soil. Areas with these soil types are used for the production of hay or salt, or left as wildlife habitat. Soils in the flood plains, low terraces, and alluvial fans comprise loams, silt loams, clay loams, and sandy loams that range from poorly drained to well drained. These soils can be very productive and are used for many kinds of wine grape vineyards and orchards.

At higher elevations and steeper slopes, loams are present with clay, stones, and gravels, which range from well drained to excessively drained. The topography in these areas is often too steep for any crop production or grazing, thus, areas with these soil types are often used for timber, or are undeveloped habitat (USDA Soil Conservation Service 1978, 1972, 1985 and 1977).

Climate

The climate of the San Pablo Bay watershed is described as "Mediterranean," with cool to warm, dry summers and cool, moist to wet winters. The cooler climate is influenced by the Pacific Ocean, which provides a source of cool, moist air that stabilizes temperatures and precipitation. Climate varies greatly within the watershed based on local topography (Southern Sonoma Resource Conservation District 1999).

Night and morning fog, blown in from San Pablo Bay, is common all seasons of the year. Because the fog acts as an insulator, it decreases the amount of heat from the sun received in the summer, and decreases the radiation of heat from the earth in the winter. The mean annual temperature for the watershed is around 60° F. Temperature patterns vary throughout the area because of the mountainous terrain, with higher elevations recording cooler temperatures than areas at lower elevations. Areas near the Bay can also experience cooler temperatures than the interior of the watershed.

Precipitation amounts differ considerably from one part of the watershed to another due to the variable terrain. Annual rainfall amounts generally increase with increase in the elevation. The northern part of the watershed, in Napa and Sonoma Counties, averages 40 to 45 inches of rain annually, while the portion around San Pablo Bay has a mean of 20 to 35 inches (USDA Soil Conservation Service 1978, 1972, 1985 and 1977). Most of the annual precipitation falls in the winter.

Hydrology

As noted previously, the San Pablo Bay watershed is part of the San Francisco Bay-Delta Estuary, one of the largest estuaries in North America. The Estuary includes San Francisco Bay, San Pablo Bay, Suisun Bay and Sacramento-San Joaquin Delta. The Estuary watershed drains more than 40% of California's surface area. San Pablo Bay lies between the less salty Suisun Bay and the saltier San Francisco Bay (Figure 2-1).

Tidal inflows from San Francisco Bay, freshwater flows from the Delta and its own watershed, the topography of the land and the climate all have an influence on the hydrology of the San Pablo Bay watershed. Twice daily, the saline waters from San Francisco Bay flow into San Pablo Bay. The effects of the tides extend well upstream into the freshwater tributaries to San Pablo Bay. The freshwater flows are continuous, but vary on a seasonal basis due their dependence on rainfall. The topography directs all water within the watershed toward the Bay, the lowest point. On the broad, flat alluvial plains where the valleys reach the Bay, an extensive network of tidally influenced wetlands was created.

The interaction between the fresh and saline water has a major influence on the circulation of water in the San Pablo Bay itself. When freshwater and saltwater meet, the denser saltwater tends to flow under the freshwater until the waters are mixed by stronger tidal currents and winds.

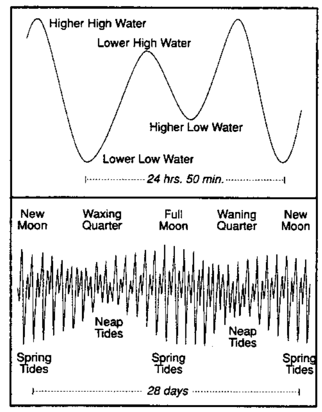
While the major source of freshwater to San Pablo Bay is inflow from Sacramento / San Joaquin Delta (over 90% on an annual basis), the San Pablo Bay watershed also has numerous rivers, creeks and small streams that all flow toward the Bay and contribute to the inflow of freshwater. The State of California recognizes 71 rivers and creeks in the watershed with a combined length of 1,100 miles (California Rivers Assessment 1997). The map in Figure 2-3 depicts these waterbodies. The major watersheds of the San Pablo Bay area are Novato Creek in Marin County, Petaluma River and Sonoma Creek in Sonoma County, Napa River in Napa County and San Pablo Creek in Contra Costa County.

Surface runoff creates the majority of freshwater flows within the rivers and streams. Consequently, stream flow in all the creeks and rivers varies enormously from season to season and from year to year depending on precipitation. Most of the water flow during a given year occurs during the rainy season, from November to April. Flows in the smaller streams located in the upper reaches of the watershed are intermittent and start to run dry after the end of the rainy season. Major streams intercept some groundwater in their lower reaches, which allows them to flow all year.

Groundwater is another important source of freshwater in the San Pablo Bay watershed, and is used primarily by agriculture and rural residents. Groundwater does not move in defined streams underground, but rather, moves slowly through

Tides

The tides within San Pablo Bay are influenced by the ocean and by upstream inflows. The tidal cycle is 24.8 hours, during which time the estuary undergoes two high tides and two low tides. The first high and low tides are more extreme than the second two, and are called the "Higher High Water" and the "Lower Low Water." The intermediate tides are more muted, and are labeled "Lower High Water" and "Higher Low Water." During a 28 day cycle, the phases of the moon will influence the extremes of the tides. Tides during the new and full moon have the greatest extremes, and are called spring tides. Neap tides occur during the moon's quarters, and have the lowest range of variability. "Mean" tides are an average over the 28-day cycle. In San Pablo Bay, the mean higher high water is 3.4 feet and the mean lower low water is approximately minus 3.0 feet, for a total tide variation of 6.4 feet.



Source: From Cohen, 1990
(graphic by Eric Vogt and Andrew Cohen)

Link to Figure 2-3
San Pablo Bay Watershed
Streams and Creeks (338 KB)

spaces in water-bearing formations called aquifers. Rain and irrigation water recharge groundwater reserves. The principal groundwater aquifers in the watershed underlie the alluvial plains of the valleys. The water-bearing formations consist of younger and older alluvium deposits, along with the volcanic and continental deposits. The principal aquifers are separated into groundwater basins based on the movement of groundwater. The major groundwater basins in the area include the Napa Valley, Sonoma Valley, Petaluma Valley and Novato Valley basins.

Stafford Lake, on Upper Novato Creek, is one of 60 water supply reservoirs within the San Pablo Bay Watershed.

The San Pablo Bay watershed contains extensive areas of various wetland types, as well as a few natural lakes and ponds. Wetlands are important to the natural hydrology of a watershed. During periods of high rainfall amounts, stream flows or tides, wetlands provide storage capacity, slow water velocities, reduce peak flows and increase the duration of flow. Many wetlands are topographic depressions that retain storm water runoff and provide supplemental capacity when rivers or estuaries overflow their banks. Some wetland soils are able to retain water like a sponge and slowly release it to the surface during periods of low water. Section 3 provides additional information regarding wetland functions.

The natural hydrology has been altered throughout the San Pablo Bay watershed. At sixty locations in the watershed, dams create reservoirs for water supply (California Rivers Assessment 1997).

An extensive system of levees extends around the edges of San Pablo Bay and along the lower reaches of some of the rivers and creeks. Farming operations used these levees as a means to reclaim the tidal wetlands for agricultural production. The levees prevent the tides from flooding these areas during each high tidal cycle. In addition, surface and groundwater are continually drained or pumped into sloughs to ensure the soils remain suitably dry for agricultural production. The levees and associated draining/pumping has changed the interaction between the fresh and saline waters at both the surface and in the ground.

Over the years, projects have altered stream channels to improve flood protection and allow for navigation. Flood control projects have been implemented along portions of the Napa River, Novato Creek, the Petaluma River and San Pablo Creek for the protection of specific urban areas and facilities. Flood control studies are currently underway for sections of the Napa River through the City of Napa, Lower Sonoma Creek and Wildcat Creek. Navigation channels are maintained in the lower portions of both the Napa and Petaluma Rivers.

The withdrawal of water from streams for both agricultural and domestic uses has affected flow rates in the streams. Lower base flow rates occur in the streams as a result of water being held in reservoirs and directly withdrawn from the streams and aquifers. Portions of Sonoma Creek and Napa Creek are “fully appropriated,” a term used by State water authorities to describe a stream that has no more water available for any purpose (State Water Resources Control Board 1998).

All five county general plans in the watershed restrict or discourage the conversion of extensive agricultural and rural lands in the project area. General Plans are, however, frequently amended to remove prohibitions against urban development.

As storm drainage systems from urban areas and agricultural fields convey storm water runoff directly to the nearest natural stream, flow rates in these streams become flashier. That is, during storm events, flow rates in the streams increase quickly and then recede in response to this inflow of runoff.

In addition to flow concerns, streams within the watershed have water quality problems. Many streams are listed as "impaired" by the San Francisco Regional Water Quality Control Board (California Rivers Assessment 1997). See Section 4 for more information on human impacts to watershed hydrology.

2.3 Land Use

Agriculture, urban development and open space comprise the largest percentage of land use in the watershed (Figure 2-4). The following section describes the most common land uses within the watershed area.

Agriculture

Agriculture is one of the dominant uses within the watershed. The following descriptions discuss the major crops within the watershed. Other agricultural uses include timber, olives, truck crops, Christmas trees, greenhouses and floral nurseries. A corollary use due to the increase in the residential population is the growth of the horse industry (breeding, boarding and training).

Oat Hay

In the diked baylands, which are the drained areas adjacent to San Pablo Bay, agricultural production is limited due to the high salinity of the soil and limited water supply. For these reasons, the only practical crop that can be grown in these areas is oat hay.

Poultry

Poultry and egg production in the Petaluma area was one of the first large-scale agricultural industries to be developed in the watershed. Poultry farming flourished from 1880 to 1960 before moving to southern California. Some poultry farming still exists within the watershed on a much smaller scale.

Dairies

With the decline of the poultry industry, the dairy industry grew. Oat hay production in the watershed provided a local source of inexpensive fodder for dairy cattle. Dairies were located throughout the watershed, with the largest concentrations found along San Antonio Creek and Adobe Creek in Sonoma County. In 1997, this area had 15 active dairies.

This is one of several dairies located in Marin and Sonoma.

Link to Figure 2-4
San Pablo Bay Watershed Land Use (347 KB)

The dairy industry and forage crop agriculture are interdependent. A reduction in forage croplands would result in higher costs from imports and could force some dairies out of business. A reduction in the number of dairies would reduce the market for forage crops and could result in the conversion of agricultural lands to other uses.

Cattle

Cattle grazing was a major land use that began nearly at the moment Spanish settlers first arrived. In the upland areas, farmers developed rangeland on hillsides to raise sheep and cattle. Grazing acreage has dropped significantly, however, as the population has increased and the agricultural economy has changed. Housing and vineyard development have replaced grazing land in many areas.

Wine Grapes

Extensive areas of the watershed are cultivated in grapes that are used almost exclusively for wine production. The Napa and Sonoma valleys contain vast areas of vineyards. New technologies are allowing grapes to be grown on steeper slopes, cooler and or drier climates, and poorer soils, and wine grape production is expected to continue to expand into other areas of the watershed.

The extent of vineyards has increased dramatically in recent years.

Urban Development

Urban development has occurred throughout the watershed. The major urban centers by county and their populations are shown in the table below.

Major Cities in the San Pablo Watershed

County	***Urban Center***	***1990 Population***
Marin	Novato	47,585
Sonoma	Petaluma	43,184
Sonoma	Sonoma	8,121
Napa	American Canyon	7,706
Napa	Napa	61,842
Napa	Yountville	3,259
Napa	St. Helena	4,990
Napa	Calistoga	4,468
Solano	Vallejo	109,199
Contra Costa	Rodeo	7,589
Contra Costa	Hercules	16,829
Contra Costa	Pinole	17,460
Contra Costa	El Sobrante	9,852
Contra Costa	San Pablo	25,158
Contra Costa	Richmond	87,425

The threat of urbanization in the San Pablo Bay watershed is increasing significantly. Much of the agricultural and open land in the area is within a 30 to 60-minute drive of San Francisco, and the market for housing within commuting distance creates pressure for the conversion of this land to residential and other urban uses. In particular, areas along Highway 101 and Highway 29 corridors are being converted to urban uses. Population trends for Marin, Napa, Sonoma, Solano and Contra Costa Counties show that Sonoma and Solano County populations are growing rapidly.

Municipal sewage ponds, adjacent to Petaluma Marsh (Pacific Aerial Surveys).

All five county general plans in the watershed restrict or discourage the conversion of extensive agricultural and rural lands in the project area. General Plans are, however, frequently amended to remove prohibitions against urban development. Various residential and public facilities projects currently proposed do, in fact, call for changes to these protective policies.

There are ten publicly owned treatment works in the watershed. These facilities are permitted to discharge up to 31.7 million gallons of treated sanitary sewage per day. The watershed also has two active solid waste landfill sites, Clover Flat in Napa County and West Contra Costa in Contra Costa County, as well as six closed or inactive landfills.

Open Space

The majority of the open space in San Pablo Bay watershed is located in portions of the watershed that are unsuitable for agriculture and housing, mainly hill sides and mountainous areas. Parkland is found scattered throughout the watershed in all five counties. Open space set aside or managed for wildlife habitat is found in several sections of the Baylands and the remaining tidal wetlands.

As discussed in detail in Section 1, large areas in the Baylands are being purchased by federal and state wildlife agencies for the purpose of restoring wildlife habitat, primarily wetlands. These sites will create new open space as their restoration efforts are completed.

Commercial Development

Wineries, which represent a large portion of commercial land use in the watershed, are located throughout the watershed, with the majority found within the Napa and Sonoma Valleys. Small commercial developments consisting of retail, office, service areas, and warehouses are located around the urban centers. Other commercial uses include the Sears Point Raceway in Sonoma County, Marine World in Vallejo, and several waterfront marinas along San Pablo Bay.

Industrial Development

As discussed in Section 1, the Cargill Salt Ponds were historically a major industrial use within the watershed. They were sold, however, to the California Department of Fish and Game in 1994 to restore the pre-existing wetland ecosystem. With the sale of the salt ponds, the main heavy industries remaining in the watershed include two oil refineries and one chemical manufacturer located in Contra Costa County, a quarry north of Sears Point Raceway and a steel pipe manufacturer in the City of Napa.

The watershed has eight inactive mine sites that were once operated for the production of magnesite, silver, or mercury.

Military Installations

The navy operated three facilities in the watershed: Mare Island Naval Shipyard, Skaggs Island Naval Reservation and Hamilton Airfield. All three are in the process of being decommissioned.

2.4 Human Habitation

Current land uses reflect the watershed's history of human habitation. Human habitation and its associated activities have shaped the San Pablo Bay dramatically over time. The cumulative impacts of human activities illustrate how the many individual factors that have shaped the condition of the watershed interrelate. Figure 2-5 shows a timeline of activities within the watershed.

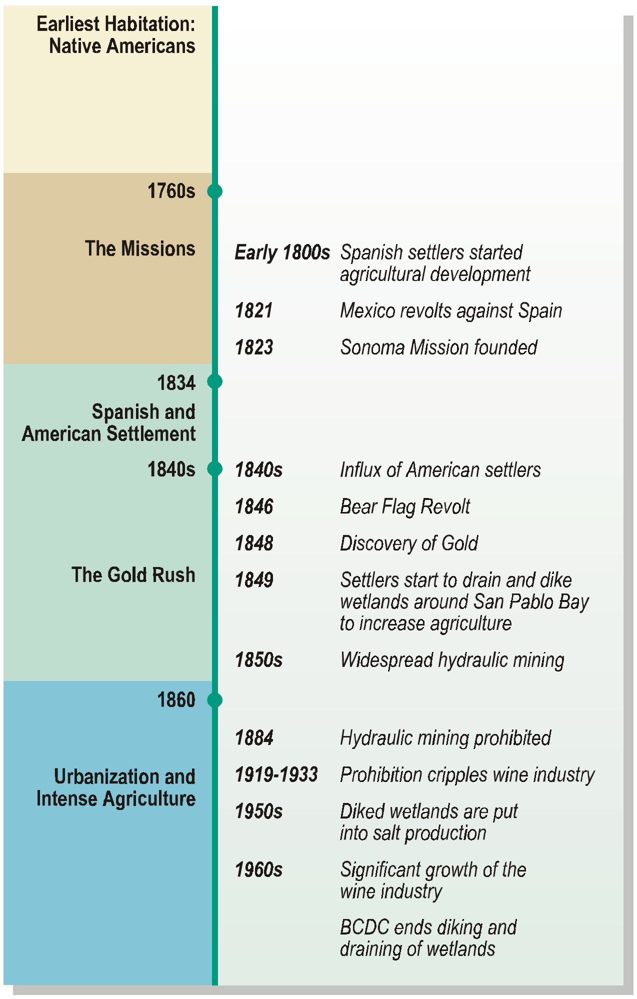


Figure 2-5
Timeline of Human Activities In the Watershed

Earliest Habitation: Native Americans

The earliest human habitation of the San Pablo Bay watershed dates back approximately 12,000 years. Numerous distinct tribes[2] of indigenous peoples populated the entire area now known as the San Francisco Bay area. Because of the abundant natural resources afforded by the estuary, these peoples lived a relatively stable existence. They were hunter-gatherers whose impact on the resources of the region was within the sustainable capacity of the ecosystem.

1760s to 1834: The Missions

Spanish missionaries began to establish missions along the California coast in 1769, in an attempt to convert the Native Americans to Christianity. The missions slowly spread northward, and the northern-most mission was started in 1823 in Sonoma. Following on the heels of friars who established the missions, the Spanish citizens arrived and started outposts in Napa, Suisun, Santa Rosa and Petaluma. Mexico revolted from Spain in 1821, and the Mexican government made the decision to secularize the missions in 1834.

It was during this part of the area's history that the first agriculture in the San Pablo Bay watershed began. The Spanish that arrived in the early 1800s used the land to grow grains and hay, cultivate wine grapes and other fruits, and to raise cattle and sheep.

1834 to 1840s: Spanish and American Settlement

With the transfer of the missions, General Vallejo and ten families of settlers took charge of the Sonoma mission to free the Native Americans and distribute lands to Mexican citizens that were willing to survey and develop the land. In practice, the land was granted to General Vallejo's friends, who established large ranchos supported by agriculture and livestock grazing, including cattle and horses. Grazing practices began to have an impact on the regional landscape through

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[2] The Native Americans that occupied the San Pablo Watershed belonged to the Coastal Miwok group. Native Americans have lived in California for at least 11,500 to 12,000 years. Probably fewer than 100,000 lived in the coastal area between San Luis Obispo County and the Oregon border. The number of Coastal Miwoks occupying the San Pablo Bay watershed would have been only a small fraction of this total.

alteration of the native vegetation. Ranchers began to fill some tidal marshes at this time, to create additional grazing land.

American citizens had been exploring California since the 1790s as a part of the fur trade, but the serious influx began in the 1840s. The Americans were joined by German, French, and Irish settlers, many of whom were unsatisfied with Mexican rule. In 1846, the American settlers overthrew General Vallejo's government at the pueblo of Sonoma during the Bear Flag Revolt. California was a republic for about a month, after which it was annexed by the United States.

1840s to 1860: The Gold Rush

It was the discovery of gold in California that precipitated the most serious alterations of the watershed's landscape. Commencing with the influx of immigrants to the gold fields in 1849 and thereafter, tidal marshes all around San Francisco Bay, including San Pablo Bay, began to be diked and drained to create grazing land and to grow hay. Wharves and railway stations were built throughout the region to ship goods.

Products from this diked land supported the burgeoning regional population. The first crop known to be grown in the reclaimed marsh was barley. Barley is one of the most salt-tolerant crops grown and is often used as part of a reclamation program. Oat hay and oats as grain soon followed. Only crops that could be planted in the early fall for harvesting in the late spring were successful in these reclaimed areas.

At this time, a movement for Statehood was broadly supported, and the ranchos were broken up or abandoned. The Treaty of Guadelupe Hidalgo purported to recognize the property rights of some of the original Spanish landowners, but, in practice, these land barons were forced out by intimidation, through economic means, or the treaty was simply ignored.

The California Gold Rush had another significant impact on San Pablo Bay. A method known as hydraulic mining was implemented to ferret out gold in the Sierra Nevada. Miners directed enormous streams of high-pressure water at entire mountainsides to blast away gold-bearing sediments. The gold was filtered out at the site of the hydraulic operation, and the "waste" sediment flowed into the streams. Up to 1.6 billion cubic yards of rock, sand, and mud flowed into mountain waterways. So enormous were the amounts of sediment flowing into the downstream areas that the bottom elevation of San Pablo Bay raised by as much as six feet. In 1884, the Sawyer Federal Court Decision prohibited hydraulic mining because it caused extensive flooding of Central Valley farmland, and well as towns, including Sacramento.

1900s: Urbanization and Intense Agriculture

By the late 19th century, urbanization of the San Francisco Bay region was well underway. Although the heart of the populated region remained in San Francisco, outlying areas were settled and developed to serve the growing populace. In the San Pablo Bay region, diking and draining of the tidal marshes continued into the 1930s, by which time fewer than 4,000 acres of the original 53,000-acres of marsh remained.

Areas in the San Pablo watershed, including the Napa, Sonoma, and Carneros regions, are famous for their wine-growing. Wine production began in the mid-1800s, but vineyard development faltered due to the combination of phylloxera, a grape disease that severely hit the region from the late 1870s to 1880s, and Prohibition (1919 – 1933). After 1935, vineyard development grew steadily. A major period of growth in the industry began in the 1960s and continues today. Currently, winegrapes are the most valuable crops in Napa and Sonoma Counties, with a 1999 value of $221.9 million and $269.3 million, respectively.

Today, this north bay region is itself a center of major cities and development. Little of the San Pablo Bay watershed has been unaffected by human occupation.

Section 3
The Ecology of the San Pablo Bay Watershed

3.1 Overview of Existing Ecological Conditions

The San Pablo Bay watershed is a rich, unique and diverse ecological system in which adverse trends threaten a variety of high value habitat types. Understanding the forms and functions of these habitat types, along with the species to which they are important, will provide restoration proponents necessary background for developing effective projects and programs to address the stressors that affect these habitats and repair the damage caused by those stressors.

Evolutionary history, varied topography, unusual soils and geology, wide differences in local climate, and the estuarine influence create a diverse array of habitats ranging from aquatic to xeric terrestrial types. In the San Pablo Bay watershed, these habitats form a mosaic pattern across the landscape, with the transition zones between adjacent habitat types, called ecotones, also providing important physical and ecological attributes for the local biota. The following section (Section 3.2) describes the major habitat types, including open water, wetlands, lakes and ponds, rivers and stream corridors, and upland habitats, and plant and animal assemblages that use them. Additional information on the major taxa and representative species is in Section 3-3. More complete (but not exhaustive) lists of species and supporting information on their status and habitats are in Appendix B.

3.2 San Pablo Watershed Habitat Types

The San Pablo Bay watershed includes numerous habitat types and comprises six distinct sub-watersheds (see Figure 2-2). Ephemeral and permanent streams that drain into San Pablo Bay define many smaller drainages, which can be difficult to delimit because, in some cases, their historic drainage patterns have been altered by storm drain and flood control projects. Virtually all of these watersheds, large or small, include multiple habitat types, from aquatic lowland habitats to terrestrial upland habitats (see Figure 3-1). These habitats are important to a wide diversity of plants and animals.

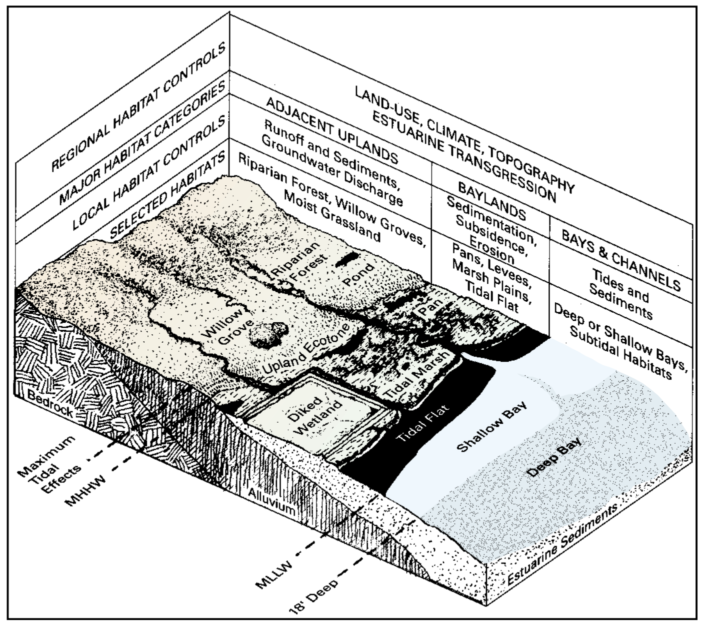


Figure 3-1. Habitat types within the San Pablo Bay Watershed (from Goals Project 1999 and Helley et al. 1979)

The San Pablo Bay watershed habitats may be categorized by their physical and biological characteristics and current management regime, contrasting naturally occurring habitats with those that were created by humans and are actively managed. Many managed habitats have habitat values and functions that attract wildlife, while many of the "naturally occurring habitats" have been heavily modified, blurring the distinction between the two categories. Table 3.1 lists the major habitat types found within the watershed, including both natural and managed habitats. Table B-1 in Appendix B relates the habitat classification scheme in Table 3-1 to similar, previously developed schemes.

The following subsections describe the distinguishing features of these habitat types, their functions, and provide examples of the species that inhabit them. The effects of human habitation on each habitat is summarized under the "trends and stressors" heading of each subsection.

Table 3-1: San Pablo Bay Watershed Habitat Types

Open Waters of San Pablo Bay
The Open Waters of San Pablo Bay are those tidally influenced areas that are permanently submerged. The amounts and variability of freshwater inflow and the twice-daily tides largely control environmental conditions in the open-water habitat.
Wetlands
Tidal Wetlands: Tidal wetlands are characterized by intermittent tidal inundation and the presence of emergent vegetation such as Pacific cordgrass and pickleweed. They are located between the levels of the lowest low tide and the highest high tide. Low tidal marshes are distinguished from high tidal marshes by longer periods of inundation and differing plant communities.
Mudflats: The extensive shallow-water mudflats located along the edge of San Pablo Bay are largely unvegetated except for algae, but are nonetheless highly productive, biologically rich habitats. Invertebrates such as clams, worms, mussels, shrimps and crabs occur in large numbers on and in the mudflats.
Freshwater Wetlands: Freshwater marshes are found adjacent to creeks and rivers in the upper San Pablo Bay watershed, above the influence of the tides. Freshwater marshes, sometimes called "tule marshes", are characterized by emergent vegetation such as tules, reeds, cattails and rushes.
Seasonal Wetlands (including vernal pools): Seasonal wetlands typically form in shallow topographical depressions that pond rainwater for a prolonged period of time, usually between one and six months.
Diked Baylands: Tidal wetlands, sloughs and waterways that were diked to "reclaim" land, usually for agriculture, are referred to as "diked baylands."
River & Stream Corridors
The River and Stream Corridor is an ecosystem composed of three major elements: the stream channel, the floodplain including the riparian zone, and the transitional upland fringe.
Lakes & Ponds
Lakes, ponds and reservoirs: Lakes and ponds are scattered throughout the region and are found behind levees on reclaimed islands. Reservoirs are predominantly found in the upper reaches of the watershed, where many streams have been dammed.
Man-made salt ponds: Salt ponds are converted tidal wetlands where salt was commercially extracted from bay water by evaporation.
Uplands (Terrestrial Lands)
Perennial grasslands: Grassland vegetation dominated by grasses and sedges was once widespread along the shores of the San Pablo Bay and in upland areas prior to European settlement. Historic grasslands were composed primarily of perennial bunch grasses and rhizomatous grasses, and were dominated by purple needlegrass and creeping "wild rye". Dominant species of present day communities are "wild" oats, soft chess, ripgut brome, and Italian ryegrass.
Oak woodlands: Oak Woodlands habitat is dominated by oak trees and is common throughout California's valleys, foothills, and lower mountain ranges. In the North Bay, there are three recognized types of oak woodland, based on species dominance: Coast live oak woodland, Valley oak woodland, and Foothill oak woodland.
Chaparral/Scrubland: Chaparral dominates areas of poor rocky soils on the hills surrounding the San Pablo Bay watershed. Dominant chaparral species are evergreen, densely branched, woody summer-dormant shrubs with small, thick, stiff leaves that are adapted to dry conditions, are highly adapted to fire and regenerate quickly.
Mixed evergreen forest: Mixed evergreen forest is mostly restricted to north-facing hill slopes in the San Pablo watershed. The dominant species include California bay laurel, bigleaf maple, and madrone with associated species such as coyote brush, California huckleberry and poison oak.

3.2.1 Open Water

The open water habitat of the San Pablo Bay watershed includes all tidally influenced areas that are permanently submerged. San Pablo Bay itself is a relatively shallow expanse of open water, averaging less than 10 feet deep and covering over 100 square miles. Intertidal mudflats, wetlands and rocky shores ring San Pablo Bay.

Description of Open Water Habitat

Environmental conditions in open water habitat are largely controlled by the amounts and variability of freshwater inflow and the twice-daily tides. Inflow from the bay's largest tributaries, the Sacramento and San Joaquin Rivers as they flow through the Delta, is the dominant influence, ranging from 4-70 million acre feet per year (see Figure 3-2). By comparison, the Napa and Petaluma Rivers, which drain the two largest San Pablo sub-watersheds, contribute less than 300,000 acre feet per year, with most inflow occurring from November to April (CALFED 2000).

Seasonal and annual variability in salinity, an important parameter influencing the ecology of open water habitat, is determined by the amount of freshwater inflow into San Pablo Bay. Salinity can vary from essentially freshwater conditions following heavy rains or rapid Sierra snowmelt, to very saline conditions during periods of low runoff, typical in the fall. The bay's responses to freshwater flows from the Delta are somewhat modulated by coastal ocean conditions such as wind direction, the spring upwelling of deep ocean water and El Nino events (warm winds and currents that typically occur every three to seven years) (SFEP 1997). Changes in inflow and salinity produce cascading effects on physical, chemical, and biological factors that resonate through the ecosystem, affecting productivity, distribution and species survival.

As in most open water systems, primary productivity is dominated by microscopic phytoplankton (floating algae). Additional primary production from benthic algae, bacteria, and sea grasses is also important. Phytoplankton and bacteria take up nutrients and carbon from rivers, fringing marshes and wastewater discharge. These organisms in turn support zooplankton (microscopic floating animals), shellfish, crabs, shrimp, fish, waterfowl and many other species. Bacterial production studies suggest that San Francisco Bay is "food limited" compared to other estuaries (Hollibaugh 1999).

The shallow San Pablo Bay has more submerged aquatic vegetation than any other part of the estuary. The only flowering plant found in open water habitat is eelgrass, which occurs in shallow areas that are seldom, or never, exposed by the tides. Few eelgrass beds remain in the estuary; a population near Point San Pablo is the species' northernmost occurrence. San Pablo Bay contains more acres of eelgrass than any other water body of the Bay-Delta System (CALFED

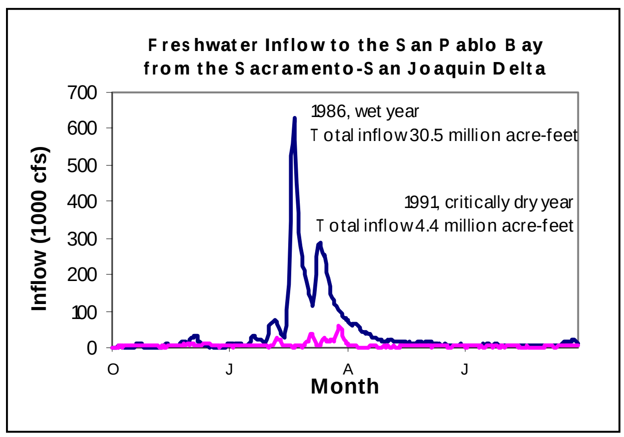


Figure 3-2. Inflows to San Pablo Bay

1999b). Eelgrass beds are valuable as a food source for invertebrate grazers, as well as a nursery ground for juvenile salmon, rockfish, Pacific herring and other fishes.

Invertebrate animals inhabiting the bottom sediments and water column of San Pablo Bay include nematode worms, flatworms, ribbon worms, segmented worms, echinoderms, bivalves, snails and crustaceans. The distribution of invertebrates in the open bay depends largely on differences in salinity levels.

The Asian Clam

The Asian clam (*Potamocorbula amurensis*) was first reported in the San Francisco Bay estuary in 1986. Within two years, this small invader was distributed from Suisun Bay to the South Bay, achieving densities in excess of 30,000 clams per square meter. In most years, the brackish San Pablo Bay is the center of Asian clam distribution. The clam is an extremely effective filter feeder, capable of removing virtually all of the phytoplankton from surrounding waters. In areas with high clam densities, the normal summertime phytoplankton bloom, critical to support zooplankton and planktivorous fishes, has failed to occur. Establishment of the Asian clam has been implicated in the declines of native estuarine fishes in Suisun Marsh and is almost certainly impacting San Pablo Bay open water and marsh habitats similarly.

Salinity levels also affect the distribution of fishes, of which there are more than 40 species in San Pablo Bay. In general, the eastern, upstream region of the Bay supports more estuarine species and has fewer marine species. Marine fishes occur in San Pablo Bay either seasonally or in dry years, when freshwater flows are low. Resident estuarine species include longfin smelt, starry flounder, and staghorn sculpin. The principal marine species are jacksmelt, shiner perch, Pacific herring, bay goby and white croaker. Several species of anadromous fishes also use the San Pablo Bay as a nursery ground during their juvenile stages. Juvenile salmon and striped bass are commonly found in the Bay's brackish waters from February to July.

The open waters of San Pablo Bay and adjacent salt ponds are of particular importance to the survival of the diving ducks. Two-thirds of the west coast population of canvasback ducks winter in the area. Canvasbacks feed on submerged vegetation, bent-nosed clams and other bottom dwelling animals. The open water also provides an important resting area for canvasbacks and other waterfowl.

Open Water Trends and Stressors

Sedimentation has converted some subtidal open water habitats to tidal marshes, effectively decreasing the size of the San Pablo Bay open water habitat. Aquatic foodweb productivity has declined over the past several decades due to a combination of factors, including: the loss of tidal exchange, changes in freshwater inflow patterns (including reduced inflow resulting from water diversions), changes in water quality (including altered salinity patterns and increased pollution), loss of wetland habitats and the introduction of exotic species. These changes have also contributed to population declines in numerous open water species.

3.2.2 Wetlands

The San Pablo Bay watershed contains extensive, complex and diverse wetlands (see Figure 3-3). There is some variation in what is meant by the term "wetland," so two widely used definitions are presented here. The U.S. Fish and Wildlife Service defines wetlands as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following three attributes:

(1) At least periodically, the land supports predominately hydrophytes (water adapted plants),

(2) The substrate is predominately undrained hydric soil, and

(3) The substrate is nonsoil and is saturated with water at some time during the growing season of each year" (Cowardin 1979).

Link to Figure 3-3
San Pablo Bay Watershed
Wetland Types (6.60 MB)

The definition above is more inclusive than the one used by the Corps for their wetlands-related permitting. By that definition, wetlands are "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (33 CFS 328.3(b) 2000)." For this section, which is focused on ecology and variability of wetlands rather than strict legal definitions, the Fish & Wildlife Service version will suffice.

The wetland habitats, their ecology and characteristic plants and animals vary geographically, seasonally and functionally. Classification and functions of these wetland types are discussed below, along with more detailed descriptions of wetland habitat types, information on wetland species and wetland habitat trends and stressors.

Wetland Classification

Several characteristics help classify wetland habitats, including: tidal influence on the wetland, if any; the level, frequency, and duration of inundation by fresh, brackish or saline water; salinity; and the degree of management.

Tidal Wetlands

Tidal wetlands are characterized by regular inundation and exposure that varies with tidal cycle.

Topographically, tidal wetlands are located between the levels of the lowest low tide and the highest high tide (see Figure 3-1). Low tidal marshes are covered with tidal waters for longer periods each day than are high tidal marshes. Tidal mudflats, the lowest of the tidal wetlands, are unvegetated. Above these are low tidal marshes, followed by high tidal marshes. The degree of tidal inundation affects many physical characteristics of wetlands. For example, soil salinity may be considerably higher in high marshes, due to infrequent flushing by the tides.

Seasonal or Permanent Wetlands

Non-tidal wetlands can be classified as "permanent" or "seasonal" depending on how long they are ponded or saturated with water each year. Permanent wetlands hold water year-round except in very dry years. Seasonal wetlands generally dry out each spring or summer. Residents of seasonal wetlands must leave these habitats during the dry season or, as is the case of many invertebrates and plants, enter a dormant stage. Some non-tidal wetlands occasionally receive tidal waters when unusually high tides overtop the dikes.

Freshwater or Saline Wetlands

Wetlands are categorized as freshwater, brackish, or saline based on the salinity of the marsh soils. Marsh soil salinity is strongly influenced by water salinity, but also by the degree to which salts are retained or leached from the soil. Marshes of intermediate salinity are called brackish. In San Pablo Bay, as in all estuaries, these marshes occur along a saline gradient, freshwater tidal wetlands are located along streams near the upper end of tidal influence, followed by brackish and saline wetlands as one is nearer the downstream confluence with the bay. The pattern is particularly complicated in the San Pablo Bay watershed due to the overarching influence of the Sacramento and San Joaquin River systems.

Managed or Unmanaged Wetlands

The term "managed wetlands" is generally applied to wetlands in which water levels or vegetation are manipulated to achieve specific habitat objectives. Most managed wetlands surrounding the San Pablo Bay are located on state or federal wildlife refuges or private hunting clubs, and most are managed primarily to benefit wintering or breeding waterfowl. Some wetlands are also managed for flood control or mosquito control. "Unmanaged" wetlands may receive occasional management such as weed control or levee repairs, but are not managed intensively on an annual basis.

"Farmed wetlands" are areas that would function as wetlands if it were not for the disking, draining, and planting associated with an ongoing agricultural operation. In the San Pablo Bay watershed, these include many of the diked baylands that are currently being farmed.

Wetland Functions

Wetland habitats may differ in certain characteristics, but they share important functions that make their restoration a critical goal. Wetlands provide valuable fish and wildlife habitat and food web support, improve water quality, moderate groundwater discharge and recharge, and provide flood and erosion protection. Table 3-2 describes wetland functions in more detail.

Table 3-2: Wetland Habitat Functions
Habitat and food for fish and wildlife.
Wetlands are among the most productive of all ecosystems, capturing, recycling and exporting nutrients and providing a structurally complex habitat for resident and migratory animals. The primary and secondary production generated in wetlands is an important contributor to the downstream estuarine and open water food web. In the San Pablo Bay watershed, wetlands are critically important rearing and foraging habitat for a wide variety of fish and wildlife.
Water Quality Protection.
Wetlands function to improve water quality by removing sediments, nutrients and other pollutants from influent water. Through a variety of physical, chemical and biological mechanisms, wetlands can retain pollutants that occur naturally, as well as contaminants from municipal wastewater and urban runoff, or transform them into forms that are less toxic to plants and animals. However, the capacity of wetland sediments to absorb contaminants is finite, and contaminated wetlands can serve as a source of pollutants.
Groundwater Discharge and Recharge
Wetlands most frequently function as groundwater discharge areas, areas in which the net movement of water is from the ground to the surface, rather than groundwater recharge sites, where surface water is transferred into the underlying aquifer. Groundwater discharge areas are represented on the surface by seeps and springs. Some riparian wetland soils retain water like a sponge and slowly release it to the surface during periods of low water. This retention of water helps to reduce the extent of flooding during periods of heavy rainfall.
Flood and Erosion Protection
Wetlands reduce the harmful effects of flooding by providing flood storage, slowing water velocities, reducing peak flows, and increasing duration of flow. Many freshwater and riverine wetlands are topographic depressions that retain stormwater runoff and provide supplemental channel capacity when rivers overflow their banks. Vegetation in floodplain wetlands can double the friction coefficient of water flow compared to channels without vegetation, decreasing water flow velocities and reducing potential flood-peaks in downstream areas. Vegetated wetlands also help to reduce erosion by stabilizing shorelines. Permanent and seasonal surface water flows, as well as tidal water movements and wave action, can erode and destroy unprotected shoreline areas, especially in those areas where aquatic vegetation has been removed.

Wetland Habitats

Wetlands in the San Pablo Bay watershed can be grouped into five broad categories: intertidal mudflats, tidal wetlands and sloughs, non-tidal freshwater marshes, seasonal wetlands and diked baylands. As noted previously, this classification scheme is compared with other, previously developed schemes in Table B-1 of Appendix B.

Intertidal Mudflats

The extensive shallow-water mudflats located along the edge of San Pablo Bay are largely unvegetated except for algae, but are nevertheless highly productive and biologically rich habitats. Tidal action, currents, and variations in salinity make mudflat communities susceptible to rapid change, so they are usually dominated by colonizer species that develop quickly, mature rapidly and have high reproductive rates.

Invertebrates such as clams, worms, mussels, shrimps and crabs occur in large numbers on and in intertidal mudflats. They are also important foraging, nursery and rearing habitat for many estuarine and marine fish species. Sharks, skates, rays and flatfishes (e.g., flounders, sole) are common. In many years, juvenile striped bass, an important sport fish in the San Francisco Bay-Delta, are the most abundant species present in the habitat. Other resident estuarine species include longfin smelt, starry flounder and staghorn sculpin. Marine species like white croaker, bay goby, jacksmelt and shiner perch are more likely to utilize this habitat in dry years.

San Pablo Bay mudflats provide an essential feeding and staging area for hundreds of thousands of shorebirds (e.g. sandpipers and plovers) of the Pacific Flyway, a bird migration corridor that stretches along the Pacific coast between Alaska and South America. When the tide ebbs, shorebirds such as sandpipers, curlews and dowitchers invade the mudflats, sweeping the surface for small clams, pecking and probing for organisms a few inches under the mud. Of the 1.2 million shorebirds that visit the San Francisco Bay in some years, about 25% are found around San Pablo Bay (ABAG 1992). In addition, harbor seals haul out on mudflats and marsh plains on Lower Tubbs Island for resting during low tides.

<u>Trends and Stressors in Intertidal Mudflats</u>
Tidal mudflats in the San Pablo Bay have been strongly influenced by human activity. From 1856 (the earliest detailed hydrographic survey) until the late 1800s, tidal mudflat area grew in response to the great influx of hydraulic mining debris. Later, as the influx of mining debris declined, mudflats eroded rapidly. Mudflat area stabilized in the early to mid-1900s and later re-eroded at a rate of about 90 acres per year from 1951 to 1983. This latest episode of erosion could be a result of dam building and water project operations on the Sacramento and San Joaquin Rivers, which reduce sediment supplies. (Jaffe et al. 2000). Not only have tidal mudflats changed in area, but exotic species modify and in some cases threaten the very existence of mudflats. The introduced Atlantic salt-marsh cordgrass *Spartina alteniflora* may lead to the rapid infill of mudflats and ultimate conversion of these areas to high marsh if measures are not taken to control its spread (See Section 3.4).

Tidal Wetlands and Sloughs
The presence of emergent vegetation distinguishes tidal salt marsh from mudflat

Birds in a Restored Tidal Wetland

Restored tidal wetlands can rapidly become well-utilized foraging, resting, and breeding habitat for many aquatic birds.

In the winter of 1976-1977, the deteriorating levees protecting White slough (northwest of the city of Vallejo near Highway 37) were breached, allowing water from the Napa River to tidally inundate the previously reclaimed land. Less than two years after “restoration” of the tidal wetland, piscivorous birds such as grebes, cormorants and pelicans, wading shorebirds such as egrets, herons, willets, and sandpipers, and many species of ducks were observed actively feeding and/or resting in the shallow water and exposed tidal flats.

The bird community varied with season and utilized different parts of the habitat on a tidal cycle. Throughout the year, shallow tidal flats provided good foraging for piscivorous birds that fed on the tidal influxes of small fishes (probably yellowfin goby, threespine stickleback and topsmelt, species that were collected in concurrent fish surveys). Most of the shorebirds that used the slough were migrants, using the habitat for foraging and resting, dependent on tidal cycles. During the winter, large numbers of ducks loafed and foraged.

The tidal dependence of habitat use by shore birds observed in these surveys demonstrates the importance of topographic and vegetative complexity in this type of wetland. Mudflat and marsh that was regularly inundated and adjacent upland habitat above the high tide were utilized alternately as foraging and refuge habitat during the tidal cycle. In inundated areas, water depth in the slough varied temporally with the tides and geographically from north to south. Deeper water maintained in the southern portion of the slough by a check dam was generally less attractive to shorebirds although one species, black-necked stilts, bred successfully on islands in the southern slough isolated and protected by high water.

Source: (US Fish and Wildlife Service 1981) habitat. A high-quality tidal marsh has many specific properties, including:

- An unrestricted tidal range (e.g. without levees) that allows sediments, nutrients, and plant propagules to move in an out of the system;
- A well-developed system of tidal channels;
- Pans in the marsh plain;
- Native plants and animals;
- A natural transition to upland habitats;
- Connections to other patches of tidal marsh to enable the migration of birds and other wildlife; and
- A wide upland buffer to minimize human disturbance (Goals Project 1999).

Salinities and duration of tidal inundation, which reflect small differences in elevation, determine the zonation of plant communities into low, middle and high marsh. Lower elevations receive greater tidal flushing and therefore have lower salinities. The reverse is true for higher elevations, which receive little flushing and therefore allow salts to accumulate through evaporation. Pacific cordgrass (*Spartina foliosa*) dominates the low marsh zone from mean sea level to mean high water, and Pickleweed (*Salicornia spp.*) dominates the middle marsh zone above mean high water. Alkali heath, gumplant and saltgrass are among the species found in the more botanically diverse high marsh zone (Josselyn 1983).

Sloughs, also called tidal creeks, are also an important feature of many tidal salt marshes. Like rivers, sloughs develop along irregularities in the marsh plain, eventually forming defined channels. Sloughs provide aquatic species important access to the marsh plain. Many fishes are known to follow the channels out into the marsh plain to feed during high tides.

The confluence between tidal salt marshes and freshwater rivers creates a salinity gradient from saline to freshwater that influences the vegetation and wildlife that inhabit tidally influenced marshes. This gradient, superimposed on the natural variation due to tides, causes tidal marshes to be characterized by a rich mosaic of vegetation communities. Tidal brackish marshes, which are less salty than true salt marshes due to freshwater inflows, are found in the lower reaches of the Gallinas Creek, Miller Creek, Novato Creek, Petaluma River, Tolay Creek, Sonoma Creek and Napa River. Tidal brackish marshes also have three zones of plant growth: low marsh dominated by California bulrush; middle marsh dominated by a mixture of cattail and bulrush; and high marsh dominated by more salt-tolerant species such as saltgrass and Baltic rush. Tidal freshwater marshes are similar to other freshwater marshes (see following section).

Tidal marshes are among the most productive habitats and support a diversity of wildlife species. Birds commonly seen in the San Pablo Bay tidal marshes include: the great blue heron, great egret, snowy egret, black-crowned night-heron, Virginia and Sora rails, and the northern harrier; various dabbling ducks such as mallard, cinnamon teal and northern pintail; shorebirds such as black-necked stilt, willet and long-billed curlew; and the marsh wren. Various native mice, shrews and voles are commonly found in tidal marshes (See Appendix B). The non-native muskrat and red fox are also found here.

<u>Trends and Stressors in Tidal Wetlands and Sloughs</u>

At one time, tidal marshes in San Pablo Bay were extensive and they graded gently into low-lying moist grasslands. Farmers began diking and draining the tidal marshes in the 1850s, encouraged in part by the federal Arkansas Act of 1850 and by subsequent state legislation, the Green Act of 1868. While most of the wetlands near San Pablo Bay and the mouths of the major rivers were once tidal, about 75% of the tidal wetlands in the San Pablo watershed have now been diked. In addition to the loss of these habitats, hydrological modifications have caused shifts in their locations.

Freshwater Marshes

Freshwater marshes are found along the margins of the river reaches of various creeks and rivers above the tidal influence in the San Pablo Bay watershed. These are permanent, non-tidal freshwater wetlands that grade into seasonal wetlands in some locations. Plant species range from partially submerged or floating aquatics to amphibious and riparian plants. As in seasonal marshes (see below), some plant species begin their lives as aquatics, but become xerophytes during summer drought.

Freshwater marshes, sometimes called "tule marshes," are characterized by emergent vegetation such as tules, reeds, cattails and rushes. Freshwater emergent marsh vegetation also occurs on channel bottoms of intermittent creeks during late spring and summer months when low flow conditions favor its development (Questa Engineering Corporation 2000). These plant species are not mixed together randomly; species distributions are controlled by the depth of water and the flow regime (Mitsch and Gosselink 1993). Emergent marsh can be found along creeks where the canopy cover is relatively open or absent, usually between willow and shrub thickets. Emergent marsh also occurs in flood control channels with artificially widened bottoms in which late season flows tend to spread out and slow down.

Spaces between tules and cattails are usually covered by a dense canopy of herbaceous submersed and amphibious species such as water plantain (*Alisma Plantago-aquatica*), willow herb (*Epilobium ciliatum*), monkey flower (*Mimulus guttatas*), water smartweed (*Polygonum amphibium* and *P. punctatum*), speedwell (*Veronica americana*) (Questa Engineering Corporation 2000). Floating aquatic plants include duckweed (*Lemna sp.*), Azola fern (*Azola sp.*) and waterweed (*Ludwigia peploides*), which are present in areas of standing water, free of emergent vegetation.

<u>Trends and Stressors in Freshwater Marshes</u>

Urban development, agriculture and other activities have decreased the areal extent of freshwater marshes, but the effects of these impacts have not been quantified.

Seasonal Wetlands

Seasonal wetlands typically form in shallow topographical depressions that pond rainwater for a prolonged period of time, usually between one and six months.

These habitats have both wetland and upland characteristics, depending on the season. In the latter part of the wet season, seasonal wetlands typically become flooded and support wetland vegetation and wildlife. In the late spring and early summer, seasonal wetlands begin to dry out, and in the late summer and fall, the habitat is dry and functions as upland habitat. Vegetation in seasonal wetlands varies greatly depending on soil salinity and the extent of seasonal inundation. Four types of seasonal wetlands occur in the San Pablo Bay watershed, characterized by salinity and dominant plant species: (1) saline seasonal wetlands that include stands of pickleweed with brass buttons; (2) brackish seasonal wetlands that include pickleweed with alkali bulrush; (3) freshwater seasonal wetlands that include spike-rush and purple loose-strife; and (4) vernal pools.

Most of the 6,800 acres of vegetated seasonal wetlands in the San Pablo Bay region are found along the Petaluma and Napa Rivers (Partnership for the San Pablo Baylands 1999). In areas near San Pablo Bay and the mouths of the major rivers, seasonal wetlands are most often found in diked baylands and abandoned salt evaporation ponds (Cowardin 1992). Although some seasonal wetlands may have occurred naturally in these areas before diking, most of the historic seasonal wetlands were found further inland. Today, most of these habitats are gone, although in the Novato area remnant seasonal wetlands are found in agricultural areas adjacent to riparian areas (Questa Engineering Corporation 2000). The new seasonal wetlands in the diked baylands provide habitat values similar to the ones that have been lost.

The value of seasonal wetlands to waterbirds is generally related to the duration of ponding in winter and spring. Even though ponding typically persists for only a few months each year, the wet period coincides with periods of high concentrations of waterfowl and shorebirds that occur during winter migration. Rainwater and inundation trigger soil-dwelling invertebrates to move to the surface or to hatch from dormant eggs. Certain small invertebrates such as brine shrimp (anostracans), seed shrimp (ostracods), copepods and water fleas (cladocerans) are uniquely adapted to the parched-to-flooded hydrologic regime of seasonal wetlands. They persist through the dry season in cysted eggs, which hatch with the winter deluges. These invertebrates are an important food resource for waterfowl and shorebirds. These birds in turn attract raptors, such as peregrine falcons, merlins, and northern harriers, which may prey on small birds and mammals.

Seasonal wetlands are also a refuge for tidal marsh and mudflat species. When high tides cover intertidal mudflats and tidal marshes, or during major storms, seasonal wetlands provide alternative shelter and roosting habitat for shorebirds such as greater yellowlegs and killdeer, waterfowl such as cinnamon teal and gadwall, as well as gulls and terns. Relatively few waterbirds nest in seasonal wetlands, because these habitats typically dry out before the end of the nesting season. Upland birds and mammals use seasonal wetlands in the dry season, but are replaced by the wetland wildlife species during the wet season.

<u>Trends and Stressors in Seasonal Wetlands</u>
Urban development, agriculture and other activities have decreased the areal extent of seasonal marshes, but the total impact of humans on this habitat type is not well understood.

Diked Baylands
Tidal wetlands, sloughs and waterways that were diked to “reclaim” land, usually for agriculture, are referred to as “diked baylands.” Unlike the other four habitat types discussed in this section, diked baylands only exist because of human modifications. The conversion of tidal wetlands to diked non-tidal wetlands has greatly reduced the habitat value of these areas for many wildlife species; however diked wetlands do support wildlife that feed, reproduce, rest, and take cover in wetland and upland portions of these areas.

Diked baylands include a variety of habitat types that are similar to natural systems (e.g. seasonal wetlands), but because the hydrology of the system is so changed, the habitats are “misplaced”. Many of the diked bayland habitats are highly managed (e.g. for agriculture or duck clubs) and often serve dual purposes. Some diked agricultural lands bordering the San Pablo Bay also function as detention basins for local flood control and wildlife support. Managed diked wetlands support wildlife while they provide recreation for duck hunters and generate revenue. Some diked baylands are farmed, usually for oat hay. Most of these areas function as uplands, at least for much of the year, but portions of them function as seasonal wetlands, with the acreage increasing considerably in wet years. These areas can provide important forage and refuge areas for wetland bird species during high tides or heavy rains, as well as roosting and nesting areas for upland birds. Seasonal wetlands on diked baylands are especially important because their formation coincides with the winter arrival of migratory waterfowl, waders and shorebirds.

In the baylands, managed diked wetlands are owned primarily by private hunting clubs and state wildlife agencies, and are managed to provide ponding and wetland vegetation

40,000 acres of tidal marsh like the above were diked and drained to create agricultural lands within the San Francisco Estuary

attractive to migratory waterfowl. Fresh water is directed into the managed marshes, and water levels are manipulated so that native and introduced plants favored by waterfowl can become established. Such plants include alkali bulrush, smartweed, brass buttons and marsh timothy. Plants such as cattail, California bulrush and Baltic rush provide cover for waterfowl and other birds. Marsh management is directed mostly at dabbling ducks, especially mallard, northern pintail, northern shoveler and American widgeon.

Trends and Stressors in Diked Baylands
Of the 280 square miles of tidal wetlands originally diked off from the San Francisco Estuary (excluding salt ponds and managed wetlands), over 70% were filled by 1982. The remaining unfilled diked baylands consist of uplands, ponds, lagoons, marshes and other wetlands. Most of the uplands are in agricultural use, primarily hay fields and pastureland. These areas, as well as marshes, are threatened by urban development.

3.2.3 Lakes and Ponds

This habitat category includes freshwater lakes and ponds, reservoirs as well as salt ponds.

Salt Ponds

Salt ponds, which are a managed habitat type, are converted tidal wetlands where salt was commercially extracted from bay water by evaporation. Depending on the stage in the process and the presence of fresh water, pond salinities can range from brackish to very saline. All of the San Pablo Bay watershed salt ponds have been retired from commercial production, with land management transferred to California Department of Fish and Game (Lewis Environmental Services, Inc. 1992).

Many plant and animal communities in the salt ponds are strongly influenced by the salinity of the water and soil. Although few species occur in ponds with salinities greater than 200 ppt, brine shrimp, brine flies, water boatmen and clams, all of which are eaten by birds, can exist in the ponds with intermediate salinities of 10 to 200 ppt (ABAG 1992, CDM 1999). Brine shrimp also are harvested commercially.

Salt ponds of intermediate salinities, where some vegetation occurs, provides seasonal foraging, roosting and nesting habitat for waterbirds. Salt ponds and levees provide nesting habitat for endangered western snowy plovers along with Caspian and Forster's terns. Double-crested cormorant, northern pintail, American wigeon, northern shoveler, canvasback, ruddy duck, American coot, dunlin, western sandpiper and American avocet also use the salt ponds in large numbers, especially during spring and fall migration and in some cases for overwintering. Large numbers of red-necked phalaropes, along with lesser concentrations of red and Wilson's phalaropes, feed on the brine shrimp in the salt ponds, primarily during the spring and fall migrations.

Trends and Stressors in Salt Ponds
As described in section 2.3 and in the case study of section 5.2.4, the salt ponds formerly owned by Leslie Salt and then Cargill Salt are now being prepared for restoration work by the California Department of Fish and Game and other partners. As a result, there is a significant research effort to study this area in preparation

to restore it (see Salt Pond Research sidebar). Future restoration has the potential to reverse the significant habitat losses that have occurred as a result of the conversion of these previously farmed lands to salt ponds.

Freshwater Lakes and Ponds

Lakes and ponds are scattered throughout the San Pablo Bay watershed, though few are naturally occurring. Man-made lakes are prevalent as a result of dams constructed along streams and outlets of natural lakes. Levees can also create lakes by trapping water when agricultural pumping ceases on reclaimed "islands."

Most of the lakes and reservoirs in the watershed are stocked with rainbow trout and catfish and are important for recreational sport fishing. Though reservoirs function differently than natural systems, they have value in terms of ecosystem support. For example, Lake Hennessey, located in northern Napa County, is the largest reservoir in the watershed and is frequented by bald eagles, osprey, and many other bird species. Ponds, which are smaller than lakes, can be classified as perennial or seasonal. Nearly all ponds in the watershed support simple invertebrate communities, and many are surrounded by riparian habitat (see below) that attracts wintering waterfowl (CALFED 1999b).

Trends and Stressors in Freshwater Lakes and Ponds

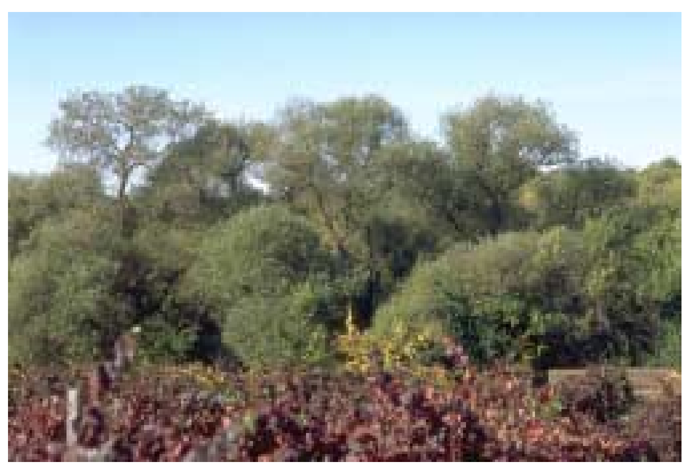
As uplands were developed and tidal marshes diked and drained, lakes and especially ponds frequently disappeared from the landscape or became significantly reduced in size. Lake Tolay, for example, was once an extensive inland lake in the hills between the Sonoma and the Petaluma marshlands, covering several hundred acres--many times larger than the total area of all other perennial, non-tidal lakes and ponds in the watershed (Goals Project 1999). The current value of managed seasonal ponds is intensified by the loss of natural seasonal ponds that existed prior to human habitation. In upland areas there are more inland lakes than found historically, as rivers have been dammed and converted to reservoirs for water storage, flood protection and recreation.

3.2.4 Stream Corridors

The stream corridor habitat is composed of three major elements: the stream channel, the floodplain including the riparian zone, and the transitional upland fringe (FISRWG 1998). These elements function as a dynamic unit, though they are often characterized as separate habitat types. During a flood event, the stream channel inundates the adjacent floodplain providing sediments and nutrients essential to plant and animal communities that inhabit the floodplain and upland fringe. The San Pablo Bay watershed includes many streams including the Napa River, Sonoma Creek, Tolay Creek, Petaluma River, Novato Creek, Miller Creek and Gallinas Creek corridors (See Figure 2-3). Each of these streams, the condition of which varies depending on natural variation and the history of human impacts, is the culmination of many smaller tributaries.

Stream Channels

Stream channels are formed, maintained and altered by the water and sediment they carry. Stream channels, are the conduits that carry the



Riparian forest along Huichica Creek provides valuable wildlife habitat. It is being protected and restored by landowners

overland and sub-surface flows that run off from the watershed area. Stream channel form and structure depends on topography and soil types of the land through which the stream passes and upon the character of the flow conveyed by the stream channel. The important habitat characteristics and functions of stream channels (see Table 3-3) necessitate their protection and restoration.

Table 3-3: Stream Channel Habitat Characteristics
Water Quality
Streams carry fresh water that originates from precipitation on the watershed and flows as surface or groundwater to San Pablo Bay. Water quality, as characterized by pH, alkalinity, acidity, dissolved oxygen, temperature, nutrients, chemical constituents and sediment, is strongly dependent on watershed condition. Water quality affects in-stream biota, water uses, and eventually the tidal marshes and open water of the bay.
Streamflow and Geomorphology
Streamflow is the collection of direct precipitation and water that has moved laterally from the land into the channel from surface and subsurface sources (groundwater). It provides the energy needed to create and maintain stream channels and riparian corridors (floodplains). Sediment erosion and deposition, which determine floodplain configurations, depend on flow and substrate quality. Upland rivers generally begin in bedrock, substrate that is not easily eroded, and have very narrow floodplains. Downstream, as soils deposit, floodplains widen and the rivers meander. In addition to determining the physical character of rivers, streamflow determines the freshwater-salinity gradient in tidally influenced rivers. Flow variability is a major influence on the abiotic and biotic processes that determine the structure of estuarine stream ecosystems. High flows, in addition to promoting sediment transport, connect floodplain wetlands to the channel, creating unique habitats for fish and waterfowl.
Wildlife Habitat & Diversity
Rivers and creeks provide important habitat for many kinds of aquatic life and terrestrial wildlife, including fish, amphibians, migrating and resident birds, and mammals. The resources of streams, along with their high structural complexity and habitat diversity, maintained by periodic flooding and channel movement, contribute to the diversity of wildlife species in these habitats.

In addition to the in-stream support of riverine aquatic foodwebs, rivers are integrally linked to the aquatic foodwebs of the intertidal and open bay ecosystems. The fishery resource illustrates this linkage. For example, two anadromous species, steelhead and Pacific lamprey, spawn in the upper reaches of the Napa River and its tributaries. Juvenile steelhead may reside for more than two years in the intermediate and uplands streams where they were hatched and then briefly in the lower portion of the river on their migration to the ocean. Larval lampreys (called ammocoetes) spend several years burrowed in the sand or silt bottoms of lowland streams before completing their migration to the ocean.

Trends and Stressors in Stream Channels

San Pablo Bay watershed stream habitat extent and quality has declined. Because of water diversion, most streams carry less water than they did in the last century and there are fewer ephemeral streams. As stream corridors have been cleared and natural vegetation replaced by impervious cover such as rooftops, roadways, and parking lots, more of the flow in the stream is delivered to the stream channel as storm runoff and less as base flow (Stream Restoration 1999).

Reduced flows and loss of vegetative shading have caused in-stream water temperatures to rise, sometimes to levels harmful for resident and migratory aquatic species (see sidebar below) Urban development and agricultural cultivation of unstable hillsides have caused significant increases in soil erosion, degrading stream channels and increasing the magnitude and frequency of floods, which increases the risks in areas of human habitation (e.g. Napa River). Pollution from urban development, agriculture and livestock practices has harmed water quality. As a result, eleven creeks in the watershed are included on the EPA and

Salmon in the San Pablo Bay watershed

Historically, three species of anadromous salmon, steelhead (*O. mykiss*), chinook salmon (*Oncorhynchus tshawytscha*), and coho salmon (*O. kisutch*), spawned in the San Pablo Bay watershed, with some runs numbering in the tens of thousands of fish. Today, remnant steelhead runs persist in some streams and occasional chinook salmon runs occur in the Napa River. Coho salmon have been extirpated from the watershed (although a small run may persist in creeks draining into the central San Francisco Bay).

Steelhead are the anadromous form of rainbow trout (resident rainbow trout also occur in upland streams in the watershed). Adults migrate up rivers and creeks in the late fall or winter when stream flows are enhanced by seasonal rainfall. Similar to chinook and coho salmon, they spawn in shallow riffles with rock, gravel or sand substrate. However, unlike the salmon that spawn only once before death, steelhead may make multiple migrations, returning to spawn in successive years. Juveniles may reside in the streams for up to two years before migrating to oceanic waters to grow and mature. Leidy (2000) reported that 12 steelhead runs persist in the northern bay watersheds, including Miller and Sonoma Creeks.

The occurrence of chinook salmon in San Pablo Bay watershed streams is episodic, dependent on seasonal rainfall patterns providing adequate stream flows to attract the fish at the time they enter the San Francisco Bay from the ocean. It is probable that these fish do not represent a native Napa River run but are instead “stray” Sacramento or San Joaquin River fall (or late fall) run fish. Among Sacramento-San Joaquin chinook salmon, fall run fish that migrate upstream after the first seasonal rainfall events and spawn immediately upon arrival at spawning grounds and die, are more opportunistic in their choice of spawning streams, frequently straying into non-natal streams. Given the variability of rainfall amounts and timing in the San Pablo Bay area and the restrictive chinook salmon lifecycle, it is unlikely that even the larger river systems within the watershed could support a native spawning run.

Up until the 1960s, coho salmon spawning runs were reported for a number of San Pablo and Central San Francisco Bay streams. This species favors coastal streams, with adults migrating during the late fall and winter. Juveniles reside in the streams, selecting cool shaded pools during the summer and fall, for one or two years prior to a springtime emigration to the ocean. Coho salmon are particularly sensitive to alteration or degradation of in-stream spawning and rearing habitat, a major factor underlying their decline along the Pacific coast (and present Endangered Species Act threatened status), and the most likely cause of their elimination from San Pablo Bay watershed streams.

Although these anadromous fishes all utilize a variety of habitat types within the watershed during their complex lifecycles, loss or degradation of upland stream spawning and rearing habitat appears to have had the greatest impact on these species. These impacts are due to dams or other barriers to migration, in-stream habitat conditions degraded by reduced stream flows, loss of riparian vegetation, siltation, and resultant elevated water temperatures and changes in habitat structure (e.g. loss of large woody debris). Coho salmon, which depend on stream habitats for both spawning and rearing (half of their lifespan) are the most sensitive to these changes and were the first to be eliminated from the watershed. Multi-year spawning steelhead and opportunistic chinook salmon persist but as severely depleted populations.

Source: (Leidy 2000)

Regional Water Quality Control Board’s list of impaired water bodies (see Table 4-2 for a complete list). Most of the creeks so identified are impaired because of the presence of diazinon, a common ingredient in pesticides that is readily washed into streams where it can kill aquatic life and contaminates the food supply of Bay fish, birds and other animals.

Riparian Habitat

The term "riparian" means the vegetation, habitats, or ecosystems that are associated with bodies of water (streams or lakes) or are dependent on the existence of perennial, intermittent, or sub-surface water drainage. Riparian habitats (or riparian corridors) are the green ribbons of trees and shrubs growing along watercourses (Warner and Hendrix 1984).

In the San Pablo Bay watershed, several drainages support riparian plant communities characterized by woody shrubs and trees growing in moist or seasonally saturated soil along stream channels. Common riparian trees are western sycamore and cottonwood with understory shrubs such as elderberry and wild grapes. Some areas are dominated by stands of willow trees and an often impenetrable understory of Himalayan blackberry. Other species occasionally present include non-native acacia trees, California buckeye and poison oak. Plant species such as ash, California Bay-laurel, and box elder are locally abundant (Goals Project 1999). Cottonwood-willow riparian areas support more breeding avian species than any other comparable broad California habitat type (Gaines 1977).

Riparian corridors along stream courses are important habitats, providing six important ecological functions, as summarized in Table 3-4 (San Francisco BCDC 1999b).

In addition, floodplains and shaded areas serve as nursery and spawning habitat for rainbow trout, Chinook salmon, steelhead, and other fishes (Partnership for the San Pablo Baylands 1996). Leaves and insects droppings from overhanging vegetation also contribute food and the associated aquatic system. Riparian trees provide habitat for foraging and nesting sites for songbirds, perches and nesting sites for raptors

Table 3-4: Riparian Habitat Functions
Wildlife Habitat & Diversity
Abundant resources, high structural complexity, and habitat diversity that is maintained by flooding and channel movement contribute to the diversity of wildlife species in riparian habitats. A wide range of organisms in the watershed depends on riparian habitats (see App. B). High value riparian habitat has a dense and diverse canopy structure with a diversity of vegetation heights creating complex microhabitats. Roots, fallen logs, and overhanging branches create diverse habitats and cover for fish, aquatic insects and invertebrates such as the endangered California freshwater shrimp.
Temperature Regulation
Overhanging trees and streamside vegetation shade streams, moderating water temperatures, particularly during the summer months when streamflows are typically lower. Elevated water temperatures can be stressful or lethal to many insects, amphibians and fish species.
Water Quality Protection
Riparian vegetation can protect water quality by removing toxins, such as oils, herbicides, and pesticides, and excess nutrients and sediments from influent water. Resident microorganisms consume many of the toxins or nutrients in surface or soil waters. Sediment is trapped as in-stream and floodplain riparian plants reduce streamflow water velocities. The effectiveness of these processes depend on the width of the riparian area, the type and extent of vegetation, the slope of the creek banks and surrounding land, and the amount of toxins, nutrients, or sediment present.
Erosion Control and Channel Stability
Streamside vegetation can help minimize erosion (loss of soil) and sedimentation (accumulation of soil), stabilizing creek banks. Excessive sedimentation reduces the capacity of the creek channel to carry water, fills in fringing and downstream wetland habitats, smothers spawning and foraging areas, smothers plants and benthic animals and increases water turbidity (potentially reducing foraging success among visual predators) and, on navigable streams, impairs boating. Sediment can also transport pollutants attached to soil particles.
Flood Storage and Groundwater Recharge
A healthy riparian corridor can moderate the force of floods, protecting downstream areas. Riparian vegetation slows the flow of water through physical resistance and facilitates groundwater recharge by increasing residence time, allowing the water to seep into the soil and enter the groundwater system. Groundwater recharge protects wetlands by maintaining the water table nearer to the surface, providing a base flow or dry season flow into rivers and wetlands.
Economic Value
The scenic value of a healthy river or creek increases property values for property owners and communities. A healthy riparian corridor enhances recreational values along streams, such as fishing, boating, wildlife viewing and hiking.

(birds of prey) and rookery sites for herons and egrets. Many mammalian species use riparian corridors for travel between upland and lowland habitats.

Trends and Stressors in Riparian Habitat

There are no contiguous pristine riparian corridors left in the San Pablo Bay watershed. From about 1850 to the turn of the century, most riparian forests were cleared for fuel wood, river navigation, and agriculture (CALFED 1999b). Modern land use practices, including on-going urban development in the watershed and conversion to more intensive agriculture (e.g. conversion of grazing lands to vineyards), have intensified the need for a coordinated conservation and restoration approach to restore riparian habitat in San Pablo Bay region. All waterways have been affected by human activity, either directly through modifications of the channel and adjacent land uses, or indirectly by activities upstream that impair water quality and flow (San Francisco BCDC 1999b). Roads and bridges fragment all of the riparian habitat corridors. Examples of intact riparian forest exist along San Antonio Creek adjacent to Petaluma Marsh and Sonoma Creek. Remnant patches of riparian habitat are also found on the water and land side of levees, berms, berm islands and in the interior of some islands and adjacent marshes (CALFED 1999b). This habitat is frequently disturbed and of less value to wildlife than more natural stands, however, some remnant stands are of high quality. Overall, stream corridors in the San Pablo Bay watershed share a number of problems, including erosion and sedimentation, flooding, high water temperatures, habitat degradation, reduced freshwater flows, and pollution.

Western Sycamore is common in riparian areas (Brousseau)

3.2.5 Upland Habitats

Upland habitats are the terrestrial areas "up land" from aquatic habitats that collect precipitation and serve as drainage areas for rivers, streams, lakes and other water bodies in the watershed. These habitats are important components of the watershed because of this drainage function and because they serve as permanent habitat or temporary refugia for a myriad of species. Upland habitat types in the San Pablo Bay watershed include grasslands, chaparral/shrublands, oak woodland and mixed evergreen forest. In addition, some "unnatural woodlands" exist in the watershed. The sections below describe these upland habitat types.

