SAN FRANCISCO BAY SUBTIDAL HABITAT GOALS REPORT

Appendix 6-1: Removal of Creosote-Treated Pilings and Structures from San Francisco Bay

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Removal of Creosote-Treated Pilings and Structures from San Francisco Bay

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Executive Summary

The remnants of old creosote-treated piers and dilapidated maritime facilities are common sights along intertidal and subtidal shorelines. Removal of these structures has been proposed as a possible restoration focus for San Francisco Bay. Removal of dilapidated pilings could mitigate the adverse effects of other environmental threats and advance long-term goals for management and restoration of subtidal habitats in San Francisco Bay.

This project included four main tasks:

- Map abandoned creosote-treated pilings throughout San Francisco Bay.
- Assess the potential impacts and benefits of creosote-treated pilings.
- Develop methods for determining potential historic significance, or lack of significance, that might assist in prioritizing structures for removal.
- Assess the methods and actions that would be needed to remove or treat the structures.

The report summarizes the findings of those tasks and also presents a section about the broader picture for artificial substrates in San Francisco Bay.

Mapping identified a total of 30,546 derelict pilings in 630 “piling complexes,” which were defined as one or more pilings that appeared to have been part of the same structure at one time. About half the pilings and complexes were found in the North Bay, and about half in the Central Bay. Relatively few pilings and complexes were found in the South Bay. Carquinez Strait, Richmond, and San Francisco were the sub-regions with the greatest numbers of pilings; Carquinez Strait, Richmond, and the East Bay had the highest numbers of piling complexes.

The project’s environmental assessment found that leaching rates of contaminants from creosote-treated wood are variable and greatest during the first few years after placement. However, leaching continues for many years. There is documented evidence of biological impacts to organisms from the contaminants found in creosote, including the Pacific herring, an important fishery species in the Bay. Piles and associated structures may also have adverse physical impacts, such as shading or increases in scouring. Invertebrates, fish, and bird species do use the creosote-treated piles, but the degree to which the structures are of beneficial use has not been quantified.

Some creosote-treated pilings and structures in San Francisco Bay are of interest because of their age and their cultural interest. While historical review is unlikely to prevent removal of most creosote-treated structures, historical analyses would have to be completed prior to removal. Experts suggest a Bay-wide programmatic approach rather than case-by-case analyses as the most efficient and cost-effective method for evaluating historical significance.

Feasibility and costs of removal will be dependent on removal techniques, location, and timing of projects. Water depth, availability of temporary storage sites near the removal project, and accessibility to the site for removal to disposal areas may be major factors in prioritizing removal projects.

Removal of creosote-treated pilings and structures has been a priority in other regions, particularly Puget Sound. The project built on that experience from other regions, as well as the findings of the project tasks, to develop a list of suggested attributes for priority removal sites in San Francisco Bay (Table 1).

Table 1. Potential attributes of high-priority removal projects

Mapping
High density
High navigation hazard

Environmental Assessment
High probability of removing contaminant effects (e.g., removal from herring spawning areas)
Low probability of introducing a new pulse of contaminants
High probability of enhancing habitat, such as eelgrass beds
Low probability of adversely affecting habitat for birds

Historical Significance
Non-historic (built in the past 50 years)
Low cultural value
Low aesthetic value

Action Plan (Feasibility and Logistics of Removal)
Availability of access for removal
Availability of temporary storage
Access to transportation to disposal sites
Low ownership/responsibility issues

1. Introduction

The remnants of old creosote-treated piers and dilapidated maritime facilities are common sights along the intertidal and subtidal shorelines of San Francisco Bay. Creosote was used for many years as a method for preserving marine structures from decay. It is a complex mixture of chemicals, many of which are toxic to fish and other marine organisms. There is particular concern that chemicals leaching from creosote-treated structures could harm the Pacific herring, one of the last fisheries in the region, because herring spawn on hard surfaces, including old pier pilings. There is also concern that dilapidated creosote-treated pilings are hazards to navigation and that they will pose even greater hazards as sea level rises.

Removal of these structures has been proposed as a possible restoration focus for San Francisco Bay. Creosote-treated wood and debris removal operations are underway in other regions of the United States. Removal of dilapidated pilings could mitigate the adverse effects of other environmental threats and advance long-term goals for management and restoration of subtidal habitats in the Bay.

To date, there has been no comprehensive effort to document the precise numbers or locations of derelict creosote-treated piles. There are questions about the extent to which they pose risks to wildlife and whether, in some cases, they provide benefits. There are questions about historic significance and whether historic preservation issues might preclude removal of some structures. There are also questions about the feasibility and logistics of removal. This report summarizes the efforts of a California State Coastal Conservancy contract with the San Francisco Estuary Institute (SFEI) and a team of subcontractors answer to these questions (Table 1-1).

The project included four main tasks:

- Map abandoned creosote-treated pilings throughout San Francisco Bay.
- Assess the potential impacts and benefits of creosote-treated pilings.
- Develop methods for determining potential historic significance, or lack of significance, that might assist in prioritizing structures for removal.
- Assess the methods and actions that would be needed to remove or treat the structures.

This report summarizes the findings of those tasks and also presents a section about the broader picture for artificial substrates in San Francisco Bay.

Table 1-1. Questions about creosote-treated pilings San Francisco Bay.

Mapping
What is the distribution of abandoned creosote-treated pilings?
How does the distribution of abandoned piles relate to herring spawning areas?

Environmental Assessment
What adverse effects of creosote-treated wood have been measured?
Are there potential beneficial effects of piles for invertebrates and birds?

Historical Significance
When was creosote used?
Why were creosote-treated pilings installed?
Do creosote-treated pilings have historic significance related to the history of development along the Bay margin?
Are there historic-preservation issues that would complicate removal?

Action Plan (Feasibility and Logistics of Removal)
What are the feasibility and costs of removal?
What are the disposal options?
What permits and authorizations are required?
What are the ownership/responsibility issues?

Next Steps
What attributes (besides herring spawning) should be used to prioritize locations for removal or treatment?

1.1 The Subtidal Habitat Goals Project and Artificial Substrates in San Francisco Bay

The project was carried out as a part of the San Francisco Bay Subtidal Habitat Goals Project, a collaborative effort to establish a vision for research, restoration, and management of the subtidal habitats of San Francisco Bay. The Subtidal Habitat Goals Project is an interagency partnership of the California Ocean Protection Council/State Coastal Conservancy, the San Francisco Bay Conservation and Development Commission (BCDC), the National Oceanic and Atmospheric Administration (NOAA), and the San Francisco Estuary Partnership.

How to manage artificial substrates, including derelict creosote-treated structures, is one key area of interest to the Subtidal Habitat Goals Project. As a highly urbanized estuary, San Francisco Bay has a varied landscape of artificial substrates, some of which are in current use and others of which have been long abandoned (Table 1-2). Artificial substrates are, in some cases, beneficial to the flora and fauna of the Bay, as they provide hard surfaces in an environment where hard habitats are relatively rare. In other cases, the artificial substrates are a negative factor, as they may, for example, impede navigation or release toxic contaminants into the water column.

Table 1-2. Types of artificial substrate in San Francisco Bay

- **Ships and Vessels**
  - Recreational boats
  - Commercial vessels
  - Abandoned vessels
  - Exposed shipwrecks (Point Molate)
  - Sunken shipwrecks
  - National Defense Reserve Fleet (Suisun Bay)
  - Houseboats (Richardson Bay)
- **Pilings**
  - Marina areas
  - Ports
  - Vehicle bridges
  - Foot bridges
  - Fishing piers
- **Wharves**
- **Floating Docks**
  - Private docks
  - Public docks
- **Unused, Derelict Piers**
  - Berkeley Pier
  - Point Molate Pier
- **Jetties**
- **Breakwaters**
  - Riprap breakwaters
  - Concrete breakwaters
- **Other Riprap**
  - Hardened shoreline functioning as levee
  - Concrete blocks and other debris
- **Sea Walls and Bulkheads**
  - Wooden sea walls
  - Concrete sea walls
- **Buoys**
- **Pipeline**
- **Cables**
- **Transmission Towers/Power Lines**
- **Power Plants**
  - Cooling-water Intakes
- **Outfall Structures**
  - Power plants
  - Water treatment plants
  - Other pipelines
- **Duck Blinds**
- **Moorings**
- **Anchors**
- **Pacific Oyster Shell (Restoration Projects)**
- **Large Debris**
  - Shopping carts
  - Tires
  - Abandoned equipment

The Subtidal Habitat Goals Project is interested in better understanding these structures—their benefits and their detriments. In the cases in which there are both benefits and adverse effects, the Subtidal Habitat Goals Project seeks to determine whether there are corrective or mitigating actions, such as removal, encapsulation, or other modifications, which might best serve the functioning of the overall subtidal habitats in the Bay. As part of the broader focus on artificial substrates, the Subtidal Habitat Goals Project has recognized removal of some structures, particularly abandoned pilings and structures that were treated with creosote, as a possible priority restoration activity for San Francisco Bay.

1.2 San Francisco Bay

San Francisco Bay is the largest estuary on the West Coast of North America. A highly urbanized region, the Bay Area is home to more than six million people. The Bay has been heavily affected by human activities since the Gold Rush of the 1850s, when hydraulic mining sent masses of sediments down its watershed, and farmers began to dike off major portions of land to support the region's growing population.

The Bay is naturally divided into major basins extending from north to south: Suisun and San Pablo Bay, which comprise the North Bay; Central Bay, which connects to the Pacific Ocean through the Golden Gate; and South Bay. Because creosote-treated pilings tend to occur at the edges of the basins, this project has delineated the region further, into eight sub-regions, focusing on the shorelines (Figure 1-1):

- Carquinez Strait, including the north and south shores, from the Carquinez Bridge to the Sacramento and San Joaquin Delta.
- San Pablo Bay, from Novato to the north side of the Carquinez Bridge.
- Marin Shore, from the north shore of Lands End of the Golden Gate to Novato.
- San Francisco, from the south shore of the Golden Gate Channel to just south of Candlestick Park.
- Peninsula, from just south of Candlestick Park to the west shore of the San Mateo Bridge.
- Point Richmond, from Richmond Harbor to the south side of the Carquinez Bridge.
- East Bay Shore, from the east side of the San Mateo Bridge to the south side of Richmond Harbor.
- South Bay, including all the area south of the San Mateo Bridge.

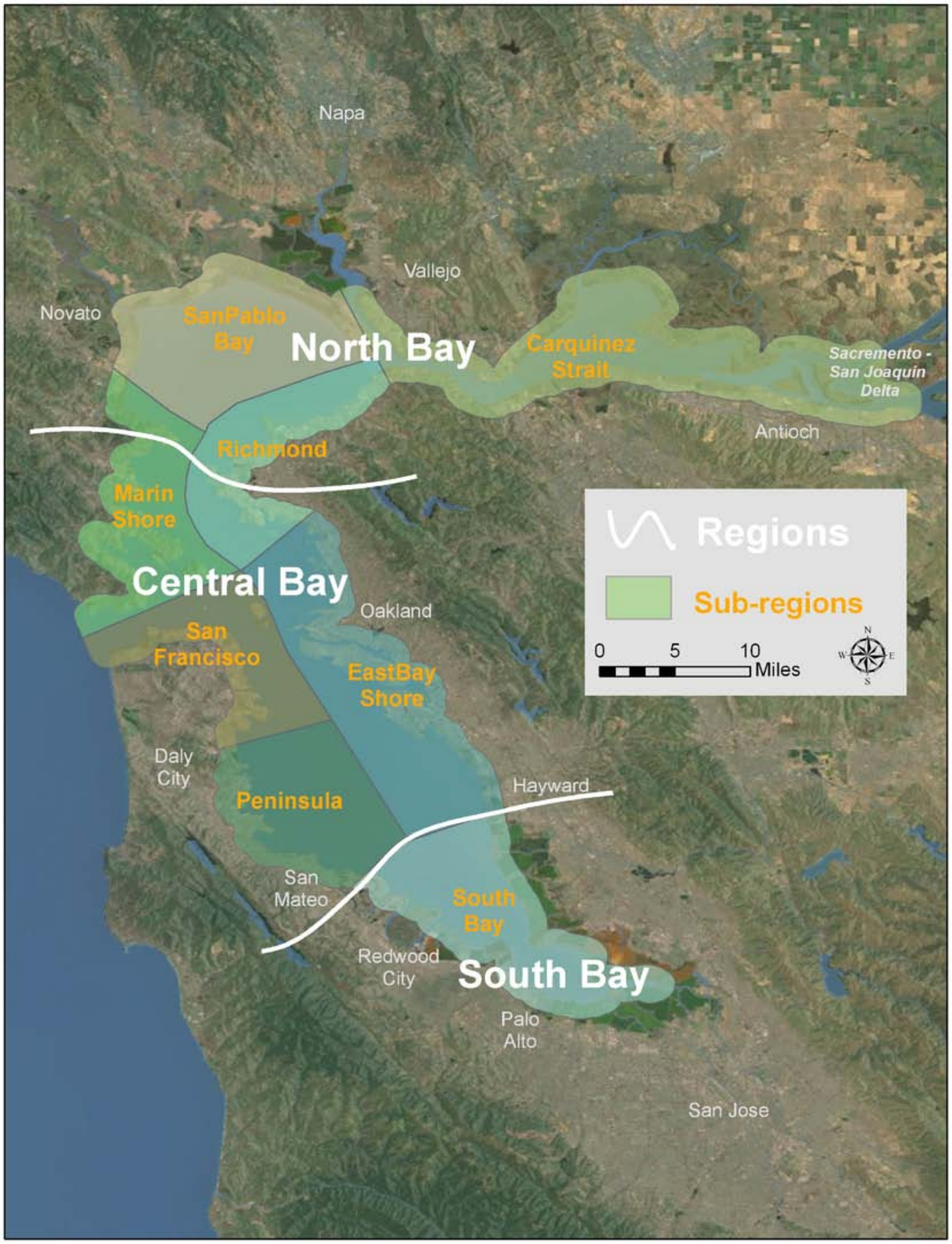


Figure 1-1. San Francisco Bay project extent and sub-regions.

The Bay has a long history of pollutant inputs and is listed under Section 303(d) of the Clean Water Act as impaired by copper, mercury, nickel, selenium, polychlorinated biphenyls (PCBs), dioxins, furans, legacy organochlorine pesticides, and polycyclic aromatic hydrocarbons (PAHs). PAHs are major constituents of creosote and are also found in gasoline, oil, and other compounds that may be discharged to, spilled into, or deposited on the Bay. The Bay is also listed as impaired by trash, including plastic and other debris.

The Bay is quite shallow, with an average depth of less than ten feet at low tide. During extreme low tides, about one-sixth of its area is exposed, largely as expansive mudflats. There are some sandy areas, mostly in maintained channels, and a few rocky outcrops, but mostly, the sediments of the Bay are composed of fined-grained silts and clays.

The Subtidal Habitat Goals Project has completed a report on the subtidal habitats and associated plants and animals in five San Francisco Bay habitat types: the hard bottom that is of primary interest to this report, soft bottom, shellfish beds, plant beds, and water column (NOAA 2007):

- **Hard substrates** include artificial substrates, boulders, and rock outcrops. Naturally occurring hard substrates are primarily located within the Central Bay, where tidal currents are sufficient to scour soft sediments. Hard substrates provide habitat for attachment by algae and invertebrates, and refuges and foraging sites for fishes and birds. Hard substrates also provide feeding habitat for harbor seals and sea lions. Pacific herring spawn on hard surfaces.
- **Soft-bottom substrates** dominate the Bay surface. Soft substrates provide habitat for algae and submerged aquatic vegetation (SAV); a diverse benthic fauna, which is highly affected by invasions of exotic species; resident and anadromous fishes; and birds and mammals that feed on benthic organisms.
- The NOAA report separates **shellfish beds** from other hard substrates. Several types of shellfish beds occur in San Francisco Bay: California mussel and bay mussel beds on hard surfaces, attached by byssal threads; ribbed horse mussel beds in salt marshes or on hard surfaces; green bagmussel beds, which lay in interconnected mats; and beds of the native Olympia oyster, which in the past developed extensive congregations on Bay sediments.
- The report also separates out **subtidal plant beds**, including algal beds and SAV. Eelgrass beds are the most common SAV in San Francisco Bay (Figure 1-2). SAV species provide primary productivity and decrease erosion by dampening the effects of waves, decreasing sediment resuspension, and increasing deposition. SAV provides a hard surface for attachment of invertebrates and habitat for fishes. Eelgrass beds are favored sites for deposition of eggs by Pacific herring. Shading by artificial substrates is one of many stresses that may limit subtidal plant beds.
- The **water column** provides habitat for plankton and feeding locations for fishes, birds, and mammals.

Figure 1-2. Distribution of eelgrass beds and other submerged aquatic vegetation in San Francisco Bay (From NOAA 2007).

Of the many fish species that inhabit San Francisco Bay, the Pacific herring is of special interest to this project, because they sometimes spawn on creosote-treated pilings. Pacific herring enter San Francisco Bay to spawn in the Central Bay and South Bay (Figure 1-3) during the winter months. Precise spawning timing and locations vary from year-to-year, almost always including Richardson Bay, an embayment located on the Marin shore. Herring spawn on hard surfaces, including eelgrass, seaweed, rock, pier pilings, retaining walls, riprap, and boat bottoms. Significant spawning has been known to occur along the San Francisco waterfront (Watters et al. 2004).

Figure 1-3. Historical herring spawning areas in San Francisco Bay.

Low spawning biomass has prompted the cancellation of the 2009–2010 herring season event (DFG 2009). Spawning biomass in 2008–2009 was about 10% the historic average. Oceanic conditions were favorable, suggesting that the low biomass was due to conditions within the Bay. The November 2007 *Cosco Busan* oil spill occurred just prior to the 2007–2008 spawning season, and it may have damaged the spawning success for that year. Drought conditions may be another factor—the 2008–2009 spawning events occurred further upstream than had been typical, as far as Point San Pablo in Richmond.

1.3 Creosote-Treated Wood in San Francisco Bay

Wooden piles have been used in marine construction projects for thousands of years. Beginning with the Gold Rush, wooden wharves and piers proliferated on the San Francisco waterfront. Railroad construction spurred development on the East Bay shoreline and in the Carquinez Strait. Because of its low cost and wide availability, wood was almost exclusively used for waterfront construction along the Bay until about 1908, when concrete also became a favored building material.

The majority of wooden piles in use in the early 1900s were owned by the Southern Pacific Railroad or the Board of State Harbor Commissioners (Kemble 1923). Pile-supported wooden structures were constructed in almost all parts of the San Francisco Bay shoreline and were used for a diverse array of activities:

- The **military** has been one of the principal builders along the shoreline, beginning with the construction of the Presidio by the Spanish in 1776. Most military facilities have been designed and constructed by the U.S. Army Corps of Engineers.
- Pile-supported structures were built to serve **industrial plants and oil refineries** throughout the Bay.
- Some of the earliest wooden pile structures were built to support small **agricultural enterprises** that shipped products to markets.
- Piles were integral parts of many aspects of the Bay’s **transportation and navigation** infrastructure, including ferry terminal piers, Key Route (mass transit) and railroad piers, automobile and railroad trestles, and navigational aids.
- Piles were also used to support **recreation**, in fishing piers, hunting clubs and duck blinds, marinas, and private docks.

Over time, individual piles and many entire piers were repaired, rebuilt, replaced, and abandoned. Ongoing maintenance and development often resulted in chaotic piling arrangements, as new piles were typically driven next to old, which were left in place rather than removed (Stilgoe 1994).

Attacks by successive waves of marine borers were the chief threats to piling integrity. The Board of State Harbor Commissioners began to explore potential wood-treatment processes to combat native marine borers as early as 1869 (Neily 1927). Attacks by two non-native species, one in the early 1870s and the other in the mid-1910s, further emphasized the need for treatment. One of the most widely used treatment options was creosote. A forerunner of what would now be recognized as coal-tar creosote was first used in South Carolina in 1716. The product (and process) that we would today recognize as coal-tar creosote was patented in England in 1838, where it went into immediate use in the railroad industry.

The use of creosote-treated wooden piles in new construction and for repairs remained very high in San Francisco Bay into the 1950s, when, as shipping in the Bay declined somewhat after the Korean War, there may have been some decline in its use. A big change came in the 1970s, when in a short time period, break-bulk shipping was superseded by container shipping. Container terminals may have been built with some wooden pilings, but the facilities were mostly constructed from concrete.

Increased environmental awareness also contributed to a decrease in use of creosote-treated wood in marine environments. The U.S. Environmental Protection Agency (EPA) began investigating creosote in 1978, and in 1993, the California Department of Fish and Game (DFG) stopped approving its use in state waters (Gibbons 1993). The San Francisco Bay Regional Water Quality Control Board (Water Board) prohibits the use of creosote-treated wood in new construction of docks, boardwalks, and other aquatic structures requiring pilings.

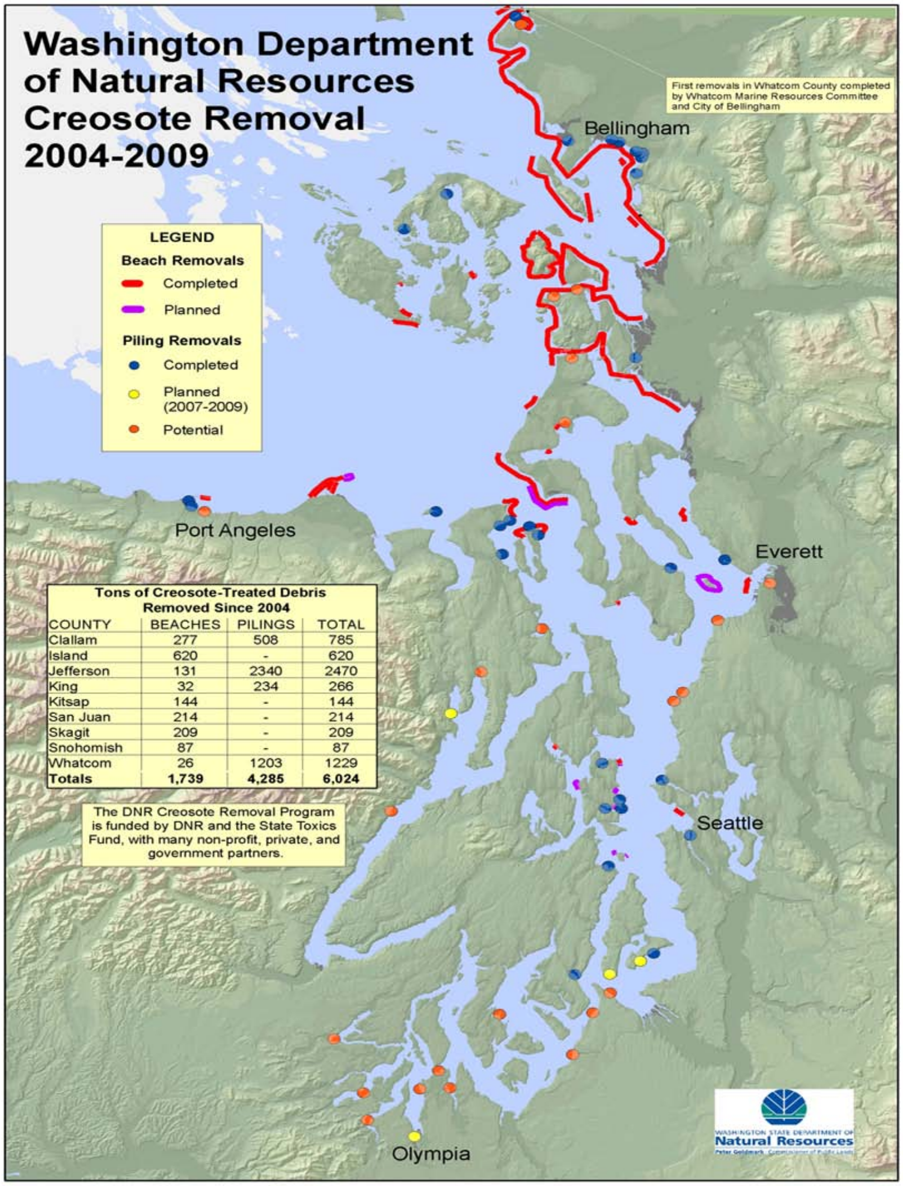
Additional information on the use of creosote in San Francisco Bay waters is included in Appendix C.

1.4 Lessons from Other Locations

The largest creosote-removal projects in the country are underway in the State of Washington, primarily in Puget Sound. In 2000, the Washington State Department of Transportation/Washington State Ferries made a commitment to environmental responsibility that included removal of creosote-treated structures from its ferry terminals (information available at www.wsdot.wa.gov/ferries). Their terminals, which had mostly been built in the 1940s and 1950s, incorporated creosote-treated wood in their wharf pilings, loading structures, and offshore facilities. Concern that leaching of contaminants from those structures could adversely affect juvenile salmon prompted plans to remove millions of board feet of pilings and other structures.

The Washington State Department of Natural Resources (DNR) began to address creosote removal in 2002, and large-scale removal of creosote-treated material was one focus of the governor’s Puget Sound Initiative (information available at www.dnr.wa.gov). The program is concerned with two possible pathways of exposure to creosote compounds: direct exposure to animals that live or spawn on upright pilings and continued exposure from derelict structures that end up washed up onto beaches. One concern was that Pacific herring eggs, English sole, and species that are part of the food chain for salmon and *Orca* whales were being exposed to toxic and carcinogenic compounds. Another concern was that people who visited the many Washington beaches with large accumulations of wood debris could be exposed to creosote compounds.

Cleanup began in 2003, when beaches in the Straits of Juan de Fuca were cleared of debris. During 2004–2009, more than 4,000 tons of standing pilings were removed, and tons of creosote-treated debris was cleaned from the beaches (Figure 1-4). Sites targeted for removal are prioritized, with highest priority given to sites with high densities of pilings; lack of other contaminant issues; a high interest by the local community; Endangered Species Act concerns; public health and safety issues, such as obstructions to navigation; and habitat concerns, such as presence of herring spawning, crabs, or other shellfish. In some areas, DNR replaces pilings with steel or concrete structures rather than removing them, and DNR has worked with the Washington Department of Fish and Wildlife and local Audubon groups to reduce impacts to birds.



Tons of Creosote-Treated Debris Removed Since 2004

COUNTY	BEACHES	PILINGS	TOTAL
Clallam	277	508	785
Island	620	-	620
Jefferson	131	2340	2470
King	32	234	266
Kitsap	144	-	144
San Juan	214	-	214
Skagit	209	-	209
Snohomish	87	-	87
Whatcom	26	1203	1229
Totals	**1,739**	**4,285**	**6,024**

Figure 1-4. Tons of creosote-treated pilings and debris have been removed from Puget Sound (http://www.dnr.wa.gov/Publications/aqr_cleanup_creosote_overview_map.pdf)

Pile-removal projects are also being contemplated for the Columbia River, which divides the states of Washington and Oregon. The Lower Columbia River Estuary Partnership, a cooperative initiative representing northwest Oregon and southeast Washington, has developed a set of draft hypotheses, prioritization criteria, and implementation criteria for a Pile Structure Removal Program designed to benefit juvenile salmonid populations (information available at www.lcrep.org). They used a shoreline inventory video to survey 638 miles of Columbia River coastline and to develop and prioritize a list of possible piling-removal projects.

In some regions, piling are considered valuable habitat or aesthetically desirable features. In New York City's Hudson River Park, pilings have been preserved as habitat for invertebrate and fish species (Hudson River Park Trust 2009; Figure 1-5). Pilings are highlighted as platforms for sculptural art in another New York installation, the Hudson River Pilings Project. The artist has "long been enamored of the pilings; the submerged logs that once supported the Hudson's busy piers," showcasing the historical interest in waterfront structures (Benafiel 2009). At South Cove (Battery Park City) on the Hudson River, new piles were installed as part of a landscape art piece along the shoreline in late 1980s. In this case, the pilings were considered to be aesthetically pleasing. One of the collaborators described how they installed "pilings into the water to make a visual transition between the land and the water" (Jasch 2004).

Figure 1-5. The Hudson River Park Trust removed decking but is committed to preservation of piles as habitat for invertebrate and fish species. (project team photograph)

2. Mapping

DFG has estimated that there are 50,000–70,000 creosote-treated pilings in San Francisco Bay, including those that remain in use, as well as dilapidated structures that are the subject of this mapping task (DFG 1996). Mapping was limited to structures that are no longer in use, because many of the in-use piles are underneath large structures and not visible. Also, the unused structures were considered to be most appropriate for removal projects. Developing a database of locations and numbers of the creosote-treated piles and structures will provide one tool for managers, planners, scientists, and the interested public to plan for removal or treatment projects.

A complete report on the mapping task is included in Appendix A.

2.1 Methods

This project mapped dilapidated “piling complexes,” which were defined as one or more pilings that appeared to have been part of the same structure at one time. Numbers of individual piles included within each complex ranged from one to thousands. Associated deck cover and other debris were also captured. Mapping covered San Francisco Bay, from the geographic northern extent of San Pablo Bay to the southern end of South Bay, and from a western boundary past the Golden Gate Bridge to an easternmost point at the City of Antioch, upstream from Suisun Bay.

Mapping was accomplished through a partnership of the SFEI Geographic Information System (GIS) department and the NOAA Southwest Region Habitat Conservation Division (Figure 2-1). The partnership allowed the project to extend mapping coverage to some areas that were not included in the project plan, such as the Napa River, Petaluma River, and the Oakland Ship Channel. SFEI’s mapping methodology primarily used aerial imagery and remote-sensing techniques to identify piling complexes. NOAA contributed field resources to map regions where remote-sensing techniques proved challenging. Both SFEI and NOAA conducted field ground-truthing of the remote-sensing data.

SFEI combined several software packages to gather information: Microsoft (MS) Bing Maps (formerly known as Virtual Earth), Google Earth, and ESRI ArcGIS. Each software package contributed to the value and accuracy of the dataset. The MS “Bird’s Eye” feature in Bing Maps offers high-resolution, oblique-angle 1998–2009 imagery for most of the San Francisco Bay shoreline (Pictometry 2009). SFEI used the Bird’s Eye feature to pan across the nearshore landscape and identify patches of pilings (e.g., Figure 2-2).

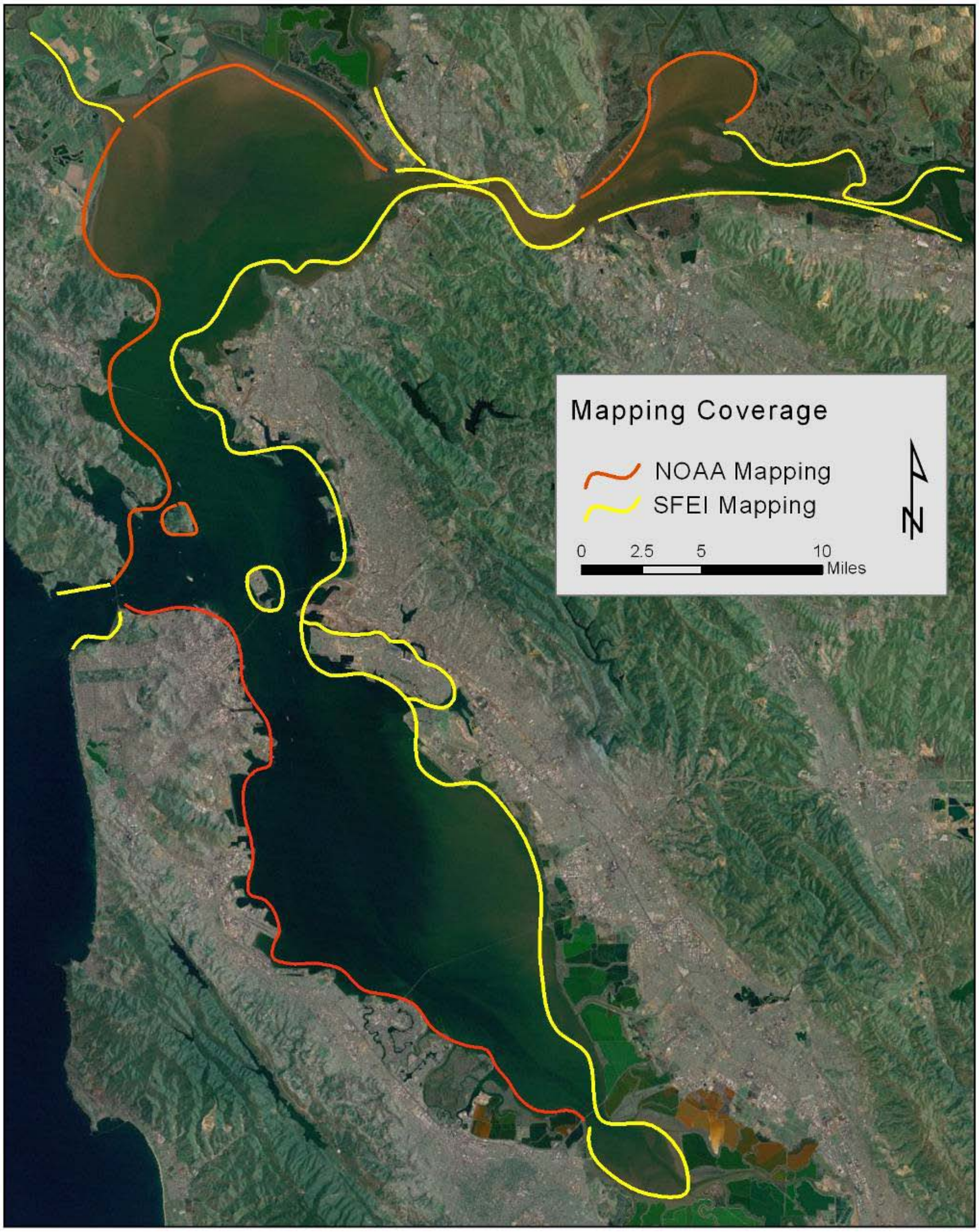


Figure 2-1. Mapping coverage by NOAA and SFEI.

Figure 2-2. Bing Maps Birds Eye screenshot from the south side of Brooks Island, Richmond.

Google Earth provides comprehensive coverage and tools to delineate and attribute polygons. These tools were used to define piling complexes as polygons (Figure 2-3). ESRI ArcGIS software can read Google Earth data and perform spatial analyses. Attributes assigned during the mapping process included estimated number of piles per complex, estimated remaining deck cover, location (water, land, or both, that is, a complex with piles both on land and in the water), region, sub-region, and identifying numbers for individual sites. Only piling complexes were defined with attributes. Individual piles were not attributed separately. Additional data were also placed in the attribute table, including minimum, maximum, and mean depth of the piling complex, computed from the DFG bathymetry layer; a designation of being above, on, or below six feet mean sea level; and a habitat type, based on the Bay Area EcoAtlas modern baylands and adjacent habitats layer, which is available through SFEI.

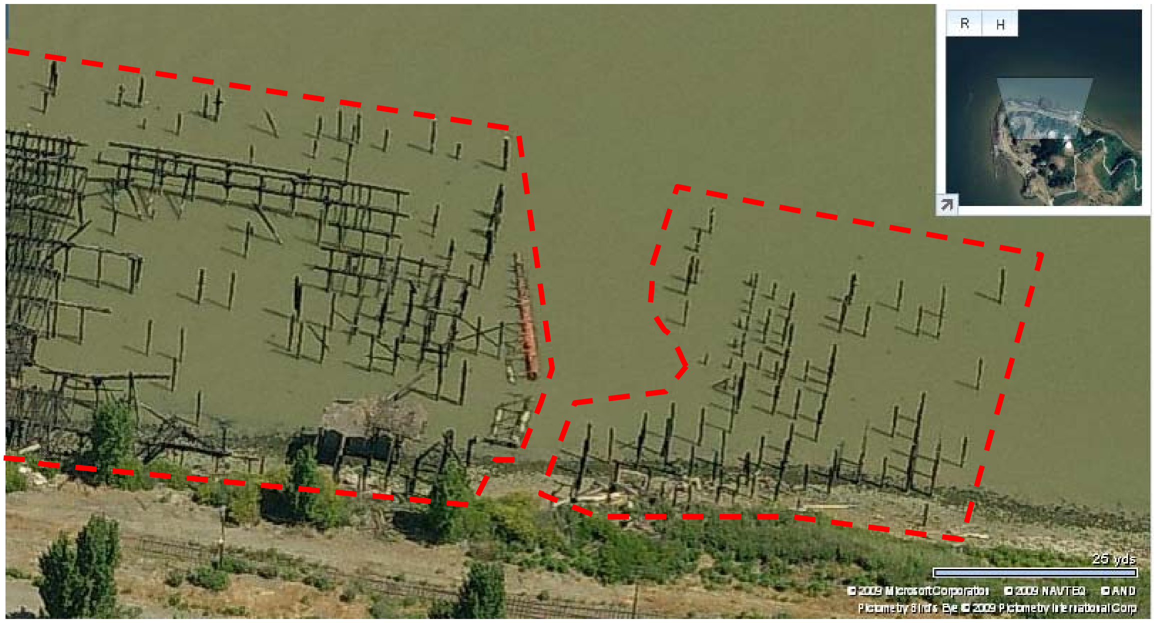


Figure 2-3. Bing Maps screenshot with outline depicting complexes to be mapped in Google Earth.

NOAA identified pilings in areas for which photographic interpretation was not available and provided ground verification of the remote-sensing information. The NOAA contribution included mapping along the western shore of San Francisco Bay, where the density of pilings and other structures made identification of piles and piling complexes difficult to determine remotely. NOAA also mapped the Grizzly Bay portion of the North Bay, included in the Carquinez Strait sub-region, where high-resolution imagery was not available. Field mapping protocols included traversing portions of the Bay in a small boat during rising tides and documenting findings with an ESRI ArcPad running ArcGIS. One or more photographs were taken for each piling complex, status was checked on nautical charts, and field data were recorded. At a minimum, field data included estimated number of individual piles, estimated remaining deck cover, location (water, land, or both), and a site identification number. When possible, field notes also included presence and identification of organisms and pile condition.

SFEI compiled the NOAA and SFEI data into one seamless dataset and conducted spot field checks to verify the information. This process removed approximately 10,000 navigational markers and other in-use piles from the dataset and corrected other errors. (Information on the piles that were removed from the dataset remains available.) The most common error found in the verification process was overestimation of the number of individual piles included in piling complexes. Consequently number of piles was recalculated for the entire study area.

Attributes included within the dataset are listed in Table 2-1.

Table 2-1. List of attributes included in the database.

Comprehensive	Not comprehensive**
Estimated number of piles per complex Estimated % deck cover Complex location (Land, Water, Both*) Region and sub-region Date and site number Inventoried by In use Habitat type (from Modern Baylands) Herring spawning habitat Depth (min, max, mean) Slope (min, max, mean)	Site description Vertical/horizontal count Description of surrounding Environment Species present Image

*A piling complex contains pilings in land and pilings in water
**These data were collected only through field mapping methodology

2.2 Numbers, Locations, and Hot Spots

Mapping identified a total of 30,546 derelict pilings in 630 piling complexes (Figure 2-4; Table 2-2). About half the individual pilings were in complexes located completely in the water, with the other half located on land or within complexes with piles located both on land and in the water. Almost 80% of the piling complexes were located in the water. Most piles were in waters with depths of less than six feet mean sea level. Neither field nor remote methods could detect pilings that were entirely submerged.

About half the pilings and complexes were found in the North Bay, and about half in the Central Bay. Relatively few pilings and complexes were found in the South Bay. Carquinez Strait, Richmond, and San Francisco were the sub-regions with the greatest numbers of pilings; Carquinez Strait, Richmond, and the East Bay had the highest numbers of piling complexes.

Thirty-seven percent of the individual derelict piles and 36% of the piling complexes were located within herring spawning areas. This result is in good agreement with the DFG estimate that about half of total piles are within the spawning areas, given that the DFG number included piles that remain in use and may not have included areas such as the Napa River, which are outside the main regions of the Bay.

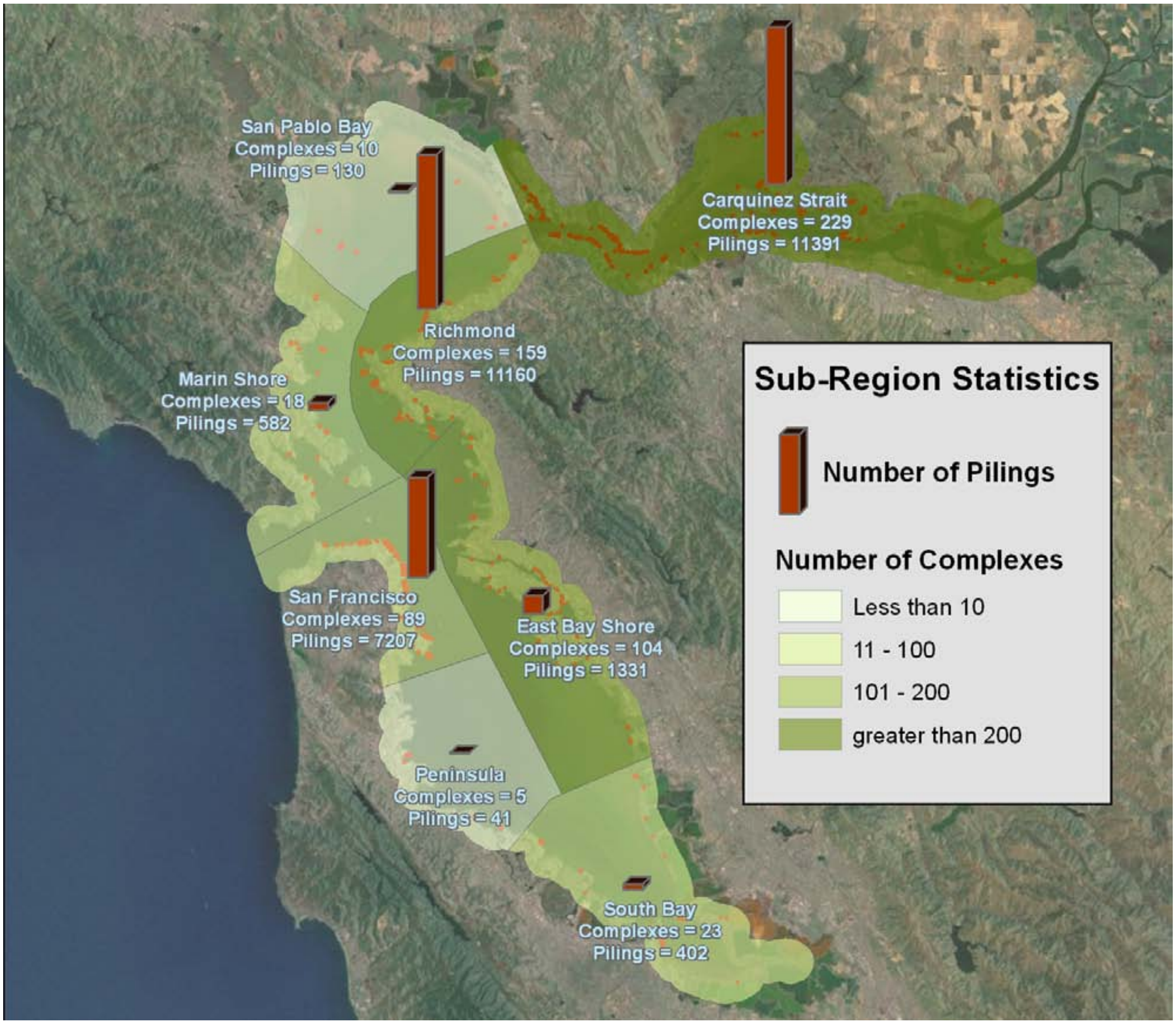


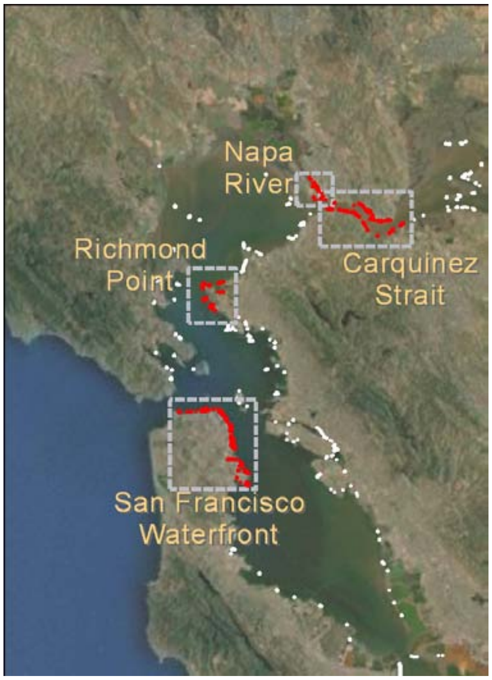
Figure 2-4. Pilings and piling complexes in San Francisco Bay.