Grasslands

Grassland vegetation, dominated by grasses and sedges, was once widespread along the shores of the San Pablo Bay and in upland areas. Native perennial grassland predominated near San Pablo Bay on valley floors and on hill slopes with southwest aspects, however, the introduction of European grazing and agriculture in the l800's shifted the region's grassland communities from native perennials to Eurasian non-native annuals. Historic grasslands were composed primarily of perennial bunch grasses and rhizomatous grasses, and were dominated by purple needlegrass and creeping "wild rye" (Goals Project 1999). There are a few remnant examples of this grassland type in Rush Ranch in Suisun and Coyote Hills near Newark (Goals Project 1999).

Dominant species of present day grassland communities are "wild" oats, soft chess, ripgut brome, and Italian ryegrass. Non-native annual grassland occurs in the interior valleys surrounding the baylands, on the unforested hill slopes with southwest aspect, and on alluvial plains. Examples of non-native annual grassland occur in the North Bay in upland areas surrounding the Petaluma Marsh.

Despite their non-native status, annual grasslands are inhabited by many species of wildlife. Amphibians such as the tiger salamander aestivate in grassland soil to avoid heat stress. Reptiles associated with grasslands include racer, coachwhip, and gopher snake. During the winter, grasslands provide important foraging habitat for sandhill crane, Canada geese, and many species of migratory

Non-native annual grasses, such as soft chess, have supplanted native perennial grasses (Brousseau).

shorebirds. Additional bird species commonly associated with grasslands include turkey vulture, white-tailed kite, red-tailed hawk, northern harrier, American kestrel, burrowing owl, western meadowlark and savannah sparrow. Mammals that reside in grasslands include ornate shrew, broad-footed mole, coyote, California ground squirrel, botta pocket gopher, western harvest mouse, and California vole. Many of these species move into the wetlands and associated lowlands (baylands) at certain times of the year, primarily to forage.

The area surrounding the wetlands of San Pablo Bay, particularly on the northern side of the Bay, is flat and composed primarily of clay and silt soils. These soils slow the movement of surface water and tend to be saturated for relatively long periods, forming areas of moist grassland and depressional seasonal wetlands. Dominant moist grassland species include Italian ryegrass, Baltic rush, iris-leaved rush, Santa Barbara sedge, and creeping wildrye. These areas tend to attract more wildlife than drier grasslands: representative species include western toad, western skink, meadowlark, horned lark, savannah sparrow and western harvest mouse.

Trends and Stressors in Grasslands

As noted above, native perennial grasslands are now present only in remnant patches in the north San Pablo Bay. Though there were historically much larger expanses of moist grassland areas in the upper reaches of Sonoma Creek and Petaluma River, there are still examples in the Petaluma River area and areas associated with vernal pools along Sonoma Creek (see seasonal wetlands). Smaller areas of moist grasslands and seasonal wetlands are in Marin County at St. Vincent's / Silveira Ranch (Goals Project 1999). Restoring these upland habitats is important for restoring contiguous ecosystems suitable for species that depend on grassland- wetland transitions, particularly those that use these areas as refuges during high tides and storm events (e.g. Black rail).

Chaparral/Shrublands

Chaparral dominates areas of poor rocky soils on the hills surrounding the San Pablo Bay watershed. Dominant chaparral species are evergreen, densely branched, woody summer-dormant shrubs with small thick stiff leaves that are adapted to dry conditions, are highly adapted to fire and regenerate quickly. Shrubs frequently form a single dense, intertwining, almost impenetrable overstory layer with a sparse ground cover below (Shuford 1999).

Chaparral plant communities vary with slope, sun exposure, elevation, soil and fire history. The watershed includes several types of chaparral communities, generally characterized by the dominant shrub. For example, Chamise Chaparral is dominated by Chamise mixed with Manzanita and ceanothus, forming almost unbroken stands on hot dry sites, usually on south- or west-facing slopes and ridges. Manzanita shrubs three to six feet high dominate Manzanita Chaparral. Manzanita and chamise chaparral often alternate on east- and west-facing slopes. In more mesic sites, Mixed Chaparral consists of manzanita, chamise, buckbrush, and interior live oak (*Quercus wislizenii var. frutescens*) ranging from three to ten feet high. This community type blends into mixed evergreen forest on shady slopes or in draws. Chaparral pea (*Pickeringia montana*), coffeeberry, and ceanothus (*Ceanothus sorediatus* and *C. foliosus*) are also associated with the mixed chaparral. Serpentine Chaparral is restricted to serpentine soils that impede the growth of many plant species. Serpentine chaparral shrub species grow sparsely interspersed with bare ground and rock outcrops, and are generally are dwarfed or stunted, often reaching only about one and one-half to three feet in height. Characteristic shrubs are leather oak (*Quercus durata*), Jepson's ceanothus (*Ceanothus jepsonii*), Tamalpais manzanita (*Arctostaphylos montana*) and Sargent cypress (*Cupressus sargentii*) (Shuford 1999).

Oak Woodland

Oak woodlands, as the name implies, are dominated by oak trees and are common throughout California's valleys, foothills and lower mountain ranges. In the San Pablo Bay watershed, there are three recognized types of oak woodland, based on species dominance: coast live oak woodland, valley oak woodland and foothill oak woodland.

Coast Live Oak Woodlands

This habitat type occurs along California's coastal foothills and valleys, typically on moderately to well-drained soils that are moderately deep and have low to medium fertility in elevations ranging from sea level to around 5,000 feet (UC Berkeley 2000). On steep slopes, coast live oak woodlands occur as relatively small woodland patches in mosaics with annual grasslands, shrublands, and riparian habitats. Overstories range from open conditions to nearly closed canopies, resulting in a variable density of understory shrubs, grasses, and forbs. Annual grasses form most of the understory in open woodlands, but are almost non-existent in very dense woodlands. Shrubs in closed canopy situations tolerate shade, and include toyon, poison oak, California coffeeberry, and several species of ceanothus and manzanita.

Live oaks dominate the hillside landscape coast.

Tree species associated with coast live oak on moister sites are Pacific madrone, California bay, tanoak, and canyon live oak, and valley oak, blue oak, and foothill pine on drier coast live oak sites. Examples of coast live oak communities exist on the ridges between Black Point and Rush Creek near Novato and at China Camp.

Trends and Stressors in Coast Live Oak Woodlands

Coast live oaks are relatively long-lived, slow-growing trees, requiring 60 to 80 years to mature to tree size under good conditions. Historically, fires frequently occurred in these woodlands. While coast live oaks are relatively resistant to low-intensity ground fires, some fire-related mortality occurs to seedlings and saplings. Because coast live oak is fairly resistant to grazing pressure, it appears to be replacing the less resistant deciduous oaks in areas with intense grazing. Coast live oak regeneration is generally good, however, it has been recently discovered that trees affected by an insect/fungus disease complex are dying rapidly in some areas of the watershed (CAMFER 2000). Furthermore, these infestations have the potential to affect mixed evergreen forests and blue oak - foothill woodlands.

Valley Oak Woodlands

This habitat type generally occurs on deep, well-drained alluvial soils found in valleys and foothills below 2,400 feet. In the Coast Range, foothill pine and coast live oak occur in valley oak woodlands (UC Berkeley 2000). Mature valley oaks have well-developed crowns, reach maximum heights of 50 to 120 ft and have massive trunks (often up to 6 feet) and branches that dominate valley oak woodlands. Tree density tends to decrease as one moves from lowlands to uplands. Associated species include the wild rye and the Santa Barbara sedge (Goals Project 1999). The understory shrub layer can be dense along drainages and very sparse in uplands. Understory grasses and forbs are mostly introduced annuals. This habitat type is widely scattered and not widespread; examples exist along the lower Napa River, and along Sonoma Creek near Schellville (Goals Project 1999).

Trends and Stressors in Valley Oak Woodlands

In many areas, there is little valley oak recruitment to replace mature tree losses due to both natural and human causes. This is presumed to be related to moisture competition with grasses and forbs, wild and domestic animals feeding on acorns and seedlings, and flood control projects. Fire suppression has also encouraged live oak and pine invasion in upland valley oak sites. Valley oaks tolerate flooding and young trees will sprout when damaged by fire; so suppression of fire and flooding has adversely affected their sustainability (UC Berkeley 2000).

Blue Oak-foothill Pine Woodlands

This habitat type is found on steeper, dryer slopes with shallower soils than the coast live and valley oak woodlands. They are a diverse mixture of hardwoods, conifers, and shrubs, with widely variable overstories that occur on a variety of well-drained soils. Blue oak and foothill pine (formerly known as digger pine) typically form most of the overstory of this highly variable habitat type. Blue oaks are usually most abundant, although foothill pines are taller and dominate the overstory. Coast live oak, valley oak, and California buckeye occur and can frequently be seen interspersed with blue oaks. Shrub associates include several ceanothus and manzanita species, poison oak and California redbud and are usually clumped in areas of full sunlight. Additional understory species include: deerbrush, coffeeberry, and pink-flowered currant.

Trends and Stressors in Blue Oak-foothill Pine Woodlands

Blue oak and foothill pine are relatively long-lived, but foothill pine tends to grow faster than blue oak. Historically, fires occurred every 5 to 25 years and regeneration is generally thought to be infrequent throughout California. Following fire, young, vigorous blue oaks sprout well, but older, more decadent trees do not. Therefore, younger stands are more likely to replace themselves after fires. Foothill pine is susceptible to severe damage to fire. This is due to the thin bark of young trees and high resin content in the sap. Furthermore, foothill pine does not reproduce by sprouting, so fire management as a tool should be carefully considered.

Mixed Evergreen Forest

Mixed evergreen forest is mostly restricted to north facing hill slopes in the north San Pablo Bay. Examples of mixed evergreen forest occur in the headward reaches of northfacing slopes surrounding ephemeral creeks in the San Pedro Ridge near China Camp. The dominant species include California bay laurel, bigleaf maple, and madrone and are with associated species such as coyote brush, California huckleberry and poison oak.

These areas are a minor but important part of the San Pablo Bay watershed ecosystem, for they provide important foraging, roosting, and breeding habitat for certain species of amphibians, reptiles, birds, and small mammals that also utilize lowland wetland and riparian habitats. Some representative species are giant garter snake, western fence lizard, Cooper's hawk, Nuttall's woodpecker, dark-eyed junco, hermit thrush, purple finch, dusky footed woodrat, brush rabbit and gray fox.

Trends and Stressors in Mixed Evergreen Forest

It is not known how much of this habitat existed prior to European settlement; however, in certain areas such as Marin County, residential areas are encroaching on this habitat type and certainly some forests have been lost.

Additional "Unnatural" Woodlands

Rows of eucalyptus trees were planted east of Route 121 and elsewhere in the San Pablo watershed to provide protection for fields. Although not native to California, eucalyptus trees provide valuable nesting sites, shelter and foraging habitat for migratory and resident birds. For example, a dead eucalyptus windrow on the east side of Knight Island supports a double-crested cormorant rookery. Nectar-eating warblers and Anna's hummingbirds are also attracted to the early-blooming eucalyptus.

3.3 Plants and Animals of the San Pablo Bay Watershed: Trends and Species Accounts

Little is known about the plant and animal communities present in the San Francisco Bay Estuary before the arrival of Europeans, or about the influence that Native Americans had on these resources. Early accounts of the San Francisco Bay Area were replete with references to the abundant fishes, waterfowl, deer, elk, antelope and other wildlife inhabiting the rich variety of habitats in the area. The local Native Americans depended heavily on all of these resources, including the large annual runs of salmon and the huge numbers of waterfowl that wintered in the area. Because the population living around San Pablo Bay was small, the impact it had on the abundant biological resources in the area was likely not very significant.

When Spanish mariners first sailed into San Francisco Bay in 1775, they found the area populated by native people who enjoyed the shelled, scaled, feathered and furred bounties of this magnificent estuarine system. Now, 225 years hence, the native peoples are all but gone, and so are major components of the ecosystem that sustained them. The San Pablo Bay watershed has changed markedly in this relatively brief period of human history. The large number of species that are under special protection in the San Pablo Bay watershed may be attributable, at least in part, to the effects of human habitation and its concomitant habitat alterations and impacts on local ecosystems. Despite these changes, there is significant potential to protect and restore species and ecosystems throughout the watershed. In addition to the importance of protecting species for their intrinsic value, certain species may serve as indicators of habitat health (see Indicator Species sidebar). Unraveling the distribution of organisms and reasons for their status requires a thorough knowledge of their natural history and the factors that influence their selection and use of specific habitats.

Indicator Species: The Salt Marsh Song Sparrow
Scientists frequently disagree over which species should serve as indicators of habitat health. Some favor endangered and threatened species as indicators. To compare sites, however, it is often useful to consider more common species. Salt marsh song sparrows are a good indicator species because they live and breed in almost all of the Bay's salt marshes, and because they use the marsh in a "compelling" way that correlates with the health of the marsh, by probing marsh channels with their bills at low tide for food. By examining song sparrow distribution and numbers in the marshes around the Bay, Steve Zack and his colleagues have confirmed that song sparrows are more prevalent in more developed marshes, with numerous dendritic channels. Mature marshes with intricate channel development offer more vegetation and food resources for the estuary's food chain, and better filter out pollutants and sediments, making them "healthier" or better functioning than less-developed or disturbed marshes. Marshes that are confined by levees that have straightened channels have fewer song sparrows. For sites in San Pablo Bay, Zack estimates sparrow density at approximately 68 birds per hectare, while in Suisun Bay, the number drops to 25 birds per hectare, and in the South Bay, to between 3 and 5 birds per hectare.
Source: (SFEP 1997)

This section describes the biota that make up the watershed's communities, and, where available, population and community trends. The section's purpose is to focus attention on resource conditions and opportunities for improved management and restoration. It should be noted, however, that a completely species-driven approach could lead to contradictory conservation agendas. For example, the ongoing controversy over the value

***California red-legged frogs have disappeared from 75 percent of their historic range*.**

of salt ponds to San Pablo Bay watershed species is essentially rooted in comparisons of the relative "value" of different aquatic wildlife**.**

During the Habitat Goals Project, the Mammals, Amphibians, Reptiles and Invertebrates (MARI) focus team recommended restoring these areas to complete tidal function while the Shorebird and Waterfowl focus team found the lower salinity ponds to be valuable for particular species of waterfowl (Goals Project 1999). It is important to understand species requirements in the context of historical changes in habitat quality and extent.

3.3.1 Plants

Evolutionary history, varied topography, unusual soils and geology, wide differences in local climate over short distances, and a variable aquatic regime combined to create the diverse flora in the San Pablo Bay watershed. The San Pablo Bay watershed includes a variety of major plant communities or habitat types arranged in a patchy mosaic over the landscape (see Appendix B). Although most animal species are associated with particular plant communities or habitat types and the structure they provide, certain plant species:

- play critical roles in determining ecosystem structure;
- are found in the ecotones between classified habitats or in unique rare habitats that are generally overlooked in most classification schemes; and/or
- may serve as unique indicators of habitat health.

Consequently, in addition to preserving and restoring the mosaic of key habitat types, it is also important to protect and restore rare plant species.

A large percentage of the wetland and terrestrial plant species listed in Appendix B are federal or state-listed species. Many of the species are highly endemic, depending on specialized soil types. Recent listings, for example, include species dependent on serpentine soils or upland seeps or springs. Little is known about the population trends in these plant species; however, their endemic character in a highly urban setting generally makes them subject to potential extinction. Other species, like Mason's lileopsis, require natural transitional habitats, which have been reduced by habitat fragmentation.

3.3.2 Invertebrates

Aquatic Invertebrates

Aquatic invertebrates inhabit the open waters and benthic substrates of the bays, rivers, lakes, tidal marshes, tidal sloughs and vernal pools of the region. There are few comprehensive studies and little information on the San Pablo Bay watershed communities. Appendix B lists aquatic invertebrate species. Generally, the listed species are either highly endemic, such as the vernal pool fairy shrimp (*Brachhinecta lynchi*), or have suffered significant anthropogenic impacts, such as the California freshwater shrimp (*Syncaris pacifica*).

Zooplankton are generally free-floating aquatic invertebrates that occur in virtually all aquatic habitats of the watershed, and are a major food source for fish and other aquatic organisms. Most species are members of groups known as protozoans, rotifers, copepods, or cladocerans, and are quite small. During the past decade, populations of zooplankton species have declined in the Estuary's northern reach. Most species of native copepods have undergone a severe, long-term decline in abundance (e.g., *Mysis* sp., *Neomysis* sp. and *Eurytemora affinis*), while two introduced copepod species, *Sinocalanus doerri* and *Pseudodiaptomous forbesi*, presumably shipped from the China Sea in the ballast water of commercial vessels, have greatly increased in number. The effects of these changes on the San Pablo Bay foodweb are not known, though the introduced Asian marine filter-feeding clam *Potamocorbula amurensis* may play a role through competition (ABAG 1992) (see Asian Clam sidebar, section 3.2.1).

Less is known about long-term trends in most riverine aquatic invertebrates. The status of one conspicuous species, the California freshwater shrimp (see California Freshwater Shrimp sidebar), indicates that the San Pablo Bay watershed lowland perennial streams in which the species is found have suffered severe impacts, though there may be some recent signs of improvement. The recent practice of using riverine benthic invertebrates as indicator species is likely to reveal additional useful information on these trends. Aquatic insect surveys have also become a popular method for evaluating water and habitat quality in streams, especially for citizen monitoring groups, because this method is less expensive than chemical tests. Pollution sensitive taxa, such as stoneflies,

California freshwater shrimp

California freshwater shrimp (*Syncaris pacifica*) live in lowland perennial streams in Sonoma, Marin and Napa counties. The shrimp, listed by the U.S. Fish & Wildlife Service as endangered in 1988, are translucent, almost ghost-like, with colored flecks scattered across their bodies. They are found within stream pools, away from the main current, especially in areas with undercut banks, exposed root systems, and vegetation hanging into the water. Optimal habitats have a mixture of willow and alder trees - dark, shaded water is necessary to help protect the shrimp from visual predators. California freshwater shrimp are detritus feeders, feeding on small, diverse particles brought downstream to their pools by the current. As the water slows, the particles are captured and filtered out by the exposed roots and other vegetation. The shrimp simply brush up the food with tufts at the ends of their small claws, and lift the collected morsels to their mouths.

Before human impacts, the shrimp were probably common in many streams within the three San Pablo Bay watershed counties; however, by the time biologists began to study the crustacean, they were only known to occur in nine streams. In 1964, the shrimp were eliminated from Santa Rosa Creek when the stream was channelized and lined with concrete for flood control purposes. By 1975, shrimp were thought to have disappeared from five more streams, apparently leaving populations only in East Austin and Salmon Creeks in Sonoma County, and Lagunitas Creek in Marin County. Fortunately, new populations were discovered in Sonoma Creek and Huichica Creek by 1981. During a subsequent distribution study of the species in the early 1980s, in which 146 sites in 53 streams were sampled, six additional streams were identified with low population numbers: Big Austin, Green Valley, Jonive, Yulupa and Blucher creeks in Sonoma County, and Stemple and Walker creeks in Marin County. A total of eleven separate stream systems (sixteen streams) are inhabited, but the future of the species is still uncertain.

Source: (Tideline 1996)

mayflies and caddisflies are present in most unpolluted streams, thus their abundance and distribution serve as indicators of water quality.

Insects

Knowledge of the status of terrestrial insect populations is very sparse in the San Pablo Bay watershed, due to a lack of comprehensive studies. Appendix B indicates that there are several species of federal or state listed insects, many of which require highly specialized habitats populated by rare plant species. The Bay Checkerspot butterfly, believed to be once very common in the San Francisco Bay area, is an example of such a species. Adults lay eggs on a native species of plantain; larvae feed on this plant as well as owl's clover. Exotic grasses and weeds have largely displaced these plants, which were once common, over most of their original range, except on serpentine soils where exotic plants cannot compete successfully. The Bay Checkerspot's primary habitat is serpentine outcrops on native grasslands, and though the butterfly is not presently known in the San Pablo Bay watershed, the presence of serpentine outcrops in Napa, Sonoma and Marin counties (Elam 1998), indicates potential for recolonization of these areas.

3.3.3 Fishes

The San Pablo Bay watershed, with its six major drainages, is home to more than 50 fish species. For fishes, the watershed offers a wide variety of habitat types that vary geographic along a continuum from the saline San Pablo Bay to clear headwater streams and temporally with the daily tidal cycle and seasonal rainfall patterns. Upstream aquatic habitats are influenced predominantly by seasonal rainfall and temperature patterns and the physical characteristics of the stream, including stream depth, width and length, channel configuration and morphology, substrate, gradient and flow velocity, and the riffle-pool sequence. Downstream estuarine and bay habitats are more sensitive to daily tidal cycles and freshwater inflow that control salinity, water depth, area of inundation, and the distribution of vegetation or algae. Estuarine habitats near the mouths of San Pablo Bay watershed streams are primarily influenced by freshwater inflow from those streams, while the open water habitat of the Bay is more sensitive to inflow from the larger Sacramento-San Joaquin watershed.

Among the fishes collected or reported in the watershed, some species are permanent residents, living their entire life span within the watershed or even a single drainage. Others may be present in the watershed only during part of their life cycle or during specific seasons. Most resident fishes utilize specific habitats within the watershed. For example, California roach (*Lavinia symmetricus*) are found in upland streams, while hitch (*Lavinia exilcauda*) are more common in lower stream reaches. In contrast, anadromous[1] steelhead (*Oncorhynchus mykiss*), require access to multiple aquatic habitats within the watershed, transiting the open water and tidal marshes on their migrations to and from spawning areas in streams and creeks.

Fish Distribution

Within the San Pablo Bay watershed, different fish assemblages characterize different aquatic habitats.

The open water of the San Pablo Bay is both a migration corridor and foraging habitat anadromous species like steelhead, chinook salmon, white and green sturgeon, and lampreys. Distribution of resident species varies with season and salinity, two factors that are closely related in this habitat. Euryhaline[2] estuarine species, such as Pacific herring, longfin smelt, splittail, Pacific staghorn sculpin and starry flounder, prefer the bay during spring when freshwater inflows are high and salinity is

[1]Anadromous fishes migrate from marine environments to spawn in fresh water. At some time after hatching, young migrate downstream to marine waters where they reside and grow until returning to fresh water to reproduce.

[2]Tolerant of wide ranges of salinity.

low. Marine species like jacksmelt, topsmelt, shiner perch, California halibut, and English sole are more prevalent during summer and fall when salinity is higher. A variety of species, including sharks, rays, skates, sturgeon, sculpins and flatfishes, are strongly oriented towards the bottom and forage on benthic invertebrates. Other fishes, like Pacific herring or jacksmelt, are pelagic, swimming in the water column and feeding on zooplankton or small fishes.

Many of the fishes found in the open waters also move into intertidal mudflats, marshes, sloughs and channels during high tide, usually to forage on the rich intertidal invertebrate biota. In these habitats, environmental conditions vary not only with season and tidal cycles but also with topographic and biological characteristics such as channel width and area, water flow patterns and depth, salinity, and the presence of emergent vegetation. Inundated mudflats and marsh plains are particularly important foraging areas for juvenile fishes, including sturgeon, salmon, striped bass and, in some years, splittail. Recent surveys of the tidal marshes on the lower Petaluma River and the northern Napa-Sonoma Marsh suggest native fishes, such as threespine stickleback and longjaw mudsucker, favor the shallower marsh plain and channels while adjacent deeper water habitats harbor greater numbers of non-native species, predominantly shad, striped bass and gobies (Hieb and Greiner 2000). This trend was also noted in the Sonoma Baylands Wetland Demonstration Project, located east of the mouth of the Petaluma River. Surveys during February, March and April reported collecting at least ten native species, twice the number of non-native species found (CH2MHill 1996). Five species, Pacific staghorn sculpin, threespine stickleback, topsmelt, bay goby and longjaw mudsucker, were collected consistently in all months. In addition, juvenile chinook salmon (fall run), splittail, and longfin smelt were also collected, demonstrating the potential importance of restored tidal wetlands for commercial and endangered fishes.

Although some estuarine species, like delta smelt and splittail, spawn in lowland streams and freshwater tidal habitats, the fish found in freshwater reaches of the San Pablo Bay watershed are markedly different than those found in intertidal and open water habitats. Many streams and drainages in the San Pablo Bay watershed have retained high degrees of physical, ecological and biotic integrity, factors that have contributed to the continued dominance of native species among the fish. For example, Leidy (2000) reported that 17 native fish species are extant in the Napa River drainage, more than are present in many relatively pristine Sacramento-San Joaquin watershed streams. One sampling site in the Napa River Ecological Preserve yielded Pacific lamprey, steelhead (or resident rainbow trout), Sacramento sucker, California roach, Sacramento squawfish, hardhead, prickly sculpin, riffle sculpin, threespine stickleback, and tule perch. Localized alterations, however, and upstream habitat have had adverse impacts on stream and freshwater tidal habitats. For example, native species are usually absent or less abundant in the channelized portions of streams where native riparian vegetation has been removed. In these areas, native species are abundant only in areas where levees have been revegetated. For many streams, the prevalence of non-native fishes in is strongly related to, and in fact a useful indicator for, the degree of habitat alteration.

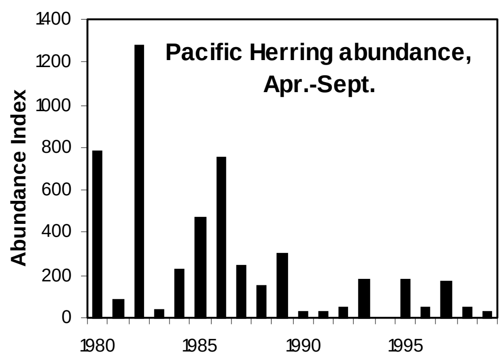
Trends in Fish Abundance

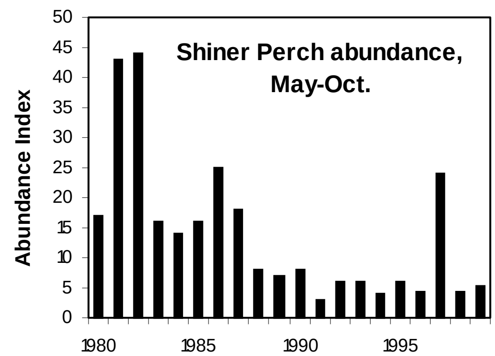
Unlike most other San Francisco Bay watersheds, native fish species predominate in the San Pablo Bay watershed, a testament to the less urbanized condition of this watershed compared to, for example, that of the South San Francisco Bay. Nevertheless, most streams and wetlands in the watershed have been altered and degraded extensively, largely for agriculture. Human modifications to the watershed’s aquatic habitats, including water diversion, dams, vegetation removal, stream channelization, and diking have resulted in direct loss of habitat

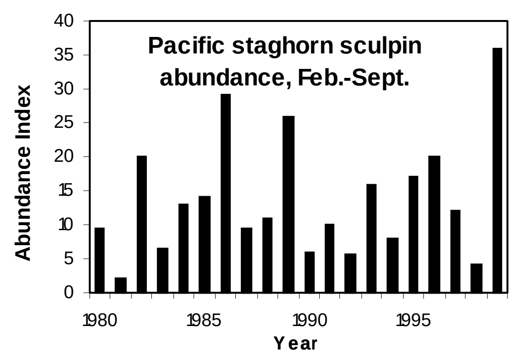
Trends in San Pablo Bay watershed Fishes

With the exception of regular surveys of open water and tidal marsh habitats conducted by California Department of Fish and Game, few quantitative data on fish population abundances or distributions are available for the San Pablo Bay watershed. For many streams and creeks in the watershed, historical records (most comprehensively compiled in Leidy, 1984) document occurrence of species in specific locations but the systematic, repeated sampling necessary to elucidate population trends is generally lacking. Even for the charismatic and commercially valuable salmonid fishes, sightings in mid- and upper watershed streams and general population declines have been reported but regular counts are not available.

The graphs below show abundances of three fishes found in San Pablo Bay open water and intertidal habitats. All report abundance as an annual "abundance index" (a value based on "catch per unit effort" for multiple sites within the San Francisco Bay) for the juvenile life stage ("age-0", hatched earlier in the year sampled). Trends or variations in juvenile abundance may reflect abundance of spawning adults or the relative success of spawning or recruitment. These graphs report abundance within the greater San Francisco Bay and the multi-year samples offer some insight into general population trends. For these species (as with most other open water and intertidal organisms), however, year-to-year variations in their presence and abundance in the San Pablo Bay and its intertidal habitats reflect variations in environmental conditions, primarily salinity, and its effects on their distributions within the greater Bay/Estuary rather than their total population levels. For example, during the 1987-1992 drought, the distributions of many estuarine species usually found in San Pablo Bay shifted "upstream" to Suisun Bay.







Abundances of two pelagic species, Pacific herring and shiner perch, declined substantially a decade ago and have remained depressed while that of Pacific staghorn sculpin, a widely tolerant bottom-oriented species, varied from year to year but over the past two decades, stayed generally steady.

Reports of population declines of most native freshwater species are widespread throughout the watershed but largely anecdotal, based on accounts of habitat loss or degradation in localities in which the species had previously been reported, recent failures to collect the species in these areas, and the prevalence of non-native fishes in the habitats. However, even in the absence of adverse anthropogenic habitat alterations, native fish populations fluctuate year to year with variations in rainfall amounts and timing. Extreme environmental conditions, such as the recent prolonged drought, can depress fish populations and reduce distributional ranges. In these conditions, the habitat is vulnerable to invasion by exotic species, typically those with greater tolerances for reduced flows and warm water temperatures such as the non-native minnows (e.g. goldfish, carp, shiners), catfish and sunfishes. The presence of these exotic species, predators and competitors for space and food, may impair recovery of native fishes, even after habitat conditions improve.

(Reference: Leidy, R. A. (1984) Distribution and ecology of stream fishes in the San Francisco Bay drainage. *Hilgardia* 52(8): 1-175.)

area, barriers to fish movement, changes in water flow and temperature regimes, siltation, and chemical pollution.

Habitat quality in the open water intertidal habitats in the San Pablo Bay has also declined, caused by reduced freshwater inflow (largely attributable to water management operations in the Sacramento-San Joaquin system), pollution, and reduced primary and secondary (i.e., zooplankton) productivity. Such changes, particularly altered flow and temperature in streams and reduced productivity in open water and intertidal habitats, have contributed to the population declines of nearly all native fishes and local extinctions of several species (see above sidebar). In turn, habitat alteration and reduced abundance and distributions of native species have fostered, and been exacerbated by, the invasion and establishment of a number of non-native fishes and other organisms. Singly and in combination, these factors are the major causes of native fish declines throughout the watershed.

Appendix B lists the fishes most commonly found in the major aquatic habitats of the San Pablo Bay watershed.

3.3.4 Amphibians and Reptiles

A variety of amphibians and reptiles inhabit small rivers, creeks, lakes, ponds, seasonal wetlands and adjacent riparian areas, agricultural areas, and grasslands of the San Pablo Bay watershed. Comprehensive studies of these taxa in the San Pablo Bay region are not available. Based on a literature review, at least 13 species of reptiles and amphibians commonly inhabit the region (see Appendix B). Many of these species are either state or federal listed species. Additional research would likely yield more species. Amphibians serve as important indicators of local freshwater habitat health in part because they have limited mobility and are entirely dependent upon aquatic systems or moist environments for critical periods in their life history. Over the last 50 years, many populations of amphibians (frogs, toads, salamanders and newts) have declined markedly throughout the world. Some species have become extinct. In many cases, the decline is a direct response to the impact of human activities, such as habitat destruction or pollution, acting at a local level.

However, in the late 1980s, biologists from many parts of the world reported declines in amphibian populations in apparently pristine habitats. This led to the suggestion that there could be one or more globally distributed factors that are also affecting amphibians adversely including: an increase in ionizing radiation (UV-B) resulting from ozone layer depletion; chemical contamination such as the estrogenic effects of pesticides; acid precipitation; the effects of fertilizers and herbicides; or the introduction of exotic competitors, predators and pathogens (The Declining Amphibian Populations Task Force 2000). While there is no single established cause of amphibian declines, many of these factors are likely implicated in the decline of populations in the San Pablo Bay region. In California, competition from non-natives like the bullfrog is known to contribute to declines in amphibian populations. Reptiles, particularly the giant garter snake and western pond turtle, are also at risk. The following brief descriptions of selected amphibian and reptile species provide insights into their habitat requirements and the reasons for their decline.

California Tiger Salamander

The California tiger salamander (*Ambystoma californiense)* can be found throughout large portions of the Central Valley, San Francisco Bay, coastal mountains and foothills below 3,000 feet, and along the coast in the southern portion of the state. This amphibian typically inhabits scattered ponds, intermittent streams, or vernal pools associated with grassland-oak woodland below 1500 feet in elevation (CALFED 1999a). Tiger salamanders take refuge in rodent burrows and other subterranean crevices (Leonard Charles & Associates 1995). The most serious

Habitat loss and competition by non-native species are threats to the California tiger salamander.

threats to the species are habitat loss and competition by non-native species. The introduction of predatory fishes and bullfrogs in known breeding ponds also seriously threaten tiger salamander populations. The western spadefoot toad, also declining, relies on much of the same habitat area and characteristics.

California red-legged frog

The California red-legged frog (*Rana aurora draytonii*), once widely distributed throughout the state, is the largest native frog in California. It lives in dense, shrubby riparian vegetation associated with deep, still, or slow moving water that supports emergent vegetation (CALFED 1999a). California red-legged frogs have disappeared from 75 percent of their historic range (Jennings et al. 1993). The small coastal drainages between Point Reyes National Seashore in Marin County and Carpenteria in Santa Barbara County are the only remaining areas with significant numbers of California red-legged frogs.

Many factors have contributed to the decline of the red-legged frog population. Although declines began as humans hunted for food beginning with the Gold Rush in 1849 (Jennings and Hayes 1985), over half of the reduction in range has probably taken place in the last 25 years (Jennings et al. 1993). Stressors include: habitat loss due to wetland reclamation and the loss of adjacent terrestrial habitats; agricultural practices resulting in direct mortality or degradation of habitat; the introduction of nonnative fish, bullfrogs, and crayfish, all of which prey on the frog at different points of its life cycle; siltation from off-road vehicle use; and livestock grazing.

Foothill Yellow-legged Frog

The foothill yellow-legged frog (*Rana boylii*) is a moderate sized frog and a California Species of Special Concern (Jennings and Hayes 1994). In the Coast Ranges north of the Salinas River, this species stills occurs in significant numbers in some drainages but is at risk due to various anthropogenic and environmental threats. Yellow-legged frog breeding sites occur in shallow, slow-flowing water with pebble and cobble substrate (Fuller and Lind 1992). Sub-adults and adults seem to prefer pebble/cobble river bars, riffles, and pools with at least 20% shading. This species is also occasionally found in other in riparian habitats, including moderately vegetated backwaters, isolated pools (Hayes and Jennings 1989), and slow moving rivers with mud substrates (Fitch 1938).

Western Pond Turtle

The western pond turtle (*Clemmys marmorata)* lives in ponds, rivers, streams, lakes, marshes, and irrigation ditches with rocky or muddy bottoms. Western pond turtles require well-vegetated backwater areas with logs for basking and open sunny slopes well away from riparian zones for egg deposition (Harvey et. al. 1992).

Western pond turtle

These turtles eat aquatic plants, insects and carrion (Leonard Charles & Associates 1995). The pond turtle can be found in every region of California except on the eastern slope drainages of the Sierra Nevada. Though populations in California were greatly reduced at the turn of the century due to exploitation for food, more recent declines in populations are attributable to habitat loss as wetland and riparian habitats are converted for agriculture, industrial, or urban uses. Additional factors include agricultural practices that degrade habitat or directly cause mortality, the introduction of large predatory fish that prey on juveniles, and mortality caused by flooding of hibernation sites (CALFED 1999a).

Giant Garter Snake

The giant garter snake (*Thamnophis gigas*) was historically found from Butte County to Kern County in California. Its current range is now much smaller, and it is believed to no longer occur south of northern Fresno County (Bury 1972, Rossman et al. 1996, CWHRS 2000). A largely aquatic species, populations of the giant garter snake have been affected by the elimination of natural sloughs and marshy areas.

The giant garter snake is rarely found away from water, and forages in the water for food (Rossman et a1. 1996, CWHRS 2000). Its diet consists mainly of small fish and frogs during its active season (CALFED 1999a). Historic habitats of the garter snake have been largely reduced or fragmented, and associated uplands, necessary for reproduction and hibernation, are largely unavailable (CALFED 1999a).

3.3.5 Birds

Climatic, topographic and geographic factors interact on a local scale to provide a suite of habitat types for birds. Birds generally base their habitat choice on the structure of plant communities (Verner and Larson 1989) rather than on particular plant species, so the preservation and restoration of a range of habitat types is key to conserving bird diversity. Some birds are resident species of the San Pablo Bay watershed and spend their entire lives in the region, while others use the area during a portion of their lifecycle, perhaps as a stopover during migration or for foraging, roosting, wintering, or breeding (see Appendix B). Understanding these life history patterns is key to conserving bird populations.

Shuford (1993) has argued that resident bird populations tend to have a disproportionate number of species with relatively restricted distributions and small populations. This pattern emphasizes the importance of understanding patterns in local habitat variation as defined by key physical and biological processes and the effects of potential impacts and restoration. Protecting habitat in one area is not the necessarily a substitute for protecting another site of similar quality.

Breeding Bird Survey

Intensive breeding bird surveys are particularly useful for depicting population distribution and diversity of breeding birds in the San Pablo Bay watershed. Until the late 1960's, bird distributions were mapped using random observations from scattered sources, often collected over lengthy periods of time (Shuford 1993). In addition, breeding bird distribution maps did not always distinguish between sightings during the breeding season and positive proof of breeding. Consequently, when using these historical data, only the most dramatic changes in distribution and abundance are apparent. The Marin County Breeding Bird Atlas (Shuford 1993) and others underway (as of 1992) in Napa and Sonoma counties are impressive efforts to fill this gap. The Marin County breeding survey provides important insights into the bird diversity of the region as a whole. In Marin County alone, the teams confirmed breeding evidence for 143 species of birds during the six-year project. A relatively high percentage of these species were year-round residents and a moderate number were summer or winter residents. This distribution is fairly typical of the central and southern coastal areas of California, which have moderate temperatures and rainfall. The fine scale data and information on natural history are important resources for those interested in preserving, protecting and restoring wildlife habitats.

The observed changes in abundance and distribution of birds in the San Pablo Bay watershed reflect the severe habitat changes that have occurred due to human habitation. Some species, like the clapper rail, have experienced dramatic declines, while others, like the eared grebe and meadowlark, have increased.

Changes are most pronounced in species that are dependent on tidal marsh and in those that exploit new habitats resulting from diking and filling of the Bay (Harvey 1992, Goals Project 1999).

Bird Abundance and Distribution

Because birds are mobile, their distributions and abundances can change daily, so determining trends in their populations is not an easy task. As with all ecological investigations, one must determine population abundances and spatial distributions through time, and there are trade-offs in developing adequate censuses. The Audubon Society Christmas bird count and the Mid-winter waterfowl survey (discussed below) are examples of efforts to record distributions during distinct seasonal periods. Both offer valuable information on population trends. Intensive breeding bird surveys are particularly useful for depicting population abundance and distributions of breeding birds in the region (see sidebar).

Waterfowl

The San Francisco bay region is known as a major coastal wintering and migration area for many Pacific Flyway ducks, such as scaup, scoter, canvasback, ruddy duck and northern shoveller. The midwinter waterfowl survey, the oldest of the continental surveys, is a cooperative effort of the U.S. Fish and Wildlife Service and the individual States. Conducted annually, generally in January, the survey attempts to count all species of waterfowl in their main areas of concentration. Once the major means of monitoring waterfowl populations, this survey now supplements better data acquired from various breeding and other special surveys. The midwinter survey provides an index to population trends, rather than an estimate of total numbers. Within the San Francisco Bay Estuary, separate counts are made for waterfowl in the Delta, Suisun Marsh, and San Francisco Bay (Harvey 1992). Midwinter surveys during 1981-1990 indicated that an average of about 193,000 waterfowl were present on the open water and salt ponds of San Francisco Bay (Harvey 1992). More recently, winter populations of ducks on the Estuary averaged over 390,000, ranging from a high of 1.3 million to a low of 109,000. Surveys have shown that the Estuary has at times supported nearly 60% of all diving ducks wintering in California.

In 1987, U.S. Fish and Wildlife Service initiated studies to better document and describe the abundance and distribution of waterfowl within San Francisco Bay region. To accomplish this goal, aerial surveys were used to census waterfowl in six sub-regions of the Bay including two areas in the San Pablo Bay watershed, the North Bay (open water of San Pablo Bay north of Richmond-San Rafael Bridge and west to Carquinez Strait) and the North Bay salt ponds (including sewage ponds, sloughs, marshes, and river mouths). During the 1987-1990 studies, more waterfowl were observed in the North Bay than in any of the other areas. The North Bay and North Bay salt ponds collectively were inhabited by 42% of the waterfowl species observed (Cowardin 1992).

Sloughs in the San Pablo Bay watershed provide valuable wintering habitat for waterfowl.

Shorebirds

The San Francisco Bay region, including San Pablo Bay, is renowned as a major North American refuge for many species of shorebirds during their migration and wintering periods (August –April) and as breeding habitat during the summer for some species (e.g. snowy plover). The area is one of three critical stopover locations for shorebirds migrating along the Pacific Flyway. According to the United States Shorebird Conservation Plan, San Francisco Bay is used by higher proportions of wintering and migrating shorebirds within the U.S. Pacific coast wetland system than any other coastal wetland.

Shorebirds are a diverse avian group of resident and migratory species including sandpipers, plovers, stilts, avocets, snipes, oystercatchers, turnstones and phalaropes. They generally have small bodies, long thin legs, and no webbing on their feet. In the San Francisco Bay area, preferred shorebird habitats are mudflats, salt ponds, diked seasonal wetlands, grazed uplands, and to a limited extent, salt marshes. Species making the heaviest use of mudflats include the black-bellied plover, willet, long-billed curlew, marbled godwit, western sandpiper, least sandpiper, dunlin and short-billed dowitcher. Species making heaviest use of salt ponds include the snowy plover, black-necked stilt, American avocet, northern phalarope and Wilson's phalarope. The snowy plover, federally listed as a threatened species, and the killdeer, black-necked stilt and American avocet nest in the salt ponds (Steere and Schaefer 1999).

Because shorebirds cover so much of the globe during their lifetime, it is difficult to obtain accurate population numbers. Thirty-eight species of wintering and migratory shorebirds were found in the San Francisco Bay between 1988 and 1995 in surveys performed by the Point Reyes Bird Observatory (PRBO). Total numbers of shorebirds in these surveys ranged from 340,000-396,000 in the fall, 281,000-343,000 in the winter, to 589,000-838,000 in spring (Steere and Schaefer 1999). Depending on the season, San Francisco Bay accounted for the following percentages of shorebirds in the wetlands contiguous U. S. Pacific coast on the PRBO surveys: black-bellied plover, 55-62%; semi-palmated plover, 40-52%; black-necked stilt, 58-90% American avocet, 86-96%; greater yellowlegs, 26-41%; willet, 57-69%; long-billed curlew, 45-65%; marbled godwit, 46-68%; red knot, 39-76%; western sandpiper, 54-68%; least sandpiper, 39-73%; dunlin, 24-38%; and dowitchers, 49-72% (Steere and Schaefer 1999).

Marsh Birds, Gulls, Terns, Rails

The San Pablo Bay provides nesting habitat for a variety of marsh birds including the snowy egret, great egret, black-crowned night heron, great blue heron, California clapper rail and Black rail (see Black Rail sidebar). The western gull, California gull, Forster's tern, Caspian tern and double-crested cormorant, are common colonial nesting species in the region.

California clapper rails are found primarily in emergent salt and brackish tidal marshes that have intricate networks of slough channels and vegetation dominated by pickleweed and Pacific cordgrass. In 1999, the total population size was estimated at around 1,200, a significant decline due to a history of impacts, including hunting in the late 1800s and, more recently, predation by non-native predators and habitat loss. California clapper rail populations are now restricted to small fragmented marshes. Restoration of larger areas of tidal marsh with significant transition zone to terrestrial habitat, and a buffer from nearby urban and industrial development, will directly benefit clapper rails.

Raptors

Marshes, tidal flats, and grasslands provide excellent feeding habitat for many raptors including the northern harrier, merlin, peregrine falcon, red-tailed hawk, short-eared owl, black-shouldered kite and burrowing owl. The bald eagle and osprey, which nest near reservoirs and lakes, are also present but rare. Loss of habitat is an enormous threat to raptors in the Bay Area.

Migratory Songbirds and other birds

The riparian areas, transitional habitats, and terrestrial habitats of the San Pablo Bay watershed are also extremely important for non-

Research on Black Rails

A statewide survey conducted in the 1970's suggested that the marshes of San Francisco Bay probably supported the bulk of the black rail (*Laterallus jamaicensis coturniculus*) population in California (Evens 1999). In mid-1980's the Marin Audubon Society and the California Department of Fish and Game funded a few small studies of 78 discrete marshes in the Delta, Suisun Marsh, San Pablo Bay, Central Bay and South Bay during the breeding season (March-June). The studies, based on recognizing rail presence by sound, determined that all territorial black rails were confined to the North Bay, with a majority in the San Pablo Bay system. The Suisun marshes also held a fair share of birds, but black rails were virtually absent as a breeding species in the Central and South bays. The researchers hypothesized that the black rail populations were constrained by limited access to marsh habitat above mean higher high water. Prime black rail habitat is the thin ribbon of salt marsh vegetation that occurs between the high tideline (mean higher high water) and the upland shore, a gently sloping plain with very little elevational rise. When forced from the protective cover of pickleweed, salt grass, sedge and other marsh vegetation by rising water levels, the birds take refuge beneath whatever overhead cover they may find on the upland edge of the tideline. Historically, the transition zone was heavily vegetated with overhanging willows, coyote bush, and perennial bunchgrasses. Those few sites where the transition zone approximates natural conditions (large tracts of marsh with adjacent wildlands like the Petaluma River marsh) are extremely valuable to the remaining populations of black rails. A follow-up National Biological Service study in 1996 indicated that the black rail appears stable at some of these high quality "core" sites, but may be declining at the margins.

Source: (Evens 1999)

aquatic birds. The Marin County breeding bird study noted that 122 of 163 species identified in the area were landbirds, either year-round residents or summer residents. Over fifty species of songbirds make use of the remnant riparian zones around the bay, including flycatchers, sparrows, thrushes, woodpeckers, warblers, vireos and swallows. Some migratory songbirds also use tidal salt and brackish marshes, including the common yellowthroat and song sparrows (see Indicator Species sidebar). The tricolor blackbird, a resident of freshwater wetlands, has felt the impact of habitat loss; its numbers have diminished by 89 percent since the 1930's. Likewise, only 6,000 pairs of Suisun song sparrow remain in the entire San Francisco Bay area.

3.3.6 Mammals

The San Pablo Bay watershed harbors numerous species of mammals, some highly endemic and endangered, and others thriving to the extent that they are considered pests. Several species have been listed by the federal or state government (see Appendix B). Many of these mammals depend on a contiguous transitional set of habitats from the water's edge; they forage within wetlands and riparian areas and require adjacent upland environments for refuge during high tides or flood events. The upland transition/buffer habitat is extremely important to the viability of most mammal species.

In tidal marshes, there are several threatened or endangered small mammal species, including the salt marsh harvest mouse, Suisun ornate shrew, and the San Pablo vole. There is evidence that these species have experienced dramatic reductions in their populations. Largely dependent on saline emergent wetlands with adjacent upland areas, they have suffered in from tidal marsh reclamation. Collectively, these species were considered key target species by the Baylands Ecosystem Habitat Goals Project MARI (Mammals, Amphibians, Reptiles and Invertebrates) Focus Team and were the basis for their recommendation of five areas in the San Pablo Bay watershed that could independently sustain these populations. The areas include:

- Hamilton/Bel Marin Keys wetlands (north of Las Gallinas Creek to Novato Creek)
- The Petaluma marshes (both sides of the Petaluma River from the mouth to south of the city of Petaluma)
- South Napa marshes from Sonoma Creek to the Napa River, bounded by Napa, South, and Dutchman Sloughs
- Napa River wetlands (including Coon Island, Fagan Slough wetlands and the west side of the Napa River south of the Newport North development)
- The Point Pinole wetlands (from Wilson Point to Point San Pablo).

Each of these large areas includes key features that support, or could support through additional restoration, one or more of these populations. The Point Pinole wetland site is extremely important because the San Pablo Creek marsh is the only locality inhabited by the endemic San Pablo vole. The slough channels throughout the salt ponds and marshes in the area between the Napa River and Sonoma Creek also provide habitat for river otter.

Salt Marsh Harvest Mouse

One of the most intensively studied and observed mammals in the San Pablo Bay watershed is the salt marsh harvest mouse. Two subspecies are endemic to the salt and brackish marshes in the region. The northern subspecies, *Reithrodontomys raviventris halicoetes* inhabits salt marshes bordering San Pablo and Suisun bays and was listed as an endangered species in 1970 (Harvey et. al. 1992). The harvest mouse depends on dense pickleweed dominated saline emergent wetlands with specific preference for areas with complete (100%) plant cover, foliage height of 30 to 50 centimeters, and pickleweed forming at least 60% of the plant cover. (Leonard Charles & Associates 1995). The mouse requires a five-acre minimum of pickleweed salt marsh to survive.(Shellhammer 1982). These explicit habitat requirements, making the salt marsh harvest mouse an indicator species of high quality marsh habitat, are also the reason that the remaining San Pablo Bay watershed tidal marsh habitats provide the most viable opportunities for protecting and restoring this species.

The salt marsh harvest mouse has been listed as a federal and state endangered species for over twenty-five years. Declines in the population and distribution of the species can be attributed in large part to a loss of habitat, caused by reclamation of tidal salt marshes. In addition to a loss of saline emergent wetlands, alterations and fragmentation of adjacent upland areas have also impacted the harvest mouse. During extreme high tides and high outflow periods, the species is forced to move into upland areas consisting of grasslands or salt-tolerant plants. During the rest of the year, these mice can also be found in these adjacent grassland and upland areas, within 200 feet of pickleweed (Questa Engineering Corporation 2000). Because of habitat fragmentation and loss, the mouse lacks sufficient brush protection in both the marsh and adjacent upland areas, making them subject to predation from herons, hawks, owls, gulls, and larger mammals. There is also concern that as habitat fragmentation occurs, populations of the salt marsh harvest mouse are becoming increasingly isolated, resulting in insufficient genetic flow within the species. In the North Bay, the marshes around Mare Island support consistently large mice populations, which, coupled with proposed restoration of part of the nearby Napa marshes, bode well for the harvest mouse (Goals Project 1999).

In addition to the listed species, there are several mammal species that are fairly ubiquitous in this area and other parts of the state. A few of these native species are highlighted to recognize their importance and persistence as members of the mammal community and to discuss the possible impacts they pose to restoration efforts.

Harbor Seal

The largest mammal found in association with mudflats and tidal salt marshes of San Pablo Bay is the harbor seal (*Phoca vitulina*). Harbor seals use mudflats for hauling-out during low tides and tidal salt marshes as rookeries, hauling out at high tides for resting and giving birth to pups. Recent studies indicate that Harbor seals now use only half of the haul out sites that they used historically (Kopec 1999). The Corte Madera marsh serves as a harbor seal haul-out and pupping site. Populations at this site range from a low of 10 seals in the winter months to a high of about 30 seals in the summer pupping and molting season (Harvey et. al. 1992). Deterioration due to shoreline erosion has occurred over the past few years, and the site would be greatly enhanced if wave action was reduced and the haul-out site stabilized (Goals Project 1999). Harbor seals prefer haul-out and breeding sites with unrestricted access to water in areas where human disturbance is minimal, as they are easily disturbed or frightened into the water by human presence.

Raccoon

Raccoons (*Procyon lotor)* prefer riparian and valley oak woodlands and wetlands (Orloff 1980) but they are well adapted to urban areas where they find abundant food. In these areas, they are considered pests and potential vectors for rabies. Studies on wild populations of raccoons in Contra Costa and Alameda counties during 1978-1988 indicated that their increasing populations correlated with human population growth in the area. Raccoons may be significant predators on nesting waterfowl and could pose a threat to restoration of marsh habitat, particularly in urban areas. Prior to 1988, raccoons had not been reported as regular salt marsh inhabitants. By 1990, however, they were encountered frequently during night surveys on the San Francisco Bay National Wildlife Refuge

(Harvey 1992). Raccoons have destroyed chicks and eggs of the western snowy plover and California clapper rail in the South Bay and mallard eggs in Suisun Marsh. The current status of this species in the San Pablo Bay watershed is not known.

Mule Deer

The Mule Deer (or Columbian black-tailed deer, *Odocoileus hemionus columbianus*) were historically plentiful until settlers began market and subsistence hunting (Schauss 1984). With the establishment of seasonal protection and hunting license requirements in 1907, deer populations began to recover, exhibiting peak population levels during the 1950s and early 1960s. Deer are still relatively common in remaining grasslands, chaparral, oak, and broad-leaved evergreen woodlands in the San Pablo Bay watershed. The Marin-Sonoma herd is part of the larger Santa Rosa herd that extends from the Marin headlands to Cloverdale and Napa. The Monticello herd extends east from Napa County into Yolo County (Harvey 1992).

Mountain Lion

Mountain lions (*Felis concolor*) are widely distributed in California, especially where deer are present. Densities vary according to the availability of prey and habitat and are estimated at 5-7 adults per l00 square miles on the central coast (Mansfield and Weaver 1989). Much of the chaparral and broad-leaved forests have been converted to agricultural and urban uses, leaving little habitat to support resident or transient mountain lions. In Marin County, mountain lions have been observed along Mount Tamalpais ridge, south of Lucas Valley Road, and on the Point Reyes Peninsula. Within the entire Marin County portion of the study area, however, there is probably not more than one transient lion present (Harvey 1992). The lion's current widespread distribution, adaptability, and stable-to-increasing populations in some portions of the state indicate that this species will continue to be a member of California's wildlife community (Mansfield and Weaver 1989).

3.4 Non-native Invasive Species

3.4.1 Introduction

The San Francisco Estuary is one of the most invaded ecosystems in North America (Cohen and Carlton 1995). Since 1970, at least one new non-native species has become established every 24 weeks, one of the highest invasion rates reported for any ecosystem. Because the Estuary is a relatively young geographic feature, its evolutionary history short, and its native aquatic biota somewhat impoverished, it may be particularly susceptible to invasion (Nichols et. al. 1986). The Estuary has a long history of invasions, some of which have been devastating while others have been relatively benign. The negative impacts of non-native invasive species received renewed attention with President Clinton's executive order in February of 1999, which authorized actions "to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause..." This order heightened the awareness of invasive species-related problems and ordered the development of a National Invasive Species Management Plan. In addition, there are a variety of other national and statewide efforts to prevent new invasions by exotic organisms, for example through ballast water regulation.

Non-native or *exotic* species are those species whose occurrence in a region is the result of human activities that have aided their dispersal. Some species not only become established but become serious invaders causing ecosystem transformation. These are termed invasive species. Non-native invasive organisms can out-compete, displace, and prey on native species, modify plant community structure, and affect local hydrology and geomorphology, causing decreased habitat value and economic impacts. Though non-native species of all types exist, certain characteristics seem to characterize successful invaders – high dispersal rates, broad environmental tolerances, high fecundity and flexible life history strategies.

Many invasive species have been present for more than a century, and are so integrated into the community that earlier, mostly likely adverse impacts are largely forgotten. For example, more than 100 years ago *Mya arenaria*, a clam native to the Atlantic coast, effectively replaced the native clam *Macoma nasuta* in regularly harvested clam beds in the Napa River (Fisher 1916 in Cohen and Carlton 1995). By the 1880s *Mya arenaria* was reported as the most common clam sold in San Francisco Bay area markets. However, following the population dynamics pattern typical of invading species, the abundance of the clam and the commercial harvest declined substantially within 10 years and was virtually gone by 1948 (Herbold et al. 1992).

Because non-native organisms tend to be more prevalent in altered or degraded habitats and have the potential to disrupt both natural and restored ecosystems, habitat restoration plans should include thorough evaluations of the pre-restoration presence of non-natives as well as the potential for new invasion during or following the restoration activities. The best method to control invasive species is prevention. Restoration strategies should be chosen carefully so that exotics are not encouraged as an undesirable byproduct of restoration efforts. For example, soil disturbance at a restoration site may encourage invasive plants to establish, since these plants are often much more aggressive than their native counterparts. This section provides information on invasive species that have the greatest potential for posing problems within the habitats of the San Pablo watershed.

3.4.2 Aquatic Habitats: Open Water, Sloughs, Lakes and Ponds

Introduced invertebrate species dominate the benthic and fouling[3] communities of San Pablo Bay. Most species have been inadvertently introduced through the ballast water of cargo ships. Two recent introductions to the San Francisco Bay watershed, the Asian clam and Chinese mitten crab, illustrate the complexity and far-reaching effects of introduced invertebrate species.

The Asian clam, *Potamocorbula amurensis*, appears to be having significant impacts on the benthic and open water communities of the northern San Francisco Bay. The species, which presumably arrived in ballast water, was first collected in the Estuary in 1986. By 1990, *Potamocorbula* was very common from San Pablo Bay through Suisun Bay. In most years, it is most abundant in the Suisun Marsh region but attains the largest sizes in San Pablo Bay (Hymanson 1991). *Potamocorbula's* establishment in the Estuary followed a major flood in the spring of 1986 that left the native benthic community nearly depauperate in the Suisun Bay area, and the species' population increase and spread throughout the system coincided with a multi-year drought that began in mid-1986 (Cohen and Carlton 1995).

Potamocorbula has maintained substantial populations in the northern Estuary and appears to have permanently changed benthic community dynamics (Nichols et al. 1990). *Potamocorbula* feeds at multiple levels in the food chain, consuming bacterioplankton, phytoplankton, and zooplankton. In areas where the species is abundant, this tiny clam can filter out phytoplankton at rates higher than the plants' ability to reproduce, competing with other benthic, planktonic and pelagic species that rely directly or indirectly upon phytoplankton production. Thus *Potamocorbula*'s effects in the Estuary can cascade throughout the food web; the uptake of phytoplankton negatively impacts copepods, the copepod-eating native opossum shrimp

[3] Grows on immersed objects such as ship bottoms, pipes or piers. Fouling clogs or obstructs passages or impedes navigation due to excessive growth on these substrates.

(*Neomysis*) and fish species (e.g., juvenile striped bass) that rely on opossum shrimp.

The Chinese mitten crab, *Eriocheir sinensis*, native to coastal rivers and estuaries of China and Korea along the Yellow Sea, was first discovered in South San Francisco Bay in 1992 and quickly spread throughout the estuary during the next several years. Mitten crabs were first collected in San Pablo Bay in the fall of 1994 and their distribution appears to be expanding in tributaries to San Pablo Bay, with sightings from all the major tributaries to Petaluma Creek and from a tributary to Sonoma Creek near Sonoma.

The mitten crab is catadromous, spending most of its life cycle in freshwater rivers and streams but reproducing in marine waters. The species is well known for its long-distance upstream migrations; freshwater rearing areas may be hundreds of miles form the ocean. During their freshwater residence, mitten crabs burrow into the mud on the bottom or edge of the stream, a cause of concern in watersheds dependent on levees for flood control or habitat management. Mitten crabs may also compete with other benthic crustaceans, including commercially important Dungeness crab. The species is also a second intermediate host of a human parasite, the oriental lung fluke *Paragonimus westermanii*. No parasites were found in the mitten crabs collected in the San Francisco Bay, but their establishment is possible, since suitable first intermediate snail hosts are present in California or adjacent states (Cohen and Carlton 1995). For these reasons, importation or collection of live mitten crabs are banned by the California Department of Fish and Game.

The economic impacts of invasive fouling species on commercial and recreational ships is suspected to be substantial, but is largely not quantified (Cohen and Carlton 1995). *Corophium acherusicum* is a common fouling organism on floats and pilings and has been found on ship hulls on several occasions (Carlton 1979). In 1993-4, it was collected at stations in San Pablo Bay and in the Petaluma River.

In California (and throughout the country), most non-native fishes were intentionally introduced by government agencies for the purpose of establishing commercial or sport fisheries or pest control. Thirty fish have been introduced to the Estuary and Delta. Among non-native fishes present in the San Pablo Bay watershed, striped bass (*Morone saxatilis*), introduced more than a century ago, initially supported a substantial commercial fishery but catch is now restricted to sport fishing. Mosquitofish (*Gambusia affinis*) and Inland silversides (*Menidia beryllina*) were introduced for the purpose of insect control.

Introduced broad leaf peppergrass competes with native plants such as pickleweed (Brousseau)

Both species have spread well beyond the ranges of their original introductions, an all too common result of intentional introductions predicated on incomplete understanding the organism's biology and the target system's ecology.

The Yellowfin goby *(Achanthogobius flavimanus)*, common in San Pablo Bay and the Napa Sonoma salt ponds, was probably introduced inadvertently in the ballast water of cargo ships from Asia. In almost all cases, introduced fishes adversely impact ecosystems and other fishes, usually by predation upon native organisms ill-adapted to cope with the novel predator. Non-native fishes are particularly prevalent in freshwater habitats degraded by loss of flow, riparian vegetation, and regular flood events. For more, detailed information about biological invasions of the San Francisco Bay and Delta, please refer to Cohen and Carlton (1995).

3.4.3 Tidal Marsh and Intertidal Mudflats

In the ecotones between open water and upland habitats, exotics impose structural changes on the habitats through competition and physical modification. The Atlantic salt-marsh cordgrass *Spartina alterniflora* has become locally abundant in San Francisco Bay and is competing with the native cordgrass *Spartina foliosa*. Although there are only a few patches of *S. alterniflora* in the San Pablo Bay, the species has broad potential for invading the mudflats surrounding the Bay and altering this ecosystem. *S. alterniflora* has larger and more rigid stems, greater stem density, and higher root densities than the native cordgrass, which may decrease its habitat suitability for native wetland fauna and birds. Dense stands of *S. alterniflora* causes changes in sediment dynamics, which may result in the infill of mudflats and conversion to high marsh, with the concomitant loss of shorebird feeding habitat (Callaway 1990; Callaway & Josselyn 1992). Tidal marsh restoration projects could inadvertently encourage the spread of *Spartina alteniflora*, by increasing the surface area in mudflats suitable for colonization by this aggressive invader.

In brackish and freshwater marshes such as the Sonoma Bayland restoration project area, peppergrass is invading newly cleared substrates from levies and spoil sites nearby (Dudley 2000). A native of Eurasia, broadleaf peppergrass *(Lepidium latifolium)* has been introduced to many parts of the United States; it is found on beaches, tidal shores, saline soils and roadsides throughout most of California. Broadleaf peppergrass produces large amounts of seed, can reproduce asexually by spread of rhizome sections, and is tolerant of a broad range of environmental conditions. It often becomes established on disturbed, bare soils, and has been observed in pickleweed (*Salicornia*) plains and among *Scirpus* spp. There is concern that peppergrass competes with pickleweed, thereby reducing habitat for the endangered saltmarsh harvest mouse, and that its dense growth is unsuitable for use as nesting cover by waterfowl, although reports show that waterfowl nests have been observed in monotypic stands of peppergrass (Cohen and Carlton 1995).

The Australian-New Zealand boring isopod *Sphaeroma quoyanum* causes fringing mudbanks to be riddled with half-centimeter diameter holes. The species has been present for over a century and it may have played a major role in the erosion of intertidal soft rock terraces along the shore of San Pablo Bay, due to boring activity that weakens the rock and facilitates its removal by wave action (Cohen and Carlton 1995).

3.4.4 Freshwater Systems: Rivers, Lakes, and Ponds

The impacts of exotics on San Pablo Bay freshwater systems are not well documented. There are, however, several species, that affect Delta tributaries and sloughs and are likely to cause similar problems in the San Pablo Bay watershed. Water hyacinth is an aggressive aquatic plant characterized by air-filled tissue (aerenchyma) that enables it to float and spread rapidly within and between connected water bodies. It reproduces asexually by fragmentation, which results in rapid increases in biomass. In some areas, continuous mats of living and decaying water hyacinth up to two meters thick covering the water surface have been reported (Cohen and Carlton 1995). Beginning in the 1980's, water hyacinth became a serious problem in the Delta, blocking canals and waterways, fouling irrigation pumps, shutting down marinas, blocking salmon migration and, by 1982-1983, blocking ferry boats at Bacon Island. Today water hyacinth is locally abundant in ponds, sloughs and waterways throughout the San Francisco Bay Area.

The American bullfrog (*Rana catesbeiana),* native to areas east of Colorado, was independently introduced to California several times between 1910 and 1920 . Adult and tadpole bullfrogs were collected from Sonoma Creek near El Verano, Sonoma County. These frogs may have been descendants of frogs purchased in New Orleans in 1914 and 1915 and planted in a nearby reservoir (Cohen and Carlton 1995). The bullfrog is a potential predator and / or competitor of the threatened California red-legged frog (R*ana aurora)* and other aquatic species.

Mosquitofish (*Gambusia affinis*) are likely present throughout the region in freshwater ponds.

3.4.5 Invasive Plant Species in Riparian and Upland Areas

Riparian and upland invasive species include plants thought of as "weeds," such as yellow star thistle and poison hemlock, as well as plants that have escaped from backyard landscaping like periwinkle and pampas grass. Non-native terrestrial plants often spread quickly, crowding out native vegetation and providing less habitat value than the vegetation they replace. As noted in tidal marshes, non-natives can threaten the success of restoration projects. The following is a partial list of invasive plants in the San Pablo Bay watershed that can be considered ecologically harmful, and thus may warrant eradication:

- *Arundo donax*, or giant reed, can quickly form a dense monoculture on streambanks that crowds out native vegetation, promotes bank instability, and offers less shade and habitat value that its native counterparts. *Arundo* and removal efforts targeted at *Arundo* are discussed more thoroughly in Section 5.2.5.

- Yellow star thistle (*Centaurea solstitialis*), native to southern Europe, was introduced to California by contaminated straw and hay seed. Star thistle pollen can be used by bees for honey, and it can be eaten by cattle in its early stages (Trinity County RCD 2000). However, it is toxic to some livestock (especially horses), and its sharp thorns make travel through heavy infestations almost impossible. Yellow star thistle has a long taproot that allows it to out-compete native plants for the available water supply. This taproot allows the plant to live well into June and July, after the native annuals have wilted (Howe 1999). Closely related purple star thistle is not as widespread, but is even more toxic and presents similar management challenges. Star thistle thrives on poor and disturbed soils, so special care should be taken not to spread the plant as part of restoration projects (Napa County RCD 1993).

- German ivy (*Senecio mikanioides*) is also known as Cape ivy (*Delairea odorata*). Because of its rapid growth rate, this plant has been used extensively in landscaping. For the same reason, it is able to grow quickly over native vegetation. German ivy is common throughout coastal riparian regions, as well as in some drier inland areas. German ivy contains alkaloids that can be toxic to fish, which makes it especially harmful in riparian zones (Southern Sonoma County RCD 1999). Since the plant reproduces via its roots, the only effective control measures are mechanical removal of the entire root system.

Biological controls are currently being researched.

- Himalaya berry (*Rubus discolor*), is a well-established weed pest in the San Pablo Bay watershed. It displaces native vegetation aggressively and may provide habitat for rats. It has, however, come to provide some valuable wildlife habitat and streambank stability (e.g. along the Petaluma river). Restoration plans to completely remove the berry should therefore be planned carefully to avoid the loss of food, cover and unprotected banks (Southern Sonoma County RCD 1997).

- Pampas grass (*Cortaderia jubata and C. selloana*), a commonly used landscaping plant, crowds out natives in both disturbed and natural areas. C. jubata is the much more invasive of the two closely related species. Pampas grass grows in low-lying upland areas and tidal marshes, and it can easily take over sand dunes/hills (Southern Sonoma County RCD 1997).

- Poison hemlock (*Conium maculatum*), like pampas grass, French broom and Cape ivy, is most prevalent in disturbed sites, and may crowd out most or all native plants, producing a low value monoculture habitat (Southern Sonoma County RCD 1997).

- French broom's (*Genista monspessulana*) prolific production of hard-coated, long-living seeds makes it especially difficult to eradicate. It can form impenetrable thickets, ruining rangeland and displacing plants and animals. French broom is also widespread along roadsides and trails and in the forests of northern California. Controlling French broom requires a long-term effort in order to remove the seed bank gradually (Swezy 1997).

- Periwinkle (*Vinca major*) is a perennial that spreads very rapidly but is susceptible to dry weather and frost. It is another escapee of landscaping, and continues to be planted for this purpose (Southern Sonoma County RCD 1997).

- Other invasive exotics include Bull thistle (*Cirsium vulgare*), Tree of Heaven (*Ailanthus altissima*), Lombardy poplars (*Populus spp.*), non-native Oaks (*Quercus spp.*), and Eucalyptus (*Eucalyptus spp.*).

3.4.6 Introduced Predators

Introduced terrestrial predators, like the red fox and feral cats, pose a serious threat to native waterfowl. Exotic predators that kill breeding waterfowl and steal eggs from their nests include the Norway rat, Virginia possum, red fox and feral cats. The following descriptions are adapted from Partnership for the San Pablo Baylands (1999):

- The estuary's close proximity to urban development, the presence of numerous garbage dumps and the widespread use of rip-rap to prevent shoreline erosion have resulted in high densities of rats along the shores. Norway rats are known to be major predators of waterfowl and the endangered clapper rail, whose eggs they steal.

- The Virginia opossum, which was introduced in San Jose in 1900, has become established throughout the Bay Area. Virginia opossums are reported as one of several predators that have caused duck nest loss in Suisun Marsh.

- The red fox, a subspecies introduced from the Midwest at the end of the 19th century (not the native subspecies of the Sierra Nevada) is an efficient predator that has adapted to urban areas. It poses a serious threat to native ground-nesting birds, including the clapper rail, shorebirds and waterfowl. In 1990, red foxes caused 100% nesting failure of several colonies of Caspian terns and California least terns by preying on eggs. They are suspected of causing the population crash of the California clapper rail in the late 1980's and early 1990's. Non-native red foxes recently have established themselves on the west and east margins of the diked historic baylands in Marin and Solano counties, respectively. These resourceful predators also could have major adverse impacts on two other endangered marshland species, the California black rail, and salt marsh harvest mouse. Little is known about the abundance of red fox in the San Pablo Bay watershed, or the extent of their current impacts on nesting birds and small mammals in the area.

- The number of feral cats has increased around the Bay Area as a result of urban development. Cats are efficient predators of small birds and mammals and are considered an increasingly serious threat to native wildlife.

- Introduced from the Colorado River, the muskrat was once harvested for its pelt. Today the main economic effect of this aquatic rodent is the damage it does by burrowing into levees and causing unwanted flooding.

Section 4
Challenges to Watershed Restoration Efforts

4.1 Introduction

Other sections in this document describe the history and ecology of the San Pablo Bay watershed, along with the factors that threaten and stress watershed habitats. This section describes why certain problems in the watershed should be addressed and overviews how that can be done. Further, this section describes the challenges associated with those potential restoration activities. Section 5 details specific restoration methods.

The fundamental threat to the ecological health of the watershed is a style of human habitation that commenced in about 1849, and which dismissed the need to safeguard the underlying watershed ecosystem. In the past, urban and agricultural development occurred without great concern for environmental impacts. Alteration of rivers, streams and tidelands proceeded without an understanding of the serious consequences of those actions on natural ecosystems. Today, however, with a growing appreciation for the importance of maintaining a highly functioning aquatic ecosystem, the need to repair the damage done by past practices is being widely embraced. In order to achieve that goal, it not only is necessary to restore the watershed's ecological resources, but to modify land use practices to prevent further damage in the future. A combination of activities and practices throughout the watershed produced both localized and cumulative effects that threaten the aquatic ecosystem. Interestingly, it is a combined approach - integrating a variety of sites and methods for watershed restoration – that can produce the localized and cumulative benefits necessary to reverse the damage done.

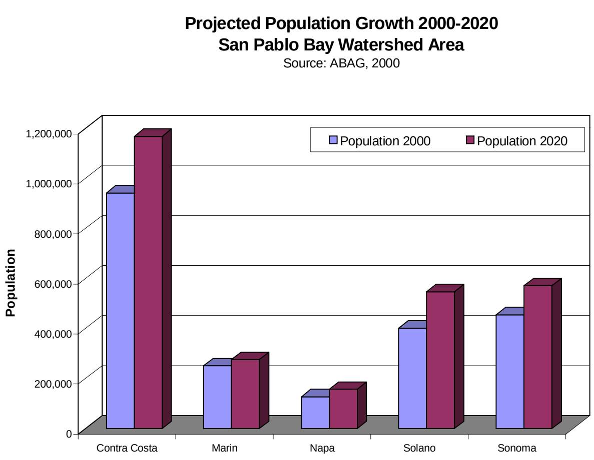


Figure 4-1

Effectively achieving restoration goals requires attention to sites and activities Upstream in the watershed as well as in streams and downstream, in San Pablo Bay. A coordinated set of activities that address sediment and pollutant sources in the upper watershed, for example, complements riparian revegetation and wetland restoration in the same drainage basin to result in more improvement in water quality downstream than would be achievable with isolated, disconnected projects. That is, prudent land use practices and restoration projects in upper watershed areas enhance the effectiveness of other watershed-friendly activities downstream.