Table 2-2. Pilings and piling complexes in sub-regions of San Francisco Bay.

Sub-Region	Location	Pilings	Complexes
Carquinez Strait	Land	211	9
	Water	5525	174
	Both	5655	46
Total		11, 391	229
Richmond	Land	180	9
	Water	2226	116
	Both	7384	32
Total		9790	157
San Francisco	Land	178	4
	Water	6348	76
	Both	353	5
Total		6879	85
East Bay Shore	Land	24	5
	Water	1021	86
	Both	286	12
Total		1331	103
Marin Shore	Land	0	0
	Water	487	14
	Both	95	4
Total		582	18
South Bay	Land	93	8
	Water	70	5
	Both	239	10
Total		402	23
San Pablo Bay	Land	0	0
	Water	130	10
	Both	0	0
Total		130	10
Peninsula	Land	1	1
	Water	32	3
	Both	8	1
Total		41	5
Grand Total		30,546	630

Four locations had especially dense piling clusters: Carquinez Strait, Napa River, Point Richmond, and the San Francisco waterfront, specific site locations that sometimes crossed the boundaries of sub-regions. The areas were considered “hot spots,” a designation made solely because of the high density and not necessarily denoting a high level of contamination (Figure 2-5, Table 2-3).

Four locations were chosen in areas of dense piling clusters. Piling count and piling complex count was calculated for each of these four areas. The shoreline was estimated manually in ArcMap using the measurement tool. The piling count and piling complex count was then normalized by this approximate shoreline count.



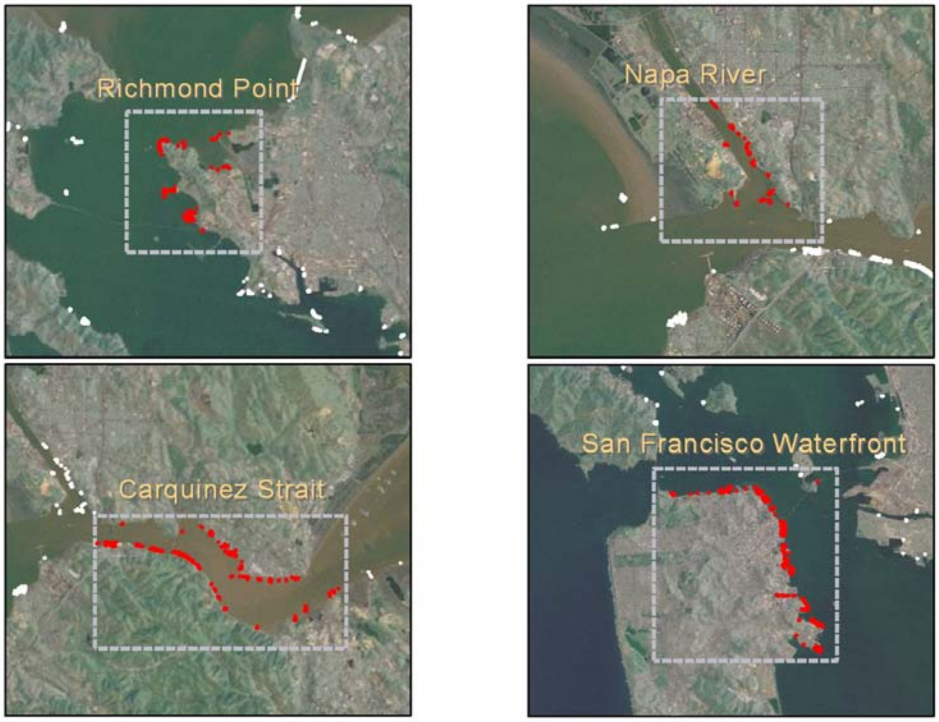


Figure 2-5. Piling hot spots.

Table 2-3. Number of piles, complexes, and area in identified hot spots.

Hot Spot Region	Number of pilings	Number of Complexes	Total Complex Area (acres)*	Acres Per Estimated Shoreline Mile
Point Richmond	6168	68	14	0.14
Napa River	1234	27	4	0.26
Carquinez Strait	6541	107	25	1.47
San Francisco Waterfront	6874	82	61	1.22

Hot Spot Region	Pilings per Shoreline Mile	Complexes per Shoreline Mile	Estimated Shoreline length in miles**
Point Richmond	61.7	0.7	100
Napa River	82.3	1.8	15
Carquinez Strait	384.8	6.3	17
San Francisco Waterfront	137.5	1.6	50

*Area is approximate. Digitization variations may cause estimates to vary from site to site.
**Shoreline estimated using ArcMap measurement tool.

2.3 How to Use the Information

The primary output of the mapping task is a digital and spatially accurate GIS dataset of the abandoned creosote-treated pilings in San Francisco Bay. Additional outputs from the mapping beyond those described in this section of the report are in Appendix A. They include summary tables and charts showing the geographical and frequency distribution of the piling complexes, piling hot spots, and associated depths. The GIS dataset generated from this task has the spatial projection of Universal Transverse Mercator (UTM), zone 10 and North American Datum (NAD) 1983. Photographs taken during the mapping task are also available and linked to the data.

3. Environmental Assessment

Environmental assessment of the potential risks and benefits of creosote-treated pilings and structures in San Francisco Bay focused on two issues:

- The potential for toxic compounds to leach from pilings, accumulate in the sediments and biota, and cause toxicity to plants and animals.
- The potential for pilings to provide for or detract from habitat.

This section describes the chemical makeup of creosote and its major constituents, including the potential availability of toxic constituents, primarily PAHs, to marine life. It presents the current status of PAHs within the Bay, including sources, pathways, and environmental levels. It reviews available information about both potential risks and benefits to marine life from creosote-treated and other artificial structures in the Bay. Additional information is included in Appendix B.

3.1 Properties of Creosote

Chemically, creosote is a brownish-black/yellowish-dark green oily product, which is distilled from crude coal tars, and which is made up of hundreds or thousands of chemical compounds (WHO 2004), including PAHs and alkylated PAHs; tar acids/phenolic compounds; tar base/nitrogen-containing heterocyclic compounds; aromatic amines; sulfur-containing heterocyclic compounds; and oxygen-containing heterocyclic compounds, including dibenzofurans. Fewer than 20% of the compounds that make up a creosote mixture are present in percentages greater than 1%. PAHs and alkylated PAHs are the major constituents, with PAHs accounting for up to 90% of creosote mixtures. Many of the PAHs present in creosote mixtures are identified as priority pollutants.

Creosote as a whole is considered to be only mildly soluble in water. However, the physical and chemical properties of individual components vary considerably, and some compounds are highly water soluble (WHO 2004). The NOAA National Marine Fisheries Southwest Division recently sponsored a review of creosote-treated wood in aquatic environments (Stratus Consulting 2006). The review included a summary of models and environmental data that have been used to predict leaching from creosote-treated wood, a process that is affected by the type of wood, the exact chemical nature of the creosote and treatment process, and environmental factors. Creosote migration from treated structures is most likely in the form of droplets, sheens, or particulate material (Goyette and Brooks 1998, Anchor Environmental 2007).

Leaching of PAHs from creosote-treated wood is affected by salinity, temperature, flow, density of the wood, length of time since treatment of the wood, whether leaching occurs from the end grain or the face, and the surface area-to-volume ratio. Leaching is faster for more soluble PAHs than for less soluble forms. In general, migration of constituents of creosote from an individual pile to the water column increases with increasing temperature and decreases with increasing age (Ingram et al. 1982, Goyette and Brooks, 1998). Studies suggest that most leaching occurs during the first few years after a pile is installed, but leaching may continue for many years. Studies conducted in Sooke Basin, British Columbia, suggested that the maximum migration of PAHs occurred during the first two to three years after installation (Brooks 1997, Goyette and Brooks 1998). The decreased level of creosote migration from older pilings is largely thought to be due to decreased surface availability. Creosote near the surface of the piling undergoes a "weathering" process, in which individual chemical constituents are adsorbed, evaporated, photo-oxidized, or dissolved (reviewed in Sved et al. 1997). However, the field mapping team for this for this project found visible slicks from piles in San Francisco Bay, all of which were installed more than 15 years ago (Figure 3-1).

Figure 3-1. Visible creosote slick detected during field mapping in San Francisco Bay. (project team photograph)

Variability in leaching rates makes it difficult to assess the contribution of creosote-treated pilings to the marine environment. For example, an eight-year study of three Douglas fir pilings in Yaquina Bay, Oregon, found that creosote content remained constant in two of the pilings, while it decreased by as much as 20% in the outer 1.25 cm in the third (summarized by Xiao et al. 2002). Loss rates for relatively new piles have been calculated as approximately 300–400mg PAH/piling/day (Ingram et al. 1982, Bestari et al. 1998a).

Studies have found patchy distributions of PAHs around creosote-treated structures, suggesting dispersion of chemicals by tides and currents (Goyette and Brooks 1998, Anchor Environmental 2007). Laboratory analyses of mostly sandy sediments from the vicinity of the San Francisco waterfront concluded the bulk of the PAHs measured were derived from moderately weathered coal-tar creosote (Anchor Environmental 2007). Whether these PAHs were available for uptake by organisms remains a question, as the PAHs were extracted in the laboratory from wood particles found in the sediments. Bioavailability in the field was not addressed.

Bioavailability of the chemical constituents of creosote varies widely. PAHs derived from petrogenic (petroleum) sources, such as creosote, tend to be more biologically available than those derived from pyrogenic (combustion) sources (Rust et al. 2004, Hylland 2006). The most toxic compounds are those with lower molecular weights, which are more soluble in water, more volatile, and are lost to the system most quickly. Higher molecular weight compounds are more persistent but less bioavailable. However, even the less available compounds are accumulated by biota.

Laboratory and field studies have examined the capacity for organisms to take up and accumulate creosote constituents and have examined acute and chronic toxicity to marine organisms. These studies were examined in detail as a part of a recent EPA Reregistration Eligibility Decision for Creosote (EPA 2008a, 2008b), an evaluation that was completed as part of an EPA program to re-evaluate older registrations.

Laboratory and field studies have demonstrated accumulation of PAHs:

- Oligochaete worms accumulated PAHs from creosote-contaminated sediments in laboratory microcosms (Hyotylainen and Oikari 1998).
- Filter-feeding mussels accumulated creosote-derived PAHs from treated wood (reviewed in Dunn and Stitch 1976).
- Oysters exposed to creosote-contaminated sediments accumulated PAHs in the same proportions that were found in the sediments (Smith 2006). Wild oysters collected from creosote-treated piles also had elevated levels of PAHs, but at lower concentrations than those exposed to the contaminated sediment.

3.2 PAHs in San Francisco Bay

San Francisco Bay receives inputs of PAHs from many sources other than creosote, including oil spills, vehicle emissions, biomass burning, thermal combustion of heating oil and coal, and biosynthesis. PAHs are transported to the Bay via several pathways, including stormwater runoff, tributary inflow, wastewater discharge, atmospheric deposition, and reintroduction of previously buried PAHs through dredging and disposal (Eisler 1997, Oros and Ross 2004). Estimated loadings to the Bay are as high as 10,700 kg/year (Greenfield and Davis 2005, Oros et al. 2006; Table 3-1), not including any estimate of loading from creosote-treated structures. Oil spills may also contribute significant loadings of PAHs to the Bay, but large spills occur sporadically and unpredictably.

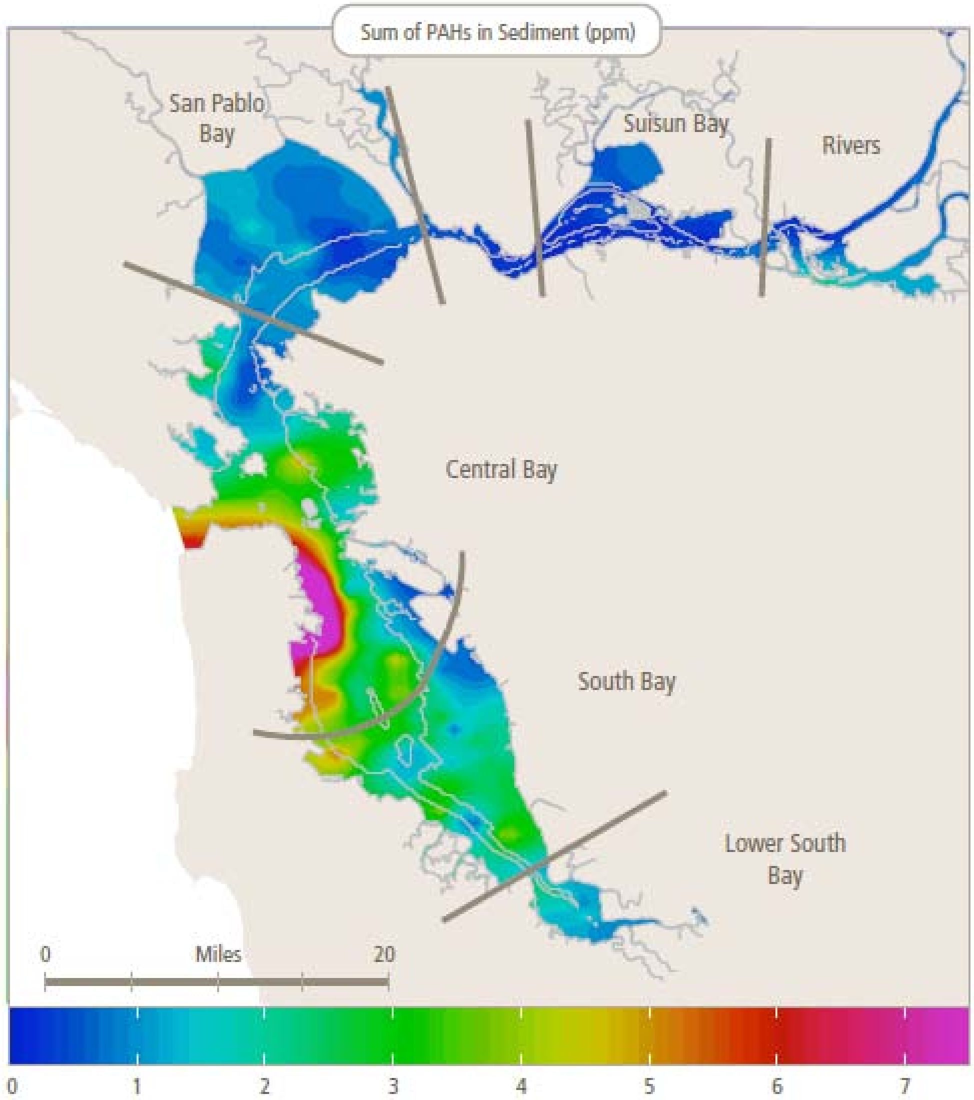
Table 3-1. Estimated loads (kg/yr) of PAHs to San Francisco Bay (from Greenfield and Davis 2005).

Source	Minimum estimate	Maximum estimate	Percent of maximum	Reference
Stormwater runoff	130	5500	51	Gunther et al. 1991
Tributary inflow		3000	28	Gunther et al. 1991
Effluent discharge	200	1100	10	Davis et al. 2000
Atmospheric deposition		890	8	Tsai et al. 2002
Dredged material disposal		210	2	Davis et al. 2000
TOTAL	330	10700	100	

Levels of PAHs in San Francisco Bay sediments are elevated in comparison to pristine areas but similar to those in other urban estuaries. The average concentration of total PAHs in sediments collected from the Bay by the Regional Monitoring Program during 2002–2008 ranged from 0.4 ppm in Suisun Bay to 3.2 ppm in the Central Bay. The maximum concentration in 2008 was 19 ppm in a sample from the Central Bay (Regional Monitoring Program data, available from SFEI). Average concentrations of total PAHs in Puget Sound have been reported as 0.04–7 ppm, with a maximum of 14 ppm (Partridge et al. 2005). PAHs are found in their highest concentrations in the sediments of the margins of the Bay, particularly along the San Francisco waterfront (Figure 3-2; SFEI 2009).

Much higher PAH levels can be found at sites specifically noted as being contaminated by creosote. For example, the Elizabeth River, near the mouth of Chesapeake Bay, once housed a creosote-treatment facility, which documented numerous creosote spills. Elizabeth River sediments have some of the highest sediment PAH concentrations recorded in marine habitats, two orders of magnitude greater than those found in San Francisco Bay (Volgelbein et al. 1990).

Using sediment data, Oros and Ross (2004) suggested that only about 1–2% of the PAHs in sediments in the Bay were derived from creosote and used engine oil. Their analyses suggested that most of the PAHs in the sediments were derived from gasoline, crude oil, coal, and biomass combustion.


Sum of PAHs in Sediment (ppm)

Footnote: Plot based on 330 RMP data points from 2002–2008. The maximum concentration was 19 ppm in Central Bay in 2008. The four highest concentrations and nine of the top ten in the seven-year period were all measured in Central Bay.

Figure 3-2. Total PAHs in San Francisco Bay sediments (ppm for random, stratified samples, 2002–2008; SFEI 2009).

Through its National Status and Trends Program, NOAA has developed sediment quality guidelines that provide some insights into the potential toxicity of sediments (Long et al. 1995). The “effects range-low” (ERL) is the concentration of a contaminant below which toxic effects rarely occur; the “effects range-median” is the concentration above which effects are frequent. Data from Central Bay, South Bay, and the San Joaquin River in 2002–2008 suggest that PAHs levels in Bay sediments sometimes exceed the ERL but do not exceed the ERM (Figure 3-3).

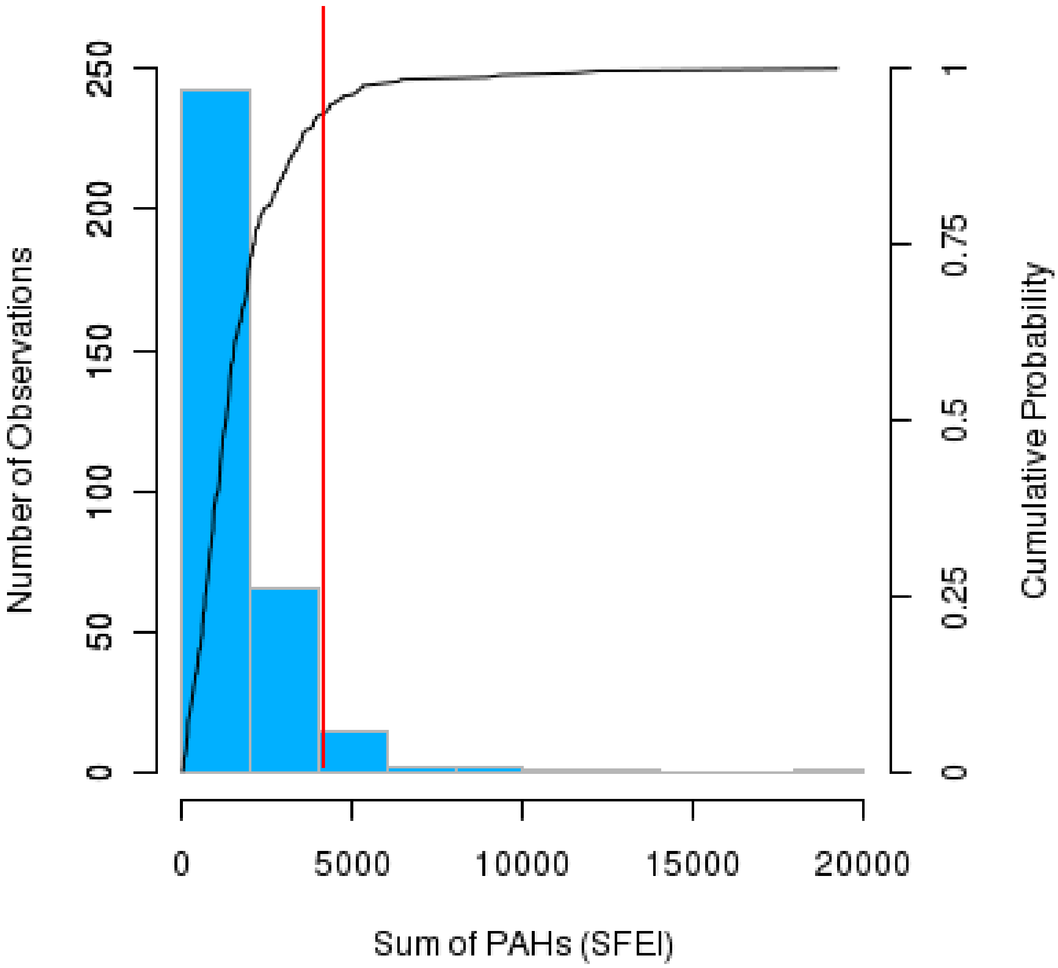


Figure 3-3. Number of observations (bars) and cumulative probability (curved line) of total PAHs in San Francisco Bay sediments (ppb), 2002–2008 Regional Monitoring Program data (available from SFEI). The red line indicates the total PAH ERL. Six percent of the samples exceeded the ERL, and no samples exceeded the ERM.

PAHs in bivalve mussels have been monitored by the Regional Monitoring Program, the NOAA Mussel Watch Program, and the California State Mussel Watch Program (reviewed in Oros et al. 2007). Oros and Ross (2005) reported concentrations of total PAHs in bivalves as ranging from 21 to 1093 ppb, with the highest concentrations measured in a sample from the Petaluma River. They detected no significant difference among total PAH concentrations in the South Bay, Central Bay, and North Bay.

PAH concentrations in the sediments across much of the Bay exceed a threshold for potential health risks to fish. Johnson et al. (2002) concluded that levels above 1000 ppb total PAHs in sediment posed a risk to English sole in Puget Sound, a species that is not common in San Francisco Bay but which can be considered representative of estuarine flatfish. About half the sediment samples from San Francisco Bay exceed that threshold.

3.3 Potential Environmental Risks

Chemical contamination and physical effects, such as shading or replacement of preferred habitats, are potential environmental risks of creosote-treated structures in San Francisco Bay (Cohen 2008). Creosote is a registered pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). EPA identified several areas of potential risk to biota from creosote-treated structures in marine waters, as part of the decision process that led to reregistering its use in marine waters (EPA 2008a, 2008b):

- The level of concern is exceeded for acute risk to listed (endangered and threatened) fish and invertebrates exposed to PAHs in the water column.
- The level of concern is exceeded for acute risk to other (not listed) invertebrates exposed to PAHs in the water column.
- Available evidence suggests that chronic risk is possible to organisms inhabiting the water column.
- Laboratory and field investigation found a major detrimental impact on hatching and development of fish (herring) eggs attached to aquatic pilings, even pilings that were 40 years old, suggesting that some sensitive species may be adversely affected by creosote-treated pilings. (This referred to a San Francisco laboratory and San Francisco Bay study (Vines et al. 2000, see discussion below).
- Impacts of creosote-treated aquatic pilings are likely to vary locally, depending on abiotic and biotic factors, such as current speed, amount of structure per unit area, air and water temperature, salinity, and the aquatic species occurring in the immediate area of the structures; thus, a site evaluation is essential prior to installation of new structures. (New creosote-treated structures are not permitted in San Francisco Bay.)

Chronic and acute effects have been measured in several species:

- Sea squirts (tunicates), which live on pilings, exhibited immunological effects when exposed to low levels (1 mg/liter) of the soluble fraction of creosote (Raftos and Hutchinson 1997).
- Mussel growth was significantly reduced 0.5 m downstream from a piling complex 185 days after installation of the complex, although PAH levels in mussel tissue did not vary from baseline levels after 384 days (Goyette and Brooks 1998).
- Oysters exposed to the water soluble fraction of creosote-contaminated sediments suffered increased infection by a marine parasite (Chu et al. 1996).
- Zooplankton abundance decreased in mesocosm studies with creosote-impregnated piles, with lowest abundance measured at week three of an 83-day study, and with a no-observed-effects level of 11 μg/liter (Sibley et al. 2004).
- Amphipods exposed to creosote-contaminated sediments in Washington State had a 4-day LC50 (that concentration at which half the test organisms die) of 666 μg/g wet weight total PAH (Swartz et al. 1998).

- English sole in Puget Sound exhibited liver lesions, reproductive abnormalities, and DNA damage at sediment PAH concentrations greater than 1000 ng/g dry weight (Johnson et al. 2002), levels that are commonly reached in San Francisco Bay (see discussion in Section 3.2, above).
- Spot exposed to creosote-contaminated sediments exhibited fin erosion, epidermal lesions, and mortality at total PAH concentrations as low as 76 µg/liter (Sved et al. 1992). (Maximum total PAH concentrations in San Francisco Bay water are two orders of magnitude lower, 0.85 µg/liter.)
- Killifish in the Elizabeth River, Chesapeake Bay, which is heavily contaminated with creosote, exhibited mitochondrial and nuclear DNA damage (Cho et al. 2009).
- Incidence of liver carcinoma was significantly elevated in killifish from the Elizabeth River and from creosote-contaminated areas of the Delaware River Estuary (Vogelbein et al. 1990, Pinkney and Harbarger 1998). (Levels observed at those sites were about four times the maximum levels measured in fish from San Francisco Bay.)

Other acute toxicity data are reviewed in WHO (2004).

Studies of potential effects on Pacific herring include DFG (1996) and Vines et al. (2000). DFG (1996) found that herring eggs attached to creosote-treated wood had low hatch success compared with untreated wood and plastic. Vines et al. (2000) examined the effect of diffusible creosote-derived compounds on herring embryonic development, finding reduced hatch success in embryos exposed to creosote-treated wood in the laboratory. Larvae that hatched exhibited morphological abnormalities. Effects were dependent on whether the embryos were in direct contact with the creosote-treated wood. The study found greater hatching success in the field compared to laboratory experiments, presumably because water flow lessened exposure to toxic compounds.

Other toxicity tests have examined the potential effects of PAHs from other sources on Pacific herring. Tests conducted after the *Exxon Valdez* oil spill in Alaska had varied results, but recorded malformations, decreased size, mortality, and other effects (reviewed in Connor et al. 2005). There are also studies underway that examine the possible effects of PAHs released during the 2007 San Francisco *Cosco Busan* oil spill on Pacific herring embryos. The spill occurred in November, just prior to the spawning period, in the north Central Bay. Visible oiling occurred in herring spawning habitat. Field studies found embryonic cardiac arrhythmia, reduced hatching success, reduced larval survival, and physical abnormalities in embryos and larvae from oiled sites (Incardona et al. 2008, Incardona et al. 2009).

Piling-removal projects will have to consider the possible risks of temporarily increasing exposure to PAHs when creosote-treated pilings are removed. A pile-removal study in Australia found that significant amounts of PAHs were released during the removal process, and that significantly elevated concentrations of PAHs remained in the sediments up to six months after the project was completed (Smith 2008).

Shading and other physical attributes may also be detrimental. For some species, there is evidence that the presence of pilings and other structures is in itself detrimental to fish and wildlife. Young-of-the-year and juvenile fish species may prefer naturally vegetated nearshore habitats to those under decks and in pile fields (Weitkamp 1982, Bryan and Scarnecchia 1992, Able et al. 1998). Winter flounder and tautog kept in cages beneath deck structures had lower growth rates than fish placed in open waters and open pile fields (Able et al. 1998, 1999).

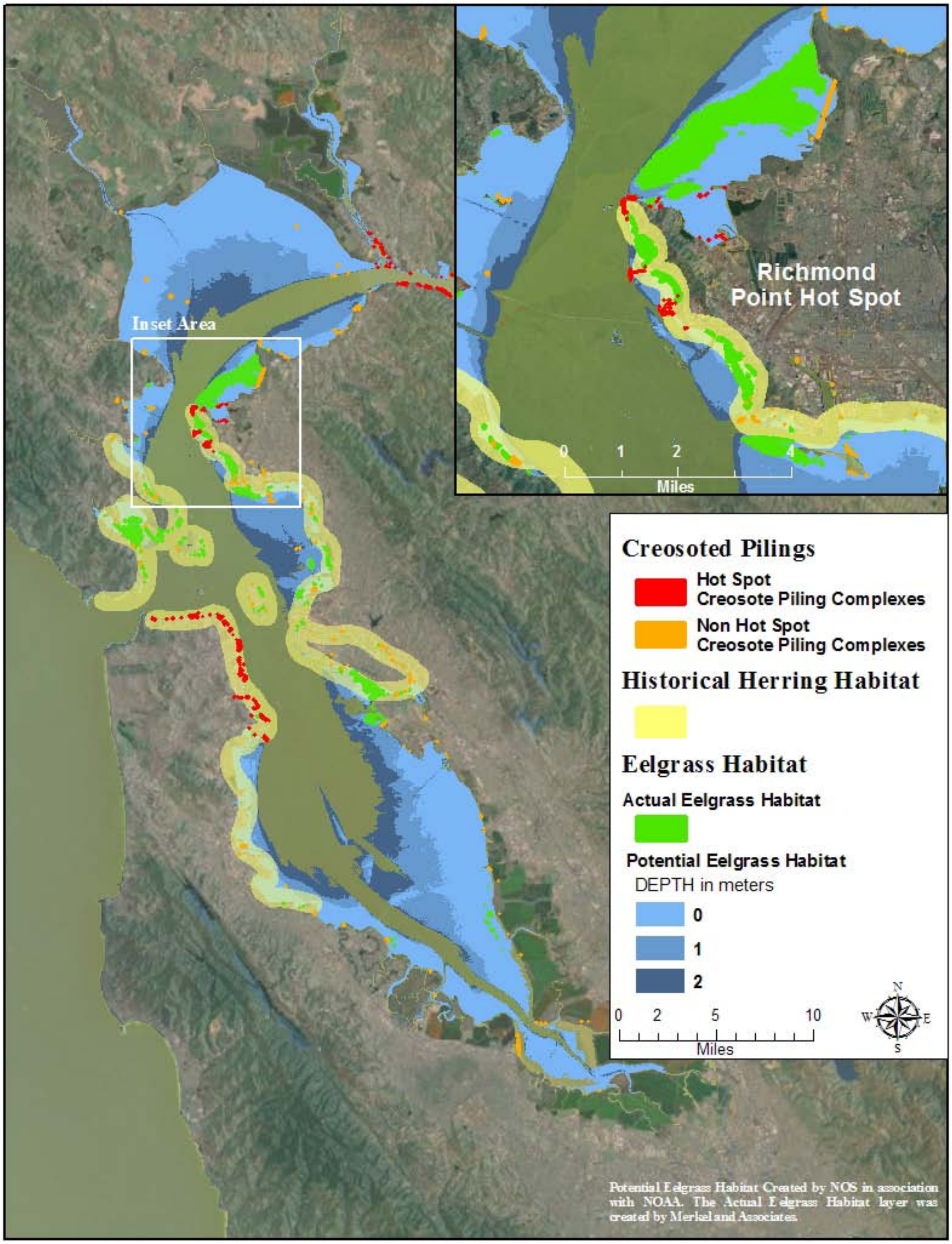
Eelgrass habitat has been adversely affected by the urbanization of the Bay, limiting the extent of eelgrass beds to only about 3,000 acres (Merkel and Associates 2004; Figure 3-4). Low light levels and shading may be limiting factors on the extent of eelgrass growth in the Bay. Recent research, mostly from the East Coast and Gulf Coast, has suggested that shading from decks and wharves could be reducing natural light penetration and impacting photosynthetic growth. Seagrass shoot density, biomass, and canopy structure were significantly reduced in sea beds directly under or adjacent to dock structures. Pier orientation, width, and distance above the water surface also negatively affected bed quality and seagrass (Burdick and Short 1999, Shafer 1999). Shading from piers has also been found to reduce growth and biomass of other submerged aquatic plants and to alter biotic assemblages in favor of shade-tolerant species.

3.4 Possible Environmental Benefits

Studies indicated that pilings and other artificial structures do provide habitat for invertebrates, herring spawn on hard structures including pilings, and pilings provide roosts for birds. Studies have not quantified the extent to which animals benefit from or depend on hard substrates.

Creosote-treated pilings have been found to host a number of invertebrate species in Fidalgo Bay, Washington, including sea anemones, sea squirts, sea stars and barnacles (Samish Indian Nation, undated). Hundreds of species of sponges, cnidarians, annelid worms, mollusks, arthropods, bryozoans, and chordates have been found to colonize pilings in San Francisco Bay (Cohen and Chapman 2005). In a New York study, benthic prey densities were higher in sediments under pier decks than in pile-field or open-water habitats (Metzger et al. 2001).

Fish species use artificial structures to avoid predation and as forage habitat (reviewed in Clynick 2008). Artificial structures have also been identified as habitat for various fish life stages. Piers and other artificial structures have always been used by anglers, as some sportfish are known to congregate around structures. Fish found in or near the fouling growth on floating docks and pilings in San Francisco Bay include bay pipefish, Pacific herring, rockfish, and shiner surfperch (Moyle 2002). In the Hudson River Park, New York City, pier pilings are considered to be “a key element in the estuarine sanctuary,” where juvenile striped bass find shelter, and many other organisms flourish (http://www.hudsonriverpark.org/estuary/river_piles.asp).



Potential Eelgrass Habitat Created by NOS in association with NOAA. The Actual Eelgrass Habitat layer was created by Merkel and Associates.

Figure 3-4. Creosote-treated pilings, historic range of Pacific herring spawning habit, and current and potential eelgrass habitat, including an inset of the Point Richmond area.

Along the San Francisco waterfront, as many as 25 bird species have been identified as roosting on pier pilings in a given year, including the Double-crested Cormorant, Great Blue Heron, Snowy Egret, Caspian Tern, and Western Grebe (Weeden 2007, Weeden and Lynes 2009). Caspian Terns and Western Gulls are known to use old structures for nesting. There is some evidence from the 1940s and more recent observations that the Bay's Double-crested Cormorant population may be dependent on the amount and value of artificial roosting area (A. Cohen, personal communication). Significant loss of structure could adversely affect cormorant populations.

Sea lions and harbor seals are dependent on haul-out sites, areas where they can absorb heat from the sun. Harbor seals also give birth at haul-out sites (typically isolated shore areas rather than artificial substrates), and mothers leave young seal pups on the site when they feed. Sea lions have become a tourist attraction at Pier 39 on the San Francisco waterfront, hauling out onto floating docks during the winter (Figure 3-5). Sea lions and harbor seals were observed on creosote-treated structures during the mapping task for this project.

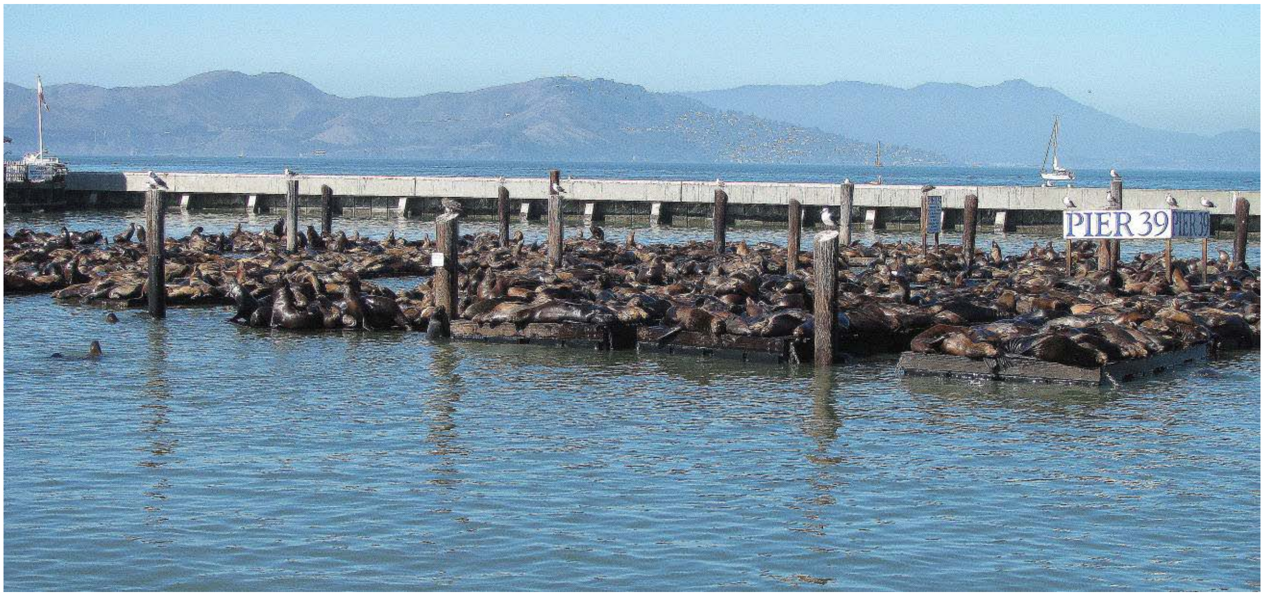


Figure 3-5. Sea lions at Pier 39, San Francisco waterfront. (project team photograph)

4. Historical Significance Assessment

Creosote-treated piles and related structures are significant features of the foreshore of San Francisco Bay, and their cultural significance must be evaluated before removal efforts are initiated. However, the cultural-resources theory and legal framework traditionally used to research and evaluate historical properties has been adapted for maritime structures relatively recently. There are few precedents for applying these criteria to waterfront resources such as piers, wharves, and pilings. This section describes the historical context and methods for evaluating significance of pilings in the Bay. Additional information is included in Appendix C-1. Appendix C-2 presents some examples of the types of research that would be used to evaluate individual sites.

4.1 Pilings as Cultural Features

Federal, state, and local laws may apply to the treatment of historic properties in California, depending upon individual site jurisdiction, ownership, project funding, and the agency in charge of the removal project. The National Register of Historic Places, created through the National Historic Preservation Act (NHPA) of 1966 and maintained by the National Park Service (NPS), was the first comprehensive approach to the preservation of cultural features in the United States. All federally licensed or funded projects that potentially affect cultural resources must comply with Section 106 of the NHPA. However, while the NPS has produced guidelines for assessing aids to navigation, mostly lighthouses, historic vessels, and shipwrecks, there is little specific guidance for assessing other foreshore features such as pilings, wharves, and piers that occur in the transitional area between land and open water (Delgado et al. 1992, Delgado and Foster 1992).

The California Environmental Quality Act (CEQA) contains state historic preservation laws and eligibility criteria, which mirror the federal framework. State agencies must determine whether a project adversely affects cultural resources and identify ways to prevent or mitigate impacts as part of the CEQA process. If a property is determined eligible, it is listed in the California Register of Historical Resources, which is maintained by the California State Parks Office of Historic Preservation (OHP). The OHP also maintains lists of California Points of Historical Interest and California Historical Landmarks. Criteria for these lists are less stringent than those for the National Register or California Register, but a site must be publicly accessible to be eligible (McCarthy 1999). The California Register includes National Register properties, as well as California Points of Historical Interest, California Historical Landmarks, and other properties with local or statewide significance (OHP 2009). New guidelines were issued in 1998, specifying that a lead agency may consider a resource to be historically significant, even if it is not eligible for inclusion on the California or National registers (California Natural Resources Agency 2007).

In addition to state guidelines, many cities or counties have local laws and processes related to identification and treatment of cultural resources. These must be identified for specific project areas before work is initiated. Local entities (such as landmarks boards or preservation commissions) must be consulted for information about their regions. Also, some piling groups may be considered significant by local groups or other stakeholders despite non-eligibility by any legal framework. There may be instances in which pilings do not meet national, state, or local guidelines for significance, but there would still be historical or aesthetic incentives not to remove them.

The Maritime Heritage Program (established by the NPS in 1987) maintains inventories of historic vessels, lighthouses, and shipwrecks, but no similar records for foreshore structures. This lack of information and precedent emphasizes the need for original, synthetic research on pilings in the Bay Area as part of any large-scale removal project.

A few Bay Area studies have discussed pilings in a cultural context. Historic resource evaluations in the Sacramento-San Joaquin Delta have included research on and inventories of historical piling complexes (Paterson et al. 1978, Owens 1991). Historic District nominations for the Bacon Island Rural Historic District in San Joaquin County and the Point Bonita Historic District in Marin County included pilings as contributing resources to a larger landscape of historic features. Conversations with maritime historians and cultural resource specialists have suggested a number of potentially significant piling complexes in the Bay and Delta, including the Steamboat Slough dolphin in the Delta, the piles just north of the Richmond side of the Richmond-San Rafael Bridge, Fort McDowell on Angel Island, and the Berkeley long pier.

4.2 Methods for Evaluating Significance in San Francisco Bay

The National Register criteria for determining significance are the most widely used standards for evaluation of cultural resources (Figure 4-1):

- The property must be historic. Barring exceptional cases, it must be more than 50 years old.
- It must be significant. It must be associated with a significant event, person, or construction type, or have the potential to yield information relevant to those categories.
- It must possess integrity. Aspects of its historic identity and authenticity must be preserved.

Before a property's significance and integrity can be evaluated, the historic context in which the property may be significant must be identified. Evaluation of a piling group's cultural significance must be completed before any removal project proceeds to ensure that potentially significant resources are not removed without establishing options for mitigation or preservation. Evaluations may be made following two approaches: a **case-by-case approach** or a **programmatic approach**.

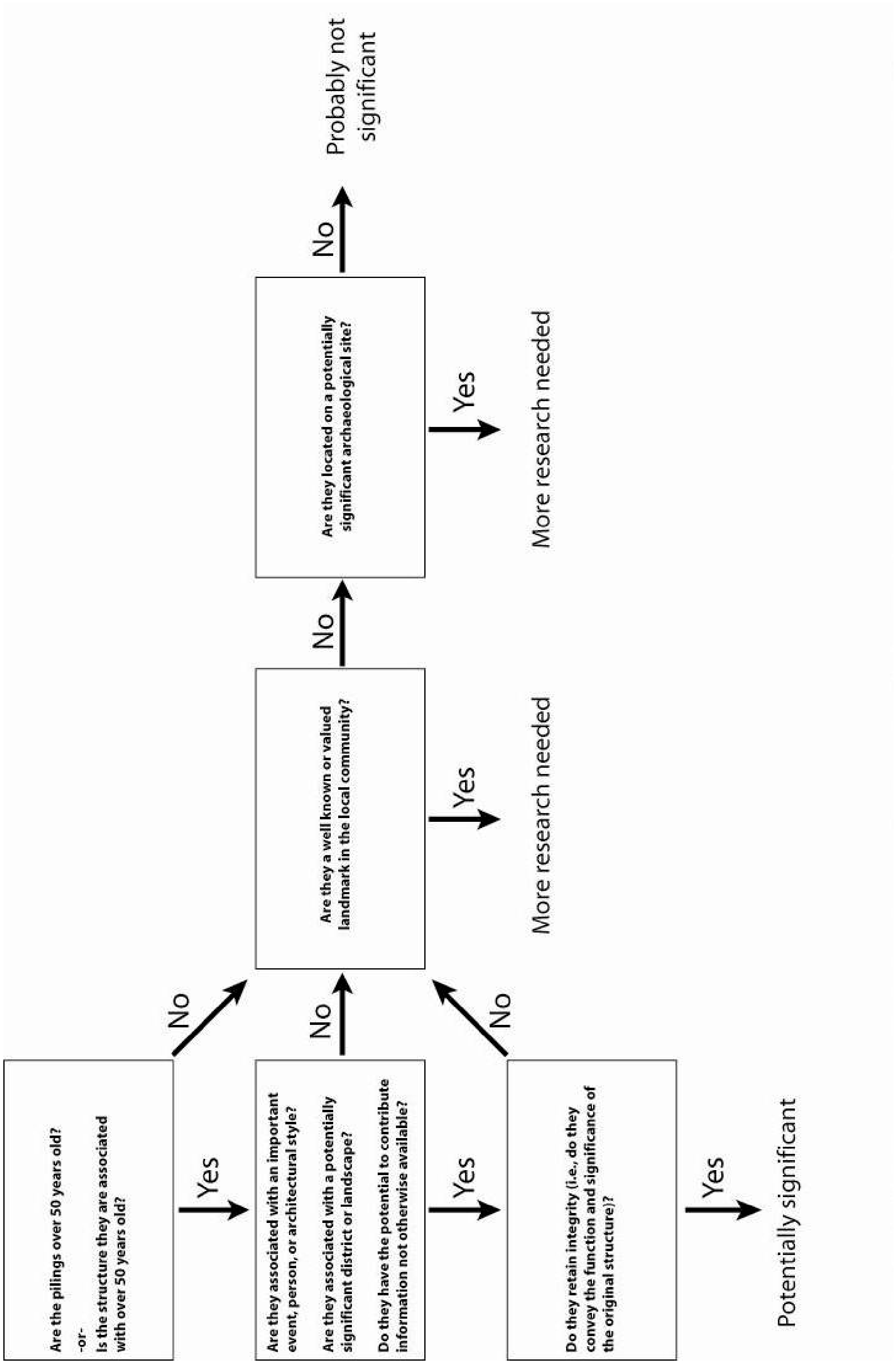


Figure 4-1. Evaluation of piling groups based on National Register and other criteria.

To demonstrate the types of research that could be conducted for specific piling complexes, the project conducted preliminary evaluations of three sites:

- The remains of a marina off the Tiburon Peninsula in Marin County, historically known as the El Campo site.
- Pilings associated with an abandoned quarry on the south side of Brooks Island.
- The Seventh Street wharf pilings in Benicia, in the Carquinez Strait.

The case studies, with documentation, are presented in Appendix C-2. They illustrate the breadth of information and types of sources that may be available to a historical researcher for a particular site.

While this type of case-by-case research may prove a valuable approach for assessing historical significance of small-scale piling-removal projects, it is not recommended as an appropriate method for evaluating historical significance for regional removal projects.

For large projects, case-by-case evaluations would be expensive, time-consuming, and impractical. The maritime historians, archeologists, and historic preservationists consulted for this project have strongly suggested adoption of a programmatic, rather than case-by-case, approach to evaluating the Bay’s abandoned pilings. Under a programmatic approach, the potential significance of a piling complex is considered within the larger context of the Bay’s maritime history, rather than as a discrete, unconnected site. The programmatic approach would provide a more efficient method for identifying potentially historic sites and districts than case-by-case evaluations.

Broadly, the steps involved in applying the approach in San Francisco Bay would be as follows:

> **Step 1**. **Initiate development of a programmatic agreement** with the California State Historic Preservation Office (SHPO) to establish a protocol for Bay-wide piling evaluation. SHPO will provide insight into how to develop a process that is in compliance with federal, state, and local laws without requiring individual evaluation for each piling group.
>
> **Step 2**. **Locate information** already assembled in existing databases, such as the National Register Information System (NRIS; soon to be replaced by NPS Focus) and the California Historical Resources Information System (CHRIS). These searches will ensure than previous research is not duplicated.
>
> **Step 3**. **Conduct detailed original research on the history of creosote-treated structures** and substructures in the Bay, expanding on the information in Appendix C-1 of this report. This research would identify the geographical limits and time period relevant to wooden piles in the Bay, would describe in detail the history of each theme (e.g., commerce, transportation, agriculture, industry) and type of structure (e.g., wharf, dolphin, trestle) associated with wooden pilings, and

provide an overview of the mosaic of structures that used wooden pilings around the Bay. Assembly of this contextual information is a critical step in determination of significance for an individual structure, and is required under National Register criteria.

Step 4. Prepare a full historical context statement, integrating existing information with new research. This report would integrate existing information (Step 2) with research conducted (and the thematic, chronologic, and geographic framework established) in Step 3. This process would provide a broader framework within which to evaluate individual piling sites (identifying some of the best preserved, most significant examples of each structure type), and would help identify areas where potentially significant piling groups that reflect important aspects of Bay Area maritime history might most likely be found. It would also help identify specific themes (such as historic events or activities) related to pilings, which could link specific areas to National Register significance criteria.

Step 5. Identify potentially significant piling groups, suggesting areas that should not be considered for priority removal projects or should be sites of additional research before removal is initiated. The historical context statement prepared in Step 4 would be used to identify potentially significant piling groups (or areas of potential significance) around San Francisco Bay. In turn, areas or sites determined to have a lower likelihood of significance could be potential sites for piling removal.

There are two premises of a programmatic approach as a piling evaluation framework. First, a programmatic approach addresses the monumental task of trying to adequately identify, research, and evaluate large numbers of abandoned pilings around the Bay. With the proper landscape context established, this “top down” approach to significance should identify potentially historic sites and districts much more effectively and efficiently than a site-by-site approach, and would ultimately be of broader value.

Second, understanding the landscape-level context in which wooden pilings were constructed and used in the Bay is essential for evaluation of an individual pile or piling group’s significance. A programmatic approach allows for comparison of piling groups in different geographic areas but with similar historical purpose or construction history, which is useful for making decisions about relative significance across similar sites. It also enables cultural resource experts to view the pilings as one element in a suite of features that contribute to the character of the shoreline, which may reveal significance not evident on a site-specific scale (Figure 4-2). The broader landscape context may also help strategically focus efforts of a Bay-wide piling removal project by identifying regional patterns and trends in piling construction, use, and distribution that hold implications for piling significance.

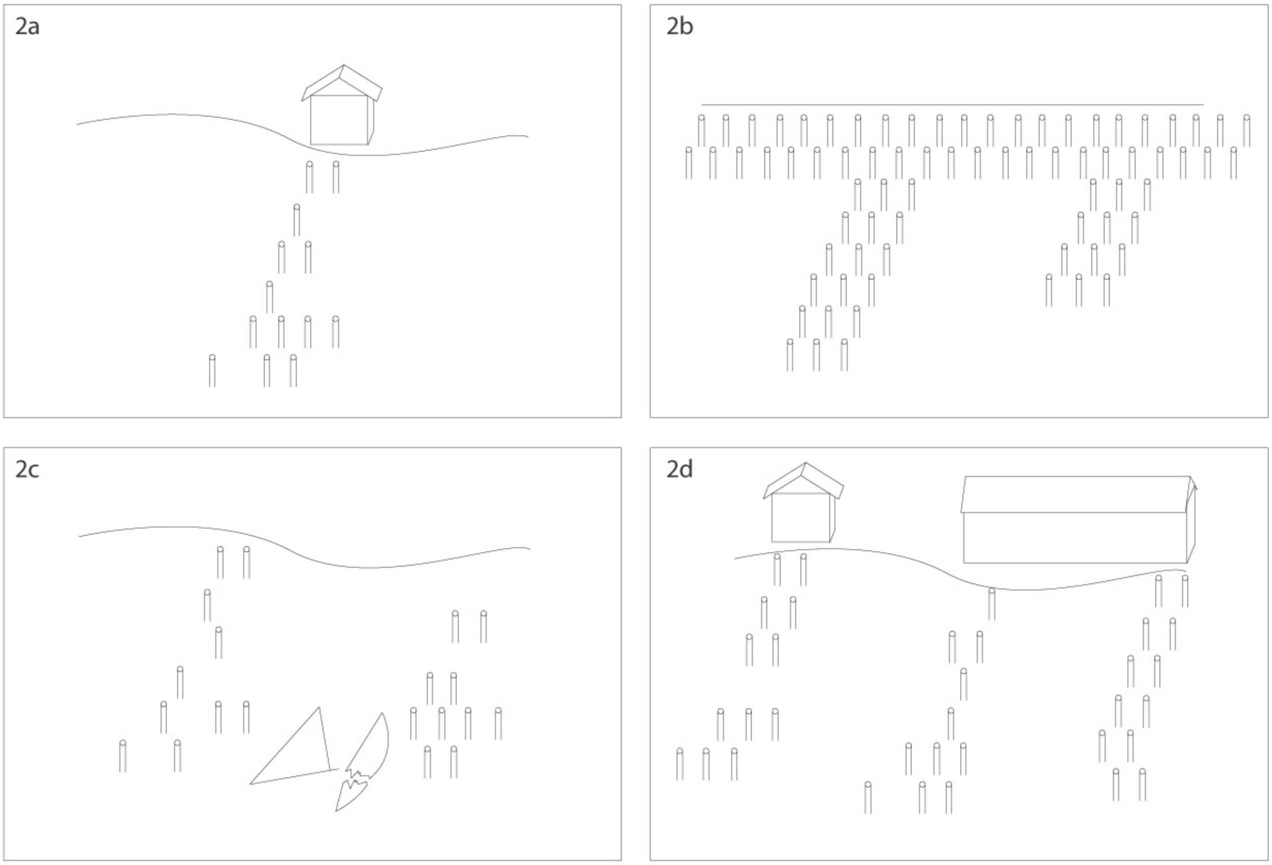


Figure 4-2. Piling significance scenarios: 2a, pilings associated with a significant onshore structure; 2b, extensive complex retaining ability to convey form, function, and association; 2c, association with an archeologically significant site; 2d, element in a multiple-property district.

5. Action Plan

Removal of creosote-treated structures from the Bay requires assessment of logistics and costs for removal and disposal, and consideration of permitting and other legal issues. This section provides information about those issues. It draws from interviews with Bay Area regulators, resource-agency staff, and marine-operations personnel, and other information developed for San Francisco Bay. This section also draws on information from the extensive creosote-removal work in Washington State.

A more complete discussion is included in Appendix D.

5.1 Removal Techniques and Costs

Pile-removal techniques include complete-removal methods, such as vertical pulling and vibratory extraction, and partial-removal methods, such as horizontal snapping and breaking:

- **Vertical pulling** involves gripping the pile with a chain, cable, or collar, and pulling with a cable or hydraulic crane. Vertical pulling may result in removal or resuspension of sediments from the immediate area surrounding the pile.
- **Vibratory extraction** involves attaching a vibratory hammer to the pile to break the seal between the pile and the sediment and pulling with a crane or excavator. This technique is usually faster than simple vertical pulling. It may result in less resuspension of sediments and lower handling and disposal costs, because of less attached sediment.
- **Horizontal snapping** or breaking typically involves pushing or pulling the pile laterally to break off the pile near the mud line. Horizontal snapping is a faster removal technique than complete extraction. It removes less of the pile, possibly lessening sediment resuspension. It reduces handling and disposal costs, because there is less material. Most regulators prefer that piles are removed to a depth of at least two feet below the mud line. However, piles tend to break at their weakest points, so this technique can be inconsistent.
- **Cutting** is completed by divers, who use hydraulic or pneumatic chainsaws or hydraulic shears to cut the pile.

Hydraulic jetting, which uses a high-pressure water hose to blow sediment from the pile, is typically combined with snapping or cutting, and is used to ensure that the appropriate removal depth is achieved. Hydraulic jetting resuspends considerable volumes of sediments, so it is not suitable for all projects.

The decision to use either complete or partial removal is typically based on considerations about future uses of the site, navigation hazards, environmental effects, and costs. If, for example, the site is likely to be dredged, complete extraction is the best option. Complete extraction is also advisable if the pile is in an area that may naturally scour or become a navigation hazard. Partial removal is usually more cost-effective.

However, snapping can result in fragmentation of the pile, introducing debris into the environment.

Depending on location, pilings can be removed using marine or land-based equipment. Under most conditions, marine techniques are necessary. Marine techniques typically include barges fitted with cable cranes, hydraulic cranes, or excavators. The barges are moved from place to place with tug boats. During removal operations, the barge holds its position with winch lines and anchors or with spuds, which are usually steel piles that are raised and lowered by the crane or winches.

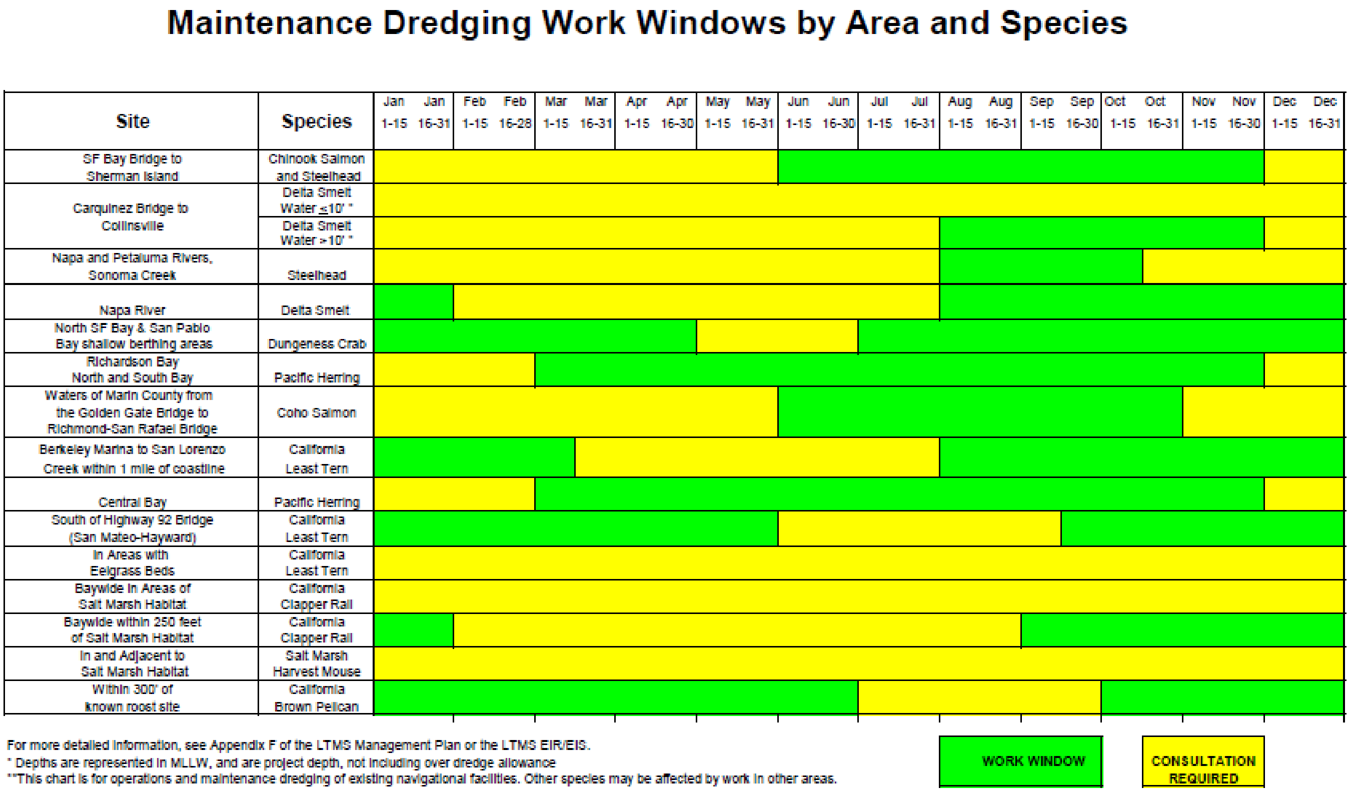
Large marine equipment used to remove piles and demolish marine structures typically has a draft of six or more feet and can only work efficiently in waters with bottom elevations of -6 feet Mean Low Low Water (MLLW) or lower. Small equipment can typically be used at sites with bottom elevations of -3 feet MLLW or lower. Large equipment can sometimes be efficient in waters as shallow as -3 feet MLLW, if a significant portion of the site is deeper. Environmentally sensitive areas, such as eelgrass beds must be managed to ensure that the equipment does not disturb the bottom.

Areas that are close to shore and have good access from the land may be suitable for land-based removal. Land-based equipment may be efficient and appropriate for nearshore sites with sensitive bottom vegetation or salt marsh. The maximum effective reach of cost-effect removal projects is probably less than 150 feet, and costs increase greatly with increased reach.

The method or methods of removal will be a major factor in determining cost of removal projects. Removal costs will also depend on the size of the project, fuel prices (which have varied widely in recent years), water depths, and funding sources. Government-funded projects may have labor requirements that are not applicable to private projects.

The timing of pile-removal projects may also significantly affect costs. Many projects undertaken by the regional marine-equipment fleet in San Francisco Bay are subject to work windows for dredging, dredged material disposal, pile driving, and other marine construction (Figure 5-1). If pile-removal projects can be permitted to work outside the work windows, costs would be significantly lower due to equipment and crew availability.

Allowing for relatively long contract-performance periods could also result in significant cost savings. Dredging projects usually have relatively short performance periods. Allowing pile-removal projects to fill in between other projects could result in lower bids.



Maintenance Dredging Work Windows by Area and Species

Site	Species	Jan 1-15	Jan 16-31	Feb 1-15	Feb 16-28	Mar 1-15	Mar 16-31	Apr 1-15	Apr 16-30	May 1-15	May 16-31	Jun 1-15	Jun 16-30	Jul 1-15	Jul 16-31	Aug 1-15	Aug 16-31	Sep 1-15	Sep 16-30	Oct 1-15	Oct 16-31	Nov 1-15	Nov 16-30	Dec 1-15	Dec 16-31
SF Bay Bridge to Sherman Island	Chinook Salmon and Steelhead	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨
Carquinez Bridge to Collinsville	Delta Smelt Water ≤10' *	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
	Delta Smelt Water >10' *	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨
Napa and Petaluma Rivers, Sonoma Creek	Steelhead	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟨
Napa River	Delta Smelt	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
North SF Bay & San Pablo Bay shallow berthing areas	Dungeness Crab	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Richardson Bay North and South Bay	Pacific Herring	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨
Waters of Marin County from the Golden Gate Bridge to Richmond-San Rafael Bridge	Coho Salmon	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨
Berkeley Marina to San Lorenzo Creek within 1 mile of coastline	California Least Tern	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Central Bay	Pacific Herring	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨
South of Highway 92 Bridge (San Mateo-Hayward)	California Least Tern	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩
In Areas with Eelgrass Beds	California Least Tern	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Baywide in Areas of Salt Marsh Habitat	California Clapper Rail	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Baywide within 250 feet of Salt Marsh Habitat	California Clapper Rail	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
In and Adjacent to Salt Marsh Habitat	Salt Marsh Harvest Mouse	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Within 300' of known roost site	California Brown Pelican	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩

For more detailed information, see Appendix F of the LTMS Management Plan or the LTMS EIR/EIS.
* Depths are represented in MLLW, and are project depth, not including over dredge allowance
**This chart is for operations and maintenance dredging of existing navigational facilities. Other species may be affected by work in other areas.

🟩 WORK WINDOW

🟨 CONSULTATION REQUIRED

Figure 5-1. Environmental work windows in San Francisco Bay.

The Washington State DNR has developed Best Management Practices (BMP) for their projects to remove derelict creosote-treated pilings from Puget Sound:

- Vibratory extraction is preferred over direct (vertical) pulling, cutting, and other methods.
- Complete removal is preferred over partial removal.
- Piles that cannot be completely removed should be cut at least one foot below the mud line.
- Sediment disturbance should be minimized.
- No barge grounding should occur over eelgrass beds.
- All piles, mud, and debris should be disposed of at a proper landfill.
- A floating boom with absorbent pads is required to capture debris suspended during removal.
- Project oversight by the state will include turbidity testing.

Similar BMPs may be appropriate for and have been required in San Francisco Bay. BCDC issued a September 2009 permit modification for removal of a fuel pier, with some similar conditions to the Washington BMPs.

Other possible guidelines include:

- Use complete extraction techniques if future dredging or dock construction is anticipated in the area or if there is significant likelihood of natural deepening.
- Use cutting, shearing, or snapping if dredging or deepening is not likely and if costs preclude complete extraction.
- In sensitive habitats, use pulling or snapping rather than jetting prior to cutting.
- In eelgrass beds, do not allow equipment to set on the bottom, and limit propeller damage.

5.2 Disposal and Reuse Options and Costs

Pile-removal projects typically require on-land storage prior to transport for disposal or reuse. On-land storage sites are best located near to the removal site, adjacent to a dock or seawall with sufficient depth to accommodate equipment. Sites must be large enough to allow for sorting, cutting, temporary stockpiling, and loading onto trucks or into debris boxes. If the wood waste is to be dried before transport, saving transport and disposal costs, the storage site must be located in an area where nearby residents, businesses, and recreation sites are not bothered by odors. Siting of a temporary storage area must also consider potential runoff of water associated with the removal operations and rainfall onto the stored debris.

Transportation from temporary storage areas to landfills or other locations will be by roads and highways, rail, marine routes, or a combination of modes. Current pile-removal projects in the Bay Area rely largely on road and highway transport. Trucking to local landfills is a flexible option, requiring a minimum of land-based temporary storage and access. Trucking is easier to coordinate and schedule than rail transport. Rail transportation could be economically feasible for large removal projects located adjacent to rail facilities. Barge transportation is also used within the Bay Area, and combination barge-and-truck operations are also typical.

Most creosote-treated debris removed in the Bay Area currently is disposed of in nearby landfills, including Vasco Road Landfill in Livermore, Keller Canyon Sanitary Landfill in Pittsburg, and Potrero Hills Landfill in Suisun. Creosote-treated wood is typically accepted at Class II landfills, which accept some hazardous and all inert wastes, and Class III landfills, which accept primarily inert wastes. Some landfills require non-hazardous waste manifests for creosote-treated wood. Costs for disposal at landfills vary, with current rates at local sites typically ranging from about $40 to about $60 per ton.

Some pile-removal projects use waste management companies, which deliver debris boxes to the storage area and pick them up for removal to the landfill. Under this option, the costs vary by volume rather than by weight. Debris boxes may be preferred if it is not practical to dry the pilings or if the removal contractor does not own trucks or want to subcontract with a trucking firm.

Reuse options for creosote-treated pilings include reuse as piles following encapsulation and other marine or non-marine reuse. Most of piles that would be removed from San

Francisco Bay are likely to be in too poor a condition for reuse after encapsulation. Possibly, the portions of the pilings that have been in a continuous anoxic environment below the mud line may be suitable for reuse in shallow-water projects, significantly reducing disposal costs. Cost-effective reuse as pilings would depend on having willing partners; rehandling, storage, and encapsulation costs; and demand for short pilings in the region.

Other shoreline or land-based reuse options could include selling or giving piles to the landscape industry, fencing contractors, or other industries. This option is likely to be practical for few projects. Regional policies on reuse of creosote-treated pilings removed from San Francisco Bay would facilitate a further evaluation of the options.

Reuse of creosote-treated pilings as fuel in cogeneration plants is a potentially good opportunity. (Cogeneration plants burn waste fuels, such as wood, and biomass, in an environmentally acceptable manner and, at the same time, generate electricity.) The rail industry uses this option for rail ties and other creosote-treated wastes. Opportunities for marine piles may be limited, because the rail industry currently supplies as much material as can be accommodated by cogeneration plants within economically feasible trucking distances of the Bay Area. However, the option has potential and warrants further research.

5.3 Encapsulation Techniques

Many types of encapsulation techniques can be applied to marine piles, including nonstructural methods, which isolate the pile, helping to preserve it from degradation while preventing release of contaminants to the marine environment, and structural methods, which restore and preserve the strength of the pile. Encapsulation techniques are carried out in place, without removal or replacement of the pile. Available materials include liquid coatings, plastic sheeting, fiberglass, and other structural overlays that are assembled over the pile and sealed with epoxy, grout, or similar products.

Piles in San Francisco Bay that could be candidates for encapsulation primarily include those that are in continued use. Abandoned piles with historic significance so great as to suggest that removal is not preferred, those that are situated in habitats that are too sensitive to disturb, and those that are difficult or too expensive to remove could also be considered for encapsulation. It is possible that an encapsulation material could provide a superior surface for Pacific herring spawning, but that issue has not been explored.

5.4 Permitting and Ownership Issues

Pile-removal projects in San Francisco Bay will come under the interest and responsibility of several federal and state regulatory and resource agencies. Personnel contacted during this project suggested that although pile-removal projects would be likely to be viewed favorably, it will be important to coordinate among the responsible agencies. Convening a focus group on permitting of pile-removal steps would be one method of ensuring smooth coordination.

All piling-removal projects will come under the jurisdiction of the **U.S. Army Corps of Engineers**. Large, complex projects would require an individual permit. Some Nationwide Permits (NWP) may be applicable, including NWP 27, Aquatic Habitat Restoration, Establishment, and Enhancement, and NWP 38, Cleanup of Hazardous and Toxic Wastes. Other NWP may be applicable if the project is conducted during maintenance and repair of existing permitted structures.

Many projects may fall under a simplified permitting process called a Letter of Permission (LOP). LOP procedure “B” may be applicable to projects that completely remove piles or remove piles to a depth of two feet below the mud line, without introducing debris into the waterway. Technically, Procedure “B” requires only after-the-fact notification to other regulatory and resource agencies and to the U.S. Geological Survey, the U.S. Coast Guard, and the U.S. Navy. In practical application, the Corps of Engineers is likely to request advance notification.

LOP procedure “A” many be applicable to projects that are considered to be more complex. Procedure “A” requires advance notification, a 30-day comment period, confirmation that BCDC will approve the project, and confirmation that the Water Board has issued or will waiver Water Quality Certification.

Pile removal will require review by **BCDC,** and permits or approval will likely be required for most removal projects. Related impacts, such as dredging or contaminated sediment movement, require permits. BCDC staff have suggested that they would prefer complete removal of piles where possible and that timing of removal projects would be based on approval or consultations with DFG, NOAA Fisheries, and the U.S. Fish and Wildlife Service.

A recent (October 2009) BCDC permit for a project that included removal of 180 creosote-treated piles required a two-day test to assess removal by vibratory hammer, a surface boom to contain floating debris, keeping removal equipment out of the water to the extent possible, primary containment of piles and related sediment and debris, slowly lifting piles through the water, no sediment removal from the extracted piles, and disposal at an authorized upland site.

The **Water Board** will require Water Quality Certification for all creosote-treated-piling removal projects. No general permits are applicable to piling removal. Projects would be evaluated on a case-by-case basis.

For projects undertaken on state lands, the **California State Lands Commission** will act to protect California’s legal interest and ensure compliance with CEQA. For some projects, it will be necessary to establish title through a State Lands Commission title search or a search of county property records. In some cases, landowners or lessees may not be available or may choose not to respond to inquiries about pile-removal projects. These situations will require a legal analysis before a removal project can be permitted.

Federally Permitted pile removal projects will require consultation with **NOAA Fisheries** and the **U.S. Fish and Wildlife Service**. Both agencies have specific interests in protection of endangered and threatened species. Projects would include Section 7 consultation relative to the Endangered Species Act, Essential Fish Habitat consultation relative to the Magnuson- Stevens Fishery Conservation and Management Act, and the Fish and Wildlife Conservation Act.

Consultation or coordination with **DFG** will be required. DFG has particular interest in projects that affect Pacific herring and would also review potential effects on eelgrass beds.

An important permitting issue will be to resolve whether work can proceed outside the established work windows (see Figure 5-1, above). There is currently no consensus as to whether the windows should apply to removal projects.

5.5 Removal of Creosote-treated Debris from Intertidal Areas

Much of the shoreline of San Francisco, San Pablo Bay, and Suisun Bay is littered with trash and debris, including creosote-treated wood (Figure 5-2). Significant quantities of wood debris can be found in the tidal wetlands of San Pablo Bay and along the edges of mudflats. Besides posing risks from leaching creosote, wood debris may damage vegetation and levee erosion protection during high water.

Figure 5-2. Intertidal debris at Point Richmond. (project team photograph)

During storms, wood debris is washed against levees and may become stranded above the mean high tide line, where it could be relatively easily removed by hand labor or small equipment. Removal projects could use nonprofit and volunteer efforts, small contracts, or cooperative efforts with the San Francisco District of the Army Corps of Engineers. Clean-up projects could be included in public outreach and education programs.

Use of volunteer groups would require developing a brief training guide about the importance of and techniques for removal and disposal of creosote-treated debris from intertidal and shore areas. Volunteer projects would also require safety training, basic supervision, and encouragement by an experienced staff person or trained volunteer, debris-containment materials and equipment, and an easily implemented disposal option.

Small contracted efforts could include more equipment, such as a crane truck for removing debris from areas within about 50 feet of roadway surfaces. Costs for this type of project could be reduced by setting relatively flexible schedules and working with nonprofit organizations that include some volunteers.

The San Francisco District has a debris collection-and-control mission, which is based out of Sausalito. It uses a modified landing craft, the M/V *Raccoon*, traveling the Bay to collect debris and trash, which is stored at the dock and removed to permanent disposal sites as needed. About 60% of the debris removed by the program is creosote-treated wood.

6. Other Artificial Substrate

This report focuses on the possible removal of creosote-treated wood from San Francisco Bay, but creosote-treated pilings are only one type of artificial substrate in the Bay. Artificial substrate is almost all hard-surface, and much of it is not suitable for removal or replacement.

Many of the artificial hardening structures were placed in the Bay to stabilize shorelines for development and to control erosion. There is some evidence, however, that these structures may be contributing to coastal erosion by inhibiting natural shoreline processes. Floats and boats associated with piers can also increase scouring and turbidity. In areas of San Francisco Bay that have been replaced with hard surfaces, the modifications often cause a decrease in the width of the nearshore environment and an increase in water depth, processes that can contribute to erosion, often leading to a cascading effect, in which it becomes necessary to progressively add hard substrates down the shoreline (Davis et al. 2002). The cumulative effects include permanent removal of sediment from the littoral system and loss of intertidal and beach zones.

The hard surfaces that have replaced vegetation in many areas of San Francisco Bay may be reducing water filtration and habitat function. These structures, especially bulkheads and seawalls, also steepen shorelines, reducing or removing valuable shallow-water nursery and refuge habitat for many estuarine species. Adverse effects of artificial hard substrates may be exacerbated by anticipated climate change and sea-level rise. A continual steepening of the Bay shore is a likely outcome of sea-level rise. Presence of sheer vertical structures is likely to result in greater storm-surge frequency and intensity, which would increase erosion and scouring.

In some cases, new approaches may provide the same functions as the existing hard substrate and also enhance or restore habitat. This section describes some of those new approaches. Additional information is included as Appendix E.

6.1 Options for Removal or Replacement of Existing Structures

For some projects, removal is the logical choice. For example, abandoned or derelict boats serve no useful purpose, and in only rare cases are they likely to be culturally significant. Abandoned boats may be in danger of breaking apart or sinking, creating risks to navigation, public health and safety, and the environment. The Washington DNR administers a Derelict Vessel Removal Program, which provides funding and expertise to assist public agencies in the removal and disposal of derelict or abandoned vessels (information available at www.dnr.wa.gov). The program provides funds for removal and disposal, with priority placed on vessels that are in danger of breaking up, sinking, or blocking a navigational channel and on vessels that present a risk to human health or the environment.

The most prominent group of derelict ships in the Bay is the Suisun Bay Reserve Fleet, which includes more than 70 obsolete or decommissioned ships, maintained by the U.S. Department of Transportation Maritime Administration. State authorities and environmental groups have sued for removal of the fleet. In 2008, the NOAA Office of Response and Restoration conducted an environmental assessment of the fleet, concluding that concentrations of contaminants in the sediment near the fleet were largely comparable to those from other areas of San Francisco Bay (NOAA 2008). However, in October 2009, the Department of Transportation announced a plan to remove two ships from the fleet, clean them of contaminants and invasive species, and tow them to Texas to be dismantled (Zito 2009). Eventually, state authorities hope the entire fleet can be removed.

For many of the artificial substrates in San Francisco Bay, removal or replacement is not an option. However, for some structures there are alternatives, which could be implemented immediately or as the structures require maintenance or replacement. On the East Coast, restoration scientists have been developing techniques for incorporating naturalized habitat into shoreline-stabilization projects. These techniques have come to be known as "living shorelines." Natural substrates used in living shoreline designs include emergent marsh, SAV, riparian vegetation, and oyster shell. These types of non-structural habitat types can be used individually or in combination with each other.

Natural habitat can also be combined with hard artificial structure, such as sills, to form a hybrid design. Hybrid designs are used to support and enhance natural habitat restoration or creation, in combination with more traditional approaches. Benefits of hybrid projects include providing space and structure for local species, wave attenuation, and improving water quality through a reduction in suspended sediments, without a commitment to a fully non-structural shoreline. Both non-structural and hybrid projects can be used in a variety of low to medium energy environments, and thus have wide applications.

The NOAA Restoration Portal (https://habitat.noaa.gov/restoration/) summarizes information about habitats, techniques, and resources for restoration studies and projects, including those that have incorporated living shorelines. For example, a North Carolina project replaced a steel sheet pile bulkhead with a hybrid living shoreline, consisting of stone sills and marsh grasses. Monitoring has shown that the sills were successful at reducing wave impact onto the marsh and shoreline, which allowed for re-colonization by a native marsh community. After three years, one of the three areas of restored marsh had similar grass-stem densities to a nearby natural fringing marsh (Currin et al. 2007). The mean numbers of fish and invertebrates sampled were also comparable between the natural and restored marshes.

In Puget Sound, the Washington State Department of Transportation, working in conjunction with the Battelle Marine Sciences Laboratory and the University of Washington, completed a hybrid project for a new ferry terminal at Clinton, Washington. The terminal was designed to mitigate effects on a nearby eelgrass bed. The design included use of glass bricks to enhance light penetration, narrowing the docks to decrease the shading footprint, construction of an artificial breakwater reef, and eelgrass plantings.

The project resulted in a significant expansion and increased density of eelgrass beds around the Clinton Terminal. Building on that success, other Puget Sound projects have used grating, glass blocks, sun tunnels, and reflective material on the underside of docks to enhance light penetration (Kelty and Bliven 2003).

In San Francisco Bay, a pilot project has integrated hybrid living-shoreline design into a site at the Marin Rod and Gun Club. The project constructed reef mounds from Pacific oyster shell and restored native eelgrass beds. During 2005–2009, more than 100,000 native oysters colonized the artificial reefs, and more than 10,000 shoots of eelgrass persisted (R. Abbott, personal communication).

6.2 Suggestions for Replacement and New Structures

Living shorelines have already been recommended as a component of the California Climate Change Adaptation Strategy (CNRA 2009). The living-shoreline approach may hold promise as replacement or new structures in San Francisco Bay. The potential will be dependent upon the scale of potential sites, the suitability of the sites for individual approaches, and the costs of construction and monitoring.

Elements to be considered in restoration or new projects will include technical constraints, conservation goals, and public concerns:

- Selection of appropriate shoreline-stabilization techniques.
- Protection and enhancement of native eelgrass habitat and shellfish beds.
- Collection of baseline information on aquatic habitats and biota.
- Assessment of sufficient light intensity for plant photosynthesis, fish recruitment, and growth.
- Minimization of shading effects and scouring.
- Documentation of success through continued monitoring of water quality, habitat variables, and flora/fauna recruitment.
- Stakeholder involvement.

Because few living-shoreline projects have been initiated in the Bay Area, additional pilot studies will probably be necessary before large projects can be undertaken. These pilot studies could continue from the oyster reef and eelgrass habitat-restoration projects that are already beginning in the North Bay. Techniques that have been pioneered in other regions of the U.S. could also be considered and tested in San Francisco Bay.

7. Conclusions and Next Steps

The four main tasks of this project have provided information to answer or begin to answer the questions that were posed at the beginning of work (Table 7-1). They have suggested some additional work that could be conducted to yield more definite answers to those and other questions (Table 7-2) and have begun to lay a framework for the last question, "What attributes should be used to prioritize locations for removal or treatment?" (Table 7-3).

Table 7-1. Answers to questions posed at the beginning of the project.

Mapping	
What is the distribution of abandoned creosote-treated pilings?	We identified more than 30,000 abandoned pilings in 630 complexes. Hot spots include the San Francisco waterfront, Point Richmond, the Napa River, and the Carquinez Strait.
How does the distribution of abandoned piles relate to herring spawning areas?	About one third (36%) of the mapped pilings are located within the herring spawning areas.
Environmental Assessment	
What adverse effects of creosote-treated wood have been measured?	Studies show that leaching rates decline following placement, but significant leaching can continue for many years. Many studies indicate that components of creosote can be harmful to Pacific herring embryos and other marine life. Studies also show adverse effects from physical attributes of pilings and overhead structures, such as shading.
Are there potential beneficial effects of piles for invertebrates and birds?	Data are limited but show that invertebrates, fish, and birds use piles and related structures.
Historical Significance	
When was creosote used?	Creosote has been used to treat pilings in the central San Francisco Bay since the 1870s. Use was widespread from the 1920s through the early 1970s. Creosote has been banned for pile treatment since the early 1990s.
Why were creosote-treated pilings installed?	Waves of marine borer infestations in various regions of the Bay in the 1850s, 1870s, and 1910s spurred creosote use.
Do creosote-treated pilings have historic significance related to the history of development along the Bay margin?	Some pilings may be considered historically significant under Federal, State, local or other guidelines.
Are there historic-preservation issues that would complicate removal?	Evaluation of cultural significance must be completed before any removal project proceeds. Appropriate treatment must be defined before removal.
Action Plan (Feasibility and Logistics of Removal)	
What are the feasibility and costs of removal?	Feasibility and costs depend on removal techniques required and the size, location, and timing of a project.
What are the disposal options?	Most creosote-treated debris from the Bay Area is disposed of in landfills. Reuse options may be considered.
What permits and authorizations are required?	Projects may require U.S. Army Corps of Engineers and BCDC permits, Water Quality Certification, and consultation with NOAA Fisheries, U.S. Fish and Wildlife Service, and DFG.
What are the ownership/responsibility issues?	For most projects, it will be necessary to establish title through the State Lands Commission or county property records.

Table 7-2. Possible additional studies suggested from the project

Mapping
Use of historic maps to enhance mapping
Site inspections to locate submerged piles

Environmental Assessment
PAH leaching: modeling and field studies
Analysis of sediment quality objectives sites near pilings
Pacific herring laboratory and field studies, including quantification of spawning on creosote-treated piles
Studies of other organisms that may be affected
Eelgrass studies
Quantification of invertebrate, bird, and fish use

Historical Significance
Implementation of programmatic approach

Action Plan (Feasibility and Logistics of Removal)
Focus group on the permitting process
Development of Bay-wide or specific area BMPs
Development of reuse standards
Encapsulation alternatives and methods studies
Project-timing and work windows resolution
Refinement of cost estimates

Table 7-3. Potential attributes of high-priority removal projects

Mapping
High density
High navigation hazard

Environmental Assessment
High probability of removing contaminant effects (e.g., removal from herring spawning areas)
Low probability of introducing a new pulse of contaminants
High probability of enhancing habitat, such as eelgrass beds
Low probability of adversely affecting habitat for birds

Historical Significance
Non-historic (built in the past 50 years)
Low cultural value
Low aesthetic value

Action Plan (Feasibility and Logistics of Removal)
Availability of access for removal
Availability of temporary storage
Access to transportation to disposal sites
Low ownership/responsibility issues

The project mapped more than 30,000 derelict creosote-treated pilings in 630 complexes. If the DFG estimate of 50,000–70,000 total pilings is correct and comparable, then about half the creosote-treated pilings in San Francisco Bay are no longer in use, an estimate that seems reasonable to the field team. About one third of the mapped piles are within the Pacific herring spawning range.

Neither the remote nor the field-based mapping techniques used for the project could detect remnants of piles that are completely submerged. Suspected locations of submerged structures could be identified through analysis of historic maps or field surveys with divers. Past pile-removal projects in the Bay have identified submerged structures during the removal process rather than as part of a preliminary project assessment.

Mapping identified four hot spots—Carquinez Strait, Napa River, Point Richmond, and the San Francisco waterfront—which have especially dense areas of pilings. Density is one factor that should be considered in identifying areas for remedial removal. Removal projects in dense areas are more cost-effective than those that remove fewer piles from more widespread areas.

Some of the mapped pilings are especially good candidates for removal, as they are hazards to navigation (Figure 7-1). Pilings may be low in the water, where they are not easily seen or they may be close to shipping lanes. These issues are likely to be exacerbated by sea-level rise.

The project's environmental assessment found that creosote-treated structures have been and continue to be a source of PAHs and other contaminants to the water, sediment, and biota of San Francisco Bay, although the degree of contribution to contaminant loadings is not well quantified. One estimate suggests that less than 2% of the total PAHs in sediments derive from creosote, but there may be localized effects.

Studies suggest that the greatest degree of leaching of toxic contaminants from creosote-treated pilings tends to occur during the first several years after placement, but rates are variable. Leaching continues over many years, and visible slicks were observed by the field mapping team. Future studies could include modeling or field efforts to estimate the contribution of PAHs migrating from piles to the water column.

Figure 7-1. Old pilings may be hazards to navigation. (project team photographs)

The project also found documented evidence of biological impacts to organisms from the contaminants found in creosote. The extensive creosote-removal activities in Washington were undertaken because available knowledge suggested potential risks to the animals that live or spawn on the pilings and because of concerns for public exposure.