A coordinated effort for restoration is further required because of the potential for unexpected or undesired results from isolated restoration actions. Bank stabilization to prevent erosion can, for example, increase flow rates and bank erosion downstream if projects are performed in an uncoordinated manner. The effects of a project, practice, or policy, both positive and negative, must be considered at a geographic and political scale that extends beyond the project's immediate boundaries.

The watershed-based approach recommended herein is one that not only incorporates a variety of physically different, spatially distributed methods, but one that unites the technical, financial and socio-political resources of restoration proponents throughout the watershed in a joint effort toward shared objectives. Empowering those with local knowledge of – or a stake in – the outcome of restoration efforts, such as land owners, local environmental groups, or municipal/ county agencies, to act in pursuit of restoration goals can foster community teamwork and a valuable spirit of cooperation.

An integrated approach, by its very nature, presents implementation hurdles. Coordination among project proponents and their activities is a well-known challenge. Implementing a watershed-based approach in the San Francisco Bay area is further complicated by the area's rapid population growth. The Association of Bay Area Governments forecasts that the counties in which the San Pablo Bay watershed is located will experience some of the region's most rapid growth, as shown in Figure 4-1. Furthermore, agricultural land uses are also increasing, with a significant growth in land areas planted in wine grapes. This expanding development increases pressure on the watershed's environmental resources, and must be managed carefully, both to avoid further damage and to facilitate restoration efforts.

This section highlights the ecological problems caused by past land use practices, and describes the modern challenges that must be met by a comprehensive watershed restoration effort.

Section 4.2 describes problems that have occurred due to human intervention in the natural system. Section 4.3 describes those effects of human intervention within the watershed that are often the focus of restoration efforts.

4.2 Causes of Alteration to the Watershed

Human activities, as described in Section 2, have led to major modifications in the natural environment of the San Pablo Bay watershed. Activities associated with human habitation have changed the landscape and waterbodies. Many of these changes are directly related to urban growth and agricultural development.

Physical Alteration of the Watershed

As people populated the San Pablo watershed, they altered the watershed to fit their needs. Many of these alterations changed the watershed physically, thereby disrupting the natural ecosystem functions.

Diking

As discussed in Section 2.4, people diked and drained large areas of the wetlands surrounding San Pablo Bay to provide additional land for agriculture. Initially, the land was used to graze livestock, but the agricultural uses of the land have expanded to include oat hay farming and raising horses (Goals Project 1999). Figure 4-2 illustrates the loss of wetlands, primarily due to diking and draining.

Levees were also placed along many of the area rivers. The levees helped to "reclaim" the land surrounding the river and utilize the land for development. As the surrounding lands subsided, the levees became increasingly important to prevent floods in the areas near rivers.

Altering the ecosystem by constructing dikes and levees has produced serious consequences both in loss of wetland habitat and increased risk of flooding. Recently, there has been a movement to restore tidal wetlands that have been diked and

Dikes are maintained by dredging bay mud From adjacent sloughs.

Link to Figure 4-2
Current and Historic Tidal Wetlands
of San Pablo Bay (357 KB)

drained. Section 5 will discuss methods used for those restorations in more detail. There have also been new approaches to flood control that do not involve levees, as discussed later in this section.

Waterway Modification

Waterway modifications in the San Pablo Bay watershed include dredging navigation channels, constructing flood control levees, and reinforcing streambanks and shorelines. The construction and maintenance of these features may cause loss of wetland habitat, modified in-stream habitat, increased turbidity, and increased temperatures.

Recommended dredging practices

The Calfed Bay-Delta Program has developed several recommendations for restoration in the San Francisco Bay, San Pablo Bay, and Delta. The Calfed vision for dredging and sediment disposal in the Bay-Delta is to maintain adequate channel depth for navigation, flood control, and water conveyance while reducing the adverse effects of dredging activities on the Bay-Delta ecosystem. The general target for dredging and dredge disposal is to reduce the loss and degradation of habitat and to contribute sediments for the recreation of shallow water habitats. The following restoration actions are advocated by the Calfed Bay-Delta Program:

- Coordinate all actions closely with federal, State, and local agencies charged with regulating dredging activities.
- Reduce the amount of contaminants flowing into the watershed and subsequently absorbed by sediments.
- Identify alternative dredged material disposal sites including upland and ocean sites, to ensure that disposal activities are flexible and avoid undue reliance on a small number of sites.
- Maximize the reuse of dredged materials for habitat restoration and other beneficial uses and minimize the amount of disposed material that is subject to resuspension and subsequent redredging.
- Support continued research on sediment transport and deposition, sediment quality and toxicity testing, the environmental effects of suspended sediment and contaminants, and the beneficial reuse of dredged materials so that dredging and sediment disposal management will continue to improve.

Source: (CalFed 1999a)

In the San Pablo Bay watershed, major waterway modification is conducted by the Army Corps of Engineers on the Napa River, Petaluma River, and Mare Island Straits. On the Petaluma River, for example, a 200-foot wide, 8-foot deep channel extends about 5 miles across the flats of San Pablo Bay to the mouth of the river and is maintenance dredged every 7.5 years on average. Dredged material from this channel is disposed of at the designated open water site in San Pablo Bay. A 100-foot wide, 8-foot deep channel extends from the mouth of the river to the City of Petaluma and is maintenance dredged every four years. Dredged material from this channel is disposed of at a confined upland disposal site provided by the City of Petaluma.

The disposal of dredged material is currently constrained by environmental and regulatory limits at the existing unconfined aquatic disposal sites in San Pablo and San Francisco Bays. The Army Corps of Engineers and other agencies have developed a Long Term Management Strategy (LTMS) to address future dredged material disposal. Restoration of tidal wetlands on subsided, diked lands using dredged material is one alternative that is recommended as a beneficial reuse of suitable dredged material. Section 5 includes more information on the beneficial re-use of dredged materials.

Development in Flood Plains and Corridors

Natural waterways occasionally overtop their banks under peak flow conditions, flowing out onto the adjacent areas. Flooding is part of the natural system and a critical component of channel geometry (San Francisco Estuary Project 1994). These flooded parts of the riparian corridor, as described in Section 3, which are normally dry, then hold and/or convey the excess flows.

In the San Pablo Bay watershed, a variety of development has occurred in natural flood plains and corridors, including both urban and rural residential land uses, agricultural development, and urban commercial and industrial uses. Development in flood prone areas interferes with the natural function of floodplains, namely, storing or conveying excess flow, and increases the likelihood that flooding will cause damage to the structures and infrastructure built there. The development also increases the amount of impervious surfaces (see the following subsection).

Because urban and other developed areas often have similar runoff patterns across wide areas, much of a rain event's associated runoff can enter streams in a large pulse, rather than gradually, making the stream more likely to flood. Another typical San Pablo Bay development practice that drastically altered the natural flooding regime was the placement of structures designed to control these flood flows.

Historically, the approach to flood control was to attempt to move the water through the stream or creek as fast as possible. The traditional approach created a large, trapezoidal channel with stable slopes (often lined with concrete or rip-rap) and straightened any curves. This approach also included the removal of vegetation from the channel because it can cause the water to reduce speeds, or cause slope instability. This design causes water to move quickly through the channel, but does not offer the same habitat benefits as a meandering creek lined with riparian zones. Pinole Creek in Contra Costa County is an example of this type of flood control project.

Increase in Impervious Surfaces

One of the major examples of environmental modification caused by agricultural and urban development is the increase in impervious surfaces within the watershed, and the ensuing change in runoff patterns. These changes have resulted from the removal of vegetation, exposure of soil in agricultural areas, the creation of hard and impervious surfaces, and the replacement of natural drainage swales with concrete channels and storm drains for the efficient removal of stormwater runoff.

As urban development has increased within the San Pablo Bay watershed, many areas have changed from natural ground cover to new structures, such as buildings and roads. These impervious surfaces prevent water from percolating into the ground, and more precipitation runoff enters the surface waterways than would normally. In addition, standing water becomes a health risk, so structures are built to drain storm water as quickly as possible into the nearest surface water body. In most urban areas, 40-80% of the land is covered by impervious surfaces such as rooftops, roadways, and parking areas (Southern Sonoma County Resource Conservation District 1997).

Impervious surfaces are not simply a problem in urban areas. In agricultural areas, removal of vegetation and exposure of soil in agricultural areas have resulted in faster runoff. Vegetation normally slows rainwater as it runs into streams and creeks, allowing time for the water to percolate into the ground. Without the vegetation, the water runs off of the agricultural lands more quickly.

One of the environmental consequences of impervious land coverage is stream degradation. Impervious surfaces cause stream degradation in four ways:

- Rainwater is prevented from moving into the soil, where it can recharge groundwater. Reduction in groundwater, in turn, reduces base flows in streams.

- Because it cannot infiltrate into the soil, more rainwater runs off, and runs off more quickly. This runoff causes increased flooding, destabilized natural channels as stream channels adjust to higher flows, and associated reduction of habitat and other stream values. To prevent flooding and channel destabilization, the natural channel may be straightened or lined, causing further loss of natural uses.

- As runoff moves over large impervious areas, it collects and concentrates pollutants from human activities within the watershed, which increases the pollutant loads entering the area waterways.

- Impervious surfaces retain and reflect heat, causing increases in ambient air and water temperatures. Increased runoff temperatures in turn increase the water temperature in creeks and streams, which can negatively affect aquatic life and oxygen content of the waterbodies (Southern Sonoma County Resource Conservation District 1997).

Deforestation

A side effect of urbanization is the need for building materials and fuel, and supplying products to fill this need has caused widespread deforestation within the watershed. Deforestation is discussed in more detail later in this section, under Loss of Habitat.

Hydrological Alteration of the Watershed

As the San Pablo watershed urban and agricultural areas have developed, the region's local water supplies have been tapped to meet their needs. The region relies on a mix of imported water, groundwater and surface water diverted from local basins and streams to serve a variety of water needs. Several water agencies and cities within the project area own and operate local water supply reservoirs, including Stafford Lake (North Marin Water District), Lake Milliken and Lake Hennessey (City of Napa), and Briones Reservoir and San Pablo Reservoir (East Bay Municipal Utility District). In addition, numerous agricultural and municipal users pump groundwater and divert water from creeks and rivers within the watershed. The State Water Resources Control Board, which has jurisdiction over use of surface water in streams and creeks in California, has determined that portions of Sonoma Creek and the Napa River are considered fully appropriated during summer and fall (State Water Resources Control Board 1998).

Minimizing effects of impervious surfaces and urbanization

In the Sonoma Creek Watershed Enhancement Plan (1997), the Southern Sonoma County Resource Conservation District has presented residential site planning and design guidance information for the community's use. Information regarding the minimization of the effects of urbanization (i.e., impervious surfaces) was provided courtesy of the Bay Area Stormwater Management Agencies Association (BASMAA). These techniques have three basic goals: to minimize overall impervious land coverage; to ensure that remaining impervious areas are not directly connected to an impervious storm drain system as far as feasible; and, to slow runoff within a drainage system

For a large hillside development site, BASMAA recommends that erosion must be prevented through siting with contours to minimize grading and careful stabilization of disturbed slopes. Drainage systems, infiltration basins, and detention devices must be located so that water does not compromise the integrity of building foundations and other structures. Techniques include:

- Avoidance of steep slopes
- Buildings clustered and aligned with topography
- Pervious concrete parking areas
- Swale with check dams that flows to creek

A small or large flat site can also be designed to maximize stormwater management opportunities. If soils have adequate percolation rates, infiltration swales and basins are easily incorporated. In more poorly drained soils, flat sites allow for detention and retention systems to slow the speed of runoff and hold it for later release. This allows sediments to settle and minimizes stream bank erosion from high velocity flows. Suggested techniques include:

- Depressed playfield with multiple use as infiltration basin
- Swale along parkway collects street runoff
- Culvert to carry parkway swale under cross street
- Riparian trees and infiltration basin at end of swale

Water supply development within the San Pablo watershed has had a profound effect on the ecology of the watershed. Construction of dams for water supply reservoirs has altered downstream flow patterns of both water and sediment, blocked historic migratory fish runs, altered water quality and effected long-term changes on the downstream riparian corridor. Use of surface and groundwater for water supply has changed seasonal groundwater and stream flow patterns and reduced summer base flows, affecting aquatic organisms, habitat and ecosystem processes. As a result, natural resource managers face the challenge of sustaining and enhancing aquatic resources under conditions highly altered from historic conditions.

Suburban expansion poses a threat to wildlife habitat and restoration efforts.

Water Pollution

Two main sources of water pollution affect the watershed: point sources and non-point sources. Point sources include pollution that is discharged directly into waterways, including municipal and industrial wastewater. Non-point sources are those that are not direct discharges, but include pollution that is carried along with runoff from areas with contaminants. Point sources are caused by people and are included in this section describing human alterations within the watershed. Non-point sources are discussed in Section 4.3, as they are the most often effects of a variety of problems within the watershed, including most of the alterations just described.

Before development began in the San Francisco area, the Estuary had few, if any, water quality problems. Sediment and naturally occurring pollutants were assimilated into the ecosystem without any adverse effects. As urban, industrial, and agricultural activities increased, the number, type and significance of pollutants expanded. In response to the algal blooms, fish kills, and low dissolved oxygen levels occurring in the 1960s, a nationwide effort was begun to control point source pollution. Over the next couple of decades, improved treatment of municipal wastes reduced nutrient loadings and improved dissolved oxygen levels in many water bodies, including the Napa and Petaluma Rivers (SFEP 1994).

These efforts to control pollution also included more stringent regulations of discharges entering waterways. Many municipal wastewater treatment plant discharges required additional treatment before the water entered the local streams or rivers. Industrial discharge was also held to higher standards, requiring additional treatment. There are still multiple wastewater treatment plants within the watershed, but the impacts on the watershed have decreased. In addition, wastewater treatment plants are prohibited from discharging into local waterways during the summer, to reduce pollutant loads during periods of low flow.

Non-native Invasive Species (NIS)

Non-native invasive species, also called “exotics,” are species that were not naturally found in the ecosystem, but have entered through human intervention. Many of these species can out-compete the natural species, and can take over areas that were previously healthy habitat. Invasive species often provide less value within the ecosystem to other species that rely on the original natives for food or shelter.

The San Francisco Estuary is now recognized as the most invaded aquatic ecosystem in North America (Cohen and Carlton 1995). Since 1970, the invasion rate has been at least one new species every 24 weeks and in the aquatic system alone, there are 212 recognized introductions along with 123 species that are considered cryptogenic (not clearly native or introduced) (Cohen and Carlton 1995). The terrestrial or upland portion of the watershed is also heavily invaded by exotics. These "exotic" or nonnative species cause profound effects on the ecosystem. They are part of nearly every estuarine food web and in some instances nearly 100% of the species in some communities are introduced (Cohen and Carlton 1995).

Star thistle, a non-native invasive plant, is widespread throughout the watershed (Brousseau).

In the San Pablo Bay watershed, invasive species can cause substantial structural changes to natural habitats and significant economic impacts. Species such as yellow star thistle (*Centaurea solstitialis*), *Arundo donax* and more recently, Atlantic cordgrass (*Spartina alteniflora*) are the subject of costly research and eradication programs. When considering restoration strategies, it is important to note the difficulty of recreating native communities due to the presence of these non-natives and the potential for encouraging additional introductions through the act of restoration. It has been suggested, for example, that tidal marsh restoration projects could encourage the spread of *Spartina alteniflora*, an introduced cordgrass, by increasing the surface area in mudflats suitable for colonization by this aggressive invader. This illustrates the importance of having significant knowledge on the presence, distribution and lifecycles of exotic species prior to implementing restoration projects.

Exotic species have entered the watershed through a variety of different human interactions. Some species, such as the Asian clam, entered the ecosystem in the ballast water of ships that were entering San Francisco Bay. Some species were introduced on purpose for a variety of reasons, such as landscaping value (periwinkle) or for commercial fisheries (striped bass). Many species did not enter the watershed in dramatic ways, but simply because seeds were in early settlers' belongings.

4.3 Effects of Alterations to the Watershed

Section 4.2 discussed ways that people have changed the watershed through both urban and agricultural development. This section describes how these changes have affected the watershed.

Many of the ecological resources remaining in the San Pablo Bay watershed are declining in quality due to activities such as waterway modification, leapfrog development of rural lands, and flow diversions. The construction and maintenance of navigation channels and flood control levees affects the fate of pollutants and fish and wildlife habitats. Leapfrog development of rural lands (even in the upper watershed) increases the need for water storage and diversions, urban stormwater runoff, and both non-point and point sources of pollution. These actions lead to high instream suspended sediment concentrations, decreased water quality, lower base flows, higher levels of toxic pollutants, loss of habitat, and loss of biodiversity. This section discusses some of the problems caused by alterations of the San Pablo Bay watershed ecosystems.

4.3.1 Erosion and Sedimentation

Definition

Soil erosion is a natural process characterized by the loss of topsoil caused by a combination of rainfall runoff, lack of vegetative cover, fragile soils, and slope of the land. The detached topsoil, known as sediment, is carried over the surface of the watershed by runoff in streams. The sediment travels in the watershed system until the process of sedimentation causes the soils to settle and deposit in the downstream reaches of the watershed, such as a culvert inlet, a stream channel, a pond, or an estuary.

Erosion and Sedimentation - Why and How it Occurs

Sources of sediment can include natural background erosion in areas that are not intensively used, erosion from intensively used areas with sparse cover, and erosion from streambanks. Types of erosion of concern include sediment sheets eroding from hillsides, gullies in rural areas, active streambank erosion that threatens property, poorly designed or maintained roads, and landslides.

In stable watersheds, soil erosion and sedimentation is a naturally occurring process, and rates of erosion are slow. The natural healing processes of the environment are able to balance out the effects of erosion and sedimentation. In the San Pablo Bay watershed, however, human use of the land has accelerated the change beyond nature's short-term healing capabilities. As a result, nature is no longer able to keep up with these processes, which have been accelerated by human activities.

Activities that may increase soil erosion include urban development, agriculture, grazing, road and general construction, and recreation. Urban development increases the amount of impervious surfaces, which can increase the volume and rate of stormwater runoff. Overgrazing and grazing in riparian corridors removes vegetation that serves a vital role in stabilizing stream banks, reducing the volume and rate of runoff and increasing infiltration.

Minimizing erosion and sedimentation

Once underway, erosion and sedimentation problems generally worsen and are more difficult to control, making pre-project erosion control planning and preventative maintenance necessary. Several management practices are available to reduce soil erosion, and many Resource Conservation Districts (RCDs) have programs that provide education and support. In addition, members of land stewardship groups throughout the watershed are implementing voluntary land management practices to reduce soil erosion. (Partnership for the San Pablo Baylands 1996)

In Napa County, for example, the Napa County RCD has developed the Napa River Watershed Owner's Manual (1996), a document that contains several recommendations for reducing and controlling erosion. This manual suggests that erosion control activities must be concentrated in high priority sub-watersheds to reduce the acceleration of erosion and manage sediment, as well as the following recommendations:

- Reduce streambank instability and erosion
- Reduce erosion resulting from agricultural activities
- Reduce soil erosion resulting from urban and residential development
- Minimize new road construction
- Manage public areas to minimize soil disturbance and threats of erosion
- Increase the use of erosion control techniques and practices for existing land uses
- Increase data management and public outreach efforts

While some sediment is needed to bring nutrients and substrate materials to aquatic ecosystems, excessive amounts of sediments can cause problems. Sediments can fill reservoirs and stream channels, which reduces their storage capacity, reduces water quality, and damages fishery and wildlife habitats. It can reduce the capacity of watercourses to hold storm flows, thereby increasing flooding. Erosion problems also translate to a loss of valuable agricultural land by removing the valuable topsoil layer from farmland. When sediment fills navigable stream channels, dredging is necessary to maintain open waterways. Dredging activities tend to re-suspend sediment back into the water column, and disposal of dredged material is also an issue of concern (Southern Sonoma County RCD 1999).

Minimizing erosion and sedimentation on ranches and farms

The Southern Sonoma County Resources Conservation District presented several recommendations to landowners in the Petaluma Watershed Enhancement Plan (1999) to control erosion and sedimentation. These included riparian fencing and revegetation, outreach activities to support land stewardship and land management activities, and repair of individual sites. The recommendations put forth by the RCD are entirely dependent upon the voluntary cooperation of willing landowners. Some of these recommendations include:

- Provide workshops and brochures for ranchette and ranch owners. Topics could include "do-it-yourself" erosion control, small farm and pasture management, management and revegetation of the riparian corridor (including fencing alternatives), how to reduce rill and sheet erosion for pastures and corrals, and other issues that landowners identify. Related recommendations include working with U.C. Cooperative Extension and the RWQCB to provide conservation plan workshops for dairy operators and ranchers.
- Identify cost-share programs for ranchette/small property owners. Although cost-share programs exist for agricultural landowners, ranchette or non-production agricultural operations usually do not qualify for these programs. Having cost-sharing available would help some small property owners address erosion problems.
- Encourage the use of Best Management Practices (BMPs) for hillside vineyards. Vineyards are increasing in the Petaluma River watershed. New and existing vineyard owners should be encouraged through workshops, field days, and distribution of manuals and other educational materials to use BMPs, especially for production on hillsides and highly erodible slopes.

The San Pablo Bay watershed is naturally a relatively high producer of sediment owing to its climate, topography, geology, and soil conditions. Soils in the uplands have a particularly serious potential for erosion. The sensitivity of the watershed to soil erosion amplifies the need for sound land management practices that minimize the loss of soil into the San Pablo Bay watershed (Napa County RCD 1994).

Erosion and Sedimentation - What Can be Done

Erosion and sedimentation are problems that affect the entire watershed and approaches for curbing them should take a watershed-based approach. Just

Hillside vineyard ordinances in Sonoma and Napa Counties

During the past decade, both Napa and Sonoma Counties have passed hillside vineyard ordinances in an attempt to control hillside erosion. The first ordinance in Napa County was passed almost ten years ago in 1991, and has undergone some revisions to include CEQA and other requirements. For new vineyards, an erosion control plan is required on slopes between 5 and 30%. In addition, there are limitations on clearing brush in municipal watershed areas. The Napa County Resource Conservation District (RCD) performs the technical evaluation of plans, and the County Planning Department is responsible for the final approval of the plans. (Zlomke 2000) The Napa River Watershed Task Force Phase II Final Report (2000) is recommending further revisions to this ordinance; specifically, that projects on slopes under 5% comply with setbacks and other requirements, and that the regulations provide more appropriate level of protection for steep slopes (greater than 30%).

A hillside vineyard ordinance was finalized in Sonoma County in February 2000. This ordinance requires all prospective vineyard developers to provide notification to the County Agricultural Commissioner's Office. If the land slope is less than 15% (or less than 10%, depending upon the soil classification and erosion potential), only notification is required. If the slope is between 15 (or 10) and 35%, the landowner must have an erosion control plan, including blueprints of sedimentation ponds, ditches, or other control measures, prepared by a county-certified engineer. Other control measures include vegetation cover crops, straw waddles instead of silt fences, and 25-foot minimum setbacks from streams. The Agricultural Commissioner's Office is responsible for the final review of the erosion control plan and a site visit. If the plan is approved by the Agricultural Commissioner, the landowner has until October 15 (beginning of the rainy season) to implement the control measures. The Commissioner will conduct a site visit after the rainy season begins to make sure all of the control measures have been implemented (Sheffer 2000, Morgan 2000).

as erosion that carries away topsoil in the upper watershed can clog stream channels in the lower watershed, damaging both upland and lowland areas in the process, so can erosion and sedimentation control methods address both upland and lowland areas. Approaches that help address erosion throughout the watershed will have the most positive effect.

Several factors influence erosion rates: vegetative cover, soil type and texture, slope, and frequency and intensity of rainfall. Approaches to address erosion on specific sites should be cognizant of these factors in planning restoration activities or alterations of land use practices, and should bear in mind that on most surfaces, vegetative cover is one of the most important control types for erosion (Marsh 1991). Agricultural development on hillsides, for example, should take into account the hillside slope, soil type and rain patterns when selecting row layout, crop type and land management practices.

In general, soil erosion can be avoided by maintaining a protective cover on the soil, creating barriers to erosion-causing flows and by making changes in the landscape that control runoff amounts and rates. Specific practices that may be used to avoid erosion associated with water in agricultural areas include: growing forage crops in rotation or as permanent cover; growing winter cover crops; interseeding; and protecting the surface with crop residue. Practices that may be used to reduce the likelihood of erosion in areas throughout the watershed include shortening the length and steepness of slopes; increasing water infiltration rates and improving soil stability (USDA 1996).

Strategic placement of vegetation, such as riparian vegetation strips and buffers, can prevent erosion through soil stabilization and by intercepting rain, reducing its force on the ground. At the same time, vegetated areas can filter out sediment, slow runoff velocity and allow some runoff to infiltrate into the soil. Appropriate use of vegetated filter strips can provide all of these erosion and sedimentation control benefits. In addition, they provide the benefit of riparian habitat area and, if incorporated properly, an aesthetically pleasing corridor for recreation such as walking or cycling (Arendt 1994).

Sediment control goes hand in hand with erosion control in that, the more effectively erosion is addressed in upstream and upland areas, the less of a problem sedimentation will be in downstream and lower watershed areas. Preventative measures to control sediment range from the use of (and the placement of) natural filtering vegetation to the installation of infiltration basins for stormwater that allow runoff to percolate into the groundwater. These methods provide the additional benefit of facilitating infiltration. Other methods, such as using structures to detain runoff flows and settle out sediment or the physical removal of sediment from waterways, are also effective in addressing sedimentation problems, but have intensive maintenance requirements, may be intrusive and do not address the problem at the source.

There are many ways to decrease erosion and sedimentation within the waterways. A combination of methods, selected to be appropriate for erosion sites, sediment sources and accumulation points, will be necessary to effectively address this problem in the San Pablo Bay watershed. The challenge for restoration planners is to be proactive in addressing erosion and sedimentation as early in the process as possible, while selecting methods that: coordinate well with other watershed restoration efforts; address the problem in an effective, cost-efficient manner; and do not compromise the economic viability of current land uses.

The Hillside Vineyard sidebar presents a specific example of minimizing polluted runoff.

4.3.2 Poor Water Quality

Definition

Pollution entering the San Pablo Bay watershed comes from two types of sources: point sources and non-point sources. Point sources were discussed in Section 4.2 because they describe human alteration to the ecosystem. Non-point pollution is contaminated groundwater and runoff from a variety of sources. When it rains, the rainwater flushes through the watershed, gathering pollutants on the ground (such as oil, sediment, detergents, and pet wastes) and carrying them to the stormdrains, streams and creeks.

Poor Water Quality - Why and How It Occurs

Many activities within the watershed involve chemicals that can be damaging or toxic to the environment. These chemicals are washed into the waterways by runoff from precipitation events, and impact water quality throughout the watershed. Table 4-1 lists the categories, sources, and types of pollutants that enter the watershed.

Precipitation, flow diversions and flow releases can have a significant effect on surface water quality. During the wet season (November through May), precipitation runs off the land and streams flow full. The higher precipitation results in increased non-point pollution and reduced water quality.

During the dry season, minimal precipitation causes streamflows to decrease dramatically. Several new problems accompany these lower flows. Dissolved solids are found in higher concentrations. In addition, higher water temperatures and nutrient levels (phosphorus and nitrogen primarily in the form of phosphates and nitrates) can cause excessive plant growth , which in turn may reduce DO levels.

Another water quality parameter which depends greatly on freshwater inflows to the estuary is salinity. Because ocean salinities stay relatively constant, salinities in San Pablo Bay are higher during the summer, when river inflows are low, and lower during the winter when inflows are high. Changes in salinity from the altered flow regime have enormous impacts on the Bay's biological resources, especially its distribution of vegetation and wildlife. In addition, when the inflows into San Pablo Bay are decreased during the summer, the tidal influence is more pronounced in rivers and creeks that flow into San Pablo Bay.

Reduced water quality can impact both environmental and recreational uses of a

Minimizing polluted runoff

The San Francisco Bay Conservation and Development Commission (BCDC) recognizes that water quality protection plans and policies should consider, wherever possible, the entire watershed when addressing sources for polluted runoff. Watershed-based polluted runoff goals and objectives should be integrated among the local governments and other regulatory authorities. Also included in a watershed approach should be the coordination of Best Management Practices (BMPs) implementation, the coordination of enforcement methods, and mechanisms for the pooling of resources and sharing of information. Key strategies recommended by the SF BCDC (1999) for preventing polluted runoff include:

- Minimize hard, impervious surfaces, such as concrete or compacted soil. Impervious surfaces block the absorption of water thereby increasing runoff
- Prevent erosion. Erosion results in sediments carried in polluted runoff, which can smother plants and animals and fill wetlands.
- Protect riparian areas. Vegetation associated with rivers and creeks can reduce the impact of polluted runoff by holding soil and decreasing erosion, holding pollutants from travelling downstream, and by allowing surface water to infiltrate soil and decreasing runoff.
- Protect vegetation. Vegetation in general increases infiltration of water, filters some pollutants by incorporating them into the plant tissue, reduces erosion by holding soil, maintains the soil's capacity to hold water, and absorbs the energy of falling rain, which further reduces erosion.
- Protect groundwater. Protecting groundwater from polluted runoff protects water supplies and may also protect rivers, wetlands, and other downstream water bodies.
- Minimize pollutants. By reducing the amount of pollutants introduced to the waterways and stormdrains, polluted runoff can be reduced.

At the local level, techniques for addressing causes of polluted runoff may include:

- Education and technical assistance projects
- General Plans
- Specific plans
- Project review procedures
- Zoning and subdivision regulations
- Ordinances
- Design guidelines
- Voluntary waste minimization, household hazardous waste and water conservation programs
- Watershed based plans
- Baselines urban runoff programs

Table 4-1

Category	Main Sources of Pollution	Contaminants
Urban	Developing areas Construction sites Existing development On-site disposal systems General (households, landscaping, commercial) Roads, highways, and bridges	Nutrients Sediment Heavy metals Petroleum hydrocarbons (mainly from automobiles) Synthetic organic chemicals Bacteria or pathogens
Agricultural	Grazing, pasture, and rangelands Vineyards Dairies	Nutrients (examples: nitrogen and phosphorus from fertilizers and manure) Sediment Synthetic organic chemicals (from pesticides and herbicides) Bacteria and pathogens (from animal wastes)
Municipal and Industrial	Wastewater treatment plants Industrial discharges	Nutrients (primarily phosphorus and nitrogen) Heavy metals (examples: cadmium, mercury, and silver) Organochlorines and other synthetic pesticides Petrochemical hydrocarbons
Dredging and Waterway Modification	Resuspended particles from waterway bed	Suspended sediments Chemicals sorbed to sediments Nutrients (example: phosphorus from eroded clay soils derived from volcanic parent rock)

waterway. The San Francisco Regional Water Quality Control Board (RWQCB), regulates water quality in the San Pablo Bay watershed, with the goal of maintaining sufficient water quality for the area's uses of the waterways. The San Francisco RWQCB's jurisdiction includes San Francisco, San Pablo, Suisun and Tomales Bays, as well as all streams and rivers that flow into them (beginning at a point just west of Antioch), ocean waters and groundwater. The RWQCB's Water Quality Control Plan serves as the master policy document that contains descriptions of the legal, technical, and programmatic bases of water quality regulation in the San Francisco Bay Region. The Water Quality Control Plan establishes beneficial uses of the surface and ground waters in the watershed and sets water quality objectives to meet the minimum water quality that supports a designated beneficial use. In the project area, such uses include agricultural supply, municipal supply, warm and cold freshwater habitats, wildlife habitat, contact and non-contact water recreation, and fish migration and spawning (San Francisco RWQCB 1995). The U.S. Environmental Protection Agency and the RWQCB establish a list of impaired water bodies, which lists waterways with significant water quality problems. In the San Pablo Bay watershed, the Bay itself, as well as 11 creeks and rivers, have been designated as impaired. Table 4-2 lists these impaired waters.

Table 4-2

Waterbody	Parameter(s) of Concern
Petaluma River	Nutrients
Sonoma Creek	Nutrients Sedimentation/Siltation Pathogens
Napa River	Nutrients Sedimentation/Siltation Pathogens
Miller Creek	Diazinon
Pinole Creek	Diazinon
Gallinas Creek	Diazinon
Rodeo Creek	Diazinon
Novato Creek	Diazinon
San Antonio Creek	Diazinon
San Pablo Creek	Diazinon
Wildcat Creek	Diazinon
San Pablo Bay	Copper, Mercury, Nickel, Selenium, Exotic Species, Diazinon, PCBs, Chlordane, DDT, Dieldrin, Dioxin Compounds, Furan Compounds, And PCBs (Dioxin-Like)

Source: (U. S. EPA 2000b)

The pollutants causing this impairment include nutrients, sediments, pathogens, toxic chemicals and heavy metals (U.S. EPA 2000b). These pollutants prevent the waterways from fulfilling their designated beneficial uses, and are targets for remediation in upcoming years.

Toxic chemicals that pose the greatest concern include synthetic organic chemicals, such as plastics, pesticides, fertilizers, solvents and pharmaceuticals. Polychlorinated biphynols (or PCBs) and pesticides, such as DDT and Malathion, are organics that may adversely affect aquatic organisms. The heavy metals, also known as trace elements, that cause the most concern are arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, tin and zinc.

Poor Water Quality - What Can be Done

The two sidebars on minimizing polluted runoff and EBMUD's efforts to ensure water quality in their reservoirs illustrate some ways to protect water quality and demonstrate how they may be considered in the watershed context. In addition, the following methods help address non-point pollution:

- Constructed wetlands remove nutrients, metals, and suspended solids;
- Infiltration basins remove contaminants as water infiltrates to groundwater; and
- Treatment facilities can be built to provide biological and chemical treatment.

Addressing pollutants at the source, such as mitigating nutrients from agricultural areas that apply nitrogen, phosphorus and organic fertilizers, can also help reduce non-point pollution.

EBMUD Reservoirs

East Bay Municipal Utility District (EBMUD) has developed several strategies for dealing with water quality challenges associated with managing its drinking water reservoirs in the San Pablo Bay watershed, including the San Pablo and Briones Reservoirs. EBMUD's goal is to maximize reservoir water quality to comply with current and anticipated future drinking water regulations, including assessing how human activities and land and water uses may affect water quality. This will include the implementation of measures when necessary to maintain water quality.

Some of the general management guidelines that EBMUD has identified in its East Bay Watershed Master Plan (1996) include:

- Identify and quantify contaminant sources before developing management and control strategies and prioritizing implementation. The District should expand its non-point-source monitoring programs to fill gaps in existing information.
- Establish or continue certain prohibitions to protect public water supplies, such as:
  - Prohibit body-contact recreation in reservoirs and tributary streams
  - Prohibit untreated sewage from entering reservoirs
  - Prohibit new easements or rights-of-way for pipelines and/or conveyances transmitting hazardous substances through District watershed lands
  - Prohibit the use of high emission motorboat engines on San Pablo Reservoir, effective January 1, 2000; and prohibit the use of motorboat engines that discharge any fuel pollutant into the water, effective January 1, 2002 (Resolution No. 33088-98, effective March 10, 1998).

4.3.3 Flooding

Definition

In the San Pablo Bay watershed, areas may become inundated with water, or flood, when peak discharges of stream flows, high tides, storm waves, levee failure or flow restrictions cause water ways or containment areas to overtop their banks and flow over or stand on normally-dry land.

Flooding - Why and How It Occurs

In the 1992 General Plan, the Napa County Planning Department noted that "in reclaimed areas in which the land surface lies several feet below the high tide line, the risk of life loss and severe property damage is high." Flooding can damage or destroy buildings, wash away soil and crops, and disrupt sewage treatment facilities resulting in adverse impacts to water quality.

The potential for flood damage is related primarily to the existence of structures, infrastructure and agricultural development within flood-prone areas and the continued development of hillsides. At the same time that developments in these areas suffer because of flooding, they are also some of the causes for increased flood magnitude and frequency. Development in the upper watershed also increases the frequency and intensity of flooding in the lower watershed because of the increased runoff from impervious surfaces. Ironically, efforts to control flooding through channel modification (to convey additional flow) can also result in problems downstream if flood control efforts are not coordinated through the watershed.

Studies demonstrate that in the San Pablo Bay watershed, flood height and return frequency are changing as development occurs. As Figure 4-3 illustrates, this occurs even in upstream areas of the watershed.

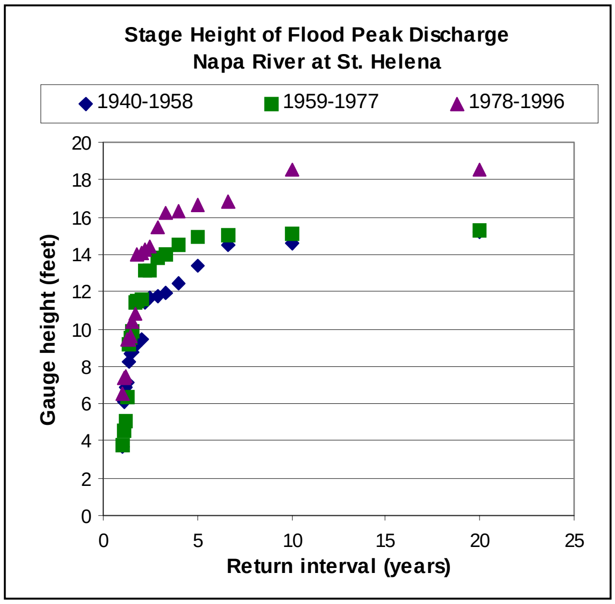


Figure 4-3

The recurrence interval of flood of a given magnitude appears to have decreased over time for the Napa River near St. Helena. It is hypothesized that the conversion of grasslands to urban and vineyard land use played an important role in this change (McKee et al. 2000).

Flooding – What Can Be Done

The Army Corps of Engineers (Corps) and local flood control districts provide flood control where economically justified. The general process is for a local sponsor to get Congressional authorization through a local representative for the Corps to do a study. The feasibility study phase is cost-shared with the agency and usually takes several years. Because flood control outside of urban settings is not usually justified economically, flood control

Napa River Flood Control Protection Project

In the past 36 years, flooding has cost Napa residents $542 million in property damage alone. Residents, businesses, and governments spent a total of $220 million to repair damage from the floods of 1997, 1982, 1967, and 1963. Worse floods, which occurred in 1986 and 1995, cost the community a total of $322 million in repairs. (U.S. Army Corps of Engineers, 1998)

In 1965, Congress authorized $80 million for the U.S. Army Corps of Engineers (Corps) to perform a flood control project on the Napa River. The Corps presented three plans to Napa residents, but the residents rejected all three. All three plans included the following actions:

- Deepen channel bed;
- Raise levees on both sides of the river;
- Line levees with concrete; and
- Dredge channel frequently.

The third plan was finally rejected in 1995, and the authorization was ready to expire. At this time, the Corps was approached with a completely different flood control method by a coalition of state and local governments, resource agencies, businesses, and environmental organizations. These agencies worked with the Corps to create a plan that incorporated flood control as well as ecosystem restoration.

The final plan was a cooperative effort between the Corps, 27 government agencies, and 25 non-governmental organizations. The new plan involved the following actions for a 7-mile stretch of the river:

- Widen floodplain (instead of deepening channel);
- Create terraced marshes and broad wetlands (instead of levees);
- Reforest riparian areas;
- Move buildings out of floodplain (16 houses, 25 mobile homes, 8 commercial buildings, and 13 warehouses);
- Rebuild 7 bridges to make them higher and stronger to withstand flooding; and
- Create a "Dry Bypass" at a horseshoe-shaped curve in the City to allow the river to follow a straight path during floods.

Napa residents were much more receptive to this plan, but it required $110 million more than the original authorization. To raise these funds, Napa passed the "Living River Initiative," which raised county sales tax by one half of one percent. The tax increase would raise $6 million per year for the next 20 years, which would provide the necessary local funding. People have a natural tendency to vote against tax increases, and they require a 2/3 vote, so it was a challenge to pass the measure. However, advocates pointed out that the project should save the community $20 million per year in flood damage, and the measure passed by a narrow margin.

measures in rural areas are the responsibility of property owners.

As noted earlier in this section, the historical approach to flood control used channel modification and stabilization, along with removal of riparian vegetation. Such flood control methods usually resulted in loss of most of the natural habitat benefits of the riparian corridor. In recent years, however, approaches to flood control have been changing. Many people and agencies no longer believe that it is necessary to reduce the environmental value of a stream to provide flood protection. A combined approach, such as one that widens and/or makes use of natural floodplain area for flood storage and conveyance, removes structures from the floodplain, and revegetates riparian areas is a desirable alternative to historical approaches. An updated flood control project, in concert with efforts to reduce runoff from impervious surfaces in a stream's drainage area, can be effective in reducing the problems associated with flooding and improving aesthetics, while simultaneously increasing the habitat value of the riparian area.

The Napa River Flood Control Protection Project demonstrates how flood control projects can incorporate environmental values (see Napa River Flood Control Protection Project sidebar). Similar efforts are underway on Wildcat Creek, Sonoma Creek.

4.3.4 Loss/Modification/Degradation of Habitat

Definition

In the San Pablo Bay watershed, significant portions of Baylands and upland habitat have been destroyed, modified, or degraded due to urbanization, agriculture development, commercial operations, and other hydro-modification activities. Acres and acres of oak woodland habitat have been cleared for residential development and agricultural uses, such as grazing and vineyards. Only 27 percent of the historic tidal marshes in San Pablo Bay remain (Southern Sonoma County RCD 1999). This section discusses the loss of various types of habitat, including loss of wetland, riparian and upland habitat. The loss of contiguous habitat is also a serious issue in the San Pablo Bay watershed.

Modification/Degradation of Habitat - Why and How It Occurs

Reduction, modification and degradation of habitat can be devastating for certain species for which that habitat is important. Even where habitat remains, fragmentation of large areas of habitat into smaller patches can reduce its usefulness for a species if the patches of habitat are smaller than the animal's natural roaming area, or if the patch of habitat provides inadequate food or shelter for the wildlife population. Conduits between the habitat patches may not exist, and boundaries between fragmented habitat patches may not be crossable by some species. A levee, for example, could split a wetland habitat, reducing its size and preventing some species from crossing to adjacent wetland patches. Highways, power line easements and fences are examples of upland habitat boundaries that may fragment a habitat beyond the resident species' ability or inclination to traverse it.

Wetlands

Over time, there has been ongoing loss of wetland habitat. An estimated 75% of the original tidal wetlands of San Pablo Bay have been converted to other uses (U.S. Army Corps of Engineers 1999). Erosion and sedimentation are other leading causes of wetland habitat loss. Many activities, such as plowing and discing for agriculture, overgrazing, road construction, urbanization, fires, quarrying, and simple recreational activities such as hiking and cycling, create siltation problems in the streams by disturbing the soil and changing natural runoff patterns. Too much sediment can cut off needed light for plants and wipe out spawning habitat for certain fish species. Excess sediment can also physically smother wetland vegetation, converting the wetland habitat into upland habitat. Sediment also can carry pollutants, thus increased sediment can also be a contributor to lower quality (San Francisco BCDC 1999).

Sinuous tidal sloughs mark the boundaries of hay farms reclaimed from tidal marsh, beginning in 1850 (Pacific Aerial Surveys).

Reduction in the acreage of wetlands, mostly due to human actions, has led to a decline of species, degraded natural habitat, and impaired water quality. Wetland and adjacent habitats in the watershed are critically important to the migratory waterbirds on the Pacific Flyway and several endangered species. Urban and agricultural encroachment, pollution, and exotic species are on-going threats to the wetland habitat. Where there were once benthic organisms within the freshwater channel and saltwater interface environments, there are fewer species, including federally listed endangered species (U.S. Army Corps of Engineers, 1999).

Riparian Habitat

Riparian habitat loss is related to channel degradation, urban and agricultural encroachment, and flood control and navigation channelization. The channel reaches that exhibit the greatest losses in riparian habitat are closely correlated with the percentage of the watershed that is developed. The subwatersheds that are the most highly developed (urban and agricultural) exhibit the most degraded riparian habitat. Native species dependent on riparian corridors for their survival, including the

federally listed endangered species in the area, have experienced a steady decline in abundance and diversity (U.S. Army Corps of Engineers 1999).

In urban areas, riparian vegetation may be removed for development, residential landscaping, or other reasons. In rural areas, riparian vegetation may be removed, for example, as part of crop preparation activities or grazing.

Removing riparian vegetation destroys important habitat and food sources for wildlife, reduces shade, reduces groundwater recharge, destabilizes streambanks, increases velocity of flood waters, increases sedimentation, and increases the amount of pollutants entering the rivers and streams. Thus, removing riparian vegetation harms both the aquatic ecosystem and the downstream habitats.

Uplands

Oak habitats in the upper watershed, particularly those along streams and rivers and those containing Valley and Engelmann Oaks, have been greatly reduced over the past forty years. Acres of oak woodlands have been converted to vineyards. Grazing has also eliminated much of the juvenile-age tree growth, as cattle trample stream and river banks. Blue oak woodland, coast live oak woodland, and oak riparian species have been particularly affected. Riparian tree and shrub cover are spotty to non-existent, and most trees present are older growth.

In past decades, Valley oaks have nearly disappeared from certain areas due to their attractiveness as fuel. To compound the problem, three species of native oaks, the valley, blue, and Engelmann, are reportedly to be regenerating poorly in portions of the watershed (Napa County RCD 1993).

Oak trees and oak woodlands are a critical part of the natural habitat, in that they support a diverse range of species, have aesthetic value, and serve to stabilize stream banks and soil. They are, however, becoming rare. The California Natural Diversity Database indicates that valley oak and Oregon oak are particularly scarce, with less than 10,000 acres remaining statewide.

Loss/Modification Degradation of Habitat - What Can be Done

Reversing the loss and degradation of habitat requires an integrated approach that protects and expands existing habitat, enhances degraded habitat and reduces or removes the threats and stressors to habitats. Such an approach targets strategic locations where habitat is endangered or gone, while brushing broadly to effect changes in the factors that do damage to habitats throughout the watershed. A mix of coordinated actions toward habitat protection, enhancement and restoration is appropriate for the San Pablo Bay watershed. Such an approach merges aggressive protection and restoration steps with policy changes and education to achieve not only direct physical change in watershed habitats but also a more wide-spread understanding of the value and importance of habitat in all geographic areas.

Restoration and enhancement efforts that target specific habitat areas may include measures for re-establishing natural processes, such as providing a natural flow regime or allowing natural stream meandering. While mimicking a natural process may occasionally require the addition of structures to retain or drain water, restoration efforts often involve removal of artificial or foreign structures, materials, plants and animals and replacement with their native counterparts. Recontouring and revegetating are methods used for restoring or enhancing disturbed areas.

As part of a watershed-based approach, the pollutants, sediment loads, disturbance and invasions that stress habitat areas can sometimes be addressed at both their sources and at the impact location. Changing land use patterns, for example, may not only help to keep wildlife corridors intact, it can reduce erosion and pollution in runoff – effects that can also be addressed through enhancement and restoration efforts at the receiving end. Efforts to remove habitat stressors, or to provide protection from them, are likely to overlap with other actions and policies that work toward Restoration Program objectives.

Oak tree protection

In Napa, interest in developing a program to protect various species of oaks is long-standing. Currently, there is no special protection or requirements for oak trees in Napa County, but the development of an oak tree/oak woodland preservation program has been on the County's advanced planning work program since 1993. As a result, the Napa River Watershed Task Force (2000) has recommended a conservation regulation to protect oak tree habitat.

This countywide requirements include the following:

- Countywide requirement that specified species of oak trees are to be preserved over 4" or 2" for blue oak. Valley oak and Oregon oak receive the highest level of protection. Black, live, blue, coast live, and interior oak are also protected, but with more leeway for occasional removal.
- Oaks can be removed only if development of a site is precluded by preservation of oaks or the trees are in poor health or safety hazard AND tree removal will not affect soil or slope stability. For black, blue, coast live, and interior oak, reduction in canopy cannot exceed 25% of pre-development cover.
- If oaks are removed, mitigation is:
  - Replant at a 4:1 ratio with a security to ensure 50% survival in 5 years
  - On-site or off-site plantings are allowed, as well as in lieu fee
  - Replacement trees must be the same species and ideally planted from local acorns or otherwise site adapted.

A change toward protection and conservation of habitat can include limiting access to some areas. It may be beneficial, for example, to exclude livestock, or to prevent humans and their pets from disturbing habitat areas. Preservation of habitat areas for the long term can sometimes be accomplished through conservation easements. While all habitat restoration and protection activities require the cooperation of the landowner, preservation of the habitat area in the long term requires building trust and credibility along with a special emphasis upon shared goals and good communication.

The sidebar discussing oak tree protection in Napa County shows an example of efforts to reverse the loss of habitat. Section 5 presents specific methods for restoring habitat.

4.3.5 Loss of Biodiversity

Biodiversity is a concept that describes the stability of an ecosystem based on the diversity of species that it supports. It is measured against the historic vitality of the ecosystem and the ecosystem's ability to recover after disruptive events.

As the habitats within the San Pablo Bay watershed have been fragmented and destroyed, the plants and animals that depend on these habitats have been drastically reduced in numbers. Non-native species have been multiplying the problem by out-competing the native species in the habitat that is remaining. As a result of these combined forces, the San Pablo Bay watershed is experiencing a loss of biodiversity, with many species threatened, endangered, or candidates for protection.

Loss of Biodiversity - How and Why It Occurs

The loss and fragmentation of habitat types within the watershed are leading causes of the loss of biodiversity. The specific reasons for decline of many species, however, are often more complicated and include interactions with other plant and animal species. Section 3.3 describes the declines of species within the watershed, and explains some of the more complex reasons that these species are declining. Some species within the watershed have declined to the point that they have become listed as endangered species. These species need immediate attention to reverse the trends that have caused them to decrease in numbers. These species are also listed in Section 3.3.

Edward O. Wilson (1992), as well as many other scientists, believes that the planet is in the midst of the sixth in a series of global extinctions. In each of the previous five episodes, some natural catastrophe occurred which initiated a period of widespread loss of species. In this sixth episode currently underway, scientists believe that it is humans who are causing the extinction. A host of human activities such as clear-cutting of forests, damming of rivers, and widespread destruction of wildlife habitat, are causing a number of species to be lost. According to biodiversity theory, this is a problem not only for the species that are destroyed, but for humans as well.

Because humans are at the top of the food chain, they are dependent upon the health and vitality of all the plants and animals of the ecosystem for their well being. Disruptions of the underlying food chain threaten to destabilize the entire ecosystem. When disruptions occur, the most vulnerable members of the ecosystem are species at the top of the food chain, including humans.

In the San Francisco Bay Estuary, many species, such as the California brown bear, are already extinct. Populations of many other plants, fish and other sea animals, birds and mammals have plummeted. Although the severe human alteration of the San Francisco Bay estuary ecosystem is a localized occurrence, it is emblematic of a more widespread process of massive alteration of the environment. The cumulative impact of such activities could be devastating for the human species.

Loss of Biodiversity - What Can be Done

There is no simple solution for the problem of diminished biodiversity. Because loss of biodiversity implies a preceding severe loss of habitat, it is logical to assume that restoration of that habitat is necessary to recapture some approximation of the pre-disturbance ecosystem.

Both the San Pablo Bay watershed and the larger Estuary are ecosystems that have experienced major alterations. It is unlikely that they can be returned to their pre-disturbance condition, however, it is possible that, given the restoration opportunities, they can be returned to some approximation thereof.

Because there are numerous significant opportunities for restoration of aquatic habitat, including restoration of stream corridors and diked baylands, it is possible that significant success can be achieved in recapturing the vitality of many species present in the region historically. Perhaps the most important actions to undertake, therefore, are those that restore these degraded aquatic habitats.

4.4 Conclusion - Challenges to Restoration

The problems described in Section 4.2 and the results described in Section 4.3 provide the impetus for restoration efforts. There are, however, multiple challenges associated with repairing these problems and restoring the ecosystem. Challenges to be overcome in improving the ecological health of the watershed include: achieving a balance between investment and reduction of risk; pursuing protection, restoration and conservation amid a growth-fueled competition for land; and maintaining public support of restoration activities in a political context in which the environment is often de-prioritized.

Not pursuing restoration, or doing it improperly, carries with it certain risks. Continued degradation and loss of habitat, along with its associated negative effects, are examples of these serious risks. Investments of money, time and social capital (such as community energy and teamwork) in restoration can offset risks, or reduce the probability that negative effects will occur. A challenge associated with conducting a watershed-based restoration effort is determining the appropriate level of such investment. The benefits of risk reduction or elimination obtained through a project or integrated group of projects should be weighed against the investments required to determine the appropriate level of effort.

The growth pressure within the population centers in the watershed is enormous. Urban development is increasing rapidly, and the desire for new developments is strong. The growing wine industry in Napa and Sonoma counties is creating additional pressure for agricultural land. These pressures for development make restoration more difficult, especially those restoration efforts that involve setting aside additional land for habitat restoration or treatment facilities.

Competition for land is not the only challenge arising from growth pressure. Current land use patterns do not always lend themselves to the restoration or preservation of habitat. Wide-spread use of impervious surfaces, especially pavement, is difficult to reverse, as are development patterns that do not incorporate open, unfenced land. Some new urban areas eschew rural development patterns in favor of more intensive ones, leaving few opportunities to incorporate reasonable expanses of natural open space. Furthermore, residential developments abutting open water, river or wetland areas are often considered highly desirable, intensifying the market pressure to increase development in those areas that may need protection most.

Water supply is already limited within the watershed, and there is little additional supply for the beneficial uses that already depend upon it. As the area continues to grow, the demand for drinking and irrigation water will grow. This push for additional water is not uncommon in the State of California, where demands for water statewide reach precariously close to the amounts of water that are ultimately suppliable. The use of delta waters up river from San Pablo Bay are, in fact, the subject of ongoing controversy and heated debate as urban, agricultural and environmental interests all seek to claim use of the water for their purposes. Restoring the watershed may require additional water for the environment in the San Pablo Bay area, which will be difficult to acquire in the current supply atmosphere.

Environmental restoration in the San Pablo Bay watershed may also be difficult because of disparate views regarding the value of ecosystems. Despite evidence that suggests it is in the public's interest to restore and protect habitat, and while many support the type of activities proposed by this plan, there are those for whom this is simply not a priority, and this fact can result in political obstacles that prevent ecological progress. For those that believe that technological, industrial or financial progress is mutually exclusive of environmental protection and restoration, pursuit of this plan's goals may seem unnecessary. It is this disparity of beliefs that places a premium on public education and outreach, such as that incorporated in - and supported by this program.

Education and outreach, along with visible, successful restoration efforts help to increase understanding of the value of natural ecosystems and can serve to promote a “land ethic” (Forman and Godron 1986) that emphasizes wise use of remaining land. Irrespective of philosophical viewpoints on the merits of focusing on the environment, an illustration of the cost-effectiveness of restoration efforts can provide proof that restoration is worthwhile.

While all of the value inherent in ecosystems cannot necessarily be measured in economic terms, it is useful for project proponents to demonstrate that the value of the project’s benefits exceeds the cost of achieving those benefits. Project proponents should consider carefully how their proposed actions will help meet Program objectives, what the environmental and social benefits of their projects are, and what kind of investments will be required to produce their desired outputs. For accepted projects to be funded by the Corps, detailed cost benefit and incremental cost analyses will be required (See Section 6). While the Corps can offer assistance in formulating these detailed analyses, it is important for project proponents to have a qualitative understanding of the costs and benefits of their proposed actions from project inception forward. Project proponents should also develop an understanding of the risks and uncertainties associated with expected project outcomes. Guidance on these concepts is provided in the Corps document ER 1105-2-100 (USACE 2000c).

Continued degradation and loss of habitat, along with its associated negative effects, has serious implications. Investments of money, time and social capital in restoration can help reverse the effects of degradation through restoration. An important aspect of conducting a watershed-based restoration effort is determining the appropriate level of such investment ecosystem-wide. Cost effectiveness evaluation will be informational in weighing the benefits of a project or integrated group of projects against the investments required to determine the appropriate level of effort.

Land use practices over the past century and a half have had a dramatic adverse impact on the ecological health of the San Pablo Bay watershed. During the same time, human demands upon the watershed’s essential natural resources such as water and arable soils have increased exponentially; today, the region must support a vastly increased human population. Nevertheless, new approaches are emerging that can both restore ecological resources and sustain healthy human communities. If both the natural and human communities of the San Pablo Bay watershed are to thrive in the future, these new management practices must replace the old ways.

Section 5
Restoring the San Pablo Bay Watershed

5.1 Restoration Opportunities in the San Pablo Bay Watershed

Introduction

Dedicated pursuit of the goals of this Program requires that each restoration project undertaken should advance Program goals and be linked to the desired outcome of improving the aquatic environment of the San Pablo Bay watershed. As part of a watershed-based approach, a coordinated effort, using many projects, will help meet Program objectives. The direct impact on aquatic habitat is quite clear for a project like restoration of diked tidal wetlands or riparian corridors. For projects involving upland areas, like oak woodlands or vineyards, improvements in erosion and runoff control make progress toward Program goals.

The watershed comprises many habitat types, yet functions as one hydrologic unit. While every habitat type within the watershed can be considered for restoration opportunities, the proposed projects most likely to be relevant to watershed health will:

- Be in or adjacent to stream corridors;
- Be in wetlands; or
- Involve explicit efforts to restore specific aquatic habitats by controlling erosion or runoff in upland areas.

Section 5 outlines the unique opportunities for restoration that exist in the San Pablo Bay watershed and provides an introduction to the various methods that can be used to achieve that restoration. This section explains the importance of planning and monitoring, and provides a real-life context for restoration with case studies that both showcase past successes and illustrate failures.

Specific Opportunities and their Benefits

While distinct restoration opportunities exist in each part of the San Pablo Bay watershed, it is the huge potential for restoring diked historic baylands that makes this watershed unique. The *Baylands Ecosystem Habitat Goals* report is an excellent resource for identifying baylands restoration opportunities within the historic tidal zone. Example restoration methods from that document include:

- enhancing circulation in existing marshes;
- restoring tidal marshes, vernal pools, salt pond habitat, seasonal wetlands, seasonal pond habitat on agricultural baylands, riparian habitat, moist grassland habitat, and marsh/upland transitions; and
- protecting oak woodlands, and controlling non-native cordgrass and peppergrass invasions (Goals Project 1999).

No such restoration template exists for the upper watershed, but Watershed Enhancement Plans written for Sonoma Creek, Petaluma River, and Napa River sub-watersheds provide possible starting points. Examples of opportunities in those

Alkali Bulrush at the mouth of a tidal slough

sub-watersheds include erosion control (especially in the headwater areas), encouraging agricultural best management practices, re-vegetating stream corridors, increasing summer stream flows in creeks, protecting streambanks, and controlling non-native plant species like *Arundo donax* (SSCRCD 1997, 1999; Napa County RCD 1994).

Ultimately, the purpose of all these restoration activities is to pursue Program goals, while overcoming, where possible, the challenges to watershed restoration efforts outlined in Section 4. The modification of natural hydrology by humans is a root cause of many of the problems in the watershed, and patterns of human habitation in the watershed pose challenges to addressing those problems. Understanding how the Efforts to restore hydrology – allowing natural, meandering stream channels and restoring wetlands, for example – will have to be a primary source of solutions.

Some restoration projects may address symptoms, rather than root causes, of problems. Removal of invasive species is an example of this type of approach. It is important to recognize which type of approach is being used; each has its strengths. The primary benefit of projects that battle underlying problems (i.e., hydrology) is that they are more likely to solve several problems at once (erosion, pollution, loss of habitat, etc.); their primary difficulty is their complexity. In fact, the complexity of the problems facing the watershed is precisely why *multiple* projects are needed to improve overall watershed health.

The watershed is an interactive system of cause and effect. One of the chief lessons of past restoration efforts is that failure to recognize the causes of degradation at a site will almost certainly impede restoration work there. For example, a number of obvious restoration opportunities are located in the lower watershed along the Bay, but those environments depend heavily on actions occurring in the *upper* watershed. If upper watershed areas continue to degrade, washing contaminated water, sediments, and the seeds of non-native species into the lower watershed, then the benefits of restoration projects in the lower areas are likely to be diminished.

Social and Regulatory Considerations

One of the fundamental considerations in the development of any restoration project is the social context in which it exists. Projects may be considered on private or public land, within urban or rural areas, to be undertaken by a single entity or in a large collaboration, and all within the larger sphere of laws and policies that may affect many aspects of the restoration project.

It is essential that restoration project sponsors evaluate and understand the social requirements and needs of their particular project. This section overviews those requirements and needs to help guide potential project sponsors and managers in responding to these important social needs effectively.

Social and Political Considerations

Although a project sponsor may believe strongly in the worthwhile nature of a restoration proposal, not everyone in the project community may share that opinion. Neighbors living adjacent to the project site may object to the project for a number of reasons: they may feel it poses some physical threat to their property or well being or they may simply oppose the project on philosophical grounds. Nor are immediate neighbors the only consideration. The property owners themselves, or others within the city or county may take issue for reasons of their own.

Whatever the reason for community objections, it is important for the project sponsor to anticipate these potential obstacles and not be discouraged by them. Many people reside within the San Pablo Bay watershed, and it is to be expected that a good deal of effort may be required to respond attentively to community interests.

One of the most effective ways to address community concerns is to engage partners in the restoration project who can help generate support and momentum for its approval. Many organizations exist whose primary missions are to promote these kinds of environmental restoration projects. Local community groups such as land trusts and wildlife organizations may offer support. In addition, state and national non-profit organizations such as the Audubon Society and the Sierra Club often have active local chapters that can be of assistance. Involving a number of such groups will be required to bring about watershed-wide progress. Working together, which presents its challenges, also offers advantages. A particular strength cooperative efforts have is the potency they provide to the outreach aspect of restoration. If the public sees various groups and interests working together toward common goals, additional public support and momentum for further teamwork can be generated.

Lower Sonoma Creek is one area of focus for tidal marsh restoration.

The project sponsor should also be familiar with the debate over the issue of private property rights. In recent years, as public support for environmental restoration has increased, those concerned about excessive government intervention in protection and restoration of environmental resources have expressed alarm. Both Congress and the Courts are airing this debate, which at times has become quite acrimonious. A great deal has been written on the topic and many resources are available to inform the interested restoration project sponsor.

Participants in the San Pablo Bay watershed Restoration Program do so completely of their own volition. The co-sponsors of this program, U. S. Army Corps of Engineers and the California Coastal Conservancy, will provide financial and technical assistance only to project proponents who request it, and who can demonstrate the required control over the lands and/or waters they propose to restore.

As an alternative to purchasing land for restoration or obtaining temporary, (rather than perpetual) control over restoration areas, securing a conservation easement is one method of obtaining control over land for restoration purposes. There are advantages for landowners in granting easements, ranging from the ability to help and display concern for wildlife, to significant tax benefits. Conservation easements can be structured to address many of the potential concerns that a landowner might have about relinquishing some control over the property (USFWS 1998). Both federal and state governments are involved deeply in protecting, restoring and managing public lands for the benefit of important public trust uses. Numerous legal authorities require the government to engage in these pursuits. One of those authorities, Section 503 of the 1996 Water Resources Development Act, created this program. The courts have upheld the responsibility of the government to participate in these programs, and have rejected the notion that the programs in any way infringe upon the rights of private property owners. It is important to note, however, that some individuals may oppose restoration proposals purely on the ground that government should not be involved in these kinds of efforts. The project sponsor should understand the nature of that belief.

Regulatory Considerations

Project proponents must secure permits from appropriate government agencies in order to undertake most activities within a body of water or stream. In many cases those permits include: one from the federal government; two from the State; and one or more from local government authorities In addition and regardless of whether the proposed restoration directly involves a body of water, the project sponsor must comply with the Endangered Species Act and must, as a part of the NEPA/CEQA process, provide a document known generally as an "environmental assessment".

It is the intent of the sponsors of this Program to assist project sponsors in fulfilling these legal regulatory requirements. Nevertheless, in most cases the project sponsor will have to be responsible as the legally designated permit applicant. As such, one or more of the following permits will have to be secured.

Federal

- Section 404 Clean Water Act

This permit authorizes the holder to undertake construction activities within Waters of the United States, a term generally meaning lakes, streams, rivers, wetlands, bays, and other coastal waters. The Army Corps of Engineers issues these permits.

- Section 401 Clean Water Act

This permit regulates impacts on water quality, certifying that the activities to be undertaken by the holder will not have an adverse impact on the quality of the water in which the project will occur. As noted below, these permits are administered by the Regional Water Quality Control Boards (RWQCB).

State

- Porter Cologne Act

This permit is very similar to the federal Section 401 CWA permit. It is the State of California that actually administers the Section 401 program on behalf of the federal government. In addition, the Porter Cologne Act articulates the State's water quality protection requirements independently. These two authorities are very similar, and concurrent issuance of both permits by a single entity, the RWQCB, simplifies the permit process.

- Lake or Streambed Alteration Agreement

This permit is issued by the State Department of Fish and Game and governed by Section 1607 of the California Fish and Game Code. A streambed alteration permit is necessary for diverting flow, modifying the channel, bed, or bank of a stream, or for using material from a streambed.

Local

Construction permits and other permissions must be secured from cities and counties in which the restoration project is to occur. Requirements vary from city to city and county to county. Inquiries can be made at local public works and planning departments.

The co-sponsors of this program stand ready to provided needed assistance to project sponsors. In addition, the Nonprofit Coordinator of the program, The Bay Institute, will provide assistance to any interested applicant. For more information on types of federal and state permits and specific requirements, the reader can contact the California Office of Permit Assistance or review the California Permit Handbook at:

www.commerce.ca.gov/business/permits.

Planning and Monitoring

It is essential that anyone interested in undertaking a restoration project recognize the central importance of project planning and monitoring. As summarized in the 1992 report by the National Research Council entitled *Restoration of Aquatic Ecosystems*, development and implementation of a comprehensive restoration plan, in the watershed context, will maximize the chances that the project will attain its restoration goals.

During the development of this restoration program, the Scientific and Technical Review Panel has stressed repeatedly the importance of incorporating a well-designed monitoring element within the restoration plan. Because aquatic restoration is a new and emerging science, it is expected that projects will need to be modified after they are constructed in order to achieve greater ecological productivity. In order to determine what those modification needs are, it is necessary for project managers to be informed by data gathered through a monitoring effort. In that regard, monitoring becomes not merely a record of the impacts of the initial restoration effort, but an adaptive management tool to guide modification of the project toward greater success. Failure to include an effective monitoring program would risk, therefore, not only the ability to learn from the actions of the original plan, but could well jeopardize the success of the entire project.

In Section 6, Restoration Project Planning and Implementation, presents a Restoration Checklist that was developed by the National Research Council. The Checklist is a comprehensive set of questions to be answered that itemize the elements that must be contained in any serious restoration plan. It was developed on the basis of research into many restoration projects, both successful and unsuccessful. The Checklist should serve as a guide to anyone interested in developing a restoration project.

Environmental Impacts of Restoration

The primary desired impact of a restoration project is to further the goals of the Program. Even successful restoration projects, however, have foreseeable negative impacts associated with them. Furthermore, project success is not a guarantee -- any given project may have unexpected negative results. Thus, identifying potential negative effects is just as important as striving to meet the goals of the Program. A few of the negative impacts that could be reasonably expected in the San Pablo Bay watershed are:

- An increase in flooding frequency or intensity, caused by modifications to stream channels, stream banks, or riparian vegetation;
- An increase in flood vulnerability due to modification of Bay levees;
- Promotion of invasive exotic plant species, caused by modifications to soil or habitat conditions, or use of contaminated seed banks;
- Promotion of harmful exotic predators, caused by increased access to the habitat of their prey;
- Loss of land for other beneficial uses, such as agriculture or urban development;
- An increase in aquatic-born pests, such as mosquitoes;
- An increase in hosts of *Xylella fastidiosa*, the bacteria that causes Pierce's disease. Certain plants in riparian zones are hosts of the bacteria (Tesconi 1998); and
- Negative effects to endangered species, caused by construction activities or habitat modification.

Although inherent risks exist for any modification of a natural system, the issues outlined above underscore the importance of taking the advised planning and monitoring steps to minimize those

Over 400 acres of tidal wetlands were restored along Tolay Creek in December 1998 (shown here in construction phase).

risks. In certain circumstances, reducing negative impacts may require specific mitigation measures. In a best-case scenario, however, these impacts can be avoided altogether by careful and complete planning, design, and implementation.

5.2 Watershed Restoration Methods

5.2.1 Introduction

The watershed's rivers, streams, and creeks affect the health of San Pablo Bay wetlands and San Pablo Bay directly — either positively or negatively. Runoff from hillside woodlands and grasslands, vineyards, and towns feeds adjacent creeks and streams. Eventually, these streams drain into the wetlands, delivering nutrients, pollutants, and sediment in the process. A healthy river system can filter out pollutants and trap soils, thus protecting downstream water quality and habitats. Proper channel alignment and slope stabilization can prevent excessive erosion. If erosion is not curbed, sediment can build up the bed of a stream and reduce its capacity to carry flow. Excess sediment can also convert wetlands to uplands, fill marshes, destroy wetland habitats, and smother spawning areas, as well as the plants and animals that live in the streambed.

Riparian floodplains can store flood water and reduce peak flows downstream, thus keeping the floods from overwhelming the wetlands below. In addition, when aquatic plants die and decompose, or upland plants drop their leaves into the stream, nutrients become available for the downstream wetlands. Where these processes are impaired, restoration projects can help return the ecosystem to a more natural state.

Restoration efforts must work within – and capitalize upon - the set of complex natural interactions that occur in the hydrological unit that is a watershed. Understanding how activities in one part of a drainage area affect areas downstream, for example, is critical for achieving

Project Idea: Upper Novato Creek Watershed Erosion Control Inventory and Sediment Reduction Plan

Sponsoring Agency: Marin County Flood Control District
Marin County Flood Control District is currently funding this project, although the District would like to obtain outside funds, if possible.

Project Location: Upper Novato Creek, below Stafford Lake Dam
Novato Creek and its tributaries are experiencing accelerated bank and terrace erosion, resulting in down-cutting of stream channels and increased downstream sedimentation. This erosion is due primarily to agricultural and grazing practices, the function of Stafford Dam as a sediment trap, and increased urbanization of the lower watershed (Collins 1998).

Project Objective: Reduce Sedimentation and Dredging in lower Novato Creek
The Marin County Flood Control District is seeking to reduce the frequency of dredging within lower Novato Creek, which it currently dredges approximately every 3-4 years. As part of the Section 401(Clean Water Act) water quality certification for removing accumulated sediment from lower Novato Creek in 1996 and 2000, the San Francisco Regional Water Quality Control Board required that the District prepare a plan to address sediment transport processes within the Novato Creek watershed. In 1998, with the help of geomorphologist Laurel Collins, the District established that significant bank and terrace erosion in the upper watershed is contributing to continuing sedimentation of lower Novato Creek (Collins 1998). Collins' report recommended addressing upstream sediment sources on public and private lands, particularly in grazed areas.

Restoration Tools Proposed for Use: Creek Bank Revegetation and Fencing
The District plans to work cooperatively with landowners to control erosion in the upper watershed. A finalized action plan and evaluation of land management practices will be completed in early 2001 by Prunuske Chatham Inc. (PCI). This report will prioritize areas in need of erosion control and list the control methods available. Restoration strategies being considered include creek bank revegetation and creek-side fencing on grazed lands. Initially, willow stakes and other willow planting methods would be used to stabilize the toe of eroding creek channels; over time, other native trees could be incorporated where feasible. Other strategies may include gully repair and road maintenance.

Special Feature: A Watershed Approach
Although a formal watershed management plan has not been written, the District is trying to approach flooding and sedimentation issues from a watershed standpoint. The project described above is complemented by the Candidate Project described in Appendix F (*Novato Creek Flood Control and Wetlands Restoration Project*), which proposes to address downstream flooding by constructing a new setback levee. The combination of an upstream sedimentation control project with a downstream flood capacity increase makes both projects more likely to succeed.

For more information contact Marin County Flood Control District, Liz Lewis, Creek Naturalist at (415) 499-7226.

effective restoration and for getting the most "bang for the buck" from a project. The efforts of the Marin County Flood Control District to control erosion in the upper Novato Creek watershed in order to reduce the frequency of dredging activities in lower Novato Creek illustrates this type of integrated approach (see Novato Creek case study).