The best evidence of potential effects of creosote on Pacific herring larvae in San Francisco Bay is the Vines et al. (2000) study, which found that even 40-year-old pilings could affect development of Pacific herring embryos in the laboratory. The ecological significance of those experiments remains uncertain and could be a focus of additional laboratory and field study.

There is information that shows that some organisms benefit from the structures. The extent to which Pacific herring, birds, and other animals benefit from the presence of artificial hard surfaces, including creosote-treated pilings, has not been documented. However, evidence of beneficial effects was sufficient to prompt a New York City project to preserve a pile field. Additional laboratory and field work could quantify beneficial uses of pilings by invertebrates, fish, and birds.

There is some argument that the process of removal of pilings can result in release of previously sequestered contaminants. A pilot removal project in a non-sensitive habitat could determine whether release of contaminants from pilings or resuspension of contaminated sediments during removal are concerns that must be mitigated.

Even with additional research, questions about the relative risks and benefits of creosote-treated structures in San Francisco Bay will probably remain. It is likely, however, that the weight of evidence will show that there is currently some risk of adverse effects on plants and animals that live or spawn on creosote-treated wood, and that those risks support removal. Evidence is also likely to suggest that there are benefits, but they may be insignificant or easily mitigated.

Priority removal sites would include those with a high probability of current contaminant effects, such as the herring spawning grounds, and those with a low probability of introducing new pulses of contaminants during the removal process. Piling-removal projects that also resulted in enhancement of eelgrass beds could significantly benefit subtidal habitats in the Bay. Eelgrass is a preferred substrate for herring spawning, so projects that increase light penetration or otherwise enhance eelgrass habitat could have significant benefits that outweigh any loss of the less-preferred substrate.

Some creosote-treated pilings and structures in San Francisco Bay are of interest because of their extreme age or their cultural interest. The pilings to the south of Brooks Island, which are shown in the Bing Maps screen shot in Figure 2-2, for example, are more than 100 years old. Some structures, such as the ferry terminal at Miller-Knox Regional Shoreline in Richmond, have already been identified with interpretive signage (Figure 7-2). Other sites that may be considered of interest include the Point San Pablo whaling station, the ferry dock at the Richmond-San Rafael Bridge, some of the older structures along the San Francisco waterfront and Angel Island, and structures associated with Carquinez Strait warehouses.

Analysis of historical significance must be completed prior to initiating any removal project. The programmatic approach suggested in this report would provide the most efficient method of completing that analysis for the Bay. In some cases, while structures may be considered significant, removal could proceed once the significance is appropriately documented.

Ferries & Freight on San Francisco Bay

Before bridges spanned the Bay, ferries and trains once linked San Francisco with the rest of the nation. At that time, the Bay Area boasted the world's largest ferry system.

Here, at Ferry Point ship and rail met in 1900 when Santa Fe tunneled through the hills to open the western terminus of its transcontinental line. Train passengers disembarked for the first time to board a ferry for San Francisco. One traveler described the trip:

"On the [ferry's] upper deck is . . . a cozy dining room where one can be served . . . while enjoying the beauties of this seven mile trip — the harbor, the shipping, the Berkeley hills upon the left, Mount Tamalpais on the right. It takes about thirty minutes . . . ."

Freight trains, too, pulled in to the Ferry Point yards. The boxcars were loaded onto barges and hauled by tugboat across the Bay.

The Santa Fe ferry-steamer San Pablo waits in the passenger slip at right, while part of a 260-foot long freight car barge is visible at the lower left, moored by the apron and gallows structure. At the upper left, the steamer Ocean Wave can been seen approaching.

Figure 7-2. The old ferry terminal at Miller-Knox Regional Shoreline in Richmond is of historic interest. (project team photographs)

In addition to historic interest, some pilings and structures may have aesthetic value, an attribute that is difficult to quantify (Figure 7-3). Assessment of aesthetic value varies widely among individual views and stakeholders. For many piles or piling groups, however, there may be consensus that the structures are eyesores, and those areas could be considered a high priority for removal. Like many coastal areas, San Francisco Bay is dealing with large increases of trash in our waters. Decrepit pilings and structures may be considered one form of trash. The NOAA Marine Debris Program focuses on preventing and removing debris from marine waters. Removal of creosote-treated wood from San Francisco's shorelines fits into this mission.

Figure 7-3. Abandoned pilings in San Francisco Bay—romantic reminders of the past or eyesores? (project team photographs)

The Action Plan portion of the project found that large marine equipment typically needs water depths of at least 6 feet, an important factor, because mapping found that most piles and pile complexes were located in shallower water. Smaller equipment requires water depths of 3 feet. Land-based cranes can cost-effectively reach a maximum of about 150 feet from shore.

Among the removal methods, vibratory pulling is considered to be the cleanest and most effective method for complete pile removal, while snapping is the easiest and most cost-effective method of partial removal. Cutting usually requires sediment removal by jetting and should not be used in areas where resuspension of sediments is undesirable. Complete pile removal should be used in all areas that will be dredged in the future and in areas that may erode, exposing the remnants of partially removed piles.

Storage of piles for drying prior to disposal can reduce disposal costs. In the Bay Area, creosote-treated piles are typically disposed of in landfills as nonhazardous wastes. Transport to disposal sites is most often by truck. Reuse opportunities for creosote-treated piles appear to be limited.

The Action Plan identified several areas in which additional consideration will be necessary. Whether San Francisco projects adopt BMPs similar to those in use in Washington is one issue. Another issue is whether the region should adopt policies for acceptable reuse. The potential for reuse of creosote-treated pilings as fuel for cogeneration plants warrants additional study. Further research on encapsulation technologies could yield other new possibilities. There was no consensus as to whether pile-removal projects could be permitted outside the work windows in which dredging currently takes place. Resolving this issue will have a significant effect on the budgets for removal projects.

Logistics and costs attributes that suggest a high priority for removal include ease of access, availability of temporary storage, ready access to disposal sites, and low ownership or responsibility issues.

As the San Francisco Bay Subtidal Habitat Goals Project moves forward, a focus on removal of creosote-treated pilings and structures from San Francisco Bay will likely include targeted studies and pilot removal projects. Removal projects could focus on the dense hot-spot areas or on areas that would enhance the subtidal habitats in sites that are also priorities for eelgrass restoration. What projects are undertaken will depend on available funding mechanisms as well as on the specific restoration goals for the Bay.

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List of Acronyms

BCDC	San Francisco Bay Conservation and Development Commission
BMP	Best Management Practices
CEQA	California Environmental Quality Act
CHRIS	California Historical Resources Information System
DFG	California Department of Fish and Game
DNR	Washington Department of Natural Resources
EPA	U.S. Environmental Protection Agency
ERL	Effects range– low
ERM	Effect range–median
GIS	Geographic information system
LOP	Letter of Permission
MLLW	Mean Low Low Water
MS	Microsoft
NAD	North American Datum
NHPA	National Historic Preservation Act
NPS	National Parks Service
NOAA	National Oceanic and Atmospheric Administration
NRIS	National Register Information System
NWP	Nationwide Permit
OHP	California State Parks Office of Historic Preservation
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
SAV	Submerged aquatic vegetation
SFEI	San Francisco Estuary Institute
SHPO	California State Historic Preservation Office
USCGC	U.S. Coastal and Geodetic Survey
UTM	Universal Transverse Mercator

Mapping of Derelict Creosote-Treated Piling and Piling Complexes in San Francisco Bay

KRISTEN CAYCE AND MARCUS KLATT
San Francisco Estuary Institute, Oakland, CA

Appendix A of
Removal of Creosote-Treated Pilings and Structures
from San Francisco Bay

Prepared by

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California State Coastal Conservancy
1330 Broadway, 13th Floor
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Final Report

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1. INTRODUCTION

1.1 MAPPING OBJECTIVE

The assessment of potential creosote piling removal in San Francisco Bay first requires answering the question, where are the pilings? The identification and location of creosote piles in the Bay is the first step in understanding the magnitude to which these structures are contributing to chemical leaching, wildlife habitat and aesthetic value. To date no comprehensive digital map of creosoted piles exist for SF Bay. Earlier volunteer efforts, guided by NOAA, have produced a digital map of creosote pilings for a limited extent of the East Bay. These data were used as ancillary data in this project guiding the development of piling characteristics recorded during the mapping process. Through the development of a comprehensive database of creosote piles and piling complexes in San Francisco Bay, scientists, planners and managers can use these data as a starting point in analysis of piling removal.

1.2 SPATIAL EXTENT

The spatial extent of the creosote piling dataset is the San Francisco Bay Estuary proper, from north to south, San Pablo Bay to the South Bay, respectively. From west to east, land's end past the Golden Gate Bridge to the City of Antioch in the northeast, respectively. Since major channels were historically used for shipping, mapping was also completed for the following major channels; Napa River, Petaluma River and the Oakland shipping channel. This area was further broken down into 3 regions and 8 Sub-regions for logistical and analytical purposes (Figure 1).

Appendix A

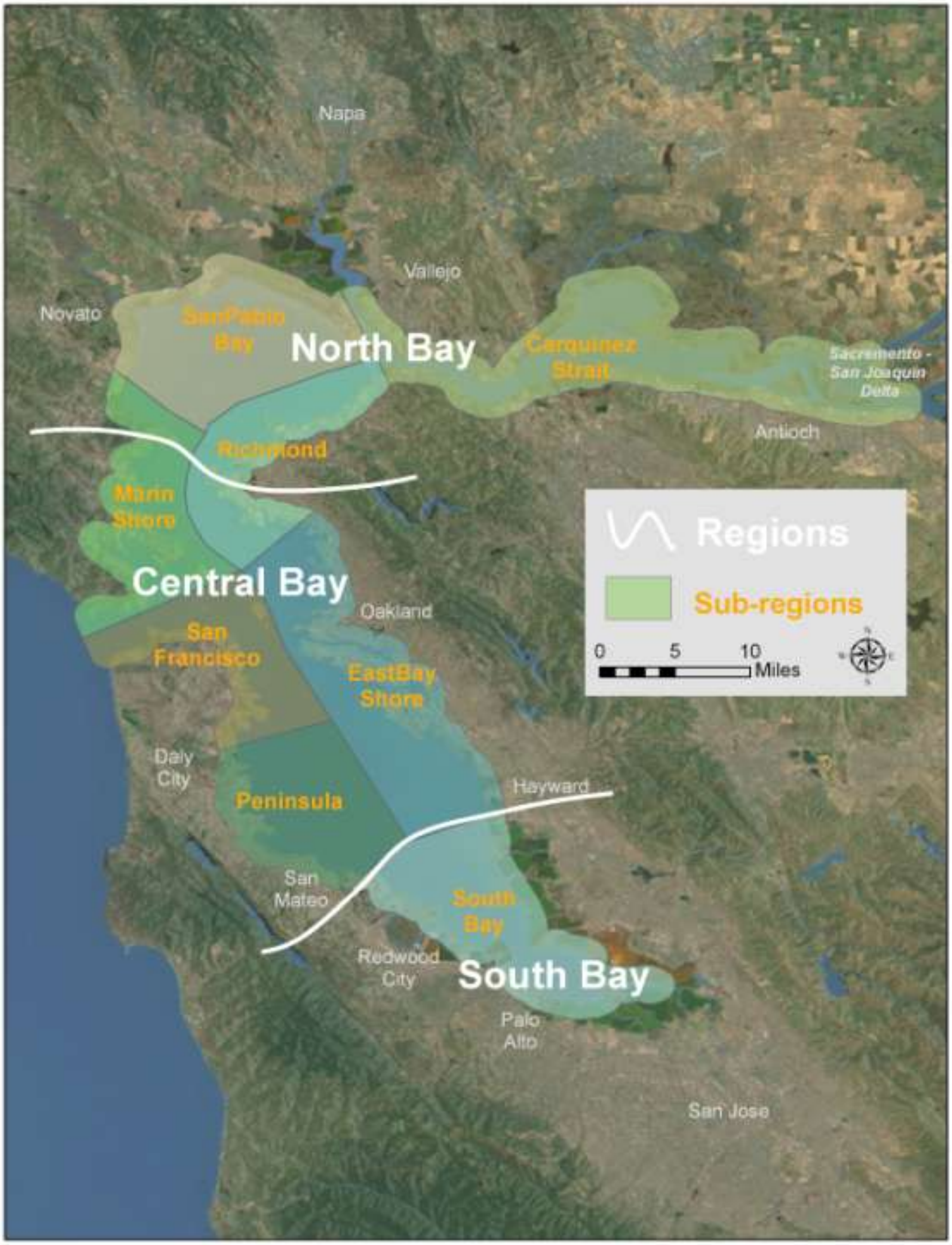


Figure 1 - Project Extent showing Regions and Sub-regions

1.3 MAPPING OUTPUT

The primary output from the mapping portion of this project is a digital and spatially accurate Geographic Information System (GIS) dataset of defunct creosote piles and piling complexes in the SF Bay Estuary. The creosote dataset is a polygon layer where each polygon represents a piling complex. Piling complexes are any/all features that were deemed part of the same structure at one time. Features captured in the mapping are any pilings, associated deck cover or other debris. Number of piles in a complex can range from 1 to 1000s. Each polygon contains descriptive fields to provide the user with as much detail as could be captured through the project's methodology. See the methodology section for more detailed description of polygon attribution. Additional outputs from the mapping are summary tables and charts showing the geographical and frequency distribution of the piling complexes, piling hot spots, and associated depths. The GIS dataset generated from this task has the spatial projection of Universal Transverse Mercator (UTM), zone 10 and North American Datum (NAD) 1983.

2 MAPPING METHODOLOGY

The mapping of creosote-treated pilings in San Francisco Bay Estuary was accomplished through a partnership of the SFEI Geographic Information System (GIS) department and the NOAA Southwest Region Habitat Conservation Division (Figure 2). SFEI's mapping methodology primarily used aerial imagery and remote-sensing techniques to identify piling complexes. NOAA contributed field resources to map regions where remote sensing techniques proved challenging. Both SFEI and NOAA were able to provide ground-truthing of the remotely sensed data.

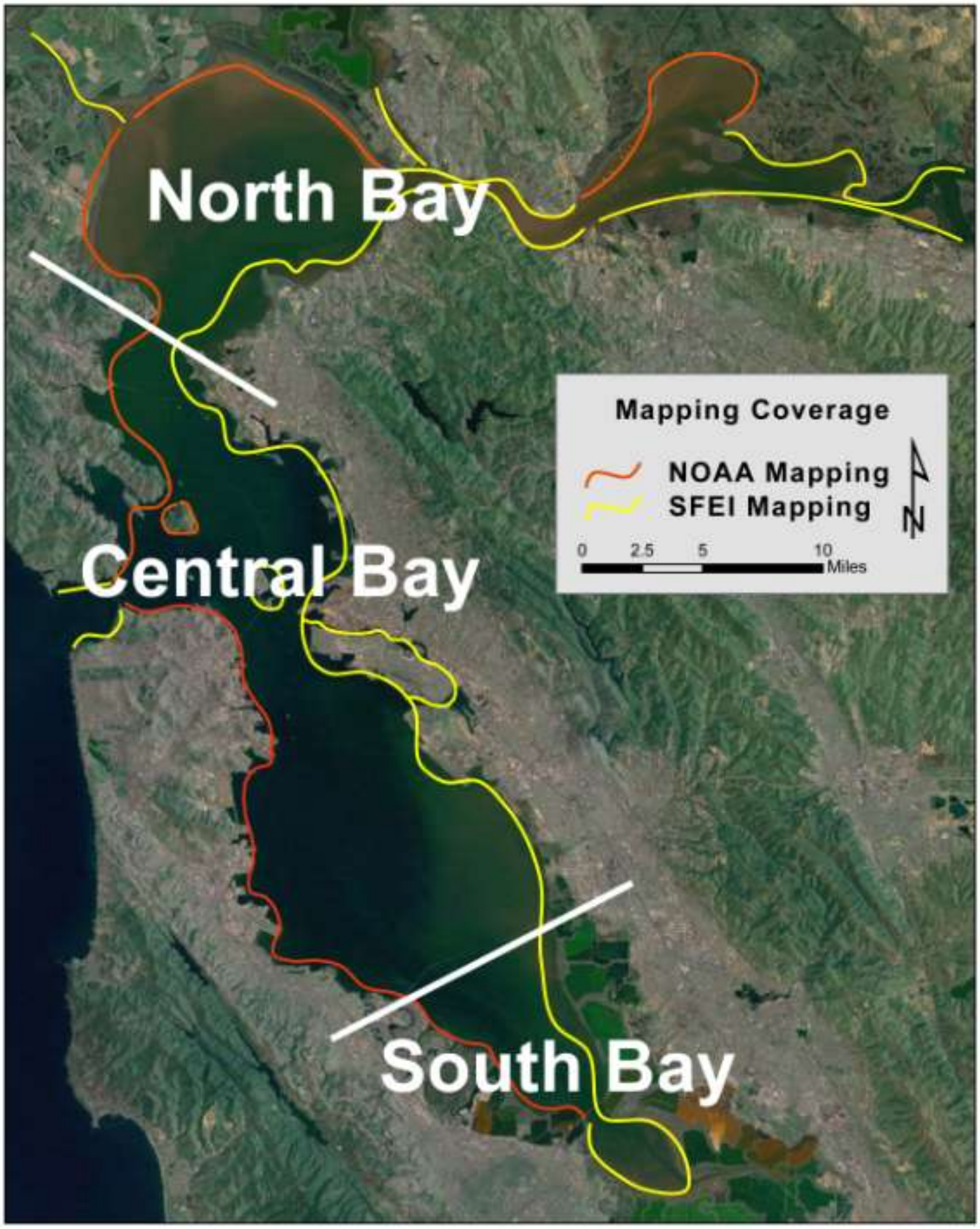


Figure 2 - Project's spatial extent and agency/organization responsible for each area.

2.1 SFEI - REMOTELY SENSED MAPPING

2.1.1 Mapping

SFEI developed a methodology to map creosote pilings in SF Bay with accuracy and cost as the principle drivers. A remote-sensing technique was identified as the most appropriate method to produce the output of a reasonably accurate and cost effective dataset for this project. Using both existing aerial imagery and free or in-house GIS software to identify and map creosote pilings kept mapping costs low and allowed for full coverage mapping of the Bay. For this project SFEI combined several software packages; Environmental Systems Research Institute (ESRI) ArcGIS, Google Earth and Microsoft (MS) Bing maps (formerly Virtual Earth) to gather piling information. This three step process using existing software and imagery provided cost and accuracy control of the mapping task. Each software package contributed to the value and accuracy of the dataset. MS “Bird’s Eye” feature in Bing Maps offers high resolution oblique angle imagery for most of the SF Bay Estuary shoreline (Figure 3, Figure 5). Google Earth provides less resolute imagery, but with comprehensive coverage of the SF Bay and tools to delineate and attribute polygons (Figure 4). ESRI ArcGIS software can read Google Earth data and perform spatial analysis. Each software package is currently licensed to SFEI or available publicly which allowed SFEI to map at such a wide spatial extent.

Creosote pilings were identified in the ‘Bird’s Eye’ feature in Bing Maps by panning across the near shore landscape. Of the three software packages, Bing Maps offers the highest resolution imagery available, image capture dates ranging from 1998 to 2009, the option of an oblique angle and at low tide imagery (in some parts of the Bay). Low tide was useful, as some pilings are completely covered at higher tides. Then, delineation of the pilings and attribution of the polygons was completed in Google Earth. Google Earth has the functionality of creating and attributing polygons and higher resolution imagery than currently available for ArcGIS (although lower than Bing and not appropriate for initial piling identification). The data generated in Google Earth were processed and exported using the third party ‘Arc2Earth’ tool then analyzed in ArcGIS software. The final data will be available in proprietary (ArcGIS) and open source (kml/kmz) formats.

Appendix A

Figure 3 - Bing Maps “Birds Eye” screenshot from the south side of Brooks Island, Richmond, CA

Figure 4 - Google Earth screenshot from the south side of Brooks Island, Richmond, CA

2.1.2 Attribution

Attribution was assigned both in Google Earth and in ArcMap. As polygons were created in Google Earth three attributes were assigned to each feature. 'Pnum', 'Dcov', and 'Loc', were assigned to represent the number of pilings in the polygon, percent amount of deck cover on the piling complex, whether the piling complex is located in land or water, respectively. These attributes were assigned to each polygon in Google Earth using the 'Description' field with the string:

Pnum:X
Dcov:X
Loc:X

Where X = number of pilings, deck cover percent or piling complex location (location values are 'w', 'l' or 'b' representing water, land, or complexes with both pilings in land and pilings in water). (Figure 6)

The Google Earth data are exported into a .kmz file. Using a third party tool 'Arc2Earth', the data were exported into an ESRI format (personal geodatabase) after each day of work with the naming convention 'SFEI_piling_yyyymmdd'. 'DateCollected' and 'PolygonID', which represent the date the polygon was digitized, and the polygon's unique ID, are generated in ArcMap along with other attribution.

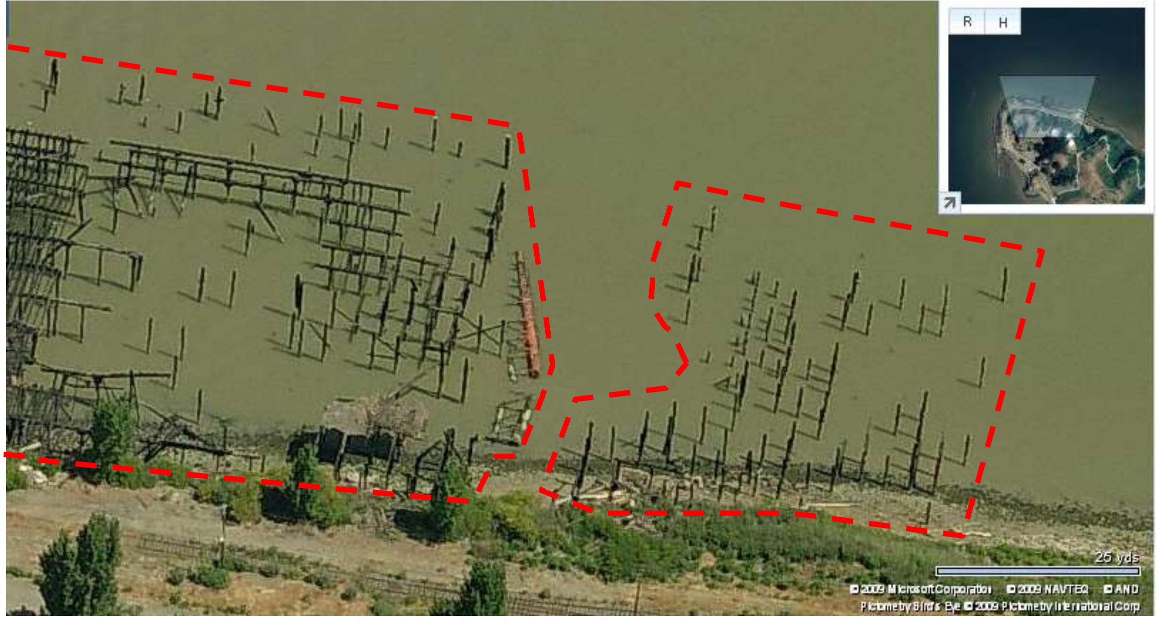
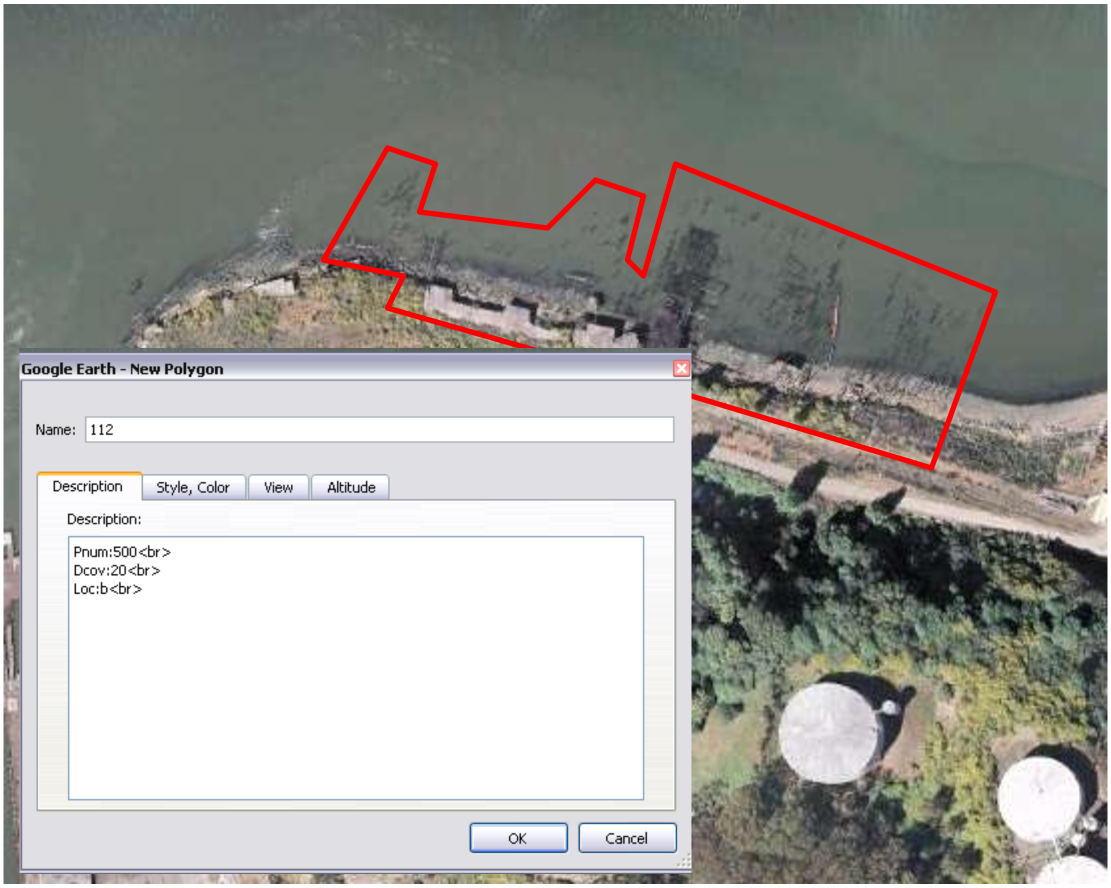


Figure 5 -Bing Maps "Birds Eye" screenshot with outline depicting piling complexes to be mapped in Google Earth



Name: 112

Description:

```
Pnum:500<br>
Dcov:20<br>
Loc:b<br>
```

Figure 6 - Screenshot of Google Earth Attribution Method

Attribution continued after the data was converted into an ArcMap compatible file. The piling complexes were classified into ‘Mapping Regions’ and ‘Analytical Sub-Regions’. The project extent was divided into three ‘Mapping Regions’ in order to assign the SFEI and NOAA mapping areas and as a first cut for analysis. The three mapping regions include: North Bay, Central Bay and South Bay. The North Bay boundary spans from City of Antioch to South of China Camp and North of Point Richmond. The Central Bay boundary spans from South of China Camp and North of Point Richmond to the San Mateo Bridge and east to the ocean-side extent of the project. The South Bay boundary includes the SF Estuary south of the San Mateo Bridge.(Figure 1) From this attribution the “Site Number” was able to be generated to serve as the feature’s unique code and is a combination of the ‘Region’, ‘Date’, and ‘_FID’ fields (Ex. ‘CB071508_1’).

For analysis, the project area was further segmented into eight ‘Sub-regions’: Carquinez Strait, San Pablo Bay, Marin Shore, San Francisco, Peninsula, Point Richmond, East Bay Shore, and South Bay. The Carquinez Strait boundary spans the north and south shores from the Carquinez Bridge to the Sacramento and San Joaquin Delta. The San Pablo region spans the shore from Novato to the Carquinez Bridge. The Marin Shore boundary spans from north shore of Lands End of the Golden Gate Channel to Novato. The San Francisco boundary spans from the south shore of Lands End of the Golden Gate Channel to just south of Candlestick Park. The Peninsula boundary spans from the shore just south of Candlestick Park to the west shore of San Mateo Bridge. The South Bay Sub-region boundary spans from the west shore of the San Mateo Bridge all the way to the south end of the bay and back up to the east shore San Mateo Bridge. The East Bay Shore boundary spans from the east side of the San Mateo Bridge to the south side of Richmond Harbor. The Richmond boundary spans from Richmond Harbor to the Southside of the Carquinez Bridge (Figure 1).

In addition, all spatial analysis results were also placed in the attribute table. This includes depth, slope and landscape information. The minimum, maximum and mean depth relative to mean lower low water was computed using the 2002 California Department of Fish and Game bathymetry layer for each piling complex. The bathymetry layer was then converted to slope and the minimum, maximum and mean slope in percent rise was then recorded for each feature. The piling complexes were defined as above, on, or below 6 feet in depth. Features were also given a habitat type based on the SFEI Eco Atlas modern baylands habitat layer produced as part of the Bayland Habitat Goals Project (SFEI, 1998).

2.2 NOAA - IN SITU MAPPING

NOAA Southwest Region Habitat Conservation Division provided in kind funding to the creosote project through man hours and field equipment. NOAA's assistance in the mapping portion of this project allowed for verification of remotely sensed data and identification of pilings in areas where photo interpretation was not available. NOAA conducted *in situ* field mapping along the west shore of SF Bay from San Pablo Bay to Dumbarton Bridge as well as the northern shore of Grizzly Bay. These areas around the Bay were identified as less suitable for remote sensing where high resolution imagery was not available from Bing Maps. In addition, the west shore of the SF Bay is densely packed with creosote piling and other artificial structures that make remote sensing difficult. NOAA focused their efforts in these areas and verified SFEI's remotely sensed data when necessary.

NOAA's field mapping protocols include traversing portions of the Bay in a NOAA owned Boston Whaler boat during rising tide and documenting piling complexes originally with a portable GIS unit (ArcPad). Field work was performed during a rising tide to ensure that the boat did not hit submerged obstructions. Using the ArcPad GIS unit proved inefficient due to the unit's long refresh times. Polygon delineation was switched from digital to manual using topographic maps and nautical charts. All attributes were documented on maps/charts and transferred to GIS back in the office. For each complex documented, one or more photos were taken using a telephoto camera; status was checked on nautical charts; and field surveys were completed. All associated data gathered is in the attribute table and each feature in the dataset is attributed with at least these fields: estimated piling number, estimated remaining deck cover, water or land location, and site identification. Water or land location was defined by piling complex. The complex was either completely on land (land), completely in the water (water), or with pilings both in land and water (both). Additional fields were attributed when verification was possible. These fields include field notes, various species presence, piling condition and more.

3. DATA COMPILATION

3.1 DATA TRANSFER

SFEI compiled the NOAA’s datasets with SFEI’s into one seamless dataset. Typically after each field trip, NOAA packaged their GIS data and photos for delivery to SFEI using established protocols. Data transferred to and from mapping partners was done so through SFEI’s File Transfer Protocol (FTP) site. Data collected in the field by NOAA was uploaded to the SFEI FTP site after each priority area has been completed.

3.2 Formatting Data

NOAA datasets had to be formatted before they could be integrated into SFEI datasets. NOAA datasets included attributes that were not in SFEI sets and vise versa. NOAA’s datasets had to include all the attributes that the SFEI dataset included but not the other way around. This meant that the ‘Site Number’ and ‘Sub-region’ fields had to be created for the NOAA dataset. In order to properly merge these two datasets, the NOAA attribute table also had to be formatted so that all these fields were populated in the same way. NOAA’s *in situ* mapping technique allowed the map creator to see more detail in the field which gave features captured by NOAA additional attribution details. These additional fields are empty in SFEI datasets.

After properly formatting the attribute table for both the SFEI and NOAA datasets, the information was merged into a single file which covered the entire project extent. Care was taken in the areas where they coverage areas of the datasets met in order to avoid overlap in the datasets creating duplicate features, or gaps in data creating missed features.

5. QUALITY ASSURANCE AND QUALITY CONTROL

Quality Assurance and Quality Control (QAQC) of the creosote piling dataset was performed periodically throughout the mapping process through visual inspection of the comprehensive dataset and by field checking discrete areas. Review of the dataset occurred each time the NOAA and SFEI data were integrated and then one final time once the mapping and field QAQC was complete. Visual inspection consisted of review of each polygon to identify and correct gross errors such as misidentification or duplication. Field checks of the mapping results were conducted by boat by SFEI staff. Data collected during the checks include absence/presence of pilings, number of pilings, condition of piling structures, and whether the structures are in use. Any additional pilings that were not identified in the imagery are noted and photographs are taken of all piling complexes. Updates to the GIS data are made after the field checks.

Creosote pilings that were mapped in the area of Richmond Bay /Brooks Island and the Carquinez Strait were surveyed for accuracy in the field (Figure 8). These areas were chosen for their proximity to a large amount of piling complexes in various conditions as well as ease of accessibility.

Figure 7 - Photo Taken beneath the south side of the Carquinez Bridge during QAQC field work on December 11, 2008.

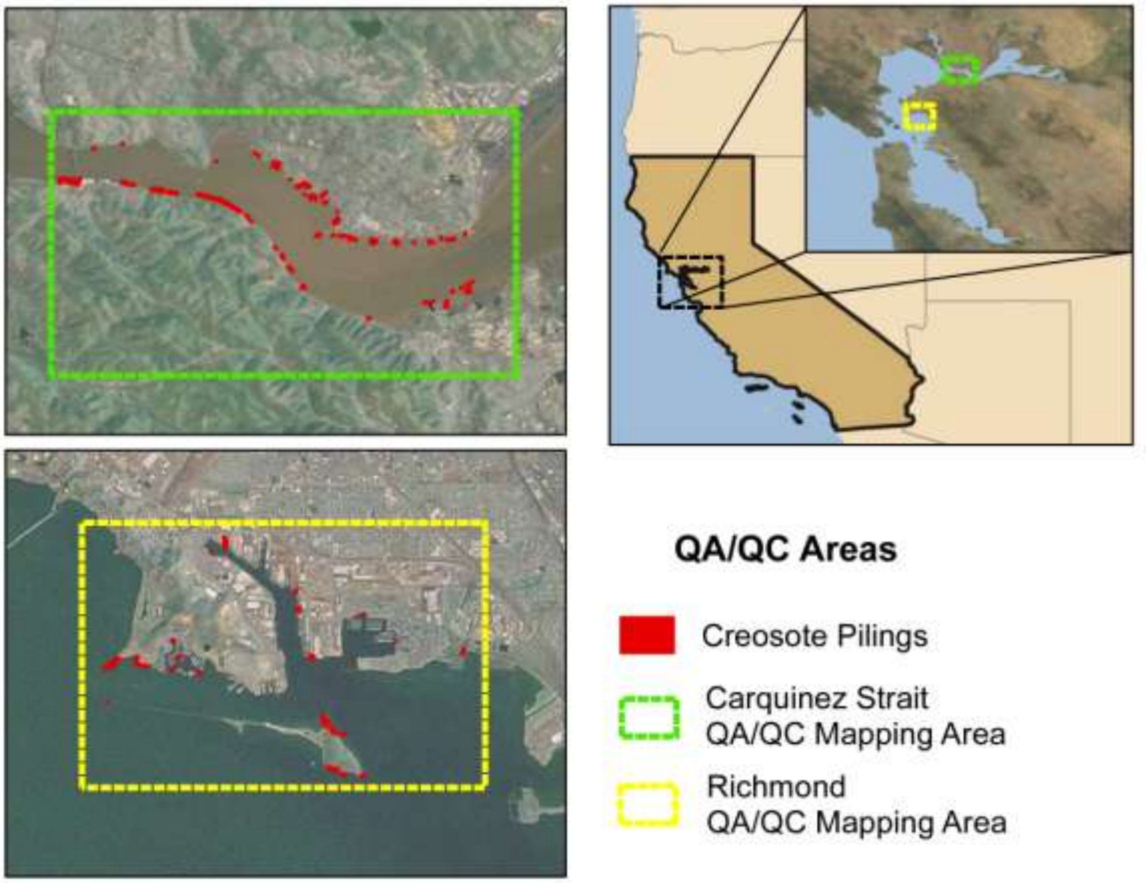


Figure 8 – QA/QC areas

Any changes to the dataset based on field observations including new pilings were added using ArcMap and existing pilings attributes were updated. The pre-QAQC data and the post-QAQC data were compared and four new fields were created based on the change in data: "Pnum Error", "Pnum Change", "PctDcov Error", "PctDcov Change", and "Percent Error".

Pnum Error and PctDcov Error have four possible values:

- Present Overmap: The creosote complex was originally mapped but the amount was overestimated.
- Present Undermap: The creosote complex was originally mapped but the amount was underestimated.
- Deleted: The creosoted complex was originally mapped but was taken out of the final data.
- Not Mapped: The creosoted complex was not originally mapped but was added of the final data.

Pnum Change is the Post-QAQC piling number subtracted from the Pre-QAQC.

Percent Error is the Pnum Change error normalized by the number of pilings per complex.

The Pnum Errors were as follows: "Present Overmap" was 17.7%, "Present Undermap" was 7.8%, "Not mapped" was 6.4%, and "Deleted" was 3.5%. The error is PCTDcov was under 1%. Percent total percent error for both QAQC areas is 32.3%. We found this to be an acceptable amount of error. This error represents the most complex areas that were mapped using the remote sensing methodology.

The post QAQC data was integrated into the final dataset so that the errors that found during the QAQC process were corrected. The rest of the study area was checked following the QAQC process to indentify and correct similar errors. Navigational markers were removed and, since overestimation of number of pilings per complex was the main source of error, large piling complexes were recounted. We are confident that the final dataset has error of no greater than 30%.

6. DATA ANALYSIS

6.1 SPATIAL ANALYSIS

As this project evaluates the complexity of creosote piling removal, piling location, density and surrounding environment become important factors. The piling dataset offers a unique opportunity to assess, in broad strokes, piling areas that may be suitable for removal or preservation based on factors developed through best professional judgments. Once the dataset was complete, analysis was performed to further understand the spatial and frequency distribution of the piling complexes and their associated environmental factors around the Bay.

Spatial and frequency distribution were of particular importance in understanding where high concentrations (in any) existed around the Bay. High concentrations of pilings may be identified as areas that would be more cost effective to remove provided the depth and slope associated with the complex were within the engineering requirements. This dataset includes both the Estuary's bottom depth and slope derived from CA Department of Fish and Game bathymetry dataset (CADFG, 2002). The overlay of historical herring spawning habitat data may also show how much of the piling complexes may be used as subtidal habitat and thus preserved or replaced. When discussing piling removal or other types of remediation, accessibility is also a key component. This project was able to use the piling dataset with existing habitat data to understand the landscape surrounding each piling complex. Similar spatial analysis can be performed on the piling dataset with other digital data of interest. Datasets that we felt were of interest, but outside of our scope of work were land use/land cover, distance from major roads, and distance from shoreline, among others.

Ancillary data used in the statistical analysis includes the 2002 California Department of Fish and Game bathymetry and the 1998 EcoAtlas Modern Bayland Habitat layers described in the Attribution sub-section of the methodology section. All results from the spatial analysis are stored in the attribute table of the creosote piling dataset. The statistical summary tables and charts in this section were created from that attribute table.

List of all the attributes within the dataset:

Comprehensive	**Not Comprehensive****
Estimated Number of Piles per Complex	Site Description
Estimated % Deck Cover	Vertical/Horizontal Count
Complex Location (Land, Water, Both*)	Description of Surrounding Environment
Region and Subregion	Species Present
Date and Site Number	Image
Inventoried by	
In Use	
Habitat Type (from Modern Baylands)	
Herring Spawning Habitat	
Depth (min, max, mean)	
Slope (min, max, mean)	

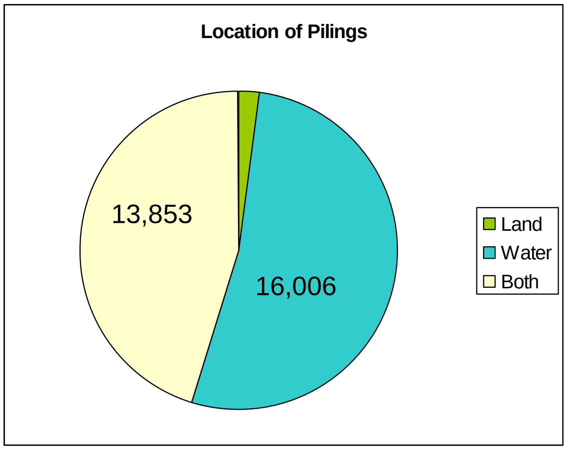
*A creosoted piling complex contains pilings in land and pilings in water

**This data was collected through *in situ* mapping methodology only

6.2 STATISTICAL SUMMARY

6.2.1 Full Project Area

The creosote piling mapping showed a total of 30,546 defunct piles within 630 complexes in the study area. Of these 630 complexes, the majority was found in the water (78%) and only 6% were on land. 17% of the complexes spanned both land and water with containing piling that were in water and pilings that were on land. However, when looking at the number of individual pilings within the complexes defined as split between in the water and spanning both land and water (both), it is closer to 50-50 (Figure 9). What we can draw from this is that there are piling complexes with large numbers of piles that are both in and out of the water at low tide. Areas like this may prove difficult for removal if multiple access points are required.



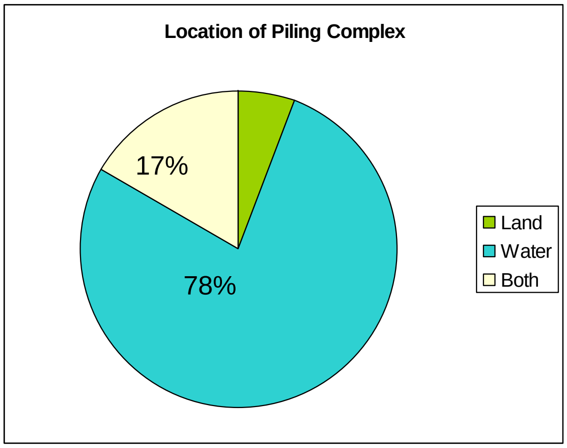


Figure 9 – Locations of piling and piling complexes

6.2.2 Totals per Mapping Region

Figure 10 –Mapping Regions

Region	Number of pilings	Number of Complexes
Central Bay	15961	281
North Bay	14183	326
South Bay	402	23

Appendix A

Region	Location	Pilings	Complexes
South Bay	Land	93	8
	Water	237	10
	Both	72	5
Central Bay	Land	336	16
	Water	9335	227
	Both	6290	38
North Bay	Land	258	12
	Water	6434	252
	Both	7491	62

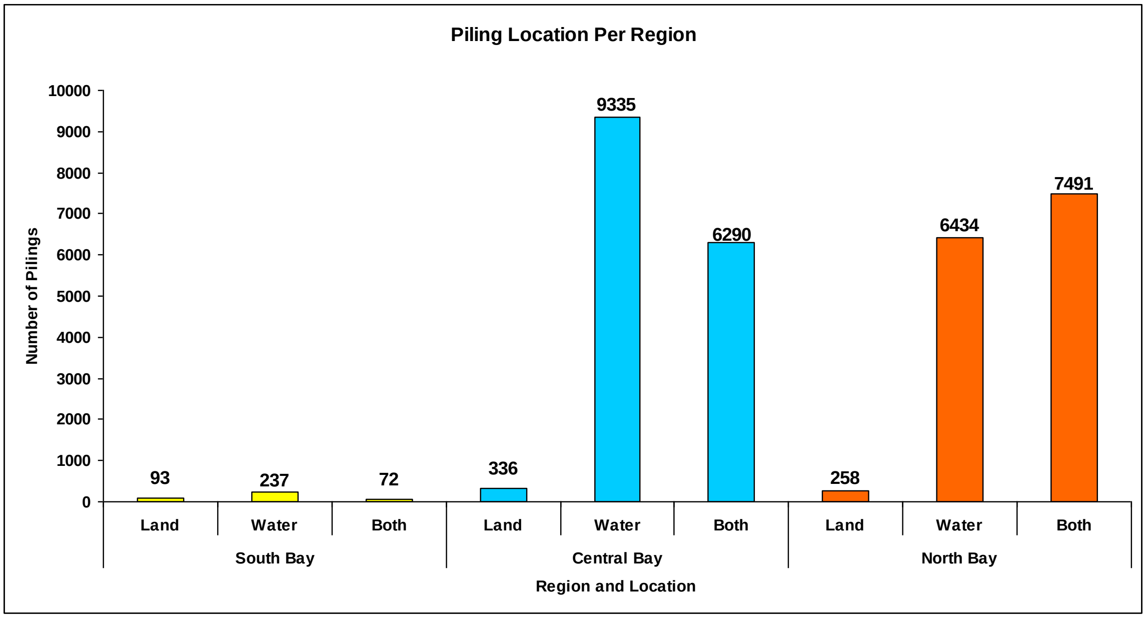


Figure 11 – Piling locations by region

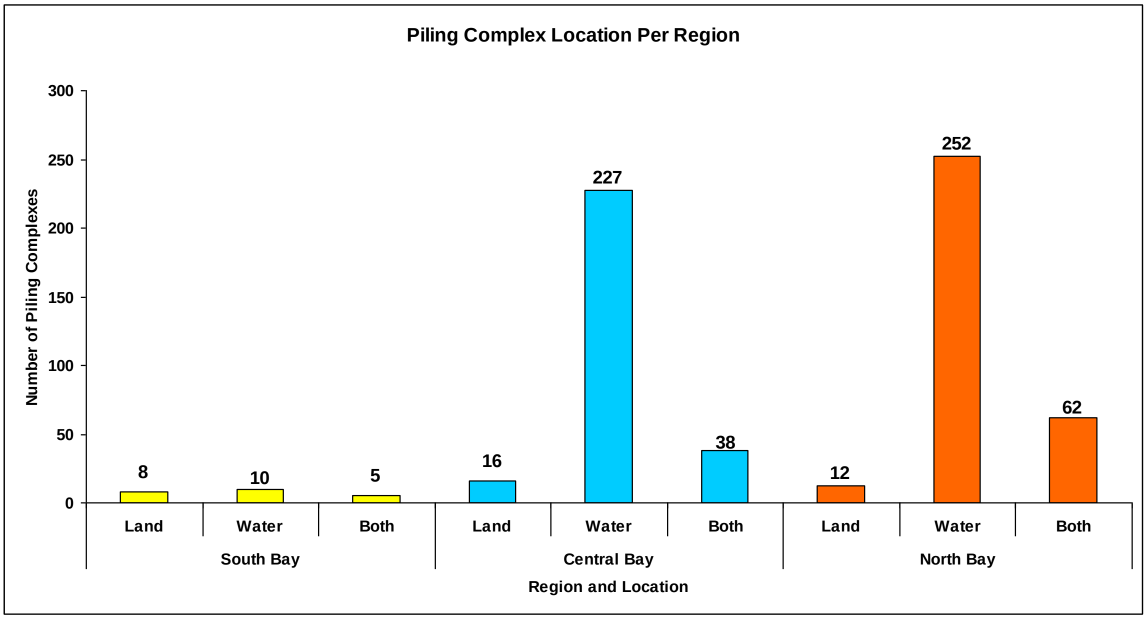


Figure 12 – Piling complex locations by region

6.2.3 Totals per Analysis Sub-Region

Sub-Region	Piling Complexes	Pilings
Carquinez Strait	229	11,391
Richmond	159	11,160
San Francisco	89	7207
East Bay Shore	104	1331
Marin Shore	18	582
South Bay	23	402
San Pablo Bay	10	130
Peninsula	5	41

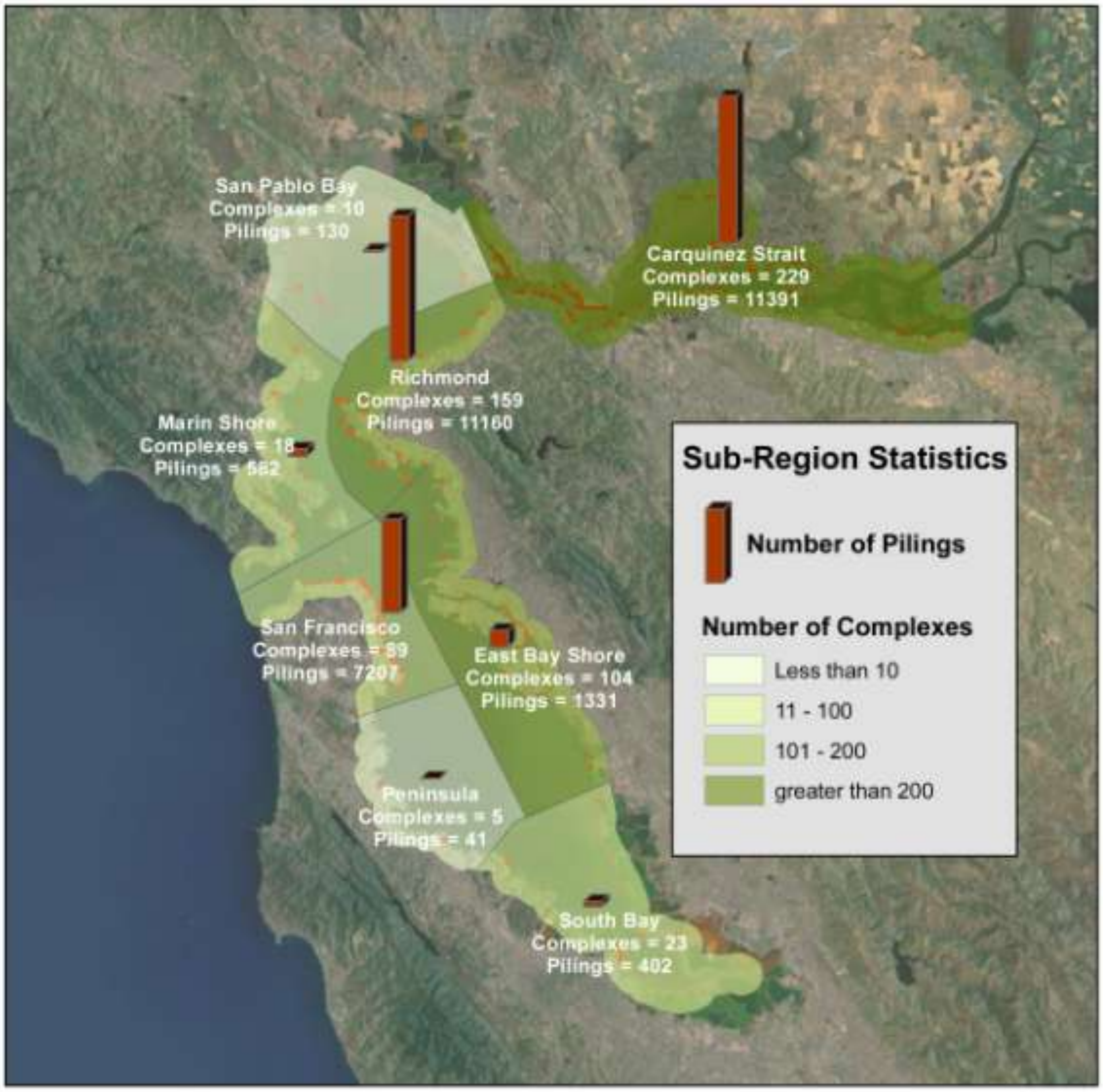


Figure 13 – Sub-Region Statistics

The total Pilings per sub-region shows that the majority of the pilings and piling complexes are located in the North and East bay (Figure 13). Carquinez Strait has the most piling complexes and individual Pilings with 229 and 11,391, respectively. Of these pilings in Carquinez Strait the majority of the complexes were located in water (Figure 14). Even though there were less complexes with both pilings in land and pilings in water these complexes were much larger. The number of pilings per complex were equally divided between land and both land and water for the Carquinez Strait (Figure 15).

Sub-Region	Location	Pilings	Complexes
Carquinez Strait	Land	211	9
	Water	5,525	174
	Both	5,655	46
	Total	11,391	229
Richmond	Land	180	9
	Water	2,226	116
	Both	7,384	32
	Total	11,160	159
San Francisco	Land	178	4
	Water	6,348	76
	Both	353	32
	Total	7,207	89
East Bay Shore	Land	24	5
	Water	1,021	86
	Both	286	12
	Total	1,331	104
Marin Shore	Land	0	0
	Water	487	14
	Both	182	4
	Total	582	18
South Bay	Land	93	8
	Water	70	5
	Both	239	10
	Total	402	23
San Pablo Bay	Land	0	0
	Water	130	10
	Both	0	0
	Total	130	10
Peninsula	Land	1	1
	Water	33	3
	Both	8	1
	Total	41	5

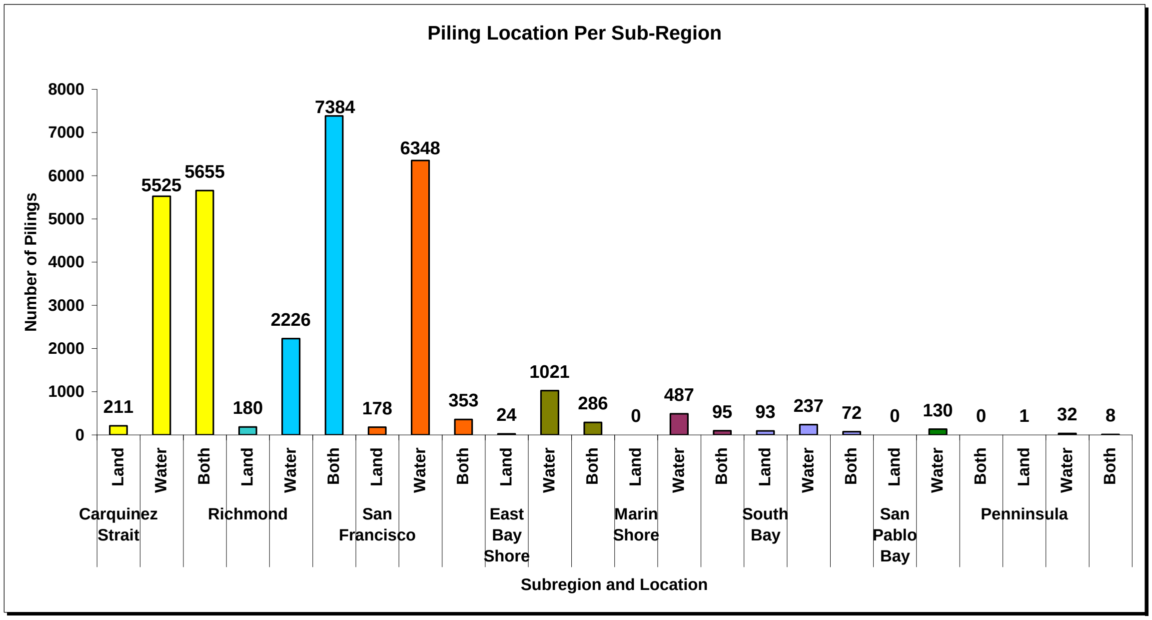


Figure 14 – Individual Pilings per sub-region by location

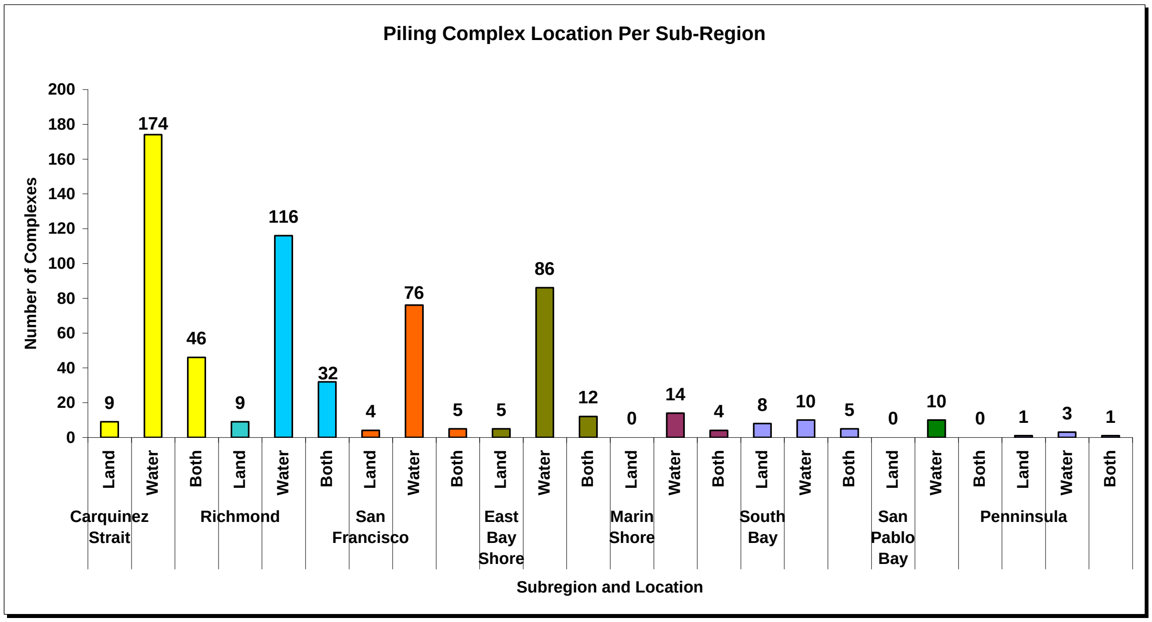


Figure 15 – Piling complexes per sub-region by location

6.2.4 Historical Herring Spawning Habitat

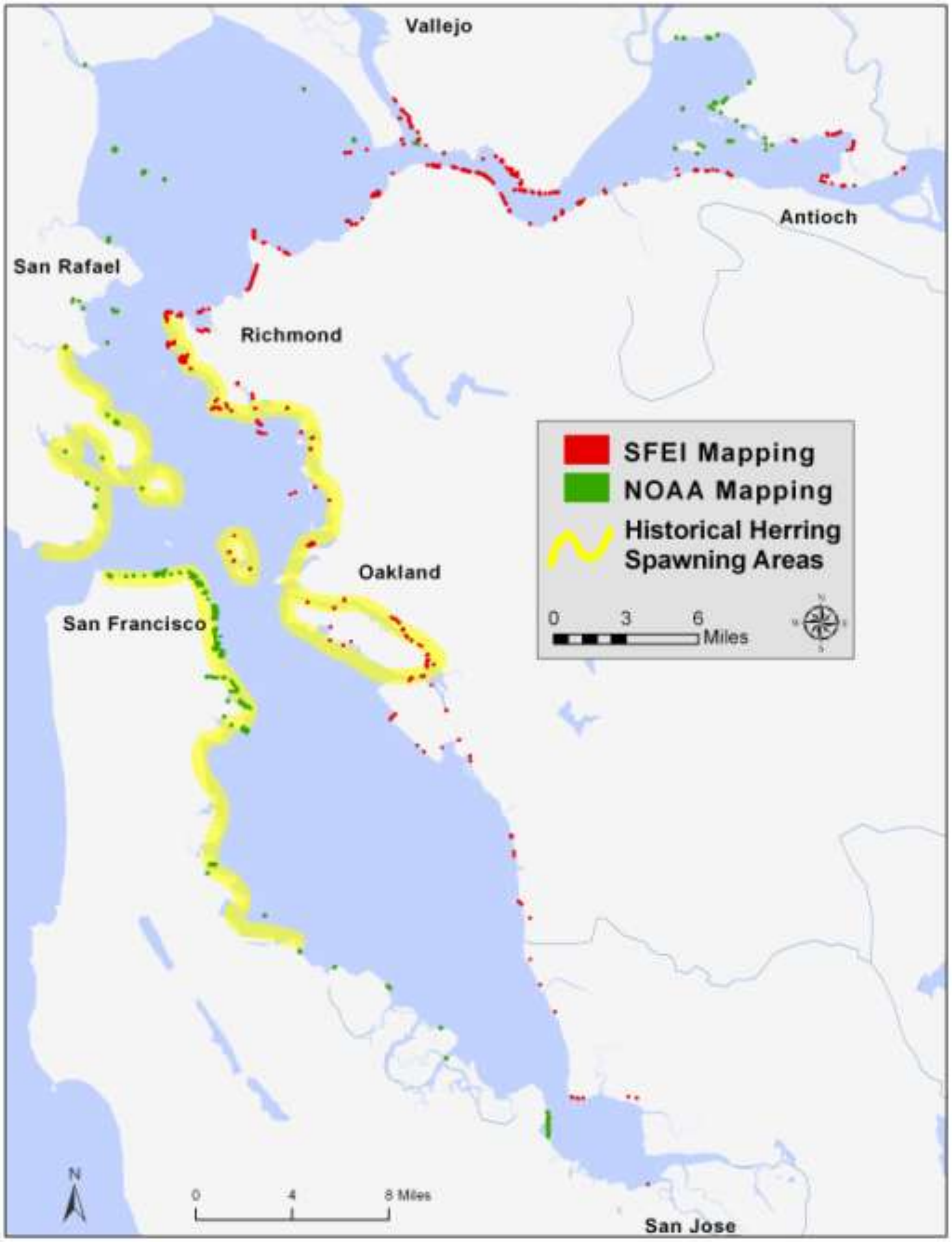


Figure 16 – Historic Herring Spawning Areas from the Department of Fish and Game

Historic Herring Spawning Habitat	Number / % of Piling Complexes	Number / % of Pilings
Within Spawning Habitat	228 / 36%	11,286 / 37%
Outside of Spawning Habitat	402 / 64%	19,260 / 63%

Herring spawning habitat extends on the east from just below Richmond Point to just Below Bay to just below Alameda and on the west from the Richmond-San Rafael Bridge to the San Mateo-Hayward Bridge (Figure 16). About a third pilings complexes and pilings for the San Francisco Bay were located in herring spawning habitat.

6.2.5 Bathymetry

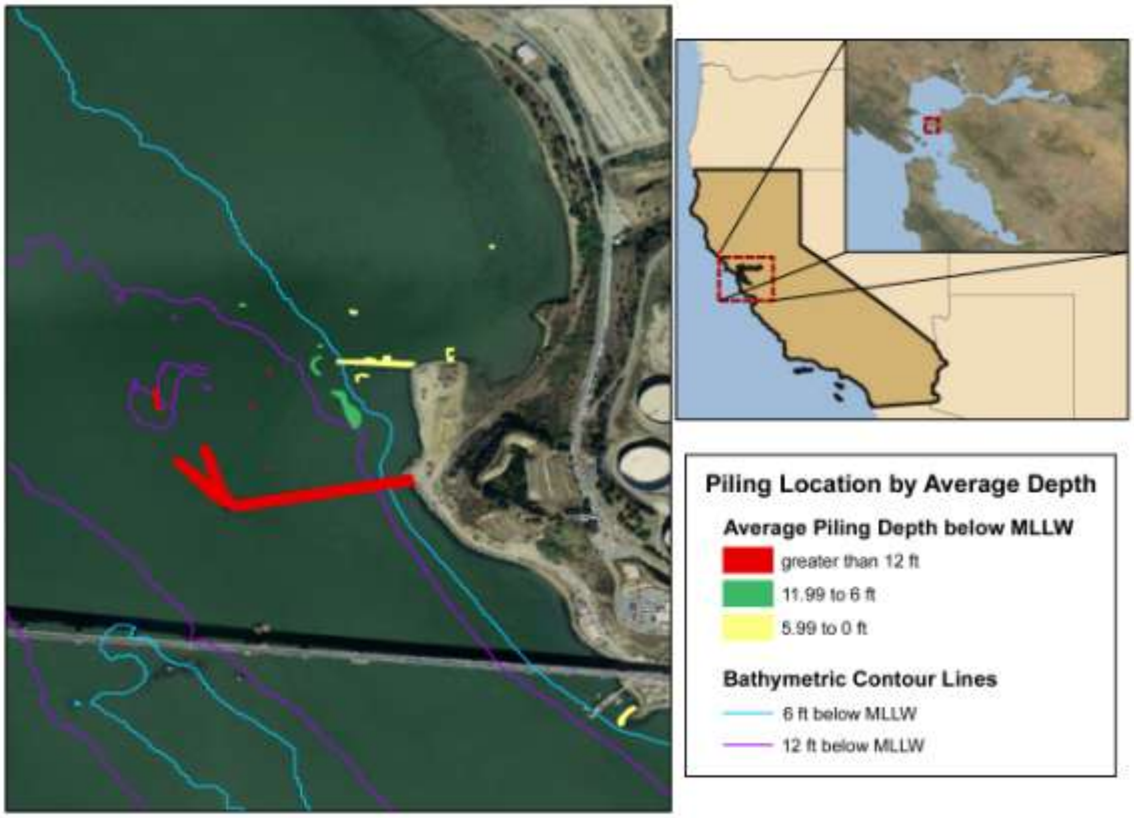


Figure 17 – An example showing the bathymetry for an area in the Point Richmond vicinity.

Depth Below Mean Sea Level in feat	**Number of Piling Complexes**
Greater than 12	77
11.99 to 6	84
5.99 to 0.001	264
No Value or Above Sea Level	206

This Depth values were calculated using the 2002 California Department of Fish and Game bathymetry layer (CaDFG, 2002).The majority of the creosoted piling complexes are located less than 6 feet below mean sea level (bmsl) and greater than 0 feet bmsl (Figure 17).

6.2.6 Hot Spots

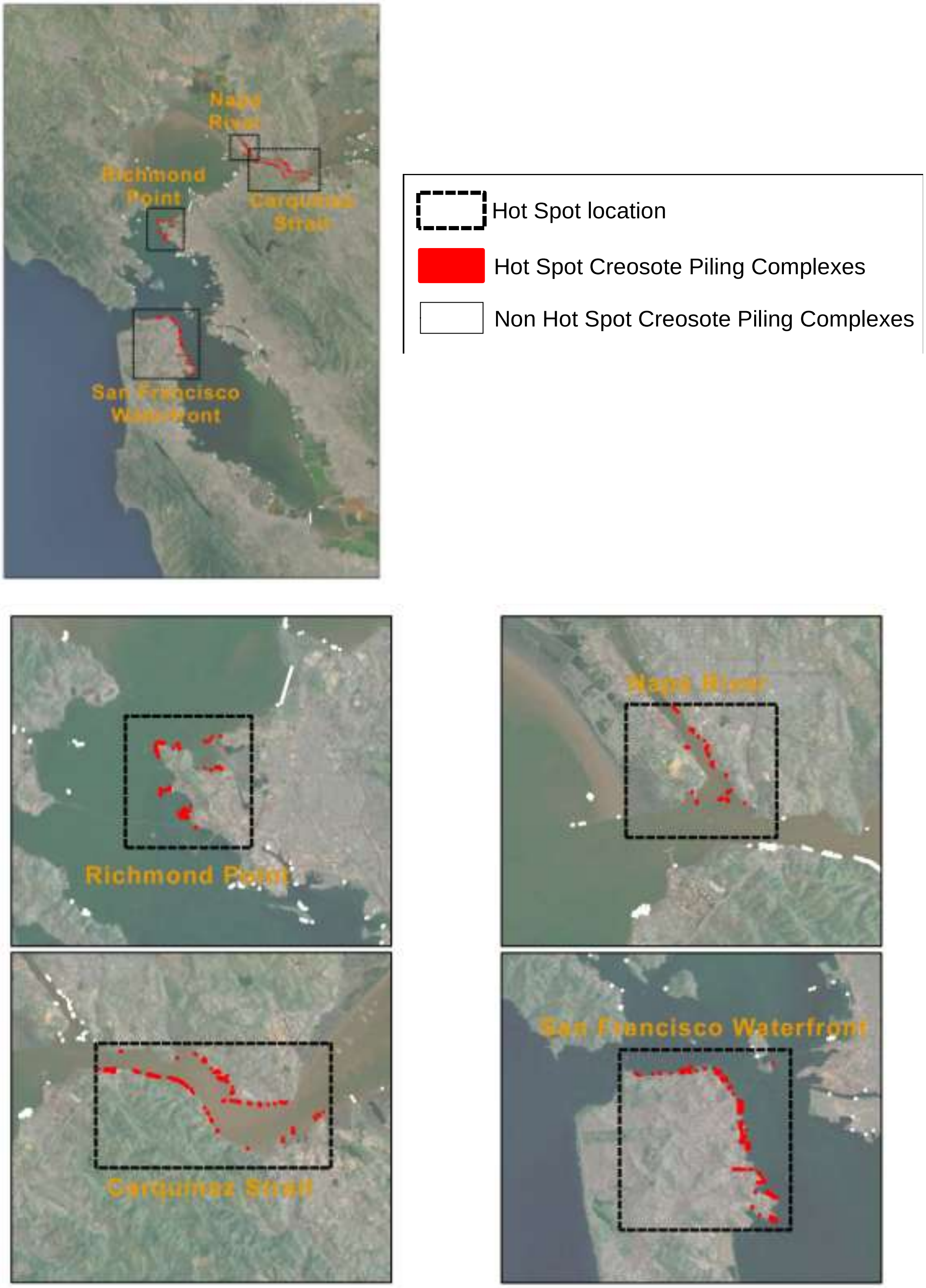


Figure 18 – Hot Spot Locations

Four locations were chosen in areas of dense piling clusters (Figure 18). Piling count and piling complex count was calculated for each of these four areas. The shoreline was estimated manually in ArcMap using the measurement tool. The piling count and piling complex count was then normalized by this approximate shoreline count (Figure 19).

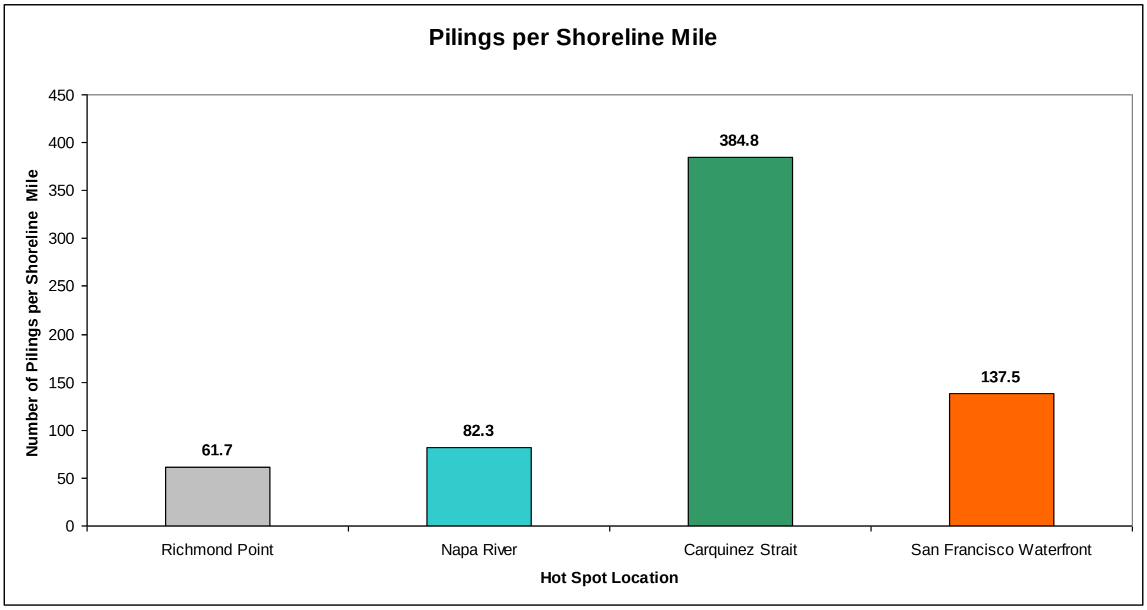


Figure 19 – Piling count per shoreline mile

Hot Spot Region	Number of pilings	Number of Complexes	Total Complex Area (acres)*	Acres Per Estimated Shoreline Mile
Richmond Point	6168	68	14	0.14
Napa River	1234	27	4	0.26
Carquinez Strait	6541	107	25	1.47
San Francisco Waterfront	6874	82	61	1.22

Hot Spot Region	Pilings per Shoreline Mile	Complexes per Shoreline Mile	Estimated Shoreline length in miles**
Richmond Point	61.7	0.7	100
Napa River	82.3	1.8	15
Carquinez Strait	384.8	6.3	17
San Francisco Waterfront	137.5	1.6	50

*Area is approximate. Digitization variations may cause estimates to vary from site to site.
**Shoreline estimated using ArcMap measurement tool.

ACKNOWLEDGMENTS

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ENVIRONMENTAL ASSESSMENT OF THE IMPACTS AND BENEFITS OF CREOSOTE-TREATED STRUCTURES IN SAN FRANCISCO BAY

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Appendix B of
Removal of Creosote-Treated Pilings and Structures
from San Francisco Bay

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Table of Contents

1.0 Issues

The Subtidal Habitat Goals Project for San Francisco Bay is developing a plan to manage and improve the subtidal resources of San Francisco Bay. The Subtidal Goals Project aims to identify subtidal habitats and the biota that live in these habitats (Schaeffer et al., 2007) and to identify the current impacts and benefits to the subtidal environment. This project will culminate in a research, management, and restoration plan for improving San Francisco Bay subtidal environments.

The 'Removal of Creosote-Treated Pilings and Structures from San Francisco Bay' project has completed mapping of San Francisco Bay derelict creosote-treated structures (Appendix A), provided an historical context for these structures in the Bay (Appendix C), and developed a framework for potential removal of these structures (Appendix D). Appendix B provides an environmental assessment of creosote-treated structures and other artificial substrate in San Francisco Bay. This section focuses on reviewing the chemical makeup of creosote, the physical and chemical properties of creosote and creosote constituents, the partitioning properties of these chemicals, PAHs in San Francisco Bay, environmental exposure of PAHs, potential environmental impacts of these chemicals in San Francisco Bay, as well as the potential benefits of creosote-treated and other artificial structures to biota.

San Francisco Bay is an urbanized and developed estuary, which has been subject to multiple anthropogenic forces. The Bay has a legacy of contamination as well as continued loading of contaminants. Creosote-treated structures have existed in the Bay for over 100 years. Many of those structures are no longer in use, and all of them continue to be a source of polycyclic aromatic hydrocarbons (PAHs) and other chemicals to the waters and sediments of the Bay. PAHs, which are major components of creosote, are of concern due to their ubiquitous sources and prevalence in Bay sediments. There are many case studies of possible and definitive adverse biological effects due to PAHs. There is also some evidence that creosote-treated structures may affect Pacific herring or other organisms that live in or spawn in the Bay. A San Francisco Bay study showed decreased hatching success for Pacific herring eggs that were spawned directly on creosote-treated wood (Vines et al., 2000). The California Department of Fish and Game (CDFG) also have concern about the potential impacts of creosote-treated wood on herring eggs (CDFG 1996). However, it is unclear whether creosote-treated structures result in significant impacts or whether removing these structures would significantly reduce PAH contamination.

Although creosote has been federally approved for use in aquatic systems, there are existing San Francisco Bay regulations that prohibit new installation of creosote-treated structures. In 1994, CDFG discontinued the use of creosote-treated structures in State Waters or in any location where creosote from treated wood could enter Waters of the State (Sullivan 1994). The San Francisco Bay Regional Water Quality Control Board (Regional Board) prohibits the use of creosote-treated wood in new construction of docks, boardwalks, and other aquatic structures requiring pier pilings. All new aquatic structures in San Francisco Bay need to be inert materials including steel, untreated wood, or concrete.

The Bay floor is composed mostly of soft sediments, and there is limited natural hard substrate (Schaeffer et al., 2007; Cohen 2000). The subtidal and intertidal habitats in San Francisco Bay have been largely modified with additions of various types of artificial substrate including piers, rip rap, and bridges (Schaeffer et al., 2007). These artificial structures provide habitat for a host of colonizing plants and animals and, subsequently, a food source for their consumers. Artificial structures also provide habitat for nesting and roosting aquatic birds. However, these structures can also physically impact the Bay environment by decreasing light penetration and changing biotic composition.

There are two documents that should be referenced for management of creosote-treated structures and other artificial substrate in San Francisco Bay. Stratus Consulting (2006) reviewed the biological impacts of creosote-treated structures in aquatic environments for the National Marine Fisheries Service (NMFS) NOAA Fisheries Southwest Division. The NMFS report reviewed potential environmental impacts to NMFS trust resources, including threatened and endangered species, and provided a risk assessment framework that can be used to perform site-specific environmental assessments. Cohen (2008) reviewed the impacts and benefits of artificial substrate on San Francisco Bay biota. The review briefly summarized impacts from artificial substrate, such as habitat alteration and increased shading.

2.0 What is Creosote?

Creosote is a wood preservative that has been used for more than 100 years to repel marine borers and preserve wooden structures placed in aquatic systems (Hutton and Samis, 2000). It is derived from crude coal tar distillates and is a mixture of hundreds or possibly thousands of chemicals (reviewed in WHO 2004). Fewer than 20% of these chemicals are at percentages higher than 1% (WHO 2004). The chemical composition of creosote has varied over the production period (reviewed in Stratus Consulting 2006).

Creosote and the chemical constituents of creosote have many physical and chemical properties that drive their behavior in aquatic environments. Creosote is slightly soluble in water and is known to leach from treated wood into aquatic environments (Figure 1) (WHO 2004). Creosote undergoes a ‘weathering’ process whereby chemical constituents are adsorbed, evaporated, photo-oxidized, or dissolved (reviewed in Sved et al., 1997). Creosote migration from treated structures is most likely in the form of droplets, sheens, or particulate material (Goyette and Brooks, 1998; Anchor Environmental, 2007). Studies have found patchy distribution of PAHs around creosote-treated structures suggesting dispersion of chemicals by tides and currents (Goyette and Brooks, 1998; Anchor Environmental, 2007; Gagnéa et al., 1994). In general, migration of creosote to the water column increases with increasing temperature and decreases with increasing age (Ingram et al., 1982; Goyette and Brooks, 1998). Lower creosote migration in older pilings is due to lower piling surface availability of creosote. This suggests that release of creosote from treated structures is variable over time with the expectation that newer treated structures will release more chemicals into the environment than older treated structures. Laboratory studies also show that creosote leaching is higher in freshwater than in saltwater and that PAH concentrations decrease with increasing distance from piling (Ingram et al., 1982; Hutton and Samis, 2000; Gagnéa et al., 1994).

Figure 1. Creosote leaching from pier piling in San Francisco Bay as observed by NOAA survey 2008 (Photo credit: William Winner).

There have been many field and laboratory experiments aiming to quantify release of contaminants from creosote-treated structures. This quantification aids in determining if contaminants from creosoted-treated wood is of environmental concern. In situ experiments of pilings showed that low molecular weight PAHs (LPAHs) in sediments decreased post-piling installation (384 day monitoring period) while high molecular weight PAHs (HPAHs) increased in the sediment over the same period (Goyette and Brooks, 1998). This is to be expected since LPAHs are more readily degraded or volatized (see next section). Total sediment PAHs 7.5 meters downstream from a creosote-treated piling complex (six piling dolphin) were significantly higher than the upstream location. Sediment PAH concentrations were elevated up to 5 meters downstream from the site but concentrations were below Washington State effects thresholds (Goyette and Brooks, 1998). This study suggests that contaminants from creosote can be distributed some distance away from piling complexes and that HPAHs tend to accumulate and remain in the sediments.

There are various estimates of creosote loss rates from treated wooden pilings (discussed as PAH loss) in the literature. Losses were estimated from 273 mg/piling/day (Bestari et al., 1998a) to 403 mg/piling/day (Ingram et al., 1982). These numbers are most likely good estimates of initial loss of PAHs immediately following installation of pilings to the aquatic environment (Bestari et al., 1998a; Ingram et al., 1982). Maximum PAH concentrations in the sediments from creosote-treated structures are predicted to occur two to three years following piling installation (Figure 2) (Brooks 1997; Goyette and Brooks, 1998). Various studies of weathered creosote-treated pilings have shown continued loss of chemicals from pilings but the loss rate from older pilings is generally lower and quite variable (Goyette and Brooks, 1998; Ingram et al., 1982). Vines also found that creosote-treated wood extracts from 50-year-old San Francisco Bay pilings were the source of PAHs to the surrounding water. However, PAH availability may have been due to splintering of the piling which may have released previously sequestered creosote. The authors note that splintering of creosote-treated pilings may result in new releases of creosote and associated contaminants to the Bay.

Brooks (1997) and others have developed predictive spreadsheet models that can estimate PAH concentrations released to the aquatic environment from creosote-treated pilings. The Brooks model takes into account a number of variables including salinity, water temperature, age of piling, and creosote retention. An extensive review of the limitations of this and other models has been provided by Stratus Consulting (2006). This review concludes that models based on laboratory derived creosote leaching experiments tend to underestimate PAHs released from creosote-treated wood. Nonetheless, models may aid in estimating the current loss rates of older creosote from San Francisco Bay pilings.

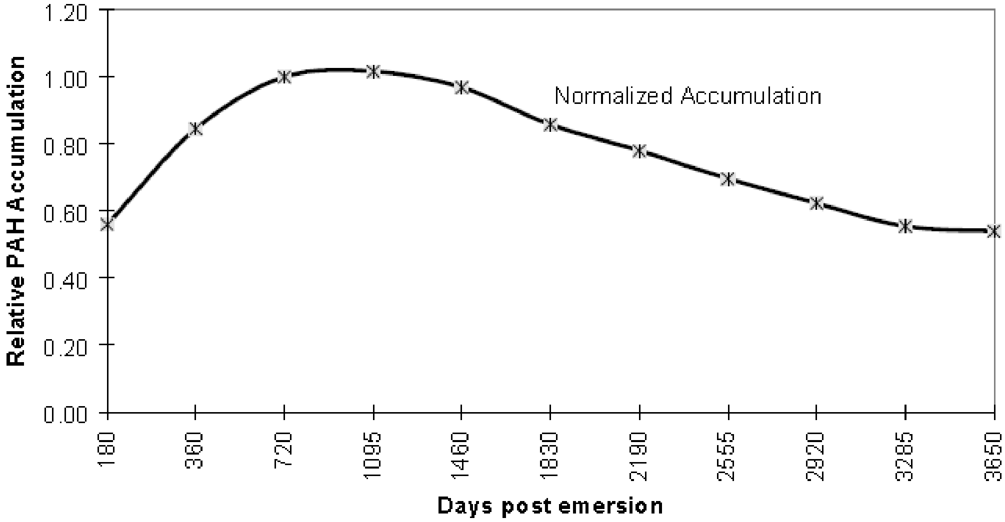


Figure 2. Maximum predicted PAH levels in sediments from creosote-treated pilings (from Brooks 1997).

Summary: Creosote is a substance used to treat wood structures in aquatic environments. This substance is made up of hundreds or thousands of individual chemicals, mostly PAHs. Creosote is slightly soluble in water and therefore certain chemical constituents do migrate from treated structures into aquatic environments. It is difficult to know the quantity of creosote and PAHs that have leached/continue to leach from pilings into the environment from creosote treated-structures or how much remains in older pilings. However, models can assist in estimating current chemical loss rates from creosote-treated structures.

2.1 Physical and Chemical Properties of Individual Creosote Constituents

The chemical formulations of creosote have varied over the production years. However, it is generally reported that PAHs make up to 90% of the creosote mixture by weight (WHO 2004). Other chemicals include phenolics (aromatic hydrocarbons with a hydroxyl group - 2 to 17% by weight) and heterocyclic compounds (10.4 to 18.7% by weight) (WHO 2004). Of these chemical groups, most of the literature on creosote pertains to PAHs.

There are two categories of PAHs: low molecular weight PAHs (compounds <=3 aromatic rings) and high molecular weight PAHs (compounds >= 4 aromatic rings) (Meador et al., 1995). Sixteen of the seventeen most commonly found PAHs in creosote are listed under the US Clean Water Act as priority pollutants and can be mutagenic or teratogenic (Stratus Consulting 2006; Eisler 1987). Some PAHs found in creosote have been identified as B2 probable human carcinogens by the US EPA and all of the B2

PAHs are within the high molecular weight category (Stratus Consulting 2006; Goyette and Brooks, 1998). Benzo[a]pyrene, a HPAH and probable human carcinogen, (Eisler 1987) has concentrations in creosote ranging from < 0.05-0.2 % by weight (WHO 2004). Despite low concentrations in creosote, this chemical has been found to bioaccumulate in bivalves transplanted in San Francisco Bay (3.4% of total PAHs) (Greenfield and Davis, 2005).

Low molecular weight PAHs (in addition to phenolics and heterocyclics) are the most soluble chemical constituents in creosote (WHO 2004). Due to their higher solubility, these contaminants are more likely to leach out of creosote-treated wood into aquatic environments (Bestari et al., 1998a; WHO 2004: Padma et al., 1999). More soluble creosote constituents tend to be found in higher percentages in the environment than exist in the original creosote mixture (Ingram et al., 1982; WHO 2004). The water soluble fraction (WSF) of creosote is generally more biologically available in the short-term and can be acutely toxic (Padma et al., 1999; Eisler 1987). Higher molecular weight PAHs tend to be less soluble and partition to the sediments (Padma et al., 1999; WHO 2004). HPAHs can also persist in the environment for long periods of time due to their adsorbent properties with sediment and particulate organic material.

3.0 Partitioning properties

Physical properties of chemicals, such as partitioning, are a determining factor for how chemicals behave in aquatic environments. PAHs with high solubility (LPAHs, phenols and heterocyclics) tend to partition to water (Figure 3) while PAHs with low solubility properties (HPAHs) tend to partition to sediments (Figure 4) (Bestari et al., 1998a; WHO 2004; Padma et al., 1999; Hylland 2006). Goyette and Brooks (1998) found that sediment PAH levels (particularly HPAHs) increased over the monitoring period (384 days) in a creosote-treated piling in-situ experiment. The authors predicted that sediment PAH levels would increase and reach a maximum at three years post installation.