Once restoration needs have been identified at a site, planners must address technical design and implementation issues. This section can be used as an informal manual towards that end. While it does *not* provide exhaustive information on each of the thirteen methods and strategies discussed, this section does provide a starting point for conducting conceptual planning and design work. The section identifies environmental, engineering, social, and regulatory constraints associated with each method, in addition to listing the types of habitats for which each method is best-suited. Several case studies from within the watershed are also included. Each case study illustrates the method(s) described, with a contact provided for more information.

The first three sections discussed below, *Dredged Materials*, *Levee Modification*, and *Water Re-Use*, are covered in detail because they apply specifically to the diked former wetlands. Because restoration of these diked wetlands has been one of the primary restoration priorities in the watershed historically, more case studies exist for those areas and it is both necessary and appropriate to present more information.

This section contains a large amount of technical information, arranged by restoration method. Table 5-1 provides a quick look at the strategies and usefulness of each method. Table 5-1's "potential location / habitat types" column refers to the area where the project would take place. Naturally, the project's benefits will extend to downstream areas, as well.

Table 5-1
Restoration Methods

Method	***Objective***	***Potential Location/Habitat Types***		
		Wetlands	***Streams***	***Uplands***
Dredged Materials	Accelerate formation of tidal wetlands on subsided land	X (tidal)		
Levee Modification	Restore tidal action to wetlands	X (tidal)		
Water Re-Use	Provide a source of freshwater for flushing or habitat modification	X	X	X
Control of Invasive Species	Promote biodiversity and native flora/fauna by removing invasive exotic species	X	X	X
Passive Restoration	Allow site to restore naturally over many years and at low cost	X	X	X
Buffers	Reduce impact of human activities on habitats and wildlife	X	X	
Re-vegetation	Promote native vegetation by planting	X	X	X
Short-Term Habitat Measures	Provide habitat, especially food and nesting space, before restoration is complete	X	X	X
Stream Channel Restoration	To the extent possible, re-create natural stream geomorphology		X	
Bank Stabilization	Reduce erosion and increase streambank vegetation		X	
Instream Habitat Structures	Improve quality and quantity of aquatic habitat and fish migration access		X	
Agricultural & Grazing BMPs	Reduce non-point-source runoff volume and pollutant loads			X
Urban & Stormwater BMPs	Reduce non-point-source runoff volume and pollutant loads			X

5.2.2 Dredged Materials

Function

Many of the diked and drained wetlands in the San Pablo Baylands have subsided to several feet below sea level. Dredged materials can provide a tool that can be used to restore tidal wetlands in these areas when a quick and natural source of sediment transport is not available.

Tidal wetlands occur in areas that have ground surfaces approximately three and a half feet above mean sea level (Marcus 1994). The standard restoration practice has been to breach a levee surrounding the diked area, and restore tidal action. The water that enters the diked area carries sediments that eventually settle out. Over time, siltation raises the bottom elevation and creates a tidal wetland. The length of time required for the process varies by site and ranges from a few months to many years.

Dredged materials can be used to fill in the site where the levees are to be breached. The dredged materials are applied to the ground surface, which decreases the amount of siltation that must occur before the wetland is restored. Utilizing dredged materials can accelerate the formation of tidal wetlands on subsided land.

Using dredged materials for wetland restoration solves another problem in the San Francisco Bay ecosystem. Channels in the San Francisco Bay and the Sacramento / San Joaquin Delta must be dredged periodically to allow navigation. Historically, dredged materials have been disposed of within the Bay at several disposal sites, including one in San Pablo Bay and another near the island of Alcatraz. The materials at Alcatraz did not disperse as originally predicted, and it has been learned that disposal of dredge spoils in the Bay can have harmful effects on fish and other wildlife. An inter-agency committee was created to form a "Long-Term Management Strategy" (LTMS 1998). The agencies in this committee include the U.S. Army Corps of Engineers, U.S. EPA, San Francisco Bay Conservation and Development Commission (BCDC), San Francisco Bay Regional Water Quality Control Board (SFBRWQCB), and the State Water Quality Control Board (SWQCB). The committee examined multiple disposal sites, including deep ocean sites, other Bay sites, and other uses for the dredged material. One goal of the final plan is to encourage beneficial re-use of materials, such as for restoration of diked baylands, rather than disposing of materials at an in-bay dump site.

Effectiveness

There are several restoration projects within the Bay area that have been studied to determine the effectiveness of utilizing dredged materials to restore tidal wetlands. Muzzi Marsh (see case study) in Marin County used dredged materials approximately 15 years ago, and has been monitored to determine the success of the restoration effort. The U.S. Army Corps of Engineers filled Pond 3, a restored salt pond in the South San Francisco Bay, with dredged materials in 1974. These two projects have been used as case studies to determine potential setbacks or causes for success.

Success in restoration is dependent on level of fill, and studies have shown that fill levels have a narrow range of acceptability. Examination of Muzzi Marsh and Pond 3 showed that, in areas where materials were not filled high enough, natural processes eventually silted in the areas to the appropriate level for tidal marsh. Areas where fill was too high eventually subsided to similar levels. It was observed, however, that in areas with higher fill, the series of sloughs and channels that characterize a tidal marsh had not formed. An intricate slough channel drainage system is critical for the success of a tidal marsh because it provides a unique habitat and evenly distributes tidal waters throughout the marsh. The lack of natural sloughs will affect the vegetation that forms in the area, and the vegetation patterns will affect the animal life that inhabits the region.

Because sloughs have proven to be critical to the success of a tidal wetland, current restoration efforts have focused on ensuring the appropriate levels of dredged fill. Dredged materials are no longer used to raise the ground level to that of a tidal wetland, but are used simply to jump-start the process. Siltation will then bring the marsh up to the final elevation, a process that will develop the natural drainage sloughs.

Using dredged materials for a portion of the fill may result in an accelerated time schedule when compared to natural wetland formation. Estimates for the Sonoma Baylands project (see case study) indicate that restoration with dredged materials will take approximately 10 years, while restoration without dredged materials would take approximately 35 years (Williams and Florsheim 1994).

Issues and Concerns

Environmental Constraints

Sediments within the Bay-Delta system range from those free of contamination to those with high levels of certain chemicals or contaminants. The LTMS has begun to address screening criteria and testing requirements to ensure that contaminated sediments are not used in wetland restoration.

For the Sonoma Baylands project, the RWQCB identified interim wetland sediment screening criteria. The sediments coming from the Port of Oakland, however, varied widely in their levels of

Case Study
Muzzi Marsh

Sponsoring Agency

The Golden Gate Bridge, Highway, and Transportation District restored Muzzi Marsh in 1976 as a mitigation site.

Project Objective

In the late 1950s, Muzzi Marsh was diked and drained for use as an industrial site. The land subsided several feet after drying out, and the industrial development never occurred. The restoration attempted to restore Muzzi Marsh to tidal salt marsh habitat similar to the surrounding marshlands.

Restoration Tools Used: Dredged Materials and Planting

Dredged materials from the construction of the Larkspur Ferry Terminal and associated facilities were used to raise the elevation of the restoration site. Approximately 750,000 cubic yards of dredged materials were placed in the marsh area with the intent of raising the ground elevation to accelerate the formation of the tidal wetland. Tidal salt marshes occur at approximately the same elevation as Mean High Higher Water (MHHW), but the fill at Muzzi Marsh was not placed at the intended elevation throughout the site. The landward side received more fill, with an elevation of 1.3 feet higher than MHHW. The bayward side received less fill, with a final elevation of 1.1 to 2.1 feet below MHHW (Gahagan & Bryant Associates, et al., 1995).

By 1980, many natural sloughs and channels had developed in the lower portion of the restoration site. The lower area also experienced rapid sedimentation rates of up to 0.8 feet during the first year. The upper section had subsided to MHHW, but no natural channels had developed. In 1986, some channels were excavated in the upper portion to increase circulation, and more channels were excavated later for mosquito control. In 1994, however, there were still few natural channels in the upper portion of the project area. The area is still being monitored for channel development to determine if channels will develop, but much more slowly than in areas with lower fill elevations.

While natural processes vegetated most of the project area, there were some small scale plantings within the project area. Within four years, common pickleweed had moved into the project area, and had colonized over half of the area (including near 100% in areas with lower fill). Pacific cordgrass followed the pickleweed, and other species developed over time, including jaumea, gum plant, saltgrass, annual pickleweed, spurrey and brass buttons (Gahagan & Bryant Associates, et al., 1995).

Several studies were performed to determine the size and distribution of the California Clapper Rail population within the project area. In 1984, eight birds were found, but the population grew to approximately 15 birds in 1987. All birds were found in the lower area of the marsh, which could be connected to the lack of sloughs and channels in the upper portion of the marsh (Gahagan & Bryant Associates, et al., 1995).

Project Location

Muzzi Marsh is located in Marin County on Corte Madera Bay, just south of San Pablo Bay. Muzzi Marsh is a 130-acre site adjacent to Corte Madera Ecological Reserve, which is also a tidal salt marsh.

Special Feature

Muzzi Marsh has been extremely useful in designing more recent projects using dredged materials because it is an old enough project to allow time to see the results of the project design. Not only was the project performed many years ago, but Ms. Phyllis Faber, a botanist who authored the book Common Wetland Plants of Coastal California, has also monitored the project throughout its existence. The information from the design of the project and the monitoring efforts has helped current project sponsors understand how their work will impact the environment.

contamination. The RWQCB approved sediments from two areas where screening criteria for mercury, zinc, PCB, and DDT were exceeded. These areas were approved because it was assumed that the soil from these areas would mix with other soils that were well below screening levels, and the final concentrations within the Baylands project would be appropriate. To ensure that this assumption was appropriate, the annual monitoring report examines the chemical constituents of the soils.

Another difficult issue associated with the interim screening criteria relates to their applicability for screening certain contaminants. The undisturbed soils within the Port of Oakland were found to have chromium levels above the screening levels. It was discovered that the chromium was derived from native serpentine rock, and was not in a form that was ecologically harmful. It was determined that the established criteria from chromium were not applicable to naturally occurring chromium.

Permanent standards to replace the interim screening criteria have not been formally adopted. Standards are currently being applied on a case-by-case basis, and may vary by application.

Engineering Constraints

When engineering a project utilizing dredged materials, the following constraints must be considered:

Fill levels

As previously mentioned, the level of fill is critical in determining the success of a restoration effort that utilizes dredged materials. Existing marshes within the baylands have an elevation of 3.4 feet above National Geodetic Vertical Datum of 1929 (NGVD). This level (+3.4 feet NGVD) is the same elevation as Mean Higher High Water (MHHW) in San Pablo Bay.

A study performed for the Corps (Gahagan & Bryant et. al., 1995) developed the following criteria for fill levels:

- No slough channels developed in areas with fill levels at or above 0.5 feet below MHHW.
- Relatively few channels developed with fill levels between 0.5 and 1.0 feet below MHHW.
- Many slough channels developed with fill levels lower than 1.0 feet below MHHW.

The Sonoma Baylands project was designed to fill the site to an elevation of +2.0 feet NGVD (-1.4 feet MHHW), with a maximum of +2.9 feet NGVD (-0.5 feet MHHW). The pilot unit of the project met this criterion, but the main unit was higher in certain areas due to the method of application.

Transportation of Materials

Transportation and off-loading of materials will be very difficult at some sites, especially those sites that are not close to navigable water. The case studies have barged the material to the restoration site, and pumped the material into the site from the barge.

Pumping of dredged materials caused problems in the main unit of the Sonoma Baylands project. During pumping, the contractor let the pump discharge in one area until the elevation increased to the specified level, then relocated the discharge point. Several of these discharge points remained above the specified level after the installation of material. These high points were not within the construction specifications, so the contractor attempted to use construction equipment to lower the peaks to allowable levels., The ground surface could not support the construction equipment, however, and this method was not successful.

To reduce the likelihood of this problem, construction specifications and inspection during the work must be rigorous.

Differential Settlement of Dredged Materials

After dredged materials are pumped onto a site, they will settle to levels below the initial installation. Estimating the settlement amount is difficult, if not impossible. For the Sonoma Baylands project, the initial elevation in the pilot unit was +3.1 feet NGVD, but the elevation two years later was +0.3 feet NGVD. In the main unit, the initial elevations ranged from +2.0 feet NGVD to +2.7 feet NGVD (not including the peaks from inconsistent application). After one year, the elevations had decreased to +0.9 feet NGVD to +1.7 feet NGVD.

For the tidal marsh restoration to be successful, settlement of dredged materials must be taken into account during placement of materials.

Wave Energy

Strong winds in the San Pablo Bay region cause significant wave action, which can prevent natural sedimentation and erode dredged materials that are already placed. Erosion from wave action increases as the water gets shallower, until eventually sedimentation and erosion reach a steady state and maintain the water at a certain depth. Wave action in San Pablo Bay has caused the Bay to remain a shallow water body instead of a large tidal wetland.

The intensity of a wave increases based on its "fetch," which is the length of open water over which the wind travels. To prevent wave action from being a problem within a restored tidal wetland, the fetch must be decreased to a length that will reduce the wave size.

In the Sonoma Baylands project, engineers researched several existing restoration projects in the area, including a project on Tolay Creek and the Warm Springs restoration site in the South Bay. Both of these projects showed significant erosion with wave fetches of 2,000 feet. Examining these projects and several others, the engineers determined that the maximum wave fetch for the project should be 1,000 feet. To reduce fetch lengths, the project incorporated low, narrow peninsulas. These barriers were designed to subside into the surrounding ground surface so that over time, they will be indistinguishable from the surrounding tidal marsh. (Williams and Florsheim, 1994)

Cost

Current costs for in-Bay disposal of dredged materials are approximately $3 - $6 per cubic yard. Cost for disposal to restoration sites will range from $6 - $30 per cubic yard, depending on location and off-loading difficulty. Left to their own devices, dredgers probably would choose the least expensive option for disposal of their materials.. However, because of the harmful affects of in-bay disposal, the LTMS agencies plan to dramatically curtail that practice in favor of beneficial reuse of dredged materials.

Case Study
Sonoma Baylands Wetland Demonstration Project

Sponsoring Agencies: Sonoma Land Trust, Coastal Conservancy, and the Army Corps of Engineers

The Sonoma Baylands Wetland Demonstration Project was initially started as a partnership between the California Coastal Conservancy and the Sonoma Land Trust. These two entities partnered together to buy the oat hay farm that was partially restored in the Sonoma Baylands project. The Coastal Conservancy later partnered with the U.S. Army Corps of Engineers to use dredged materials to help in the ecosystem restoration.

Project Objective: Restore Tidal Marsh Habitat

The Sonoma Baylands Wetland Demonstration Project restored an oat hay farm to a 289-acre tidal salt marsh. The primary objectives of the project were to restore the historic Baylands habitat and create habitat for local endangered species, including the salt marsh harvest mouse and the California clapper rail. The restoration was performed using dredged materials to accelerate the time frame to provide habitat benefits as soon as possible.

Restoration Tools Used: Dredged Materials and Levee Modification

The Sonoma Baylands project sparked a cooperative spirit between groups that have historically disagreed, such as the U.S. Army Corps of Engineers, California Coastal Conservancy, environmental groups, the Port of Oakland, shipping companies, and commercial fisheries. The California Coastal Conservancy and the Sonoma Land Trust began the restoration project, but realized quickly that it would take many years of natural sedimentation to fill in the subsided farmland to the elevation of tidal salt marsh. The land had subsided up to 4 feet below sea level, and tidal wetlands occur approximately 3.4 feet above sea level.

At the same time that the restoration effort was beginning, the Port of Oakland was struggling to dredge their inner port to a depth of 38 feet. Environmental groups were opposed to the disposal sites suggested for the dredged materials, and it appeared that litigation was imminent. The Sonoma Baylands project created a common ground by allowing the disposal of dredged materials in an environmentally beneficial way. The concept of reusing dredged materials beneficially has become increasingly popular, and the Corps' included this concept in its Long Term Management Strategy for dredged materials disposal.

The Sonoma Baylands project also piloted a new method for using dredged materials. Historically, wetlands were restored by filling the land with dredged materials to the final elevation, then constructing channels to allow water to enter the marsh. The Sonoma Baylands design team opted for a new approach, where the dredged materials were used to accelerate the time frame for restoration, but natural sedimentation filled in the last several feet. This change was made because studies on past restoration projects revealed that filling tidal wetlands to their final elevation inhibits the formation of natural sloughs and channels. These sloughs and channels are a critical component of tidal wetlands, and the design team wanted to ensure that these channels would form.

Project Location: Mouth of the Petaluma River

The cooperative effort resulted in the restoration of a 29-acre pilot unit and a 260-acre main unit on the site, located on the northwestern shore of San Pablo Bay, near the mouth of the Petaluma River. The main unit and pilot unit were separated by a levee that was designed to allow access to two high voltage electrical towers on the site. The pilot unit was filled with 207,000 cubic yards of dredged materials from the Petaluma River navigation channel between October and November, 1994. The pilot unit was opened to tidal action by breaching a levee on January 24, 1996. The main unit was filled with 1.7 million cubic yards of dredged materials from the deepening of Oakland Harbor from May to November, 1995. The levee was breached for the main unit on October 25, 1996.

Special Feature: Monitoring

When Congress authorized the Sonoma Baylands project, it included money for an extensive monitoring program. The sponsors realized that they benefited from past project information, and wanted to monitor the progress of their design to ensure the success of future efforts. In October 1996, the Corps and the Coastal Conservancy approved a monitoring plan with concurrence from the U.S. Fish and Wildlife Service, the Regional Water Quality Control Board, and the National Marine Fisheries Service. The plan identified success criteria associated with the topics indicated in the following table.

Physical Success Criteria	***Biological Success Criteria***
Dredged material fill elevations	Marsh vegetation establishment
Chemical constituents	Marsh vegetation cover
Exterior tidal channels	Birds
Tidal regime	Fishes
Peninsula crest elevations	Endangered species
Internal channel development	

5.2.3 Levee Modification

Function

The purpose of levees is to protect land from high water stages and associated flooding. In the Baylands, extensive levee networks, which were constructed beginning around 1850, protect land for grazing and agriculture. Continuous draining of the diked land is necessary to keep it in production, and in the years since their creation the man-made “islands” have subsided considerably. Most of the diked baylands surrounding San Pablo Bay region are agricultural lands or managed marshes with sporadic tidal influence, while the undiked areas include tidal flat, salt and brackish tidal marsh, and lagoon habitat (Goals Project 1999).

Making modifications to the existing tidal levees is one method of restoring lost habitat. Options for modification include removing the levee altogether, breaching the levee, or altering the outlet(s) in existing managed marshes to increase tidal circulation. All of these methods share a

Case Study
Tolay Creek Marsh Restoration Project

Lead Agency: San Pablo Bay National Wildlife Refuge and California Department of Fish and Game

The San Pablo Bay National Wildlife Refuge (NWR) is a division of the US Fish & Wildlife Service. The Refuge and the California Department of Fish and Game (DFG) each own land and cooperatively manage the Tolay Creek marsh and during the restoration process, they were assisted by numerous partners listed below.

Project Location: Tolay Creek

Tolay Creek is actually a tidal slough that is connected to San Pablo Bay south of Sears Point. The project extends upstream to a newly constructed lagoon located south of the intersection of Highways 37 and 121. The total project area includes 435 acres of tidal channel, marsh, and lagoon.

Objective: Restore Tidal Marsh in the historic Tolay Creek floodplain

Since dikes were constructed along Tolay Creek many years ago, tidal flows were reduced, leading to sedimentation of the slough and dessication of the marsh. The Fish & Wildlife Service recognized the opportunity for restoration: by dredging the channel and creating a new lagoon, tidal action could be returned to the marsh. In the mid 90s, restoration of Tolay Creek was given an increased priority when mitigation for agricultural levee maintenance along Sonoma Creek and southern Sonoma County wetlands became necessary.

Restoration Tool : **Dredging and Levee Modification**

In order to allow tide waters to reach the project area, project partners removed a section of old levee, constructed a new levee to ensure continuing flood protection, widened and deepened Tolay Creek via dredging, and constructed a public access and viewing area (Bias 2000). There was one pre-existing lagoon along the slough, and a new 53-acre lagoon was constructed at the upstream end of the project area. The new lagoon is an important project component because it increases tidal circulation, and thus decreases sedimentation, in the slough. The lagoon itself was used for mitigation credit, but the rest of the project was for restoration and enhancement purposes only.

Most of the levee modifications were centered around the new mitigation lagoon, which is surrounded by agricultural lands. A temporary coffer dam was breached in December 1998, finishing several months of dredging and construction work. The total cost of the project was about $1.2 million.

Project Outcomes: Successes and Concerns

Biologically, the Tolay Creek marsh restoration is proceeding successfully. The lower lagoon has been gradually filling with sediment, and *Spartina* is emerging. The new lagoon and surrounding floodplain areas have experienced good bird use. Initially, there were problems with levee seepage, and some levees adjacent to the lagoon had to be reinforced in order to alleviate the problem. Additionally, tidal waters came nearer to private structures than originally predicted. The California DFG has been working with CalTrans on levee protection for the lagoon/mitigation pond, and the Refuge has been working with adjacent landowners to resolve issues related to the restoration of tidal flows in the floodplain.

Special Feature: Monitoring

The San Pablo Bay NWR is working with the USGS to monitor Tolay Creek marsh. Southern Sonoma County RCD and the DFG are assisting with monitoring of the mitigation pond.

Project Partners

The following project partners and sponsors assisted the DFG and San Pablo Bay NWR greatly: Ducks Unlimited, Save The Bay, California Wildlife Conservation Board, CALFED, Sonoma Community Association, Sonoma County Fish & Wildlife Board, Marin-Sonoma Mosquito Abatement District, National Resource Conservation Service, Southern Sonoma County RCD, PG&E, Shell Oilspill Litigation Settlement Trustee Committee, USEPA, and the Vallejo Sanitation and Flood Control District.

For More Information: Contact the San Pablo Bay National Wildlife Refuge

Bryan Winton, Manager -- 707-562-3000.

common goal: to increase the amount of tidal action at a site.

Note: When one levee is removed and another constructed further upland, the project may be called a "setback levee." The term "setback levee" is most often used to describe levee modification projects along rivers, which will be discussed in the "Channel Restoration" section.

Effectiveness

The effectiveness of restoration using the levee modification method hinges on the ability to restore the **correct amount of tidal action**, which will depend on the specific habitat goal. Examples of projects that have successfully used major levee modification to restore tidal baylands habitat include the Sonoma Baylands and Tolay Creek projects (see case study). Smaller changes at the gates or culverts of a managed marsh levee can also be helpful; the Rush Creek/Cemetery Marsh (see case study) is an example of this type of project. The effectiveness of a levee modification project is sometimes difficult to judge alone, because of the critical role that sediment levels also play in determining habitat type. The subsidence prevalent in diked baylands means that additional sediment, perhaps dredged material, may have to be added to a site to meet habitat goals. The size of the opening in the levee will determine the natural sediment transport rate in and out of the site. Insufficient circulation may be a problem of an undersized inlet/outlet, or an incorrectly engineered bottom elevation in the marsh or lagoon.

Perhaps the best examples of restoration via levee modification are those sites where accidental levee breaches caused wetland habitat to gradually return. The White Slough marsh, along the Napa River near the City of Vallejo, illustrates this phenomenon quite well.

Rush Creek/Cemetery Marsh Enhancement Project

Sponsoring Agency: Marin Audubon Society
The Marin Audubon Society, founded in 1956, has been active in efforts to restore habitat for birds and other wildlife for about fifteen years. Marin Audubon Society served as the project manager of the Rush Creek/Cemetery Marsh Enhancement Project.

Project Location: Rush Creek Marsh and Cemetery Marsh
Rush Creek is a tributary of the Petaluma River. Rush Creek marsh is a 230-acre site located on the northern side of Novato, and is owned and managed by the California Department of Fish and Game (DFG). Cemetery marsh is an adjacent 50-acre site owned by the Marin County Open Space District. Among other uses, the site provides habitat to local and migratory shorebirds.

Objective: Improve Circulation and Water Quality
Competing management interests, combined with aging infrastructure and poor circulation, were contributing to degrading conditions in the marsh. At least one culvert was badly damaged, and the four tide gates that regulate flow to the site were not easily adjustable. In addition to the DFG and Open Space District, the Marin-Sonoma Mosquito Abatement District and the Marin County Public Works Department have management interests at the site, for mosquito control and flood control, respectively. One of the project's potential successes will be the joint effort and agreement of these four groups t to more actively manage the site for wildlife habitat, by carefully avoiding water conditions too deep or too shallow for feeding shorebirds.

Restoration Tools Used: Excavation and Replacement of Tide Gate
Restoration work at the site involved excavating new channels through the marshes to improve tidal circulation, replacing two culverts, and replacing one tide gate with a combination slide-flap gate. The new gate can be operated actively, and it allows much more water to flow into the marsh, greatly reducing stagnation problems. Construction was completed in late summer 1999, and efforts since then have focused on calibrating the new slide-flap gate to determine how it can be used most effectively to manage water levels in the marsh.

Funding Sources
The Rush Creek/Cemetery Marsh Enhancement Project cost about $200,000, and was funded by the following partners: RWQCB, Coastal Conservancy, NAWCA (North American Wetlands Conservation Act), Fish and Wildlife Service San Francisco Bay Program, Marin County Open Space District, Marin County Wildlife and Fisheries Committee, Wildlife Conservation Board, and Marin Community Foundation.

For More Information: Contact Barbara Salzman at Marin Audubon Society
As a member of Marin Audubon Society's Board of Directors, Barbara Salzman is well-informed about the challenges and successes of the Rush Creek/Cemetery Marsh project. She can be reached at (415) 924-6057.

White Slough

In the winter of 1976-1977, the levee separating White Slough marsh from the Napa River was accidentally breached. The Bay Conservation and Development Commission learned of the break about one year later, and the property went under their jurisdiction soon after (The regulations governing transference of jurisdiction to the BCDC have since changed).

Time and the tides have allowed White Slough to restore itself. Since the levee break, the area on the northern side of Highway 37 has been naturally restored to brackish marsh with full tidal action. Pickleweed and cordgrass are the dominant vegetation, broken by patches of mud and open water. The area on the southern side of Highway 37 receives muted tidal action and consists primarily of open water with fringe high-marsh vegetation. The Vallejo Sanitation & Flood Control District operates tidal gates on the southern section, and lowers the water in the winter to gain flood control storage (McAdam 2000).

Issues and Concerns

Engineering Constraints

The existing levee network provides flood protection to adjacent agricultural and urban property. Assuming this flood protection will continue to be required throughout the duration of the restoration project, one of the major components of a levee modification project may be the construction of a new levee around those sides of the site adjacent to dry land. If all the appropriate levees are already present (for example, at a managed marsh that is undergoing relatively minor gate/culvert modifications) there may be no requirement to construct a new levee, but flood protection capability will need to be maintained. Extensive rehabilitation work might be required just to bring existing levees up to code. The discussion in this section applies to those levees that protect adjacent properties, not the levee that is being altered for tidal exchange.

Level of Flood Protection

Adjacent lands may require differing levels of flood protection depending on whether they are in agricultural or urban use. This use will dictate height requirements for the levee. In order to be part of the Federal Emergency Management Agency (FEMA) flood insurance program, which is a norm for all urban areas, a levee must provide protection from the 100-year flood.

Generally speaking, the following flood protection criteria apply:

Category	Criteria
Tide	The mean higher high water in San Pablo Bay is 3.4 feet and the mean lower low water is approximately minus 3.0 feet, for a total tide variation of 6.4 feet (USACE 1981). The 100-year stillwater tide at Point San Quentin is 6.5 feet and at Richmond is 6.4 feet (USACE 1984).
Wave Height & Runup	The top of levee must be above the design water surface elevation and above the wave height and wave runup. Wave height is a function of wind velocity, wind direction, and duration and distance along the water the wind is blowing. Wave runup is the distance along the sloped side of the levee that waves travel above the wave height. In San Pablo Bay the wave height plus runup is generally in the range of 3 to 4 feet (USACE 1984). Therefore, the top of the levee would be designed for the 100-year tide plus 3 to 4 feet for wave height and runup.
Subsidence	Land and levees along the perimeter of San Pablo Bay have subsided in the past. The projection of future subsidence is 1 inch every 10 to 20 years (USACE 1981). Although there are no mandatory requirements, subsidence should be considered in the design of levees.

Vegetation

Levees that support vegetation are typically wider and flatter than non-vegetated levees. While vegetation may be a desired restoration element, it is important to remember that wider levees will have a larger footprint and therefore will require more land, which increases cost and decreases wetland habitat area. Project managers may have to make a choice: will the levee be a bare, engineered structure that simply represents the property line, or will it be an integral part of the project? Vegetation maintenance should also be considered in advance; vegetation is undesirable when it hides animal burrows that threaten levee stability. The USACE Engineering Manual “Guidelines for Landscape Planting and Vegetation Management at Floodwalls, Levees, and Embankment Dams” (2000) provides additional assistance on this topic.

Geotechnical and Construction Requirements

Category	Criteria
Foundation	Extensive geotechnical testing and analyses are required for the design of levees. Subsurface soils in this region are primarily San Francisco Bay mud, a soft, unconsolidated grey silty clay that varies in thickness up to 100 feet or more. Foundations and bedding layers for levees must be designed considering this Bay mud. Proper levee foundations reduce undermining, loss of fine material by piping, and settlement.
Material Source	Ideally, the site for obtaining borrow material should be relatively close, to minimize cost and limit disruption of local traffic. "Recycling" the old levee may also be an option in some areas.
Construction Sequence	Levee construction schedules should consider the requirements for phasing with other construction activities related to utility and road relocation, interior drainage considerations, the farming operation of the adjacent lands, and should not be performed during the wet winter season when there is a risk of flooding.
Surface Finishing	The surface of the levee on the water side must be protected from wave action and erosion. Vegetation, riprap or gabions are commonly used. The top of the levee should be wide enough for maintenance vehicles, unless maintenance roads on the land side are available.

Operations & Maintenance
To ensure flood protection, levee owners are required to do periodic monitoring. This might include inspection of the levees for erosion, slope failure, and animal damage, surveys of the levees and the channel to determine settlement and sedimentation rates, and flood watch operations.

Environmental Constraints

Habitat type
The desired habitat will determine the amount of tidal action that should be available to the restored site. Tidal marsh, for example, usually requires the maximum possible tidal exchange. Muted tidal marsh, which might be created to fulfill a specific habitat need or because flood concerns preclude the option of true tidal marsh, accepts a smaller tidal flow that can be regulated by tide gates or artificial channels (Goals Project 1999).

Fish Stranding and Predation
The size and number of tidal connections should be protective of native fish. When small levee culverts serve as the only connection to the Bay, for example, juvenile fish born behind the levee must enter the Bay in concentrated groups, making them easy targets for predators like striped bass. It is also important not to allow fish to be stranded behind the levee during low tides.

Construction Disturbance
As outlined in the next section, levee modification can require significant amounts of earth moving. The impact of this construction on neighboring habitats should be considered carefully and minimized if possible, through careful timing and use of appropriate materials (local or non-local, as the case may be).

Social Constraints

Property ownership and management rights are central to levee modification projects. Assuming that the owner of the restoration project area is also the owner of the levee, the responsibility for flood control assurance and levee maintenance could become a major project component and cost. The Tolay Creek restoration project (see case study) is an example of the importance of this issue. Also, as in the case of Rush Creek / Cemetery Marsh, competing management interests may represent a significant social constraint. The actual decisions of site managers will affect the project's success from a technical perspective. Equally importantly, the ability of management groups to reach consensus will determine the project's success from a procedural perspective.

Costs

The cost of levee modification depends primarily on the extent of new levee construction that is necessary, the source of material for that levee, and, for smaller projects, the cost of any special equipment (i.e., new tide gates). Basic project costs, such as property costs, also factor into the total cost.

5.2.4 Water Reuse

Function

Certain restoration projects, whether they involve wetlands, riparian corridors, or upland areas, require the continual application of fresh water., Water may be required, for example, for flushing out contaminants or for habitat modification. Treated municipal wastewater has the potential to be a significant source of this fresh water. Recycled water that meets the applicable water quality standards can be used for a variety of beneficial projects, such as supporting restored wetland habitat or offsetting agricultural needs to enhance natural flows. Given that some of the watershed's natural supplies are "fully appropriated," planners should, wherever possible, make use of alternate supplies such as recycled water to put less pressure on the watershed's natural supplies.

Effectiveness

Unlike most of the other methods outlined in this section, using recycled water is not only a technique for enhancing the success of a specific restoration project. Rather, its use also is intended to benefit the environment as a whole, by offsetting the need to develop additional water supplies via diversions and storage reservoirs. Furthermore, applying recycled water to natural, biologically productive systems can decrease nutrient and metal concentrations. water ultimately reaches a natural water body.

Recycled water use is effective when it fulfills a need for freshwater without otherwise compromising the integrity of the project – a water quality concern. For most projects in the San Pablo Bay watershed, it is too soon to tell whether the use of recycled water has had any long-term negative effects. Two case studies illustrate work in progress. The Hudeman Slough project by the Sonoma County Water Agency (see case study) resulted in the creation of subsaline marsh habitat, while helping the SCWA meet its summertime

Hudeman Slough Mitigation and Enhancement Project

Sponsoring Agency: Sonoma County Water Agency
The Sonoma County Water Agency (SCWA) provides flood control, drinking water, and sanitation services to residents of Sonoma County. They are the current managers of the Hudeman Slough site, but it was originally designed and built by the County of Sonoma Public Works Department, which formerly held responsibility for wastewater operations in the county.

Project Location: Hudeman Slough
The County of Sonoma Public Works Department initiated this mitigation and enhancement effort about ten years ago, in connection with a project to build recycled water storage ponds at the site. The site is located in southern Sonoma County along the upland edge of diked historic baylands, not far from the Carneros wine grape region. Hudeman Slough itself is connected to the bay via the Second Napa Slough.

The project uses secondary-treated wastewater from SCWA's Sonoma Valley County Wastewater Reclamation & Disposal Facility. SCWA has a zero-discharge mandate in the summer months, during which time it provides recycled water to agricultural users from these storage ponds. SCWA's long-term goals are to upgrade its treatment plant to provide tertiary recycled water and to identify enough recycled water users to permit it to achieve zero-discharge status year-round.

Objective: Restore Freshwater and Muted Tidal Marshes
Before the storage ponds and mitigation/restoration marshes (called "management units," or "MU's") were constructed, the site was unused agricultural land that already included some pickleweed habitat. Some mitigation was required for the storage pond construction, but enhancements at the site exceeded this requirement. Three management units were created through enhancement: MU1 (20 acres) and MU3 (32 acres), which are subsaline marshes, as determined by the vegetation growing there and MU2 (48 acres), which is a brackish marsh managed for pickleweed/Salt Marsh Harvest Mouse habitat at the request of the US Fish & Wildlife Service. In addition, ten upland ponds were created as mitigation.

Restoration Tools Used: Water Reuse
The freshwater marshes MU1 and MU3 are flooded annually with treated wastewater in September and October in order to encourage use by shorebirds and waterfowl. In November, the SCWA is again allowed to discharge into surface waters, so the ponds then fill naturally from direct precipitation and runoff from nearby hills and vineyards. The plant community contains species typical of low salinity wetland habitat, such as brass buttons, barnyard grass, and rye grass, and the ponds are used by thousands of birds each year. MU2 is a salt marsh that receives no recycled water. Direct precipitation and limited runoff mix with a high, saline water table to provide moisture in the winter and it can be flooded with a limited amount of baywater in the summer to improve pickleweed habitat. Eight upland ponds are also flooded with treated wastewater from October to April, with two ponds flooded perennially.

Special Feature: Research Project
SCWA is completing a two-year research project on the benefits and effects of using recycled water for restoration and enhancement purposes. The study, which will be finished next summer, will compare the water and sediment quality, nutrient levels, zooplankton, benthic invertebrates, vegetation, and avian wildlife between the SCWA sites and other diked baylands that do not use recycled water.

For More Information: Contact the SCWA at (707) 526-5370. Sean White, Lorraine Parsons, and Jessica Martini-Lamb are SCWA employees with thorough knowledge of the Hudeman Slough project.

zero-discharge requirement. The SCWA is also a potential provider of recycled water for flushing the Napa Salt Marsh (see case study), formerly Cargill salt evaporation ponds.

Napa Salt Marsh Restoration Project

Sponsoring Agencies: California Department of Fish and Game, Army Corps of Engineers, California Coastal Conservancy, and the Sonoma County Water Agency
The California Department of Fish and Game (CDFG) is the owner and manager of the Napa Salt Marsh Complex, which was formerly used by Leslie Salt Company, and then Cargill Salt, for producing salt in solar evaporation ponds. The Sonoma County Water Agency (SCWA) provides domestic water supply and sanitation services to portions of the County. The project to restore the salt ponds is a joint effort of the CDFG, SCWA, US Army Corps of Engineers and California Coastal Conservancy.

Project Location: Napa Salt Marsh
The Napa Salt Marsh is located along the mouth of the west side of the Napa River, just to the north of Highway 37. The Marsh is surrounded primarily by agricultural land.

Objective: Restore former Salt Ponds to Tidal Marshes
In the early 1990s, production at the Cargill salt ponds in San Pablo Bay ceased, and subsequently the CDFG acquired 9,850 acres of the complex with the intention of creating a wetland restoration site (CDM 1999b). Tidal marshes had formerly existed on the property, and the salt ponds continued to serve as a stopping and feeding zone for birds on the Pacific Flyway. When the salt ponds became inoperative, however, lower water levels and higher salinities were observed, resulting in a decline in the food and habitat value of the ponds.

Restoration efforts at the site are complicated by the high concentrations of salts and heavy metals present. Pond 7, one of ten ponds on the site, also contains a highly concentrated by-product of the salt evaporation process called bittern. It is estimated that approximately 100,000 ac-ft. of freshwater would be needed to flush the salts from Pond 7 (CDM 1999b). One potential source of this freshwater is recycled water from the Sonoma County Water Agency.

Restoration Tool to be Used: Water Reuse
Although it is one of several strategies currently being explored for restoration at the site, the SCWA is in conceptual discussions with partners in the North Bay about providing recycled water to the Salt Ponds in the first several years of the restoration. In order to do so, the SCWA would probably need to construct additional tertiary treatment facilities at the site, utilizing wastewater from treatment plants in unincorporated Sonoma County. When restoration is complete and the recycled water is no longer needed for flushing the ponds, it would become available to agricultural or urban users.

Two modes of operation have been proposed for the salt pond flushing:

- After flowing through the ponds, the diluted effluent will be discharged into San Pablo Bay, or
- If effluent water quality is too low, it will be treated again and possibly distributed for re-use.

Other parties would carry out additional restoration plans, such as re-vegetation or levee modification.

Issues and Concerns

Regulatory Restraints

The California Department of Health Services holds the authority to set criteria for recycled water production and use. Title 22, Division 4 of the California Administrative Code lists these regulations, which pertain to treatment processes, water quality, and reliability. Title 22 establishes minimum water quality requirements for various use categories, including irrigation, wetlands and industrial uses. The RWQCB, acting under the guidance of the SWQCB, issues permits and establishes actual water use regulations for specific projects (CDM 1999a).

The term “Title 22 Water” is often used to refer specifically to disinfected tertiary recycled water, the category approved for “unrestricted use.” As the table below illustrates, “unrestricted use” or disinfected tertiary water can be safely used for many purposes. “Restricted use” water is only secondary treated and generally contains many more microorganisms than tertiary disinfected water. For this reason, public and worker contact to secondary treated wastewater should be restricted. It is an established practice within the watershed to apply secondary recycled water to pasturelands and some golf courses. Tertiary-disinfected water may also be used for toilet flushing and cooling, and is suited for drip-line vineyard irrigation.

Minimum Water Quality Required	User Categories
Undisinfected Secondary	Agricultural Irrigation: fodder crops and orchards and vineyards with no contact on edible portion Wetlands
Disinfected Tertiary	Residential Irrigation Parks Golf courses with unrestricted access Agricultural Irrigation: Food crops with water contact on edible portion Industrial/Commercial (Process or Toilet flushing) Streamflow Augmentation (may also require Reverse Osmosis, chilling and nutrient removal)

(Adapted from CDM 1999a)

Definitions:

- Secondary Treatment: Following initial sedimentation, an aerobic biological treatment process (activated sludge, trickling filters, etc.) is used for the removes organic matter, microorganisms and nutrients. Disinfection is also required before discharge. Secondary treatment is usually required by law.

- Tertiary or Advanced Wastewater Treatment: Depending on water quality, tertiary treatment may include filtration through granular media, nitrification / denitrification, phosphorus removal, coagulation-sedimentation, carbon adsorption and disinfection (Crook 1992).

Environmental Constraints

Recycled water generally contains higher levels of nutrients, metals, organic contaminants, and dissolved solids, and is generally warmer than drinking water. This section discusses some of the concerns associated with these constituents.

Nutrients
Recycled water will contribute nutrients to the wetland or riparian zone undergoing restoration. Potential effects associated with the nutrient contribution include algae blooms or reduced concentrations of dissolved oxygen. Tertiary-treated recycled water generally contains fewer nutrients than secondary-treated recycled water (CDM 1999a).

Trace Metals and Organic Contaminants
Wetlands are known to accumulate trace metals and other contaminants via precipitation as salts, binding to soils and sediments, and uptake by plants, algae, and bacteria. While this effect may be intended in treatment wetlands, it can certainly present a problem when pursuing restoration goals. The difficulty may be compounded by the fact that salts, heavy metals, or organic contaminants, like petroleum or pesticides, may already contaminate certain potential restoration sites. The ultimate cause for concern related to trace metals and organic contaminants is bioaccumulation or toxicity in wildfowl and aquatic life. In addition, the effects of hormone disruptors may be problematic, especially for fish, but much less is known about this issue (CDM 1999a).

Temperature
Recycled water is often significantly warmer than ambient conditions, so cooling may be required prior to discharge. Temperature affects dissolved oxygen content and the survival of aquatic species directly. Most of the threatened and endangered fish in San Francisco Bay streams, for example, have difficulty tolerating temperatures above 75-79°F (24-26 °C) (CDM 1999a).

Dissolved Solids
In freshwater streams, high levels of total dissolved solids (TDS) can increase the osmotic pressure of water over the respiratory membranes of fish and other aquatic species, resulting in cell damage (CDM 1999a).

Habitat Conversion
The constant addition of recycled water may result in an undesirable conversion of habitat type, from seasonal to perennial marsh or from saline to freshwater marsh. Possible strategies for preventing this unwanted habitat conversion include mixing recycled water with bay water before discharge, as has been successfully demonstrated at the Hayward Treatment Marsh. Vernal pools, moist grassland, and buffer zones are all valuable habitat types, and should be protected and restored as part of a comprehensive restoration program. The Goals project recommends that the best approach to avoid the disproportionate loss of any habitat types is to restore the entire mosaic of aquatic habitat types in the San Pablo Baylands. (Goals Project 1999).

Engineering and Social Constraints

Once water quality regulations and concerns regarding recycled water have been addressed, two major tasks remain: identifying a recycled water supplier and a distribution method. Sanitary districts in the San Pablo Bay watershed are undergoing a gradual transition towards providing tertiary treatment. It is generally easier to find customers for tertiary recycled water than for secondary recycled water, but treatment is also more expensive. The cost and length of time required to construct a new or modify an old treatment plant is another major hurdle for providing the higher-quality water. Once high-quality recycled water becomes available, however, most providers have found that available demand easily equals, and even surpasses, the available supply.

A crucial constraint for sanitation districts on the northern and western sides of San Pablo Bay is that most may not discharge wastewater into streams or the Bay between May and October. This zero-discharge constraint has been a driving force for developing recycled water. Novato Sanitary District, Las Gallinas Valley Sanitary District, Napa Sanitation District, Sonoma County Water Agency, the City of Petaluma, and the City of Yountville are all examples of sanitation agencies that have found beneficial uses for treated wastewater in response to the zero-discharge requirement. As treatment levels increase, there has been an overall trend toward providing more water for golf courses, vineyards, and urban uses like cooling, toilet flushing, and firefighting. Providing low-cost water for pasture continues to be a priority, however, because dairy farmers in the Watershed depend upon locally produced hay..

In California, distribution of recycled water is normally the responsibility of the local water purveyor, not the local sanitation agency. Treatment beyond the secondary level may be done by the wastewater treatment plant or by the water purveyor. In many areas, these two agencies may be part of the same municipal government. Cooperation between agencies is crucial. Water purveyors often have an inherent interest in providing recycled water since it offsets the need for the limited drinking water supply. The motivation for sanitation agencies, on the other hand, is usually to comply with zero-discharge constraints. The following are a few examples of the ways that local agencies have creatively approached the problem of providing recycled water:

- West County Wastewater District (in Contra Costa County) treats its wastewater to secondary standards, then sends about 3.5 mgd of the water to EBMUD’s North Richmond Water Reclamation Plant. There, the water undergoes advanced treatment to prepare it for use in three of Chevron’s cooling towers (Johnson 2000). In a similar arrangement, Las Gallinas Valley Sanitary District sends 1-1.8 mgd of its summertime secondary-treated effluent to the Marin Municipal Water District (MMWD). MMWD treats the water to Title 22 unrestricted use standards, then provides the water to its customers for irrigation, car-washing, flushing toilets, etc. (Sartain 2000).

- In the summer, Novato Sanitary District applies the 5.2 mgd of secondary recycled water that it produces to farmers, to irrigate pasture that is leased by the District. The local water purveyor is encouraging them to upgrade their treatment disinfection process, so the District can provide water to a local golf course, as well (Mann 2000). The City of Petaluma uses its secondary recycled water to irrigate 800 acres of pasture on seven privately held ranches as well as half of the Adobe Creek golf course. Petaluma is to upgrade to tertiary-level treatment when it can build a new treatment plant, about six years from now (Ban 2000).

- The City of Yountville provides about 2.2 mgd of uncertified tertiary recycled water to two golf courses, two vineyards, and the local Veterans’ Home. When the water is certified for unrestricted use, Yountville will provide it for firefighting, as well. Likewise, the Napa Sanitation District produces 6.5 to 7 mgd of Title 22 unrestricted-use recycled water, which is used for irrigating pasture, vineyards and landscaping at commercial buildings. As demand increases, this District expects to irrigate less pasture (Alexander 2000).

The use of recycled water supply in the San Pablo Bay watershed is in a state of evolution. As population growth puts pressure on the existing drinking water supply, recycled water distribution is expected to increase in supply and quality, and the customer base is expected to change . On the whole, the sanitation districts in the watershed appear to be flexible about meeting these challenges: they are, one-by-one, upgrading to tertiary treatment and negotiating with customers to facilitate extension of distribution networks.

The task for restoration project sponsors is to find a way to make the existing recycled water supply benefit watershed health. Major opportunities exist in the San Pablo Bay watershed in the Napa-Sonoma Marsh restoration project, as well as in riparian and stream restoration projects.

Costs

When recycled water first became available about thirty years ago, users were paid to accept it, usually for use on pasture. That situation continues today in some water/ sanitary districts, but new users of tertiary recycled water can expect to pay for their recycled water. The total cost for using recycled water for restoration projects will depend on the following factors:

- Distance from distribution network, which will determine construction costs for a new pipeline, if needed;
- Quality and quantity of recycled water needed;
- Current availability of supply; and
- Attitude of supplier – environmental uses might be subsidized.

5.2.5 Control of Invasive Species

Function

Invasive exotic species threaten the health of the watershed in both an ecological and hydrological sense. The purpose of invasive species control is to encourage native flora and fauna to establish and thrive, thereby increasing habitat value and biodiversity. It is difficult to generalize among invasive vegetation, aquatic invertebrates, and predators, but two main methods of control are universal: **prevention** and **removal**. Some restoration projects may be targeted at the removal of invasive exotics; all other projects should have the ancillary goal of preventing the spread of invasive species.

Effectiveness

Effectiveness of measures taken to address non-native invasive species should be gauged not only by the absence of exotics, but also by the presence of natives. Two fundamental challenges stand in the way of success: (1) Any success is likely to be temporary, since re-introduction of invasive species cannot be prevented entirely, and (2) Effectiveness is difficult to quantify because of the expense and difficulty of monitoring, especially for aquatic species or predators on the move. Thus, success in removing invasive exotic species generally requires several rounds of control and monitoring. Control of invasives is most likely to be successful when paired with an effort to correct the habitat disturbance which may have encouraged the original invasion – for example, restoring natural river hydraulics is assumed to encourage the competitiveness of native riparian vegetation, which will naturally act to reduce exotic vegetation.

Controlling the original source of invasives, like discharged ballast water or plantings in domestic gardens, is pro-active and beneficial but may do little to control current infestations. The desired outcome of restoration projects using this method is not control for control's sake, but rather is control for the purpose of improving aquatic habitat. Because the Estuary is already the "most invaded aquatic ecosystem in North America" (Cohen and Carlton 1995), projects should be targeted at those species which are identifiable, exceptional threats to watershed health. *Arundo donax*, for example, is a recent invader that threatens to spread wildly as it has in southern California, unless groups like Team *Arundo* del Norte work to eradicate it (see case study).

Arundo donax Eradication Efforts: Sonoma Creek and Beyond

Sponsoring Agencies: Team *Arundo* del Norte and Sonoma Ecology Center
Team *Arundo* del Norte (TAdN) is a partnership of federal, state, and local stakeholders dedicated to the reduction and eventual elimination of *Arundo donax* in northern and central California. The Sonoma Ecology Center (SEC), a group that coordinates volunteer *Arundo* eradication and mapping efforts along Sonoma Creek, founded TAdN . SEC will serve as the project coordinator for TAdN's CalFed project, which will coordinate and fund *Arundo* removal projects around the Bay and its tributaries.

Objective: Restore Riparian Habitat by Eliminating *Arundo donax*
Arundo donax is a threat because of the numerous physical and chemical changes that it brings to the riparian environment: it forms dense monocultures that displace native vegetation; provides less shade than natives; is highly flammable; and promotes bank instability because of its shallow rhizomes. *Arundo* does not provide substantial food or habitat for native animals, and its incredible rate of growth – up to 5 cm per day – requires large quantities of water (TAdN 1999b). For all these reasons, the removal of *Arundo* is a high priority throughout the state, especially in northern California where, the problem is still moderate enough to allow for successful eradication. *Arundo* removal allows native vegetation to spread, preserves natural stream geomorphological processes, conserves water and protects habitat for native fish (TAdN 1999a)

Restoration Tool to be Used: Mechanical and Chemical Control Methods
Options for *Arundo* control vary according to the size of the infestation. SEC's method of choice for small infestations near water is to cut off the stalks of the plant and immediately apply glyphosphate, a systemic herbicide (Newhouser 2000). Glyphosphate is sold under the trade names Roundup™ and Rodeo™. Rodeo™ is the only herbicide approved for aquatic use. Less preferable control methods include burning or aerial spraying of herbicide (TAdN 1997).

The SEC is currently in the second year of a long-term project to monitor and remove *Arundo* infestations along upper portions of the Sonoma Creek watershed. This effort, which seeks to control the downstream problem at its upstream source, is in addition to their ongoing *Arundo* eradication efforts elsewhere in the watershed. In fact, *Arundo* removal is only one facet of SEC's Restoration Program, which also includes regular creek cleanups, bank stabilization projects, other invasive plant species eradication, native tree planting and restoration consultation.

TAdN's CalFed project will expand and coordinate efforts by SEC and similar groups to remove *Arundo* from the entire Bay-Delta watershed. The three focuses of the CalFed project are: (1) to deliver funds and expertise to eradication partners in the Putah Creek, Big Chico Creek, Sonoma Creek, Walnut Creek, Napa River, and San Francisquito Creek watersheds; (2) to provide strategic and fund-raising assistance to at least 20 potential eradicators; and (3) to consolidate *Arundo* information and make it available on the Internet (TAdN 1999a). The project is expected to last three years.

For More Information: Contact TAdN or SEC
Team *Arundo* del Norte's website (http://ceres.ca.gov/tadn/) provides a wealth of information on *Arundo* biology and control efforts. Deanne DiPietro is TAdN administrative coordinator and can be reached for more information at deanne@ceres.ca.gov. Mark Newhouser is the CalFed Arundo Eradication Project Coordinator at the Sonoma Ecology Center (http://www.vom.com/sec/) and is available at mnewhouser@vom.com

Issues and Concerns

The following section outlines some of the control strategies available for two high-profile categories of invasive exotic species: vegetation and predators. Both removal and prevention are emphasized. Aquatic invertebrates like Asian clams and Chinese mitten crabs merit equal concern, but few effective removal strategies exist for already-established populations, and large-scale preventative measures, like exchanging ship ballast water, are outside the scope of this Program. Control of predatory fish like striped bass is equally difficult, and will not be discussed here.

Vegetation

Removal

The two most common methods for the small-scale removal of unwanted vegetation are mechanical (mowing, cutting, digging, etc.) and chemical (herbicides). Often, the two are combined. For example, removal of Eucalyptus or another large tree might involve cutting the trunk, applying herbicide, then digging up the root system (CNWCPI/ICE 2000). Plants with extensive root systems, like ivies and Pampas grass, are best removed by mechanical means – the entire root structure must be dug up. Others, like poison hemlock, periwinkle, and bull thistle, will also respond to repeated mowing. Repetition is most important for plants with large seed banks, like French broom, Pampas grass, and many other annuals. The seed source must first be removed (by pulling or mowing), and then seedlings must be removed for several seasons in order to successfully deplete the seed bank.
Though the herbicide Rodeo™ (glyphosphate) is approved for aquatic use and its stronger counterpart, Roundup™ is frequently used in upland areas, some groups may prefer not to use herbicides at all.

More control methods are available to agencies with the regulatory authority to implement them. For example, the Marin Municipal Water District has experimented with fire control of French broom in the Mt. Tamalpais Watershed (which is not a part of the San Pablo Bay watershed) (Swezy 1997), while UC Davis research demonstrated successful use of fire to control yellow star thistle (CNWCPI/ICE 2000). Fire's side effects, like air pollution, make it unattractive to use on a frequent basis, but it may be one component of an integrated control effort that could also include mechanical and chemical methods as well as grazing.

Biological control methods are often preferable from an environmental standpoint, especially if the control agent has already been introduced. The introduction of new species is much more difficult from a regulatory standpoint, since the impacts must first be determined. As with fire control, biological control is restricted to those agencies with the appropriate authority, like those with USDA affiliation. For example, the five county Departments of Agriculture within the watershed are involved in biological control research projects on klamathweed (*Hypericum perforatum*), puncturevine (*Tribulus terrestris*), yellow star thistle (*Centaurea solstitialis*), Italian thistle (*Carduus pycnocephalus*),water hyacinth (*Eichhornia crassipe*), and gorse (*Ulex europaeus*) (CNWCPI/ICE 2000). All the aforementioned projects use insects for biological control. Biological control is not an option for invasives that are closely related to native plants, like *Spartina alterniflora* and other exotic cordgrasses.

All vegetative control efforts should be viewed in a watershed context, with work progressing from uplands and upstream riparian zones to downstream areas. This approach ensures that an infestation will not be renewed or sustained by seeds and progagules from populations upstream.

<u>Prevention</u>
At sites that have been cleared of vegetation, it is important to discourage colonization by invasive exotics. This is especially true at marsh restoration projects, where *Spartina alterniflora, Spartina densiflor*a, or *Spartina patens* might establish a stronghold and choke out native *Spartina foliosa*. (SFEP 1998). Immediate revegetation with native plants is one option for reducing invasives, although a clean seed bank must be ensured if this strategy is chosen. For passive revegetation, which costs much less, it may be necessary to monitor for and remove invasive exotics (and hybrids, in the *Spartina* case) as they germinate – before the infestation grows to an unmanageable size.

<u>Environmental Constraints</u>
The removal of invasive exotics involves significant environmental tradeoffs, because it is sometimes difficult to effectively remove a persistent invasion without adopting a "scorched-earth" policy. Aerial herbicide applications usually cannot select for a target plant and therefore kill all vegetation, while mechanical removal methods can release large amounts of sediment into nearby water bodies.

Some invasive exotics plants, like Himalaya berry (*Rubus discolor*), are known to provide valuable habitat to native fauna and contribute to streambank stability, and thus their removal should be approached with extra caution (City of Petaluma 1995).

<u>Social Constraints</u>
Some mature trees, like eucalyptus, Lombardy poplar, and non-native oaks and buckeye fall into the category of invasive exotics (City of Petaluma 1995), but public sentiment may support their preservation because of aesthetic benefits. This type of problem can only be solved on a case-by-case basis.

Predators
In order to minimize the damage caused by introduced predators like feral cats and red foxes, one must protect the prey while working to eliminate the predator. Because each predator must be handled differently, this section is organized by predator type rather than control method. However, one strategy that works against multiple predator types is restoration of vast expanses of habitat (rather than isolated patches). This approach limits urban/natural boundaries and restricts easy predator access.

Red Fox (*Vulpes vulpes*)
Fencing-in nesting areas and creating artificial nesting islands are examples of habitat management measures that can reduce predation by red fox. Different types of birds require different types of habitat protection; for example, California least terns require islands free of vegetation, while California clapper rails prefer to hide in a dense cover of pickleweed or cordgrass. Fences are less preferable for large areas because of their high maintenance costs, considering their limited effectiveness. Fences may be appropriate for small areas, however, such as established nesting areas.

If none of these alternatives work, the California Department of Fish and Game recommends live trapping and euthanasia. Though less preferable, red fox populations can also be managed naturally by coyotes. Relocation, adoption, and sterilization are not considered to be effective (CDFG 2000).

Feral cats (*Felis catus*)
Public opinion is often the controlling factor in feral cat management. Although removing cats by trapping and euthanasia is the most effective way to control their numbers, this approach is often viewed as inhumane. For example, the Alley Cat Allies, a feral cats rights organization, recommends a program of trapping, vaccination, spaying/neutering, and re-release or adoption. Feral cats are sometimes fed as a way to reduce their need to kill native rodents and birds, but this approach may be counterproductive: “cats hunt because they are hunters, not because they are hungry.” Feeding may actually attract more cats to the site and make them stronger, more efficient hunters (Slack 1998).

Efforts to keep cats indoors may be helpful where urban development is adjacent to wildlife habitat.

Birds of Prey
Avian predators like raptors and ravens can be discouraged from attacking native wildfowl by eliminating perches like fences, power poles, lighting, and trees from the area (Goals Project 1999).

5.2.6 Passive Restoration

The expression “time heals all wounds” applies to many restoration sites. Passive restoration involves simply eliminating or reducing the sources of degradation and allowing recovery time. Before actively altering a restoration site, it is important to determine whether passive restoration will be sufficient to allow the site to naturally regenerate. Sometimes there are reasons for restoring a site as quickly as possible, but there are other situations when immediate results are not absolutely critical. In many former wetlands, for example, passive measures can lead to the reemergence of wetland vegetation and waterfowl. For some rivers and streams, passive restoration can re-establish stable channels and floodplains, recover riparian vegetation, and improve in-stream habitats without a specific restoration project (FISRWG 1998).

Simply by turning off pumps that kept this hay farm drained during winter, a 1,500-acre seasonal wetland was created.

When active restoration projects are undertaken, the danger remains that in treating one symptom of impairment, another unwanted change in habitat conditions will be triggered. In analyzing bank erosion, for example, one conclusion might be that accelerated watershed sediment delivery has produced lateral instability in the stream system. Bank hardening in one location might interfere with sedimentation processes critical to floodplain and riparian habitats, or it might simply transfer lateral instabilities from one location in a stream reach to some other location. The applicability of passive techniques on larger streams and rivers is also limited, particularly where there are multiple stresses, competing uses, and downstream effects from upstream disturbances (NRC 1992).

Cullinan Ranch is an educational example of passive restoration of seasonal wetlands (See case study) with minimal cost and effort. This former freshwater wetland was converted to a hayfield, and rainwater was pumped out via drainage ditches. After the cessation of hay planting and drainage pumping, the wetland responded with a new cover of native wetland vegetation.

Cullinan Ranch, Phase I Restoration

Sponsoring Agency: USFWS
The U.S. Fish and Wildlife Service sponsored this project .

Objective: Restoration of seasonal wetland
the US Fish and Wildlife Service acquired this former wetland area was in 1991 . At the time, the land was used as a hayfield. During the wet season, rainwater would accumulate on the site, and pumps were used to drain out the water. In 1993, pumping stopped in order to allow water to inundate the wetland. The ultimate objective will be to restore the diked bayland into tidal marsh, but the first phase is converting the hayfield into a seasonal wetland. Currently, the site is thriving as a seasonal freshwater wetland with abundant vegetation and wildlife.

Restoration Tools Used: Passive restoration
Passive restoration was the driving force behind the successful restoration of the seasonal wetland. The only tool that was used in this project was the cessation of pumping. Once the pumps were shut off, the area was able to retain water coverage during the wet season. After just two years, the dry hayfield transformed into a fully functional freshwater wetland.

Project Location: Cullinan Ranch
Cullinan Ranch is located just north of Highway 37 and west of the Napa River. The area is within the Sonoma Creek watershed.

Special Feature: Model for restoration
Because of the successful recovery of this site to a seasonal wetland, Cullinan Ranch has been used as a model for current and future restoration projects in the San Pablo Bay. The US Geological Survey has conducted monitoring of vegetation, birds, and mammals at the site. The information gathered has been used as a reference source for other freshwater wetland restoration projects.

Special Issues: Active management necessary
The recovery of wetland vegetation at Cullinan Ranch was achieved in a rather short time frame. This project shows that passive restoration can have a profound impact on the reemergence of wetland plants. The vegetation is so abundant, in fact, that active management is needed to curb the growth of certain native species. In particular, cattail growth has increased substantially and must be actively managed through the use of herbicides or flooding. Active management has to be implemented in this case to retain a diverse wetland cover and prevent the site from becoming a mono-culture of cattails.

For More Information: Contact the Refuge Manager at (707) 562-3000
Bryan Winton is the refuge manager in charge of Cullinan Ranch.

5.2.7 Buffers

Importance

Existing and restored wetlands and streams must be protected from factors that diminish wildlife habitat quality. It makes little sense to expend private or public funds to restore a site, only to have its positive functions compromised by human and animal encroachment. One of the best ways to help provide maximum benefits for wildlife and minimize the effects of adjacent land uses is to incorporate buffers into project design and management (Goals Project 1999). Buffers are simply strips of land surrounding a riparian area or wetland that offer isolation and protection from current human activities and future development.

The establishment of buffer areas along streams can preserve wetlands and floodplains, help stabilize stream banks, reduce erosion and sedimentation, reduce the volume of runoff, reduce pollutant loads, protect wildlife and habitat, and provide recreation, among other functions. Some buffers are implemented voluntarily by farmers or landowners seeking to protect their streambanks, farmlands and water quality for their crops. When wetland restoration is undertaken, buffers should be provided to protect restored wetlands, ensuring that coastal wetlands have room to change shape. (NRC 1992).

Buffer Design

The *Baylands Ecosystem Goals Project* report (1999) includes several recommendations about buffer design. They suggest a minimum buffer width of 300 feet, if possible. "Where existing land uses or other factors such as steep terrain preclude this, wetland buffers should be no narrower than 100 feet. For riparian habitats, the recommended minimum buffer width is 100 feet beyond the outside boundary of the riparian vegetation" (Goals Project 1999).

The manual *Stream Corridor Restoration: Principles, Processes, and Practices* was prepared in 1998 by fifteen federal agencies working as the Federal Interagency Stream Corridor Restoration Working Group, and it is the source for much of the material on stream restoration presented here. Their advice on buffer zones in urban areas is excerpted here:

"Effective urban stream buffers have three lateral zones—streamside, middle core, and outer zone. Each zone performs a different function, and has a different width, vegetative target and management scheme. The streamside zone protects the physical and ecological integrity of the stream ecosystem. The vegetative target is mature riparian forest that can provide shade, leaf litter, woody debris, and erosion protection to the stream. The middle zone extends from the outward boundary of the streamside zone, and varies in width, depending on stream order, the extent of the 100-year floodplain, adjacent steep slopes, and protected wetland area. Its key functions are to provide further distance between upland development and the stream. The vegetative target for this zone is also mature forest, but some clearing may be allowed for storm water management, access, and recreational uses.

The outer zone is the buffer's 'buffer,' an additional 25-ft. setback from the outward edge of the middle zone to the nearest permanent structure. In most instances, it is a residential backyard. The vegetative target for the outer zone is usually turf or lawn, although the property owner is encouraged to plant trees and shrubs, and thus increase the total width of the buffer. Very few uses are restricted in this zone. Indeed, gardening, compost piles, yard wastes, and other common residential activities often will occur in the outer zone" (FISRWG 1998).

Buffer Education and Enforcement

The integrity of a buffer system requires a strong education and enforcement program. It is important to make the buffer "visible" to the community, and to encourage greater buffer awareness and stewardship among adjacent residents. Permanent signs should mark buffer boundaries. These signs should describe allowable uses, and landowners should be educated about the benefits and uses of the buffer (FISRWG 1998). Fencing can be an effective way to ensure protection of areas that are to remain undisturbed. Most buffers should be fenced to prevent entry of humans, dogs, and livestock (Goals Project 1999). Fencing material should be easy to see, and areas should be labeled as protection areas.

Concerns

Problems with buffers nationwide include poorly designed buffers and buffer destruction by new owners unaware of their purpose. For example, throughout the country, river buffers near homes are often removed and turned into lawns and other residential landscaping. Another buffer problem is failure to see buffers as a comprehensive system. For example, many local governments find themselves unprepared for changes in the buffer, such as storm damage, runoff cutting channels into the buffer, or people clearing out the buffer to plant a lawn. Nor do most local governments consider the buffer system during their general planning process or open space acquisition efforts. Furthermore, some landowners see buffers as an economic burden because it makes less land available for farming or development (BCDC 1999b).

5.2.8 Re-vegetation

Introduction

The growth of healthy, diverse, native vegetation is often a stated project goal, but the decision to spend large amounts of money to achieve that goal is a difficult one. Purposeful re-vegetation with native plants can help control invasive species and can help speed up the restoration process. Natural re-vegetation via colonization can be equally successful, however, especially in certain types of habitats. Wetlands, for example, are difficult to plant, and natural colonization is usually quite rapid (Salzman 2000). Re-vegetation efforts should focus on species that are unlikely to colonize the site on their own, or whose high habitat value makes their planting worth the effort. This section focuses primarily on riparian re-vegetation, though some of the techniques and problems, like ensuring proper hydrological conditions, apply to re-vegetation of wetlands and upland areas, as well.

The objective of stream corridor restoration work is to restore natural patterns of plant community distribution within the stream corridor. Nearby reference conditions can generally serve as models to identify the appropriate plant species and communities. Once reference plant communities are defined, the design can begin to detail the measures required to restore those communities (FISRWG 1998). Designs should emphasize native plant species from local sources.

EBMUD's Community Creek restoration project combines elements of re-vegetation and bank stabilization; please refer to Section 5.2.11 (*Bank Stabilization*) for the case study information.

Riparian Forest

Riparian habitats comprise the ecotone between the river or stream and the rest of its watershed. According to the *Habitat Goals* report (1999), the riparian habitat of the Bay Area is "characterized by steep and variable gradients of moisture and light, lush vegetation, and very high biological diversity. Of all the riparian habitats in the Bay Area, riparian forests are the most complex and support the greatest total number of plants and animal species."

Due to the difficulty and expense of re-vegetation, it is rarely desirable to plant the full array of appropriate species on a particular site. Instead, as stated above, a more typical approach is to plant the dominant species and those species unlikely to colonize the site readily. The *Stream Corridor Restoration* manual puts a heavy emphasis on planting oaks: "Oaks are heavy-seeded, are often shade-intolerant, and may not be able to readily invade large areas for generations unless they are introduced in the initial planting plan . . . It is assumed that lighter-seeded and shade-tolerant species will populate the site at rates sufficient to ensure that the resulting forest is adequately diverse. This process can be accelerated by planting corridors of fast-growing species (e.g., cottonwoods) across the restoration area to promote seed dispersal" (FISRWG 1998).

Past cattle grazing has stripped upper San Pablo Creek of vegetation. Replanting efforts will restore the riparian corridor (Photo EBMUD 2000).

In areas typically dominated by cottonwoods and willows, the *Stream Corridor Restoration* manual advises that "the emphasis might be to emulate natural patterns of colonization by planting groves of particular species rather than mixed stands, and by staggering the planting program over a period of years to ensure structural variation" (FISRWG 1998). The concept of staggering over time also applies to the planting of understory species, which can provide essential components of endangered habitat. Common riparian understory species are elderberry, wild rose, and blackberry (Goals Project 1999). It is often difficult to establish these understory species, which are typically not tolerant of full sun, if the restoration area is open. To avoid this difficulty, understory vegetation can be introduced in adjacent forested sites (if any), or planted after the initial tree plantings have matured sufficiently to provide shade. The staggering approach may also be necessary for sun-intolerant overstory species (FISRWG 1998).

Native Species

In the past, stream corridor planting programs often included nonnative species selected for their rapid growth rates, soil binding characteristics, ability to produce abundant fruits for wildlife, or other perceived advantages over native species. These actions sometimes have unintended consequences and often prove to be extremely detrimental (Olson and Knopf 1986). As a result, many local, county, state, and federal agencies discourage or prohibit planting of nonnative species within wetlands or streamside buffers. Stream corridor restoration designs should emphasize native plant species obtained from local sources. For example, the Capri Creek Restoration Project involved planting natives purchased from a local nursery. The Petaluma Watershed Enhancement Plan was consulted to reference the historic riparian plant species in the area (see case study).

Plant Establishment Techniques

Plant establishment techniques vary greatly depending on site condition and species

Capri Creek Restoration

Sponsoring Agency: Joint Partnership
This project was sponsored under the joint partnership of the Southern Sonoma County Resource Conservation District (RCD), the Santa Rosa Junior College (SRJC), and the City of Petaluma. The funding for this project came from a CalFED grant obtained by the RCD.

Objective: Riparian Enhancement
The objectives of this project are enhancement of the Capri Creek riparian corridor and control of discharges to the creek. Capri Creek has problems with downcutting of slope banks as well as excessive weed growth. Revegetating the creek banks and riparian corridor will help stabilize the banks, in addition to improving water quality and wildlife habitat.

Restoration Tools Used: Revegetation
The project involves revegetating the creek banks and riparian corridor with native trees and shrubs. The Petaluma Watershed Enhancement Plan was used to identify native plant species such as Oregon ash, buckeye, and valley oak. Students planted the new vegetation, which was obtained from a local nursery that specializes in natives and was selected to mimic the composition of historic creek communities in the area. Mulch prevents further weed growth and promotes the progress of perennial native grasses, such as Mediterranean barley. Thus far, perennial native grasses have faired well with the addition of mulch. The initial revegetation stage has been completed, but the freshly planted natives are being maintained through direct irrigation and weed control. This process will be carried on for 3-5 years, after which the plants become self-sustaining.

Project Location: Capri Creek
Capri Creek is located adjacent to the Petaluma Campus of SJRC off of Sonoma Mountain Parkway. The creek is one of the smaller tributaries of the Petaluma watershed; the project's location was not chosen so much for integral water quality issues as it was for educational purposes.

Special Feature: Stream Restoration for Educational Purposes
The project serves as an educational tool for students and the general public. Capri Creek runs through a local college, so the study is conducted at the heart of an educational setting. The restoration of the creek gives college students an opportunity to apply what they learn in the classroom. The project is prominent in the community, and offers a visible and accessible tool for teaching the public about general watershed restoration. College students have provided most of the labor to restore riparian habitat, with help from Petaluma area school children participating in the Adopt-A-Watershed program administered by Susan Haydon and Jennifer Allen of the RCD.

Special Issues: Additional Measures
College students and faculty have conducted water quality tests on the creek throughout the year and have found that a significant source of poor water quality is the discharge from adjacent landowners. In particular, run-off from a nearby nursery contributes nitrate to the water. Even after revegetation efforts, any meaningful change in water quality will not be achieved unless there is some discharge regulation in effect. The next step is to work with adjacent landowners to regulate discharge into the creek. Due to severe bankcutting of existing slopes, the upper portion of the creek ultimately needs to be recontoured as well, but that task will require more help than student volunteers can provide.

For More Information: Contact Abigail Zoger at (707) 527-4524. Abigail Zoger is a faculty member at SJRC, and she has provided the leadership and planning for this project.

characteristics. Methods include planting stem cuttings from plants such as willow, cottonwood, thimbleberry, coyote bush, or other species that sprout readily, and planting them to depths that will ensure contact with moist soil during the dry season. Where water tables have declined precipitously, temporary irrigation is used to establish new vegetation. Planting container-grown or bare-root stock, such as alder or oak, is employed in environments where precipitation or ground water is adequate to sustain planted vegetation. On large floodplains, direct seeding of plants may be appropriate. Other options include the transplant of plants found growing near the restoration site. Some species are best acquired by thinning surpluses in nearby thickets and stands (Flosi 1998).

Planting tubes provide shade, protection and moisture for new plantings. (EBMUD 2000)

Oaks, buckeyes, and other vulnerable plants may need to be initially protected by planting tubes. The tubes shade the young plants, reduce evapotranspiration, and provide protection from hungry wildlife.