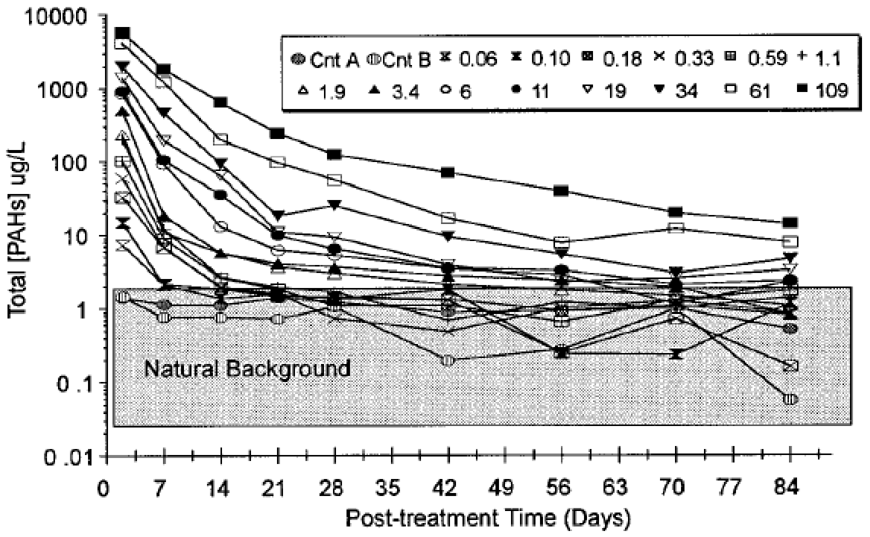


Figure 3. Total water PAH concentrations in µg/L over an 84 day experimental period using liquid creosote applied directly to aquatic microcosms (freshwater with sediment and PVC). Each line represents a distinct creosote microcosm treatment (14 microcosms of various creosote concentrations from 0.06 to 109 mg/L) (From Bestari et al., 1998b).

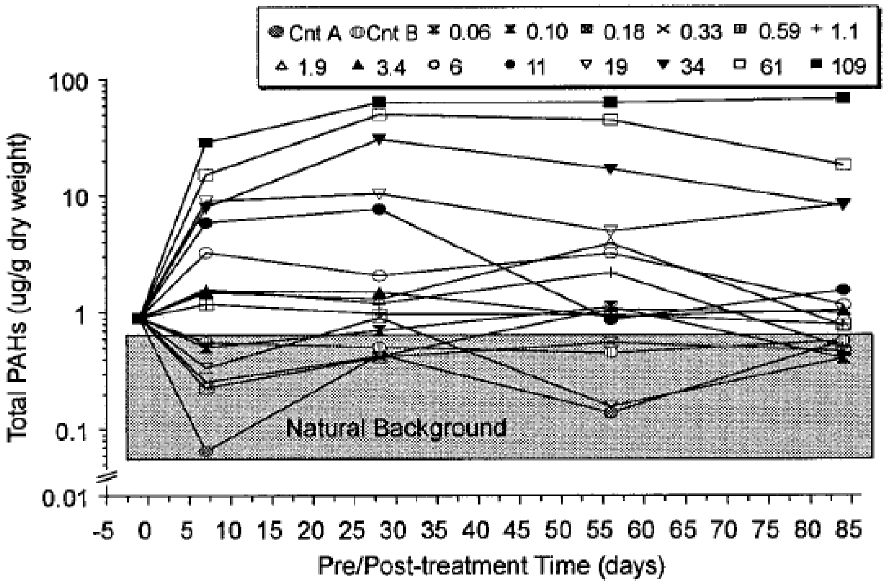


Figure 4. Total sediment PAH concentrations in µg/g over an 84 day experimental period using liquid creosote applied directly to aquatic microcosms (freshwater with sediment and PVC). Each line represents a distinct creosote microcosm treatment (14 microcosms of various creosote concentrations from 0.06 to 109 mg/L) (From Bestari et al., 1998b).

Physical properties also dictate duration of contaminant persistence in the environment. Lower weight PAHs are generally transformed more quickly in aquatic systems via photo or biological degradation (Bestari et al., 1998a; WHO 2004; Hylland 2006). PAH complexes sorbed on sediment (generally HPAHs) can persist in the environment for decades (WHO 2004; Eisler 1987 Goyette and Brooks, 1998). Creosote compounds that partition to the sediment can be sequestered or resuspended back into the water column (Padma et al. 1999). This is a concern for biological resources, as these complexes can be bioavailable for long periods of time. Lower molecular weight PAHs have shorter half-lives in sediment and water due to volatilization, photolysis, and biological decomposition (Bestari et al. 1998; Goyette and Brooks, 1998; Eisler 1987).

Some chemicals are also more likely to partition into living tissues (Figure 5). HPAHs are more fat soluble than LPAHs and therefore can bioaccumulate (Eisler 1987; Meador et al., 1995). This relationship is defined by the K_{ow} which is the ratio of solubility of the chemical in octanol/water. A chemical with a higher K_{ow}, partitions more readily to fat and tends to be more hydrophobic. Chemicals with higher K_{ow} tend to bioaccumulate in living organisms.

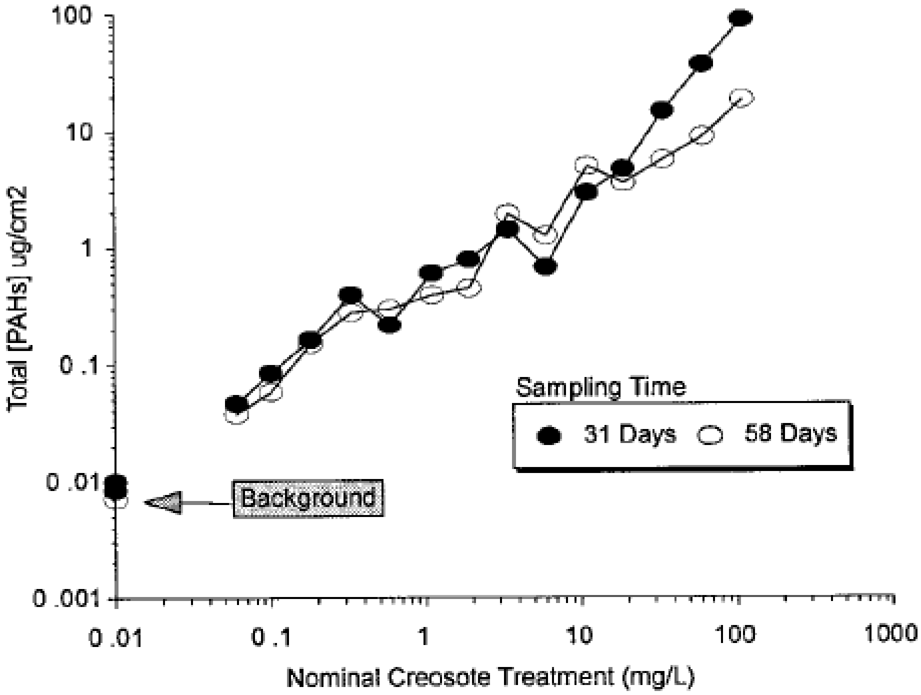


Figure 5. Total PAH concentrations on PVC material in µg/cm^2 over an 84 day experimental period using liquid creosote applied directly to aquatic microcosms (freshwater with sediment and PVC). Lines represent two time scales for the various microcosm treatments (14 microcosms of various creosote concentrations from 0.06 to 109 mg/L) (From Bestari et al., 1998b).

The bioavailability of PAHs in aquatic systems is also controlled by physical and chemical mechanisms. The more soluble constituents of creosote tend to be more bioavailable (Padma et al., 1999). Bioavailability of PAHs is generally controlled by the source of the PAH to the aquatic environment (Hylland 2006; Rust et al., 2004). Rust found that infaunal, deposit feeding, benthic organisms did not take up coal-derived PAHs (combustion source) while these organisms were able to accumulate significant amounts of PAHs derived from soot and rubber sources. Petroleum sourced PAHs (fuel oil, creosote, and crude oil) were found to be more bioavailable than combustion source PAHs. Laboratory extractions of various PAH sources showed that petroleum sourced PAHs, including creosote, were more readily desorbed from particulate material than combustion sourced PAHs (Rust et al., 2004). Kirso (1990) found that pyrene (HPAH) was the dominant PAH in both water and two filter feeding marine algal species while other HPAHs dominated the sediment, suggesting higher uptake rates of the more soluble PAHs.

Biota that live in benthic sediments or the water column are potentially at risk for exposure to PAHs and other creosote constituents that leach out of treated structures. Invertebrates in the water column, take up PAHs by diffusion across their integument and diet (Meador et al., 1999). While benthic organisms take up PAHs by diffusion from the water column/porewater, diet, or diffusion from the sediment across their integument. Benthic and pelagic fish can also be exposed to PAHs and other contaminants. They share similar PAH uptake routes with invertebrates but fish can also take up contaminants via gills (Meador et al., 1999). Various studies in the literature have shown that fish can metabolize PAHs to more soluble forms that can subsequently be excreted. However, PAH metabolites can also be carcinogenic (Gagnéa et al., 1994). Research has also shown that invertebrate metabolic mechanisms are more variable and that invertebrates are, generally, less able to metabolize PAHs (Meader et al. 1999).

Summary: Creosote is made up of hundreds to thousands of chemicals with PAHs accounting for 90% of the mixture. Many of the PAHs identified in creosote are considered priority pollutants by the EPA. The behavior of a chemical in aquatic environments is dependent on physical and chemical properties. Creosote and its constituents are soluble in aquatic environments to varying degrees. LPAHs and other low molecular weight constituents of creosote are more water soluble, have higher rates of volatilization and degradation, are lost from aquatic systems more quickly, and can be acutely toxic. High molecular weight PAHs have lower solubilities and tend to partition into the sediments of aquatic systems. HPAHs sorbed to sediment or other particulate material can persist in the environment for decades. PAH bioavailability is controlled by chemical and physical properties in addition to the PAH source. Pelagic and benthic organisms are at risk for exposure and contaminant uptake in PAH contaminated environments.

4.0 PAHs in San Francisco Bay

PAHs are ubiquitous contaminants that are generally associated with urban environments (Meador et al. 1995; Mix and Schaffer, 1983). Portions of San Francisco Bay including Castro Cove (Richmond), Central Bay, Islais Cove (San Francisco Waterfront), and Oakland Inner Harbor are on the 303(d) list for impaired water bodies due to PAH contamination of the sediments. The sources of PAHs to aquatic systems, including San Francisco Bay, include petroleum spillage, vehicle emissions, biomass burning, thermal combustion (heating oil and coal burning), creosote, and biosynthesis while pathways include atmospheric deposition, wastewater and stormwater runoff (Oros and Ross, 2004: Eisler 1987). Current maximum loading estimates of new PAHs to the Bay are 10,700 kg/year (Table 1) while in-Bay sediment PAH mass is estimated at 120,000 kg (Oros et al., 2007; Greenfield and Davis, 2005).

Source	Minimum	Maximum	Percent maximum	Reference
Stormwater runoff	130	5500	51	Gunther et al. 1991
Tributary inflow		3000	28	Gunther et al. 1991
Effluent discharge	200	1100	10	Davis et al. 2000
Atmospheric deposition		890	8	Tsai et al. 2002
Dredged material disposal		210	2	Davis et al. 2000
TOTAL	330	10700	100	

Table 1. Estimated loads (kg/yr) of PAHs to San Francisco Bay (from Greenfield and Davis 2005)

San Francisco Bay is a highly urbanized estuary with an urban signal of PAHs. Total PAHs in sediments (corrected for TOC) were significantly lower in the Delta area than in the more urbanized portions of San Francisco Bay (Oros and Ross, 2004). Central Bay and South Bay (more urbanized) had the highest total PAH concentrations in sediments (Figure 6). Previous analysis of PAH isomers from Bay sediments suggests that combustion (gasoline, crude oil, coal, and biomass) is the major source of PAHs to the Bay (Oros and Ross, 2004). There are other possible minor sources as well including creosote and used engine oil. However, these minor sources account for only about 1 to 2% of total PAHs in Bay sediments. Based on Bay PAH sediment mass estimates (120,000 kg), creosote has contributed approximately 2400 kg of PAHs to Bay sediments.

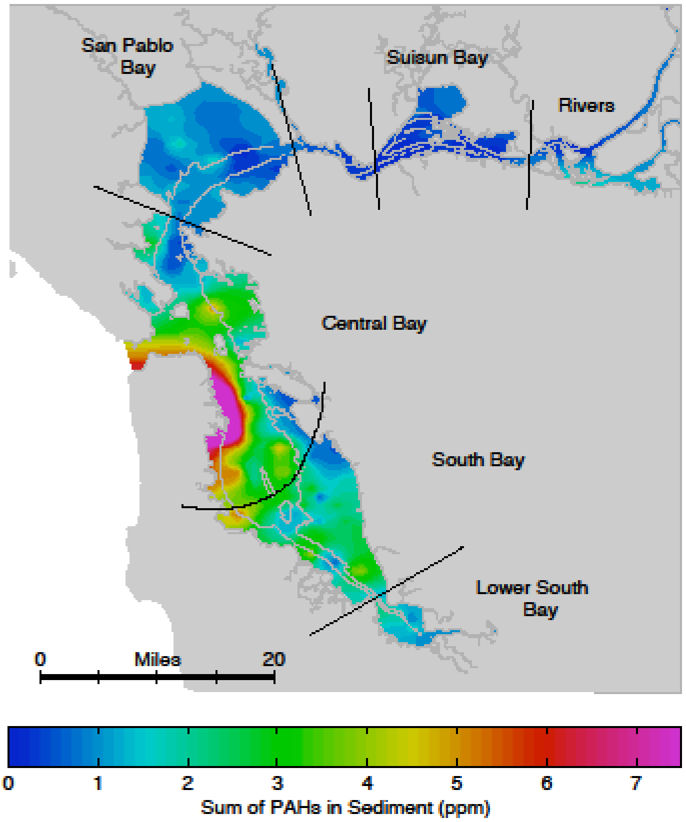


Figure 6. Sediment total PAH concentrations ppm dry weight for random stratified samples in San Francisco Bay 2002-2008. Maximum concentration over the monitoring period was 19 ppm dry weight. Note lower concentrations in Suisun and San Pablo Bays and higher concentrations in Central and South Bays. (Reproduced from the Pulse of the Estuary).

Ambient samples of San Francisco Bay PAH sediments are similar to levels in other urbanized estuaries such as Puget Sound, Washington. Average San Francisco Bay sediment PAH concentrations, over the period 2002 through 2008, range from 0.4 ppm dry weight (Suisun Bay) to 3.2 ppm dry weight (Central Bay) (SFEI data) while average PAH concentrations in Puget Sound ranged from 0.04 – 7 ppm (Partridge et al., 2005). Maximum concentrations, over this time period, were measured in Central Bay at 19 ppm dry weight while maximum PAH levels in Puget Sound Washington have been measured at 14 ppm (Partridge et al., 2005). San Francisco Bay sediment PAH concentrations are much lower than sediments found at creosote-contaminated sites, such as the Elizabeth River, in other parts of the country (Vogelbein et al., 1990).

Creosote has been identified as a source of PAHs to sediments along the San Francisco waterfront. Small wood fragments, that were most likely creosote-treated wood chips from pilings and wharves, were found in the sediments in the vicinity of the San Francisco Waterfront (Anchor Environmental 2007). Laboratory analysis of these sediments (mostly sand) concluded that the majority of PAHs were derived from ‘moderately weathered’ coal tar creosote. The PAHs were dominated by 3-6 ring structures. However, PAHs were chemically extracted from these wood particles and therefore the bioavailability of PAHs sorbed to wood, in the environment, is probably lower than these results suggest. It is unknown how much of the creosote sourced PAHs in the Bay are tied up in wood particles or other materials that render the PAHs less biologically available.

Bay biota have been shown to take up and accumulate PAHs. PAHs in bivalve mussels have been monitored by the Regional Monitoring Program, the NOAA Mussel Watch Program, and the California State Mussel Watch Program (reviewed in Oros et al., 2007). All of the common PAHs have been found in bivalves transplanted in San Francisco Bay (Greenfield and Davis, 2005). The most dominant PAHs were pyrene (19.6%), fluorenthene (16.4%), benzo[e]pyrene (7.0%), and benzo[b]fluoranthene) (6.5%). All of these PAHs are in the high molecular weight category. Oros and Ross (2005) reported concentrations of total PAHs in bivalves ranging from 21 to 1093 ppb dry weight, with the highest concentrations measured in a sample from the Petaluma River. They detected no significant difference among total PAH concentrations in the South Bay, Central Bay, and North Bay. High molecular weight PAHs were found in higher proportions (compared with LPAHs) in laboratory bioaccumulation tests with San Francisco Bay Waterfront sediments (test organisms were polychaetes and clams). The authors suggest that HPAHs are more lipophilic and therefore tend to bioaccumulate in tissues more readily.

Summary: PAHs are urban contaminants with multiple sources. Sources of PAHs to aquatic systems include petroleum spillage, vehicle emissions, biomass burning, thermal combustion (heating oil and coal burning), creosote, and biosynthesis while pathways include atmospheric deposition, wastewater, and stormwater runoff. Current loading estimates of new PAHs to the Bay are 10,700 kg/year with 98% being new PAHs. Sediment PAH levels were statistically higher in the Central and South Bays due to the more urban landscapes in these areas. San Francisco Bay sediment PAH levels are generally lower than creosote contaminated sites such as the Elizabeth River and similar to other West Coast urbanized estuaries such as Puget Sound. Creosote was identified as the source of PAHs along the San Francisco Waterfront. However, PAHs were bound to wood particles making them not biologically available. PAHs have been found to accumulate in bivalves transplanted in San Francisco Bay.

5.0 Environmental Exposure

Creosote is a registered pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The United States Environmental Protection Agency (EPA) has identified the following concerns of risks to biota from PAHs (derived from creosote) in aquatic environments (EPA 2008a):

- The level of concern is exceeded for acute risk to listed (endangered and threatened) fish and invertebrates exposed to PAHs in the water column.
- The level of concern is exceeded for acute risk to other (not listed) invertebrates exposed to PAHs in the water column.

- Available evidence suggests that chronic risk is possible to organisms inhabiting the water column.
- Laboratory and field investigation found a major detrimental impact on hatching and development of fish (herring) eggs attached to aquatic pilings, even pilings that were 40 years old.
- Impacts of creosote-treated aquatic pilings are likely to vary locally, depending on abiotic and biotic factors such as current speed, amount of structure per unit area, air and water temperature, salinity, and the aquatic species occurring in the immediate area of the structures; thus, a site evaluation is essential prior to installation of new structures.

After reviewing available risk assessments and scientific literature, the EPA recently renewed commercial registration of creosote under their re-registration process (EPA 2008b).

There is much research in the literature looking at creosote and PAH exposure and possible biota effects at various levels of aquatic food webs. This section will review environmental exposure in both laboratory and field experiments and extrapolate, where possible, to San Francisco Bay conditions.

5.1 PAH Experiments with Invertebrates

Bioaccumulation

Invertebrates have been shown to take up PAHs from creosote-treated structures.

- The filter feeding mussel *Mytilus edulis* was found to have PAHs derived from creosote-treated wood (reviewed in Dunn and Stitch, 1976).
- Lab experiments placing oligochaetes in creosote contaminated sediments show that the worms accumulated the same PAHs that were found in microcosm sediments suggesting a mechanism for biological uptake of the PAHs through the sediments (Hyotylainen and Oikar, 1998).
- PAH levels in transplanted mussels spiked after 14 days of exposure to both weathered piling complexes (aged 5 to 8 years) and BMP piling complexes (0.5 m downstream from pilings) (Goyette and Brookes, 1998).
- Sydney rock oysters and Pacific oysters exposed to creosote contaminated sediments accumulated PAHs in the same proportions that were found in the sediments suggesting uptake through the sediments (Smith 2006).
- Wild oysters removed from creosote-treated piles also accumulated PAHs but at much lower concentrations (Smith 2006).

These studies provide evidence of direct (sediment/piles) and indirect (filter feeding) PAH uptake from creosote-treated structures or creosote contaminated sediments. PAH uptake and accumulation in invertebrates provides a mechanism for PAH transfer to higher levels of the aquatic and benthic food webs.

Potential Impacts

Invertebrates live in both pelagic (filter feeders) and benthic (deposit and filter feeders) environments in San Francisco Bay. As noted earlier, high molecular weight PAHs generally partition to the sediments and can persist there for long periods of time. Lower molecular weight PAHs are generally more water soluble and can therefore be biologically available to filter feeders. Through its National Status and Trends Program, NOAA has developed sediment quality guidelines to provide some insights into the potential toxicity of sediments (Long et al. 1995). The "effects range-low" (ERL) is the concentration of a contaminant below which toxic effects rarely occur; the "effects range-median" is the concentration above which effects are frequent. Table 2 shows the ERL and ERM for PAHs. There were no San Francisco Bay sediment PAH levels above the ERM while 16 out of 283 sediment samples (6%) were above the ERL over the period 2002-2008 (Central Bay, South Bay, San Joaquin River) (Table 2 and Figure 7). This suggests that sediment PAH levels are in the effects range for occasional effects to benthic invertebrates.

	Effects Lower Range	**Effects Higher Range**	**Percent Occurrence**
TPAH			
No Effects	0	4021	94%
ERL	4022	44791	6%
ERM	44792		0%

Table 2. Total PAH (in ppb) effects range marine sediment quality guidelines for benthic invertebrates and percent occurrence in San Francisco Bay from 2002-2008 (from Long et al., 1995).

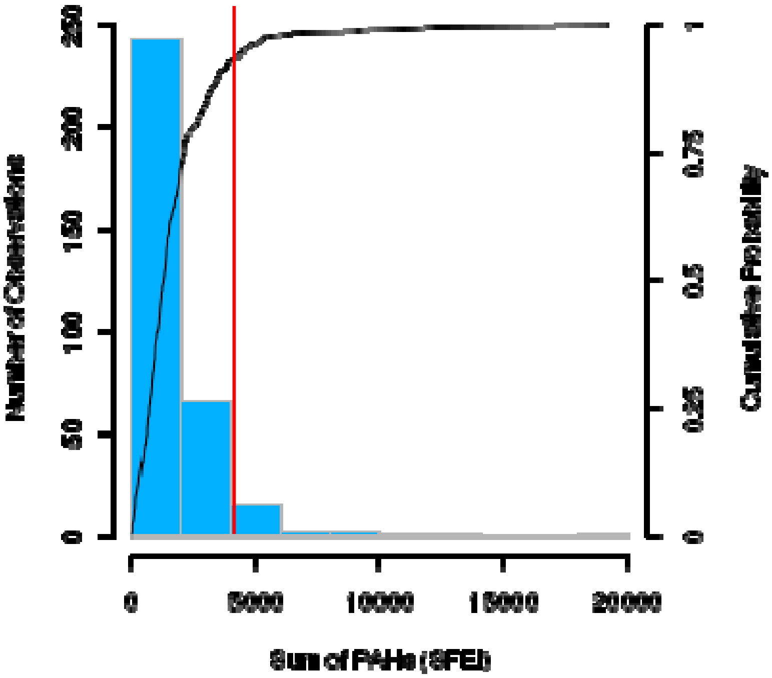


Figure 7. Number of observations (bars) and cumulative probability (curved line) of total PAHs in San Francisco Bay sediments (ppb) 2002- 2008. Red line indicates the Total PAH ERL. Six percent (6%) of San Francisco Bay sediment samples were above the ERL and there was no exceedance of the ERM.

Some PAHs, particularly the HPAHs that tend to accumulate in sediments, are teratogenic and carcinogenic. Therefore there is concern for biota effects due to aquatic exposure to PAHs. Organism effects can be either lethal or sublethal. Sublethal effects include impacts to growth and reproduction.

- Tunicates, tube-like filter feeding invertebrates that often colonize structures in marinas, were found to have sub lethal immunological effects after exposure to the soluble portion of creosote at PAH concentrations of 1 mg per liter (Raftos and Hutchinson, 1997). The authors suggested that these effects could reduce immunological responses in tunicates living on or near PAH contaminated areas.
- Mussel growth was significantly reduced in locations 0.5 meters downstream from BMP creosote-treated piling complex at 185 days post pile installation (Goyette and Brooks, 1998). By the end of the study period (384 days) PAH levels in mussels were below baseline levels (Goyette and Brooks, 1998).
- Mysids exposed to the water soluble fraction (low molecular PAH dominated) of creosote contaminated sediments showed sublethal effects including decreased weight gain and decreased proportion of gravid females (Padma et al., 1999).
- Oysters (*Crassostrea virginica*) exposed to the water soluble fraction of creosote contaminated sediments at varying concentrations had increased infection by a marine parasite (Chu et al., 1996).

Lethal effects from contaminants are generally measured as mortality of laboratory test organisms.

- Zooplankton abundance decreased in mesocosm studies with creosote impregnated piles with lowest abundance measured at week three of an 83 day study (Sibley et al., 2004). A no observed effects level (NOEL) was estimated at 11 ug/L TPAH. The authors suggested that zooplankton toxicity was most likely acute and immediately following pile installation.
- Low amphipod toxicity (from creosote contaminated sediment) was seen in sediments collected up to 2 meters from a piling complex (six piling complex) (Goyette and Brooks, 1998).
- There was 100% mortality to the amphipod *Rhepoxynius abronius* exposed to creosote contaminated sediments (Eagle Harbor, Washington) (Swartz et al., 1998). The amphipod sediment toxicity established a 4-day LC50 (PAH level where 50% of test organisms died) of 666 ppm wet weight TPAH.
- There were many laboratory tests with creosote contaminated sediments that caused test organism mortality (Sasson-Brickson & Burton, 1991; Pastorok et al., 1994; reviewed in WHO 2004).

Locally, laboratory toxicity tests performed with San Francisco sediments and water have shown some level of effects.

- Toxicity tests on water and sediments from Pier 35 in San Francisco (Tier III requirements for testing dredged sediments) showed no acute toxicity to aquatic test organisms, some acute toxicity to benthic organisms (3 out of 35 tests), and were generally below published PAH effects thresholds for bioaccumulation in test organisms (polychaete and clam) (Anchor Environmental 2007). This is an important finding since the study did find patchy distribution of creosote-treated wood chips in the collected sediments. However, the authors concluded that the creosote contaminants were probably not biologically available since the creosote was bound to wood chips.
- Increasing sediment PAH levels were found to be inversely correlated with % amphipod survival at Castro Cove (LPAH and HPAH), San Bruno Shoal (LPAH), and Alameda (LPAH and HPAH) suggesting that PAHs could be a source of the toxicity (Thompson et al., 1999).
- Amphipod toxicity, aggregated San Francisco Bay data, showed a highly statistical, positive relationship between total PAHs and amphipod mortality (Ross and Oros, 2006). Toxicity was seen at total PAH levels as low as 280 ppb dry weight.

These findings provide evidence that effects were seen in test organisms at environmentally relevant concentrations for San Francisco Bay suggesting PAHs are a potential factor in local toxicity to benthic invertebrates.

5.2 PAH Experiments with Fish

PAHs have also been linked, in laboratory and field experiments, to lethal and sublethal effects in fish. Effects thresholds have been established for benthic feeding fish based on sediment PAH levels. The most commonly used effects threshold was developed by the National Marine Fisheries Service (NMFS) based on experiments with English sole in Puget Sound (Johnson et al., 2002). The authors concluded that the incidence of fish effects including liver lesions, reproductive abnormalities, and DNA damage significantly increases at sediment PAH levels greater than 1000 ppb dry weight. Although effects were seen at sediment PAH levels less than 1000 ppb, the incidence of effects were lower. Over the period 2002-2008, there were 162 San Francisco Bay sediment samples above the 1000 ppb dw PAH threshold. This number accounted for 57% of all samples taken over this time period. Based on the data, sediment PAH levels are at and above the threshold for potential benthic fish effects.

Potential Impacts

PAHs have been linked to a host of sublethal effects.

- Some PAHs are known to induce CYP1A induction (as reviewed in Meyer et al., 2002). CYP1A is a protein that is synthesized in response to certain contaminants, including PAHs, which attaches to genetic receptors. CYP1A also plays a part in Phase 1 metabolism of foreign chemicals (Meyer et al., 2002). CYP1A is both induced by PAHs and part of the metabolic process for reducing PAH toxicity. This protein can be used as a biomarker indicating exposure to PAHs and other contaminants.
- Killifish reared in creosote contaminated sediments on the Elizabeth River had lower incidence of CYP1A induction (Meyer et al., 2002). Further research on refractory CYP1A induction suggests that killifish reared at this site have developed some resistance to PAH toxicity (Meyer et al., 2002).
- Spot (*Leiostomus xanthurus*) were exposed to creosote contaminated sediments containing TPAH water concentrations ranging from 15 µg/L – 320 µg/L. Effects including fin erosion and epidermal lesions. Mortality was seen at TPAH levels of 76, 150, and 320 µg/L (Sved et al., 1992). In contrast, maximum TPAH water column concentrations measured in San Francisco Bay were 0.85 µg/L.
- Sved (1997) identified the high molecular weight PAH fraction (derived from creosote contaminated sediments and similar to the composition of weathered creosote) to be the toxic agent to fish. Spot had fin erosion and were hemorrhaging after a 7 day exposure to contaminated sediments. Mortality occurred in spot on day 8 of the experiment.

Embryos and larvae are often more sensitive to pollutants than later life stages (Moore and Dwyer 1974, Weis and Weis 1989). Therefore it is important to look at all life stages when determining effects.

- Killifish embryos (spawned from reference site adults) exposed to Elizabeth River creosote contaminated sediments showed teratogenic affects including pericardial edema, heart elongation, and tail shortening (Wassenburg and Di Gulio, 2004). CYPIA induction also occurred.

- Decreased survival was seen in the F2 generation of fathead minnow adults exposed to 1 µg/L benzo[a]pyrene (White et al., 1999).
- Larval exposure of Japanese medaka to 30-50 µg/L benzo[a]pyrene resulted in neoplasms (Hawkins et al., 1990). Over the period 2002 through 2007, maximum benzo[a]pyrene concentrations in San Francisco Bay (lower South Bay) were 0.02 µg/L.

DNA damage has also been associated with PAHs.

- Atlantic killifish collected from the creosote contaminated Elizabeth River were found to have higher levels of mitochondrial and nuclear DNA damage than fish collected from a reference site (Cho et al. 2009).
- DNA adducts, DNA that is covalently bonded to carcinogenic chemicals and is considered to be the beginning stages of tumor development, were higher in wild perch from a creosote contaminated site in Sweden and Elizabeth River killifish compared to reference site fish of the same species (Ericson et al., 1998; Rose et al., 2000). This effect was reproduced in the laboratory using organic extracts from the contaminated sediments suggesting that the sediments were the source of the effect.
- Incidence of liver carcinoma was significantly higher in killifish from creosote contaminated areas in the Delaware Estuary and the Elizabeth River (Delaware Estuary total PAHs range from 100-13,000 ppm dry weight) (Pinkney and Harshbarger, 1998; Vogelbein et al., 1990). For reference, San Francisco Bay PAH sediment levels are two to four orders of magnitude lower.

Immune function alterations have also been linked to creosote contamination.

- The LOEC (lowest observed effect concentration) from a rainbow trout lab experiment was 611.63 ng/L total PAH (Karrow et al., 1998). Average total PAH concentrations in the water column of San Francisco Bay (1993-2007) ranged from 9.78 ng/L to 181 ng/L. Maximum water column concentrations over the time period were 847 ng/L (Southern Sloughs). Therefore, some of the higher PAH levels in the bay are above the LOEC for immunological effects.
- The dissolved fraction of PAHs derived from Alaskan North Slope crude oil were linked to edema, hemorrhaging, and cardiac abnormalities in zebra fish embryos (Carls et al., 2008).

Potential Impacts to Pacific Herring in San Francisco Bay

Pacific herring is one of the last commercial fisheries in San Francisco Bay. CDFG herring spawn surveys have shown a decline in the herring spawn biomass since the 2005-2006 season (CDFG 2009). For the 2008-2009 spawn season, CDFG estimated herring spawn biomass to be less than 10% of the historical average. In response to this decline, the commercial herring fishery has been closed for the 2009-2010 winter spawn period. Bay herring spawn on eelgrass, seaweed, rock, creosote-treated and concrete pier pilings, retaining walls, rip-rap, and boat bottoms (Spratt 1981, Watters *et al.* 2004). Pacific herring in San Francisco Bay, particularly along the San Francisco waterfront, spawn on pilings, so effects of exposure to compounds in creosote is of special concern.

Creosote has been shown to effect Pacific herring eggs in lab experiments. Pacific herring in San Francisco Bay, particularly along the San Francisco waterfront, spawn on a variety of structures including vegetation, boat hulls, concrete structures, and creosote-treated pilings/structures. CDFG has concerns over possible effects of creosote contaminants on herring eggs (CDFG 1996). Vines *et al.* (2000) examined the effect of diffusible creosote-derived compounds on herring embryonic development and found reduced hatch success of embryos exposed to creosote-treated wood in the laboratory. Embryos were removed from creosote-treated wood or PVC piping in the field, brought into the laboratory, and exposed to three conditions including creosote-treated wood (embryos hatched on creosote-treated wood), non-chemically treated wood (embryos hatched on creosote-treated wood), and a filtered seawater control (embryos hatched on PVC piping). None of the embryos exposed to creosote-treated wood in the laboratory hatched while 24% in the wood control treatment hatched. All hatched embryos from the wood control experiments died post hatching. Larvae that did hatch in experimental wood control treatments exhibited morphological abnormalities. Effects were dependent on whether the embryos were in direct contact with the creosote-treated wood. The LC_{50} for reduced hatching success was 50,000 ng/liter. Total PAH concentrations in the water column of San Francisco Bay have ranged from 9.78 ng/L to 181 ng/L and maximum concentrations were 847 ng/L, well below this effects threshold.

Under field conditions in San Francisco Bay, Vines *et al.* (2000) found greater hatching success compared to laboratory experiments, presumably because water flow lessened exposure to toxic compounds. In an earlier experiment, herring eggs attached to creosote-treated wood had the lowest hatch success rate (5.4%) compared with other substrate material (range 12.3%-21.2% for other materials including non-treated wood and plastic) (CDFG 1996). Cardiac effects were seen in developing Pacific herring embryos exposed to weathered crude oil (Incardona et al., 2009). The authors link the cardiac effects to tricyclic PAHs derived from the oil. Embryo effects, including cardiac arrhythmia, were also seen in naturally spawned herring eggs from *Cosco Busan* oiled areas in San Francisco Bay (Incardona et al., 2008). Other effects seen in herring embryos from spill areas included reduced hatching success, reduced larval survival, physical abnormalities, and tissue opacity. It is unclear from this study if PAHs, derived from *Cosco Busan* oil, are correlated with these impacts on herring.

Additional research on Pacific herring spawning substrate would be beneficial in determining associated risks in development of herring embryos spawned on creosote-treated wood. It is important to quantify/qualify the extent to which Pacific herring eggs adhere directly to creosote-treated wood or if they adhere to biota (algae, barnacles, mussels) that have colonized these pilings. Further research could provide a more certain assessment of impact to herring egg development and hatching in San Francisco Bay.

Summary: There are many laboratory and field studies that link creosote and PAHs to effects in invertebrates and fish. The effects range marine sediment quality guidelines were established to provide a range of effects incidence for benthic invertebrates due to sediment PAHs. There were no San Francisco Bay sediment PAH levels above the ERM while 16 out of 283 sediment samples (6%) were above the ERL over the period 2002-2007. Locally, laboratory toxicity tests performed with San Francisco sediments and water have shown some level of effects to invertebrates. These findings provide evidence that effects were seen in test organisms at environmentally relevant concentrations for San Francisco Bay suggesting PAHs are a potential factor in local toxicity to benthic invertebrates. NMFS has established a total PAH sediment level of 1000 ppb dry weight as a threshold for potential increased incidence of effects in benthic fish. Many recent San Francisco Bay sediment samples were above this threshold indicating a potential for effects in benthic fish. Locally, reduced hatching success was seen in Pacific herring eggs spawned on creosote-treated wood in laboratory and field experiments. The effects were less pronounced in the field most likely due to increased water flow. More quantitative/qualitative information showing if/how much herring eggs directly adhere to creosote treated structures would be beneficial in determining potential impacts of these structures on San Francisco Bay Pacific herring. San Francisco Bay water and sediment PAH levels are generally below the other effects thresholds reported in the literature though many studies are from sites with extremely high sediment PAH levels due to creosote contamination.

6.0 Other Potential Environmental Risks of Artificial Structures

There are multiple associated risks to the San Francisco Bay environment from creosote-treated structures. Cohen (2008) reviewed the biological impacts from artificial structures in San Francisco Bay. Impacts range from chemical contamination (as reviewed above) to physical impacts such as increased shading and replacement of natural substrate. The subtidal environment, and associated biota, is particularly impacted by these artificial structures. Appendix E of this report discusses artificial substrate in more detail.

There is evidence that artificial structures can be both detrimental and beneficial to subtidal habitats and their inhabitants. A literature review of artificial reefs found possible negative effects on fish including increased fish congregation, increased fishing effort, and increased catch rates which were facilitated by increased access to fish (reviewed in Grossman et al., 1997). It is largely unknown whether artificial structures actually increase fish production or simply concentrate fish in limited habitat environments (Grossman et al., 1997; Barwick at al., 2004). A lake study showed that YOY fish species preferred naturally vegetated nearshore habitats over developed nearshore (Bryan and Scarnecchia, 1992). The total number of fish and species diversity was lowest in habitats under decks, and these habitats were not utilized by young-of-year fish (Able et al., 1998). In contrast, fish abundance and species diversity was high in pile fields and open water habitats. The authors conclude that under deck habitats are probably not suitable for YOY fishes. There is also evidence that platforms (horizontal decks associated with pier pilings) result in poor adult fish habitat in areas directly below these structures (Able et al., 1999; Able et al., 1998). Fish growth of winter flounder and tautog, caged under deck structures, were significantly lower than caged fish in open-water and pile field habitats. Juvenile salmon avoided subtidal areas shaded by overwater structures in the Port of Seattle (Weitkamp 1982).

Eelgrass habitat is another part of the subtidal environment that has been adversely affected by the urbanization of the Bay. The extent of eelgrass beds is limited in San Francisco Bay to about 3,000 acres (Merkel & Associates 2004). Low light levels and shading may be limiting factors on the extent of eelgrass growth in the Bay. Recent research, mostly from the East and Gulf Coasts, has suggested that shading from decks and wharves could be reducing natural light penetration and impacting photosynthetic growth. Seagrass shoot density, biomass, and canopy structure were significantly reduced in sea beds directly under or adjacent to dock structures (Burdick and Short, 1999; Shaefer, 1999). In addition, pier orientation, width, and distance above the water surface negatively affected bed quality and seagrass beds (Shaefer, 1999; Burdick and Short, 1999). Light penetration into the water column was positively and significantly correlated with height of the deck above the water surface. This finding as well as other research suggests that dock design could reduce impacts to submerged aquatic vegetation by increasing light availability to submerged vegetation (Burdick and Short, 1999; Shaefer and Lundin. 1999). Floating docks were found to have a greater impact on reducing eelgrass in habitats below the structures then did piers supported by pilings (Burdick and Short, 1999). Boats were also found to decrease lights availability in the water column and no plants were found beneath these structures (Garrison et al., 2005).

In addition to eelgrass impacts, shading from piers has also been found to reduce growth and biomass of other submerged aquatic plants and to alter biotic assemblages in favor of shade tolerant species (Garrison et al, 2005). Shading also resulted in a decrease in the numbers of macro invertebrates and Centrarchid fish species directly under piers (Garrison et al., 2005). Shading from wharves or other artificial structures can also change the subtidal biotic assemblages on pier pilings (Glasby 1999).

There are also potential risks in removing creosote-treated piles from aquatic systems. A pile removal study in Australia estimated that 0.67 grams of PAHs (mostly LPAHs) were released to the environment during pile removal (Smith 2008). Total PAH levels in the sediment significantly increased post-removal of the piles and persisted up to six months post-removal. The amount of PAHs released during pile removal would probably depend on the age of the pile (e.g. how much creosote remains in the pile) and method for extraction. It would be important to perform a pilot study(s) to determine if more PAHs are released to the environment upon pile extraction than would be released if the structures remained in place.

There is need to explore the cumulative impacts of artificial structures in urbanized aquatic systems. Jennings (1999) and others expressed the importance of defining the appropriate spatial scale with which to measure biological effects due to habitat modification (e.g. piers and other artificial substrate). The site scale may not provide beneficial information on biological diversity and integrity. The landscape scale is the more appropriate scale to look at subtidal impacts due to habitat modification. NOAA is also concerned with the cumulative impacts of habitat modification, particularly in permitting private docks and piers (Kelty and Bliven, 2003). NOAA has called for a science based regulatory process that takes into account potential cumulative environmental impacts from dock and pier development. This process could also be developed for any habitat modification that occurs in aquatic systems thereby providing a landscape scale analysis of benefits and impacts.

Summary: There are both physical and chemical impacts from creosote-treated structures and other artificial substrate. Physical impacts include increased access to fish by congregating fish near artificial structures, replacement of preferred natural habitats, reduced fish growth, changed biotic assemblies of fish and invertebrates, reduced light penetration and subsequent impacts to submerged aquatic vegetation. There are also potential impacts from removing creosote-treated structures. Cumulative impacts of artificial structures in San Francisco Bay should also be considered as well as consideration of landscape scale effects. Additional information is needed as to the status of herring spawn on creosote-treated structures in San Francisco Bay.

7.0 Potential Environmental Benefits

Research has shown that there are multiple environmental risks from creosote-treated structures and other artificial substrate. Since the Bay is heavily urbanized, these artificial structures can also provide habitat for Bay biota. Studies have shown that fish utilize artificial structures to avoid predation and to forage for food (reviewed in Clynick 2008). By providing habitat these structures could potentially be beneficial to some species or particular life stages of species. There is not much in the literature on the benefits of these structures and much of what will be discussed here is anecdotal.

Creosote-treated pilings have been shown to be suitable substrate for various colonizing invertebrates. Creosote-treated pilings were found to host a number of invertebrate species in Fidalgo Bay, Washington including sea anemones, sea squirts, sea stars and barnacles (Samish Indian Nation). In San Francisco Bay, algae, invertebrates and one fish species were found to colonize pier piling dolphins, navigational structures, and bridge pilings (Cohen and Chapman, 2005). Many of the taxa identified were exotic species.

Many species of birds have been noted to use artificial structures in the Bay for nesting or roosting. Eighteen bird species (2007) and 25 bird species (2008) were identified roosting on San Francisco Waterfront pier pilings/wharves during the 2007 and 2008 nesting season including double crested cormorants, great blue herons, snowy egrets, Caspian terns, and western grebes (Weeden 2007; Weeden and Lynes 2009). Caspian terns and Western gulls were observed using the structures for nesting (Weeden 2007; Weeden and Lynes 2009). Some species observed using structures along the San Francisco Waterfront, such as black oyster catchers, have been identified as species of concern (although they are not state or federally listed species). Western gulls and double-crested cormorants were the most abundant species observed using artificial structures along the San Francisco Waterfront (Weeden and Lynes 2009). On the Hudson River estuary, least terns have also been observed using pier decks as nesting sites (http://library.fws.gov/pubs5/web_link/text/urb_core.htm).

Artificial structures have also been identified as habitat for various fish life stages. Piers and other artificial structures have always been used by anglers as fish are known to congregate around these structures. Pier structures in a Wisconsin lake study were found to provide habitat for juvenile bluegills. Smallmouth bass were found to have a slight preference for pier/developed habitat rather than open water habitat (Garrison et al, 2005; Bryan and Scarnecchia, 1992). Habitat modification (addition of plastic fish habitat modules and addition of woody debris) of reservoir piers found that fish utilized the modified piers four to five times more than non-modified piers (Barwick et al., 2004). Fish had the highest preference for the woody debris modules. The authors suggest that complex habitats (e.g. woody debris) provides shelter and predator avoidance for young fish while older fish use these habitats to forage for invertebrates. Rip-rap habitat was found to have greater fish species diversity than other modified habitats (Jennings et al., 1999). Rip-rap, when looked at on the site scale, is considered a more complex habitat than other artificial habitats due to crevices providing increased surface area for cover and habitat. Complex habitats have been shown to positively correlate with species diversity (reviewed in Jennings et al., 1999).

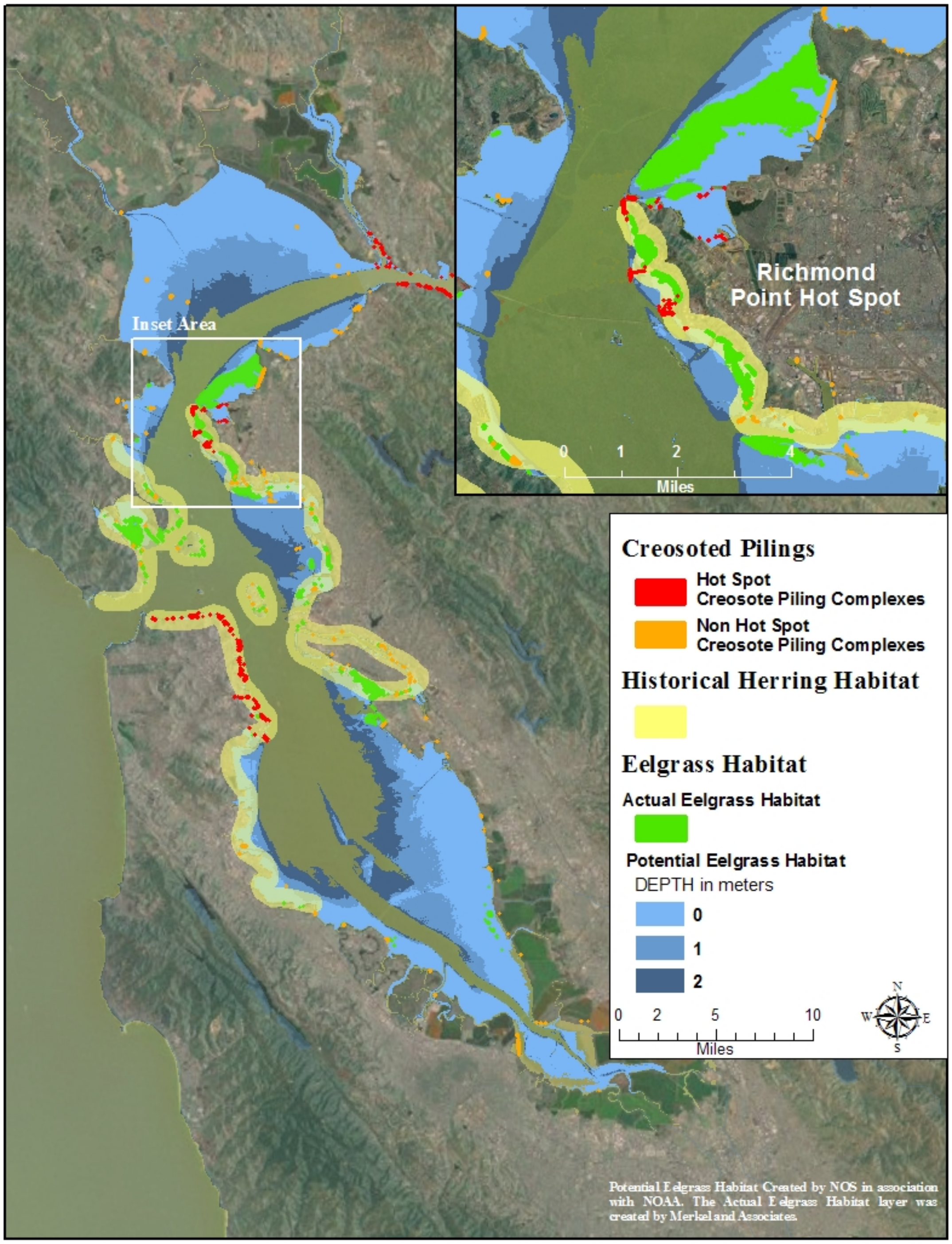
The Hudson River Park Estuarine Sanctuary in New York City has an ongoing effort to retain pier pilings for habitat (http://www..org/estuary/river_piles.asp). Juvenile striped bass and oyster toadfish have been shown to use the piling fields as shelter and many colonizing species such as barnacles and sea grapes have also been found associated with these pilings. Benthic prey densities were higher in sediments under pier decks than in pile field or open water habitats (Metzger et al., 2001).

As noted in Appendix A, the mapping task was completed using aerial imagery and on the ground fieldwork. The fieldwork component included a survey of the environment proximate to pilings/complexes including presence of biota, presence of creosote smell and/or sheen, and whether the piling was colonized. Since the fieldwork was not part of a randomized, statistically designed, sampling plan, the data are anecdotal only. However the data do show that creosote pilings and associated structures provide some benefit for Bay biota. Bird species associated with creosote pier pilings included cormorants, herons, pelicans, and other unidentified bird species. See lions and harbor seals were also observed on/near creosote-treated structures. Piling colonization was also observed during the field effort. Colonized pilings were most frequently observed in the Central Bay (San Francisco, Marin Shoreline, Peninsula shoreline). However species were not identified. Rainbow sheen was identified at one location along the San Francisco shoreline. This location was also observed to have a colonized piling. No creosote smell was observed at any of the locations.

Summary: San Francisco Bay is a hard substrate limited environment. Therefore creosote-treated wood and other artificial structures provide benefit to some Bay species. Fish, algal, and invertebrate species were found to colonize many artificial structures in the Bay. Pacific herring use artificial structures such as boat hulls and creosote-treated structures for spawning. Many local bird species including double crested cormorants and Caspian terns use artificial structures for nesting and roosting. Harbor seals and sea lions have also been known to use artificial structures as haul out sites. Artificial structures are beneficial to some species in San Francisco Bay. The impacts of removing these structures is currently unknown but should be investigated before large-scale structure removal.

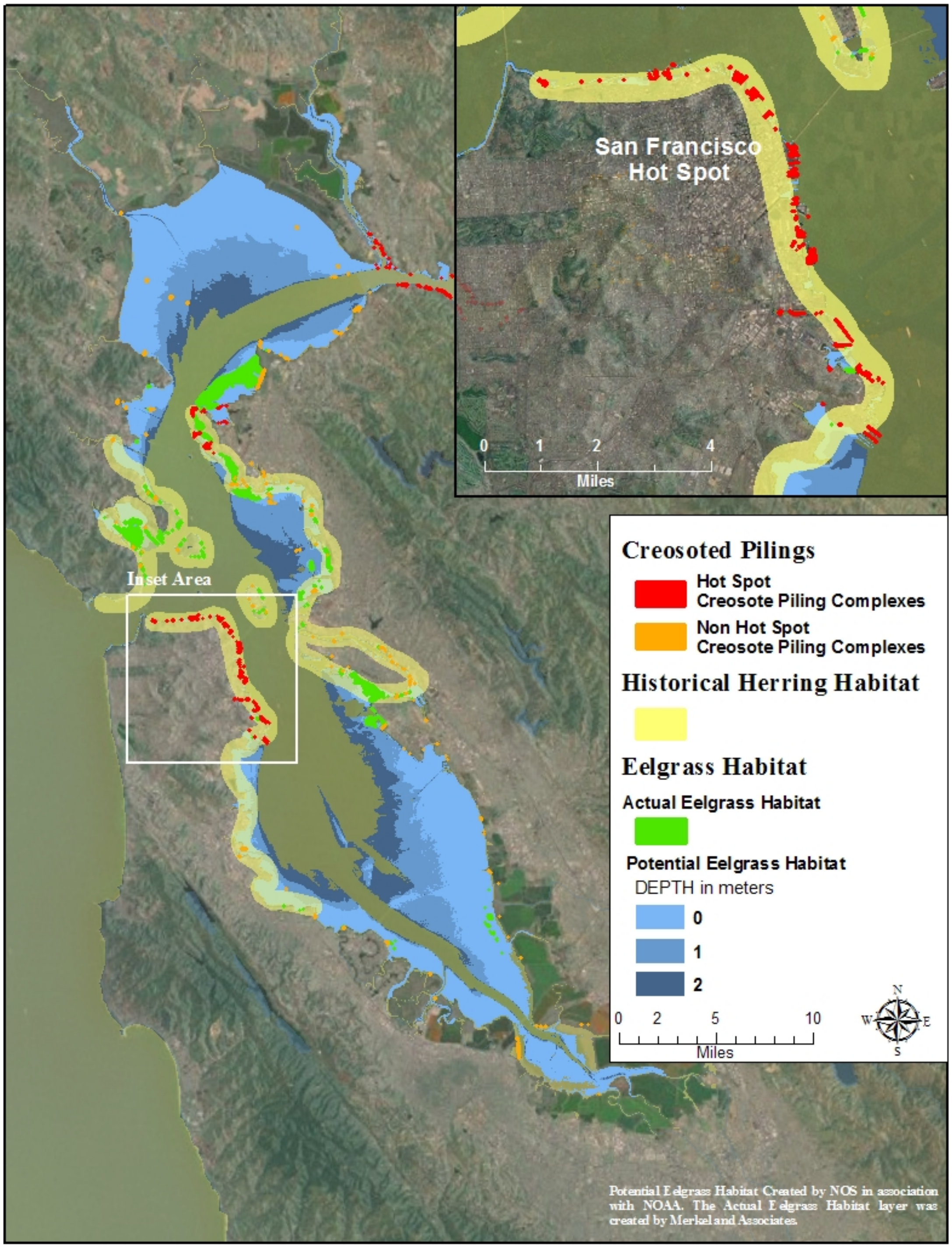
8.0 Conclusions and Next Steps

There are an estimated 50,000 to 70,000 pilings with associated structures in San Francisco Bay. There are concerns that these and other artificial structures are negatively impacting biota as well as the subtidal and intertidal habitats of the Bay. This project has estimated that there are approximately 30,000 derelict creosote-treated pilings/complexes in San Francisco Bay. Some consider derelict pilings trash that should be cleaned up and disposed of. Many studies in the literature show linkages between creosote/PAHs and effects on biota. Effects range from immune suppression to mortality. Contaminant levels are higher with increasing density of pilings. Piling associated deck structures have also been linked to reduced light penetration and impacts to submerged aquatic vegetation. These impacts are of particular concern in sensitive habitats such as herring spawning areas and current/potential eelgrass habitat (Figures 8 and 9).



Potential Eelgrass Habitat Created by NOS in association with NOAA. The Actual Eelgrass Habitat layer was created by Merkel and Associates.

Figure 8. Map of San Francisco Bay, with inset of Point Richmond, showing historic range of Pacific herring spawning habitat (yellow), current eelgrass habitat (green), potential eelgrass habitat (blue) and creosote treated piling complexes (red and orange). Point Richmond is an area of high density creosote-treated complexes overlapping herring and eelgrass habitats.



Potential Eelgrass Habitat Created by NOS in association with NOAA. The Actual Eelgrass Habitat layer was created by Merkel and Associates.

Figure 9. Map of San Francisco Bay, with inset of San Francisco Waterfront, showing historic range of Pacific herring spawning habitat (yellow), current eelgrass habitat (green), potential eelgrass habitat (blue) and creosote treated piling complexes (red and orange). San Francisco Waterfront is an area of high density creosote-treated complexes overlapping herring and eelgrass habitats.

This assessment has provided information on the potential impacts and benefits from creosote-treated, and to a lesser extent, other artificial structures. There are potential concerns for effects to biota from creosote and associated contaminants. However, the contribution of contaminants from creosote-treated structures to the Bay is largely unknown. Additional information should be gathered to increase the certainty as to the benefits of removing creosote-treated structures. This information could provide a weight of evidence as to the cost/benefit of removing these structures. Based on the existing information, it is accurate to state that the subtidal and intertidal habitats of San Francisco Bay have been largely altered with installation of artificial structures. The impacts of this alteration, in combination with other anthropological stressors, have resulted in the Bay's diminished biological functioning. Areas of biological sensitivity or biological significance such as herring spawning areas and current and potential eelgrass habitat could be appropriate candidates for creosote-treated piling removal. Removal of these structures and restoration to more natural condition could be a factor in enhancing and improving these habitats and the biota that inhabit them.

Below is a summary of potential next steps that can be used by managers in the assessment to retain or remove creosote treated structures from the Bay.

• Quantifying Current Contaminant Release from Creosote Treated-Structures

The San Francisco Bay environment has been impacted by contaminants associated with creosote-treated structures. However, without an accurate estimate of the quantity of PAHs that have leached/are currently leaching from these treated structures, it is difficult to measure the magnitude of this impact. PAHs are ubiquitous urban contaminants with multiple sources. It is currently estimated that fossil fuel/petroleum combustion is the largest source of PAHs to the Bay with creosote accounting for an estimated 1 to 2% of PAH sources. A more comprehensive modeling effort could provide a better estimate of the quantity of PAHs currently leaching from older creosote-treated structures. Another possible pilot study to quantify current contaminant release from creosote-treated structures, would involve installation of Passive Sampling Devices (PSDs). PSDs are used to measure the dissolved portion of contaminants in the water column. Measuring the dissolved portion of these contaminants would provide an estimate of the contaminant portion that is most readily biologically available to pelagic organisms. These devices could be used to estimate current leaching rates of creosote and/or PAHs from creosote-treated structures in the Bay.

• Determination of Pacific Herring Use of Creosote-Treated Structures

Pacific herring use a variety of artificial structures, in San Francisco Bay, including creosote-treated structures, for spawning. The extent to which herring embryos are deposited directly onto pilings is unknown. A field study that quantifies/qualifies embryo location on creosote-treated structures would help in identifying potential impacts to embryo survival and health. This field study could also identify the extent to which herring embryos adhere to biota that have colonized Bay pilings (providing a buffer from potential creosote effects) thus identifying if creosote-treated structures provide any beneficial habitat to Pacific herring.

- Determination of Contaminant Release from Creosote-Treated Structure Removal

There is some evidence that removal of creosote-treated structures may result in releasing previously sequestered contaminants. A pilot study removal project in a non-sensitive habitat could be beneficial in estimating contaminant release from pilings and from re-suspension of contaminated sediments.

The information in this report as well as any future pilot studies will hopefully provide the information managers need to make decisions regarding the cost/benefit of creosote-treated structure removal. It would be most beneficial to focus any piling removal efforts in areas of high derelict piling density and in areas of high biological significance that could be potentially restored to more natural condition. Potential removal of creosote-treated structures in combination with other Subtidal Habitat Goal efforts could restore and enhance some of the Bay's biological functioning.

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HISTORICAL SIGNIFICANCE OF CREOSOTED PILINGS IN SAN FRANCISCO BAY

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Appendix C of
Removal of Creosote-Treated Pilings and Structures
from San Francisco Bay

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Final Report

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This appendix addresses questions about the potential historical value of creosote-treated wood piles in the context of San Francisco Bay Area maritime history, and relative to other potential drivers for preservation or removal (as covered in other report sections). Research was completed as part of a project for the California State Coastal Conservancy which addressed various values and risks associated with creosote-treated piles in the Bay. The first portion of the report, which discusses the historical context of creosoted pilings, was drawn largely from a report completed by researcher Michael Corbett for this project (Corbett 2008).

INTRODUCTION

"Few technological artifacts are as prosaic as the railroad tie," wrote one historian to describe the most widely preserved wood object (Aldrich 2006). Certainly the same sentiment applies to the creosoted wooden pile, used widely for over 100 years in marine structures in the San Francisco Bay. Creosoted wooden piles are common in many places around the Bay, in various states of repair. Many still function as the supports of piers, wharves, and other structures. Others, however, are attached to failing structures or are associated with structures that have deteriorated completely, leaving only scattered piles to mark the site.

Prosaic as they are, creosoted wooden piles have a rich and complex history. To understand their history in the San Francisco Bay and their significance to the regional cultural landscape requires some understanding of the history of the wooden pile, the economic and social history of the Bay, the types of (and invasion histories of) marine borers in the region, the history of the widespread adoption of creosote as an effective wood preservative, and the creosote manufacturing and treatment industries. Creosoted wooden piles are a small part of a big story.

In addition, the cultural resources theory traditionally used to research and evaluate historical properties has only been adapted for maritime structures relatively recently; there are few precedents for applying these criteria to waterfront resources such as piers, wharves, and pilings. An understanding of this legal framework and the history of ideas such as the maritime cultural landscape is essential to the evaluation of historic pilings in the Bay.

This report provides preliminary background on these subjects: first, on the historical context in which creosoted pilings were constructed and used, and then on the cultural resources theory and legal framework that applies to pilings as historical resources. It is a brief introduction to an enormous subject, and is intended only to provide preliminary historical context and cultural resources background for evaluating creosoted wooden piles as cultural resources. Additional research, including production of a more complete historical context statement in consultation with a maritime cultural resource specialist, would be necessary in order to apply this research to individual piling groups around the Bay.

HISTORICAL CONTEXT OF CREOSOTED PILINGS

Addressing basic research questions about wooden pilings and the creosoting process will allow us to better understand the landscape of pilings around the Bay: where we might expect to find creosoted piles, why they were used in certain parts of the Bay but not others, and what kinds of structures they may have supported. Understanding these themes allows us to view creosoted wooden piles in the context of the general maritime history of the Bay, providing essential background for assessing wooden piles as cultural resources.

This section briefly describes the use and construction history of creosoted wooden piles in San Francisco Bay. It is derived largely from research completed for this project on the history of creosoted wooden piles in San Francisco Bay (Corbett 2008). It will provide preliminary background for addressing the complex task of viewing creosoted wooden piles as cultural resources. It may also serve as the foundation for a larger historical context statement for evaluation of piles as cultural resources.

WOODEN PILES

For all that has been written about creosoted wood and wooden pilings by engineers and wood preservation specialists, little attention has been paid to the subject by historians. Much of what has been written is focused on the railroad industry and its huge appetite for cross-ties (Olson 1966, Oaks 1999). However, some excellent treatments of pilings from a historical or cultural perspective do exist (e.g., Neily 1927, Stilgoe 1994, Aldrich 2006).

The use of wooden piles in construction goes back at least 6,000 years, when pile-supported houses were built on lakeshores and in river valleys in Europe (Ulitskii 1995, Timber Piling Council 2004). Ancient Greeks built temples on pile foundations, and Romans used them extensively as the underpinnings of much of the city of Ravenna and for hundreds of bridges (Haldeman 1982). In medieval and Renaissance times, piles were used to build on wet or marshy ground (such as for the cities of Venice and Amsterdam). By the eighteenth century, piles were used in the American colonies for bridges and other structures.

Use of Piles in San Francisco Bay

Wooden pilings supported wharves and piers used by ships in San Francisco beginning with the Gold Rush in 1849 (Delgado 2009). In 1863 the Board of State Harbor Commissioners was established to manage the Port of San Francisco, including the proliferating structures of the city’s waterfront. By this time, pile-supported structures related to local and transcontinental railways were being built around the Bay (Hill and Kofoid 1927). The completion of the railroad spurred waterfront development in the East Bay, which was followed by wharf building in the Carquinez Strait. Since then, wooden piles have been an integral part of many types of structures all over the Bay Area.

Because of its low cost and wide availability, wood was used in almost all marine construction around San Francisco Bay until about 1908. Nearly all wharves and piers around the Bay were built completely out of wood — piles, beams, decks, fenders, and transit sheds. Among the few 19th century exceptions were the stone training walls at the Port of Oakland (begun in 1874), the stone seawall in San Francisco (begun in 1877), and an iron screw pile wharf at Alcatraz (around 1863).

Beginning in 1909, some new piers for the Port of San Francisco were entirely of reinforced concrete construction, including piles. At that time, only a few years after the earthquake of 1906 and in view of persistent problems with marine borers and fire, the progressive view at the Port was that henceforth all piers would be concrete.

It soon became clear, however, that there was no single best way to build a pier. From 1909 to the mid 1920s piers with many structural combinations were built, including wood piles and concrete decks, all concrete piers, and all wood piers. Some piles were all wood, some were wood with concrete jackets, and some were reinforced concrete. One model, preferred both by engineers and cost-watchers, was a reinforced concrete pier on concrete piles with wood aprons on creosoted wood piles. Wood piers or aprons could better absorb the impact of ships without damaging either the ship or the pier and were cheaper to repair than concrete piers. Whether the aprons were wood or concrete, fenders of wood piles were driven along the edges — not to carry any vertical loads, but to absorb impacts.

Distribution of Piles

As this project's mapping efforts indicate (see Appendix A), pile-supported wooden structures were constructed on nearly all parts of the San Francisco Bay shoreline. However, dense collections of structures were most common in a few areas around the Bay, including the Carquinez Strait, San Francisco, and Richmond. These were areas of particularly intense industrial, commercial, or military activity. The densest concentration of wooden pile-supported structures was in San Francisco along the waterfront between the Presidio and Hunter's Point. Secondary concentrations were at every port city on the bay: Oakland, Alameda, Sausalito, Redwood City, Richmond, Alviso, and Berkeley. Others were located along the Carquinez Strait between Rio Vista and San Pablo Bay: at Mare Island, Vallejo, Benicia, Port Costa, Collinsville, Martinez, Bay Point, Pittsburgh, Antioch, and Rio Vista. Fewer pile-supported structures were constructed in the South Bay and San Pablo Bay (see Appendix A, p. 19).

Ownership and Function of Piles

The characteristic pile-supported waterfront structures were wooden wharves and piers built on piles (for clarity and consistency, in this report we define wharves as structures built along the shoreline, and piers as structures that project out from the shoreline). However, piles were also used to support a range of other buildings and structures. Bridge trestles, landings, ferry infrastructure (slips and moles), levees, bulkheads and seawalls, marinas, fender systems, moorings, and navigational aids (dolphins and markers) all used wooden pilings. In addition, pilings were used as structural support for waterfront buildings such as warehouses and transit sheds.

The activities that pile-supported structures supported are as diverse as the types of structures they were used to build. A few of the most significant themes are listed below.

Military

One of the largest builders along the waterfront of the bay has been the military, beginning with the establishment of the Presidio by the Spanish in 1776 and Mare Island by the United States Navy in 1854. The Army, Navy, Marines, Air Force, and Coast Guard have built an unknown number of bases. The Army alone built 32 installations between 1850 and 1958 (Hagwood 1980). These military facilities had seawalls or bulkheads, wharves, piers, dry docks, marine railways, and other structures that utilized wood piles in their construction. Military facilities and structures for the harbor in general were designed by the Army Corps of Engineers.

Commercial/Industrial

Pile-supported structures were built to serve industrial plants and oil refineries scattered around the Bay. The largest and best-known were on the northern shore of Contra Costa County along San Pablo Bay at Pinole, Hercules, Rodeo, Oleum, Selby, and Avon. Wharves, warehouses, transit sheds, and other pile-supported structures were ubiquitous where commercial waterfront activities required storage, processing, and shipping. A number of industries were located on the waterfront, including sugar and flour factories, logging, and extensive Port activities.

Agricultural

Some of the earliest wooden pile structures were small landings built to serve agricultural areas in the shipment of products to markets in San Francisco. These were constructed all over the bay, often a short distance inland from the mouths of navigable sloughs, creeks, and rivers. They have mostly long disappeared.

Transportation and Navigation

Piles were integral parts of many aspects of the Bay’s transportation and navigation infrastructure, including ferry terminal piers and slips, Key Route and railroad piers, auto and railroad bridge trestles, and navigational aids such as dolphins and channel markers. By far the biggest and most sophisticated early use of piles around San Francisco Bay was for the foundation of the Ferry Building in San Francisco. Begun in 1896, the foundation of massive concrete piers was supported by 5,000 wood piles, each 80 feet long.

Recreational

Piles were also used to support recreational structures such as fishing piers, hunting clubs and duck blinds, marinas, and private boat docks. A relatively small group of individuals and organizations has built for private recreational purposes, especially since 1945 (Paterson et al. 1978).

Although wooden piles were used in structures built by many different groups, the majority of piles around the turn of the 20th century were used by only two of them. The

Marine Piling Committee reported in 1923 that 60% of the pilings in the Bay were owned by either the Southern Pacific Railroad or the Board of State Harbor Commissioners (Kemble 1923).

Pile Production

Piles were commonly made of Douglas fir, which was widely recognized as the best material for pile construction (Chellis 1951). Over many decades, experiments were made with different types of trees in the hope that some were naturally resistant to various pests. Redwood, Port Orford cedar, western red cedar, eucalyptus, and black cottonwood were all used in San Francisco Bay at various times, but Douglas fir was almost universally adopted, not necessarily because it was better, but because it was cheaper. While Douglas fir was considered superior to other timbers in "form, strength, available lengths, quantity obtainable, and moderate cost," it was unable to withstand marine borer attacks in many parts of the Bay without treatment (Neily and Kirkbride 1927). It was also not ideal for a high concentration creosote injection (McKeon 1904).

The earliest pilings (through about 1851) were produced from redwood harvested in San Francisco Bay Area. Later pilings were produced from Douglas fir from the Pacific Northwest and British Columbia, including Puget Sound, Vancouver Island, and Burrard Inlet (Delgado pers. comm.).

Shipworms and the Deterioration of Wooden Piles

> It is likely that no type of structure is subjected to such severe and adverse conditions as that serving in seawater. (Neily and Kirkbride 1927)

Wooden piles are subject to damage and destruction from many sources: damage during installation, abrasion from the impact of ships, and destruction by fire. Piles are under constant stresses from loads, currents, and waves. For the portion exposed to both air and water, temperature fluctuations and the action of salt water both weaken the wood.

Over time, individual piles (and often entire piers) were repaired, rebuilt, replaced, and abandoned all over the San Francisco Bay waterfront. The ongoing process of repairing and replacing wooden piles resulted in chaotic piling arrangements in areas with dense concentrations of structures, as "new spiles [regional term for piles] are driven alongside the old, making over the years a haphazard, twisted arrangement" (Stilgoe 1994).

The principal hazard for piles in the San Francisco Bay in the 20th century was attack by marine borers, which infest parts of the pile exposed to sea water. Widespread borer infestations meant that piles needed to be frequently repaired or replaced; one pile driver (known colloquially as a "pile butt") called borers "the pile butt's best friend" because they provided a steady source of employment (Chellis 1951, Green 1993). Borers could cause a structure to fail in only a few years (Neily 1927).

From the beginning of San Francisco's history as a major port, its development was defined and hindered by marine borers. One traveler, upon returning to the city a few years after the first wave of the Gold Rush, observed the damage caused by borers:

> When I landed again in San Francisco in 1857, I was astonished…Some of the wharves had broken down; others were in a fair way to share the same fate, being veritable mantraps…Many of the houses erected on the wharves were unoccupied and tottering on their insecure foundations of piles half demolished by the timber-worm. (Neily 1927)

Three types of marine borers attacked piles in San Francisco Bay: *Limnoria lignorum, Teredo navalis,* and *Bankia setacea. Limnoria* (the "gribble") is a crustacean, while *Teredo* (often called "shipworm") and *Bankia* are both mollusks. Limnoria attacks a pile from the outside, cutting through from the outside in. It first appeared in the San Francisco Bay around 1870 (Neily 1927). Unlike the limnoria, the teredo attacks piles without showing damage to the outside. The teredo first appeared in the Bay around 1914 at Mare Island. Bankia produces damage similar to that of the teredo. Unlike the teredo and limnoria, it is native to at least some parts of the Bay. It was almost universally mistaken for the teredo in the 19th century (Neily 1927).

Salinity was a determining factor in marine borer distribution in the Bay. Bankia, the first marine borer present in the Bay, required high salinity. Thus the biggest concentration of early borers in San Francisco Bay was historically in areas closest to the Golden Gate, including San Francisco. Limnoria was more tolerant to less saline waters: "The limnoria will go where the fresh water and the salt water meet, but not so with the teredo [bankia]" (McKeon 1905). In places with higher freshwater inputs and lower salinity levels, such as San Pablo Bay and the Carquinez Strait, borers were less prevalent or nonexistent until the arrival of the teredo in the 1910s. Unlike bankia or limnoria, the teredo could survive better in more fresh or brackish waters (Cohen 1996). In these places, untreated wooden piles were not susceptible to borer damage, and lasted longer (and were thus used much later) than in the central Bay. Untreated wood piles at Rio Vista may still have been in place in the early 1910s (Purser and Shaver 2008), and many untreated piles from the boom in wharf construction around 1870 along the Carquinez Strait were in good shape until they were attacked by the teredo beginning about 1914 (Neily 1927).

Water temperature may have also influenced borer activity. One observer in the early 20th century noted that shipworms were active in a warm patch of water near Tiburon: "where it is warm the worms are more active than where it is colder. Over there they eat an unprotected pile in a year, while under the Long Wharf untreated piles last from three to five years" (Beal 1905).

Experiments in the Treatment of Wood

> 'As for wood,' concludes the Chronicle, 'you may dope, you may paint the piles as you will, but the teeth of the shipworm will gnaw at them still. Indeed, so unequal has been the success of creosoting wooden piles that a strong suspicion has arisen that instead of poisoning the teredo, creosote is merely an appetizer.' (Unknown 1920)

The Board of State Harbor Commissioners began to explore potential wood treatment processes for San Francisco structures by 1869, including early methods of treatment with creosote (Neily 1927). However, in other areas of the Bay less influenced by early borer attacks (such as the Carquinez Strait and, to a lesser degree, the East Bay), untreated piles were used until much later. One early report referred to the “immunity of the wharves on the eastern side of the Bay…undoubtedly due to the fresh water from the Strait of Carquinez” (Montague 1873, in Neily 1927).

A series of episodes involving the dramatic failure of wooden piles due to marine borer infestations drove the search to find cost-effective, borer-resistant alternatives to untreated wooden piles. In 1863, the year that the Board of State Harbor Commissioners took over the port of San Francisco from the City (in large part in order to clean up the chaotic conditions embodied in the collapsing wharves and piers and the absence of a seawall), major wharves collapsed on Steuart, Vallejo, and Jackson streets. In 1892, the *Cyrus Wakefield* pulled the wharf it was tied to into San Francisco Bay in rough weather. Similar failures elsewhere were also noticed here; in 1875, a railroad bridge collapsed into Biloxi Bay in Mississippi.

These and other failures stimulated research in wood preservation by railroads all over the country, and around San Francisco Bay by the Port of San Francisco, the military, and scientists at the University of California. In 1869, the Board of State Harbor Commissioners decided that it was “of great importance to make some experiments with well-known processes for the preservation of timber used in wharf structures” (Neily 1927). In the 1870s and 1880s many methods were tried, including timber piles with the bark left on, cast iron piles, wooden piles encased in metal, and an array of wood preservatives of different formulas and concentrations. Many of these experiments were costly, and few substantially extended the life of piles. Some creosoting techniques were attempted, but used an insufficient concentration of creosote (around 1 pound per cubic foot). It was recognized at the time that more intensive processes were needed for creosote to be effective:

> It is to be regretted that no thorough attempts have been made to saturate timber with creosote…The only attempts made here in this line were the Robbins, Wood, Von Jensen, and the coal-tar processes; these hardly merit being classed as processes injecting creosote, so flimsy were the attempts. (Manson 1885)

The state of knowledge changed in the 1880s with the publication of a British government report (1884) and an influential report by the American Society of Civil Engineers (1885). These reports stated unequivocally that creosote was the only effective wood preservative for marine structures. In 1888 the more creosote-intensive Bethell process for treating wood under pressure was patented, and began to be used as a method of treatment. However, it would be more than twenty years before creosote was nearly universally accepted and before the treatment process was improved and standardized sufficiently for consistent results. Over time the amount of creosote injected per cubic foot of wood increased, to over ten pounds by 1904 (McKeon 1904).

During the 19th and early 20th century, there was a thriving industry in competitors for creosote. This appears to have been in large part because of the variable character of the manufactured creosote, the careless handing of wood before and after it was treated with creosote, a lack of clarity about the best way to creosote wood and the amount needed for efficacy, and a lack of consistency in treatment, even when the best processes were used. The theoretical understanding of what needed to be done was better than the practice of creosote treatment which occurred in an unregulated market with competing companies making unsubstantiated claims about the value of their products.

In the course of demonstrating the effectiveness of creosote, the Marine Piling Committee (established in 1920) called attention to numerous ineffective and "abandoned processes" for the preservation of wood piles. Among these were the Key West Armor Process, the Perfection Process of H.L. Rood, the Paraffine Paint Process, the Moran Process, the Columbia Paint Process, the Argentine Quebracho Process, built-up piles, float protectors, electrolysis, dynamiting, and various external protections using sheet metal, paints, "paint and batten," and the natural bark of the tree (Neily and Kirkbride 1927). Experiments with concrete piles (or casing around wooden piles as a method of treatment) were also favored by some beginning in 1895, and continued to develop alongside creosote as an alternative treatment, with each falling in and out of favor over time.

CREOSOTE

Coal-tar creosote is a byproduct of the steel industry, the result of a process that starts with production of coal tar from bituminous coal of coke. Creosote is produced from a distillation of coal tar. For many years after its discovery in the 1830s, creosote varied greatly in both its chemical composition and in its application to the treatment of wood (Aldrich 2006). Historically, the largest use of creosote was for the treatment of railroad crossties.

The effort to understand creosote and establish standards began with the establishment of the Committee on Preservation of Timber by the American Society of Civil Engineers in 1880, followed by the organization of the Wood Preservers' Association in 1904. The standards established by this organization in 1904 were modified in 1978 (Webb pers. comm.).

Widespread Use of Creosote

> "The creosote-laden water has painted the piles as if with tar. They are black-coated to high-water mark, and in the vistas under the wharves look like rows of asparagus tips with the colors reversed." (Craft 1897)

Many decades passed from the first use of creosote to treat piles in the Bay in 1869 until the time when it, along with concrete, was accepted as one of the only methods of avoiding attack by marine borers in use.

The railroads had led the way in consumption of creosoted wood with their tremendous appetite for creosoted crossties, and the railroads led the way in research and experimentation in wood preservation. They also built many of the first creosoting plants and, collectively, the largest number of them. By the early 1900s, perception of creosote use for piles began to change as a result of work by the railroads:

> By 1908 or 1910…certain technologies began to pay off on the large railroads which pioneered them, and by 1915 the most promising solutions were sifted out. The most important was wood preserving with creosote. With it were associated new practices in the handling of timber and design of timber structures. (Olson 1966)

The sudden invasion of the teredo in the Carquinez Strait coincided with this growing interest in creosote as a wood preservative, and was a key event in the history of creosote use in the Bay. Teredo were first documented at Mare Island in 1914. By the fall of 1919, severe structural damage was inflicted by teredo on over 50 untreated pile-supported wharves in the North Bay, many of which collapsed. In the most extreme cases, teredos could cause the collapse of an untreated pile in under four months (Neily and Kirkbride 1927).

While it is unclear why the teredo infestation and subsequent crisis began when it did, it seems that a number of factors contributed to its spread, including a rise in salinity levels in the north Bay. Several years of drought preceding the invasion reduced fresh water runoff into the bay. This was aggravated by the rise in rice farming north of the Carquinez Strait, which diverted large amounts of fresh water from the Strait. This rise in salinity “allowed borers to move further into harbors and estuaries” that would have been inhospitable to them previously (Stilgoe 1994).

The invasion prompted the formation of the San Francisco Bay Marine Piling Committee in 1920, in cooperation with the National Research Council and the American Wood-Preservers’ Association. In a series of four reports published between 1921 and 1927, the Committee performed research into the history of piles in the San Francisco Bay and the various techniques available for extending the life of wooden piles. In addition to affirming the value of creosote and pressure treatment, the committee recognized that many of the failures of creosote in the past were due to use of an insufficient amount of creosote and damage to the pile during treatment, shipment and handling, and pile driving.

By 1924, creosote injection was described to be “generally regarded as the best practical protection at present” (Science Service 1924). The widespread use of creosote injection signified a major change in the lifespan of wooden piles. While untreated piles generally lasted around three to five years in infested areas, the Marine Piling Committee estimated the lifespan of well-treated creosoted piles at 15 to 25 years on the San Francisco side of the Bay and 20 to 30 years elsewhere in the Bay (Neily and Kirkbride 1927). In some instances piles could function for longer; creosoted wood piles used in the 1934 construction of the Bay Bridge were in good condition when they were removed thirty years later in 1964 (Baechler and Alpen 1965).

Creosote Manufacturing and Wood Treatment

The production of creosoted wooden piles required two steps: the manufacture of creosote and the treatment of wood. For piles bound for the San Francisco Bay, these steps were often carried out by different companies at different locations.

As a by-product of the steel industry, creosote was generally produced near the centers of steel production. The first creosote in the U.S. was imported from Great Britain; most American creosote was produced in the Midwest. As late as 1904, creosote was being imported to the United States from England, where creosote was said to be superior to the American counterpart (Curtis 1895, McKeon 1904). Creosote was easily transported by ship or rail, either to centers of timber production or to places where it would be used to treat timber.

While the railroads harvested timber close to where it was needed (and therefore built numerous regional creosoting facilities), commercial operations provided most of the smaller demand for marine piles, and were mostly located near the sources of wood. Most of the successful creosoting businesses on the West Coast were located near timber supplies in Washington and Oregon. Creosoted piles would then be transported to San Francisco.

Creosoted wood piles became commercially available for the first time on the Pacific Coast around 1868 with the establishment of two creosoting treatment plants: the Pacific Wood Preserving Company in Oregon and the North American Wood Preserving Company in New York and Missouri (Neily 1927). Both companies sold creosoted wooden piles to the Board of State Harbor Commissioners for construction at the Port of San Francisco. Directories show that these companies survived at least into the mid 1880s.

A number of creosoting plants on the Pacific Coast supplied treated piles to the Bay Area. From 1888 to 1890, the West Coast Wood Preserving Company was located in Los Angeles. The Puget Sound Wood Preserving Company, located in Seattle in 1888, was still selling creosoted piles to the Port of San Francisco in 1912. The Pacific Creosoting Company was listed in Seattle directories at least since 1893; in 1904 the company built a plant on Bainbridge Island, Washington, which grew through a succession of names into one of the largest in the world by the 1930s. The Perfection Pile Preserving Company, managed by H.R. Rood, was listed in Seattle in 1899-1900 before merging with the Pacific Creosoting Company around 1906. In 1920, it became the West Coast Wood Preserving Company, in 1959 the Baxter-Wykoff Company, and in 1964 the Wykoff Company. The plant closed in 1993. From 1897 to 1912, H.R. Rood & Company (a large timber company with operations in at least nine states) provided creosoted piles to the Port of San Francisco. In 1914-1916, creosoted piles were provided to the Port of San Francisco by the J.M. Colman Company of Seattle. In 1916-1918, creosoted piles were provided by the St. Helen’s Creosoting Company in Oregon.

Despite the proliferation of creosoting companies in the Pacific Northwest, few plants existed in the San Francisco Bay Area. (This contributed to borer infestations, since treated piles shipped long distances were more likely to be compromised – and thus infested – than piles treated where they would ultimately be used.) A temporary plant for creosoting piles for the construction of Oakland’s Long Wharf was built in 1889 in San Pedro near Los Angeles; after it burned, a permanent company plant was built in Oakland near the foot of Peralta Street in 1890 (*San Francisco Chronicle* 1895). This plant, operated by the Southern Pacific Railroad, was the only known creosoting plant in the Bay Area for several years. According to a newspaper article at the time it opened, "the Southern Pacific Company…intends to creosote piles and timbers exposed to dampness, not only for their own use, but also for the State Harbor Commissioners and any private concern that may require accommodation" (*San Francisco Chronicle* 1891). Whether Southern Pacific ever provided services to anyone but themselves is unknown.

In 1895, a commercial creosoting enterprise was established in San Francisco when the San Francisco Timber Preserving Company received permission from the Board of State Harbor Commissioners to build part of its creosoting works across the new seawall between Powell and Mason Streets (*San Francisco Chronicle* 1898). The creosoting plant supplied the Board of State Harbor Commissioners with treated piles for waterfront construction. By 1903 the San Francisco Timber Preserving Company moved from its location on the north waterfront, where it depended on a lease from the Board of State Harbor Commissioners, to a new, privately owned site at Illinois and Santa Clara streets near Potrero Point. The Marine Piling Committee reports of the 1920s make no mention of the continued existence of this plant; it was likely dissolved by that time.

In 1925, the Marine Piling Committee noted that there was no longer the much needed local source of creosoted piles for the Bay Area, observing that "the process is expensive and the demand for this type of creosoted product has not been large enough that commercial treating plants could be maintained on the local consumption, or could compete in the general field with plants at the source of production of the timber" (Neily and Kirkbride 1927). By the mid-1920s, J.H. Baxter and Company of San Francisco (with production facilities in Alameda) and Pan Pacific Piling & Construction Company (with a plant in Richmond) had been established, both of them treating wood piles (Bender 2003). While the latter plant was short lived, Baxter's Alameda plant remained in operation until about 1970. In recent years, the only West Coast creosote treatment plants have been in Washington, Oregon, and British Columbia.

Decline of Creosote Use

The use of creosoted wooden piles for new construction and repairs remained very high into the 1950s. As shipping in the Bay declined somewhat after the Korean War, there may have been some decline in the use of wood piles as fewer wharves and piers were needed.

A big change came around 1970 when, in a very short period of time, break-bulk shipping was almost completely superseded by container shipping. Up until that time, port facilities were built to accommodate break-bulk cargo handling in which many workers were needed to load and unload ships, the load of each ship broken down into sizes that longshoremen could handle on their own — with the help of forklift trucks, cranes, and other technologies. Break-bulk cargo was efficiently handled on "finger-piers," long narrow piers at which a ship could dock along each side.

The advent of containers brought bigger ships that would not fit along existing finger piers. Instead of finger piers and transit sheds, the optimum loading and unloading facility was a large open space where containers could be stacked and moved on and off trucks and rail cars with outdoor cranes. Larger ships requiring deeper water had to anchor alongside the container yard. A container terminal may have been built with some wood piles, but these facilities were largely reinforced concrete — that is, they were built with concrete bulkheads and earth and rock fill. With this transformation, old wharves and piers were abandoned or dismantled, removing facilities that previously required continual repair and replacement of wood piles.