Horizontal and Vertical Structure

A stream corridor in its pristine state functions as habitat, conduit, filter, and barrier. In the Bay Area, natural stream corridors tend to be long and narrow, but urban development and roads have created gaps in the riparian zones of most streams (Goals Project 1999). Wide or frequent gaps can be barriers to migration of smaller terrestrial fauna, aquatic fauna and indigenous plant species (FISRWG 1998). Gaps can also interfere with the stream corridor's filtering function, because areas with no vegetation cannot slow overland flow. In some cases, re-vegetation and aid in re-connecting the pieces of a fragmented stream corridor. More extreme measures, like re-building bridges to increase space for the stream, may be necessary before re-vegetation is a possibility (FISRWG 1998).

Vertical and horizontal heterogeneity are important features of a stream corridor. The topography, aspect, soil, and hydrology of the corridor change over space, resulting in naturally diverse layers and types of vegetation (FISRWG 1998). The differences between edge and interior vegetative structure are especially important design considerations of re-vegetation projects. Although most riparian habitat in this watershed is constrained by levees or adjacent land uses (Goals Project 1999), developing a transitional zone of gradual vegetation change might still be possible in some areas. The goal of creating transition zones, which is also the main idea behind the buffer concept, is to encourage species diversity and encourage more interaction between ecosystems, while limiting human encroachment. The reference stream corridor can provide helpful information about the types of plants that can provide the necessary transition between the riparian zone and upland or wetland areas.

Hydrological Conditions

A good understanding of stream migration and flooding is necessary for the design of appropriately restored plant communities within the floodplain. Water management and planning agencies are often the best sources of such data. Generally, planting efforts are easier when moisture conditions are suitable for the desired vegetation (FISWRG 1998). When more vegetation is planted than the flow conditions would naturally support, the site might require continued maintenance. The Capri Creek riparian restoration project, for example, calls for continued maintenance of newly planted species through irrigation and weed control for the first 3-5 years. After that period, it is assumed that the plants will be stable enough to function on their own.

Projects that require long-term supplemental watering should be avoided due to high maintenance costs and decreased potential for success. Inversely, there may be cases where the absence of vegetation, especially woody vegetation, is desired near the stream channel. Alteration of streamflow or inundating discharges may make moisture conditions on these sites unsuitable for woody vegetation (FISRWG 1998).

5.2.9 Short-Term Habitat Measures

Some measures may be implemented to provide short-term habitat until overall restoration results reach the level of maturity needed to provide the desired habitat. These techniques cannot stand on their own as complete restoration projects, but they can certainly complement other efforts. Nest structures and food patches are two examples of short-term restoration measures that may be effective in this area.

Nest Structures

The loss of riparian or terrestrial habitat in stream corridors has resulted in the decline of many species of birds and mammals that use associated trees and tree cavities for nesting or roosting. The most important limiting factor for cavity-nesting birds is usually the availability of nesting substrate, generally in the form of snags or dead limbs in live trees (Sedgwick and Knopf 1986). This can be reconciled by physically creating snags, using explosives, girdling or topping of trees. Artificial nest structures can compensate for a lack of natural sites in otherwise suitable habitat since many species of birds will readily use nest boxes or other man-made structures (FISRWG 1998). In many cases, providing such structures has increased breeding bird density (Brush 1983). Artificial nest structures can also improve nestling survival (Cowan 1959).

Nest structures must be properly designed and located, meeting the biological needs of the target species. They should also be durable, predator-proof, and economical to build. Besides the most commonly used nest boxes, nest structures include nest platforms for waterfowl and raptors; nest baskets for doves, owls, and waterfowl; floating nest structures for geese; and tire nests for squirrels (FISRWG 1998). Specifications for nest structures for riparian and wetland nesting species can be found in many sources including Yoakum et al. (1980), Kalmbach et al. (1969), and various state wildlife agency and conservation publications.

Food Patches

Food patch planting is often expensive and not always predictable, but it can be carried out in wetlands or riparian systems mostly for the benefit of waterfowl. Environmental requirements of the food plants native to the area, proper time of year of introduction, management of water levels, and soil types must all be taken into consideration. Two commonly planted native species include wild rice (Zizania) and wild millet. Details on suggested techniques for planting these species can be found in Yoakum et al. (1980).

5.2.10 Stream Channel Restoration

This section addresses the most difficult aspect of stream restoration: modifying the channel itself. Geologists and engineers are learning how to design a stream channel that mimics natural geomorphology and produces suitable habitat conditions, though it is still a young science. This is not a task to be undertaken without professional help, but where streams have been channelized, leveed, buried, choked with sediment or eroded away, it is certainly a necessary one. However, stream channel restoration will only be successful if instream flow problems have first been addressed.

Please refer to Appendix E for information about the Wildcat Creek de-channelization project. That project was one of the first in the country to include environmental benefits (a natural stream channel with riparian zone) with a flood control project.

Incised Channel Restoration

Incised stream channels are typically much larger than the size required to convey the channel-forming discharge. In selecting the proper channel width and depth, the simplest approach it to use dimensions from stable reaches elsewhere in the watershed or from similar reaches in the region. Designers should use an evaluated reference reach with a stable channel design to make sure that restored channels are stable and has a desirable morphological and ecological condition. Restoration of an incised channel may involve one of three strategies:

- Raising the bottom of a stream to restore overbank flow and ecological functions of the floodplain.

- Excavating one or both sides to create a new bankfull channel with a floodplain (Hey 1995).

- Stabilizing the incised channel in place, and enhancing the low-flow channel for environmental benefits. The creation of a floodplain might not be necessary or possible as part of a stream restoration.

Channel Alignment

In some cases, it might be desirable to divert a straightened stream into a meandering alignment for restoration purposes. The transformation reintroduces natural dynamics to improve channel stability, habitat quality, and aesthetics, and dissipate flood energy. The design prototype for bed slope and channel dimensions is for the discharge velocity to be great enough to prevent suspended sediment deposition and small enough to prevent erosion of the bed. Meanders can be laid out such that the meander arc length L (the distance between inflection points, measured along the channel) ranges from 4 to 9 channel widths and averages 7 channel widths. Meanders should not be uniform (FISRWG 1998). Several out-of-state examples of projects to re-create channel meanders can be found in the *Stream Corridor Restoration* manual.

Stream meander restoration does have many constraints. The process requires a high level of analysis, and has a significant risk of failure. Meander restoration requires adequate area where adjacent land uses may constrain locations. This may not be feasible in watersheds experiencing rapid changes in land use. Lastly, changing the channel alignment in such a way may also cause significant increases in flood elevations (FISRWG 1998).

Setback levees

Setback levees are defined as a fixed earth ridges or embankments located a distance of 20 feet to 1,000 feet from a stream channel, while conventional levees are located at the edge of the stream. Both types of levees are designed to protect life and property in the event of a flood, but setback levees offer the additional benefit of providing room for riparian habitat along a floodplain.

Where streams have been channelized and can no longer spill onto a floodplain without overtopping their conventional levees, setback levees can offer a more natural channel alternative that allows the stream to meander within its floodplain. The construction of setback levees is no minor undertaking; flood protection capacity must be preserved, so the vegetation along the new floodplain must be managed and monitored carefully. Significant amounts of property acquisition may also be necessary if a large floodplain is to be restored. Where property acquisition is not a prohibitive expense, however, the potential to create additional floodplain storage while enhancing riparian habitat represents a win-win situation.

Bank Stabilization

Bank stabilization on Sulphur Creek using slope contouring, planting and an erosion control blanket (Napa RCD 2000) .

Streambank instability, as discussed previously, is a symptom of problems caused by irresponsible land use, hydrological modification, and losses of riparian vegetation. Bank stabilization in the restoration context should therefore be viewed as a "temporary" measure undertaken while streambank and floodplain vegetation recovers, and while the causes of excessive erosion can be addressed. This section explains some of the methods that can be used to protect streambanks, which generally have one of two aims: (1) to act as surface "armor," or (2) to act indirectly, re-directing flow so that hydraulic forces are reduced to a non-erosive level. (FISRWG 1998). Vegetation can function in either or both of these capacities.

Re-vegetation and "soil bioengineering" techniques, which rely on plant materials for erosion protection, should be viewed as the first course of action for protecting vulnerable streambanks. Willows and other pioneer species exhibit rapid growth, and if planted at high enough densities can provide immediate moderation of flow velocities. Often, these species can be placed deep enough to maintain contact with adequate soil moisture levels, thereby eliminating the need for irrigation. More extreme approaches, like riprap, logs, and natural fabrics, can be can be incorporated into design for streams with large erosive forces.

The descriptions below are based on the *Stream Corridor Restoration* manual. Often, these techniques are combined.

Method	Techniques
Anchored Cutting Systems	Large numbers of cuttings are arranged in layers or bundles, which can be secured to streambanks and partially buried. The cuttings should quickly develop dense roots and sprouts, providing direct protection from erosive flows and promoting trapping of sediments. Cuttings can be laid side-by-side against the face of the bank and fastened down (see adjacent picture), or dug into terraces and left with their ends extending. (FISWRG 1998)
Geotextile Systems	The typical streambank use of geotextiles is in the construction of vegetated geogrids, which are layers of cuttings with the spaces between them encased in fabric. If possible, it is best to use natural, biodegradable materials, like jute or coconut fiber. Geotextiles are frequently used for erosion control in upland settings, usually in combination with seeding or with plants placed through slits in the fabric. (FISRWG 1998)
Trees and Logs	Whole tree trunks are laid parallel to the bank and fastened down. Large trees are sometimes used in conjunction with stone to provide bank protection as well as improved aquatic habitat. This technique's main advantage is that it reestablishes one of the natural roles of large woody debris in streams by trapping organic material, providing colonization substrates for invertebrates, and offering refuge for fish. The logs eventually rot, resulting in a more natural bank. (FISRWG 1998)
Boulder Structures	Boulder structures are a preferred stabilization technique because of their longevity and resistance to movement. Boulders can be used to riprap streambanks or to construct wing-deflectors to deflect flow away from an unstable bank. Although boulder riprap can provide bank protection and resist erosion, it may also accelerate stream flow, thus creating a new erosion hazard downstream (Flosi 1998).

Community Creek Restoration Program

Sponsoring Agency: East Bay Municipal Utility District
East Bay Municipal Utility District (District) supplies municipal drinking water to 1.2 million customers in the East Bay, and manages 28,000 acres of land around 5 reservoirs in Contra Costa and Alameda Counties. The District operates a successful joint agency/school-based service learning program to implement creek restorations on these lands.

Objective: Revegetate Creek Banks
Creeks within the EBMUD's watershed lands had been over-grazed for the past two centuries until grazing practices were changed 16 years ago. As a result, many of the trees had been stripped away by age, cattle, ranching operations and erosion. Revegetating the creek banks in EBMUD's watershed help improve drinking water quality for the District's reservoirs and improve wildlife habitat as well.

Restoration Tools Used: Replanting, Bank Stabilization and Fencing
The District has selected low-impact, bio-engineered methods for restoration. Plantings used by the District, in combination with bank stabilization and fencing, include willows, alders and cottonwoods in the creek beds, and valley oaks, live oaks and buckeyes on the creek banks.

Initially, willows are planted to establish cover and shade the creeks. Once willows have 3 to 4 years of growth, oaks, buckeyes and other native trees are planted adjacent to the creek. This second "wave" of trees enjoys the shady conditions provided by the established willows. Planting tubes protect the upland trees. These tubes simulate the shade conditions of willows, retain the evapo-transpired moisture otherwise lost, and protect the tree for years from rodent damage. They are used as much as possible to encourage earlier establishment of the second wave of trees.

To control erosion, restoration activities include placement of fencing (around sensitive areas), mulch and willow bundles. Follow-up monitoring is also conducted to determine restoration success, and to schedule additional plantings where necessary.

Project Location: Simas, Pavon, Circle X and Nunes Creeks
To date, the District has begun restoration efforts on the west and east forks of Simas Creeks, all three forks of Pavon Creek, Circle X Creek and Nunes Creek. All of these creeks except Nunes flow into Pinole Creek, which is home to steelhead trout and the red-legged frog, both threatened species. Along Nunes Creek, which flows into San Pablo Reservoir, the District has planted willows – over 1,600 in 1999-2000 alone. These are intended to slow creek flow and form natural check dams to help keep silt upstream from the reservoir until the stream banks can be further stabilized.

The District grazes its watershed lands for fuel management purposes. With the help of over 500 students each year, the District is now able to continue to graze the uplands while simultaneously protecting and restoring the creeks. In grazed areas, electric fencing has been installed to protect plantings. The District plans to continue to offer this program on these and other creeks as part of its resource management plan and community outreach efforts.

Special Feature: Interpretive Educational Program for Local Schools
Since 1993 the District has integrated its restoration efforts with an interpretive education program that involves students from local schools. Classes get involved both in growing native plants from seed and in field trips that include real "field work." Through these hands-on classes, students gain direct experience with restoring the environment and have opportunities to view wildlife and enjoy outdoor learning. Their teachers incorporate the visits with their curricula, so students can relate their classroom learning to problem solving in the real world. Through this program, the District builds relationships with local schools and teachers, most of who return with their students year after year, and who have made the creek restoration project an integral part of their annual coursework.

For More Information: Contact the District Rangers at (510) 287- 2033 and (510) 287-2036.
The District is happy to share materials, ideas and techniques with anyone interested in low impact, bio-engineered creek restoration. If you would like to see the District's restorations in person, just call. The District also offers an annual workshop in November as part of the Kids in Creeks Fall Conference. To register, call Aquatic Outreach Institute (AOI) at (510) 231-5778.

EBMUD's Community Creek Restoration program (see case study) is an example of a restoration project that combines re-vegetation and bank stabilization techniques to reduce erosion and increase riparian habitat.

Instream Habitat Structures

This section discusses the design of instream habitat structures, which can be used to increase and enhance aquatic habitat. As with bank stabilization measures, the addition of instream habitat structures should be viewed as a "temporary" fix, even though the lifespan of the structures may be quite long. "The best approach to habitat recovery is to restore a fully functional, well-vegetated stream corridor within a well-managed watershed. Man-made structures are less sustainable and rarely as effective as a stable channel" (FISWRG 1998). Over the long term,

For this CalFed-funded project on Sulphur Creek, large boulders that were causing the bank to erode (left side of photo) were moved, and the banks were sloped and stabilized with an erosion control blanket and native grasses and shrubs (Napa RCD 2000).

aquatic habitat should rely on natural hydrology interacting with streambank and floodplain vegetation.

Habitat structures will have little effect on populations that are limited by factors other than physical habitat, like instream flows or barriers to fish passage. They can be quite effective, however, for meeting specific habitat goals, like diversifying flow, creating riffle-pool sequences and providing refuges for aquatic species. It is desirable to create a variety of stream flow velocities because juvenile salmonids will select different velocities depending on whether they are feeding or resting. Different water velocities will also sort gravel and create diversity in the substrate (Flosi 1998). The table on the following page provides descriptions of the most commonly constructed instream habitat structures:

At both Ashbury Creek and Carriger Creek in the Sonoma Creek watershed, structures will be constructed to provide transport passages for fish (see case study).

Case Study
Asbury Creek and Carriger Creek Restoration

Sponsoring Agency: Joint Partnership

This project was sponsored under the joint partnership of the Southern Sonoma County Resource Conservation District (RCD), the Sonoma Ecology Center (SEC) and the Sonoma Valley Vintners and Growers Alliance (SVV&GA), combining to form the Sonoma Creek Watershed Conservancy (SCWC). The funding for this project came from a CalFED grant obtained by the RCD.

Objective: Fish Habitat Restoration

The Sonoma Creek watershed is at risk of losing its anadromous fish habitat. Although salmonid runs, primarily steelhead trout, are sustainable, critical rearing habitat has become increasingly degraded by sedimentation and effects of urbanization. The overall objective is to restore the creek and riparian system to a natural healthy state. Specifically, the restoration projects at Asbury and Carriger Creek seek to improve transport passageways for fish, stabilize the eroding streambank, and revegetate the riparian corridor.

Restoration Tools Used: Instream structures and bank stabilization

The project at Asbury Creek consists of installing Washington baffles to break up the consistency of sheet flow. Washington baffles are structures that are placed at opposing angles along the creek to prevent fast flow. The baffles provide pockets within the waterway for fish to rest, serving the same purpose as natural boulders. At Carriger Creek, a step pool ladder will be constructed to help the fish swim upstream. Currently, a scour pool exists where there is a 4 to 5 foot drop in elevation. During low flows, this elevation change prevents fish from transporting upstream. The step pool will moderate the severe slope and allow the fish to mobilize. Willow walls have already been initiated to stabilize aggrading banks. Trenches are dug, and willows are planted in them to help divert flow and prevent flooding of the stream channel. The system was successful when first implemented in 1999, and should be even more effective as the willows mature in size. The project will also include revegetating the riparian buffer with alders and other native plant species.

Project Location: Asbury Creek and Carriger Creek

Both Asbury and Carriger Creeks are tributaries to the Sonoma Creek watershed. Asbury Creek is located west of the valley and south of the city of Glen Ellen. Carriger Creek joins Sonoma creek just above the Highway 121/Sonoma Creek bridge. Carriger Creek has records of being an excellent fishery for Steelhead trout.

Special Feature: Public Awareness

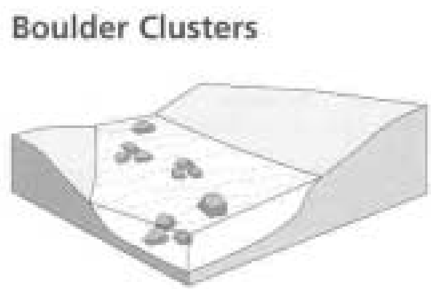
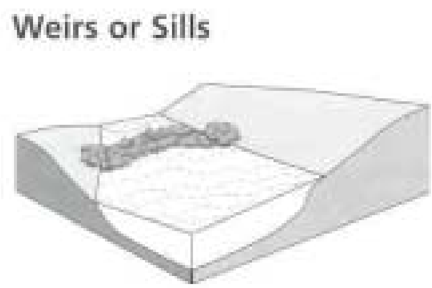
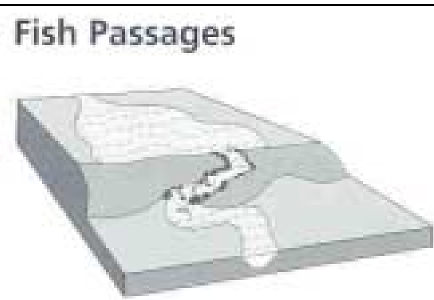
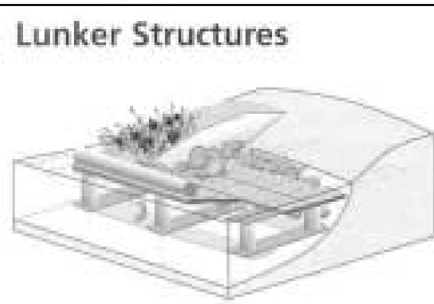
Both of these projects have prioritized public awareness as an integral part of the project, and demonstration tours will be conducted to address the need to restore the stream corridor, highlighting specific tools used at Asbury and Carriger Creeks. Carriger Creek, in particular, is highly visible from Arnold Drive, and its current tree-less condition makes it an excellent demonstration site for proper riparian corridor enhancement.

Special Issues: In the Works

Most of the planned initiatives for both projects are not in effect yet. . The design for the Asbury Creek project has been submitted and is currently in the permitting stage. Permitting is expected to be resolved soon, and construction of the project is planned for either the end of this year or in 2001. The Carriger Creek has initiated biotechnical stabilization through the addition of willow walls, but the fish ladder and riparian replanting have not been implemented. Thus far, the project has secured funding and initial survey work has been conducted. The survey work will be the basis for engineering design.

For More Information: Contacts

For information regarding the Asbury Creek project, contact the Sonoma Ecology Center at (707) 996-9744. For more information regarding Carriger Creek, contact David Luther, the resource conservationist at RCD. He can be reached at (707) 794-1242 ext 3.

Method		Techniques
Boulder Clusters		Boulder clusters are placed in the base flow channel to provide cover, create scour holes, or create areas of reduced velocity. Their main advantage is that they are resistant to displacement by high flows. The disadvantages of boulder use include the cost of transportation if local materials are not available, and the tendency of boulders to get buried in streambeds composed of fine material. (Flosi 1998)
Weirs		Log, boulder, or quarrystone structures can be placed across the channel and anchored to the streambank and/or bed to create pool habitat, control bed erosion, or collect and retain gravel. The selection of material is important. Large, angular boulders are most desirable as they are least likely to roll out of place during high flows. Although logs are more cost-effective, they will eventually decompose, making the structure less durable than one of boulders.
Wing-Deflectors		Wing-deflectors are similar to weirs in material and construction, but do not extend completely across the stream channel. Opposing wing-deflectors, which reduce channel width by 40-80%, and single wing-deflectors are both common configurations. Both types of deflectors create quiet resting areas for migrating fish, but can also create scour and bank erosion. Streambanks must either be naturally resistant to erosion or bank protection should be incorporated into the design (Flosi 1998).
Fish Passages		Fish passages are appropriate in streams where natural or man-made obstructions interfere with fish migration. Natural obstructions like waterfalls and debris piles can be modified to provide fish passage, or new structures (i.e., fish ladders) can be built to allow passage. In some streams, obstructions act as barriers to undesirable exotics (e.g. sea lamprey) and are useful for creating diverse and valuable habitat, so careful evaluation is required before natural obstructions are removed (Flosi 1998).
Lunker Structures		Lunker structures are cells of heavy wooden planks and blocks that are imbedded into streambanks at bed level to provide covered fish habitat and prevent bank erosion. They are appropriate only where water depths can be maintained above the top of the structure. Heavy equipment may be necessary for excavating and installing the materials, so this practice is generally expensive compared with the installation of other habitat structures (FISRWG 1998).

5.2.11 Best Management Practices – Agricultural & Grazing

Agriculture

Overview

Best management practices (BMPs) for agriculture are aimed at mitigating runoff volumes and pollutant loads from agricultural land. Where crops are raised and the land class allows, pastures should be managed with crop rotation sequences to provide vigorous forage cover while building soil and protecting water and wildlife qualities. Orchards and nursery production should actively monitor pest and water management techniques to protect ecosystem quality and diversity. Farm woodlots, wetlands, and field borders should be part of an overall farm plan that conserves, protects, and enhances native plants and animals, soil, water, and scenic qualities. BMPs may include: contour farming, proper irrigation, conservation tillage, terracing, critical area planting, nutrient management, sediment basins, filter strips, waste storage management, and integrated pest management.

Vineyards

Hillside vineyards, especially those that are newly-planted, are often highly susceptible to erosion. This section outlines some of the BMPs that are becoming standard practice throughout the vineyards of Napa and Sonoma counties.

<u>Cover Crops</u>

Existing vineyards should be planted with either annual or perennial cover crops, and new vineyards should be planted with cover crops as soon as the area has been cleared. Cover crops provide aesthetic benefits in addition to controlling erosion, aerating the soil, harboring beneficial insects, and protecting water quality. Depending on the benefits desired, cover crops might include legumes (pea, clover, vetch, clover), grasses (oat, barley, rye, fescue, brome) or wildflowers. The main drawback of cover crops is their water demand, although use of summer-dormant plants can eliminate that need (UCCE 1999).

<u>Terraces</u>

Terraces (or benches) control erosion by interrupting and slowing down the flow of runoff water. They need to be designed so that runoff flows will not erode the terrace and cause drainage system failure, or create gullies and loss of soil.

Terraces are either *outsloped* or *insloped*. Outsloped terraces are designed to retain the natural sheet flow of runoff over a site while still providing a sufficiently level surface for farming. These are appropriate for moderate slopes of moderate length, with surface vegetative cover to prevent rilling of the terrace faces. Insloped terraces are designed as water conveyance structures when slopes are too long and steep to prevent destructive runoff directly downslope.

<u>Filter Strips/Buffer Zones</u>

Filter strips are undisturbed or planted strips of land located between vineyard rows and riparian zones. They allow runoff water to drop its silt and sediments, while slowing the water's velocity. Although it is best to set aside a buffer zone/filter strip area before vineyard planting, many vineyards were developed before wildlife habitat protection was a priority, and thus may now need restoration. At least 25 feet of riparian corridor on each side of a water body is recommended (SSCRCD 1997).

The Sonoma Valley Vintners & Growers Alliance has been a strong force for encouraging the adoption of BMPs (see case study), especially restoration of riparian zones.

<u>Roads</u>

Water should be diverted away from unpaved roads and into proper drainage systems in order to reduce erosion. Allowing roads to conform to the terrain and ensuring proper grading and compacting will help achieve these goals (SSCRCD 1997).

Vineyards often share space with riparian habitat.

Sediment Basins

On hillside vineyards, sediment basins can be constructed to collect runoff water and to settle out soil and sediment. A well-constructed and well-maintained sediment basin system can prevent the loss of significant amounts of precious soil.

Mulching

Straw mulch can help temporarily stabilize the soil, reduce weeds, and enhance the growth of the cover crop. Mulch is recommended, particularly for the first winter season of new vineyards. On the steeper slopes, mulch should be patted firmly into the soil (SSCRCD 1997).

Grazing

Livestock exclusion or management consists of fencing, alternate sources of water and shelter, and managed grazing to protect, maintain, or improve riparian flora and fauna and water quality. BMPs are appropriate where livestock grazing is negatively impacting the stream corridor by reducing growth of woody vegetation, decreasing water quality, or contributing to the instability of streambanks. Once the system has recovered, rotational grazing may be incorporated into the management plan. A good example of this recovery be found at Wildcat Creek (see case study) in Contra Costa County. After rotational grazing was introduced, native grasses and wetland vegetation have recovered in abundance.

Vegetative Recovery

In stream corridors that have been severely degraded by grazing, rehabilitation should begin with grazing management to allow for vegetative recovery. Vegetative recovery is often more effective than installing a structure. The vegetation maintains itself in perpetuity, allows streams to function in ways that artificial structures cannot replicate, and provides resiliency that allows riparian systems to withstand a variety of environmental conditions (Elmore and Beschta 1987).

Kauffman et al. (1993) observed that fencing livestock out of the riparian zone is the only grazing strategy that consistently results in the greatest rate of vegetative recovery and the greatest improvement in riparian function. Fencing is, however, very expensive, requires considerable maintenance, and can limit wildlife access—a negative impact on habitat or conduit functions.

Manure Management

Manure management is an important part of controlling pollution into the watershed. It is important to recognize that runoff water from clean and manured areas should be separated to the extent possible, maximizing benefits to the landowner and to the environment. Waste liquids, including manures, wash water, and surface runoff from manured areas, must by law be diverted to retention ponds and effectively contained for later removal. Similarly, waste solids from confinement areas and remote locations should be contained and stored in a manner that will prevent contact with stormwater runoff.

Livestock should be prevented from entering streams and runoff channels where wastes can be deposited directly into waterway. Livestock traffic quickly erodes banks and stream bottoms,

Wildcat Creek Grazing Management Demonstration Project

Sponsoring Agency: Joint Project
The project was jointly designed and implemented by the East Bay Regional Park District, the Contra Costa Resource Conservation District, a private rancher, and the University of California at Berkeley. The project was made possible by funding from the U.S. EPA through the San Francisco Estuary Project.

Objective: Protect wetlands and native grasses
This project is intended to manage grazing activities over a portion of the 2,000 acre park in order to promote the growth of native perennial grasses and protect sensitive areas, including riparian and wetland habitats. The project also set out to reduce soil erosion from the site.

Restoration Tools Used: Rotational grazing
Four separate pastures have been divided within the park and separated by fencing. The area accounts for 312 acres of grazed land. Rotational grazing has been implemented, to allow for appropriate "rest" period during a six week stretch in late spring. This permits the perennial grasses to flower and set seed without grazing pressure. The exclusion of livestock improves forage production while protecting the watershed from soil erosion. Grazing is then scheduled for the remaining months during seed development so that the cattle can grind and disperse the seeds, thereby encouraging vigorous regrowth during the growing season. In order to provide clean water away from wetland areas, five horizontal wells have been installed at the demonstration site. Each well taps water from natural springs in the hillsides. Fencing has been constructed to exclude livestock from springs and wetlands to ensure the protection of vegetation. Havey Creek, a tributary to Wildcat Creek, is also fenced to exclude cattle from riparian habitat.

Project Location: Wildcat Canyon Regional Park
The project location is at Wildcat Canyon Regional Park, east of the city of Richmond.

Special Feature: Monitoring
A monitoring program was initiated for the first few years to gauge plant species diversity and growth, including native grasslands as well as wetland vegetation. Monitoring has since stopped due to lack of additional funding. Even though formal monitoring has stopped, informal monitoring indicates that the grazing management scheme used at Wildcat Creek has led to a significant reemergence of local vegetation.

Special Feature: Sharing the Tools
The project was intended to provide information about grazing management to ranchers, public land managers, environmental groups, and the general public. At a grazing field day in spring 1995, over 40 people came to learn more about the project. The horizontal wells, in particular, were very popular. East Bay Regional Park District has begun installing them throughout their lands. The project demonstrates that in fact, when measures are taken to protect riparian and wetland habitats, vegetation does recover.

For More Information: Contact Ray Baczynski
For information regarding the Wildcat Creek project, contact Ray Baczynski with the East Bay Regional Park Division at (510) 635-0135 ext. 2344.

contributing more sediments to the waterway. Vegetated filter strips will help prevent excessive sediments from reaching waterways and may help with natural breakdown of dairy wastes. Filter strips are not very effective, however, at limiting nutrient loading to receiving waters, so control of manure at the source is still important with these improvements (SSCRCD 1997).

Erosion Control

Grazing operations that result in soil erosion are another form of non-point source pollution. Overgrazing, poor pasture cover, roadways, or drainage problems can cause low-level degradation occurring over a wide area. Gully formation in swale areas can be caused by concentrated runoff flows and results in large volumes of soil loss.

Good land stewardship can reduce or eliminate soil loss. Maintaining a good vegetative cover is the most simple and effective way to limit soil erosion and transport from an area. Runoff controls to protect sensitive areas from excess flows are beneficial. Defined waterways and culverts can be sized to handle storm flows. Channels can be armored with vegetation or rock to minimize down cutting. Recently disturbed areas can be protected until stabilized with much, erosion control netting, and revegetation efforts. Where necessary, engineered structures can be developed to prevent new cuts and gully formation (SSCRCD 1997).

Outreach and Education

A discussion of BMPs must ultimately include educating landowners on restoration methods. It is important for landowners to recognize the advantages that these practices have on the overall watershed, as well as on their own private land. In the Sonoma Creek Watershed Enhancement Plan, includes recommendations to conduct outreach to targeted landowners who draw water from, dam or otherwise manipulate the natural flow of the creek (39 were observed) to provide up to date information about responsible water usage. Sponsors should also educate, landowners about the natural and positive role woody debris plays in the system, and encouraged not to remove woody debris from the stream (SSCRCD 1997).

5.2.12 Best Management Practices – Urban & Stormwater

Few changes in watershed have greater potential to affect the ecological functions than the conversion of land from rural to urban conditions. Urbanization replaces the natural habitats, increases the impervious cover, decreases infiltration, increases stormwater runoff, increases pollutant loading, increases the demand for remaining natural resources, and displaces wildlife. Best management practices in urban areas can be applied to improve and / or restore ecological functions that have been impaired by urban activities. The more common BMPs to consider are presented in Table 5-2. The table is divided into three categories of BMPs with specific types and purposes listed.

Stormwater

The RWQCB has a program that regulates stormwater discharges for municipalities and local agencies responsible for maintaining storm drain systems, industries, and construction sites through the National Pollutant Discharge Elimination System (NPDES). The RWQCB issues permits with requirements to prevent or reduce discharges of nonpoint source pollutants that cause or contribute to exceedances of the water quality objectives established for given water bodies. Applicant achieve compliance with a permit through implementation of a stormwater management plan or stormwater pollution prevention plan. Most cities and counties in the San Pablo Bay watershed are participating in the NPDES stormwater program at some level. Sponsor should contact local NPDES stormwater coordinators prior to proposing any restoration program within urban areas to ensure the program will be consistent with local goals and requirements.

Changes in hydrology caused by urbanization of a watershed are best mitigated during the planning phase through practices designed to control storm runoff. These practices emphasize the use of vegetation and biotechnical methods, as well as structural methods, to maintain or restore water quality, dampen peak runoff rates, and increase base flows. Strategies for managing runoff include the following (FISRWG 1998):

Table 5-2
Major BMPs for Urban Stormwater Control

Category	***Type***	***Purpose***
Detention/Retention	Dry ponds Wet ponds Constructed wetlands Vegetated swales	Capture and detain stormwater before releasing at a lower rate
Infiltration	Infiltration basins and trenches Porous pavement Dry wells Cisterns Swales	Promote infiltration of stormwater runoff by reducing impervious surfaces or capturing and storing runoff until it can infiltrate into the surrounding soil.
Treatment	Ponds and basins Constructed wetlands Vegetated swales Vegetated buffer zones Clean neighborhood or business programs Illicit/illegal connection program	Reduce pollutant levels by promoting settling or filtering of suspended solids, removal through biological uptake, pollution prevention and runoff management at the sources, and the identification of illicit or illegal discharges.

- Increasing infiltration of rainfall to reduce runoff and to remove pollutants.
- Increasing surface and subsurface storage to reduce peak flows and induce sediment deposition.

Both of the above techniques can be implemented in urban areas.

Urban Stream Restoration

Restoration design for urban streams is greatly limited by pre-existing development and its effects on restoration objectives. This section will present some of the specific methods and tools that can be applied to help restore urban streams. Techniques that overlap with those discussed in previous sections, like restoring channel geomorphology and installing instream habitat structures, are only mentioned briefly here. Much of the information in this section is adapted from Schueler (1996). Below are methods and tools for restoring urban streams.

- Partially restore the predevelopment hydrological regime. For any urban stream restoration program to be successful, the primary objective has to be the return of stream flows to more natural levels. This requires reducing peak flows during precipitation events and increasing base flows during dry-weather conditions. BMPs for controlling runoff and promoting infiltration are listed in Table 5-2. They are often critical in the restoration of small and mid-sized streams, but may be impractical in larger streams and rivers.
- Reduce urban pollutant pulses. A second need in urban stream restoration is to reduce concentrations of nutrients, bacteria and toxics in the stream, while trapping excess sediment loads. Generally, three tools can be applied to reduce pollutant inputs to an urban stream: stormwater ponds or wetlands, watershed pollution prevention programs, and the elimination of illicit or illegal sanitary connections to the storm sewer network.
- Stabilize channel morphology (see Section 5.2.10) once stream flows have been stabilized.

Case Study:
Best Management Practices at Sonoma Valley Vineyards and Wineries

Sponsoring Agency: Sonoma Valley Vintners and Growers Alliance

The Sonoma Valley Vintners and Growers Alliance (SVVGA) partnered with the Southern Sonoma County Resource Conservation District (SSCRCD), the Sonoma Ecology Center, and a local chapter of Adopt-a-Watershed to form the Sonoma Creek Watershed Conservancy. The Conservancy worked with the San Francisco Estuary Institute to obtain CalFed funding for various restoration and demonstration projects around the Sonoma Creek watershed.

The first year of the Conservancy's CalFed funding has been used, and a second round of funding has already been approved. SVVGA's portion of the CalFed grant was for the project described below.

Objective: Develop and Promote Environmentally Responsible Agricultural Practices

The primary goals of SVVGA's project were to improve riparian water quality by reducing erosion and pollutant inflows, and to improve riparian habitat through revegetation and streambank stabilization measures. The CalFed funding, which supported 60% of each of the thirteen small projects, was designed to be an incentive for vintners and vineyard managers to go "above and beyond" their normal agricultural practices. The property owner conceived each project where the project took place, and members of the SVVGA decided which of the proposed projects would be funded. Notably, they did NOT fund projects that they considered to be normal agricultural practices, such as planting cover cops, replanting vineyards, rock-lining terrace walls, or taking other steps to mitigate the effects of growing grapes on steep hillsides. The growers, not the federal government, were expected to fund these types of projects.

Restoration Tool Used: Agricultural Best Management Practices

Projects supported by the first year of funding included the following:

- Installing rock- and vegetation-lined drainage ditches;
- Stabilizing washed-out streambanks with willow cuttings;
- Installing drywells and other underground drainage systems to reduce run-off;
- Reducing the need for pesticides and rodenticides by providing nesting boxes for raptors and owls;
- Re-vegetating the banks of a vineyard reservoir;
- Improving riparian habitat by re-establishing native vegetation and completing vineyard setbacks.

The SVVGA also led conservation planning workshops and purchased copies of the SSCRCD's Vineyard Manual for its members. The Vineyard Manual explains and encourages the use of agricultural Best Management Practices.

Special Feature: Participation of Private Property Owners
This project features the involvement of individual private property owners and managers, a factor which provides project direction by those with an especially close knowledge of the sites and who can bring the perspective of the vineyard industry to the Program.

For more information:
Contact the SVVGA at (707) 935-0803.

- Restore instream habitat structures (See Section 5.2.12) and remove fish barriers once stream flows have been stabilized.

- Reestablish riparian cover (See Section 5.2.8). It is often essential that the riparian corridor be protected by a wide urban stream buffer (See Section 5.2.7).

- Protect critical stream substrates. A stable, well-sorted streambed is often a critical requirement for fish spawning and a healthy habitat for aquatic insects. The bed of urban streams, however, is often highly unstable and clogged by fine sediment deposits. Often, the energy of urban storm water can be used to create cleaner substrates—through the use of tools such as double wing deflectors and flow concentrators. If thick deposits of sediment have accumulated on the bed, mechanical sediment removal may be required.

Section 6
Restoration Project Planning and Implementation

The purpose of the San Pablo Bay Watershed Restoration Program is to facilitate development and implementation of ecosystem restoration projects in the San Pablo Bay watershed. Interested parties are encouraged to apply to this program for support to achieve that end. This section describes the manner by which sponsors of a candidate project may determine if their proposal might qualify for financial and technical support, and the process by which they may apply for that support.

6.1 General Guidelines

Any individual or organization may apply for support from this program, provided that they can meet the criteria described below. In general, any proposal to undertake a restoration project within the boundaries of the San Pablo Bay watershed is eligible, if the proposal meets the following conditions:

- It promotes attainment of the goals of the San Pablo Bay Watershed Restoration Program.
- The project sponsor has legal ability to effectuate the proposed activities.
- A professionally developed, comprehensive restoration plan is created as part of the proposed project.
- The project sponsor is able to pledge the required matching resources to the project.
- The project sponsor agrees to work collaboratively with the Watershed Restoration Program sponsors.
- The project sponsor is capable of performing or ensuring that necessary operations and maintenance actions are performed.

If these six general conditions are met, any proposal may qualify for support. However, not all qualifying proposals are guaranteed to be selected. The Watershed Restoration Program has limited financial and technical resources available, and the number of projects ultimately selected for funding will be correspondingly limited.

The following Question and Answer information is intended to help give guidance to those who might be considering submitting a restoration proposal.

What is the San Pablo Bay watershed?

The San Pablo Bay watershed includes all the lands whose streams and rivers flow to San Pablo Bay. See Figures 2-1 and 2-3 to determine whether the area that you are interested in lies within the watershed. Figure A-1 in Appendix A illustrates the location of the larger San Pablo Bay watershed with respect to the Napa River and Sonoma Creek sub-watersheds, both of which are being evaluated for more specific USACE watershed restoration programs.

What is the San Pablo Bay Watershed Restoration Program?

The San Pablo Bay Watershed Restoration Program was authorized in 1996 through an act of the United States Congress. Specifically, Congress instructed the U. S. Army Corps of Engineers to study and undertake restoration of aquatic resources in certain watersheds within the United States that offered the greatest opportunity for restoration.

There are six goals for the San Pablo Bay Watershed Restoration Program:

- Rehabilitate natural processes within the San Pablo Bay watershed system.

- Protect existing high quality habitat throughout the watershed.
- Restore degraded habitat to high quality ecological and hydrological function.
- Sustain a healthy community of native species.
- Improve and maintain water quality and in-stream flow.
- Prevent the establishment of new non-native species, and curb the expansion of existing non-native species.

The watershed restoration program recognizes that achievement of these goals will result in many additional public benefits, including improved flood protection, reduced need for dredging of navigation channels, decreased introduction of pollutants into waterways, and expanded recreation opportunities, to name only a few.

The program's Federal sponsor is the U. S. Army Corps of Engineers (USACE). The State sponsor is the California Coastal Conservancy. The USACE and the Conservancy stand ready to provide technical and financial assistance to eligible restoration project sponsors. The Bay Institute (TBI) is the regional non-governmental organization (NGO) sponsor of the San Pablo Bay watershed Program. TBI will provide application assistance to potential project sponsors.

What kinds of watershed restoration projects are eligible for assistance?

Many different kinds of ecological restoration projects can qualify for assistance. The kinds of projects that could qualify include:

- Restoration of vegetated corridors (riparian corridors) along streams and rivers. This may include plantings of willows, sycamores or other vegetation that has been removed by past land management practices.
- Restoration of tidal wetlands. This may include removal of dikes that obstruct the natural flow of tide waters over historic wetlands.
- Construction of environmentally friendly structures, such as gravel spawning beds or shaded pools, to promote reproductive and survival success of native fish species.
- Restoration and preservation of upland habitat, especially on hillslopes, to prevent excessive erosion and the loss of native plants.
- Eradication programs aimed at harmful, non-native species, such as *Arundo donax*, an invasive plant that damages habitats in rivers, streams and wetlands.

Who may sponsor a watershed restoration project?

Any group or individual may sponsor a project. The most important qualification is that the project sponsor must have the necessary legal authority to undertake a proposed project. Fundamentally, that means that the sponsor must have control over the lands or resources proposed for restoration. The sponsor, therefore, must either own the land, or have permission of the landowner to undertake the project. If the project is proposed on private lands, the sponsor must either be the landowner, or have authorization from the landowner. If the project is proposed on public lands, the sponsor must have the authorization of the appropriate government agency.

What are the obligations of the project sponsor?

The project sponsor must–

- demonstrate that the project promotes the goals of the San Pablo Bay Watershed Restoration Program.

- have a strong interest in promoting his or her particular restoration project.
- be willing to secure the required matching funds or in-kind services for the project.
- either have a knowledge of guiding a restoration project, or be willing to secure the necessary assistance to assure the project's success.
- be willing to enlist the support of interested community members and to work with others on the restoration project.
- strive not to duplicate other restoration efforts at the same location.
- be willing to work cooperatively with the federal, state, and NGO sponsors of the San Pablo Bay Watershed Restoration Program.

What type of assistance is available from the Program Sponsors? (USACE, CCC, TBI)

There is financial, technical and project development assistance available from the program sponsors. See section 6.5 for more information than the brief description here.

The USACE and the Coastal Conservancy may provide matching funds to qualifying high priority projects. The amount of the match will depend upon the particular project and the matching funds or in-kind contributions that the project sponsor is prepared to offer. Matching funds do not necessarily have to be provided by the project sponsor. Contributions from private foundations, for instance, may serve as the cash contribution of the project sponsor. In-kind contributions may include: the value of the land on which the project will occur; volunteer labor; or donated community services such as public information brochures.

The Coastal Conservancy and The Bay Institute can also provide assistance with identifying additional financial supporters of the restoration project, such as private foundations or corporate sponsors.

The USACE and the Coastal Conservancy can also provide technical assistance. Such assistance can include reconnaissance studies of the proposed restoration site, technical design of the proposed project, help with securing permits, and project construction.

The Bay Institute can provide early consultation to help determine whether the project qualifies or not, assistance with formal application, and help with securing necessary permits.

How does an interested project sponsor apply for assistance under the San Pablo Bay Watershed Restoration Program?

If you're interested in determining whether you have a qualifying project, contact The Bay Institute at 415/721-7680. TBI will arrange to meet with you and discuss the particulars of your project. If it is determined from that preliminary meeting that your project is a good candidate, TBI will guide you through the formal application process. Information can also be obtained from the Coastal Conservancy (510/286-1015) or the Corps of Engineers (415/977-8539).

6.2 Specific Selection Criteria

The proposal must be responsive to the Program Goals (Section 6.1) and should help further the achievement of the following primary objectives. There is no prioritization among these objectives.

Primary Objectives

- Restore tidal wetlands.
- Restore non-tidal wetlands, both perennial and seasonal.
- Restore riparian wetlands and associated woodland and grasslandhabitat.

- Replenish depleted populations of native fish, amphibians, reptiles, mammals, and invertebrates.
- Replenish depleted populations of native waterfowl.
- Improve water quality in streams and wetlands so that demonstrable benefits are achieved for aquatic wildlife.
- Expand habitat for rare, threatened and endangered species, such as: California clapper rail; salt marsh harvest mouse; black rail; fairy shrimp; etc.
- Restore vernal pool habitat.
- Improve stream conditions for native fish, such as by providing necessary natural stream flow rates, shading, gravelly substrate for spawning, and by other means.

Associated Objectives

In a restoration project that is designed to first attain the primary objectives, the attainment of associated objectives is desirable.

- Reduce erosion of soils within the watershed.
- Reduce sedimentation of waterways.
- Prevent or reduce nutrient loading in water bodies.
- Reduce the threat of flooding.
- Enhance recreational opportunities.

6.3 Restoration Project Design and Implementation

The adequacy of project planning will be a key criterion in the selection of any proposed restoration project for funding and other support. The National Research Council recommends that the following Restoration Checklist (see sidebar, next pg.) be employed to promote effective planning and implementation of a successful restoration project. It is not expected that applicants will have completed the planning and design phase at the time of their funding request, but rather that they will work with Program Sponsors, as appropriate, to achieve these goals.

6.4 Proposal Evaluation Criteria

If a preliminary meeting within The Bay Institute or program sponsors determines that a potential project is a good candidate, potential local project sponsors must submit a completed application form (proposal). The application form requires general project information such as project location and ownership, cost, schedule, and design information, along with an identification of potential evaluation methods, sponsors, opponents, and funding sources. Appendix C contains a sample blank application form.

Restoration project proposals will be reviewed on a rolling basis by the sponsors of the San Pablo Bay Watershed Restoration Program, i.e., the U. S. Army Corps of Engineers and the California Coastal Conservancy, in consultation with The Bay Institute.

An important goal of the San Pablo Bay Watershed Restoration Program is to promote the implementation of as many worthy restoration projects as possible. The primary purpose of the evaluation process will be to maximize the likelihood that the project selected will succeed in attaining their restoration objectives. Therefore, the primary limitations on project selection will be 1) the quality of the restoration proposal and 2) available funding.

The quality of the restoration proposal will be evaluated using multiple measures, beginning with the consistence of the proposed project with Program Goals (Section 6.1) and Objectives (Section 6.2). There are, of course, several other quality-related criteria that a worthy proposal

Restoration Checklist*

Project Planning and Design

- Has the problem requiring treatment been clearly understood and defined?
- Is there a consensus on the restoration program's mission?
- Have the goals and objectives been identified?
- Has the restoration been planned with adequate scope and expertise?
- Does the restoration management design have an annual or midcourse correction point in line with adaptive management procedures?
- Are the performance indicators–the measurable biological, physical, and chemical attributes– directly and appropriately linked to the objectives?
- Have adequate monitoring, surveillance, management and maintenance programs been developed along with the project, so that monitoring costs and operational details are anticipated and monitoring results will be available to serve as input in improving restoration techniques used as the project matures?
- Has an appropriate reference system (or systems) been selected from which to extract target values of performance indicators for comparison in conducting the project evaluation?
- Have sufficient baseline data been collected over a suitable period of time on the project ecosystem to facilitate before-and-after treatment comparisons?
- Have critical project procedures been tested on a small experimental scale in part of the project area to minimize the risk of failure?
- Has the project been designed to make the restored ecosystem as self-sustaining as possible to minimize maintenance requirements?
- Has thought been given to how long monitoring will have to be continued before the project can be declared effective?
- Have risk and uncertainty been adequately considered in project planning?

During Restoration

- Based on the monitoring results, are the anticipated intermediate objectives being achieved? If not, are appropriate steps being taken to correct the problem(s)?
- Do the objectives or performance indicators need to be modified? If so, what changes may be required in the monitoring process?
- Is the monitoring program adequate?

Post-Restoration

- To what extent were project goals and objectives achieved?
- How similar in structure and function is the restored ecosystem to the target ecosystem?
- To what extent is the restored ecosystem self-sustaining, and what are the maintenance requirements?
- If all natural ecosystem functions were not restored, have critical ecosystem functions been restored?
- If all natural components of the ecosystem were not restored, have critical components been restored?
- How long did the project take?
- What lessons have been learned from this effort?
- Have those lessons been shared with interested parties to maximize the potential for technology transfer?
- What was the final cost, in net present value terms, of the restoration project?
- What were the ecological, economic, and social benefits realized by the project?
- Would another approach to restoration have produced desirable results at lower cost?

*From Restoration of Aquatic Ecosystems, National Research Council, 1992.

must meet, and those additional criteria are listed below.

The availability of funding will be an obvious and important measure of a proposal's likelihood of success. The more reliable the funding for the proposed project, the less effort that needs to be devoted to a time-consuming and unpredictable search for funds.

Restoration Proposal Evaluation Criteria

Each proposal will be evaluated using the following criteria:

- Consistency with Goals and Objectives.
- Control of target resources.
- Matching funds.
- Cost-effectiveness of project
- Demonstration of a partnership base.
- Assembly of knowledgeable professional assistance.
- Possession of an attainable restoration plan.
- Permanence of restoration project.
- Demonstrated commitment to following through with restoration project.
- Adequate and comprehensive monitoring of project performance.
- Community support.

It is a goal of the Program sponsors to cultivate the participation of a broad and diverse group of local sponsors. Not all local sponsors, however, are expected to have the necessary knowledge to prepare a proposal without assistance. It is the intention of the Program sponsors and the NGO co-sponsor to assist interested applicants in developing restoration project proposals that meet the evaluation criteria, and that are ultimately selected for sponsorship under the Program.

Consistency with Goals and Objectives.

As noted throughout this document, the primary purpose of the San Pablo Bay watershed Program is to promote rehabilitation of the aquatic ecosystems of the San Pablo Bay watershed. Any proposal must share this purpose as its primary goal. Associated benefits may also be achieved via successful implementation of a restoration project, but may not be substituted for the primary restoration goals and objectives.

Control of target resources.

For any proposal to be selected, it is essential that the local project sponsor have control of the resources that are the target of the restoration project, or have a binding commitment from those who do control those resources. If a local sponsor proposes to replant a riparian corridor along a stream channel, for instance, he or she must either own the land, or have a commitment from the landowner to authorize the restoration, subject to all of the conditions described here.

Matching funds.

This Program was authorized by Congress to assist financially with the implementation of qualifying restoration projects. One provision of the Program is that local sponsors must provide "matching" funds for the projects. The amount of the match can vary, as can the nature of the match. That is to say, "in-kind" contributions such as labor and land value may also be counted as part of the match. Local sponsors should be prepared to secure this important match in order to qualify their proposals. See Section 6.5 for more information on the requirements and restrictions on matching funds.

Cost-Effectiveness.

Although a formal economic analysis is not required at the time of application, applicants should demonstrate, if possible, that their proposed project maximizes benefits for the level of funding required. "Benefits" include both monetary and non-monetary benefits, such as habitat improvements.

Demonstration of a partnership base.

In most cases, it will be very helpful for local sponsors to enlist the support partners to enable the successful implementation of their proposal. Partners may range from local community groups who donate labor or money, to regional environmental organizations, to civic-minded corporations. It will primarily be the responsibility of the local sponsor to build this support.

Assembly of knowledgeable professional assistance.

Local sponsors must be willing to employ the services of knowledgeable professionals to maximize the chances of success of the proposal. Because of the complicated nature of aquatic restoration, the program sponsors will discourage projects that do not recognize the need to involve trained and experienced professionals.

Possession of an attainable restoration plan.

A well-thought out restoration plan is an essential element of a successful application. The more concrete and attainable the proposed plan's objective(s), the better. Whether large or small-scale, a restoration plan that describes measurable and reasonable objectives must be in hand.

Permanence of restoration project.

Projects that are designed to attain permanent benefits will be assigned a higher priority than those seeking short-term benefits. Corps projects involving the expenditure of public funds normally require that the site be maintained as a permanently restored site.

Demonstrated commitment to following through with restoration project - Community support.

An important consideration will be whether adequate support exists within the affected community for implementation of the project. Those proposals that have strong community support will be regarded favorably.

6.5 Project Funding and Process

The San Pablo Bay Watershed Restoration Program, as explained in Section 1, was **authorized** in 1996 through Section 503 of the Water Resources Development Act (WRDA). As of the current fiscal cycle, however, there is no **funding** associated with that authorization for the San Pablo Bay watershed. Therefore, the purpose of the Watershed Restoration Program is to coordinate various project sponsors and advocates and help them identify other sources of federal, state, or local funds.

The following sections outline the roles of The Bay Institute (the NGO sponsor), the USACE (the federal sponsor) and the California Coastal Conservancy (the state sponsor) in this Program. **Neither the USACE nor the Coastal Conservancy is serving as a granting agency for this program**, but both have funds available for ecosystem restoration. It is the intent of this program to streamline the process by which project sponsors may obtain these funds for projects within the San Pablo Bay watershed. As the following descriptions suggest, considerable complexity can surround federal and state funding – which is precisely why The Bay Institute will work with local sponsors to identify and secure appropriate funding sources.

The Role of The Bay Institute

The Bay Institute is the nonprofit Program Coordinator for the San Pablo Bay Watershed Restoration Program. TBI can provide assistance with a variety of tasks to restoration project sponsors. Among other things, TBI can: consult with sponsors during project development, helping to identify professionals to design the restoration project; assist with the application process; identify potential project funders; help with permitting requirements; and coordinate outreach to the larger community in order to develop support for the project. TBI will work with the two governmental sponsors of the program to make project development and implementation as efficient and speedy as possible

The Role of the U.S. Army Corps of Engineers

There are three distinct types of project support available through the USACE. Figure 6-1 illustrates these three levels, which are described below.

Technical Assistance Only

Local project sponsors may need only technical and/or planning assistance from the USACE. In order to establish each party's obligations to the project, the local sponsor would most likely sign a Memorandum of Understanding (MOU) with

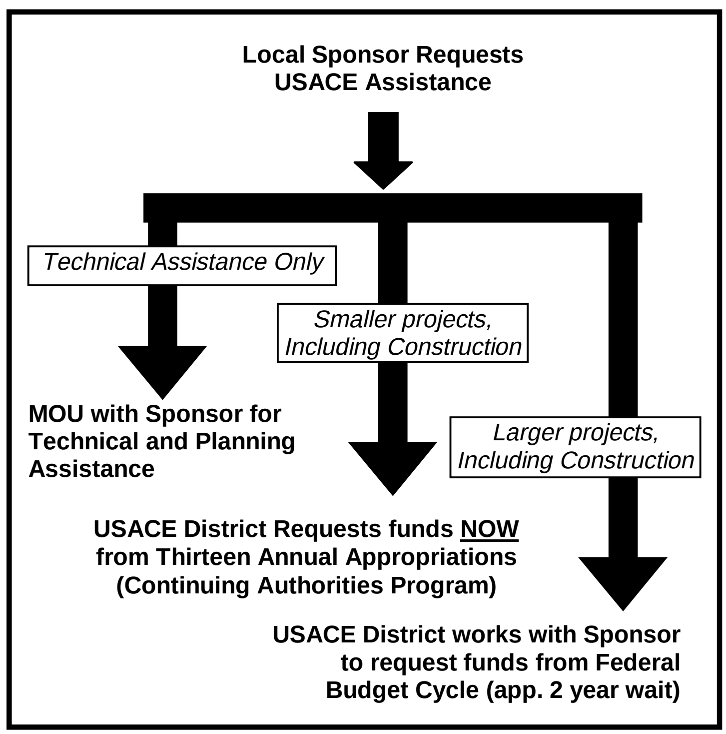


Figure 6-1: Obtaining Funding from the USACE

the USACE. Section 503 authorizes the USACE to provide this assistance and mandates a 50/50 cost share between local and federal sponsors. Up to 50% of the local cost share could be provided by in-kind contributions (25% of total project cost). Under this scenario, the project remains a **local project**, and any permit fees or environmental review documents would be the sole responsibility of the applicant.

Although the USACE is authorized to provide this assistance, it is not their primary mission to provide it. Applicants requesting assistance for a complete project, including planning through construction, will receive priority for funding.

Continuing Authorities Program

Small projects that need assistance for their entire life cycle (planning through construction) may request funding through the USACE's Continuing Authorities Program (CAP). Nine different authorities are relevant to this Watershed Restoration Program, as listed below in Table 6-1. Maximum project size, as determined by total cost to the federal government, varies by authority and ranges from $500,000 to $7,000,000. The decision to grant CAP funds rests with the USACE Division Commander. Individual CAP projects can be identified in Congressional legislation.

Table 6-1: Funding through the Continuing Authorities Program

Section	Authority	Purpose	Cost Share % (Fed/non-Fed)	Federal Project Limit
14	Emergency Streambank Protection	Protection of public and nonprofit facilities	65/35	$1 Million
103	Beach Erosion Control	Protection of public shorelines	65/35	$3 Million
107	Small Navigation Projects	Small river and harbor improvements	80/20*	$4 Million
111	Mitigation of Shore Damage attributable to Navigation works	As a result to a Federal navigation project	Same as original project	$5 Million
204	Beneficial Uses of Dredged Material for Ecosystem Restoration	Restoration or creation of aquatic habitat associated with dredging for authorized projects	75/25	None
205	Flood Damage Protection	Small flood control projects	65/35	$7 Million
206	Aquatic Ecosystem Restoration	Restore degraded aquatic ecosystem in the public interest	65/35	$5 Million
208	Snagging & Clearing for Flood Control	Removal of snags & debris in navigable streams & tributaries in the interest of flood control	65/35	$500,000
1135	Modification for Improvement of the Environment	Restore a degraded ecosystem that resulted from Corps project operation	75/25	$5 Million

* Non-Federal pay 10% of cost during construction and 10% over a 30-year period Source: (USACE 2000b)

The cost share between federal and non-federal sponsors varies by authority, as shown in Table 6-1. For information about the differences among CAP authority in-kind contribution limits, phasing, typical timelines, and national program limits, please see the more detailed Tables C-2 and C-3 in Appendix C. Funding through CAP is controlled by a Project Cooperation Agreement between the local sponsor and USACE. In most cases (all authorities except Section 206), the local sponsor must be a local or state government agency. However, this obstacle to NGO involvement can be overcome by partnering with local governments or the Coastal Conservancy to sign the cost-sharing agreement. The NGO can, in effect, continue to act as the lead project sponsor.

Typically, if a project fits within the CAP guidelines, the USACE District requests funds (approximately $10,000-$20,000) from the Division to initiate a short reconnaissance effort to determine if there is federal interest in proceeding with the study (USACE 2000b). If the USACE decides to proceed, the restoration effort becomes a **federal project**. The rest of the process continues as described below under the heading "Federal projects."

General Investigation New Start Project

For proposed projects that exceed the cost limits set by the CAP program, the USACE and local sponsor can seek special Congressional authorization and funding. This would come from a Senate Resolution, House Resolution, or language in the WRDA that is passed every two years (USACE 2000b). The restoration effort would effectively become a **federal project** with a local sponsor. For information about the process of General Investigation New Start Projects ("GI" projects), refer to Table C-4 in Appendix C.

Federal Projects

For both CAP projects and GI projects, the project will follow a standard USACE process. Reconnaissance and Feasibility studies will lead to the "Selected Plan," which is the locally preferred, environmentally acceptable, cost-effective alternative. A formal cost-effectiveness/incremental cost analysis will be performed by the Corps at this stage. The Selected Plan must be approved by the USACE Division (for CAP projects) or by Congress (for GI projects), at which point it will proceed through the pre-construction engineering and construction phases. Most projects completed through CAP or GI would receive funding for a minimum of three years of monitoring as part of the operations & maintenance phase.

When projects are to become "federal projects" and receive federal funding, it is important that local sponsors take steps to secure political support from their federal legislators. Public involvement and support becomes increasingly critical as funding decisions are made by government agencies that are far-removed from local restoration efforts.

Permitting and Environmental Documents

Federal and Local projects will proceed differently through the permitting and NEPA/CEQA processes. For federal projects, the USACE and local sponsor will jointly apply for non-USACE permits, while the requirements for USACE permits will be fulfilled internally. The sponsors of local (i.e., non-federally-funded) projects must apply for all permits, USACE or non-USACE, as usual.

For federal projects, the NEPA/CEQA process will be the joint responsibility of the USACE and the local sponsor. Cost-sharing rules as described in Appendix C will apply; preparation of these documents by the local sponsor may qualify as an in-kind contribution. For local projects, the NEPA process may not be required. Each case will be unique, so coordination with the USACE will be necessary.

The Role of the California Coastal Conservancy

The Coastal Conservancy has several roles to play in this Watershed Restoration Program. The agency may provide funds to meet the "local" (non-federal) cost-sharing requirements of USACE projects, or it may partner with NGOs to serve as the local government agency for contractual purposes.

The Coastal Conservancy can fund restoration projects through the San Francisco Bay Area Conservancy Program, which it administers. The primary goals of that program are to protect and enhance natural habitats as well as improve public access to open space. Funds may be used for property acquisition and project planning, design, and construction. Contact the Coastal Conservancy for more information.

Other Funding Sources

The Coastal Conservancy, USACE, and The Bay Institute will provide as much assistance as they can to aid local sponsors in their efforts to secure project funding. Nevertheless, local sponsors should recognize the decision by funders to award grants is strongly influenced by the efforts exhibited by the local sponsors themselves.

Table C-1 in Appendix C summarizes some of the many programs designed to assist local sponsors with funding or other assistance to promote implementation of restoration projects. For example, funding may be available through the EPA, the U.S. Fish & Wildlife Service, the National Resources Conservation Service, or various NGOs.

6.6 San Pablo Bay Watershed Pilot Restoration Projects

Introduction

Three Pilot Projects have been selected for inclusion in this document: American Canyon, Pinole Creek and Las Gallinas Creek. Based on the Evaluation Criteria described in this section, these Pilot Projects demonstrate great likelihood of success.

Conceptual restoration plans for each of the Pilot Projects are included in Appendix D. On the basis of these conceptual plans, as well as on the basis of additional information gathered about the project sponsors, the San Pablo Bay Watershed Restoration Program will pursue development of these projects through to the next level. Specifically, this preliminary investigation authorizes the Corps of Engineers to consider providing technical and/or financial support to these projects.

The evaluation of the Pilot Projects was based on the following review.

Consistency with Goals and Objectives of the San Pablo Bay Watershed Restoration Program. All three Pilot Projects are consistent with the Goals and Objectives. Each would provide high value habitat that promotes restoration of important aquatic plant and animal species, including endangered or threatened species. Additionally, each project would achieve important second level objectives, such as provision of flood control, reduction of erosion and abatement of pollution.

Control of Target Resources
Each potential project sponsor either has control of target resources, or can gain control through implementation of a collaborative project. It should be noted that it is relatively unusual for a single sponsor to have control over all target resources. Therefore, the review standard applied here is whether it is reasonable to expect that control can be achieved through normal project implementation processes.

Matching Funds
It is likely that in each of the restoration scenarios, matching funds could be attained in a timely manner to enable prompt implementation of the project. In the case of the American Canyon project, funding already is in hand.

Demonstration of a Partnership Base
Adequate partnerships have been established in each of the three restoration projects to facilitate smooth and collaborative implementation of the projects. Consideration of each of these projects has been in the works for years, and several public and private civic organizations support their implementation.

Assembly of Knowledgeable Professional Assistance
Project sponsors of each of the restoration projects are committed to acquiring the necessary professional assistance to maximize the chances of project success.

Possession of an Attainable Restoration Plan
In the case of American Canyon, a restoration plan has already been completed. All other project sponsors view the development of an effective restoration plan as an essential foundation of the project.

Permanence of the Restoration Project
All projects are proposed to be permanent. Deed restrictions are expected to be secured by all project sponsors.

Demonstrated Commitment to Following Through with Restoration Project
All project sponsors have a demonstrated track record of development and implementation of habitat restoration or enhancement projects. Although some community co-sponsors of the projects will be undertaking restoration projects for the first time, they propose to establish partnerships with veteran agencies and/or organizations.

Adequate and Comprehensive Monitoring of Project Performance
All project sponsors propose to include a comprehensive monitoring and adaptive management element within the restoration plan.

Community Support
Broad community support exists for each of the projects. In each case, the project emerged as a highly viable candidate primarily because of a long and solid history of community promotion.

Because of the foregoing evaluation, the American Canyon, Pinole Creek and Las Gallinas Creek restoration projects have been selected as high priority projects that merit support from the San Pablo Bay Watershed Restoration Program. The next step is for project sponsors to work with Program sponsors to accelerate project implementation and optimize their chances for success.

6.7 San Pablo Bay Watershed Candidate Restoration Projects

In addition to the Pilot Restoration Projects discussed previously, thirteen Candidate Restoration Projects have been identified. These Candidate Projects are in a more preliminary state of design than the Pilot Projects, but have been selected as likely to advance the goal of aquatic restoration throughout the watershed.

During the development of the Program, several public meetings were held to present information on the Program and to solicit information on potential restoration opportunities within the watershed. Thirteen projects were identified during the public scoping process, and subsequently, an additional thirteen projects were added, based on information gathered from public contacts during the development of this document.

An initial screening was performed on all 26 projects to determine compatibility with program goals and/or constraints that would preclude advancing these projects. Based on this initial assessment:

- Seven projects were rejected due to incompatibility with program goals (e.g. projects are required for mitigation, project goals inconsistent with the Program goals, project not under sponsor ownership or control);
- Two projects were eliminated to avoid jeopardizing acquisition negotiations;
- One project was eliminated because it has alternate funding; and
- Four projects were combined because they all involve potential additions to the San Pablo Bay Wildlife Refuge.

The remaining thirteen projects were carried forward for project analysis and screening. Table 6-2 summarizes these projects and compares them with overall program goals. Full descriptions for these thirteen projects are included in Appendix E.

The designation as "Candidate" does not guarantee that these projects will qualify for assistance from the San Pablo Bay Watershed Restoration Program. It is rather an indication that they generally are the type of restoration project that the WRP would like to see pursued. In addition, these projects have been conceived and under consideration for some time. In many cases, a considerable amount of work has been invested in them by their proponents. Consequently, the necessary public support for the projects has a solid foundation.

Another reason for the selection of these Candidate Projects is that they represent efforts from around the entire San Pablo Bay watershed, consistent with the goals of the WRP that focus on initiatives that benefit the entire regional ecosystem. Nevertheless, the reader will note that there are more candidate projects from the lower elevations of the watershed than from upper elevations. One of the main reasons for this is the fact that many of the most appealing restoration opportunities exist in areas that once were part of San Francisco Bay, but were diked and drained beginning in the mid-1800s. [See Section 2, Diked Baylands.] Considerable attention has been devoted to these restoration opportunities by wildlife agencies over the past twenty years. Therefore, more specific proposals have developed in that time.

Finally, these Candidate Projects still need to be integrated into efforts within their sub-watersheds. Sponsors of Candidate Projects should strive to develop restoration plans that address impacts above and below the project site in the sub-watershed, in order to assess the long-term benefits of the Candidate Projects.

Despite the wide variety of detail found in the thirteen project write-ups, they should be useful tools to project sponsors and overseers. Please refer to Appendix E and to the Table 6-2 on the following two pages for more information.

6.8 Project Planning From Start to Finish

Figure 6-2 (at the end of this section) is a representation of the project development and implementation process a project proponent might go under the Watershed Restoration Program. As the figure shows, during project formulation, reconnaissance and feasibility stages, project proponents should work with the Program NGO Coordinators. Utilizing the resources and knowledge available through a dialog with The Bay Institute and/or Coastal Conservancy will help project proponents to conceptualize, formulate and do preliminary planning for a project that helps to further the goals of the Program.

Project Formulation

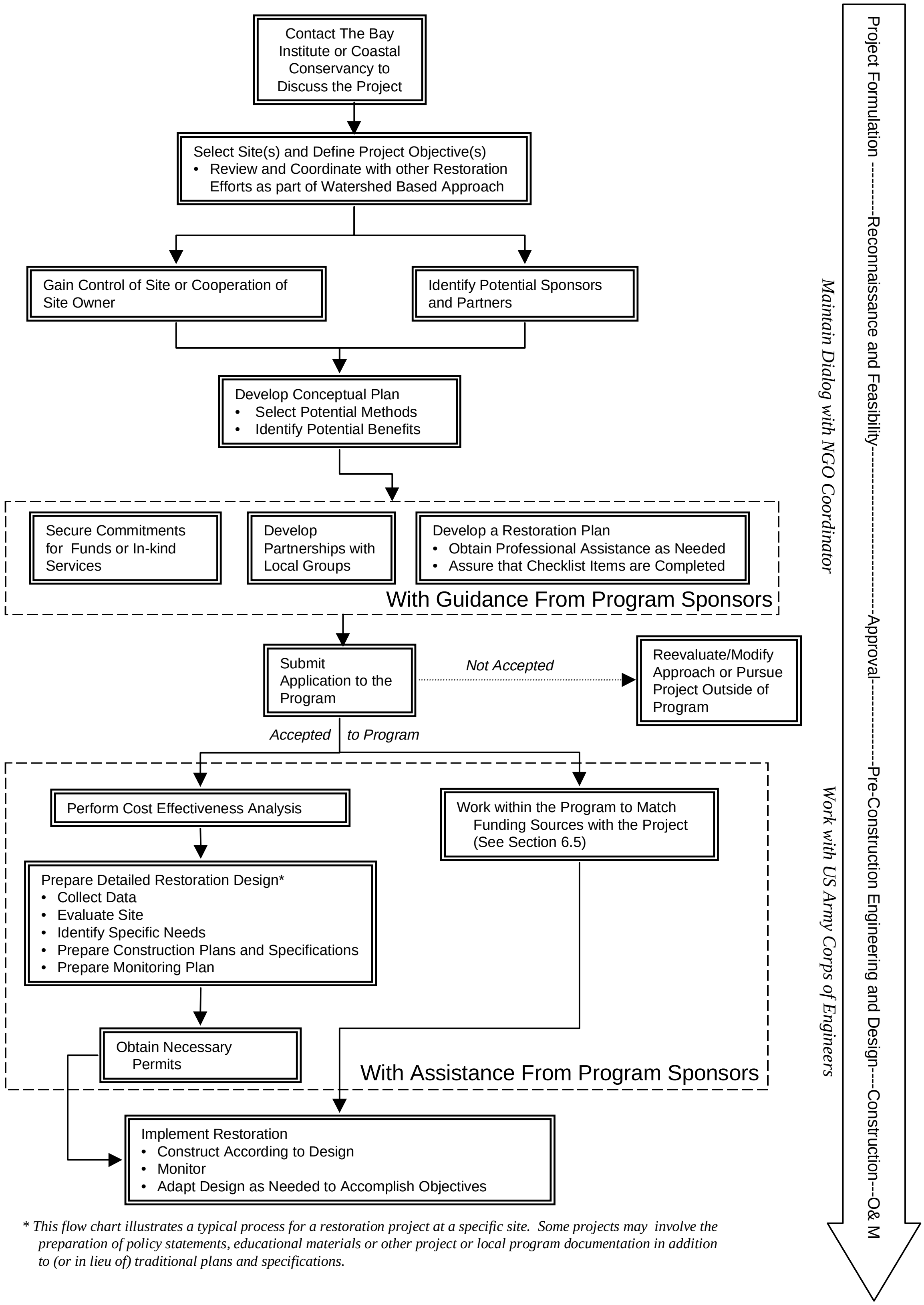
People and groups interested in restoration may be in a variety of starting places when they first seek assistance from the Program. Some project proponents may already have a project site or restoration idea in mind. Others may just have the desire to become involved in restoration efforts, but need a starting place. Some groups with funds available may be "shopping" for project ideas. Still others may be far enough along that they already have a restoration plan in hand. In any of these cases, project proponents should begin their interaction with the Program by contacting the Bay Institute and/or Conservancy to discuss project ideas.

Table 6-2 Candidate Project Summary Information

#	Project Name	Location	Problems Addressed	Possible Restoration Methods	Program Goals					
					Rehabilitate Natural Processes	Protect Exist. Habitat	Restore Habitat	Sustain Native Species	Improve Water Quality & Instream Flow	Address Non-native Species
1	Marin County Fire Road Sediment Reduction Project	Novato, Miller, and Las Gallinas creek watersheds, Marin County	High erosion rates from soils on or adjacent to unpaved fire roads.	Protect roads with gravel; re-vegetation and mulching on disturbed soils; re-vegetation and protection of streambanks	X		X	X	X	
2	Mare Island and North Bay Discovery Center Wetlands Restoration	Mare Island, near the City of Vallejo	Diked wetlands have been used as a repository for dredged spoils	Levee modification to allow full or muted tidal exchange and restore wetlands; Removal of munitions.	X		X	X		
3	Montalvin Manor Culvert Project	Contra Costa County, Garrity Creek watershed	Localized flooding and conversion of brackish marsh habitat to freshwater marsh	Repair culvert to reduce flooding and restore tidal action to marsh; preserve site as part of development permitting.	X		X			
4	Napa River Runoff Management	Napa River watershed	Urbanization and increased impervious land coverage, resulting in indirect stream degradation	Promote infiltration by modifying drainage systems, installing ponds and swales, and reducing area of impervious surfaces.	X				X	
5	Novato Creek Flood Control and Marsh Restoration	Novato Creek, Marin County	Insufficient flood protection and historic draining of wetlands	Levee modification to allow tidal or seasonal freshwater flows to reach the diked floodplain. Connected to flood control project.	X		X			
6	River Park, Vallejo	Northern Vallejo, adjacent to Mare Island Strait	Degraded tidal mudflat habitat	Relocation of dredged materials; re-vegetation to provide food, cover, and nesting.	X	X	X	X		
7	Rodeo Creek Sediment Reduction Project	Contra Costa County	Channelization and loss of riparian zone; erosion in upper watershed	Channel restoration and revegetation of lower creek; BMPs and re-vegetation of upper watershed.	X		X		X	

Table 6-2 Candidate Project Summary Information (continued)

#	Project Name	Location	Problems Addressed	Possible Restoration Methods	Program Goals					
					Rehabilitate Natural Processes	Protect Exist. Habitat	Restore Habitat	Sustain Native Species	Improve Water Quality & Instream Flow	Address Non-native Species
8	San Pablo Bay Wildlife Refuge Additions	North of Highway 37, East of Sonoma Creek, West of Napa Slough	Historic diking and draining of tidal wetlands	Passive restoration of wetlands, with infrastructure clean-up where necessary.	X	X	X	X		
9	Leonard Ranch Tidal Wetlands Restoration	Near Port Sonoma and the mouth of the Petaluma River	Historic diking and draining of tidal wetlands	Levee modification to restore tidal action and ensure continuing flood protection	X		X	X		
10	Sonoma Valley Vineyard and Wineries BMPs	Sonoma Creek watershed	Erosion and riparian degradation due to poor vineyard management	Implementation of vineyard BMPs, including riparian re-vegetation, vineyard setbacks, and installation of drywells.	X		X	X	X	
11	Sulphur Creek Enhancement Projects	Napa River watershed	Degradation of aquatic habitat due to erosion and stream modification	Enhance fish habitat (pools/riffles); remove fish barriers and install fish ladders; re-vegetation; remove invasive species; erosion control.	X		X	X	X	X
12	Wildcat Creek Dredging Project	Western Contra Costa County, near Richmond	High sedimentation rates degrade the channel and clog fish passage systems	Further channel and floodplain de-siltation; erosion control in upper watershed; more to be determined.	X		X	X	X	
13	San Antonio Creek Wetlands Enhancement Plan	Highway 101 at the Marin-Sonoma County border	Loss of habitat due to former development; stormwater backup onto Highway 101	Remove pavement and increase water storage to allow seasonal ponding on site	X		X	X		



** This flow chart illustrates a typical process for a restoration project at a specific site. Some projects may involve the preparation of policy statements, educational materials or other project or local program documentation in addition to (or in lieu of) traditional plans and specifications.*

Figure 6-2: Project Planning Flowchart

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Appendix A

1. Link to Figure A-1 (1.2 Mb). Relationship of San Pablo Bay Watershed Restoration Program to Other Army Corps of Engineers Programs

Appendix B
Habitat and Species Lists

1. Table B-1. San Pablo Bay Watershed Habitats and Cross-References to Other Classification Schemes

2. Table B-2. Species List for the San Pablo Watershed

Table B-1 San Pablo Bay Watershed Habitats and Cross-References to Other Classification Schemes

Naturally Occuring Habitats	Types (from this document)	Subtypes (from this document)	MSCS NCCP Habitat Type	CALFED ERP Habitat Type	Cowardin et al. (1979) (System/Subsystem)	S.F. Estuary Project (category)	Goals Project (Key Habitats)
Open water of San Pablo Bay					Estuarine/Subtidal	Open Water; Shallow Bay & Channel	Deep Bay & Channel; Shallow Bay & Channel
Wetlands							
	intertidal mudflats		Tidal perennial aquatic	Tidal perennial aquatic (includes estuary edge waters; tidal mudflats; transitions between open waters & emergent wetlands)	Estuarine/ Intertidal	Mudflat	
	tidal wetlands and sloughs						
		tidal salt marsh	saline emergent	Saline Emergent Wetland (includes salt & brackish low, middle, and high tidal marsh)	Estuarine/ Intertidal	Tidal Marsh	Tidal Marsh (and channels)
		tidal brackish marsh	saline emergent	Saline Emergent Wetland (includes salt & brackish low, middle, and high tidal marsh)	Estuarine/ Intertidal	Tidal Marsh	Tidal Marsh (and channels)
		tidal freshwater marsh	tidal freshwater emergent	Fresh emergent wetland	Estuarine/ Intertidal	Tidal Marsh	Tidal Marsh (and channels)
	seasonal wetlands		Managed seasonal wetlands	Seasonal wetlands	Palustrine	seasonal & permanent vegetated wetlands	diked wetland
		includes vernal pools	Natural seasonal wetlands (vernal pools)	Seasonal wetlands	Palustrine	freshwater marsh	
	managed wetlands				Palustrine	Diked vegetated wetlands; seasonal & permanent vegetated wetlands; farmed wetland	diked wetland; agricultural bayland

Table B-1 San Pablo Bay Watershed Habitats and Cross-References to Other Classification Schemes

Naturally Occuring Habitats	Types (from this document)	Subtypes (from this document)	MSCS NCCP Habitat Type	CALFED ERP Habitat Type	Cowardin et al. (1979) (System/Subsystem)	S.F. Estuary Project (category)	Goals Project (Key Habitats)
	diked baylands				Palustrine	Diked vegetated wetlands	diked wetland; agricultural bayland
Lakes and Ponds	natural lakes and ponds		Lacustrine	Non-tidal perennial aquatic	Lacustrine	Perennial Lakes & Ponds	
	salt ponds		Lacustrine	Non-tidal perennial aquatic	Lacustrine	Salt Evaporator; Crystallizer; Bittern Pond	Storage/ Treatment Pond; Salt Pond
Streams and Creeks			Valley Riverine Aquatic/ Valley Foothill Riparian	Riparian & Riverine Aquatic	Riverine	Tidal River; Nontidal River; Perennial & Intermittent Creeks	Lowland Creek
Riparian habitat			Valley Foothill Riparian	Riparian & Riverine Aquatic	Riverine	Tidal River; Nontidal River; Perennial & Intermittent Creeks	Lowland Creek
Perennial grasslands			Grasslands	Perennial grasslands		Adjacent Upland	Grassland
Chaparral							
Oak Woodland						Adjacent Upland	Oak Woodland
Mixed Evergreen Forest						Adjacent Upland	Mixed Evergreen Forest
Agricultural			Seasonally flooded Agriculture; Upland cropland	Agricultural lands	Palustrine	Diked Vegetated Wetlands; Seasonal & Permanent Vegetated Wetlands; Farmed Wetland	Diked Wetland; Agricultural Bayland

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
PLANTS							
Box elder	*Acer negundo californicum*	N		riparian forest		2	
Chamise	*Adenstoma fasciliculatum*	N		chaparral and woodland communitites	P	10	
California buckeye	*Aesulus california*	N		riparian		8	
Oat bent-grass	*Agrostis avenacea*			diked baylands		2	
Hairgrass	*Aira elegans*					8	
Sonoma alopecurus	*Alopecurus aequalis car sonomensis*	N	E, 1B	Ledson Marsh; Bennett Mountain; Sonoma Mountain		3, 5, 7	
Large-flowered fiddleneck	*Amsinekia grandiflora*	N	E, CE, 1B		P	5	
Fiddleneck	*Amsinekia sp. A*					8	
Scarlet pimpernel	*Anagallis arvensis*					8	
Mayweed	*Anthemis cotula*					8	
Mount Diablo manzanita	*Arctostaphylos auriculata*	N	1B	chaparral and woodland communitites in sandstone	P	5, 10	
Baker's manzanita	*Arctostaphylos bakeri ssp. bakeri*	N	R, 1B/SC	serpentine soils in localized chaparral and woodland communities of Sonoma County	P	5, 10	
Manzanita	*Arctostaphylos manzanita*	N				8, 10	
Contra Costa manzanita	*Arctostaphylos manzanita ssp. laevigata*	N	1B	rocky slopes in chaparral habitats	P	5, 10	
Mt. Tamalpais manzanita	*Arctostaphylos montana*	N	FC2	chaparral and valley foothill grassland habitat types		7, 10	
Palid manzanita	*Arctostaphylos pallida*	N	T, CE, 1B	slopes and ridges of maritime chaparral and coastal scrub communitites	P	5, 10	
Bolinas manzanita	*Arctostaphylos virgata*	N	C2	broadleafed upland forest, closed cone coniferous forest, and chaparral vegetation types		7, 10	
Sea-pink	*Armeria maritima ssp. Californica*	N		tidal marsh, salt marsh		2	
Mugwort	*Artemesia douglasiana*					8	
Giant reed	*Arundo donax*	I		riparian forest		2	
Suisun Marsh aster	*Aster lentus*	N	FC2, 1B	riparian habitat		5, 9	
Clara Hunt's milk-vetch	*Astragalus clarianus*	N	E, CT, 1B	rocky, thin, clay soils in sparsely vegetated openings within blue-oak woodland and grassland communities	P	5	
Ferris' milk-vetch	*Astragalus tener var. ferrisae*	N	1B	adobe clay grasslands and alkaline vernal pools	P	5	
Alkali milk-vetch	*Astragalus tener var. tener*	N	1B	clay soils of alkaline flats and meadows, valley foothill grasslands, and alkaline vernal pools	P	5	
Fat hen	*Atriplex*				P	10	
California saltbrush	*Atriplex californica*	N		tidal salt marshes		2	
Heartscale	*Atriplex cordulata*	N	1B	alkaline or saline soil in chenopod scrub, desert scrub, or sandy grassland habitats	P	5	
Brittlescale	*Atriplex depressa*	N	1B	alkaline or clay soils of chenopod scrub, playas, and grassland communitites	P	5	
San Joaquin spearscale	*Atriplex joaquiniana*	N	1B	alkaline desert scrub, chenopod scrub, seasonal alkali meadows, and grasslands of alkaline soils	P	5	
Salt bush	*Atriplex patula ssp. Hastata*					8	
Valley spearscale	*Atriplex patula ssp. Spicata*	N	FC2	alkali sink		9	
Spear scale, fat hen	*Atriplex triangularis*			tidal marsh, salt marsh		2	
Slender wild oat	*Avena barbata*	I		grasslands		2, 8	
Wild oat	*Avena fatua*	I		grasslands		2, 8	
Common coyote bush	*Baccharis pilularis ssp. Consanguinea*	N				8, 10	
Sonoma sunshine	*Blennosperma bakeri*	N	E, CE, 1B	West and south of Sonoma; Sonoma Valley Regional Park		3, 5, 7, 8	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Big tarplant	*Blepharizonia plumosa ssp. plumosa*	N	1B	dry hills and grassy plains	P	5	
Common mustard	*Brassica campestris*	I				8	
Wild mustard	*Brassica ssp. And Hirschfeldia incana*			diked baylands		2	
Black mustard	*Brassica nigra*					8	
Foxtail chess	*Bromus rubens*	I				8	
Rattlesnake grass	*Briza maxima*	I				8	
Harvest brodiaea	*Brodiaea elegans*	N				8	
Brodiaea	*Brodiaea laxa*					8	
Rip-gut grass	*Bromus diandrus*	I		grasslands		2, 8	
Soft chess	*Bromus mollis*	I		grasslands		2, 8	
Tiburon Mariposa lily	*Calochortus tiburonensis*	N	T, CT, 1B	serpentine grasslands on the north slope of Ring Mountain	P	5	
Italian thistle	*Carduus pycnocephalus*	I				8	
White sedge	*Carex albida*	N	E, CE, 1B	Freshwater marshes		9, 10	
Santa Barbara sedge	*Carex barbarae*	N		riparian forest, grasslands, moist grassland		2	
Johny-nip, salt marsh owl's clover	*Castilleja ambigua ssp. Ambigua*			tidal marsh, salt marsh		2	
Pitkin marsh indian paintbrush	*Castilleja uliginosa*	N	SF, FC1	Freshwater marshes		9	
Rincon Ridge ceanothus	*Ceanothus confusus*	N	CSC	Hood Mtn		3, 10	
Calistoga ceanothus	*Ceanothus divergens*	N	CSC	West slope of Trinity Mountain, Hood Mountain; Along Sonoma Creek; at the foot of Mt Hood; Bennett Mtn, Annadel State Park		3, 10	
Mason's ceanothus	*Ceanothus masonii*	N	R, 1B/SC	chaparral vegetation communities		7, 10	
Sonoma ceanothus	*Ceanothus sonomensis*	N	CSC	West slope of Trinity Mountain, Hood Mountain		3, 10	
Purple star thistle	*Centarea calcitrapa*	I				8	
Centaurium	*Centarium muhlenbergii*					8	
Mouse-ear chickweed	*Cerastium glomeratum*					8	
Goosefoot	*Chenopodium berlandieri*			diked baylands		2	
Soaproot	*Chlorogalum pomeridianum*	N	1B	serpentine outcrops and chaparral communities		8	
Sonoma spineflower	*Chorizanthe valeda*	N	E, CE, 1B	sandy soils of coastal grassland prarie habitats	P	5	
Suisun thistle	*Cirsium hydrophilum var. hudrophilium*	N	E, 1B	brackish tidal marshes		1, 2, 5, 9	
Bull thistle	*Cirsium vulgare*	I				8	
Rock-rose	*Cistus vilosus*					8	
Miner's lettuce	*Claytonia perfoliata*	N				8	
Poison hemlock	*Conium maculatum*			diked baylands		2	
Orchard morning glory	*Convolvulus arvensis*	I				8	
Point Reyes bird's-beak	*Cordylanthus maritimus ssp. palustris*	N	FC2, 1B	coastal salt marshes and swamps		2, 5, 7, 9	
Hispid bird's-beak	*Cordylanthus mollis ssp. hispidus*	N	FC2, 1B	brackish and salt tidal marshes		5, 9	
Soft bird's-beak	*Cordylanthus mollis ssp. Mollis*	N	E, R, 1B	salt marshes bordering the San Pablo Bay		1, 2, 3, 5, 7, 8, 9	
Mount Diablo bird's-beak	*Cordylanthus nidularius*	N	R, 1B/SC	serpentine chaparral communities	P	5	
Brass buttons	*Cotula coronopifolia*	I		diked baylands		2, 8	
Dodder	*Cuscuta salina*	N		tidal salt marshes		2	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Nievitas	*Cryptantha torreyana*					8	
Artichoke	*Cynara scolymus*					8	
Dogtail	*Cynosurus echinatus*					8	
Umbrella sedge	*Cyperus eragrostis*	I				8	
French broom	*Cytisus monspessulanus*	I				8	
Wild carrot	*Daucus carota*	I				8	
Baker's larkspur	*Delphinium bakeri*	N	E, R, 1B	coastal scrub habitats		5, 7	
Hospital Canyon larkspur	*Delphinium californium ssp. interius*	N	1B	moist areas on slopes in open woodlands and chaparral habitats	P	5	
Yellow larkspur	*Delphinium luteum*	N	E, R, 1B	coastal scrub		5, 7, 8	
Blue dicks	*Dichelostemma pulchellum*					8	
Salt grass	*Distichlis spicata*	N		tidal marsh, diked baylands		2, 8, 10	
Dittrichia	*Dittrichia graveolens*			diked baylands		2	
Downingia	*Downingia pulchella*	N		grassland/ vernal pool complex		2, 10	
Dwarf downingia	*Downingia humilis*	N	FC3c	valley and foothill grassland habitats in mesic sites and vernal pools		7, 8	
Green algae	*Dunaliella salina*	N		salt pond	P	2, 10	
Watergrass	*Echinochloa crus-galii*			diked baylands		2	
Green algae	*Entermorpha*	N			P	10	
Turkey mullein	*Eremocarpus setigerus*					8	
Ben Lomond buckwheat	*Eriogonum nudum varr. Decurrens*	N	1B	maritime pondorosa pine sandhills, chaparral and cismontane woodlands on sandy soil	P	5	
Broad-leaf filaree	*Erodium botrys*	I				8	
Red-stem filaree	*Erodium cicutarium*	I				8	
Coyote thistle	*Eryngium aristulatum*	N		grassland/ vernal pool complex		2	
Lock Lomond button-celery	*Eryngium constancei*	N	E, 1B	meadow-like bed of Lock Lomond Lake	P	5	
Contra Costa wallflower	*Erysimum capitatum ssp. angustatum*	N	E, CE, 1B	fine sand and some clay among grasses, shrubs, and other forbs on or near the tops of remnants of ecologically stabilized interior dunes	P	5	
California poppy	*Eschscholzia californica*	N				8	
Blue gum	*Eucalyptus globulus*	I				8	
Red fescue	*Festuca rubra*					8	
Sweet fennel	*Foeniculum vulgare*	I		diked baylands		2, 8	
Alkali heath	*Frankenia grandifolia*	N		tidal salt marshes		2, 8, 10	
Mission bells	*Fritillaria affinis*	N				8	
Fragrant fritillary	*Fritillaria liliacea*	N	FC2	coastal scrub and valley and foothill grasslands		7, 8	
Galium	*Galium nuttallii*					8	
Cudweed	*Gnaphalium purpureum*					8	
Boggs Lake hedge-hyssop	*Gratiola heterosepala*	N	CE, 1B	shallow waters or moist clay soils of vernal pools and lake margins	P	5	
Gumplant	*Grindelia stricta var. angustifolia*			tidal marshes		2, 10	
Great Valley gumplant	*Grindelia camporum var. parviflora*			deep soils of valley grassland communities		7	
Marsh gumplant	*Grindelia humilis*			coastal salt marsh communities		7	
San Francisco gumplant	*Grindelia maritima*	N	FC2	tidal salt marshes		9	
Diablo Helianthella	*Helianthella castanea*	N	C2, 1B	grassy hillsides in broad leaf upland forest and chaparral from 500 to 4000 ft elevation		5, 7	
Hayfield tarplant	*Hemizonia congesta*			northern coastal scrub communities near the coast		7	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Tiburon tarplant	*Hemizonia multicaulis ssp. Vernalis*	N	FC2	Sonoma and Marin counties, mostly away from the immediate coast		7	
Congdon's tarplant	*Hemizonia parryi ssp. congdonii*	N	1B	alkaline grasslands	P	5	
Cow parsnip	*Heracleum lanatum*				P	10	
Marin western flax	*Hesperolinun congestum*	N	T, CT, 1B	serpentine grassland		5, 7, 8	
Napa western flax	*Hesperolinun serpentinum*	N	1B	chaparral and woodland communities in serpentine soils	P	5	
Toyon	*Heteromeles arbutifolia*	N				8	
California hibiscus	*Hibiscus californicus*	N	FC2	riparian habitat		9	
Santa Cruz tarplant	*Holocarpha macradenia*	N	E, 1B	coastal prairie and grassland communities, often in clay soils	P	5	
Mediterranean barley	*Hordeum hystriz*					7	
Barley	*Hordeum marinum var gussoneanum*			diked baylands		2	
Cat-ear	*Hypoc radicata*					7	
Ground iris	*Iris macrosiphon hoeris*					7	
Carquinez goldenbrush	*Isocoma arguta*	N	1B	alkaline soils, on flats, and on low hills of grassland habitats	P	5	
Poverty weed	*Iva axillaris*					8	
Jaumea	*Jaumea carnosa*			tidal salt marshes		2	
Hind's walnut	*Juglans hindsii*	N	FC2	riparian habitat		9	
Baltic rush	*Juncus balticus*	N		tidal brackish marsh, diked baylands, moist grasslands		2, 10	
Toad rush	*Juncus bufonius*	N				8, 10	
Salt rush	*Juncus lesuerii*	N		diked baylands		2	
Iris-leaved rush	*Juncus xiphiodes*	N		moist grassland		2	
Goldfields	*Lasthenia ssp*	N		grassland/ vernal pool complex		2	
Burke's goldfields	*Lasthenia burkei*	N	C2	vernal pool		8, 9	
Contra Costa goldfields	*Lasthenia conjugens*	N	E, 1B	vernal pools and seasonally moist grassy areas		5, 9	
Smooth goldfields	*Lasthenia glabrata*			tidal marshes		2	
Delta tule pea	*Lathyrus jepsonii ssp. Jepsonii*	N	C2	tidally influenced brackish or freshwater wetlands		2, 7, 9	
Legenere	*Legenere limosa*	N	1B	lake shores, vernal pools, marshes, and other seasonally innundated habitats	P	5	
Dwarf pepper-grass	*Lepidium lapites*			alkaline flats and beds of winter pools below 2000 ft, largely in valley grassland communities		7	
Pepper grass	*Lepidium latifolium*	I		tidal marshes, diked baylands		2	
Creeping wildrye	*Leymus triticoides*			diked baylands, grasslands, moist grasslands		2	
Mason's lilaeopsis	*Lilaeopsis masonii*	N	R, 1B/SC	saturated clay soils, in areas where freshwater is prevelant and are regularly innundated by waves and tidal actions		2, 5, 9	
Pitkin Marsh lily	*Lilium pardalinum ssp. pitkinense*	N	E, CE, 1B	freshwater marshes, wet meadows, and cismontane woodlands		5, 9	
Meadow foam	*Limnanthes douglasii*	N			P	10	
Sebastopol meadowfoam	*Limnanthes vinculans*	N	E, CE, 1B	seasonally wet meadows, pastures, vernal pools, and creek drainages		5, 8, 9	
Sea lavender, marsh rosemary	*Limonium californicum*	N		tidal salt marshes		2	
Delta mudwort	*Limosella subulata*	I		eroding banks innundated by the tide where freshwater is prevalent	P	5	
Sweet alyssum	*Lobularia maritima*					8	
Italian ryegrass	*Lolium multiflorum*	I		grasslands, moist grasslands+D355		2, 8	
California honeysuckle	*Lonicera hispidula var. Vacillans*	N				8	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Bird's-foot trefoil	*Lotus corniculatus*			diked baylands		2, 8	
Spanish clover	*Lotus formosissimus*	I				8	
Loosestrife	*Lotus purshianus*			diked baylands		2, 8	
Dove lupine	*Lupinus bicolor*	N				8	
Lupine	*Lupinus densiflorus*	N				8	
Loosestrife	*Lythrum hyssopifolia*	I		grassland/ vernal pool complex		2, 8	
Tarweed	*Madia sativa*					8	
Sweet clover	*Melilotus indicus*					8	
Diatoms	*Melosira moniliformis*				P	10	
Bush monkeyflower	*Mimulus aurantiacus*	N				8	
Curly-leaved monardella	*Monardella undulata var. undulata*			sandy places below 500 ft, in coastal strand communities; may also occur in northern coastal scrub and closed-cone pine forest communities		7	
Little mousetail	*Myosurus minimus*			south slope of Mt. Burdell		7	
Purple needlegrass	*Nassella pulchra*	N		grasslands		2	
Few-flowered Navarritia	*Navarretia leucocephala ssp pauciflora*	N	E, CT, 1B	vernal pools occuring on volcanic ash deposits	P	5	
Many-flowered Navarretia	*Navarretia Leucocephala SSp Plieantha*	N	E, 1B	Bennett Mountain Lake (Ledson Marsh); Annadel State Park		3	
Colusa grass	*Neostapfia colusana*	N	T, CE, 1B	large or deep vernal pools on clay substrates	P	5	
Antioch Dunes evening-primrose	*Oenothera deltoides ssp. howellii*	N	E, CE, 1B	freshly disturbed sand	P	5	
Owlsclover	*Orthocarpus faucibarbatas*					8	
Blue-green algae	*Oscillatoria*	N			P	10	
White-rayed pentachaeta	*Pentachaeta bellidiflora*	N	E, CE, 1B	open, dry rocky slopes in north coastal scrub and coastal prairie habitats		5, 7	
Gairdner's yampah	*Perideridia gairderi ssp. Gairdneri*	N	FC2	wet meadows		9	
Canarygrass	*Phalaris tuberosa var. stenoptera*	I				8	
Fiesta flower	*Pholistoma auritum*					8	
Reeds	*Phragmites communis*	I			P	10	
Bristly ox-tongue	*Picris echioides*					8	
California pinefoot	*Pityopsis californicus*	N	FC3c	deeply shaded places from 1000 to 5000 ft in mixed evergreen and redwood forests		7	
Glabrous allocarya	*Plagiobothrys glaber*	N	FC2	vernal pools		9	
Bearded allocarya	*Plagiobothrys hystriculus*	N	FC2	vernal pools		9	
Petaluma popcorn flower	*Plagiobothrys mollis var. Vestitus*	N	C2	on alkaline sites near thermal springs, on vernal pool margins in heavy, dark clay.		8	
Popcorn flower	*Plagiobothrys nothofulvus*			grassland/ vernal pool complex		2, 8	
Calistoga popcornflower	*Plagiobothrys strictus*	N	E, CT, 1B	vernal pools		5, 9	
English plantain	*Plantago lanceolata*	I				8	
Western sycamore	*Platanus racemosa*	N		riparian forest		2	
North Coast semaphore grass	*Pleuropogon hooverianus*	N	R, 1B/SC	broadleafed upland forest habitats in moist grassy, sometimes shaded areas		5, 7, 8	
Semaphore grass	*Pleuropogon monspeliensis*					8	
Napa blue grass	*Poa napensis*	N	E, CE, 1B	moist meadows		5, 8	
Poa	*Poa scabrella*					8	
Dooryard knotweed	*Polygonum aviculare*					8	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Marin knotweed	*Polygonum marinense*	N	FC2	coastal salt marsh, along the Petaluma River		5, 7, 8, 9	
Rabitfoot grass	*Polypogon monspeliensis*					8	
Sword fern	*Polystichum munitum*				P	10	
Cottonwood	*Populus fremontii*	N		riparian forest		2	
Sago pondweed	*Potamogeton pectinatus*			diked baylands		2	
Silverweed	*Potentilla anserina ssp. Pacifica*	N		tidal brackish marsh		2	
Bracken fern	*Pteridium aquilinum*	N				8	
Coast live oak	*Quercus agrifolia*	N				8, 10	
Blue oak	*Quercus douglasii*	N				8, 10	
Oregon oak	*Quercus garryana*	N				8, 10	
California black oak	*Quercus kelloggii*	N				8, 10	
Valley Oak	*Quercus lobata*	N		rich loam valleys, slopes below 2000 ft, associated with foothill woodlands and valley grassland communities		2, 7, 8, 10	
Loeb's aquatic buttercup	*Ranunculus lobbii*			valley and foothill grasslands and oak woodland		7	
Buttercup	*Ranunculus muricatus*					8	
Wild radish	*Raphanus sativus*	I				8	
California beaked-rush	*Rhynchospora californica*	N	1B	seeps, bogs, and freshwater marshes of meadow and lower montane coniferous forest habitats		5, 9	
Parish's gooseberry	*Ribes divaricatum var. publiflorum*			broadleafed upland forest and north coast forest communitites		7	
Victor's gooseberry	*Ribes victoris*			wooded slopes in shaded canyons; broadleafed upland forest and chaparral communities		7	
Black locust	*Robinia pseudo-acacia*	I				8	
California rose	*Rosa californica*	N		riparian forest		2, 8	
Blackberry	*Rubus vitifolius*			riparian forest	P	2, 10	
Curly dock	*Rumex crispus*	I		diked baylands		2, 8	
Dock	*Rumex pulcher*					8	
Pickleweed	*Salicornia virginica*	N		tidal salt marshes, diked baylands		2, 8, 10	
Red willow	*Salix laevigata*	N		riparian forest		2	
Arroyo willow	*Salix lasiolepis*	N		riparian forest		2	
Blue elderberry	*Sambucus coerulea*	N		riparian forest		2, 8	
Snake root	*Sanicula lacinitata*					8	
Hardstem bulrush	*Scirpus acutus*	N		tidal brackish marsh		2	
California bulrush	*Scirpus californicus*	N		tidal brackish marsh	P	2, 10	
Tule	*Scirpus*	N			P	10	
Olney's bulrush	*Scirpus pungens*	N		tidal brackish marsh		2	
Alkali bulrush	*Scirpus robustus*	N		tidal brackish marsh, diked baylands		2, 8, 10	
California bee plant	*Scrophularia californica*					8	
Groundsel	*Senecio vulgaris*					8	
Marin checkerbloom	*Sidalcea hickmanii ssp. viridis*	N	1B/SC	serpentine and volcanic soils in chaparral and grassland habitats near the coast	P	5	
Checkerbloom	*Sidalcea malvaeflora*					8	
Marsh checkerbloom	*Sidalcea oregana ssp. hydrophila*	N	1B	wet soils of riparian forest streambanks and meadows	P	5	
Kenwood Marsh checkermellow	*Sidalcea oregana ssp. Valida*	N	E, CE, 1B	freshwater marshes		1, 3, 5, 9	
Windmill pink	*Silene gallica*					8	
Milk thistle	*Silybum marianum*					8	
Blue-eyed grass	*Sisyrinchium bellum*					8	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Smooth cordgrass	*Spartina alterniflora*	I		tidal marshes		2	
Dense-flowered cordgrass	*Spartina densiflora*	I		tidal marshes		2	
Cordgrass	*Spartina foliosa*	N		tidal marshes	P	2, 10	
Saltmeadow cordgrass	*Spartina patens*	I		tidal marshes		2	
Corn spurrey	*Spergularia arvensis*					8	
Hedge nettls	*Stachys rigida*					8	
Chickweed	*Stellaria media*	N				8	
Green algae	*Stichococcus bacillaris*				P	10	
Tamalpais jewelflower	*Streptanthus batrachopus*	N	FC2	chaparral and closed-cone forests below 2000 ft		7	
Mt. Tamalpais jewelflower	*Streptanthus glandulosus ssp. Pulchellus*	N	FC3c	chaparral and valley grassland		7	
Mount Diablo jewelflower	*Streptanthus hispidus*	N	1B	rocky outcrops in chaparral and grassland habitats	P	5	
Tiburon jewelflower	*Streptanthus niger*	N	E, CE, 1B	shallow, rocky soils derived from serpentine rock on south or west-facing slopes within a native bunchgrass community	P	5	
Mt. Diablo cottonweed	*Stylocline amphibloa*	N		shallow soil in rocky places, in broadleafed upland forest communities		7	
California seablite	*Suaeda californica*	N	E, 1B	salt marsh		2, 5, 8	
Suaeda	*Suaeda sp. B*					8	
Common dandelion	*Taraxaum officinale*	I				8	
Hedge parsley	*Torilis nodosa*					8	
Poison oak	*Toxicodendron diversilobum*	N				8, 10	
Showy Indian clover	*Trifolium amoenum*	N	E, 1B	low rich fields and swales		5, 7, 8, 9	
Gray's clover	*Trifolium grayi*			meadows		7	
Crimson clover	*Trifolium incarnatum*					8	
Clover	*Trifolium microdon*					8	
Wheat	*Triticum aestivum*	I				8	
Cattail	*Typha*			tidal brackish marsh, diked baylands	P	2, 10	
Narrow leaf cattail	*Typha angustifolia*	I				8	
California bay laurel	*Umbellularia californica*	N		riparian forests		2, 8	
Vetch	*Vicia sativa*					8	
Johnny-jump-ups	*Viola pendunculata*					8	
Italian cocklebur	*Xanthium strumarium var. italicum*					8	
Eelgrass	*Zostera marina*	N		intertidal and subtidal baylands		2	
INVERTEBRATES							
Opler's longhorn moth	*Adela oplerella*	N	FCR2	serpentine grasslands in Marin county		7	
Lange's metalmark butterfly	*Apodemia mormo langei*	N	E	close association with host plant, naked-stemmed buckwheat	P	5	
Franciscan brine shrimp	*Artemia franciscana*					2	
Conservancy fairy shrimp	*Branchinecta conservation*	N	E	large, clay-bottomed vernal pools	P	1,2	
Longhorn fairy shrimp	*Branchinecta longiantenna*	N	E	rock outcrop vernal pools and clay or grassy bottomed vernal pools	P	5	
Vernal pool fairy shrimp	*Branchinecta lynchi*	N	T	grassland vernal pools, rock outcrops, roadside ditches	P	1, 5	
Marin blind harvestman	*Calicina diminua*	N	FCR2	serpentine grasslands		7	
Monarch butterfly	*Danaus plexippus*	N	SCR	winter roost sites along coast		5, 7	
Brine flies	*Ephydra*					10	
Bay checkerspot butterfly	*Euphydryas editha bayensis*	N	FT	restricted to native grasslands on outcrops of serpentine		7	

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Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Yellow shore crabs	*Hemigrapsus oregonensis*				P	10	
Rickseeker's water scavenger beetle	*Hydrochara rickseckeri*	N	FC2	found in pinds, seeps, and pooling water in sluggish streams		7, 9	
Ribbed mussels	*Ischadium demissum*	I			P	10	
San Francisco forktail damselfly	*Ischnura gemina*	N	FC2	small shallow ponds, marshes and man-made canals in Marin county		7	
Vernal pool tadpole shrimp	*Lepidurus packardi*	N	E	stockponds and vernal pools	P	1, 5	
Valley oak ant	*Proceratium californicum*	N	FC2	leaf litter beneath valley oak		7	
Callippe silverspot butterfly	*Speyeria callippe callippe*	N	E	grasslands where primary food sources are Johnny-jump-ups for larval stage and mule ears for adult stage		1, 5, 7	
Behren's silverspot butterfly	*Speyeria zerene behrensii*	N	E		P	1	
Myrtle's silverspot butterfly	*Speyeria zerene myrtleae*	N	E		P	1	
California freshwater shrimp	*Syncaris pacifica*	N	E	shallow pools away from main stream flows in winter, lives in exposed roots in summer. Occurs in creeks in Marin County		1, 3, 5, 7, 8, 9	
Water boatmen	*Trichocorixa reticulata*				P	10	
California brackishwater snail	*Tryonia imitator*	N	FC2	coastal lagoons and salt marshes; lives subtidally, inhabits variety of sediment types		7	
FISH							
Yellowfin goby	*Acanthogobius flavimanus*	I		IM, BM, LS - Estuarine		6, 10, 12	
Whitesturgeon	*Acipenser transmontanus*	N		OW, IM - Anadromous, bottom-oriented		12	
Green sturgeon	*Acispenser medirostris*	N	CSC	OW - Anadromous, bottom-oriented	P	5	
American shad	*Alosa sapidissima*	I		OW - Anadromous, pelagic			
Topsmelt	*Atherinops affinis*	N		OW - Marine, pelagic	P	10	
Jacksmelt	*Atherinopsis californiensis*	N		OW - Marine, pelagic			
Goldfish	*Carassius auratus*	I		FM, LS - Low elevation, disturbed habitat		12	
Sacramento sucker	*Catostomus occidentalis*	N		FM, LS - Bottom oriented		12	common
Speckled sanddab	*Citharichthys stigmaeus*	N		OW - Marine, bottom-oriented		6	
Pacific herring	*Clupea pallasii*	N		OW, IM, BM - Estuarine, pelagic		6, 13	declining
Coastrange sculpin	*Cottus aleuticus*	N		US - Riffles, gravel substrate		12	rare
Prickly sculpin	*Cottus asper*	N		IM, BM, LS - Estuarine or freshwater, bottom oriented		12	common
Riffle sculpin	*Cottus gulosus*	N		US - Upland, shaded streams		12	locally common
Shiner perch/Shiner surfperch	*Cymatogaster aggregata*	N		OW - Marine		13	
Carp	*Cyprinus carpio*	I		FM, LS - Low elevation, disturbed habitat		12	
Threadfin shad	*Dorosoma petenense*	I		IM, BM - Estuarine or freshwater, pelagic			
Tidewater goby	*Eucyclogobius newberryi*	N	FE, CSC	brackish water habitats, in shallow lagoons and lower stream reaches		1, 5, 7, 8	
Mosquitofish	*Gambusia affinis*	I		FM, LS - Channelized streams		12	
Threespine stickleback	*Gasterosteus aculeatus*	N		IM, BM, LS - Anadromous and freshwater forms present	P	10, 12	common
Long-jawed mudsuckers	*Gillichthys mirabilis*	N		IM, BM, LS - Estuarine	P	10, 12	
Delta smelt	*Hypomesus tanspacificus*	N	T	BM, LS - Estuarine, pelagic		1, 5, 9, 13	
Tule perch	*Hysterocarpus traski*	N		IM, BM - Estuarine, pelagic		12	
White catfish	*Ictalurus catus*	I		FM, LS - Sluggish water		12	
Black bullhead	*Ictalurus melas*	I		FM, LS - Deep turbid water		12	
Channel catfish	*Ictalurus punctatus*	I		FM, LS		12	

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Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
River lamprey	*Lampetra ayresi*	N		OW - Transits San Pablo Bay during migration		12	
Pacific lamprey	*Lampetra tridentata*	N		OW - Transits San Pablo Bay during migration		12	
Hitch	*Lavinia exilicauda*	N		FM, LS - Pelagic		12	declining but locally common
California roach	*Lavinia symmetricus*	N		US - Clear streams, shaded pools		12	
Bay goby	*Lepidogobius lepidus*	N				6	
Pacific staghorn sculpin	*Leptocottus armatus*	N		OW, IM, BM - Estuarine, marine		6, 12	common
Rainwater killfish	*Lucania parva*	I		LS - sluggish stream, ponds	P	10, 12	
Inland silverside	*Menidia beryllina*	I		IM, BM, LS - Estuarine or freshwater, pelagic		12	
Smallmouth bass	*Micropterus dolomieui*	I		US - Napa River drainage		12	
Largemouth bass	*Micropterus salmoides*	I		US - Napa River drainage		12	
Striped bass	*Morone saxatilis*	I		OW - Anadromous, pelagic		12	common
Brown smoothhound	*Mustelus henlei*	N		OW - Bottom-oriented and common in shallow coastal bays			
Bat ray	*Myliobatus californica*	N		OW - Bottom-oriented and common in shallow coastal bays			
Golden shiner	*Notemigonus crysoleucas*	I		FM, LS - Low elevation, unshaded streams		12	
Coho salmon	*Oncorhynchus kisutch*	N	T		P	1, 12	extinct in San Pablo Bay watershed
Rainbow trout	*Oncorhynchus mykiss*	N		US		12	
Steelhead	*Oncorhynchus mykiss*	N	FT	OW, LS, US - Anadromous, juveniles rear in streams		1, 5, 8, 12	
Chinook salmon	*Oncorhynchus tshawytscha*	N	E	OW, LS, US - Anadromous, juveniles forage in OW/IM		1, 5, 8, 9, 12	
California halibut	*Paralichthys californicus*	N		OW - Marine, bottom-oriented			
English sole	*Parophrys vetulus*	N		OW - Marine, bottom-oriented			
Fathead minnow	*Pimaphales promelas*	I		FM, LS			
Starry flounder	*Platichthys stellatus*	N		OW, IM - Estuarine/marine, bottom oriented			
Sacramento splittail	*Pogonichthys macrolepidotus*	N	FT, CSC	BM, LS - Estuarine, spawn on floodplains		1, 5, 9, 12	populations abundance increased in recent wet years
White crappie	*Pomoxis annularis*	I		US - Sage Creek, Napa River drainage		12	
Plainfin midshipman	*Porichthys notatus*	N				6	
Sacramento squawfish	*Ptychocheilus grandis*	N		US- Clear shallow pools		12	locally common
California skate	*Raja inornata*	N		OW - Bottom-oriented and common in shallow coastal bays.			
Shovelnose guitarfish	*Rhinobatos productus*	N		OW - Bottom-oriented and common in shallow coastal bays.			
Longfin smelt	*Spirinchus thaleichthys*	N	CSC	OW - Estuarine/marine		5, 6, 13	declining
Spiny dogfish	*Squalus acanthias*	N		OW - Bottom-oriented and common in shallow coastal bays.			
Leopard shark	*Triakus semifasciata*	N		OW - Bottom-oriented and common in shallow coastal bays.			
AMPHIBIANS AND REPTILES							
California tiger salamander	*Ambystoma californiense*	N	CSC	Freshwater marsh, other freshwater habitats, oak woodlands		2, 5, 6, 7, 10	populations small, isolated and declining
California slender salamander	*Batrachoseps attenuatus*			low- to middle-elevation habitats, including valley-foothill hardwood, hardwood-conifer, riparian, mixed conifer, Douglas-fir, redwood, and montane hardwood-conifer		11	
California toad	*Bufo boreas halophilus*					2	

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Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Western pond turtle	*Clemmys marmorata*	N	CSC	Freshwater marsh, diked marsh, freshwater habitats, farmed wetlands, riparian wetlands, lakes and ponds		2, 5, 6, 7, 10	population greatly reduced, but probably stable
Western rattlesnake	*Crotalis viridis*			Found in virtually all habitats, except desert	P	10	
California alligator lizard	*Elgaria multicarinata multicarinata*					2	
Western skink	*Eumeces skiltonianus*			early successional stages or open areas within habitats in which it occurs		11	
Pacific tree frog	*Hyla regilla*					2	
Striped racer/ California whipsnake	*Masticophis lateralis*			mixed chaparral, chamise-redshank chaparral and valley-foothill riparian habitats	P	10	
Coast horned lizard	*Phrynosoma coronatum*			valley-foothill hardwood, conifer and riparian habitats, as well as in pine-cypress, juniper and annual grass habitats	P	10	
Gopher snake	*Pituophis melanoleucus*			all habitat types		11	
California red-legged frog	*Rana aurora draytonii*	N	T	Ledsen Marsh, Annadel State Park, brackish marsh, freshwater marsh, diked marsh, freshwater habitats, riparian woodlands, lakes and ponds		1, 2, 3, 6, 7, 8, 10	populations small, isolated and declining
Foothill yellow-legged frog	*Rana boylii*	N	CSC	shallow, flowing streams, with at least cobble sized substrate	P	5	
Western fence lizard	*Sceloporus occidentalis*			throughout California except in true desert	P	10	
Western spadefoot toad	*Scaphiopus hammondi hammondi*	N	2R	grasslands, occasionally in hardwood woodlands		7	
Rough skinned newt	*Taricha granulosa*			ponds, lakes, sloughs and slow-moving streams. Favored terrestrial habitats include riparian, Douglas-fir, redwood, montane hardwood-conifer, valley-foothill hardwood and hardwood-conifer		11	
California newt	*Taricha torosa*			valley-foothill hardwood, valley-foothill hardwood-conifer, coastal scrub and mixed chaparral, but is also known from annual grassland and mixed conifer types		11	
Western aquatic garter snake	*Thamnophis couchii*			permanent or semi-permanent bodies of water, especially rocky creeks, from slow-moving, low-elevation seasonal creeks to high-elevation mountain streams, ponds, and lakes in a variety of habitats including Montane Riparian, Montane Hardwood Conifer, Montane Chaparral, and Sierran Mixed Conifer		11	
Western terrestrial garter snake	*Thamnophis elegans*			Coast Ranges from the Oregon border south to southern Santa Barbara Co.; associated with permanent or semi-permanent bodies of water in a variety of habitats	P	10	
Central coast garter snake	*Thamnophis elegans terrestris*					2	
Giant garter snake	*Thamnophis gigas*	N	T	Freshwater habitats, lakes and ponds, oak woodlands		1, 6	populations small, isolated and declining
San Francisco garter snake	*Thamnophis sirtalis tetrataenia*	N	E	Salt marshes, lakes and ponds		1, 2, 6	populations small, isolated but stable during the last decade
BIRDS							
Cooper's Hawk	*Accipiter cooperii*	N	CSC	winter, spring, summer residents; favor woodland edges and riparian areas for foraging & nesting		7, 8	
Sharp-shinned hawk	*Accipiter stiatus*	N	CSC	woodland edges and riparian forests		7, 8	
Clark's grebe	*Aechmorphorus clarkii*			Napa-Sonoma salt ponds		2, 11	

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Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Western grebe	*Aechmorphorus occiedentalis*			Napa-Sonoma salt ponds		11	
Red-winged blackbird	*Agelaius phoeniceus*			fresh and saline emergent wetlands of cattails and tules, moist, open habitats with thickets of sedges, willows, dense forbs, grasses, cropland, grassland, and wet meadow habitats.		8, 10	
Tricolored blackbird	*Agelaius tricolor*	N	FC2, CPT	near freshwater, esp. marsh areas; nest in heavy growth of cattails and bulrushes		6, 7	steep population decline throughout range; several colonies in Freemont eliminated in past decade.
Sage sparrow	*Amphispiza belli*			low, fairly dense stands of shrubs	P	10	
Northern pintail	*Anas acuta*			salt marsh, brackish marsh, freshwater marsh, diked marsh, farmed wetlands, lakes and ponds, agricultural lands		2, 6, 8, 10, 11	97,000 birds wintered in estuary in 1990; 10% of 1977 population
American wigeon	*Anas americana*			common in lacustrine and fresh emergent habitats and nearby herbaceous and cropland habitats, in lowlands throughout California, and in the southern mountains		10, 11	
Northern shoveler	*Anas clypeata*			shallow, freshwater lacustrine habitats bordered by emergent wetlands, coastal slope lowlands		10, 11	
Green-winged teal	*Anas cyanoptera*			Napa-Sonoma salt ponds		11	
Mallard	*Anas platyrhynchos*			fresh emergent wetlands, estuarine, lacustrine, and riverine habitats, ponds, pastures, croplands, and urban parks		2, 8, 10, 11	
Gadwall	*Anas strepera*			interior valleys, wetlands, ponds, and streams		8, 10, 11	
Tule greater white-fronted goose	*Anser albifrons gambelli*	N	T		P	1, 2	
Scrub jay	*Aphelocoma coerulescens*					8	
Golden Eagle	*Aquila chrysaetos*	N	CSC	rolling foothills or coast range terrain where open grassland turns to scattered oaks/other large trees		5, 7	
Great blue heron	*Ardea herodias*	N	CSC	colonial nesters in tall trees, cliffsides, sequestered spots on marshes		7, 8, 10, 11	160 nesting pairs in many habitats
Black turnstone	*Arenaria melanocephala*					2	
Short-eared owl	*Asio flammeus*	N	CSC	grasslands, freshwater and salt marshes		5, 7, 10	
Long-eared owl	*Asio otus*	N	CSC	Riparian habitat required; also uses live oak thickets and other dense stands of trees	P	5	
Burrowing Owl	*Athene cunicularia*	N	CSC	open, dry, level grasslands, prairies, and desert floors		3, 5, 7, 8	
Lesser scaup	*Aythya affinis*			estuarine and lacustrine habitats throughout much of California		8, 11	
Greater scaup	*Aythya marila*			Napa-Sonoma salt ponds		11	
Canvasback	*Aythya valisineria*	N	HA	open water, salt marshes, brackish marshes, freshwater marshes, and lakes and ponds		2, 6, 10, 11	during 1980's, wintering population declined, then increased to 40,000
American bittern	*Botaurus lentiginosus*			fresh emergent wetlands		8, 10	
Aleutian Canada goose	*Branta canadensis leucopareia*	N	T	lakes, reservoirs, ponds, flooded fields, agricultural land		1, 9	
Great-horned owl	*Bubo virginianus*			variety of forests with meadows and other openings, extending from valley foothill hardwood to mixed conifer habitats		8	
Bufflehead	*Bucephala albeola*			coastal estuarine waters (salt ponds, lagoons, bays) and lacustrine habitats (lakes, ponds)		8, 10, 11	
Common goldeneye	*Bucephala clangula*			estuarine (bays, lagoons, and salt ponds) and lacustrine waters (usually the deeper lakes and ponds)		8, 10, 11	

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Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Red-tailed hawk	*Buteo jamaicensis*			Found in almost all habitats		8, 10	
Swainson's hawk	*Buteo swainsoni*	N	CT	riparian woodlands, oak woodland, agricultural land		5, 6	statewide population is 550, 78% in Central Valley, 9% in Delta
Green-backed heron	*Butorides striatus*			Napa-Sonoma salt ponds		8, 11	
Dunlin	*Calidris alpina*			Common on bay tideflats, on salt ponds at high tide (especially on San Francisco Bay), and along upper reaches of intertidal saline emergent wetlands		10, 11	
Red knot	*Calidris canutus*					2	
Western sandpiper	*Calidris mauri*			intertidal mudflats, rocky shore, salt marsh, brackish marsh, fresh marsh, other freshwater habitats, farmed wetlands, lakes and ponds, agricultural land		2, 6, 10, 11	475,000-700,000 in Bay during spring; most abundant shorebird in estuary
Least sandpiper	*Calidris minutilla*			from August to April along shores of aquatic habitats, in fresh and saline emergent wetlands, and wet pastures		10, 11	
California quail	*Callipepla californica*			shrub, scrub, and brush, open stages of conifer and deciduous habitats, and margins of grasslands and croplands		8, 10	
American goldfinch	*Carduelis tristis*			valley foothill riparian, chaparral		8	
House finch	*Carpodacus mexicanus*			common in valley foothill hardwood, valley foothill hardwood-conifer, and riparian habitats		8	
Great egret	*Casmerodius albus*	N	CSC	fresh, and saline emergent wetlands, along the margins of estuaries, lakes, and slow-moving streams, on mudflats and salt ponds, and in irrigated croplands and pastures		8, 10, 11	
Turkey vulture	*Cathartes aura*			open stages of most habitats that provide adequate cliffs or large trees for nesting, roosting, and resting		8, 10	
Hermit thrush	*Catharus guttatus*			chaparral species; common in mixed and montane chaparral habitats		8	
Willet	*Catoptrophorus semipalmatus*			estuarine habitats, saline emergent wetlands, intertidal mudflats, and salt ponds		10, 11	
Belted kingfisher	*Ceryle alcyon*					2	
Wrentit	*Chamaea fasciata*			chaparral habitat, shrub understory of coniferous habitats from the coast to lower regions of mountains throughout cismontane California		8, 10	
Snowy plover	*Charadrius alexandrinus*			Napa-Sonoma salt ponds		11	
Western snowy plover	*Charadrius alexandrinus nivosus*	N	T	intertidal mudflats, salt ponds, agricultural lands		1, 2, 5, 6, 10	
Semipalmated plover	*Charadrius semipalmatus*			Napa-Sonoma salt ponds		11	
Killdeer	*Charadrius vociferus*			shores of lacustrine, riverine, and, less commonly, estuarine habitats, and on nearby alkali scrub, herbaceous, and cropland habitats with low or sparse vegetation		8, 10, 11	
Lark sparrow	*Chondestes grammacus*			sparse valley foothill hardwood, valley foothill hardwood-conifer, open mixed chaparral and similar brushy habitats, and grasslands with scattered trees or shrubs		8	
Northern Harrier	*Circus cyaneus*	N	CSC	lowland marshes, meadows, grasslands, open rangelands, desert sinks, fresh and saltwater emergent wetlands		2, 5, 7, 10	
Marsh wren	*Cistothorus palustris*			Breeding is restricted to cattails, bulrushes, sedges, and other vegetation in emergent wetland habitat	P	10	

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Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Northern flicker	*Colaptes auratus*			all forest and shrub habitats		8	
Rock dove	*Columba livia*			annual grassland, perennial grassland, cropland, pasture, and urban habitats		8	
American crow	*Corvus brachyrhynochos*			valley foothill hardwood, valley foothill riparian, annual grassland, perennial grassland		8	
Common raven	*Corvus corax*			Occurs in most habitats		8	
Steller's jay	*Cyanocitta stelleri*			mountains and foothills throughout the state		8	
Black swift	*Cypseloides Niger*	N	CSC	Mount Veeder, on Sonoma County line		3	
Yellow-rumped warbler	*Dendroica coronata*			woodlands, chaparral, residential areas, even grasslands and agricultural areas where bordered by trees or shrubs		8	
California yellow warbler	*Dendroica petechia brewsteri*	N	CSC			2	
Townsend's warbler	*Dendroica townsendii*			moist, coastal oak woodlands and coniferous forests, valley foothill hardwood, closed-cone pine-cypress, redwood, and Douglas-fir habitats, and in stands of planted pines		8	
Snowy egret	*Egretta thula*	N	CSC	shores of coastal estuaries, fresh and saline emergent wetlands, ponds, slow-moving rivers, irrigation ditches, and wet fields		2, 5, 10, 11	
Black-shouldered kite	*Elanus caeruleus*			low rolling foothills and valley margins with scattered oaks; river bottomlands or marshes adjacent to deciduous woodlands		7, 10	
Horned lark	*Eremophila alpestris*					2	
Brewer's blackbird	*Euphagus cyanocephalus*			herbaceous, urban, and cropland habitats, in sparse woodlands and brushlands, and in vicinity of lacustrine and riverine habitats		8	
Merlin	*Falco columbarius*	N	CSC	open woodlands		7	
American Peregrine Falcon	*Falco peregrinus anatum*	N	CE/FP	salt marshes, brackish marshes, freshwater marshes, riparian woodlands, coastal scrub, mixed chaparral		2, 5, 6, 7, 8, 9	during the past 20 years, local population up by tenfold. 10-20 birds in estuary region
American kestrel	*Falco sparverius*			Occurs in most open habitats, in a variety of shrub and early successional forest habitats, in forest openings, and various ecotones.		8, 10	
American coot	*Fulica Americana*			fresh and saline emergent wetlands, wet grasslands, pastures, lacustrine, estuarine, cropland and urban habitats		10, 11	
Common moorhen	*Gallinula chloropus*					2	
Common loon	*Gavia immer*	N	CSC	salt marsh , brackish marsh, lakes and ponds		6, 11	1984-89: 21-83 birds in Oakland 1975-89: 10-40 birds in Marin
Saltmarsh Common Yellowthroat	*Geothlypis trichas sinuosa*	N	CSC	Along creeks and sloughs of Napa and Sonoma marshes		2, 3, 5, 7, 9	
Black-necked stilt	*Himantopus mexicanus*			intertidal mudflats, salt marshes, brackish marshes, freshwater marshes, other freshwater habitat, farmed wetlands, lakes and ponds, agricultural land		6, 10, 11	8,000-12,000 in Bay during fall; mostly in South Bay salt ponds
Cliff swallow	*Hirundo pyrrhonota*			meadows, grasslands, shrublands, pastures, croplands, open bodies of water		8	
Barn swallow	*Hirundo rustica*			Found in virtually every open habitat from coastal grassland and shrubland to mixed conifer habitats. More common at lower elevations. Usually breeds near water.		8	
Yellow-breasted chat	*Icteria virens*	N	CSC	valley foothill riparian, desert riparian habitats	P	5	
Western least bittern	*Ixobrychus exilis hesperis*	N	CSC	marshes, other freshwater bodies of water; hide in thick vegetation		5	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Dark-eyed junco	*Junco hyemalis*			valley foothill hardwood, valley foothill hardwood-conifer, and riparian habitats, as well as in closed-cone pine-cypress, montane hardwood, Douglas-fir, and redwood habitats		8	
Herring gull	*Larus argentatus*			bays, harbors, river mouths, sewage outfalls, and refuse disposal areas	P	10	
California gull	*Larus californicus*	N	CSC	open water, intertidal mudflats, rocky shores, brackish marshes, freshwater habitats, farned wetlands, salt ponds, lakes and other ponds		2, 6, 10, 11	2,221 breeding pairs in 1990
Ring-billed gull	*Larus delawarensis*			dumps, wet croplands and pastures, lacustrine and riverine habitats, and emergent wetlands		10, 11	
Glaucous-winged gull	*Larus glaucescens*			Rare inland		10, 11	
Western gull	*Larus occidentalis*			open water, intertidal mudflats, rocky shores, salt marshes, brackish marsh		2, 6, 10, 11	
Bonaparte's gull	*Larus philadephia*			open seashores, bays, emergent wetlands, salt ponds, offshore waters, and islands		10, 11	
California black rail	*Laterallus jamaicensis corturniculus*	N	CT/FP, CSC	Tolay Creek Marsh; yearlong resident of saline, brackish, and fresh emergent wetlands		1, 2, 3, 5, 7, 8, 9, 10	
Short-billed dowitcher	*Limnodromus griseus*			Napa-Sonoma salt ponds		11	
Long-billed dowitcher	*Limnodromus scolopaceus*			Napa-Sonoma salt ponds		2, F14911	
Marbled godwit	*Limosa fedoa*					2	
Marbled godwits	*Limosa fedoa*			most common on estuarine mudflats, but also occurs on sandy beaches, open shores, saline emergent wetlands, and adjacent wet upland fields		10, 11	
Acorn woodpecker	*Melanerpes formicivorus*			stands with large oaks and snags		8	
Surf scoter	*Melanitta perspicilata*					2	
Scoter	*Melanitta sp.*					8	
Song sparrow	*Melospiza melodia*			prefers riparian, fresh or saline emergent wetland, and wet meadow habitats		8, 10	
Suisun song sparrow	*Melospiza melodia maxillaris*	N	CSC	brackish water marshes	P	2, 5, 10	
Alameda song sparrow	*Melospiza melodia pusillula*	N	CSC	salt marshes		2, 6, 10	habitat stable, except at Coyote Creek
San Pablo song sparrow	*Melospiza melodia samuelis*	N	FC2, CSC	southwest of Ammo Hill at Hamilton		2, 5, 7, 9, 10	
Common merganser	*Mergus merganser*			Napa-Sonoma salt ponds		11	
Red-breasted merganser	*Mergus serrator*			coastal bays, estuaries, and along rocky inshore coastal areas		10, 11	
Long-billed curlew	*Numenius americanus*	N	CSC	intertidal mudflats, salt marshes, brackish marsh, freshwater marsh, diked marsh, other freshwater habitats, farmed wetlands, salt ponds, and lakes and ponds		5, 6, 7, 8, 11	fall population as high as 2,300; fewer in winter
Whimbrel	*Numenius phaeopus*			Napa-Sonoma salt ponds		11	
Black-crowned night heron	*Nycticorax nycticorax*	N	CSC	Feeds along the margins of lacustrine, large riverine, and fresh and saline emergent habitats and, rarely, on kelp beds in marine subtidal habitats. Nests and roosts in dense-foliaged trees and dense emergent wetlands.		2, F926, 8, 11	at least 1,500 pairs nesting; greatest number in North Bay
Ruddy duck	*Oxyura jamaicensis*			estuarine (bays, salt ponds) and lacustrine habitats, and occasionally found on marine waters near shore		2, 8, 10, 11	
Osprey	*Pandion haliatus*	N	CSC	large, fish-bearing waters, such as lakes, rivers, pools and bays		5, 7	
Titmouse	*Parus inornatus*					8	
Chestnut-backed chickadee	*Parus rufescens*			Prefers closed-cone pine-cypress, Douglas-fir, and redwood habitats, but often found in riparian, hardwood, and other habitats		8	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Savannah sparrow	*Passerculus sandwichensis*			grassland, saline emergent wetland, and wet meadow habitats		2, 8, 10	
Fox sparrow	*Passerella iliaca*			dense montane chaparral and brushy understory of other wooded, montane habitats		8	
American white pelican	*Pelecanus erythrorhynchos*			Napa-Sonoma salt ponds		2, 11	
California Brown Pelican	*Pelecanus occidentalis*	N	E	estuarine, marine subtidal, and marine pelagic waters along the California coast	P	1, 2, 5, 9	
Double-crested cormorant	*Phalacroeorax auritus*	N	CSC	open water, rocky shore, salt marsh, brackish marsh, freshwater marsh, diked marsh , salt ponds, and lakes and other ponds		2, 5, 6, 10, 11	Breeding population in Bay increasing over past 5 years; 1989-90=1,185 nesting pairs
Red-necked phalarope	*Phalaropus lobatus*			Spring migration: mainly over the open ocean; Fall migrants: more numerous and widespread inland, especially on alkaline lakes; also in coastal lagoons, bays, and estuaries the length of the state.		10, 11	
Wilson's phalarope	*Phalaropus tricolor*					2	
Wilson's phalarope	*Phalaropus tricolor*			wet meadows	P	10	
Greater flamingo	*Phoenicopterus ruber*			Napa-Sonoma salt ponds		11	
Nuttall's woodpecker	*Picoides nuttallii*			low-elevation riparian deciduous and oak habitats		8	
Downey woodpecker	*Picoides pubescens*			yearlong resident of riparian deciduous and associated hardwood and conifer habitats		8	
California towhee	*Pipilo crissalis*			open chaparral and coastal scrub, as well as brushland patches in open riparian, hardwood hardwood-conifer, cropland, and urban habitats		8, 10	
Spotted towhee	*Pipilo maculatus*					8, 10	
White-faced ibis	*Plegadis chihi*	N	CSC	fresh emergent wetland, shallow lacustrine waters, and muddy ground of wet meadows and irrigated, or flooded, pastures and croplands	P	5	
Black-bellied plover	*Pluvialis squatarola*			On the coast, forages primarily on intertidal mudflats, but also occurs on rocky intertidal and sandy-beach marine habitats, and on nearby pasture and wet meadow habitats. Away from the coast, occurs on plowed fields, short grasslands, wet meadows, and the shores of riverine, estuarine and lacustrine habitats		10, 11	
Horned grebe	*Podiceps auritus*			Napa-Sonoma salt ponds		11	
Eared grebe	*Podiceps nigricollis*			abundant on salt ponds, common to fairly common on estuarine waters		2, 10, 11	
Pied-billed grebe	*Podilymbus podiceps*			Napa-Sonoma salt ponds		11	
Purple martin	*Progne subis*	N	CSC	woodlands, low elevation coniferous forests		7	
Sora	*Prozana carolina*			Napa-Sonoma salt ponds		11	
Virginia rail	*Rallus limicola*			breeds in fresh emergent wetlands and wet meadows the length of the state. Occurs in saline emergent wetlands in the nonbreeding season, but apparently not while breeding		10, 11	
California clapper rail	*Rallus longirostris obsoletus*	N	E	Along creeks and sloughs of Napa and Sonoma marshes, salt marshes, brackish marshes		1, 2, 3, 5, 6, 7, 8, 9, 10	during past decade, population declined from 1,500 to 300-500. 90% occur in South Bay.
American avocet	*Recurvirostra Americana*			salt ponds, fresh and saline emergent wetlands, mudflat habitats		10, 11	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
Ruby-crowned kinglet	*Regulus calendula*			Abundant in winter at lower elevations throughout the state in a variety of habitats containing trees or shrubs		8	
Black phoebe	*Sayornis nigricans*			valley foothill, montane, and desert riparian habitats. Closely tied to streams, rivers, ponds, lakes, agricultural ditches, sewage ponds, bays, tidepools, almost any body of water.		8	
Western bluebird	*Sialia occidentalis*			open woodlands of oaks, riparian deciduous trees, or conifers with herbaceous understory, sparse to open-canopied, mature, valley foothill and montane hardwood and valley foothill hardwood-conifer habitats, open-canopied mature forests		8	
White-breasted nuthatch	*Sitta carolinenses*			hardwood and hardwood-conifer habitats dominated by oaks		8	
Burrowing owl	*Speotyto cunicularia hpugaea*					2	
California least tern	*Sterna antillarum browni*	N	E	open water, salt marshes, lakes and ponds		1, 2,5, 6, 9, 10	started nesting in Bay in 1967. Recent average nesting population= 74 pairs
Canada goose	*Sterna caspia*			Napa-Sonoma salt ponds		2, 11	
Forster's tern	*Sterna forsteri*			marine subtidal and estuarine waters from May to September; common to uncommon then inland at open lacustrine and riverine habitats.		2, 10, 11	
Northern Spotted Owl	*Strix Occidentalis Caurina*	N	T	Calabazas Creek area; Sonoma Mountain		3, 5	
Western meadowlark	*Sturnella neglecta*			herbaceous and cropland habitats with sufficient ground cover for concealment		8	
European starling	*Sturnus vulgaris*			common in urban, cropland, pasture, and orchard-vineyard habitats		8	
Tree swallow	*Tachycineta bicolor*			valley foothill and montane riparian habitats below 2700 m (9000 ft), lowlands near estuaries, rivers, lakes, and emergent wetlands		8	
Violet-green swallow	*Tachycineta thalassina*			most wooded habitats in the state		8	
Bewick's wren	*Thryomanes bewickii*			Principally a chaparral species; common in mixed and montane chaparral habitats.		8, 10	
Lesser yellowlegs	*Tringa flavipes*			Napa-Sonoma salt ponds		11	
Greater yellowlegs	*Tringa melanoleuca*			shallow emergent wetlands, wet meadows, borders of small pools, flooded fields, stream channels, drainage ditches, and intertidal mudflats		10, 11	
American robin	*Turdus migratorius*			Prefers open, wooded areas with moist, herbaceous understories. Common and widespread in winter throughout most lowland and foothill areas.		8	
Orange-crowned warbler	*Vermivora celata*			chaparral, coastal scrub, valley foothill hardwood, riparian		8, 10	
Mourning dove	*Zenaida macroura*			croplands, pastures and other grasslands, open chaparral, Great Basin and desert habitats, open hardwood, hardwood-conifer, riparian, and low-elevation conifer, etc.		8	
Golden-crowned sparrow	*Zonotrichia atricapilla*			moist, open brushlands, riparian thickets, and understory of open-canopied forest habitats		8	
White crowned sparrow	*Zonotrichia leucophrys*			open brushlands, in wet meadows with low shrubs, or in open, wooded habitats with understories of similar structure		8, 10	
Allen's hummingbird	*Selasphorus sasin*			coastal scrub, valley foothill hardwood, valley foothill riparian	P	10	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
California thrasher	*Toxostoma redivivum*			moderate to dense chaparral habitats and, less commonly, extensive thickets in young or open valley foothill riparian habitat	P	10	
Caspian tern	*Sterna caspia*	N	SBS	open water, brackish marsh, salt marsh , freshwater marshes, lakes and pons		6, 10	1,409 nesting pairs in 1989-90
Common yellowthroat	*Geothlypis trichas*			Mostly breeds and winters in wet meadow, fresh emergent wetland, and saline emergent wetland habitats; also breeds in valley foothill riparian, and occasionally in desert riparian, annual grassland, and perennial grassland habitats.	P	10	
Scaup	*Aythya sp.*				P	10	
MAMMALS							
Pallid bat	*Antrozous pallidus*			grasslands, shrublands, woodlands, forests from sea level up through mixed conifer forests		7	
Ringtail	*Bassariscus astutus*	N	FP	various riparian habitats, in brush stands of most forest and shrub habitats at low to middle elevations		6	
Coyote	*Canis latrans*			open brush, scrub, shrub		8, 10	
Virginia opossum	*Didelphis virginiana*			moist woodlands and brushy habitats at low elevations; riparian, wetlands		8	
Steller sea lion	*Eumetopias jubatus*	N	T		P	1	
Greater Western Mastiff-Bat	*Eumops perotis californicus*	N	CSC	crevices in cliff faces, cracks in boulders, occasionally in buildings		5, 7	
Red bat	*Lasiurus borealis*					8	
Hoary bat	*Lasiurus cinereus*			any location in California; breed in woodlands and forests with medium to large sized trees and dense foliage		8	
Black-tailed jackrabbit	*Lepus californicus*			lower elevation herbaceous areas and desert-shrub areas; open, early stages of forest and chaparral habitats	P	8, 10	
Striped skunk	*Mephitis mephitis*			grass/forb stages of most habitats; riparian areas		8	
California meadow vole	*Microtus californicus*	N				2, 8, 10	
San Pablo California Vole	*Microtus californicus sanpabloensis*	N	CSC	salt marshes and adjacent uplands of San Pablo Creek		4	
Duskey-footed woodrat	*Neotoma fuscipes*			chaparral habitats		8, 10	
Black-tailed deer	*Odocoileus hemionus columbianus*			coastal scrub	P	8, 10	
Deer mouse	*Peromyscus maniculatus*			throughout California in virtually all habitats		8, 10	
Harbor seal	*Phoca vitulina*			open water, intertidal mudflats, rocky shore, salt marsh, brackish marsh		2, 6, 10	population stable at about 300-500; more than 350 used two South Bay haulout sites in 1990
Townsend's western big-eared bat	*Plecotus townsendii townsendii*	N	CSC	most abundant in mesic habitats, found througout CA		7	
Raccoon	*Procyon lotor*			most abundant in riparian and wetland areas at low to middle elevations		8	
Western harvest mouse	*Reithrodontomys megalotis*	N		shrublands, grasslands		8	
Salt Marsh Harvest Mouse	*Reithrodontomys raviventris*	N	E	Napa and Sonoma marshes, salt marsh, diked marsh, brackish marsh		1, 2,3, 4, 6, 7, 8, 9, 10	great seasonal and annual population fluctuations
Broad-footed mole	*Scapanus latimanus*	N		perrenial grasslands, valley foothill riparian		8	
Suisun ornate shrew	*Sorex ornatus sinuosus*	N	CSC	Sears Point Rd, NW of Vallejo, salt and brackish marshes of N San Pablo Bay		2, 3, 4, 9, 10	
Gray fox	*Urocyon cinereoargenteus*	N		valley foothill riparian, shrublands, montane riparian, brush stages of many deciduous and conifer forest and woodland habitats		8, 10	
Botta's pocket gopher				coastal scrub, grass and forb stages of most riparian-deciduous forests	P	10	

Table B-2 Species List for the San Pablo Watershed

Species	Scientific Name	native/non-native*	status	habitat**	occurr.	sources	recent trends
California pocket mouse					P	10	
Mountain lion	*Felis concolor*			chaparral and broad-leaved forests			
Mule deer	*Odocoileus hemionus columbianus*	N		grasslands, chaparral, oak, and broad-leaved evergreen woodlands			
Norway rat	*Rattus norvegicus*	I		along streams and rivers, urban areas, wetlands, lower elevation riparian habitats	P	2, 10	
Roof rat	*Rattus rattus*	I				2	
Red fox	*Vulpes vulpes regalis*	I		salt marsh, brackish marsh, freshwater marsh , other freshwater habitats, coastal scrub, mixed chaparral, agricultural lands		2, 6	population increasing since arribal in Bay Area in early 1980's.
Salt Marsh wandering shrew	*Sorex vagrans haliocoetes*	N	CSC	salt marsh, diked marsh		2, 6, 10	stable, except where marsh erosion and conversion are occuring
North American river otter	*Lutra canadensis*					2	
Southern sea otter	*Enhydra lutris nereis*					2	
California sea lion	*Zalophus alifornianus*					2	
Sonoma chipmunk		N		common in open forests, chaparral, bushy clearings and streamside thickets		10	

Native or non-native*= Native= N, non-native=I

status**: T=threatened; E=endangered; 1B=Category 1B; CE=State of California Endangered; FE=federally endangered;

CT= State of California Threatened; FT=Federally Threatened; PE=proposed endangered; PT=proposed threatened; CSC= California Species of Special Concern

habitat***: *OW* :open water; *IM* : intertidal mudflat; *SM* : salt marsh; *BM* : brackish marsh; *FM* : fresh marsh; *DM* : diked marsh;

FH : other freshwater habitat; *FW* : farmed wetlands; *RW* : riparian woodland; *SP* : salt pond; *LP* : lakes and ponds;

AL : agricultural land; *CS* : coastal scrub; *BF* : broad-leaved forest; *MC* : mixed chaparral; *WS* : oak woodland

occurrence: P= the species is known to occur in the San Francisco Bay region, and relies on habitat found in the San Pablo Bay Watershed.

It is unclear, however, if the species actually occur within the San Pablo Bay Watershed.

1*:*Restoring the Estuary: An Implementation Strategy for the San Francisco Bay Joint Venture* , October 1999

2*:*Baylands Ecosystem Habitat Goals,* Goals Project 1999

3*: *Sonoma Creek Watershed Enhancement Plan* , June 1997

4*: Calfed listing, June 1999 in San Pablo bay

5*: Calfed Listing, June 1999 in Suisun Marsh/SF Bay Eco-zone

6*:*SFEP State of the Estuary*

7*:*EIR: Novato General Plan* , 1995

8*:*Stream Management Guidelines, City of Novato* , 2000

9*:*Status and Trends Report on Wetlands and Related Habitats*

10*:*Status and Trends Report on Wildlife of the San Francisco Estuary* , 1992

11*:*California Wildlife Habitat Relationships System (CWHRS)* . 2000.

12*: Leidy, R. A. 1984. Distribution and ecology of stream fishes in the San Francisco Bay drainage. Hilgardia 52:1-175.

13*: Population abundance trends from *Interagency Ecological Program for the Sacramento-San Joaquin Estuary,* 2000. Vol 13 (2).

invasive species listings found in ANS Task Force Biological Study, 1995

Appendix C
Restoration Project Information

1. Sample Project Application Form
2. Table C-1. Potential Funding Sources for Restoration Projects
3. Table C-2. Phases, Rules and Typical Timelines for Continuing Authorities (CAP) Projects
4. Table C-3. Typical Continuing Authorities Program Timelines
5. Table C-4. Typical Timeline for a General Investigation New Start Project

RESTORATION PROJECT PROPOSAL–SAMPLE APPLICATION FORM

PROJECT SPONSOR INFORMATION

Name: Organization (if any): Telephone: Email address:	Address: City: State: Zip Code:
(If there are multiple project sponsors, please fill out the above information for each co-sponsor.)	

GENERAL PROJECT INFORMATION

Name of Proposed Restoration Project: Project Location: Purpose of Proposed Project: One Paragraph Description of Proposed Project:

GENERAL PROJECT INFORMATION, continued

Describe the Benefits of the Proposed Project to the Aquatic Resources of the San Pablo Bay Watershed:

Describe How the Proposed Project Promotes Attainment of the Goals of the San Pablo Bay Watershed Restoration Program.

PROJECT COST AND TIMELINE

Estimated Project Cost:

Estimated Time for Project Completion:

PROJECT SITE OWNERSHIP INFORMATION

Is the proposed project site privately owned?

If you answered “Yes”, who is the legal owner of the property?

Is the proposed project site publicly owned?

If you answered “Yes”, what public entity has legal title to the property?

Has the owner of the proposed project site agreed to participate in the project?

PROJECT DESIGN INFORMATION

Describe how the project will be designed–who will be in charge of detailed design? How will the design be evaluated? If you plan to ask for design assistance from the Watershed Restoration Program sponsors, please indicate here that you will be making that request. (You may attach additional pages as needed.)

Do you have a plan to maintain and monitor your project after construction is complete? If so, please attach that plan to this application.

PROJECT CONSTRUCTION INFORMATION

Describe how you propose to construct the project. Who will provide construction services? If you plan to ask for construction assistance from the Watershed Restoration Program sponsors (US Army Corps of Engineers, Coastal Conservancy, The Bay Institute), please indicate here that you will be making that request.

PROJECT EVALUATION

Please describe how you plan to evaluate the outcome of your project. If you plan to ask for assistance from the Program Sponsors in evaluating the success of your project, please indicate here that you will be making that request.

PROJECT ENDORSERS

Please identify local, regional, state or national supporters / endorsers, (other than co-sponsors or co-applicants) of your project.

PROJECT OPPONENTS

Please indicate if there are any individual or organizations who oppose, or who you think might oppose, your project.

MATCHING FUNDING AND IN-KIND CONTRIBUTIONS

Matching funds or in-kind contributions are required of the project sponsor. Please list the matching funding you propose to contribute and when they will be available and / or describe the in-kind contributions you propose.

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
Farm Service Agency	Conservation Reserve Program		The Conservation Reserve Program reduces soil erosion, protects the Nation's ability to produce food and fiber, reduces sedimentation in streams and lakes, improves water quality, establishes wildlife habitat, and enhances forest and wetland resources. It encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as tame or native grasses, wildlife plantings, trees, filterstrips, or riparian buffers. Farmers receive an annual rental payment for the term of the multi-year contract. Cost-sharing is provided to establish the vegetative cover practices.	Funds may be used for annual rental payments, and for cost-share uses for resource coverage (wetlands, trees, grass coverage).	Most conservation cost-sharing activities=50% Wetlands Restoration=25%
National Marine Fisheries Service	Habitat Conservation		To provide grants and cooperative agreements for biological, economic, sociological, public policy, and other research, administration, and public education projects on the coastal environment to benefit U.S. fisheries, conserve protected resources, and add to the economic and social well being of the Nation. Projects are funded to carry out public policy pertaining to protection and restoration of the Nation's wetlands and other coastal habitats, pursuant to the Fish and Wildlife Coordination Act, Magnuson Fishery Conservation and Management Act, endangered Species Act, Marine Mammal Protection Act	Funds can be used by recipients to support a wide variety of research, construction, management, and public education activities for marine and estuarine habitats, especially for species currently under or proposed for, future Federal or Interjurisdictional management.	Up to 100% of project costs
National Parks Service	Outdoor Recreation: Acquisition, Development, and Planning		Also called Land and Water Conservation Fund (LCWF) Grants, this program provides financial assistance to States and their political subdivisions for the preparation of Statewide Comprehensive Outdoor Recreation Plans (SCORPs) and acquisition and development of outdoor recreation areas and facilities for the general public, to meet current and future needs.	Acquisition and development grants may be used for a wide range of outdoor recreation projects, such as picnic areas, inner city parks, campgrounds, tennis courts, boat launching ramps, bike trails, outdoor swimming pools, and support facilities such as roads, water supply, etc. Facilities must be open to the general public and not limited to special groups. Development of basic rather than elaborate facilities is favored. Fund monies are not available for the operation and maintenance of facilities. Grants are also available to States only for revising and updating existing SCORPs, preparation of new plans and for statewide surveys, technical studies, data collection and analysis and other planning purposes which are clearly related to SCORP refinement and improvement.	
Natural Resources Conservation Service	Environmental Quality Incentives Program (EQIP)		The purposes of the EQIP program are achieved through the implementation of a conservation plan which includes financial, educational and technical assistance to implement structural, vegetative, and land management practices on eligible land. Five-to ten-year contracts are made with eligible producers.	Funds are limited to technical, educational, and financial assistance.	Variable cost-sharing up to 75%

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
Natural Resources Conservation Service	Wildlife Habitat Incentives Program (WHIP)		The WHIP provides financial and technical assistance to develop habitat for fish and wildlife on private lands.	Funds are to be used for wildlife development. Participants who own or control land agree to prepare and implement a wildlife habitat development plan. The NRCS provides technical and financial assistance for the establishments of wildlife habitat development practices. In addition, if the landowner agrees, cooperating State wildlife agencies and non-profit or private organizations may provide expertise or additional funding to help complete a project.	All projects 50%
Natural Resources Conservation Service	Wetlands Reserve Program		The Wetlands Reserve Program is a voluntary land-retirement program created in the 1990 Farm Bill to assist owners of eligible lands in restoring and protecting wetlands.	To purchase easements and implement restoration cost-share practices on easement and agreement lands. To complete needed reality and administrative processes.	Permanent easements=100% 20-year easements=75% 10-year cost-share agreements=75%
Natural Resources Conservation Service	Soil and Water Conservation		To plan and carry out a national natural resource conservation program, and to provide leadership in conservation, development, and productive use of the nation's soil, water, and related natural resources.	Technical assistance to the general public in planning and applying natural resource conservation practices and treatment; and furnishing technical natural resource conservation information to State and local governments.	
Natural Resources Conservation Service	Watershed Protection and Flood Prevention		Provide technical and financial assistance in carrying out works of improvements to protect, develop, and utilize the land and water resources in small watersheds.	Technical assistance is provided in designing, and installing watershed works of improvement. Financial assistance is provided for sharing costs of measures for watershed protection, flood prevention, agricultural water management, sedimentation control, public water based fish, wildlife recreation; and in extending long term credit to help local interests with their share of the costs.	

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
Natural Resources Conservation Service	Watersheds Surveys and Planning		Provide planning assistance to Federal, State, and local agencies for the development of coordinated water and related land resources programs in watersheds and river basins. Special priority is given to the objective of setting priorities in helping to solve problems of upstream rural community flooding, water quality improvement coming from agricultural nonpoint sources, wetland preservation and drought management for agricultural and rural communities. Special emphasis is given to assisting communities which desire to adopt floodplain management regulations to meet the requirements of the National Flood Insurance Program and State agencies in developing a strategic water resource plan.	Technical assistance is provided to sponsoring organizations for planning activities to help solve water and related land resources problems. It is available through disciplines such as engineering, economics, social sciences, agronomy, range management, forestry, biology, hydrology, archaeology, landscape architecture, waste management, recreation, etc.	
Natural Resources Conservation Service	Watershed Protection and Flood Prevention		Also called the Small Watershed Program, or PL-566 Operations Phase, the program provides technical and financial assistance in carrying out works of improvements to protect, develop, and utilize the land and water resources in small watersheds.	Technical assistance is provided in designing, and installing watershed works of improvement. Financial assistance is provided for sharing costs of measures for watershed protection, flood prevention, agricultural water management, sedimentation control, public water based fish, wildlife, recreation; and in extending long term credit to help local interests with their share of the costs. Watershed area must not exceed 250,000 acres. Capacity of a single structure is limited to 25,000 acre-feet of total capacity and 12,500 acre-feet of floodwater detention capacity.	100% for flood prevention 50% for agricultural water management, public recreation, and fish and wildlife purposes
U.S. Fish and Wildlife Service	Coastal Wetlands Planning, Protection, & Restoration Act		To grant funds to coastal States to carry out coastal wetlands conservation projects. This Program is also referred to National Coastal Wetlands Conservation Grants.	Funds are used for acquisition of interests in coastal lands or waters, and for restoration, enhancement or management of coastal wetlands ecosystems on a competitive basis with all coastal States. Must provide for long term conservation of such lands or waters and the hydrology, water quality and fish and wildlife dependent thereon.	No cost sharing information found for this program
US Army Corps of Engineers	Section 219 Environmental Infrastructure	Stockton East Water District is authorized	Provide assistance to state and local entities to improve water-related environmental infrastructure projects, including wastewater treatment facilities, water supply, storage, treatment and distribution facilities.	Funds may be used to carry out technical, design and planning activities for water-related environmental infrastructure projects.	

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
US Army Corps of Engineers	Section 503 Watershed Management, Restoration, and Development		Provide technical, planning and design assistance to non-Federal interests carrying out watershed management, restoration and development projects at a variety of locations specifically cited in statutory language (see Program Background for listing).	Funds may be used for the following purposes: 1) management of water quality; 2) remediation of toxic sediments; 3) restoration of degraded waterways to their natural condition as a means to control flooding, erosion, and sedimentation; and 4) restoration of watersheds, including urban watersheds; and, 5) demonstration of technologies for nonstructural measures to reduce destructive impacts of flooding.	
US Army Corps of Engineers	Flood Mitigation and Riverine Restoration Program (Section 212)		This program is also referred to as "Challenge 21" and its purpose is to reduce flood hazards and restore the natural functions and values of rivers throughout the United States.	Funds may be used for local flood damage reduction, riverine and wetland restoration studies with projects that conserve, restore, and manage hydrologic and hydraulic regimes and restore the natural functions and values of flood plains. The studies shall emphasize, to the maximum extent practicable and appropriate, nonstructural approaches to preventing or reducing flood damages.	65%
US Army Corps of Engineers	Aquatic Ecosystem Restoration		This program is intended to fund aquatic ecosystem restoration projects that will improve the quality of the environment, are in the public interest and are cost-effective.	Funds may be used by the non-Federal sponsor for construction, provision of all lands, easements, rights-of-way and necessary relocations.	All projects=65%
US Army Corps of Engineers	Section 204 Beneficial Uses of Environmental Dredging		The purpose of the program is to support the removal of contaminated sediments from navigable waters of the United States for the purposes of environmental enhancement and water quality improvement, if such removal is requested by a non-Federal sponsor and the sponsor agrees to pay 50 percent of the cost of such removal.	Funds may be used for studies, construction, right-of-way acquisition, and other costs associated with the dredging project.	All projects=75%
US Army Corps of Engineers	Section 1135 Project Modifications for Improvement of the Environment		The purpose of the program is to provide for acquisition of wetlands previously affected by an Army Corps project and for environmental restoration by modifying existing structures or operations of a permanent project constructed by the Corps.	Funds may be used for studies, construction, right-of-way acquisition, and other costs associated with the restoration of areas that have been adversely impacted by water resource projects.	All projects=75%

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
US Army Corps of Engineers	Construction of Flood Control Projects by Non-Federal Interests (Section 211)		The purpose of this program, authorized in Section 211of the Water Resources Development Act of 1996, Public Law 104-303, is twofold. First, the program provides a mechanism for non-Federal interests to prepare their own studies and design documents for the construction of a flood control project and have the Corps of Engineers Review the documents and serve as the bvasis for a favorable recommendation for federal participation n the project and congressional authorization for funding. Once authorized by Congress, the program provides the mechanisma for the non-Federal sponsor to construct a flood control project and be reimbursed later by the Federal Government, once appropriations have been approved. Second, the program provides the mechanism for the planning, design and construction of flood control projects by non-Federal sponsors prior to the completion fo a feasibility study, a favorable recommendation by the Chief of Engineers and approval of that recommendation by the Secretary of the Army, without jeopardizing Federal participation in the funding of the project.	Funds appropriated pursuant to this authority can be used to reimburse the non-Federal sponsor for the cost of construction, and, in the case of those projects specifically referenced in the statutory language, the cost of all studies, planning, design and construction.	First $100,000 for planning=100% Feasibility Phase=50% (Not more than half of the non-Federal share can be satisfied by the provision of services, materials, supplies or other in-kind services necessary to prepare the feasibility study.) Pre-construction engineering & design=75% Construction=75%
			In fact, for eight projects specified in the Act, a favorable recommendation by the Chief of Engineers and approval of the project by the Secretary is all that is required for the non-Federal sponsor to be eligible to recieve reimbursements for the Federal share of the project through teh appropriations process. For these eight demonstration projects, congressional suthorication fo the flood control project, a process that usually delays initiation of construction by at least a year, is not required in order to be eligble for reimbursement.		
US Environmental Protection Agency	Environmental Programs and Management (EPM)		This program is made up of Congressional earmarks, or projects that are specifically requested by Members of Congress and included in the annual EPA funding bill. It can include a wide range of infrastructure projects and there are no explicit rules made by Congress as to the type of projects that may be funded under this program.	Funds may be used for any number of activities, including planning, design and construction. Despite the fact that all EPM projects are eligible for 95% federal funding, we encourage clients to indicate a willingness to cost-share all projects on a dollar-for-dollar basis. No limit on in-kind contributions.	All Projects=95%

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
US Environmental Protection Agency	Sustainable Development Challenge Grants		The purpose of this program is to (1) catalyze community-based regional projects that promote sustainable development, thereby improving environmental quality and economic prosperity; (2) leverage significant private and public investments to enhance environmental quality by enabling community sustainability efforts to continue past EPA funding; (3) build partnerships that increase a community's long-term capacity to protect the environment through sustainable development; and (4) enhance EPA's ability to provide assistance to communities and promote sustainable development, through lesson learned.	For the purposes outlined in statutes. Also see Program Purpose.	80%
US Environmental Protection Agency	Wetlands Protection Development Grants		Funds may be used for a broad range of watershed-related purposes that fall under the following priorities that EPA has listed: 1. Wetland/Watershed Protection Approach Demonstration Projects, which are projects that address watershed protection in a comprehensive, integrated manner. 2. River Corridor and Wetland Restoration Projects--examples of projects funded under this category are wetland mitigation banking programs and pilot projects for demonstrating the benefits of using dredged materials in wetlands restoration.To support the development or enhancement of state and tribal wetlands protection programs. Under a special set-aside, EPA will also fund certain local wetlands protection projects.	Funds may be used for a broad range of watershed-related purposes that fall under the following priorities that EPA has listed: 1. Wetland/Watershed Protection Approach Demonstration Projects, which are projects that address watershed protection in a comprehensive, integrated manner. 2. River Corridor and Wetland Restoration Projects--examples of projects funded under this category are wetland mitigation banking programs and pilot projects for demonstrating the benefits of using dredged materials in wetlands restoration.	
National Oceanic and Atmospheric Administration	Community-Based Habitat Restoration (CPR) Program		The purpose of the program is to implement grass-roots projects to restore fish habitat. CPR seeks to encourage collaboration among different levels of government, public and private agencies and organizations, businesses, and academic institutions.	Eligible projects must involve local citizens in efforts to restore marine, estuarine, and anadromous fish habitat. Eligibility: State, local and tribal governments, public and private agencies, and organizations. The grant is intended to provide seed money, rather than funding an entire project. Funding: $500,000 to fund all projects.	There is a minimum 50 percent match required. The match may include in-kind goods and services.
National Fish and Wildlife Foundation (NFWF)	National Fish and Wildlife Foundation Challenge Grant		The purpose of the grant program is to stimulate private, state, and local funding for conservation efforts. The Foundation's funding priorities are: * Habitat protection and restoration on private lands; * Sustainable communities through preservation; * Conservation education.	The Foundation will not support political outreach or advocacy, administrative overhead, basic research, multi-year grants, or shortfalls in government agency budgets. Eligibility: Federal, state, and local governments, educational institutions, and nonprofit organizations. Funding: Individual awards range from $25,000 to $75,000.	A few grants have been awarded over 150,000. There is a 1:1 non-federal match required.

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
California Coastal Conservancy	Bay Area Conservancy Program	Contact the State Coastal Conservancy at 510-286-1015. Website: http://www.coastalconservancy.ca.gov.	The Conservancy has grant funding for the acquisition, restoration and enhancement of significant coastal and Bay Resource and habitat lands. Grants are also available for the preparation of plans for the enhancement and restoration of wetlands, dunes, rivers, streams, and watersheds. State and local agencies and non-profits may apply.		
CALFED Bay-Delta Program	Bay-Delta Program	Call Rebecca Fauver at 916-654-1334 for more information. CALFED Bay-Delta Program, 1416 Ninth Street, Suite 1155, Sacramento, CA 95814. Website: http://calfed.ca.gov/programs.html	This program is comprised of both state and federal agencies that have been charged with finding a solution to the long-standing water wars in the Delta. Ecosystem restoration is a major component of the program and over $100 million has been allocated to date. Projects and programs must be within the Bay Delta and it's tributary watersheds, and local, state and federal agencies, non-profits and individuals are eligible to apply. Future RFPs will be released in January. A wide range of grant amounts have been allocated, from a few thousand to millions.		

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
California Department of Transportation	Transportation Enhancement Activities Program	Contact: Marsha Mason, Caltrans TEA Office, 1120 N Street, Sacramento, 95814, 916-654-5275 or your local regional transportation planning agency. Website: http://www.dot.ca.gov/hq/TransEnhAct	The federal Transportation Equity Act for the 21st Century (TEA-21) extends the life and intent of ISTEA through 2003, including the requirement that states spend a minimum of 10% of their Surface Transportation Program funds on "transportation enhancements" or conservation-related projects such as the acquisition of scenic lands, easements, and historic sites, construction of bicycle trails, removal of outdoor advertising, and archeological/historic preservation. Eligible projects must relate to a transportation facility and be above and beyond normal transportation projects or mitigation. California's TEA funds are separated into four pots, with the bulk of the funding available through regional transportation planning agencies. Local, state, and federal agencies are eligible to receive funding; non-profits are encouraged to submit joint applications. Application deadlines vary.		Non-federal matching funds are required.
Wildlife Conservation Board (WCB)	Inland Wetlands Conservation Program and Riparian Habitat Conservation Program		WCB acquires and restores wildlife habitat throughout California. WCB also manages the Inland Wetlands Program for the acquisition and restoration of wetlands in the Central Valley and the Riparian Habitat Conservation Program that focuses on protecting and restoring riparian systems throughout the state. For more information on available funding, contact Marilyn Cundiff-Gee (Inland Wetlands) or Scott Clemons (Riparian) at 916-445-8448. Website about WCB: http://ceres.ca.gov/wetalnds.agencues/wcb.html		
California Farmlands Conservancy Program	The CA Farmlands Conservancy Program (formerly the Agricultural Land Stewardship Program)		Provides long-term protection of farmland through grants to for the purchase of agricultural conservation easements, fee title acquisition projects, policy/planning projects and land improvement projects. Local agencies and non-profits are eligible to apply. Contact: Charles Tyson, Program Coordinator, Office of Land Conservation, 801 K Street, MS 13-71, Sacramento CA 95814. 916-324-0862. Website: http://www.consrv.ca.gov/dlrp/CFCP		

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
California Resources Agency	Environmental Enhancement and Mitigation Program (EEM)		Established in 1989, the EEM Program requires the state to spend an additional $10 million a year over a 10- year period from FY 1991-92 to FY 2000-01 beyond what is legally required to mitigate the effects of transportation facility development. Grants are available for projects that mitigate, directly or indirectly, the environmental impacts of transportation facilities. This program awards funds in the following three categories: Highway Landscape and Urban Forestry, Resource Lands, and Roadside Recreation. Local, state, or federal agency, non-profit organizations, or public/private partnership are eligible to apply. Requests are generally limited to $250,000. No matching funds are required, although matching funds greatly strengthen your application. Contact: Bill Borden, California Resources Agency, 1416 Ninth Street, Room 1311, Sacramento, 95814, 916-653-5656. For more information about the Resources agency, CERES Website: http://ceres.ca.gov/cra/		
California Department of Parks and Recreation	Habitat Conservation Fund		A grant program for local public agencies for the acquisition and restoration of wildlife habitats and significant natural areas. Eligible projects include acquisition/restoration of deer/mountain lion, rare, threatened and endangered species, wetlands, riparian, anadromous fish and trout habitat and urban trail/wildlife corridor projects. Contact Odel King at 916-653-8758, California Department of Parks and Recreation; PO Box 942896; Sacramento, 94296-0007. Website: http://www.cal-parks.ca.go/grants/HCF.htm		
State Water Resources Control Board (SWRCB)	Nonpoint Source & Water Quality Planning Programs		SWRCB offers funding (grants and loans) for projects that improve or protect water quality that is impaired or threatened by non-point source pollution through the NPS section of the SWRCB. State and local agencies and non-profits may apply. For more information, contact Paul Roggensack (loans to address water quality associated with discharges and estuary enhancement) at 916-657-0673, Paul Lillebo [205(j) planning grants] at 916-657-1031, or Lauma Jurkevics [319(h) implementation grants] at 916-657-0518. Website: http://www.swrcb.ca.gov/nps/grants.html		
Department of Fish and Game (DFG)	Fines		DFG collects fine monies for fish and game code violations. County fish and game committees typically administer these funds. Contact your local Fish and Game office for information.		
Caltrans	Mitigation		Caltrans frequently looks for wetlands projects that can be used to mitigate approved highway projects. Contact your local Caltrans office.		

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
Local cities, counties, and recreation and park districts	General Obligation Bonds		Cities, counties, and recreation and park districts have authority to issue bonds for park and open space purposes. If approved, bonds and the interest they incur are re-paid through an increase in property taxes. Current law requires passage by a 2/3 vote - bonds issued to fund specific, popular projects are more likely to be approved.		
Local cities, counties, and recreation and park districts	Assessments		An assessment may also be referred to as a "special" or "benefit" assessment, and involves the levying of a charge on property owners to provide financing for public improvements. A Landscaping and Lighting Act Assessment District is specifically designed to fund landscaping, street lighting, and open space acquisition/improvement projects. For example, Proposition KK approved by voters in 1994, created a landscaping and lighting assessment district in Eastern Contra Costa County that is used by the East Bay Regional Park District and its municipal partners to fund open space and trail improvements in this portion of the Park District.		
Local Park Districts	Park acquisition		Many local or regional park districts are actively involved in acquiring and restoring wetland and riparian habitat. For more information, contact your local park district office.		
Flood Control Districts	Wetland acquisition		The acquisition and restoration of wetlands is increasingly recognized as providing both environmental and flood control benefits. Contact your local district to determine if funds are available.		
San Francisco Bay Regional Water Quality Control Board	Administrative Civil Liability fines		The Regional Board makes an effort to direct Administrative Civil Liability fines to local projects. For more information, contact Will Bruns at 510-622-2327 or Carol Thornton at 510-622-2419.		
San Francisco Foundation	Wetland research and restoration grants program		The SF Foundation has a newly established grants program to support wetland research and restoration projects in the SF Bay and its surrounding watersheds. The focus is on those projects that improve water quality or reduce pollution. For more information, call Jane Rogers at 415-733-8517. Website: http://www.sff.org		
Ducks Unlimited	Grants and Technical Assistance		Ducks Unlimited (DU) provides technical assistance, matching funds and help in securing grants for the completion of wetland habitat restoration projects on both public and private land. Call the Western Regional Office of DU at 916-852-2000. Website: http://www.caldu.com		

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
Packard Foundation	Conserving CA Landscapes Initiative		Packard Foundation: The foundation's Conserving CA Landscapes Initiatives funds habitat protection and watershed projects in the Central Valley, Sierra, and Central Coast. For more information and grant guidelines, call 650-948-7658. Website: http://www.packard.org		
Conservation Fund	American Greenways Awards/Grants		The Conservation Fund provides small grants to local organizations to support greenways' planning and development. Contact: Kevin Houlihan, Coordinator, The Conservation Fund, 1800 No. Kent St., Ste. 1120, Arlington, VA 22209; tel: 703-525-6300. Website: http://www.conservationfund.org.		
U.S. Fish and Wildlife Service	North American Wetlands Conservation Act (NAWCA)		NAWCA provides federal funds specifically to "conserve North American wetland ecosystems and waterfowl and the other migratory birds and fish and wildlife that depend on such habitats." (PL 101-233) Eligible projects include acquisition and restoration of wetlands, among other activities. Proposals are accepted twice a year in April and August and require a 50/50 nonfederal match. A small grants program is also available with a May deadline. Contact: US Fish & Wildlife Service, 703-358-1711. Website: http://northamerican.fws.gov/granpro.html		
U.S. Congress Appropriations	Land and Water Conservation Fund (LWCF)		LWCF is composed primarily of revenue from outer-continental shelf leases and royalties. Although the authorized level of funding annually is $900 million, Congress appropriates much less for the acquisition of land for conservation by the U.S. Forest Service, Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and the U.S. Forest Service. Contact your Congressional representative or regional office of any of the federal agencies for more specific information. Website: http://www.ahrinfo.org/		
U.S. Department of Agriculture, Natural Resource Conservation Service	Wetlands Reserve Program (WRP)		Funds are available through the U.S. Department of Agriculture, Natural Resource Conservation Service for the acquisition of conservation easements on agricultural lands. Both permanent and 30-year easements can be purchased under the WRP, with priority given to projects that maximize wildlife values. Contact: Alan Forkey, Wetlands Biologist, 530-792-5653 or Anita Brown, State Information Officer 530-792-5644. Website: http://www.wl.fb-net.org/ca.htm		
Army Corps of Engineers	Section 206		Section 206 funds provide for the restoration of aquatic ecosystem structure and function. Projects usually include the manipulation of the hydrology in and along bodies of water, including wetlands and riparian areas. No relationship to an existing Corps project is required. Contact Guy Brown at 916-557-5270.		

Table C-1
Potential Funding Sources for Aquatic Restoration Projects

Agency	Program	Notes	Program Purpose	Use of Funds	Cost Share
Environmental Protection Agency	Various grants		Various grants in the range of $25,000-$350,000 are available through the EPA for watershed planning, restoration and stewardship studies for state, tribal and local governments. Grants are also available for Environmental justice issues, Pollution prevention, Brownfields assessment, Community/Economic development and Environmental education. Their public information line is 415-744-1500 and may be reached at Environmental Protection Agency, Region 9; 75 Hawthorne Street; San Francisco, CA 94105. Website: http://www.epa.gov/epahome/grants.htm		
The River Network	Watershed Assistance Grants (WAG)		The River Network allocated funding to build capacity of existing or new watershed partnerships to protect and restore their watersheds. Website: www.rivernetwork.org.		
U.S. Fish and Wildlife Service	Partners for Fish & Wildlife Program		The U.S. Fish and Wildlife Service offers cost-share programs to restore and enhance wildlife habitats on private and enhance wetlands on private land. For more information, call 916-414-6446. Website: http://partners.fws.gov/index.htm		
The Bureau of Land Management (BLM)	Land Exchange Program		The Bureau of Land Management (BLM) seeks to preserve wildlife habitat and provide improved public access through this exchange program. The BLM exchanges public land for prime private wildlife habitat based on fair market value of lands. Private landholders and land trusts are eligible applicants. Contact: Dave McIllnay, 2800 Cottage Way, Suite West-1834, Sacramento, CA 95825-1886, 916-978-4671. Website: http://pub4.ca.blm.gov/caso/landsales.html		
Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service	Pacific Coastal Salmon Recovery Fund (part of the Lands Legacy Initiative)		This program is designed to enhance the recovery of threatened and endangered coastal salmon by providing assistance in the conservation of Pacific salmon runs at risk of extinction in the western states of California, Oregon, Washington, and Alaska.	These funds will be used to enhance the recovery of threatened and endangered coastal salmon by providing Federal funds to help share the costs of conservation actions by tribes, States and local communities.	Of these funds, those provided to coastal tribes do not require matching funds, while those provided to States have a 25 percent matching fund requirement.

<table>
<tr><th colspan="13">TABLE C-2: Phases, Rules and Typical Timelines for Continuing Authorities (CAP) Projects</th></tr>
<tr><th>Authority</th><th colspan="12">(Note: Sponsor provides lands, easements, rights-of-way, relocations (LERRDs) under each authority. Credit for LERRDs counts toward sponsor cost share. The sponsor is also responsible for operation and maintenance costs. Construction seasons may be dependent on in-water work windows.)</th></tr>
<tr><td>Section 14
Emergency Streambank Protection</td><td colspan="6">Planning & Design Analysis
- 1st $40K full Fed, anything over is cost shared 65/35
- Fed up-front financed, Sponsor costs recouped at time of construction
- Up to 12 months</td><td colspan="6">Construction
- Cost shared 65/35 (at least 5% in cash)
- Project Cooperation Agreement (PCA) must be executed by Govt. and Sponsor before construction begins.
- No in-kind credits
- 1 to 2 seasons</td></tr>
<tr><td>Section 208
Snagging and Clearing for Flood Control</td><td colspan="6">Planning & Design Analysis
- 1st $40K full Fed, anything over is cost shared 65/35
- Fed up-front financed, Sponsor costs recouped at time of construction
- Up to 12 months-</td><td colspan="6">Construction
- Cost shared 65/35 (at least 5% in cash)
- Project Cooperation Agreement (PCA) must be executed by Govt. and Sponsor before construction begins.
- No in-kind credits
- 1 to 2 seasons</td></tr>
<tr><td>Section 205
Flood Damage Protection</td><td colspan="4">Feasibility Study
- Initial $20K Federal funds to determine Fed interest
- Additional $80K Federal funds for feasibility
- Any amount > is cost shared 50/50 with Sponsor through Feasibility Study Cost Share Agreement (FCSA). Up to 25% can be in-kind
- 12-16 months typical</td><td colspan="4">Plans & Specs
- Cost shared 65/35
- Minimum sponsor cash contribution of 5%
- Fed up-front financed
- Sponsor costs recouped at time of construction (No in-kind)
- 6 months typical</td><td colspan="4">Construction
- Cost shared 65/35
- Project Cooperation Agreement (PCA) must be executed by Govt. and Sponsor before construction begins. (No in-kind)
- 1 to 2 seasons</td></tr>
<tr><td>Section 1135
Modifications for Improvement of the Environment</td><td colspan="3">Preliminary Restoration Plan (PRP)
- Full Federal cost not to exceed $10,000
- 2 to 6 months</td><td colspan="3">Feasibility Study Ecosystem Restoration Report
- Cost shared 75/25
- Fed up-front financed, Sponsor costs recouped at time of construction
- 12 months</td><td colspan="3">Plans & Specs
- Cost shared 75/25
- Fed up-front financed
- Sponsor costs recouped at time of construction
- 6 months</td><td colspan="3">Construction
- Cost shared 75/25
- Govt. and sponsor execute PCA before construction begins
- 80% of cost share can be in-kind. PCA must be executed to get credit for in-kind
- (1 to 2 seasons)</td></tr>
<tr><td>Section 206
Aquatic Ecosystem Restoration</td><td colspan="3">Preliminary Restoration Plan (PRP)
- Full Federal cost not to exceed $10,000
- 2 to 6 months</td><td colspan="3">Feasibility Study Ecosystem Restoration Report
- Cost shared 75/25
- Fed up-front financed, Sponsor costs recouped at time of construction
- 12 months</td><td colspan="3">Plans & Specs
- Cost shared 65/35
- Fed up-front financed,
- Sponsor costs recouped at time of construction
- 6 months</td><td colspan="3">Construction
- Cost shared 65/35
- Govt. and sponsor execute PCA before construction begins
- 100% of cost share can be in-kind. PCA must be executed to get credit for in-kind
- 1 to 2 seasons</td></tr>
</table>

Source: (USACE 2000b)

TABLE C-3: Typical Continuing Authorities Program Timelines (Months)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Section 14	**Planning & Design Analysis (PDA) (12 months)**											**Construction (1 to 2 seasons)**																									
Section 208	**Planning & Design Analysis (PDA) (12 months)**											**Construction (1 to 2 seasons)**																									
Section 205	**Feasibility Study** (If > $100K, Project Study Plan – PSP is required) **(12 to 16 months)**															**Plans & Specs (6 months)**						**Construction (1 to 2 seasons)**															
Section 1135	**Preliminary Restoration Plan (PRP) (2 to 6 months)**					**Feasibility Study/ Ecosystem Restoration Report (ERR)* (12 months)**												**Plans & Specs (6 months)**						**Construction (1 to 2 seasons)**													
Section 206	**Preliminary Restoration Plan (PRP) (2 to 6 months)**					**Feasibility Study Ecosystem Restoration Report (ERR)* (12 months)**												**Plans & Specs (6 months)**						**Construction (1 to 2 seasons)**													

*For Section 1135 and 206, projects with an estimated Federal share of $300,00 or less do not have separate Feasibility and Plans and Specifications phases. The formulation, analysis, justification and design tasks as well as NEPA coordination/ environmental compliance documentation take place in the one-step planning and design process (approximately 12 months).

Source: (USACE 2000b)

TABLE C-4: Typical Timeline for a General Investigation New Start Project Upon Receipt of First Federal Funds

Reconnaissance Phase	Feasibility Phase	Preliminary Engineering & Design (PED)	Construction
- Full Federal cost of $100K - Identifies Project Study Plan and cost share responsibilities for Sponsor - 9 to 12 months	- Cost share with Sponsor 50/50 - Avg. cost $700K to $1.5 million, up to 25% can be in-kind - 1 to 3 years	- Cost share with Sponsor: 65% Federal, 35% non-Federal for Ecosystem Restoration - 1 to 2 years	- Cost share with Sponsor: 65% Federal, 35% non-Federal for Ecosystem Restoration - Time varies

Source: (USACE 2000b)

Appendix D
Conceptual Restoration Plans
For Pilot Projects

Projects

1. Las Gallinas Creek and Tidal Salt Marsh Restoration Concepts
2. Pinole Creek Restoration Concepts
3. American Canyon Creek and Wetland Restoration Concepts

SAN PABLO BAY WATERSHED RESTORATION PROGRAM
LAS GALLINAS CREEK AND TIDAL SALT MARSH
RESTORATION CONCEPTS

Prepared by:

H.T. HARVEY & ASSOCIATES

Daniel Stephens, Principal, Senior Restoration Ecologist
Eric Webb, Ph.D., Senior Restoration Ecologist
Patrick Reynolds, Project Manager, M.S., Senior Restoration Ecologist
Regine Castelli, M.S., Restoration Ecologist

Prepared for:

Ginger Strong
Camp Dresser & McKee Inc.
2151 River Plaza Drive, Suite 200
Sacramento, California 95833

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

The San Pablo Watershed Restoration Program is designed to assist landowners in the restoration and enhancement of agricultural lands and wildlife habitat in San Pablo Bay. The Las Gallinas Creek project area is one of three pilot restoration projects in the San Pablo Watershed for which restoration concepts are being developed. Implementation of these pilot restoration projects will provide examples of the type of land stewardship activities that promote sustainable living in the watershed. This report also provides an example of the type of restoration projects that could potentially receive funding from the Watershed Restoration Funding Program and other sources.

1.2 SITE DESCRIPTION

The Las Gallinas Creek tidal salt marsh project site is located in John McInnis Park, Marin County, California (Figures 1 and 2). The project site consists of approximately 146 acres of diked wetlands and ruderal habitat. It is bordered by a system of levees upon which a complex of trails have been developed. Beyond the levees lie Las Gallinas Creek to the south, tidal marsh and San Pablo Bay to the east, water treatment ponds to the north, a golf park center, airport, and the north fork of Las Gallinas Creek to the west.

The site consists of two different topographic areas: a highly subsided diked salt marsh and a former dredged material disposal site. The northern half and southernmost portions of the project site have substantially subsided due to the construction of levees and dewatering of the site. The center portion of the project area has been filled with dredged materials and is at an elevation that supports upland habitat (Figure 2).

The Las Gallinas Creek tidal salt marsh project site currently consists of two habitat types: diked salt marsh and ruderal. The diked salt marsh habitat type is dominated by pickleweed (*Salicornia virginica*) of low to moderate health and vigor. Also present are California cordgrass (*Spartina foliosa*), alkali bulrush (*Scirpus maritimus*), salt grass (*Distichlis spicata*), gumplant (*Grindelia* sp.), and spearscale (*Atriplex triangularis*). Some non-vegetated salt pannes were present within the diked salt marsh. The ruderal habitat was dominated by native and non-native species including Italian ryegrass (*Lolium multiflorum*), foxtail barley (*Hordeum jubatum*), prickly lettuce (*Lactuca cerriola*), brass buttons (*Cotula coronopifolia*), pickleweed, and rabbitfoot grass (*Polypogon monspliensis*).

Habitat restoration concepts were developed for the Las Gallinas Creek site based on a reconnaissance level site visit. General restoration concepts that could be implemented to improve existing habitat functions and values are presented in this report. This report also includes a list of additional studies required prior to or concurrent with preparation of a detailed habitat restoration plan.

Figure 1
Las Gallinas Creek
Project Site Vicinity Map

2.0 REVIEW OF AVAILABLE INFORMATION

2.1 EXISTING DATA

No known reports were available for the Las Gallinas Creek tidal salt marsh restoration site. It is believed that, at one time, Marin County intended to create lagoons at the site. The central portion of the project site has been used for dredged material disposal while the northern half and the southernmost portions have subsided as a result of levee construction that precludes tidal inundation of the site and dewatering as a result of the use of a water control structure.

3.0 HABITAT RESTORATION GOALS AND OBJECTIVES

The goal for the Las Gallinas Creek project is to restore the site to self-sustainable, fully tidal salt marsh habitat dominated by native vegetation.

The Las Gallinas Creek project has the following objectives;

1. Establish high quality tidal salt marsh dominated by native species;

2. Enhance the habitat functions and values of Los Gallinas Creek and San Pablo Bay;

3. Create and enhance habitat for special-status species including the salt marsh harvest mouse (*Reithrodontomys raviventris*) and California Clapper Rail (*Rallus longirostris obsoletus*); and

4. Create a salt marsh-upland ecotone dominated by native grasses and salt-tolerant forbs.

4.0 RESTORATION OPPORTUNITIES AND CONSTRAINTS

4.1 PHYSICAL FACTORS

Opportunities. The physical conditions at the project site provide an excellent opportunity for tidal salt marsh restoration. Key estuarine ecological processes (e.g. tidal energy, sedimentation, nutrient exchange) can easily be restored by increasing the connectivity to Los Gallinas Creek and San Pablo Bay. Furthermore, estuarine sedimentation processes can be used to restore the marshplain.

Constraints. The foremost physical constraints to habitat restoration at the Las Gallinas Creek tidal salt marsh restoration project site are the existing elevations. In particular, the diked salt marsh is highly subsided while the dredged material disposal area is substantially elevated relative to adjacent tidal marsh habitat. Unsuitable elevations limit tidal marsh restoration potential since cordgrass and pickelweed establish within narrow elevational ranges relative to the tides. To overcome the elevational constraints, on-site dry dredged material could be used in conjunction with imported dredged material to create areas with suitable elevations for native salt marsh vegetation establishment.

Dredged material availability and quality may be limiting to restoration. Stockpiled dredged materials, such as those in the central portion of the project site, may become acidic when exposed to air as a result of the transformation of iron sulfides to sulfuric acid (H.T. Harvey & Associates 1997, Lynn 1964). Acidic soils may limit native plant establishment. Additionally, dredged spoils often lack adequate amounts of organic matter and are nutrient poor. Dredged materials can also contain contaminants making them unsuitable for habitat restoration. Thus, any dredged materials proposed for the site must be analyzed prior to use. It must also meet or surpass the guidelines established by the San Francisco Bay Regional Water Quality Control Board (2000).

Alterations of existing hydrology to implement the tidal marsh restoration may affect drainage patterns on adjacent lands. The restoration plan should carefully model the altered hydrology to avoid any impacts to sensitive habitats and/or reduce existing flood protection.

4.2 BIOLOGICAL FACTORS

Opportunities. This project site offers a remarkable opportunity to restore a considerable expanse of a valued and relatively rare habitat type. It is expected that wildlife and biota from the adjacent tidal salt marshes will migrate to and colonize the restored area soon after completion of project site construction.

Constraints. Few biological constraints exist to habitat restoration at the project site. Of primary concern is the potential temporal loss of salt marsh harvest mouse habitat. In the process of restoration implementation, the existing pickleweed within the diked salt habitat will be lost. This loss, however, will be more than mitigated through the eventual creation of much higher quality tidal salt marsh habitat dominated by dense pickleweed. Additionally, other special-status plant and wildlife species could be impacted as a result of implementation of the proposed habitat restoration. Further data review and field surveys will be required to determine which, if any, special-status species may occur on the project site and how they would be affected by the habitat restoration.

The project site contains seasonal wetlands and perhaps some tributary waters. Wetlands and tributary waters are under the jurisdiction of the U.S. Army Corps of Engineers (USACE). Impacts to USACE jurisdictional habitat the habitat restoration proposed in this report should more than mitigate for any impacts associated with implementation of the recommended restoration concepts. It should be noted that little if any long-term impacts are likely to occur as a result of the proposed habitat restoration.

The airport west of the project site and its flight path are an additional constraint. It is essential that the habitat restoration proposed not attract concentrations of waterfowl beyond those that are currently present. Substantial increases in bird use could potentially increase air strike hazards. In particular, measures should be taken to ensure that the project site is not dominated by open water habitat that will attract large numbers of waterfowl. However, it should be noted that bird strikes to aircraft at airports adjacent to open water and wetland habitats are rare. Only 13 bird strikes have been recorded at San Francisco Bay Airports since 1988 and the majority of these reports are from San Jose International which does not have an approach over aquatic habitats.

5.0 POTENTIAL RESTORATION ALTERNATIVES

Suitable restoration alternatives for the Las Gallinas Creek tidal salt marsh restoration project site are described below. These alternatives are based upon the physical and biological constraints and opportunities (see Section 4).

Alternative 1. This is a no-project/no-action alternative under which no restoration measures would be initiated and the site would remain in its existing condition. It would perpetuate the site's limited biological values and compromised hydrology, but would not impact the hydrology of adjacent lands.

Alternative 2. This alternative includes breaching the primary levee adjacent to Las Gallinas Creek and the secondary levee on the bayside of the project site at one or more locations to create a fully tidal marsh system (Figure 2). Possible breach locations include the existing flap gate adjacent to Las Gallinas Creek and/or along levees in the central portion of the site.

The subsided portions of the site will be initially dominated by open water habitat upon exposure to tidal action. The portion of the project site used for dredged disposal will not be affected by tidal action and therefore, will remain as upland ruderal habitat. Initially, sediments will rapidly accumulate throughout the subsided portions of the project site. The sediment deposition rate is expected to decrease with time as the project site elevation increases and the tidal prism decreases. Eventually, the site elevation will reach mean tidal level and cordgrass will naturally establish. The site will continue to accumulate sediment and, once the elevation exceeds mean high water level, pickleweed will begin to colonize the site. Ultimately, the site would become a pickleweed dominated tidal salt marsh.

Alternative 3. This alternative is similar to Alternative 2 in that it includes breaching the primary levee adjacent to the Las Gallinas Creek channel as well as the secondary levee on the bayside of the project site at one or more locations to create a fully tidal system that connects to existing tidal channels. However, Alternative 3 also includes relocating the on-site dry dredged material and importing off-site dredged material to those areas that have subsided prior to breaching the levees. This would bring the entire site to the elevation that would allow for cordgrass establishment (between mean tidal level and mean high water). In addition, low gradient transition zones (minimum 50:1 slope) between the tidal salt marsh and the adjacent uplands would be created where appropriate to reestablish a tidal marsh-upland ecotone, a rare habitat in San Pablo Bay.

Cordgrass would be planted after site elevations are modified and before the area is opened to tidal action. Planted and naturally recruited cordgrass will establish rapidly after the site is opened to the tides. The site will begin to accumulate tidally imported sediments and increase in elevation immediately after the levees are breached. As the site evolves through time, pickleweed will begin to naturally recruit on site. Eventually, the site will reach an equilibrium and should support a tidal salt marsh dominated by

SAN PABLO BAY WATERSHED RESTORATION PLAN
LAS GALLINAS CREEK AND TIDAL SALT MARSH
RESTORATION CONCEPTS

Link to Figure 2 (930 Kb)

Las Gallinas Creek Tidal Marsh
Restoration Site Plan

pickleweed. As with Alternative 2, the tidal prism for Alternative 3 will decrease with increasing elevation. Therefore, the sediment deposition rate is expected to decrease with time as the site evolves.

Alternative 3 would produce the target cordgrass and pickleweed habitats more quickly than Alternatives 1 or 2 due to the mechanical transport of dredged material and cordgrass plantings at the onset of the project. This alternative would also reduce the air strike hazard associated with Alternative 2 since the design would not produce expansive areas of open water that would attract waterfowl. Alternative 3 would be the most expensive of the alternatives to implement due to the transport of dredged material and extensive grading and revegetation efforts required. Conversely, this alternative would provide the highest biological value in the shortest period of time.

Recommended Alternative. Given the restoration options provided above, the recommended alternative is #3. This alternative would provide high quality, sustainable tidal salt marsh habitat in a relatively short period of time, and reduce the potential air strike hazard associated with Alternative 2.

6.0 CONCEPTUAL RESTORATION DESIGN: RECOMMENDED ALTERNATIVE

Based upon the recommended alternative (see Section 5.0) and the existing site constraints (see Section 4.0), the following discussion outlines the conceptual restoration design for the recommended alternative. Figure 2 shows the area considered for habitat restoration in plan view and Figure 3 shows it in cross-section.

Prior to restoration implementation, a geo-rectified aerial photograph should be taken of the site and existing habitats mapped. This photo will serve to document the baseline conditions of the site and will be compared to subsequent photos to track habitat development.

Non-native species such as Atlantic cordgrass (*Spartina alterniflora),* dense-flowered cordgrass (*Spartina densiflora),* and peppergrass (*Lepidium latifolium*) should be eradicated from the site and adjacent marshes and waterways before restoration implementation. Non-native species eradication will also need to be a part of the long-term management of the site. This will help to prevent colonization of the site by non-native species. It will also reduce competition with non-natives and accelerate restoration of native salt marsh habitat.

The on-site dry dredged material and any imported dredged material should be analyzed to determine if it is appropriate for habitat restoration. The dredged material should be tested for substances including hydrocarbons, pesticides, and heavy metals prior to use. It is essential that the materials meet or exceed the sediment screening criteria guidelines established by the San Francisco Bay Regional Water Quality Control Board (2000). The dredged material should also undergo a standard bioassay and textural analysis to confirm that it is suitable for use in tidal marsh habitat restoration.

A hydrologic study and topographic survey of the site should be conducted to determine the elevation of tidal ranges adjacent to the site. Once the mean tide level (MTL) and mean high water (MHW) elevations are determined, a site design should be developed that will specify the amount of material to be spread throughout the subsided portions of the project site. The on-site dry dredged material should be excavated to an elevation in which cordgrass can establish. If off-site dredged material is applied as a slurry, time should be allowed for the material to decant prior to grading and planting. The rate of draining can vary depending on several factors including the water content of the material used, the depth and texture of material applied, and the site's physical characteristics. Once all material is dry, it should be graded to an elevation between MTL and MHW (Figure 3). Gently sloped transition zones (minimum 50:1 slope) should be created between the tidal salt marsh and the adjacent uplands where appropriate. Soil amendments will be incorporated into the top six inches of soils if necessary to ameliorate acidity and improve fertility as appropriate. This will encourage plant establishment and help secure restoration success.

SAN PABLO BAY WATERSHED RESTORATION PLAN
LAS GALLINAS CREEK AND TIDAL SALT MARSH
RESTORATION CONCEPTS

Link to Figure 3 (41 Kb)

Las Gallinas Creek Tidal Marsh
Restoration Site Cross-Section

Cordgrass will be installed throughout the site where the elevation is between MTL and MHW. Plantings will be installed at regular intervals using container stock from locally obtained seeds and propagules. Approximately 20 plants per acre will be installed. It is expected that cordgrass will reproduce rapidly by vegetative means and will colonize most of the site within two to three growing seasons. Native forbs and grasses will be installed along the salt marsh-upland ecotone using container stock and a hydroseed slurry of locally obtained seeds and propagules. Likewise, these species are expected to quickly colonize the transition areas. Table 1 lists the species to be planted at the project site and their appropriate locations.

Table 1. Potential Species to be Planted and Their Locations at the Las Gallinas Creek Tidal Salt Marsh Restoration Site.

Plant Species		Mean Tidal Level to Mean High Water	Lower Ecotone	Upper Ecotone
Common Name	**Scientific Name**			
Alkali heath	*Frankenia salina*		X	
Big salt bush	*Atriplex lentiformis*			X
Cordgrass	*Spartina foliosa*	X		
Coyote brush	*Baccharis pilularis*			X
Marsh gumplant	*Grindelia stricta*		X	
Meadow barley	*Hordeum brachyantherum* var. **Salt**		X	X
Pickleweed	*Salicornia virginica*		X	
Pt. Molate Fescue	*Festuca rubra**		X	X
Salt grass	*Distichlis spicata*		X	X
Tufted hairgrass	*Deschampsia cespitosa cespitosa*		X	X

* Salt tolerant variety

Both the primary and secondary levees shown in Figure 2 will be breached within two weeks of plant installations. A minimum of one breach is required for effective restoration, however, multiple breaches are ideal since increased tidal action will expedite the natural restoration processes. The recommended breach locations include the existing flap gate adjacent to Las Gallinas Creek, the area between the dredged disposal site and Las Gallinas Creek, and the bay side levee where tidal channels exist. Erosion and scouring within the restoration site and adjacent areas is expected upon levee breaching due to friction associated with tidal hydrology. It is anticipated that this will decrease with time as the restoration site and adjacent areas evolve.

A 3-year long maintenance program including dead plant replacement, hand weeding around the plantings, non-native plant species control, trash removal, noting any herbivory or vandalism. Tracking maintenance activities should commence once site construction and plant installation is complete.

Within eight weeks of completing site construction, an as-built plan should be written detailing any deviations from the final restoration design plans. A long-term monitoring program for the project site should begin thereafter to ensure that the restoration site is well on its way toward meeting the success criteria. In Years 1-3 of the monitoring program, a geo-rectified aerial photograph should be taken of the site and the habitats mapped. Site hydrology and rate of aggradation should be monitored at multiple points using staff gauges and sedimentation gauges, respectively. Each breach point should be visually inspected on a regular basis to record any unusual sedimentation or erosion. Percent cover by plant species (native and non-native) should be annually monitored to assess habitat development.

Annual management recommendations should be made based upon the monitoring results. Recommendations should focus on adapting management efforts to produce a high quality, self-sustaining tidal salt marsh throughout the Las Gallinas Creek site.

7.0 ADDITIONAL STUDIES

It is necessary that all physical and biological aspects of the project site be well understood prior to developing a detailed design for the tidal marsh restoration efforts. The following describes the additional studies needed in order to gain a better understanding of the project site.

1. Hydraulic Analysis. The existing and predicted hydrology and sediment transport of the project site and the adjacent areas should be evaluated in detail to assess the potential affects of restoration on local hydrology and geomorphology. Flood control and drainage are of particular hydrologic concern while erosion and scour are of geomorphic concern.

2. Soil Analysis. Once a source of dredged material is located, a detailed study of the chemical, physical, and biological characteristics of the dredged material should be completed prior to the restoration design. If the on-site or dredged material is not suitable for restoration purposes alternative measures will have to be developed to overcome the elevational constraints at the project site.

3. Regulated Habitats and Special-Status Species. Impacts to regulated habitats and special-status species will have to be evaluated as part of the permit application process. A wetland delineation will be required to determine what, if any, impacts will occur to areas that fall under the jurisdiction of the U.S. Army Corps of Engineers. In addition, surveys will be required to determine the potential impacts to special-status species. Based on these evaluations, permits may be required for the project along with consultations with the resource agencies.

4. Bird strike potential should be studied to determine if the restoration design would increase bird strike hazard.

These studies should be completed by qualified professionals and peer reviewed to ensure their validity. Upon completion of the studies, it will be possible to accurately assess the site dynamics and how to best integrate them to the desired habitat restoration concepts.

8.0 LITERATURE CITED

H.T. Harvey & Associates. 1997. Concord Naval Weapons Station Remedial Action Subsites 1-4: Year 2 Revegetation Monitoring Report. 68 pp.

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SAN PABLO BAY WATERSHED RESTORATION PROGRAM
PINOLE CREEK RESTORATION CONCEPTS

Prepared by:

H.T. Harvey & Associates

Dan Stephens, Principal
Eric Webb, Sr. Restoration Ecologist
Patrick Reynolds, M.S., Project Manager
Regine Castelli, M.S., Restoration Ecologist

Prepared for:

Ginger Strong
Camp Dresser & McKee Inc.
2151 River Plaza Drive, Suite 200
Sacramento, CA 95833

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

The San Pablo Bay Watershed Restoration Restoration Program is designed to assist landowners in restoration and enhancement of agricultural lands and wildlife habitat in San Pablo Bay. The Pinole Creek project area is one of three pilot restoration projects sites in the San Pablo Watershed for which restoration concepts are being developed. Implementation of these pilot restoration projects will provide examples of the type of land stewardship activities that promote sustainable living in the Watershed. This report also provides an example of the type of restoration projects that could potentially receive funding from the Watershed Restoration Funding Program and other sources.

1.2 SITE DESCRIPTION

The Pinole Creek project site is located along Pinole Creek in Contra Costa County, California. The project area is a one-mile reach of Pinole Creek located between Interstate 80 and San Pablo Bay (Figures 1 and 2). It includes the existing stream channel bed and banks Pinole Creek has a 20-foot wide access roads along the tops of both banks (Capen and Tobias 1999). Beyond each access road, the site is bordered by a mosaic of private land (residential homes and trailer park) and public land (roads, Collins School field, Fernandez Park, and bridges).

The Pinole Creek project site currently supports three habitat types: woody riparian, tidal marsh, and ruderal. Woody riparian habitat is found mainly in the middle project reach and is dominated by willow (*Salix* sp.) and California black walnut (*Juglans californica* var. *hindsii*) trees. Some coast live oak (*Quercus agrifolia*) saplings are also present. Tidal marsh (mainly salt marsh) occupies a relatively small area within the downstream quarter of the project site and is dominated by pickleweed (*Salicornia virginica*), saltgrass (*Distichlis spicata*), and Pacific gumplant (*Grindelia stricta*). Ruderal habitat occupies the majority of the streambanks throughout the project area and is dominated by non-native grasses and forbs including wild oats (*Avena* sp.) and yellow starthistle (*Centaurea solistitialis*).

Habitat restoration concepts were developed for the Pinole Creek site based on a reconnaissance level site visit and review of a proposed restoration plan for the site (Capen and Tobias 1999). This report presents general concepts that could be implemented at the site to improve the functions and values of the existing habitat. It also includes a list of studies that will be required prior to or concurrent with preparation of a detailed habitat restoration plan.

Figure 1
Pinole Creek
Project Site Vicinity Map

SAN PABLO BAY WATERSHED RESTORATION PROGRAM:
PINOLE CREEK RESTORATION CONCEPTS

Link to Figure 2 (1.3 Mb)

Pinole Creek
Restoration Site Plan

2.0 REVIEW OF AVAILABLE INFORMATION

2.1 EXISTING DATA

There is limited available data for the Pinole Creek project site, however, a 1999 report by Capen and Tobias assessed the existing conditions, discussed the potential constraints to riparian habitat restoration, and proposed a restoration schematic plan. The authors assumed that the access roads adjacent to Pinole Creek were available for habitat restoration. Prior to any specific restoration design efforts, the Contra Costa County Flood Control Agency would need to be consulted to ensure that this is, in fact, the case.

The Capen and Tobias report summarized the existing physical conditions at the project site by examining historical photographs and determining the location of infrastructure developments and available open space (defined as the area between the flood access roads and adjacent buildings or roads). The authors also analyzed the Pinole Creek channel capacity (hydraulic radius, slope, velocity, discharge, and 100-year water level) and various channel geometry designs. Based on the data collected, the report proposed a restoration schematic plan and cross-sections that focused on grading down the existing streambanks to create wider floodplains for flood flow conveyance and revegetation using woody riparian species.

The Capen and Tobias report provides an adequate base for developing a conceptual restoration design, however, the report failed to properly address the following issues. In the opinion of Mitch Avelon of the Contra Costa Country Flood Control District, the roughness coefficient used to calculate the stream discharge and 100-year water level was incorrect (Capen and Tobias 1999). As written in the report addendum, Avelon stated a roughness coefficient of 0.55, not 0.45, most accurately reflects a meandering creek that contains live vegetation and coarse woody debris. It is important that all hydrologic modeling accurately characterize the site conditions since a change in roughness will alter the predicted 100-year water levels that, in turn, could substantially affect the project site restoration design. A second element not discussed in sufficient detail is the degree of tidal influence along the lower quarter of the project site. Capen and Tobias proposed riparian revegetation throughout the entire project corridor. This is inappropriate since higher interstitial soil salinities within the zone of tidal influence can severely limit the establishment of riparian vegetation. In this downstream quarter of the project site, it is more appropriate to establish tidal marsh vegetation in the channel and adjacent floodplain. Further upslope and along the top of bank above high tide, riparian vegetation would likely establish. Lastly in Appendix 3, Capen and Tobias suggested planting northern California black walnut (*Juglans californica* var. *hindsii*) trees along the upper bank and top of bank areas. Although this species is native to California it is not native to riparian ecosystems within the project area. Therefore, it should be excluded from the habitat restoration planting plan.

3.0. RESTORATION GOALS AND OBJECTIVES

The goal for the Pinole Creek restoration project is to establish riparian and tidal marsh vegetation in appropriate locations along Pinole Creek without worsening flood hazard or risk. The Pinole Creek Restoration Project has the following objectives:

1. Establish native riparian vegetation upstream of the zone of tidal influence and above the high tide line within the zone of tidal influence.

2. Restore tidal salt marsh vegetation with the zone of tidal influence.

3. Enhance habitat function and values along Pinole Creek.

4. Provide additional habitat for special-status species (e.g. salt marsh harvest mouse) as appropriate.

5. Maintain flood capacity within Pinole Creek so flood hazard or risk is not increased.

4.0. RESTORATION OPPORTUNITIES AND CONSTRAINTS

4.1 PHYSICAL FACTORS

Opportunities. Site hydrology, in particular flow volume, appears to be perennial throughout the project reach and able to support a mix of riparian and tidal marsh vegetation. Also, soils within the upper and middle portions of the project area appear to be suitable for riparian plant establishment based upon the presence of the existing riparian vegetation. Habitat restoration could also reduce flood hazard risks if done in conjunction with expansion of the creek's floodplains. These restoration activities could also improve water quality by increasing the volume of water the flows through vegetation.

Constraints. The potential for riparian and tidal marsh habitat restoration at the project site is limited by several physical factors. If riparian vegetation is established within Pinole Creek bed and banks, channel roughness will increase thus intensifying stream flow resistance. Increased stream flow resistance will cause elevated surface water levels and subsequent greater flood hazards. Creation of new habitat could also impede channel maintenance activities. For these reasons, any restoration revegetation plan must incorporate means to offset the increased flood potential through expansion of the site's floodplains.

Due to the tidal influence of San Pablo Bay, site soils, surface flows, and groundwater may be unusually saline. Elevated salinity levels in soil and/or water can substantially decrease the potential to establish riparian vegetation. Therefore, caution should be exercised when determining the species to be established and their respective locations.

The lands adjacent to the project reach are both privately and publicly held. In order to complete habitat restoration and accommodate flood flows it may be necessary to acquire portions of these properties to increase the floodplain width. Habitat restoration may be limited by landowner willingness to sell their property and costs associated with purchase of these properties. In addition, existing infrastructure within the project area including access roads on the top of banks, culverts, and bridges limit the habitat restoration opportunities. In some cases, it may not be possible to remove or relocate the infrastructure within the project area.

4.2 BIOLOGICAL FACTORS

Constraints. Invasive exotic plant species such as yellow star-thistle are present throughout the project site. Invasive species could aggressively colonize disturbed areas and potentially outcompete native plant species. The occurrence of jurisdictional habitats within the project site may also limit habitat restoration. The U.S. Army Corps of Engineers (USACE) jurisdictional habitat includes wetlands and tributary waters while California Department of Fish and Game (CDFG) jurisdictional habitat includes streambeds and banks. Both USACE and CDFG jurisdictional habitats exist within the

Pinole Creek project site. In general, permanent impacts to USACE and CDFG jurisdictional area must be mitigated for. The habitat restoration proposed in this report should more than mitigate for any impacts associated with implementation of the recommended restoration concepts.

There may also be constraints related to potentially occurring special status wildlife species, particularly fishes and amphibians that utilize aquatic habitat. Further data review and field surveys would be required to determine which, if any, special status wildlife species may occur within the project reaches. The species' population sizes, potential to breed within the reaches, seasonal movement patterns, etc. would all need to be assessed to determine potential impacts.

Opportunities. The Pinole Creek site provides several biological opportunities. These opportunities include:

1. Restoration and enhancement of several acres of riparian and wetland habitat

2. Restoration of riparian/tidal salt marsh ecotone

3. Enhance and/or create habitat for special status species

4. Create additional recreational aesthetic benefits

5. Manage non-native, invasive plant species in Pinole Creek.

5.0 POTENTIAL RESTORATION ALTERNATIVES

Due to the physical and biological constraints (see Section 4.0), restoration opportunities at the Pinole Creek project site are somewhat restricted. Three potential restoration alternatives were selected for further evaluation and are described below.

Alternative 1. This is a no-project/no action alternative that would entail leaving the site as is. This would result in continued low habitat value, high flood hazard and continued maintenance within the channel. There are no ongoing direct expenses associated with the Alternative 1, however, recurring flood events would likely result in damage and subsequent costly repairs to both private and public lands.

Alternative 2. This alternative involves excavating the streambanks within the existing project site to create a wider (up to 60 feet) floodplain. This would allow for the creek to form meander bends and to transport higher volumes of flow. Native riparian and tidal marsh vegetation would be established in appropriate locations along the recreated channel, floodplain, streambanks, and top of banks. Alternative 2 would moderately increase habitat values and could decrease the site's flood hazard. However in the course of lowering the streambanks, steeper post-construction banks would be created. Ideally, post-construction slopes would be no steeper than 3:1. Such slopes would help to maximize vegetation establishment and restoration success. However, 3:1 slopes may not be possible due to limited area available. If this is the case, streambanks as steep as 2:1 could be created and limited riparian vegetation could be established on their slopes. Alternative 2 would incur moderate costs associated with grading and disposal of soil, and possible infrastructure protection and soil stabilization measures.

Alternative 3. This alternative focuses on acquiring key properties adjacent to Pinole Creek to establish a wider floodplain (>60 feet) and gently sloped streambanks (minimum 4:1). A corridor such as this would permit the creek to form high amplitude meander bends within the floodplain as well as transport and retain high flows within the creek bed and banks. The recreated channel, floodplain and streambanks as well as the top of banks would be planted with native riparian and/or tidal marsh vegetation depending on the location. Alternative 3 offers the highest habitat value and the lowest flood hazard of those alternatives listed here. Nevertheless, this alternative involves tremendous costs since adjacent lands would need to be acquired and extensive grading, soil disposal, and possible infrastructure protection and soil stabilization measures would be required.

Recommended Alternative. Based on the above options and their advantages and disadvantages, the recommended alternative is #2. This alternative is the most feasible and cost-effective choice for improving flood flow conveyance while concurrently improving habitat values at a somewhat reasonable cost.

6.0 CONCEPTUAL RESTORATION DESIGN: RECOMMENDED ALTERNATIVE (#2)

The following discussion is based upon the concepts presented for the recommended alternative (see Section 5). The area considered for habitat restoration is shown in plan view on Figure 2.

Streambank excavation is the initial step required to create a wider (0-60 feet) floodplain along Pinole Creek. A typical cross-section of the restored reach is shown in Figure 3. The grading design should take into account the predicted 100-year flood flow discharge in combination with the proposed planting plan. This will ensure that the floodplain is graded to a sufficient width and depth to accommodate flood flows while simultaneously supporting riparian and tidal marsh vegetation. It should be noted that space constraints will be the most significant limiting factor in determining the size of the enlarged floodplain. Removal of one of the flood access roads that border the creek should be considered to provide space to widen the creeks channel. Removal of flood access roads would require negotiations with the local flood control agencies to ensure that these could be removed without increasing the site's flood hazard.

Depending on the predicted hydrology and proposed channel configuration, it may be necessary to relocate or protect existing infrastructure developments to prevent excessive streambed scour and debris jams. Infrastructure relocation and protection could include increasing culvert size, removing portions of the flood access road(s), and construction of floodwalls along the top of the bank. In addition, soil stabilization measures may be necessary in susceptible areas along Pinole Creek such as meander bends subject to scour (e.g., the steep hillside across from Collins School).

Soil physical and chemical analyses should be completed prior to developing a detailed restoration planting plan. Of particular interest are the soil texture, macro- and micronutrient status, and salinity concentration. If necessary, amendments (e.g., organic matter or gypsum) will be incorporated into the site's soils prior to establishing riparian and tidal marsh vegetation.

A detailed riparian and tidal marsh planting plan should be developed based upon the project site constraints, surface and shallow subsurface hydrology, and soil characteristics. For each species to be planted, the relative abundance, planting location, on-center spacing, and container size should be determined by a qualified restoration ecologist. Potential riparian species to be planted and their locations are listed below in Table 1. All riparian plantings should receive supplemental irrigation for the first 2-3 years to encourage plant establishment and assure that the success criteria are met.

Since it is expected that tidal marsh species will naturally recruit and colonize the project site, plantings are not necessary. However, if desired, limited tidal marsh starter plantings could be installed to expedite the revegetation process. These plantings should be concentrated in the channel and adjacent floodplain of the lower quarter of the project site.

Table 1. Potential Riparian Species to be Planted and Their Locations at the Pinole Creek Restoration Site.

Plant Species		Channel	Floodplain	Lower Bank	Upper Bank	Top of Bank
Common Name	**Scientific Name**					
Arroyo willow	*Salix lasiolepis*		X	X		
Big leaf maple	*Acer macrophyllum*			X	X	X
Blue elderberry	*Sambucus mexicana*				X	X
Box elder	*Acer negundo*				X	X
California bay	*Umbellaria californica*			X	X	X
California bulrush	*Scirpus californicus*	X				
Coast live oak	*Quercus agrifolia*			X	X	X
Common tule	*Scirpus acutus*	X				
Coyote brush	*Baccharis pilularis*				X	X
Fremont cottonwood	*Populus fremontii*		X	X		
Mugwort	*Artemisia douglasiana*		X	X		
Oregon ash	*Fraxinus latifolia*			X	X	
Pacific blackberry	*Rubus californicus*		X	X	X	X
Red willow	*Salix laevigata*		X	X		
Snowberry	*Symphoricarpos albus*			X	X	
Valley oak	*Quercus lobata*			X	X	X
Western sycamore	*Platanus racemosa*		X	X	X	X
White alder	*Alnus rhombifolia*		X			
Yellow willow	*Salix lasiandra*		X	X		

A 3-year long maintenance program should commence once site construction and plant installation is complete. Regular maintenance activities should include dead plant replacement, hand weeding around the planting basins, controlling invasive exotic plant species, repairing the irrigation system, removing trash, noting any herbivory or vandalism, and tracking maintenance activities.

A long-term monitoring program should be initiated following site construction and plant installation. An as-built plan should be written within eight weeks of site completion. This plan should detail any deviations from the final habitat restoration plans. The project site should be monitored annually for a minimum of five years to ensure that the site is well on its way toward developing high quality riparian and tidal marsh habitat.

Annual monitoring should include establishing permanent transects in random locations throughout the site. Along the permanent transects plant survival, percent cover by species, tree height, plant health and vigor, and natural recruitment should be assessed. A qualified restoration ecologist should complete all monitoring. Permanent photo points should also be established throughout the site. Photos should be taken annually and following any unusual events (e.g., flooding or vandalism) from these fixed points. In addition, a series of permanent channel cross-sections should be established throughout the creek corridor and surveyed annually to note changes in channel geometry.

Annual management recommendations should be made based upon the yearly monitoring results. Recommendations should focus on adapting management efforts to produce high quality, self-sustaining riparian and tidal marsh vegetation throughout the Pinole Creek site.

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PINOLE CREEK RESTORATION CONCEPTS

Link to Figure 3 (217 Kb)

Pinole Creek Restoration Site:
Typical Post-Construction Cross Section

7.0 ADDITIONAL STUDIES

The Pinole Creek site offers many potential opportunities for habitat restoration and enhancement. However, prior to implementation of a specific restoration design, additional studies will need to be undertaken to understand the physical, biological, and financial limitations present at the site. These studies include:

1. Additional Hydraulic Analysis. Revising the stream flow calculations by Capen and Tobias (1999) using the suggested roughness coefficient of 0.55 for the upstream three quarters of the project site. A smaller roughness coefficient should be used for calculations relating to the downstream quarter of the project site due to the shift from riparian to tidal marsh vegetation (assumed to be less resistant). Precise discharge calculations will help to determine the appropriate combination of stream bank downcutting and revegetation needed to retain flood flows and increase habitat values within the channel bed and banks. Results should be reviewed by a qualified hydrologist to confirm their accuracy.

2. Soils. Soil physical and chemical analyses, including interstitial soil salinities, should also be completed prior to formulating a habitat restoration design. The soil analyses will help to better understand the site's suitability to support riparian and tidal marsh vegetation.

3. Sediment Transports. Sediment transport should be evaluated prior to site design to determine if the project reach is experiencing unusual geomorphic activity (e.g. bank erosion, channel incision, aggradation, etc.) that may affect habitat restoration success. Results of this study will be used to assess the need to include bank stabilization measures and stream channel restoration into the overall restoration design for the project.

4. Landowner Liaison. Landowners along the site will have to be contacted to determine those who are willing and/or interested in implementing habitat restoration on their lands.

5. Regulated Habitats and Special-Status Species. Impacts to regulated habitats and special-status species will have to be evaluated as part of the permit application process. A wetland delineation will be required to determine what, if any, impacts will occur to areas that fall under the jurisdiction of the U.S. Army Corps of Engineers. In addition, surveys will be required to determine the potential impacts that could occur to special-status species. Based on these evaluations, permits may be required for the project along with consultations with the resource agencies.

6. Cost Analysis. An implementation cost-analysis should be conducted to assist in determining if the benefits derived from the habitat restoration exceed its costs.

7. Vegetation Maintenance Review. Current vegetation maintenance activities along Pinole Creek should be determined. Following restoration, vegetation removal and control should be discontinued to the extent possible. The effect of the change in maintenance activities will need to be addressed.

8.0 LITERATURE CITED

Capen, Heather and Jacob Tobias. 1999. Pinole Creek Restoration Potential: An Assessment and Schematic Plan. Department of Landscape Architecture, University of California, Berkeley. 51 pages

SAN PABLO BAY WATERSHED RESTORATION PROGRAM
AMERICAN CANYON CREEK AND
WETLAND RESTORATION
CONCEPTS

Prepared by:

H.T. HARVEY & ASSOCIATES

Daniel Stephens, Principal, Senior Restoration Ecologist
Eric Webb, Ph.D., Senior Restoration Ecologist
Patrick Reynolds, M.S., Project Manager, Senior Restoration Ecologist
Max Busnardo, M.S., Restoration Ecologist

Prepared for:

Ginger Strong
Camp Dresser & McKee Inc.
2151 River Plaza Drive, Suite 200
Sacramento, California 95833

September 26, 2000 Project # 1855-01

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

The San Pablo Bay Watershed Restoration Restoration Program is designed to assist landowners in the restoration and enhancement of agricultural lands and wildlife habitat in San Pablo Bay. American Canyan Creek project area is one of three pilot restoration projects in the San Pablo Watershed for which restoration concepts are being developed. Implementation of these pilot restoration projects will provide examples of the type of land stewardship activities that promote sustainable living in the Watershed. This report also provides an example of the type of restoration projects that could potentially receive funding from the Watershed Restoration Funding Program and other sources.

1.2 SITE DESCRIPTION

The project area was delineated by a preliminary restoration plan prepared by the U. S. Army Corps of Engineers (USACE 2000). The project area is located in the City of American Canyon and in unincorporated areas of Napa County, California. It is bordered by salt evaporation ponds to the north, residential development to the south, the Napa River to the west and the City of American Canyon to the east (Figure 1). A large diked marsh situated west of the City of American Canyon comprises the majority of the approximately 1190-acre restoration area. This diked marsh is labeled as Marsh Restoration Areas A, B and C in Figure 2. Although originally part of an extensive network of tidal salt marshes and sloughs within the Napa River estuary, levees currently separate the majority of the marsh from the Napa River tidal system. The project area also includes the lower reaches of three main tributaries that flow into this marsh; American Canyon Creek, Walsh Creek and Little North Slough (Figure 2). The tributaries have been impacted by removal of riparian vegetation, realignment and channelization, farming/ranching practices and urban encroachment.

The City of American Canyon in collaboration with the California Department of Fish and Game (CDFG) has obtained a CALFED grant to design and implement the restoration of tidal salt marsh habitat in the majority of Marsh Restoration Areas A and B (Wankum 2000, pers. comm.)(Figure 2). The following plan includes restoration concepts for Areas A and B even though restoration of these areas is currently funded separately. A description of these restoration concepts for Areas A and B is still relevant since one purpose of this document is to provide examples of habitat restoration opportunities and constraints typically encountered at aquatic restoration sites in the San Pablo Bay Watershed.

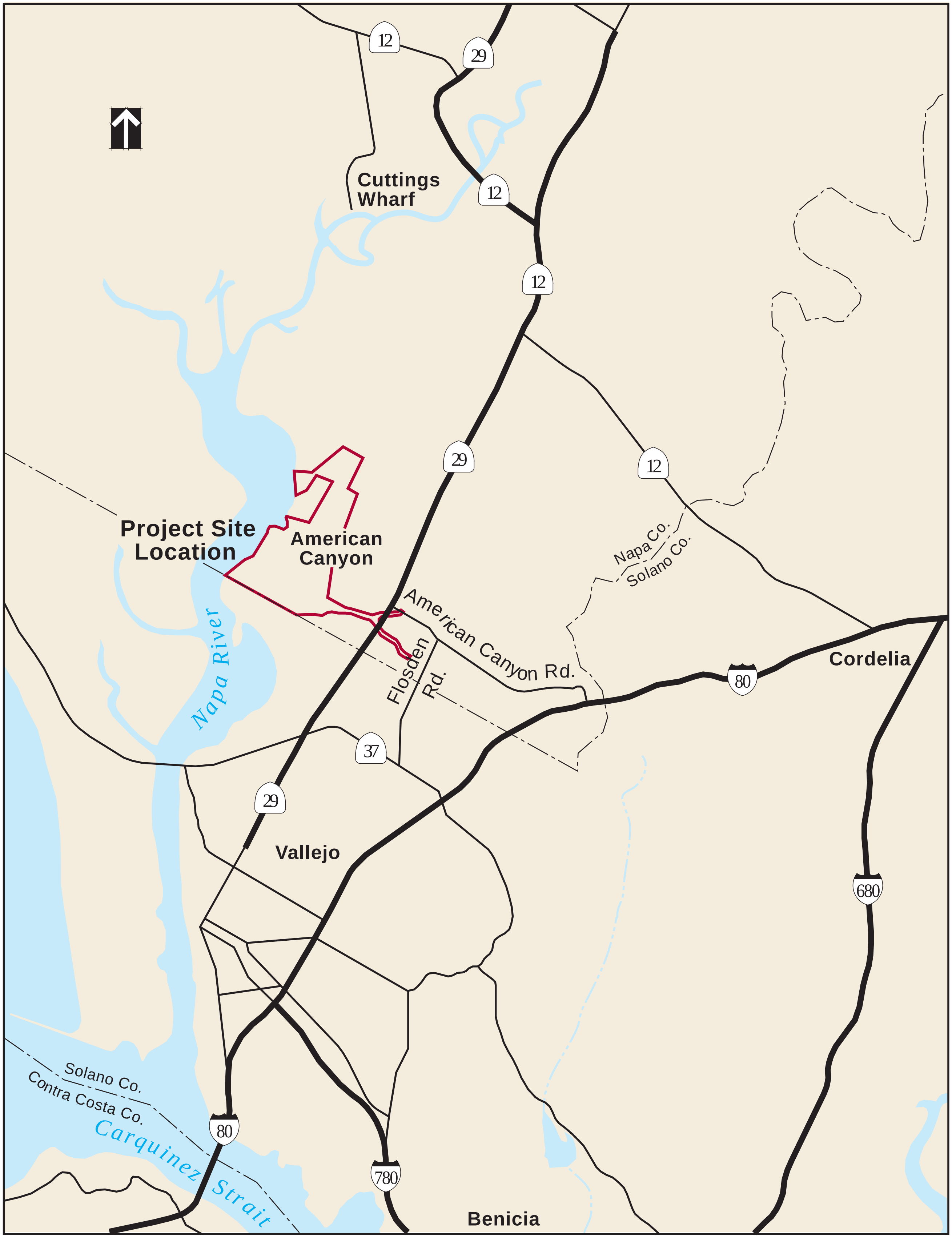

Figure 1
American Canyon
Project Site Vicinity Map

H.T. Harvey & Associate's restoration ecologists conducted one brief field reconnaissance and a limited review of existing information on the project area. Reconnaissance-level surveys for regulated habitats and special-status plant and animal species were not conducted. As such, the existing conditions, restoration constraints and restoration concepts presented below are general and preliminary and intended to provide a starting point for the restoration design process. Additional planning work, including topographic mapping, habitat mapping, special-status species surveys, hydrologic baseline studies and modeling, and detailed restoration design is left for subsequent analyses.

2.0 EXISTING AND HISTORIC CONDITIONS

2.1 MARSH RESTORATION AREA-EXISTING CONDITIONS

The following description is based on a reconnaissance-level site visit conducted on September 6, 2000. During the site visit, water salinities were measured at a depth of 0-0.2 feet at four locations with a hand-held refractometer. The salinity measurements are shown in Figure 2. The marsh restoration portion of the project area comprises three distinct areas labeled Marsh Restoration Areas A, B and C in Figure 2. Areas A (~170 acres) and B (~ 650 acres) are muted-tidal marshes separated from the Napa River by a north/south levee and separated from American Canyon Creek and Area C (350 acres) by an east/west levee (Figure 2). Areas A and B are characterized by a mosaic of diked salt marsh and shallow, open-water habitats. The salt marsh habitat in Areas A and B is dominated by saltgrass *(Distichlis spicata),* alkali bulrush *(Scirpus maritimus)* and pickleweed *(Salicornia virginica)* with lower abundances of alkali heath *(Frankenia salina),* spearscale *(Atriplex triangularis)* and marsh gumplant *(Grindelia stricta).* In contrast, Area C consists primarily of shallow open water habitat. The land surface in Areas A, B, and C appears to have subsided substantially as typically occurs in diked marshes.

Area B receives muted-tidal flushing through an existing tide gate (tide gate # 1) south of the closed landfill (Figure 2). In addition, an existing breach in the east/west levee also provides muted-tidal action from Area C to Area B (Wankum 2000, pers. comm.). Surface water salinities were comparable between Big North Slough (18.5 ppt) and the Napa River (18 ppt) adjacent to the outboard side of tide gate # 1 (Figure 2). Tidal flows to Area A are restricted by culverts under Eucalyptus Drive, the landfill and a levee between the Napa River and Little North Slough (Figure 2). Tidal flushing within Area A is likely less than that of Area B as the surface water salinity immediately north of Eucalyptus Drive (29 ppt) was higher than observed in Area B and the Napa River. Area C appears to be fully tidal since, unlike Areas A and B, Area C was completely submerged during the site visit during the peak of a high tide. The surface water salinity in Area A was comparable to the Napa River (i.e. 18 ppt).

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Link to Figure 2 (216 Kb)

American Canyon Creek
Locations of Proposed
Restoration Areas

Soils within the marsh restoration areas are mapped as Reyes silty clay loam (SCS 1978). These soils are characterized as poorly drained, strongly acidic (pH= 4.5) soils occurring in basins and tidal flats (SCS 1978). The acidic conditions may have developed as a result of diking and draining of the marsh soils.

2.2 RIPARIAN RESTORATION AREA-EXISTING CONDITIONS

The riparian restoration area includes American Canyon Creek and its tributary Walsh Creek (Figure 2). Some riparian habitat restoration may be possible on the upper portion of Little North Slough within Area A, however this portion of Little North Slough was not covered during the brief field reconnaissance. American Canyon Creek and Walsh Creek within the project area appear to be perennial streams as low flows were present during the September 6, 2000 field reconnaissance. Riparian habitat is fragmented and sparse throughout the majority of the project reaches along these creeks. The alignment of both creeks has been straightened and the channels were likely deepened downstream of Highway 29 where residential housing borders both sides of the creeks. The channel bottom within the lower reach of American Canyon Creek is vegetated by emergent freshwater wetland species including California bulrush *(Scirpus californicus)* and cattails *(Typha* sp.). Patches of willow-riparian habitat are present upstream of Highway 29 along both creeks. In contrast, a dense corridor of mature willow-riparian habitat is present along American Canyon Creek immediately upstream of American Canyon Road, beyond the project reach.

Soils within the American Canyon Creek reach are mapped as Clear Lake clay (SCS 1978). These soils are characterized as poorly drained, slightly acidic to slightly alkaline (pH 6.2 - 8.0) and occur on old alluvial fans and basins (SCS 1978). In contrast, soils within the Walsh Creek reach are mapped as Fagan clay loam (SCS 1978). These soils are characterized as well drained and moderately acidic (pH 5.8) (SCS 1978).

2.3 HISTORIC CHANGES AND BACKGROUND INFORMATION

A limited review of maps, aerial photos, and reports (available at H.T. Harvey & Associates) was conducted to assess past land use practices and hydrologic and topographic modifications within the project area. The levees isolating the marsh restoration areas from the Napa River tides were present as of 1916 (USGS 1916). While the Napa-Sonoma Marshes Wildlife Area immediately west of the site and the marshes immediately north of the site (Figure 1) were converted to salt evaporation ponds, the marshes within the project area do not appear to have been used for salt production. Rather, Areas A, B, and C were likely diked and drained for use as farmland. Tillage lines are apparent throughout the majority of Areas A and B in a 1977 (6/22/77) aerial photograph.

We have designated the northern portion of North Slough as Little North Slough and the southern portion as Big North Slough (Figure 2) since historically they likely had independent connections to the Napa River (USGS 1916, 1949). The confluence of Little North Slough with the Napa River was likely located at the existing artificial lagoon between the closed landfill and the salt pond to the north (Figures 2). Sometime between

1949 and 1981 Little North Slough was diverted under Eucalyptus Road and into a drainage ditch around the eastern perimeter of the closed landfill to tide gate #1 (Figure 2). A drainage ditch along the south side of the east/west levee appears to have diverted American Canyon Creek from its historic connection to Big North Slough.

The north/south Napa River levee appears intact and unbreached in a 1977 aerial photograph, since Area C does not appear inundated. The USACE preliminary restoration plan stated that floodwaters breached a levee at the southern end of the project area in the 1980's (USACE 2000). A large breach appears to connect Area C directly to the Napa River.

3.0 RESTORATION GOALS

The following would be appropriate goals for the restoration project and should be pursued to the extent feasible given existing constraints:

- Restore tidal marsh habitat to conditions present prior to Napa River levee construction.
- Restore a continuous corridor of riparian habitat along the creek corridors.
- Maximize the diversity of wildlife use by increasing the diversity and quality of restored habitat types (e.g. salt marsh, shallow open water, mud flat, brackish-freshwater tidal marsh, willow riparian, oak woodland, grassland).
- Restore the salt marsh/upland ecotone.
- Remove barriers to anadromous fish passage.
- Educate the surrounding community regarding the ecological values of the restoration area.
- Increase habitat quality and quantity for special-status species.

4.0 RESTORATION CONSTRAINTS

4.1 BIOLOGICAL CONSTRAINTS

Potential short and/or long-term impacts to special-status species and regulated habitats pose constraints to the restoration design. Regulated habitats within the project area would include wetlands and tributary waters (USACE jurisdictional areas), as well as the bed and banks of American Canyon and Walsh creeks (CDFG jurisdictional areas). Impacts to wetlands and tributary waters, such as the fill of wetlands due to new levee construction, would require permits from the USACE, the Regional Water Quality Control Board (RWQCB) and the Bay Conservation and Development Commission (BCDC). Proposed modifications to the creeks such as grading, sediment removal and revegetation within the bed and banks would require a streambed alteration agreement from CDFG.

Consultations with the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS) and/or CDFG, depending on the species, would be required if the restoration design could potentially impact special-status species. Special-status species that could be potentially affected would include federally-listed species such as the California clapper rail (*Rallus longirostris obsoletus*), salt marsh harvest mouse *(Reithrodontomys raviventris)* Chinook Salmon *(Oncorhynchus tshawytscha),* steelhead rainbow trout (*Oncorhynchus mykiss*) and California red-legged frog *(Rana aurora draytonii*), among others.

Marsh restoration areas A and B provide suitable habitat for the salt marsh harvest mouse. Assuming this species actually occurs on site, potential impacts to the salt marsh harvest mouse would be of particular concern. Restoration of full tidal action would result in a short-term loss of low quality mouse habitat due to conversion of diked-subsided marsh to shallow open water. However, introduction of full tidal action would result in a long-term gain of high quality mouse habitat after sediment accretion and re-establishment of tidal salt marsh. This long-term gain could take years or decades depending on sedimentation rates in the project area.

The introduction of full tidal action to marsh areas A, B and C would also result in the long-term loss of shorebird and waterfowl habitat due to the conversion of shallow, open-water habitat to vegetated marsh. However, tidal marsh habitat is much less abundant in the region compared to the shallow open water and mud flat habitats preferred by shorebirds and waterfowl.

In addition, introduction of full tidal action could increase the potential for flooding of urban areas upstream on American Canyon Creek and Little North Slough. Increased flooding potential could occur especially during times when storm events coincide with spring tides. If the introduction of full tidal action would increase flood potential, then the installation of water control structures might be required at the downstream end of the riparian restoration areas. However, installation of water control structures could conflict with the goal of facilitating the movement of anadromous fish.

The potential for transport of contaminants to the aquatic food chain also represents a potential constraint. Landfill-associated contaminants could enter the restored marsh and Napa River via scour of the landfill side-slopes or leeching into the shallow groundwater and subsequent seepage into the restored tidal sloughs. In addition, pesticides from past farming activities, if present at significant levels in the soil, could also present a constraint to restoration efforts.

4.2 PHYSICAL CONSTRAINTS

Potential flooding of existing roads, facilities and residences is the primary physical constraint to restoration of tidal marsh and riparian habitat. The restoration design could incorporate flood control design elements (e.g. construction of new levees) where necessary to protect the water treatment pond facility, existing roads and adjacent residential areas. In addition, an existing wastewater pipeline, located along the eastern edge of Area B, would need to be protected as appropriate. The closed landfill also represents a significant physical constraint to tidal marsh restoration. The restoration design must protect the landfill side-slopes from erosion due to increased tidal flushing.

5.0 RESTORATION ALTERNATIVES

5.1 MARSH RESTORATION

5.1.1 Alternative A- No Action

With no intervention, the existing levee system would continue to erode resulting in the eventual restoration of full tidal action to the marshes. The levees would tend to breach at the weakest points, not necessarily at the locations of historic connections between remnant sloughs and the Napa River. This could seriously compromise the accretion of sediments throughout the marsh, and thus limit the restoration of vegetated marsh habitat. Introduced tidal flows may also tend to divert through man-made drainages in lieu of remnant slough channels. The no-action alternative would also leave existing infrastructure, housing, and the closed landfill unprotected from flooding.

5.1.2 Alternative B- Improve Tidal Flushing of Muted-Tidal Marsh

Alternative B would involve upgrading existing culverts and tide gates and installing new tide gates at strategic locations to improve tidal flushing. The culvert and tide gate improvements would be designed to increase the volume of tidal water exchanged with the Napa River while maintaining the existing elevation of mean high water within the restoration area. The project would also necessitate on-going maintenance of the existing levee system as well as measures to protect the landfill side-slopes from erosion. Alternative B would tend to increase the productivity, diversity and surface area of salt marsh vegetation without resulting in the short-term loss of existing salt marsh habitat. However, this increase in productivity would be relatively small compared to restoration of full tidal action (Alternatives C and D). This alternative would likely increase the productivity of the benthic invertebrate and fish communities. Alternative B would also decrease the need to protect infrastructure from tidal flooding.

5.1.3 Alternative C- Restore Full Tidal Action-No Imported Dredged Material

Alternative C would restore full tidal action to marsh restoration areas A, B, and C. This would be accomplished by breaching levees in strategic locations. Measures would be taken to ensure flood protection for existing infrastructure and housing adjacent to the site and to protect the landfill side-slopes from erosion. This alternative would rely on natural sedimentation of the subsided marsh plain to regenerate elevations suitable for natural recruitment of salt marsh vegetation. In the short term, restoration of full tidal action would result in the conversion of existing diked-salt marsh habitat to shallow open water habitat. As sedimentation gradually builds the marsh plain, the marsh ecosystem would undergo a temporal transition of habitat types from dominance by shallow open water to predominantly intertidal mud flat and eventually to salt marsh habitat. Natural sedimentation and plant colonization would ultimately result in the establishment of a mosaic of high quality salt marsh habitat as well as some intertidal mud flat and shallow open water habitat within the restored slough channels.

5.1.4 Alternative D- Restore Full Tidal Action - Reuse Imported Dredged Material

Alternative D is identical to Alternative C, but would also incorporate the reuse of imported dredged material. Dredged material would be utilized to raise the soil surface to elevations suitable for the establishment of intertidal mud flat and cordgrass *(Spartina foliosa).* Natural sedimentation would then raise the site to elevations suitable for colonization by mid and upper marsh plant species. Potentially suitable dredged material would likely be available from dredging projects in the Napa River adjacent to the project area. The use of dredged material would hasten the ultimate establishment of high quality salt marsh habitat and thereby shorten the temporal loss of salt marsh habitat. The reuse of dredged material would likely increase the costs of design and installation above that of Alternative C. However, dredge material installation costs might be reduced or covered by a Napa River dredging project assuming the cost of dredge material placement in the marsh is less than that for dredged material disposal.

5.1.5 Preferred Marsh Restoration Alternative

Alternatives C or D would be preferred to Alternative B because unlike Alternative B they would result in the restoration of a self-sustaining tidal marsh to approximately historic conditions. Moreover, the productivity and diversity of plant and animal species is typically higher for a tidal marsh compared to a diked, muted-tidal system. A hydrologic analysis should be performed to predict the natural rate of sedimentation within the marsh restoration site. Assuming that the rate of sedimentation is moderate to rapid for this site, Alternative C would be the recommended as the preferred alternative. Alternative C would likely be less expensive than Alternative D and would still result in the restoration of high quality tidal marsh habitat. In addition, the interim habitat types (shallow water and intertidal mud flat) would have high values to shorebirds and waterfowl.

5.2 RIPARIAN RESTORATION

5.2.1 Alternative A-No Action

Since the factors that currently limit the natural establishment of riparian habitat would likely remain in place under the no-action alternative, riparian habitat within the project area would remain fragmented and poorly developed.

5.2.2 Alternative B- Revegetate Riparian Corridor

Alternative B would entail revegetation of the riparian corridors along American Canyon and Walsh Creeks with native woody species. The revegetation effort would likely be limited to the top-of-bank throughout the majority of American Canyon Creek due to flood control concerns associated with increased channel roughness.

5.2.3 Alternative C- Restore Creek Hydrologic Functions and Revegetate Riparian Corridor

Alternative C would integrate a fluvial geomorphologic analysis of the creeks with riparian habitat revegetation planning. The purpose of this alternative is to restore natural hydrologic function and form to the creek as well as riparian habitat to the extent feasible given the constraints of existing development. Under this approach, the channel cross-section would be widened and new lower floodplain terraces excavated (where feasible) to allow for riparian habitat restoration within the banks of the creek. Native riparian species would be planted in appropriate locations on the restored floodplains. This alternative would also remove any barriers to the migration of anadromous fish.

5.2.4 Preferred Riparian Restoration Alternative- Alternative C

Alternative C would be the preferred alternative since it offers the best opportunity to restore high quality riparian habitat and conditions suitable for migration of anadromous fishes.

6.0 CONCEPTUAL RESTORATION DESIGN FOR PREFERRED ALTERNATIVES

6.1 MARSH RESTORATION AREA

Tidal marsh restoration would involve breaching existing levees in appropriate locations to reconnect the marsh restoration areas to the Napa River. Potential breach locations are shown in Figure 3. These breach locations were based upon locations of historic hydrologic connections interpreted from USGS maps (1916, 1946) and remnant channels visible on the 1993 aerial photograph. Selected existing drainages would be "plugged" with soil where necessary to direct tidal flows to existing remnant slough channels. Potential soil "plug" locations are also shown in Figure 3. The existing culverts under Eucalyptus Road would be replaced with larger culverts to improve tidal circulation in the northern portion of Area B. In addition, the ecotone between the salt marsh and upland habitat would be restored where possible. The surface area available for restoration of this ecotone would depend upon the relationship between post-construction mean higher high water and the existing grades along the perimeter of the site. As mentioned above, appropriate measures would be taken to protect existing roads, residential areas, water treatment facilities and the closed landfill from flooding and erosion.

Since the City of American Canyon's CALFED funded tidal marsh restoration covers the majority of Areas A and B, additional tidal marsh restoration within the project area should focus primarily on Area C. Information regarding the details of the CALFED funded project and existing hydrologic conditions in Area C would be required to develop restoration goals and objectives for Area C. Area C may currently be fully tidal (e.g. not muted). A hydrologic study should be performed to determine if levee breaches along the north/south levee could improve tidal exchange in Area C compared to the

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Link to Figure 3 (214 Kb)

American Canyon Creek
Conceptual Tidal Marsh
Restoration Site Plan

existing condition. This study should factor in the hydrologic modifications proposed by the CALFED funded project.

Wind/wave action in Areas A, B, and C could preclude natural sedimentation and accretion of the marsh plain. Therefore, hydrologic design studies should also include an analysis of the effects of wind/wave action on natural sedimentation rates within Areas A, B, and C. The installation of internal berms may be necessary to reduce the fetch and minimize wave-induced resuspension of sediments. Dredged material could be used for this purpose.

6.2 RIPARIAN RESTORATION AREA

Based on field observations, it is likely that American Canyon and Walsh Creeks within the project reach could also support dense stands of willow-dominated riparian habitat. Willow-dominated riparian habitat is a rare and valuable habitat type throughout California and supports high bird species diversity including breeding neotropical migratory bird species. Consequently, the design would seek to maximize the locations where willow-dominated riparian habitat could be established without causing flood control problems. This might be accomplished by widening the channel cross-section in appropriate areas (e.g. upstream of Highway 29) to include a lower floodplain terrace at the elevation of the 2-year flood event. The upstream portion of Walsh Creek within the project area is devoid of riparian vegetation where willow-dominated riparian habitat ends abruptly at a fence crossing. Riparian restoration design studies in this area would focus on determining the reason for the absence of willow-dominated riparian habitat. A coast live oak-dominated association would be restored where appropriate in creek bank and top-of-bank areas within the riparian corridor.

The primary objectives of the fluvial geomorphology design would be to maximize the stability of the restored creek channels, maintain sediment transport, minimize erosion and remove barriers to anadromous fish passage. All creek bed and bank stabilization structures would be composed of natural materials such as boulders, logs and root wads.

The eastern portion of Area C (Figure 2) requires further examination to determine appropriate habitat restoration treatments. This area is the transition zone between the creek and the tidal marsh and may provide unique opportunities for restoration of a willow riparian marsh and freshwater/brackish tidal marsh ecotone.

7.0 ADDITIONAL STUDIES

Additional baseline and design studies would include the following:

- Prepare ortho-rectified aerial photograph and topography map
- Review historic aerial photographs of the project area
- Map existing habitats
- Delineation of regulated habitats
- Surveys for special-status species
- Characterization of existing hydrologic conditions in the marsh and creeks
- Hydrologic analysis of appropriate levee breach locations, predicted sedimentation rates within restored marshes, and locations of necessary levee construction and road improvements
- Analysis of potential for erosion of landfill side-slopes and ecological risks associated with movement of landfill contaminants
- Fluvial geomorphology analysis (e.g. HEC-RAS, study of a model reach) of creeks
- Analysis of factors responsible for lack of riparian vegetation along creeks (e.g. land use practices, soils, groundwater levels)
- Characterization of vegetation, soils and hydrology in reference reaches of the creeks

After completion of conceptual design alternatives the preparation of an EIR/EIS would likely be required.

8.0 LITERATURE CITED

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Appendix E
Candidate Project Summaries

<u>List of Projects</u>

Map of Project Locations

1. Marin County Fire Road Sediment Reduction Project
2. Mare Island and North Bay Discovery Center Wetlands Restoration
3. Montalvin Manor Culvert Project
4. Napa River Runoff Management
5. Novato Creek Flood Control and Marsh Restoration
6. River Park, Vallejo
7. Rodeo Creek Sediment Reduction Project
8. San Pablo Bay Wildlife Refuge Additions
9. Leonard Ranch Tidal Wetlands Restoration
10. Sonoma Valley Vineyard and Wineries Best Management Practices
11. Sulphur Creek Enhancement Projects
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Candidate Project 1: Marin County Fire Road Sediment Reduction

Project Overview

Unpaved fire roads under the jurisdiction of Marin County have been identified as potentially significant sources of sediment to waters within the drainages and to the San Pablo Bay. The proposed project employs various best management practices (BMPs) to stabilize soils on and adjacent to these roads to reduce erosion and improve downstream water quality.

Project Description

The system of unpaved fire roads covering approximately 300 square miles in the Novato, Miller and Galinas Creek watersheds includes areas of high erosion where the road surfaces and the disturbed soils around the roads are not adequately protected from the erosive forces of wind, rain and runoff. In addition, the areas where unpaved roads travel close to streams, and where they cross streams, typically create direct connections between disturbed soils and streams.

This project can enhance the natural value of soil and water resources. Erosion control BMPs will hold soil in place to provide a growth substrate for plants and animals, while reducing the amount of sediment in the water draining through the watershed.

The Marin County Fire Road Sediment Reduction project will accomplish this by protecting the surfaces of unpaved roads with gravel or other surfacing and by grading the roads for proper drainage. Revegetation, mulching and other methods will stabilize other areas that have disturbed soils. Damaged or deteriorating streambanks will be restored with rock protection, retaining walls and vegetation. All of these measures will function together to stabilize soil and maintain high quality in the water flowing into the San Pablo Bay.

A comprehensive implementation program will help ensure that proper BMPs are selected, installed and maintained in a cost-effective manner. The program will allow for the development of realistic goals through an evaluation of resources, selection and prioritization of specific sites and the identification of treatment alternatives. The components of the implementation program for this project will include, but may not be limited to:

- Road inventories, classification, and mapping;
- Database construction and management;
- Identification of areas of high erosion potential, and planning and prioritizing specific erosion and sediment control projects;
- Identification of unneeded roads which may potentially be decommissioned;

- Coordination with outside agencies and permitting;
- Erosion control BMP implementation; and
- BMP performance monitoring and optimization.

Planning to date has not included identification of specific sites to include. Future efforts need to identify potential sites, project goals, sponsorship, and costs. While costs to repair unpaved roads range widely and are very site specific, repair costs for roads with no erosion control are generally much higher than the costs of maintaining roads with proper BMPs in place. Furthermore, the elements of an effective erosion and sediment control program can be easily integrated into existing road system maintenance and management programs.

Sponsorship and Oversight

Marin County is the owner of the unpaved fire roads that will be included in this project. Potential sponsors include various County agencies such as Department of Public Works and Department of Parks, Open Space, and Cultural Services. Other potential sponsors may include North Marin Water District and Marin Community Development Agency.

Potential Benefits

The proposed erosion control BMPs will help to slow down the increased soil erosion rates brought about by human activity. The project will help create a healthier and more balanced ecosystem in the watersheds of the San Pablo Bay. Revegetation efforts using native plant species will provide increased habitat for wildlife while preventing soil loss to streams.

Decreasing the sediment loads in the streams of these watersheds will protect spawning areas, maintain stream capacity, and reduce the potential of flooding. The amount of organic materials and nutrients being transported downstream will also be reduced, leading to fewer algae blooms, increased dissolved oxygen and water clarity.

The implementation of a BMP program will also produce community benefits such as reduced maintenance costs for the unpaved road system, safer fire roads and cleaner water for public water supplies.

Candidate Project 2: Mare Island/North Bay Discovery Center Wetlands Restoration

Project Overview

The Mare Island Candidate Restoration Site is approximately 160 acres of diked wetlands surrounding the San Pablo Bay National Wildlife Refuge North Bay Discovery Center. The project proposes to use seasonal wetland restoration to recreate habitat for salt marsh species in an area where diked wetlands have served as repositories for dredge spoils from channel maintenance activities undertaken at the naval facility.

Project Description

The 160-acre diked site once was part of tidal San Pablo Bay, but was diked off at an unknown time. Since then, the naval facility has been depositing dredge spoils at the site, some of which contain munitions. The Navy already has completed an effort to remove the munitions from the soils. The goal of the restoration project would be to manage the wetlands as habitat for salt marsh species. To accomplish this goal, the site would be restored as seasonal wetland.

Although these wetlands formerly were tidal, the dredge spoils that were deposited on them raised their elevation beyond the reach of the tides. Therefore, restoration to tidal action is not an option. However, since the soils are bay muds with a high salt content, the restored wetlands would function as seasonal wetlands that support salt-tolerant plants, especially pickleweed.

Restoration as a seasonal wetland would entail retaining existing dikes. Since the underlying soils are saline, the diked wetlands would support high tidal marsh plants, predominantly pickleweed. Such marsh already exists on the diked wetlands.

Environmental benefits of the non-tidal, seasonal wetland would be to provide habitat for mammal, invertebrate and avian habitat, but not for bay fish species.

Possible indicators of restoration success would be:

- State and Federal government certification of the site as fully remediated of contaminants and unexploded ordinance; and
- Increased counts of wildlife populations inhabiting the site.

Sponsorship and Oversight

The project site is owned by The U. S. Fish and Wildlife Service, and it was added to the Refuge as part of the closure of the Mare Island Naval Base. This proposed project could be linked to other restoration activities underway in the vicinity of the Discovery Center. The San Pablo Bay National Wildlife Refuge sponsors all of these activities.

Potential Benefits

This project has the potential to provide environmental and community benefits. Environmental benefits of the restoration would include expanded tidal circulation and creation of new habitat for bay fish and other wildlife. Because of its location adjacent to the public Discovery Center, the restored wetlands would also serve as an amenity for local residents and visitors. Classes already are being conducted periodically in the region, and could be expanded if the wetlands were restored to make them safe for public access.

Candidate Project 3: Montalvin Manor Culvert Repair Project

Project Overview

Repairing a collapsed culvert in the neighborhood of Montalvin Manor in Contra Costa County would result not only in flood control benefits but also would create a small, tidally-influenced estuarine marsh, one of the rare and valuable habitats of the San Pablo Bay watershed.

Project Description

The neighborhood of Montalvin Manor lies just outside the cities of Richmond and Pinole, near San Pablo Avenue and Montalvin Park within the Garrity Creek watershed. The development there has had drainage problems and frequent flooding throughout its thirty-year history due to a collapsed culvert located under the railway tracks between the development and San Pablo Bay.

As a result of the collapse, water backs up behind the culvert and a year-round freshwater marsh has been created there inadvertently. Just to the west of this location, two working culverts are supporting a tidally influenced estuarine marsh at their drainage outlet; it is assumed that the Montalvin Manor drainage outlet would also support this type of habitat if the culvert there worked properly.

In the past, a standard way to approach the flood control problem would have been to repair the culvert and dredge the wetland to increase flood flow capacity. The Contra Costa County Flood Control and Water Conservation District (FCD)[1] has, however, embraced a more innovative approach, one that recognizes the habitat benefits created by an estuarine marsh while seeking to maintain necessary flood control capabilities.

The conversion of the marsh from freshwater to brackish water will be achieved by repairing the culvert, but the *preservation* of the newly created marsh will require a more political approach. Potential developers have filed an application to create the Point Pinole Business Park for the property surrounding and including the current freshwater marsh, which lies within the City of Richmond. By working with the City of Richmond, the FCD hopes to arrange for the restoration and preservation project to be a condition of approval for the development application. Under this arrangement, the marsh area would still belong to the owner of the surrounding property but would not be developed.

Restoration as part of this project could take place passively or could be aided by revegetation efforts. The marsh currently supports freshwater vegetation such as willows and cattails, which might have to be removed as they are replaced by salt-tolerant vegetation.

This project is somewhat unusual in that it solves a problem in one place (the flooding in Montalvin Manor) by creating a solution at another location (a tidally influenced marsh at

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[1] Source for information regarding this Candidate project: Cece Sellgren, FCD, Personal Communication 8/00

the repaired culvert). Although this proposed project is comparatively small, it represents an opportunity to produce real results without intense effort.

Sponsorship and Oversight

The FCD would participate in the project as a local sponsor. One possible source of financial support for this project would be mitigation funding from an unaffiliated agency. For example, the East Bay Regional Park District will need mitigation credit for the bay filling necessary for the completion of the San Francisco Bay Trail.

Potential Benefits

The primary benefits of this project would be improved flood control for the neighborhood of Montalvin Manor and the habitat benefits of a tidally influenced estuarine marsh. Performance measures for these two benefits have not been determined at this early stage of the project.

Candidate Project 4: Napa River Watershed Urban Storm Water Runoff Reduction Program

Project Overview

The quantity of storm water runoff generated from the urban areas of Napa County has the potential to cause significant increases in the flow rates within the Napa River and its tributaries. The proposed project will employ various best management practices (BMPs) to retrofit an existing urban development as a means to reduce, retain and attenuate runoff rates.

Project Description

Urban developments in the Napa River watershed are located within the cities of Calistoga, St. Helena, Napa and American Canyon and the town of Yountville. One fundamental characteristic of urban areas is impervious land coverage (Southern Sonoma RCD 1997). Impervious surfaces can be defined as any material that prevents the infiltration of rainwater into the underlying soil. These surfaces include rooftops, roadways, parking areas, sidewalks, patios, bedrock outcrops and compacted soil. If rainwater does not infiltrate into soil, stream degradation can result in the following direct and indirect ways:.

- Precipitation events cause higher peak flows and more frequent high flows in streams and cause more bank erosion.
- The reduction in groundwater infiltration leads to lower base flow rates during periods of dry weather; and
- Constructed stream channel modifications are employed to contain increased flows.
- As the area of impervious land coverage increases, so does the degree of stream degradation.

Runoff control BMPs used as part of this project will reduce impervious land coverage, store runoff or slow down the speed at which runoff is allowed to enter the receiving streams. BMPs will promote runoff infiltration to increase groundwater reserves and base flow rates during the dry season. By storing or retaining runoff, peak flows will be attenuated, preventing additional flooding or channel modification.

The Napa River Watershed Urban Storm Water Runoff Reduction Program area will include 20-100 homes and will be selected to be representative of existing urban developments within the watershed. The project area storm drainage system. An area whose storm drainage system is isolated from adjacent areas will be able to provide the most information on the effectiveness of the retrofitting.

At individual homes or businesses, BMPs will be installed that reduce the amount of impervious surfaces, collect or retain runoff, and redirect runoff away from existing drainage systems and on to pervious areas. Local drainage systems may be retrofitted with BMPs to slow down flow or promote infiltration using swales, ponds, wetlands and basins. All of these measures will function together to reduce runoff and return flows to near-normal levels in the Napa River watershed.

A comprehensive implementation program will help ensure that the proper BMPs are selected, installed and maintained in the most cost-effective manner. The elements of the retrofit program can be easily integrated into existing storm water management programs. The program will allow for the development of realistic goals through an evaluation of resources, selection and prioritization of specific sites, and the identification of treatment alternatives.

The specific site or sites for the storm water runoff reduction program area has not yet been identified. Future efforts will identify potential sites, project goals, sponsorship, and costs. Costs to retrofit existing sites range widely and are very site specific. Runoff reduction represents an alternate approach to storm drain capacity enhancement. Increasing storm drain capacity, which would also likely require flood and streambank protection, would entail similar or higher costs than a runoff reduction program, and would not offer the same environmental benefits.

Sponsorship and Oversight

Sponsors have not been identified for this project. Potential sponsors include the various cities or towns with existing urban developments. Cities that are currently experiencing problems with their storm water systems may be receptive to conducting this program. Another potential sponsor may include the Napa County Resource Conservation District, an organization that could potentially provide oversight as well. Homeowners and private businesses may also provide sponsorship.

Potential Benefits

The proposed runoff control measures will help to reduce the quantity of storm water runoff brought about by human activity. The project will create a healthier and more balanced ecosystem in the freshwater streams of the San Pablo Bay watershed. Using vegetation with some BMPs (swales and detention ponds) will provide increased habitat for wildlife while reducing runoff to streams.

Decreasing the runoff quantity to the streams will reduce the pollutant loads associated with urban runoff. BMPs can also provide some level of treatment and further reduce the amount of pollutants entering the receiving waters.

The implementation of a BMP program will also produce community benefits such as reduced overall costs for flood protection and drainage system capacity.

Candidate Project 5: Novato Creek Flood Control and Wetlands Restoration Project

Project Overview

The proposed project[2] would explore the feasibility of restoring tidal or seasonal wetland habitat to improve flood protection and expand habitat for sensitive wetland species.

Project Description

The Marin County Flood Control District (District) is currently completing construction of a new 6000-foot long setback levee along the southwest bank of Novato Creek, running from the Northwestern Pacific Railroad tracks to Highway 37. The District is interested in incorporating habitat restoration as an element of this proposed project (Lewis 2000).

The purpose of the new levee is to provide a wider floodplain and increase channel capacity of the lower creek during flood events. Once the levee construction is completed, the existing levee needs to be breached to provide flood storage capacity in the area between the levees. As a means to divert seasonal flood waters to the floodplain area, the District has considered the installation of weirs in the existing levee. The District is also interested in exploring other means to these ends, such as restoring tidal action to the area, provided that flood control objectives of the project can also be met.

The project area encompasses approximately 47 acres on the southwest bank of the creek, between the old and the new levee. The project area was historically farmed for oat hay, but has been fallow for many years. While restoration has been identified as a potential option for this site, to date there has been no detailed assessment or planning for restoration options for the site. A preliminary design study is needed to assess restoration options, specific levee modifications required for these options, and compatibility with the project's flood control objectives. Once various options are assessed, funding would be needed for project implementation.

Sponsorship and Oversight

The project site is operated by the District, which would participate in the project as a non-federal sponsor. The State Department of Fish and Game owns the pond area and grants an easement to the Flood Control District for purposes of levee maintenance.

Potential Benefits

The Baylands Ecosystem Habitat Goals report (Goals Project 1999) identifies the following restoration opportunities for lower Novato Creek:

- Restoration of tidal marsh in areas where natural marsh / upland transitions can be restored;

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[2] Information on this Candidate Project provided by Liz Lewis, Marin County Department of Public Works. For more information contact the Marin County Department of Public Works, 415 499-6549.

- Establishment of enhanced seasonal pond habitat on baylands that are not restored to tidal marsh; and

- Restoration of riparian habitat along the creek.

Tidal marsh restoration would expand suitable habitat for many tidal marsh species, including the endangered California clapper rail. Providing wide transitions between marshes and adjacent uplands would benefit rare plant species, such as Point Reyes bird's-beak and johnny-nip. Establishment of seasonal pond habitat would benefit several shore bird species.

The project would also provide social and community benefits through increased flood protection along lower Novato Creek.

Candidate Project 6: River Park, Vallejo

Project Overview

The proposed River Park[3] will improve conditions for local wildlife, including rare and endangered species,[4] by restoring degraded tidal and non-tidal marsh habitat, while providing community recreational areas.

Project Description

The primary restoration objective of the River Park plan is to restore, protect, and enhance tidal and freshwater wetland habitat in the northern side of the project site to support the diversity of birds and wildlife. The secondary objective is to provide passive recreation opportunities focused in the southern portion of the site. The site is a 75-acre tract of land and marsh just south of Highway 37 in Northern Vallejo, on the eastern bank of Mare Island Strait. In 1977, the site had been earmarked for recreation facilities such as softball fields and tennis courts, and deposition of dredged materials was used to prepare the site for development, thereby degrading the natural tidal mudflat habitat. As a result of the public's environmental concern, a new community master planning process resulted in a revised River Park plan to restore this area, incorporating lower-impact recreation areas than were originally planned for the site.

Creation of the park will be accomplished through relocation of nearly 250,000 cubic yards of material from the northern portion of the park to the southern portion of the park, along with vegetation plantings that emphasize habitat for food, cover, and nesting. This will help restore the natural tidal marsh environment to the northern side of the project site, and will allow the creation of a vista point at the southern end. Incorporating both wildlife and public park areas meets the Program's objectives while addressing community concerns regarding the appropriateness and ecological soundness of activities at the site, two themes that featured prominently during public participation in the development of the River Park Master Plan.

Sponsorship and Oversight

Previously owned by the U.S. Navy, the property is now owned by the City of Vallejo and designated for recreational development. The City has contracted with the Greater Vallejo Recreation District (District), an independent district with a board of directors

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[3] Information for this Candidate Project provided by Rosemary Alex
Park Planner, of the Greater Vallejo Recreation District. For more information, contact the Greater Vallejo Recreation District at 707-648-4602, or by mail at 395 Amador Street
Vallejo, CA 94590

[4] Surveys for sensitive wildlife species in the tidal and non-tidal salt marsh habitats and upland vegetation on the project site observed six wildlife species of special concern: the California clapper rail, California brown pelican, common yellowthroat, San Pablo song sparrow, northern harrier, and osprey. The tidal and non-tidal salt marsh habitat on the site potentially provides suitable habitat for the salt marsh harvest mouse, salt marsh wandering shrew, and Suisun shrew. One rare plant species, Mason's lilaeopsis, was also found in the tidal salt marsh.

appointed by the Mayor and Board of Supervisors, to oversee the project management. The District is serving as the lead agency for the River Park project.

An environmental assessment, which was begun in mid-August 2000, will investigate the project footprint and site hydrology. This assessment will also include soil sampling and an update of a sensitive species survey for the area. Next steps include the preparation of construction documents, tentatively scheduled to begin in June 2001 and to be completed in June 2002. Project construction will follow. The table below shows current and potential sponsors for these activities.

River Park, Vallejo – Tidal Mudflat Restoration Current and Potential Sponsors		
Current Sponsors		
Coastal Conservancy	Environmental Assessment	$118,000
State Of California	Preparation Of Construction Drawings	$150,000
Potential Sponsors		
U.S. EPA	Preparation of Construction Drawings	$150,000-200,000
Coastal Conservancy	Construction	$1 million
Sponsor Needed	Construction	$4-5 million

Potential Benefits

Freshwater marshes are proposed utilizing stormwater runoff around some naturally occurring wetlands. The freshwater marsh areas will promote species diversity, particularly for mammals, reptiles, amphibians, and birds historically known to utilize the site. Tidal wetlands will be established with plantings identical to existing adjacent wetland areas, emphasizing habitat for food, cover, and nesting. Potential aquatic species that will benefit include the Chinook salmon, Delta smelt, Sacramento splittail, longfin smelt, and green sturgeon. Numerous migratory birds might also be encouraged to use the River Park as habitat.

The plan combines latent habitat and open space resources with low-impact recreational activities such as wildlife observation, environmental education, walking, jogging, bicycling, and picnicking. Public accessibility is incorporated into the northern and southern ends of the site, and limited parking areas are provided at each end. The northern end is to be intended for wildlife-oriented users and is buffered from habitat areas. The south area is the more public-intensive area, and includes a restroom, children's play area, and picnic areas. A central open space in a meadow is provided for active play areas. Limited trails, observation decks, and jogging trail are also provided.

Potential Performance Indicators

As a result of the environmental assessment currently underway, mitigation measures will most likely be determined and put into place, and the District will develop a framework monitoring program to follow up on the mitigation efforts. During the preparation of the construction drawings, the District anticipates that a more detailed monitoring program will be developed to monitor the success of the project. This will include the monitoring of the flow regime and wildlife mainly in the northern part of the site. The District foresees the program to last approximately five years.

Candidate Project 7: Upper and Lower Rodeo Creek

Project Overview

Restoration opportunities along Rodeo Creek include the potential to decrease pollutant and sediment loads and improve habitat, through creation of a meandering channel along the lower creek, and implementation of a watershed plan addressing erosion control in the upper watershed.[5] The middle portion of the creek is already included in a restoration/preservation plan associated with a transportation project now in progress.

Project Description

Rodeo Creek has headwaters in the hills of Contra Costa County, runs parallel to State Route 4 along its middle section, and meets San Pablo Bay in the City of Rodeo. Specific opportunities for restoration exist along each of the three sections. Restoration work is already underway along the middle section, as part of a State Route 4 improvement project sponsored by CalTrans and the Contra Costa County Transportation Authority. In order to truly make an impact on a watershed scale, however, more work is necessary along the other two portions of the creek. Specifically:

- The upper portion of the creek, which suffers from high erosion rates, is in desperate need of a watershed plan to identify restoration opportunities.

- The lower portions of the creek have been channelized for flood control purposes and would benefit from efforts to restore a meandering channel with a functional riparian zone.

Both of these potential projects are needs identified by the Contra Costa County Flood Control and Water Conservation District (FCD). While a lower Rodeo Creek restoration project is more in tune with the specific aquatic restoration goals identified as part of this San Pablo Bay Watershed Restoration Restoration Program, the acknowledgement of the need for a watershed study along upper Rodeo Creek demonstrates the sort of long-term, watershed-wide thinking that is critical for *all* restoration projects. Below are descriptions of current and potential work in the three creek sections.

Middle Rodeo Creek – State Route 4 Project

The middle portion of Rodeo Creek runs just to the south of State Route 4. Along this corridor, CalTrans and the Contra Costa County Transportation Authority (CCCTA) are currently involved in the construction phase of the State Route 4 Gap Project, which will turn the only non-freeway section of Route 4 between I-80 and Route 160 into a four-lane freeway and provide an access road to the nearby Tosco coke plant. Because jurisdictional wetlands will be filled, mitigation was required for the project. A federally-listed endangered wetland plant, the Contra Costa goldfield (*Lasthenia conjugens*), grows in the project area. The mitigation wetlands have already been installed and are currently in their monitoring phase. In addition to this mitigation, 3,600 feet of riparian zone along Rodeo Creek will be restored and preserved in a conservation easement. The Muir

[5] Source for information regarding this Candidate project: Cece Sellgren, FCD, Personal Communication 8/00

Heritage Land Trust has signed a Memorandum of Agreement with Caltrans and the CCCTA establishing a three-year trial period for this conservation easement. The parcel contains habitat for California red-logged frog and Western pond turtle (*Clemmys marmorata).*

Proposed Project: Upper Rodeo Creek Watershed Plan

The upper portion of the Rodeo Creek watershed is already heavily affected by grazing, and proposed development could further threaten the health of this area. Incision rates (based on informal monitoring) are very high, which has resulted in unacceptably large sediment loads being washed into the creek. The area provides habitat to the endangered California red-legged frog (*Rana aurora draytonii*), making further degradation especially undesirable.

No formal watershed plan has been established for this area, but the FCD has identified a real need for one. A watershed plan would not only enable prioritization of the various erosion and habitat degradation problems that upper Rodeo Creek faces, but would hopefully bring concerned parties together to brainstorm ways to solve these problems.

Sponsorship and Oversight

Ideally, watershed plans are produced by collaboration of government agencies, community members, and NGOs. It is likely, therefore, that the FCD would need to partner with multiple groups in order to prepare an acceptable plan for the upper Rodeo Creek watershed.

Potential Benefits

The environmental benefits resulting from the creation of a watershed plan would naturally depend on the conclusions of that document. Erosion control is one of the most pressing needs, so reductions in downcutting, sediment loading and non-point-source pollution are potential environmental benefits. Because this project is in such preliminary stages, performance measures cannot be identified at this time.

Proposed Project: Flood Storage Augmentation and Restoration of Lower Rodeo Creek

Lower Rodeo Creek, which was channelized to increase flood control, would benefit from a project to restore the Creek's meandering channel and create adjacent riparian habitat. The potential restoration area stretches from downstream of Highway 80 to approximately 6th Street in the City of Rodeo, where the channel becomes concrete-lined. A project of this type would be contingent upon the creation of an offline floodwater and sediment detention basin elsewhere along the creek, so that restoration work would not jeopardize total flood storage capacity. The FCD hopes to construct the new flood control basin, but plans are in their infancy – a site has not been officially selected, and funding sources have not been identified. An additional constraint is the presence of a railway trestle passing over the creek; this trestle has the capacity to restrict flow, taking discharge control out of the FCD's hands. This problem would need to be addressed as part of any restoration / flood control project.

Sponsorship and Oversight

Sponsors for this restoration work on lower Rodeo Creek have not been identified. If a grant or other sponsorship cannot be obtained, mitigation credit for nearby development might be a possible source of funding.

Potential Benefits and Performance Measures

The possible benefits of a restored stream channel include improved riparian habitat, improved water quality and aesthetic benefits. Specific measures of these benefits have not yet been proposed.

Candidate Project 8: San Pablo Bay National Wildlife Refuge Additions

Project Overview

The proposed expansion of the San Pablo Bay National Wildlife Refuge (Refuge)[6] will increase habitat available to local and migratory wildlife, including rare and endangered species, by restoring diked historic tidal marsh habitat, while providing wildlife viewing and recreational opportunities.

Project Description

San Pablo Bay National Wildlife Refuge is 13,980 acres of open water, mudflats, tidal salt marsh, and upland habitat located 25 miles northeast of San Francisco along the northern edge of San Pablo Bay between the cities of Vallejo and the Petaluma River. The USFWS has proposed to expand the Refuge by acquiring 7,124 acres of diked historic tidal marsh north of Highway 37, east of Sonoma Creek and west of Napa Slough.[7] These diked areas include Skaggs Island, Detjen Duck Club, Camp Three Island, Haire Ranch and the former West End Club. The objective of this project is to restore these properties to functioning tidal marsh habitat in a manner requiring minimal maintenance.

Skaggs Island is located north of Highway 37 and is surrounded by Sonoma Creek on the west, Napa Slough on the southeast and Second Napa Slough to the north. The island is protected from flooding by levees. The Navy occupies approximately 3,310 acres on the island. A local farmer leases about 2,959 acres from the Navy for cultivating oat hay. Sixty (60) acres, located on a panhandle at the north end of Skaggs Island, served as a Naval Security Group Activity Base until 1993. This land is being negotiated for fee-title transfer from the Navy to the USFWS (USFWS 1995). Upon transfer, restoration is most likely to occur passively on all areas except the 60 acre abandoned naval compound, which will require removal of structures and associated infrastructure including antennas, support and functions buildings, administrative buildings and military housing. In addition, the Federal Aviation Administration has a VOR Ground base navigation facility that has many associated underground wires. This facility will likely need to be raised to protect it from flooding (Vicencio 2000).

Detjen Duck Club is a 500 acre parcel that is currently being managed as a private duck hunting club within the approved boundaries of the Refuge. The owner has recently expressed concern over the siltation of the west end of South China Slough at the northeast corner of duck club. Historically, the slough was deep and wide, and until a few years ago speedboats navigated it. With the past few years, however, the slough has silted in significantly and is now choked with bulrush. Siltation of the slough has reduced the velocity of outflow from the Duck Club to the slough, complicating water level

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[6] Information on this Candidate Project provided by Louise Vicencio, Wildlife Biologist, of the U.S. Fish & Wildlife Service. For more information phone (707) 562-9453 or mail the San Pablo Bay National Wildlife Refuge, P.O. Box 2012, Mare Island, CA 94592.

[7] Listed as Alternative A in the *Draft Environmental Assessment of Proposed Additions to San Pablo Bay National Wildlife Refuge* (USFWS 1995).

management in the duck club (Detjen 2000). Ducks Unlimited has expressed an interest in this project and may help to match funds for the restoration (Lament 2000).

Camp Three is a 1,450 acre island adjacent to and north of Skaggs Island and west of Sonoma Creek. It has been farmed for oats and oat hay since the early 1900's. Tidal marsh vegetation found on the island includes bulrush, pickleweed, cattail, cordgrass, soft bird's beak, yarrow and silverweed (USFWS 1995).

Haire Ranch is adjacent to Skaggs Island, separated by Rainbow Slough. Strict language in the Naval Base deed requires maintenance of the levees along Rainbow Slough to prevent flooding of the Haire Ranch. Because of this, the type of habitat enhancement that may occur on either property is directly influenced by the status of the adjacent property. Enhancement options within the range of possibility include, tidal marsh, damped marsh and seasonal wetland.

The West End Club is a 774 acre site located east of Detjen Duck Club, north of Highway 37 and east of Sonoma Creek. It was originally owned by the Cargill Salt Company but was never used for salt production. The property was purchased by the State of California in 1994 and is now managed as a damped tidal marsh, with the other retired salt ponds, by the California Department of Fish and Game (CDFG) as part of their Napa-Sonoma Marshes Unit. Because it was never developed as a salt pond and much of the natural topography remains intact, passive restoration should proceed quickly.

Sponsorship and Oversight

The Refuge is part of the San Francisco Bay National Wildlife Refuge Complex, and was established to protect migratory birds and threatened and endangered species by restoring and enhancing sensitive bay land habitats. The complex includes eight refuges within the greater San Francisco Bay region: Salinas; Elliott; San Francisco Bay; Alameda; Antioch; Farallon; and Marin Island.

Land will be acquired through the use of fee-title purchase, conservation easements, leases or cooperative easements. Skaggs Island is currently owned by the Navy and is being negotiated for fee title transfer to the USFWS. The USFWS is satisfied with the current management of Detjen Duck Club; however, it is still being considered for purchase. The USFWS is not currently pursuing the purchase of Camp Three and the Haire Ranch due to funding limitations (Vicencio 2000). The USFWS plans to lease the West End Club from CDFG and restore tidal flow to the property (USFWS 1995).

Restoration of the areas listed for acquisition by the USFWS will be predominantly passive, with building removal of and infrastructure clean up where necessary. This type of restoration is particularly effective in historic wetland areas, where heavy planting are already present, and the use of heavy equipment can compact the soil and further degrade the condition of the land.

Ownership, Acreage, and Acquisition Priorities of Proposed Additions to San Pablo Bay National Wildlife Refuge (USFWS 1995)				
Tract	***Acres***	***Priority***	***Interest***	***Current Owner***
Skaggs Island	3,310	1	Fee title (via Transfer)	Dept. of Defense (Navy)
Detjen Duck Club	500	2	Fee/easement	Detjen Club
Camp Three Island	1,450	3	Fee/easement	Kiser
Haire Ranch	1,090	4	Fee/easement	Haire Ranch
West End Club	774	5	Lease	State of California
Total	7,124			

Potential Benefits

The expansion of the Refuge and subsequent restoration of diked bay lands to tidal marsh and mud flat would aid the recovery of endangered and sensitive species populations and would enhance resident and migratory bird populations. Acquired land would be managed to maximize wildlife values. Expanding the Refuge would also provide new opportunities for wildlife viewing by providing educational and recreational opportunities to the visiting public. Increased public environmental knowledge and understanding may help increase support for existing and future conservation and management programs (USFWS 1995).

Upon acquisition of the proposed lands, the USFWS may grant limited access on a case-by-case basis for scientific research and study groups. Non-consumptive use would be encouraged to enable the public to understand and appreciate the distinctive characteristics of lands reserved for natural resource protection. Federal spending for development and management of the Refuge would have a beneficial economic impact on the local economy. County property tax revenues lost due to USFWS acquisition of agricultural land could be partially offset by annual payments to affected counties in agreement with the Refuge Revenue Sharing Act, depending on congressional appropriations (USFWS 1995).

Potential Performance Indicators

Intermittent monitoring efforts within the existing boundaries of the Refuge include occasional vegetation transect surveys, annual fish surveys, ocular bird counts, small animal trapping, sediment deposition rates and water quality analyses for salinity, turbidity, dissolved oxygen, temperature and other parameters (Vicencio 2000). Passive restoration of tidal marshland is essentially a slow geologic process involving the deposition of sediment upon the flooded historic tidal marsh. It could take more than 20 years to accrue enough sediment to support tidal marsh vegetation and even longer before the area is colonized by birds and small mammals. Two ongoing surveys of bird populations in the San Francisco Bay area would be useful in determining the success of these projects: the Midwinter Survey conducted by the USFWS; and the California Department of Fish and Game Monitoring Study on Salt Pond 2A.

Candidate Project 9: Leonard Ranch, Sonoma County

Project Overview

The Leonard Ranch project is a candidate restoration of tidal wetlands on diked baylands. The project is promotes attainment of the goals and objectives of the San Pablo Bay Watershed Restoration Restoration Program by restoring diked tidal marsh to its original condition.

Project Description

The objective of the project is to restore tidal marsh on diked baylands.

The project is proposed on a 244-acre site near the Port Sonoma marina in southern Sonoma County, near the mouth of the Petaluma River.

The problem to be address is the scarcity of tidal marsh habitat resulting from historic diking and draining.

A containment levee would be constructed around the site, in a similar manner to the adjacent restoration project known as Sonoma Baylands. Connection to tidal waters probably would be achieved by linking the project to the existing Sonoma Baylands project, which already is tidal. However, other alternatives would need to be considered in any initial design.

Few planning efforts have been developed for the entire Leonard Ranch site. Approximately 40 acres of the site are planned to be included in a seasonal wetland restoration that also encompasses 288 acres of a site to the north known as the North Parcel. Highway 37 separates the two sites.

There are four significant site constraints. The property is bounded by Highway 37 to the northwest, Port Sonoma Marina to the southwest, a railroad line to the southeast, and private agricultural land to the northeast. The site would have to be surrounded entirely by a containment levee as long as these adjacent constraints remain.

Possible linkage to the existing Sonoma Baylands restoration project could occur via culverts or other structure allowing passage of tidal waters beneath the railroad right-of-way.

Sponsorship and Oversight

The entire property is owned by the Sonoma Land Trust (SLT), a non-governmental organization. Among other activities, SLT protects environmentally significant lands in Sonoma County, and restores them when indicated and feasible.

Sonoma Land Trust would be the primary project sponsor. SLT reports that the current Seasonal Wetlands Enhancement Project on the property has been developed in close cooperation with the U. S. Fish and Wildlife Service, the California Department of Fish and Game, the Marin / Sonoma County Vector Control District, Audubon Society, the lease-farmer of the property, and others. It is likely that a similar cooperative approach would be employed to develop a tidal restoration project on the Leonard Ranch.

Potential Benefits

Significant environmental benefits would be achieved by tidal restoration of the Leonard Ranch. Because of its adjacency to the Sonoma Baylands restoration project, almost a doubling of the area of restored tidal marsh would be accomplished. Many wetland-dependent species use the Sonoma Baylands site, and it would be expected that the number of species inhabiting the expanded area would increase significantly. Those species include many kinds of shorebirds, wading birds and waterfowl, among them white pelicans, egrets, black neck stilts, sandpipers, mallards, and many others. The area would serve as feeding, resting, and refuge habitat. In addition, because the area would colonize with wetland plants such as cordgrass and pickleweed, it also would provide habitat for mammals such as the endangered salt marsh harvest mouse.

By expanding habitat for Bay species whose populations are endangered or in decline, restoration of the Leonard Ranch would add incrementally to the stabilization of the population numbers, and help remove those species from protective status under the law. Thereby, the project would contribute to the eventual reduction or removal of current legal restrictions on development that poses threats to the few patches of habitat that exist at present.

Candidate Project 10: Sonoma Valley Vineyards and Wineries Best Management Practices

Project Overview

The Sonoma Valley Vintners and Growers Alliance (SVVGA), working with other members of the Sonoma Creek Watershed Conservancy, proposes to continue the restoration work, implementation of best management practices (BMPs), and education efforts begun under their current CalFed funding.

Project Description

As explained previously in the Case Study of the same name (see section 5.2, "Best Management Practices – Agriculture / Grazing"), the SVVGA is currently working with the Southern Sonoma County Resource Conservation District (SSCRCD), the Sonoma Ecology Center, and a local chapter of Adopt-a-Watershed on a variety of restoration and demonstration projects around the Sonoma Creek watershed. Over the past year, the SVVGA portion of the collective CalFed-funded project has included efforts to re-vegetate and stabilize streambanks, re-vegetate the banks of a vineyard reservoir, install drywells, install raptor and owl boxes, and complete vineyard setbacks. Future projects could also include integrated pest management or improved chemical application methods.

As with past efforts by the SVVGA, funding obtained from outside co-sponsors would allow local vintners and grape-growers to propose and complete the restoration or BMP projects on their own property. These projects are approved by members of the SVVGA before detailed planning takes place. Projects that the SVVGA considers to be normal agricultural practices, like planting cover cops, replanting vineyards, rock-lining terrace walls, or taking other steps to mitigate the effects growing grapes on steep hillsides will NOT be funded. The growers, not the federal government, will be expected to fund these types of projects.

In addition to their current project, the SVVGA would very much like to update, re-print, and distribute a document prepared in 1997 with the Sonoma Ecology Center and the SSCRCD. The document is an informational packet for prospective vineyard owners in the Sonoma Valley that stresses the importance of protecting limited soil resources and outlines the often-difficult realities of vineyard management.

Sponsorship and Oversight

Any restoration or BMP project would be managed by the property owner at the site of each project. The property owner is expected to pay some of the project costs, but the SVVGA hopes to obtain outside funding to help support the majority, or at least a substantial fraction, of the costs.

Potential Benefits

The potential environmental, social, and community benefits of this project are ultimately widespread improvements that could be made within this important San Pablo Bay watershed industry. Potential environmental benefits of this project include: improved water quality in streams due to reduced pollutant and sediment inflows; reduced water temperatures and increased protective cover for aquatic fauna due to stream bank revegetation; and reduced stream bank erosion. This project could result in social and community benefits including improved cooperation among vintners, grape-growers, and environmentalists, along with increased awareness by grape-growers of agricultural BMPs. An additional benefit will be the aesthetic benefits provided by increased riparian vegetation.

Candidate Project 11: Sulphur Creek Enhancement Projects

Project Overview

The Sulphur Creek Land Stewardship has identified six medium-sized potential restoration projects that would act collectively to improve fish habitat and access to upstream areas, reduce sediment loading, and increase native riparian vegetation along Sulphur Creek.

Project Description

The Sulphur Creek Land Stewardship ("the Stewardship") is a group of private citizens concerned with the quality and management of Sulphur Creek and the three sub-watersheds of its tributaries. Sulphur Creek itself is a tributary of the Napa River, which it meets just outside the town of St. Helena. The Sulphur Creek Stewardship has worked closely with the Napa County Resource Conservation District (Napa RCD)[8] to identify restoration needs and to begin to plan projects to address those needs.

Following are descriptions of six projects that the Stewardship is currently exploring. Although each project could be implemented separately, it is their collective impact that would provide real benefits to the aquatic habitat of Sulphur Creek:

Devil's Slide

This very large slide – 500 ft. at the toe, 250 ft. high, and 10 ft. deep – has contributed approximately 46,000 cubic yards of sediment to Sulphur Creek. It has created a log jam in the creek, and artificially raised the bed of the stream by about 8 feet. Stopping the slide is not a possibility, but reducing its impacts on the stream could be achieved with buttressing, revegetation, and erosion control measures. The Stewardship proposes to work with a geologist to develop plans for addressing this issue.

Fish Ladder

Over the years, down-cutting has occurred downstream of a bridge over Sulphur Creek, creating a 8- to 10-foot high barrier to steelhead migration. A fish ladder was installed to address this problem, but flooding in the winter of 1995 washed it out. Concrete, rebar, and other pieces of the failed ladder now block fish migration. The Stewardship is currently consulting with the Department of Fish & Game to identify funding and develop a plan of action for constructing a new fish ladder.

Native Revegetation

Various restoration efforts are needed at a gravel extraction site that ceased operation two years ago. At this location, where the stream reaches the Napa valley floor, Sulphur Creek is a braided stream. No clear channel exists for fish migration, so work may be

[8] Source for information regarding this Candidate Project: Phil Blake and Chris Auld of Napa RCD.

needed to redefine the channel. In addition, current vegetation is sparse, so the site needs to be re-vegetated with native plants.

Concrete Removal

At a site adjacent to a concrete plant, an existing bridge and accumulation of concrete have created a flow constriction that represents a potential threat to fish migration. The Stewardship has been working with the property owners to replace the bridge with a less damaging structure. Plans to install a fish ladder are currently in design phase.

Fish Enhancement

The Napa RCD, funded by a CalFed grant, has already worked with three property owners in the upper watershed to improve steelhead habitat. These projects include developing a clearly-defined flow channel for fish migration, construction of pools and riffles, and revegetation of stream banks. Funds are needed to continue this work in other parts of the Sulphur Creek watershed.

Invasive Species

Tree-of-Heaven, Tamarisk, and Arundo have been identified as problematic invasive exotics within the Sulphur Creek watershed. These plants would be located and removed so that native vegetation can thrive.

Sponsorship and Oversight

The projects listed above would be managed directly by either the Napa RCD or the Stewardship, or jointly by the two groups. However, significant cooperation by property owners is needed in order for the projects to succeed. One of the Stewardship's successes thus far has been its ability to recruit and involve property owners constructively in restoration planning; hopefully, this trend will continue.

Funding for this project could come from various public sources. One additional potential funding source is the Mennen Foundation, which has expressed interest in aiding restoration projects along Sulphur Creek.

Potential Benefits

Improved migration access for steelhead

Improved water quality due to reduced sediment input

Improved fish habitat (pools, riffles, etc.)

Revegetated stream banks, providing improved fish habitat and aesthetic benefits

Improved habitat for fish and terrestrial species, due to removal of invasive exotic vegetation

Improved cooperation of community groups, property owners, and government agencies

Candidate Project 12: Wildcat Creek

Project Overview

Past urban stream restoration efforts along Wildcat Creek have been progressive, but not entirely successful. Ongoing projects aim to de-silt and restore the active channel of Wildcat Creek in North Richmond, and future projects would further enhance the channel and improve fish passage.

Project Description

Wildcat Creek is frequently cited as a case study of a combined ecological restoration and flood control project. The lower portions of Wildcat and San Pablo Creeks run through North Richmond, where the need for flood control improvements was recognized as early as 1950. In 1985, after federal funding for a project with flood control and environmental elements fell through, Contra Costa County Public Works proposed a traditional, “bare-bones” flood control/channelization project with no environmental enhancements (Riley 2000). This plan was not well-received by the public, and permits were denied by the US Fish & Wildlife Service and the San Francisco Bay Conservation and Development Commission (EPA 1996).

In response, the Wildcat San Pablo Creek Design Team was formed and given the responsibility of developing a more environmentally sensitive proposal. The resulting plan, which was constructed beginning in 1986, was the “first attempt in the country to design a flood damage reduction project on the basis of more geomorphic compatible concepts” (Riley 2000). These concepts included an active channel surrounded by a riparian reserve approximately 50 feet wide, a floodplain, set-back berms, and a regional trail. A sediment detention basin was also built upstream of the area.

The floodplain of Wildcat Creek is actively managed by the Contra Costa County Flood Control and Water Conservation District (FCD), while the active/low-flow channel, in theory, is left to run its natural course. However, in 1996 it became clear that more sediment was arriving from the upper watershed than expected, causing siltation of both the low-flow channel and the floodplain. The FCD lowered only the floodplain in a 1998 de-siltation project, and worked with the Waterways Research Institute (WRI) in the summer of 2000 to de-silt and reestablish the active channel of the creek. The project with WRI restored Wildcat Creek from Giaramita St. to Richmond Parkway in North Richmond (Riley 2000). The Corps of Engineers Section 1135 grant program supported this work.

High sedimentation rates in Wildcat Creek have clogged the fish passage systems that are critical for access to spawning areas. The Wildcat-San Pablo Creeks Watershed Council has been working on redesigning the fish ladders as part of another Section 1135 grant, and hopes to work with the Coastal Conservancy in implementing these plans in 2001. It is believed that upper Wildcat Creek provides habitat to Coastal Steelhead.

Restoration projects may be needed in the future to further improve the low-flow channel and floodplain, to improve the sediment basin (Riley 2000), or to maintain efforts to control erosion in the upper watershed (EPA 1996).

Sponsorship and Oversight

The FCD holds the responsibility of maintaining flood protection and has authority over the floodplain, so the agency is committed to involvement in channel modification activities along Wildcat Creek. The FCD has been joined by the WRI, the Urban Creeks Council, the San Francisco Estuary Institute, the East Bay Conservation Corps (Riley 2000), and others in past projects. This collaboration of public and private agencies will likely continue into the future.

A second grant (Section 1135 grant from the Army Corps of Engineers) may fund the next phase of restoration, which involves improving fish passage systems.

Potential Benefits

Wildcat Creek shows considerable promise for offering much-improved habitat to Coastal Steelhead and Chinook Salmon; the primary environmental benefit of restoration projects there is the improvement of fish passage and fish habitat. Flood control improvements are also possible if siltation of Wildcat Creek and its floodplain can be prevented or reversed.

Performance Measures

Future projects along Wildcat Creek have not yet been planned in detail, and it would be difficult to point to specific success indicators at this time.

Candidate Project: San Antonio Creek Wetlands Enhancement Plan

Project Overview

The Sonoma County Water Agency's (SCWA) proposed implementation of the Wetland Enhancement Plan will create habitat for local wildlife by restoring seasonal habitat, while eliminating stormwater backup onto a State Highway.

Project Description

The SCWA retained ecological restoration consultants to develop a Wetland Enhancement Plan (SCWA 1989) in preparation for implementation of this project. The primary restoration objective of the Wetland Enhancement Plan is to develop habitat for wetland plants and animals within the framework of a flood control project.[9] The site is a 15.6-acre property on State Highway 101 at the Marin / Sonoma County border. Current land use at the site is a drive-in theater, which in a state of disrepair. The levees surrounding the site have breached in several places, allowing flood flows to pass through the site. The plan is to enhance shallow freshwater ponds in the eastern portion of the site to support shorebird and waterfowl species, which are currently using the site in small numbers (Granholm 1989).

- The enhancement concept is to increase the amount of seasonal water that ponds on the site and provide vegetation for food and cover, for the benefit of both wetland and upland wildlife. Accomplishing this will involve demolition and removal of pavement and other existing site features, grading, planting of wetland species, and providing for increased water on the site. Groundwater and an adjacent creek will provide the water necessary to create the ponds. The plan includes augmenting an existing dam at the southeast corner of the property. The rip-rapped dam will be used to impound and control the water on the site. The plan also includes the construction of a trail and public viewing area in the southeast corner of the site.

Sponsorship and Oversight

Previously owned privately, the SCWA now owns and oversees the site. The State Coastal Conservancy provided funding to the SCWA for preparation of the Wetland Enhancement Plan. While the State Coastal Conservancy and SCWA have expressed an interest in providing funds for the project, a sponsor commitment for constructing, maintaining and monitoring the site enhancement has not yet been secured.

A recommendation contained in the Wetland Enhancement Plan is to have an agency or organization with expertise in wetland management take responsibility for the site during the first several years of operation. Thereafter, the plan suggests, a committee of local citizens, wildlife agency personnel and the site owner can conduct operations.

[9] Information regarding this candidate project was obtained through personal communication (Webber 2000) and the Wetland Enhancement Plan (SCWA 1989).

Community/Social and Environmental Benefits

The plan combines flood control with habitat benefits. By reducing the likelihood of flooding across the state highway, implementation of the plan will provide an important public safety benefit and will reduce the potential for damage to infrastructure. According to the plan document, shallow freshwater ponds on the site will provide the following benefits to wildlife:

- "Foraging and resting habitat for shorebirds and waterfowl;
- A refuge area during storms for species foraging on nearby tidelands;
- A renewing supply of food as the shoreline recedes, exposing new areas to feed; and
- Brood water for dabbling ducks such as mallards and cinnamon teal, which hide their nests in upland vegetation and lead their chicks to freshwater." (SCWA 1989)

These habitat benefits are especially important in this area, where seasonal wetlands have been depleted (Granholm 1989). The plan also provides the public benefit of a place for wildlife observation and environmental education area by providing public access (along the southern border of the site) and a viewing area.

Potential Performance Indicators

■ The Wetland Enhancement Plan calls for a variety of ongoing monitoring associated with implementation of the plan. Monitoring of physical and biological changes is recommended for the first several years of implementation. The resulting data will provide site-specific insight as to how quickly vegetation colonization or sedimentation occurs. Examination of monitoring data will help to determine the appropriate schedule and measures for maintenance to control sedimentation, vegetation, water quality, mosquitoes and disturbance caused by human visitors. The results of this monitoring will have the added benefit of providing on-the-ground evidence regarding the effectiveness of wetland creation and enhancement methods.