Increased awareness of potential environmental problems associated with creosote, which was limited in the first half of the 20th century, also contributed to the decrease in use of creosoted wood. The EPA began investigating creosote in 1978, and worker protection guidelines were issued in 1984. In 1993, because of environmental concerns, the California Department of Fish and Game stopped approving the use of creosote-treated wood products in State waters (Gibbons 1993). In 2002, environmental and labor groups sued the EPA to ban creosote and other wood preservatives.

PILINGS AS CULTURAL FEATURES

The previous sections provided context on how creosoted wooden pilings relate to and reflect the broader history of the Bay's maritime structures and activity. The following sections provide context for how piles fit into the broader framework of cultural resource theory and regulation. This kind of assessment may be needed as part of any systematic effort to remove pilings for toxicity reduction from the Bay.

PILES AS FORESHORE FEATURES

The area between the high-water mark and the low-water mark of the Bay is referred to as the "foreshore." The term is in use by many archaeologists and cultural resources specialists to refer to the transitional zone between the landside shoreline and open water, and is where piers and wharves (and thus abandoned pilings) are often found. Abandoned pilings are thus one type of foreshore feature.

Foreshore features connect the Bay to the Bay Area; the water to the shore and surrounding lands. They articulate the physical transition between water and land, and represent the activities that occurred in – and relied on – this interface. They are one of the few extant physical reminders of the link between water and land, a link that was essential to the development and history of the region.

While much research has been conducted on onshore resources (e.g., waterfront buildings) and maritime resources (e.g., shipwrecks), there has been little focus on foreshore features. Foreshore features –including docks, piers, and pilings – have been largely underdocumented by the historical and archaeological research communities (Ford pers. comm.). Few studies focus on foreshore features, and they are often overlooked in traditional terrestrial archeological surveys. Historic resources surveys often focus on onshore coastal resources, such as buildings and bases, but may overlook or de-emphasize foreshore features (Cooney 2004, Purser pers. comm.). Because of this, site records traditionally used by archaeologists may be less useful for foreshore sites, since sites may have been outside the purview of a terrestrial archaeologist's research and have not been systematically recorded. Different information may also be gained by researching piling complexes from an offshore perspective: "If a careful observer looks towards either shore, he or she will notice wood pilings at frequently spaced intervals…A view from the levee offers a broad overview of the region and its patterns, but a view from the water offers more subtle detail" (Esser 1999).

Maritime archaeology as a field is relatively new; the National Park Service's (NPS) Maritime Heritage Initiative (now called the Maritime Heritage Program) was established in 1987. Maritime research efforts since then have been largely directed toward resources such as historic ships and shipwrecks, lighthouses, and naval facilities. One group of maritime resources described by the NPS – "marine sites and structures" – includes wharves, piers, and waterfront structures (Delgado 1991). However, while maritime resources are specified to include shoreline and foreshore features, these have not been a focus of efforts to date. Few of the shoreline resources that have been researched, such as canals, canneries, and landing sites, are on the West Coast (NPS 2001). Inventories are maintained through the Maritime Heritage Program of historic vessels, lighthouses, and shipwrecks, but no such listing yet exists for foreshore resources such as piers and wharves.

In this paper, we will consider abandoned creosoted pilings as one prominent aspect of the Bay Area foreshore landscape. We will study how these features have been treated as potential cultural resources under local and national regulations by other institutions, and how this might be applied to pilings in the Bay Area.

This is a relatively new field; few precedents exist for how to view piles through a cultural or historic lens. However, identification and evaluation of potentially historically significant (or otherwise culturally valuable) pilings is an essential part of any removal project. This paper provides some context for understanding pilings as part of the Bay's maritime cultural landscape, and a framework through which to evaluate them.

SURVEYS INCLUDING PILINGS

While a large volume of work evaluating piles as historical or archaeological features does not exist, a few studies have acknowledged pilings as historic features or have focused more generally on foreshore cultural features. More recently, a few piling removal projects in the Pacific Northwest have precipitated studies directed toward piling research. A few notable or local examples are described below.

Foreshore and Shoreline Surveys

In the San Francisco Bay and Delta, a few resource evaluations and Historic District nominations have focused on shoreline and foreshore resources. An early evaluation of navigation hazards in the Delta commissioned by the State Lands Commission focused almost exclusively on pilings, and documented dozens of piling groups with a brief explanation of the history of each (Paterson et al. 1978). In 1991, another historical resources inventory was conducted in the Sacramento-San Joaquin Delta (Owens 1991). A few Historic District nominations have been produced that include shoreline resources of historical significance in the Bay Area, including the Port of San Francisco Embarcadero, Mare Island Naval Shipyard, Alviso, Alcatraz, Aquatic Park, the Presidio, Fort Baker, and Fort Mason.

Outside of California, an inventory of structures of the New York Harbor included wooden pilings (Raber et al. 1985). Communication with archaeologists and historic preservationists across the country suggests that research has also been conducted in Washington (Dismal Nitch), the Great Lakes, and Florida (Manatee River; Burns pers. comm., Cooper pers. comm., Reese pers. comm.).

Foreshore archaeological surveys have also been supported in England by English Heritage's maritime archaeology program and Shoreline Management Plan (cf. Murphy 2006, Paddenberg and Hession 2008). These surveys note the presence and general extent of piles as part of general survey work. However, high-priority sites are largely very old (e.g., a timber fish trap dating from the 14th century; Murphy pers. comm.).

Pile-specific Surveys

Piling removal projects in Puget Sound and the lower Columbia River Basin have precipitated research on each region's abandoned pilings. As of September 2009, Washington State's Department of Natural Resources (DNR) had completed a number of reports on a case-by-case basis documenting the history and archaeology of pilings slated for removal in the Puget Sound region (Major pers. comm). On Bainbridge Island in Puget Sound, an inventory of piling groups was conducted by the City of Bainbridge Island's Historic Preservation Commission and the Bainbridge Island Historical Society (City of Bainbridge Island 2007). Preliminary research was conducted for pilings from 33 historic docks, landings, and other structures. In Oregon, the Lower Columbia River Estuary Project has classified and mapped over 500 structures in the lower Columbia River Basin as part of their Pile Structure Removal Program. However, they have not conducted extensive research on the history of specific pile groups.

The best example found of a pile-specific survey is the Delta report commissioned by the State Lands Commission, mentioned in the previous section (Paterson et al. 1978). While this report was concerned with pile removal for navigational rather than environmental reasons, pile history was researched for each site through maps, texts, photographs, interviews, and field surveys. A few paragraphs were written for each site documenting the location, character, and history of the site, and providing an evaluation of its potential significance and eligibility for inclusion on the National Register of Historic Places. While the overwhelming majority of sites were found by the authors to likely have no historic significance, a few were highlighted as potentially significant or eligible.

REGULATORY SUMMARY

Federal, state, and local laws all may apply to the treatment of historic properties in California, depending on the site's jurisdiction and ownership, the project funding source, and the agency in charge of the removal project. While this subject is treated far more extensively elsewhere (cf. McCarthy 1999, EDAW 2005), a brief overview of regulations is provided here. (A "historic property" is a structure, site, or district eligible for the National Register; see p. 17.)

Federal Laws

The National Register of Historic Places, created through the National Historic Preservation Act of 1966, was the first comprehensive approach to preservation of historic cultural resources in the U.S. The National Historic Preservation Act provides information on how to evaluate resources for inclusion in the National Register. The National Register is a federally maintained list of historically significant properties, and is administered by the NPS.

Section 106 of the National Historic Preservation Act provides the most often used guidelines for evaluation and preservation of historic resources in the U.S. Evaluation under Section 106 is triggered when federally licensed or funded projects may affect potentially historic resources. The lead agency must determine if any potentially impacted resources are already listed on (or may be eligible for) the National Register, and propose ways to avoid or mitigate project effects on eligible properties. For example, U.S. Army Corps of Engineers permits for piling removal projects require compliance with Section 106. Since a large portion of Bay Area near-shore waters are under U.S. Army Corps of Engineers jurisdiction, any large-scale piling removal project would likely require federal permitting by the Corps, and thus would be subject to compliance with Section 106 of the NHPA (see McCarthy 1999).

The NPS has produced guidelines on how to assess aids to navigation (mostly lighthouses) and historic vessels and shipwrecks in the context of the National Register, but provides no specific guidance on pilings and piers except as related to sites of aids to navigation (Delgado et al. 1992, Delgado and Foster 1992).

The criteria used to determine a structure's eligibility for inclusion on the National Register are the most widely used standards for evaluating historic significance. These criteria are discussed more fully in the Significance Criteria section (p. 17).

State and Local Laws

The California Environmental Quality Act (CEQA) contains historic preservation laws and eligibility criteria that mirror the federal framework. State agencies must determine if a project adversely impacts cultural resources and identify ways to prevent or mitigate impacts as part of the CEQA process. If a property is determined eligible, it is listed in the California Register of Historical Resources. Evaluation of pilings' eligibility for the National Register is performed during the CEQA process.

California State Parks' Office of Historic Preservation (OHP) maintains the California Register. In addition, the OHP maintains lists of California Points of Historical Interest and California Historical Landmarks. Criteria for these lists are less stringent than for the National or California registers, but a site must be publicly accessible to be eligible (McCarthy 1999). The California Register includes National Register properties, as well as California Points of Historical Interest, California Historical Landmarks, and other properties with local or statewide significance (OHP 2009).

In 1998 new guidelines were issued specifying that a lead agency may consider a resource to be historically significant, even if it is not eligible for inclusion on the California or National Register (California Natural Resources Agency 2007).

In addition to state guidelines, many cities or counties have local laws and processes related to identification and treatment of cultural resources. These should be identified for a specific project area before work is initiated. Local entities (such as landmarks boards or preservation commissions) should be consulted for information on the region.

SIGNIFICANCE CRITERIA FOR PILINGS

The National Register criteria for significance are the most widely used standards for evaluation of cultural resources. However, there is little guidance for the application of these guidelines to foreshore resources such as piles. In this section, we will outline the general criteria for National Register eligibility, and discuss their application to abandoned creosoted piles. For more detailed information on National Register guidelines and application, refer to the Park Service's bulletin on the subject (NPS 1997).

WHAT IS HISTORICAL SIGNIFICANCE FOR A PILING?

To be considered eligible for inclusion on the National Register, a property must be historic, significant, *and* must possess integrity (fig. 1):

1. **Historic:** Over 50 years old (barring exceptional cases);
2. **Significant:** Associated with a significant event, person or construction type, or must hold the potential to yield information relevant to one of these categories;
3. **Possess Integrity:** preservation of the historic identity and authenticity of a structure, as defined by seven aspects.

In order to evaluate a property's significance and integrity, however, the property must first be classified (as a district, site, building, structure, or object) and the specific historic context within which it may be significant must be identified.

Property Type

Historic properties are classified as one of five property types: buildings, structures, objects, sites, or districts. Buildings, structures, and objects are physical entities, while sites and districts are locations which are historic.

Transit sheds and warehouses would be considered buildings; wharves and bridges would be considered structures (constructions not meant to shelter humans or human activities). Navigational aids or dolphins might be considered objects: that is, relatively small-scale constructions. The term “structure” is often used to refer generally to these three categories of constructions.

Structures must “include all of the extant basic structural elements” to be eligible for nomination to the National Register (NPS 1997). Thus, while the intact resources the wooden piles once supported may have been considered structures, buildings, or objects, most abandoned wooden piles would likely not be classified as any of these. Few piles were built to be structures in and of themselves, so most piles are considered substructure – supporting components of a larger structure. Most of the abandoned piles around the Bay are missing most of their original superstructure (e.g., deck cover). (A possible exception would be navigational aids or dolphins, which could be considered mostly intact objects or structures.)

The vast majority of piles will not be significant as intact structures, since they are only a remnant of the former structure they once supported. However, it is possible that piles could be categorized as a subsidiary feature related to an intact, significant building or structure. For example, a group of piles related to a significant transit shed could be classified with the transit shed under “building,” and the piles would give context to the structure (fig. 2a. Depending on the case, this could also be considered a district; see below.) It is also possible that a highly significant pile complex would be so extensive that it would be able to adequately convey the original structure and could be considered significant, although this is very unlikely (fig. 2b).

A pile complex may also be considered significant as one element of a larger site or district. A site is a location where the place itself “possesses historic, cultural, or archaeological value regardless of the value of any existing structure” (NPS 1997). Sites may be significant irrespective of the presence or significance of structures. Sites may be archaeological or historical. For example, piles could be considered a (non-significant) feature of a site with archaeological significance, whose significance predates the piles’ but overlaps with them spatially. (In this case, the pilings would not be significant, but removal could be inadvisable.) Wharves represent sites of waterfront activity, and may mark historically significant sites even if the pilings are not significant themselves. It is also possible that the location itself is historic if it marks the location of a significant event related to the piles (such as a shipwreck or historic landing), despite the deteriorated condition of the structure the piles supported (fig. 2c).

The most likely designation for a pile complex is a district. Districts are groups of historic properties that are linked either by historic context, construction, or use. A district can include buildings, structures, sites, and objects that, when evaluated together, contain historical value. However, an individual feature incorporated in a district need not have significance by itself:

> Any one of the properties in a historic district may not have particular historical, architectural, engineering, or archaeological distinction, but the collection must have significance in one of these areas. (Chandler and Power n.d.)

Thus pilings may be a contributing element to a multiple property district even if they would not be eligible for the National Register themselves (fig. 2d). Examples might include abandoned piles associated with a historically significant bridge, or piles associated with an intact historic pier and warehouse. In a district, it is not the individual pile that is significant, but what groups of piles convey in the context of the district's (and larger Bay's) history.

One type of district, called a cultural landscape, is particularly relevant to the discussion of creosoted piles. The term will be discussed in more detail in the Maritime Cultural Landscape section (p. 26). In the following sections, we will assume the case of piles as contributing elements to a larger district unless otherwise specified.

Historic Context

In order to evaluate the significance of a property type, the historic context which it represents must first be determined. Historic context provides the broader historical trends and themes that a property reflects and characterizes. The property illustrates an aspect of the historic context, and the historic context provides a framework through which the property is understood to be meaningful and through which historical information is organized. The historic context addresses questions about the property: what were the pilings used for? Why were they built where they were?

A historic context must define an activity or theme (maritime history, transportation, agriculture), a geographic region (San Francisco Bay, Point Richmond), and a relevant time period. It helps researchers understand the relationship of an individual property to other properties which share the same context, and to the larger history and development of the region. This, in turn, helps determine significance, since "the grouping of properties having similar patterns of historic development [make] it possible to weight their relative importance" (McClelland et al. 1999).

A historic context statement may be prepared to define and contextualize the historical patterns (geographic, temporal, and spatial) through which a district's significance can be appreciated. The statement provides background to understanding how a district represents and reflects significant aspects of its broader context.

Significance

The National Register outlines four criteria (A-D) for evaluating the significance of a property within its historic context. To be considered significant, a property must possess at least one of the following (from NPS 1997):

Criterion A. Association with an important event, activity, or historic trend;
Criterion B. Association with an important person;

Criterion C. Embodiment of a distinctive, notable style of architectural design or engineering construction; or
Criterion D. Potential to yield important information about a facet of human history or prehistory.

Abandoned pilings could be contributing elements in a district eligible under Criteria B or C: if the pilings were related to John Sutter's activities, for example (B), or if the pilings were made from a "one of a type" kind of wood, treated with an early creosote-treatment process notable in the history of creosote development, or installed in a unique, distinctive way (C). However, it is most likely that the district would be significant in association with an important event or activity under Criterion A. Pilings could be a contributing element to a district associated with the railroad system, the shipping industry, or World War II. Significance may be evaluated in a national, state, or local context.

Criterion D, information potential, is most often applied to archaeological sites (NPS 1997). While under Criteria A-C pilings would be significant mainly as contributing elements in a district, under Criterion D abandoned pilings could potentially be significant in and of themselves (Delgado pers. comm.). Pilings must be able to convey information not available through any other means to be eligible. This could involve providing information on early construction methods, shipping history and methods, and pile-driving or creosote treatment technology (Johnck pers. comm., Minor pers. comm.).

Even if the pilings themselves are clearly not significant (or even older than fifty years), the site of a piling removal project must be evaluated to assess whether any archaeological site would be threatened or compromised by piling removal. Since optimum sites for pile-supported structures may coincide with prehistorically favorable sites (e.g., at the mouths of navigable rivers), this may occur in many instances. These sites, while unassociated with the piles, may also be eligible under Criterion D. Archaeological sites composed of material associated with the piles (e.g., a shipwreck or debris related to the use of the former structure) should also be considered.

The time period during which the property attained significance, called the period of significance, must also be determined for each property. Defining the period of significance relates to the area of significance (A, B, C, or D) relevant for the property. For example, for a piling group significant for its construction type or design, the date of construction (and any significant modifications) would define the period of significance. For pilings associated with a significant event, the period of significance would be the duration of the event. Pilings associated with a significant activity or historical trend would be significant during the period that the feature played an active role in that activity.

Integrity

Integrity is "the ability of a property to convey its significance" through retention of its historical identity and character (NPS 1997). There are seven aspects of integrity as defined by the National Register: location, design, setting, materials, workmanship, feeling, and association. While eligible properties will often possess integrity in multiple categories, understanding the context in which a property is considered significant helps determine which aspects of integrity are most essential to the property's ability to convey its significance. This includes determination of the period of significance for the property, since evaluations of integrity should relate to the property's status during that relevant time period.

Integrity is one of the most challenging aspects of viewing pilings as a potentially significant historic resource. Experts interviewed for this project had widely varying opinions on how to apply National Register criteria to assess the integrity of groups of abandoned wooden piles. Some consider nearly all pile groups to have had severe loss of integrity, since they are only a portion of the original structure. Others believe that in a few cases, pile groups may retain the ability to convey the significance of the former structure. Regardless, it is clear that in the absence of robust physical integrity, the historic significance of the pile group would need to be considerable in order for the piles to be listed.

Through the Port of San Francisco Embarcadero Waterfront Historic District nomination, the Port of San Francisco drafted review guidelines for pier substructures, including piles (Port of San Francisco 2004). While the report focuses on the repair and maintenance of intact structures, it provides some guidance on how to apply the concept of integrity to wooden piles. The Port identified five "character-defining features," including location, design, and materials, to be maintained during maintenance and repair of pier substructures. The National Register Bulletin on nominating historic vessels also describes ways that integrity may be assessed for maritime resources (Delgado et al. 1992).

The following is a brief discussion of the seven types of integrity as they may relate to abandoned pile groups. For resources considered significant under Criterion D (information potential), the conventional categories of integrity are less important. Instead, integrity relates to the presence of features that would allow significant research questions to be addressed.

Location and Setting

Since most (if not all) pilings are located at the original site of construction and use, most would retain integrity of location. However, integrity of setting is more complex, since much of the Bay waterfront has changed drastically over the past 100 years. If the surroundings are substantially changed from historic conditions, or if more recent development compromises the ability of the landscape to convey the historic setting, the piles may not have integrity of setting. However, in areas where less change has occurred, the piles may possess integrity of setting.

Design, Materials, and Workmanship

Integrity of design, materials, and workmanship all relate to the change over time in the physical construction of the piles. Integrity of design is the broadest category, and is maintained when modifications to the substructure are conducted in a manner that maintains the style and original feel of the structure. Integrity of materials means that alterations have utilized the same physical materials as the historic structure, and workmanship relates to whether the quality of construction has been maintained over time.

Since wooden piles are ephemeral by nature, deteriorate relatively quickly, and are designed to be continually replaced, these categories of integrity can be difficult to apply (and may be less relevant than other categories, such as setting, feeling, and association). How long the site has been occupied by a structure may be more important than the age of the individual pilings. A historic pier where some wooden piles had been replaced in the 1980s by concrete piles, or where recent pile driving has substantially altered the appearance of the original structure, may have suffered a loss of integrity. Piles may also be seen to have no integrity of design in and of themselves, since they are only a fraction of a previous structure.

Most experts agree that a site with a mixture of historic pilings and more recently driven pilings could still retain integrity. This is consistent with the Port of San Francisco guidelines:

> By their nature, even the most durable chemically treated wood piles were not expected to last more than 30 years in water. Wherever they were used, they were expected to be replaced, often before the life of the structure they supported…Thus, integrity of wooden piles is not a matter of original piles, but of routine maintenance and replacement by piles similar to those used before. (Corbett and Dobkin 2006)

Feeling and Association

Integrity of feeling and association are the most subjective of the aspects of integrity, and probably the most significant for piles. Feeling refers to the ability of the piles to convey a sense of the structure and time period they are intended to represent. Association is the piles' ability to convey the associations with the event or activity that made them significant.

Structural integrity is difficult to retain for any maritime or foreshore feature, since prolonged exposure to water accelerates deterioration. It is clear that in order for pilings to retain any integrity of feeling, they must retain the ability to convey a sense of the original structure's extent and function. Thus structural integrity plays a role in integrity of feeling, since a highly deteriorated structure with only a few piles remaining is unlikely to convey the function and scope of the former structure. A few scattered pilings isolated from other features are extremely unlikely to retain any integrity, while a massive complex which still reflects the footprint of the original structure and its orientation to shoreline resources may be more likely to. An organized group of pilings that clearly represent the former structure's shape and function may be able to convey the sense of scale and feeling of a former wharf or warehouse (Ford pers. comm., Herbert pers. comm., Minor pers. comm.). In a larger district or landscape, pilings may retain integrity of feeling for their ability to convey the historic connection between land and water.

If a group of piles is the only remaining marker of the site of an extremely significant event or activity, the piles may retain integrity of association. Even if the piles are not important as historic resources, they may contribute integrity of feeling and association to a larger historic district.

Informal Significance

While the National Register is an important guideline for determining cultural resource value, it is not the only standard for determining significance. State and local guidelines may also be used to determine significance. California state guidelines acknowledge that "some resources lacking individual distinction nevertheless may contribute to the understanding and appreciation of California's history and prehistory" (OHP 1995).

In addition, some piling groups may be considered significant by local groups or other stakeholders despite non-eligibility by any legal framework. There may be instances where pilings do not meet national or state guidelines for significance, but there would still be incentives (historical or aesthetic) not to remove them.

Some pilings may be worth retaining for historical reasons, even if they do not meet National Register standards. For example, the State Lands Commission evaluation of pilings in the Delta identified a number of pile complexes that were not recommended for removal, despite non-eligibility (Paterson et al. 1978). These included sites in the Mokelumne River and near Bouldin Island, where pilings in poor condition were not "strictly eligible" for the National Register, but nevertheless contributed local historical value and provided "graphic evidence of the manner in which the Delta's geography has been altered and realtered" over time. In these cases, the report recommended that as many old pilings as possible be retained, though removing some to remove navigation hazards would "not materially reduce the historic value of the site."

Community residents may also value pilings for their representation of an area's history. On Bainbridge Island, local historians consider their pilings important visual reminders of the island's maritime history, features that are "intrinsic to the fabric of this community's history" (Lorraine Scott, in Baurick 2007) and "help people feel and enjoy the history here" (Jerry Elfendahl, in Baurick 2009). Residents note that the pilings help create a sense of history difficult to reproduce without them:

> It means so much more if there's a specific place where you can point to the pilings and say, 'That's where the dock was.' When they [residents] see it, there's an 'aha!' moment. (Andrea Mercado, in Follansbee 2007).

In Astoria, Oregon, at the mouth of the Columbia River, extensive pilefields are a prominent part of the waterfront, and are recognized as a "reminder and remainder of a bygone era" (Benoit pers. comm.).

Pilings are also valued by some for their aesthetic or artistic importance. The Hudson River Pilings Project, a public art installation in New York slated for completion in late 2009, uses the pilings as platforms for sculptural art. The artist, Joan Benafiel, has “long been enamored of the pilings; the submerged logs that once supported the Hudson’s busy piers” (Benafiel 2009). Located in Hudson River Park, these pilings have been preserved by the Hudson River Park Trust for fish habitat value (Hudson River Park Trust 2009). Also on the Hudson River, at South Cove (Battery Park City), piles were actually installed as part of a landscape art piece along the shoreline in late 1980s. One of the collaborators described how they installed “pilings into the water to make a visual transition between the land and the water”:

> You come to the edge and get a sense of the edge. I am always interested in how the built environment and the natural environment contact. (Mary Miss, in Jasch 2004)

Lastly (and as mentioned previously), pilings that are themselves insignificant may mark unrelated, potentially significant archaeological sites that could make pile removal undesirable (Esser 1999).

EVALUATING HISTORICAL SIGNIFICANCE OF BAY AREA PILINGS

Abandoned pilings must be evaluated as part of any removal project to ensure that potentially significant resources are not removed without establishing options for mitigation or preservation.

The challenge for any large-scale piling removal project is that this is a daunting task for a great number of pilings. There are around 30,000 abandoned pilings in San Francisco Bay, far more than would be practical to research for historical value on a case-by-case basis.

Others faced with evaluating historical significance of pilings slated for potential removal have adopted different approaches to dealing with large numbers of pilings, including case-by-case research as needed, initial inventories, and a programmatic approach. A few of these precedents are outlined here. The examples of approaches from other regions are illustrative; however, the Bay Area will likely have its own unique application of federal, state, and local guidelines that will ultimately guide piling evaluation.

While different approaches have been applied in other regions, conversations with experts in maritime archaeology and shoreline historic preservation have highlighted the benefits of adopting a programmatic approach to evaluating the Bay’s abandoned pilings. Using a programmatic approach, individual piling complexes around the Bay are considered within the larger context of the Bay’s maritime resources and maritime history, rather than as disarticulated, discrete sites. Central to the programmatic approach is the cultivation of an understanding of the Bay as a maritime cultural landscape (a "landscape" is a type of district; see p. 26), a concept that provides the broader framework within which to evaluate piling groups. These two related frameworks – a programmatic approach to piling significance and the idea of a maritime cultural landscape – are discussed here.

APPLYING SIGNIFICANCE CRITERIA TO PILINGS

Piling Removal Projects: approaches to determining the significance of pilings

While we were unable to find many examples of large-scale piling removal projects, a few have addressed the cultural resource aspect of pilings. These projects have largely taken a preventative method: if a piling group seems to have any potential for significance, it is generally not recommended for removal. This approach alleviates some of the need for in-depth, site-by-site historical research and analysis, since sites which might require substantial research are mostly avoided.

Washington State's Department of Natural Resources (DNR) provides the most robust example of a piling removal project's approach to cultural resources. They have adopted a case-by-case approach to documenting the history and archaeology of pilings in the Puget Sound region, completing reports only for pilings identified for removal by the project manager. A cultural resource specialist conducts research on the history of the pilings and of the site, as well as field surveys and GIS work to identify potential historical or archaeological sites in the area that are not associated with the pilings, but that could be affected by piling removal. The completed reports document the construction and ownership history of the piling complex, and evaluate the significance of the site under National Register and Washington Heritage Register criteria.

Since Washington DNR has considered the majority of piling sites to lack integrity, most are recorded as archaeological sites rather than historic resources. A process for preventing damage to culturally significant properties and archaeological sites has been established and is followed for each piling removal project. The process includes background research to determine presence of known or unrecorded historical or archaeological sites in the vicinity of the piles, research on and documentation of pilings over 50 years old, and monitoring of piling removal projects by a cultural resource specialist in areas that may be archaeological sites.

A few other approaches to large-scale documentation have been used. The Lower Columbia River Estuary Project has been using potential historical significance as a criterion to help choose pilot project sites. Pilot projects were primarily chosen for their potential for ecological benefit, but sites identified in conversations with the State Historic Preservation Office (SHPO), local historians, and community groups as potentially significant were also avoided (Collins pers. comm.). The State Lands Commission report on Delta waterways conducted a site-specific, multi-volume inventory of piling complexes to evaluate the potential significance of each one (Paterson et al. 1978). Lastly, the Port of San Francisco Embarcadero Waterfront Historic District National Register nomination identified and researched each pile-supported structure in the district, evaluating each one as either a contributing or non-contributing resource to the district.

Pilings Found Potentially Eligible for National Register Status

While some piling complexes were avoided as candidates for removal based on their potential historical significance, we found no examples of pilings which had been formally determined eligible for National Register status. The closest examples were allusions to pilings listed as contributing resources in the Bacon Island Rural Historic District in San Joaquin County (Herbert pers. comm.) and the Point Bonita Historic District in Marin County (Delgado pers. comm.). The State Lands Commission Delta report identified a few piling groups that are “potentially eligible for inclusion in the National Register of Historic Places and should not be disturbed” (including at least two sites adjacent to Bacon Island); however, it is not clear if nominations were ever completed (Paterson et al. 1978). One navigational aid in the Delta, the Steamboat Slough dolphin, was surveyed in 1991 and proposed as a potential historical site (Owens 1991, Delta Protection Commission 1994).

PROGRAMMATIC APPROACH AND THE MARITIME CULTURAL LANDSCAPE

In our conversations with maritime historians, archaeologists, and historic preservationists, we repeatedly heard two recommendations: that a programmatic approach to evaluating the significance of abandoned pilings is the preferable process to adopt for San Francisco Bay, and that understanding abandoned pilings in the context of the Bay Area maritime cultural landscape is an essential part of assessing their significance within a programmatic framework:

> Sites and structures are frequently treated as individual elements, having outlived their useful life, and are not seen as part of an overall system. Such disarticulated study, though conducted according to the legal mandate, tends to result in the removal of elements from the spatial ensemble without adequate consideration of the cumulative alteration of the area’s industrial footprint or the loss of maritime cultural knowledge. (McCarthy 1999)

While for a small number of piling removal projects, a site-by-site approach to historic evaluation may be adequate, a more systematic, Bay-wide removal project requires a more systematic, Bay-wide approach to evaluating historical significance. This kind of landscape-level, programmatic approach has the potential to be both more efficient and informative than site-by-site analysis.

The Maritime Cultural Landscape

Cultural landscape studies explore the interaction between humans and their environment – how people relate to (and shape) place (Groth 1997). The idea of a cultural landscape in the United States dates back to John Brinckerhoff Jackson’s writings in the 1950s, but was not formally incorporated into NPS and National Register terminology until 1992 (NPS 1996), defined as:

> a geographic area (including both cultural and natural resources and the wildlife

> or domestic animals therein), associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values. (Birnbaum 1994)

Under the National Register, cultural landscapes are categorized as a type of district (or less often as a site). Of the four types of cultural landscapes defined by NPS (historic sites, historic designed landscapes, historic vernacular landscapes, and ethnographic landscapes), piling complexes would most likely be considered part of a vernacular landscape or a historic site. Vernacular landscapes are shaped unintentionally (without broader design) by those who use them and live and work in them, evolving with multiple layers of use over time (see Alanen and Melnick 2000). Historic sites are landscapes that possess significance irrespective of any significant structures present.

The term “maritime cultural landscape” was coined in Scandinavia in the late 1970s to encompass archaeological and historical features associated with maritime culture into one framework, from maritime features (such as shipwrecks) to terrestrial features such as shipyards and harbors (Westerdahl 1992). This is a particularly useful framework for contextualization of foreshore resources such as piers and wharves, whose purpose is to connect land to water. Abandoned pilings are one visually prominent aspect of the maritime culture of the historical Bay, reflecting Bay Area residents’ past relationship to the Bay itself as an integral part of transportation, commerce, and other activities. “In many places,” writes John Stilgoe (1994) of East Coast shorelines, “only decaying wharves document otherwise vanished industry and shipping.”

Maritime cultural landscapes can occur at many scales, from small districts of a few structures and piles to the entire Bay Area foreshore. The broader, Bay-wide maritime landscape provides context for evaluating the smaller, district-scale (and potentially National Register eligible) landscapes.

The maritime cultural landscape as applied to foreshore cultural resources is a relatively new field. Stilgoe (1994) has written extensively on the shoreline as a cultural landscape, though most of his research focuses on the East Coast. There are a few recent local examples of a cultural landscape approach to foreshore cultural resources, mostly associated with Dr. Margaret Purser, a researcher in the Anthropology department at Sonoma State University who has focused on maritime cultural resources. Her students’ work includes a thesis on the South Bay Salt Ponds as a cultural landscape (Johnck 2008), a thesis on the maritime landscape of the Port of Oakland (McCarthy 1999), and research on the Delta as a maritime landscape (Esser 1999).

There are a number of reasons why this broader, Bay-wide maritime landscape approach is an appropriate framework for viewing pilings in the Bay Area. First, it allows one to understand the relationship between abandoned pilings and other associated elements of a district, such as shore-side structures. Cultural landscapes emphasize the relationship between the structures, other elements of a district, and their larger physical and cultural context (Goetcheus 2002). Even if a piling group is not individually valuable, a landscape approach may identify it as a contributing resource for a historic structure or larger historic district of which the pile-supported structure was a part. The pilings could be considered “small-scale elements” of a cultural landscape, defined as features such as fence posts or road signs that are "characteristic of a region and occur repeatedly throughout an area… that mark the location of historic activities, but lack significance or integrity as archeological sites" (McClelland et al. 1999).

Second, the maritime cultural landscape lens enables one to view pilings as one element in a suite of similar features contributing to the character of the entire Bay shoreline. This allows for comparison of piling groups in different geographic areas but with similar historical purpose or construction history, which is in turn useful for determining relative significance. Viewing pilings as one aspect of the shoreline cultural landscape provides insight into how pilings relate to landside resources and to other piling groups. McCarthy (1999) writes that "seemingly useless elements of the transportation infrastructure can take on new meaning when viewed in relationship to the articulation between the water and the land."

Third, this framework places piles within the broader context of Bay maritime history. Piles are visual reminders of the ways in which Bay residents related to and used the Bay, and of the everyday life and commerce built around the Bay shoreline. Even in a ruined state, pilings contribute to the feeling of the historical Bay, an aspect that would be lost when viewing disarticulated sites.

Lastly, the cultural landscape approach lays the groundwork for a programmatic approach to piling evaluation by providing a way to evaluate pilings within a regional context. This approach views pilings as part of the Bay's maritime cultural landscape, and treats them in the context of this historical fabric. It is discussed more fully in the following section.

Programmatic Approach to Pilings

There are two premises of a programmatic approach as a piling evaluation framework. The first is that without understanding broader, landscape-level context in which wooden pilings were constructed and used, one is not able to make statements regarding the significance of an individual piling group. Broader context provides the information necessary to make decisions about relative importance, and may also reveal significance not evident on a site-specific scale:

> Pilings are mundane, ubiquitous, and nearly always evidence of some other structure that is no longer present…However, pilings may also constitute "surface" evidence of larger, more substantive elements, features, or associated sites in the vicinity. Their significance and information potential thus only emerge at a much larger scale, as part of local or regional patterns, and articulated in the context of other related sites, features, and material culture. (Purser pers. comm.)

The "Bay as maritime landscape" approach provides the framework for a programmatic evaluation of pilings. The broader landscape context may also help strategically focus efforts of a Bay-wide piling removal project by identifying regional patterns and trends in piling construction, use, and distribution.

Second, a programmatic approach addresses the monumental logistical problem of trying to adequately identify, research, and evaluate tens of thousands of abandoned pilings around the Bay. With the proper landscape context established, this “top down” approach to significance should identify potentially historic sites and districts much more effectively than a site-by-site approach, and could ultimately be of more value.

What follows is a broad-brush, preliminary description of the steps that could be involved in establishing a programmatic approach to piling evaluation. It provides an initial outline of what the process might entail. However, this process should be further refined through consultation with qualified professionals such as maritime archaeologists and historic resource specialists, and through discussions with SHPO, before major work is undertaken.

Step 1. Discuss development of programmatic agreement with SHPO for evaluation of creosoted pilings.
The first step would be to initiate a programmatic agreement in conjunction with SHPO to establish protocol for piling evaluation in San Francisco Bay. The scope of the project at hand should be explained to SHPO (at least 30,000 abandoned creosoted wooden pilings around the Bay, a portion of which might need to be removed for environmental reasons). SHPO may recommend protocol to programmatically approach the large number of abandoned wooden pilings around San Francisco Bay that is sensitive to the potential historicity of the resource, but that does not involve inventorying tens of thousands of pilings. SHPO will also have insight into how to develop a process that addresses Section 106, CEQA compliance, and other applicable local laws.

Step 2. Locate previous research and existing eligible properties.
Databases of already recorded resources, such as the National Register Information System (NRIS; soon to be replaced by NPS Focus) and the California Historical Resources Information System (CHRIS), should be searched for existing research on relevant Bay Area properties such as piers, wharves, transit sheds, dolphins, and other shoreline resources. These searches will provide background on which areas of the Bay shoreline have already been surveyed (and how, and by whom) and on any relevant studies that have already been conducted that reference pilings or pile-supported structures. SHPO should also be queried for any nautically-themed historical context statements already prepared for portions of the San Francisco Bay region.

Step 3. Conduct original research on the history of creosoted wooden structures and substructures.
In preparation for the creation of a historic context statement, research should be conducted to explore the historical aspects of abandoned wooden creosoted piles in the Bay. This would be along a similar vein as the preliminary historical context provided earlier in this paper, but would involve far more research and provide much more detail.

It would identify the geographical limits and time period relevant to wooden piles in the Bay, and would describe in detail the history of each theme (e.g., commerce, transportation, agriculture, industry) and type of structure (e.g., wharf, dolphin, trestle) associated with wooden pilings, and provide an overview of the mosaic of structures that used wooden pilings around the Bay. This step would involve a combination of historical archival research and fieldwork.

Step 4. Prepare historical context statement on creosoted wooden pilings in San Francisco Bay.
A full historical context statement on wooden creosoted pilings (or pile-supported structures) in San Francisco Bay would be prepared by a qualified researcher. The researcher would integrate existing information (Step 2) with research conducted (and the thematic, chronologic, and geographic framework established) in Step 3 to prepare a document that provides background information on the history of treated wooden pilings. The historical context statement would document the evolution of the Bay waterfront with respect to wooden pile-based structures; the history of creosote fabrication and use; the history of the types, distribution, and functions of wooden pilings; and a detailed history of shoreline construction and the wooden creosoted pile in the Bay. The mapping conducted as part of this study (Appendix A) will be of enormous value, and could be expanded to include data on the distribution of different pilings driven for different uses, identifying locational patterns of different types of pilings.

This process would provide a broader framework within which to evaluate individual piling sites (identifying some of the best preserved, most significant examples of each structure type), and would help identify areas where potentially significant piling groups that reflect important aspects of Bay Area maritime history might most likely be found. It would also help identify specific themes (such as historic events or activities) related to pilings, which could link specific areas to National Register significance criteria.

Step 5. Identify potentially significant piling groups.
The historical context statement would be used to identify potentially significant piling groups (or areas of potential significance) around San Francisco Bay. These areas could be de-prioritized as sites for piling removal projects (as practiced by Washington DNR, the Lower Columbia River Estuary Project, and the State Lands Commission’s Delta project), while areas or sites determined to have a lower likelihood of significance could be prioritized (with site-specific research then conducted before removal begins). Alternatively, further research could be conducted in potentially significant areas to establish or disprove significance.

It is important to recognize that historic significance does not necessarily preclude piling removal. In many cases, documenting historic use along with other measures (such as mapping pilefields or creating signage) may be sufficient to mitigate the impact of the removal project. The programmatic approach would involve consultation with SHPO to develop appropriate measures for treatment for eligible sites.

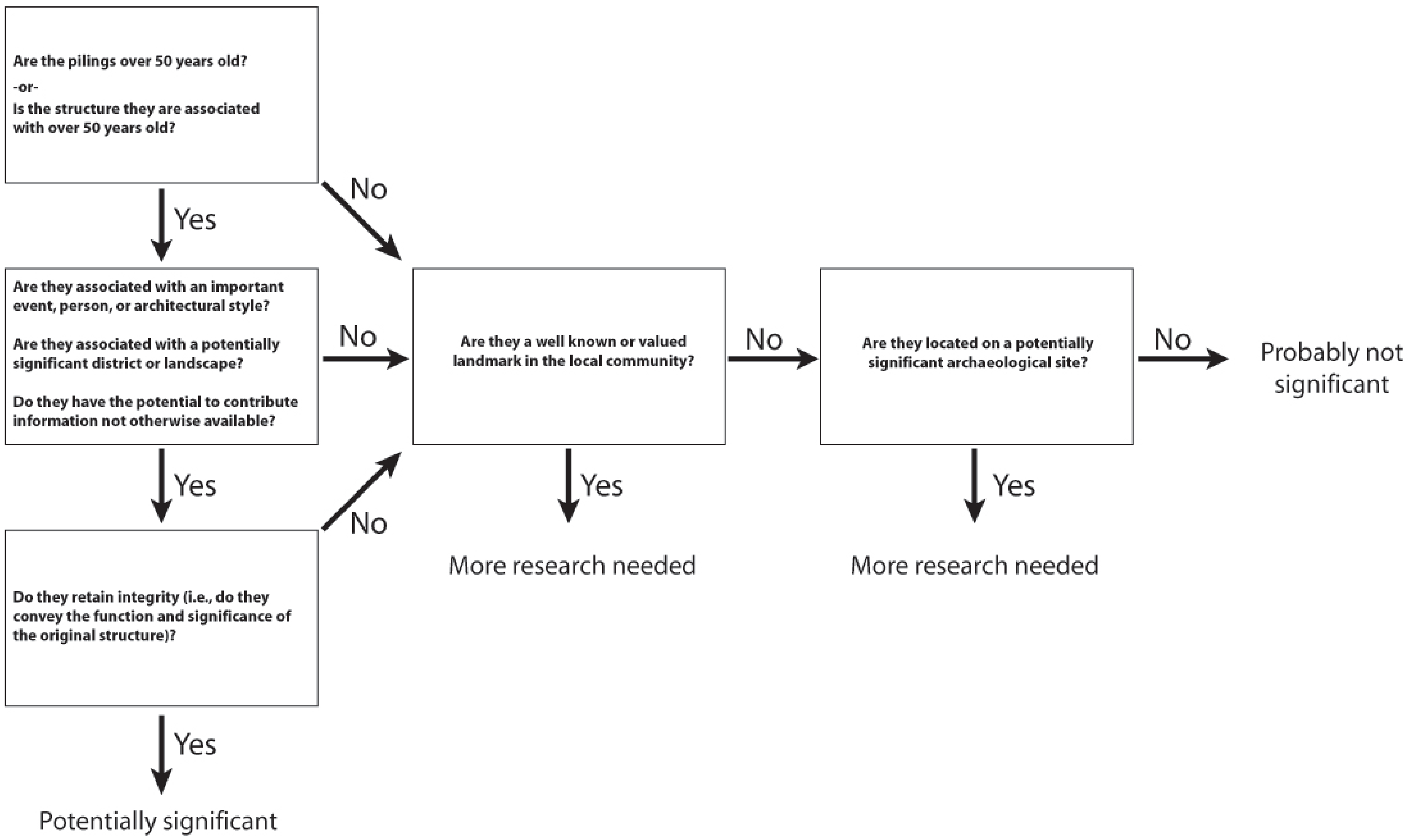

Figure 1. Applying criteria for National Register eligibility (and informal significance) to creosote pilings. Pilings determined to be "potentially significant" are likely poor candidates for removal projects, while pilings determined "probably not significant" would likely be appropriate candidates for removal. Pilings in the "More research needed" category would need to be evaluated on a case-by-case basis.

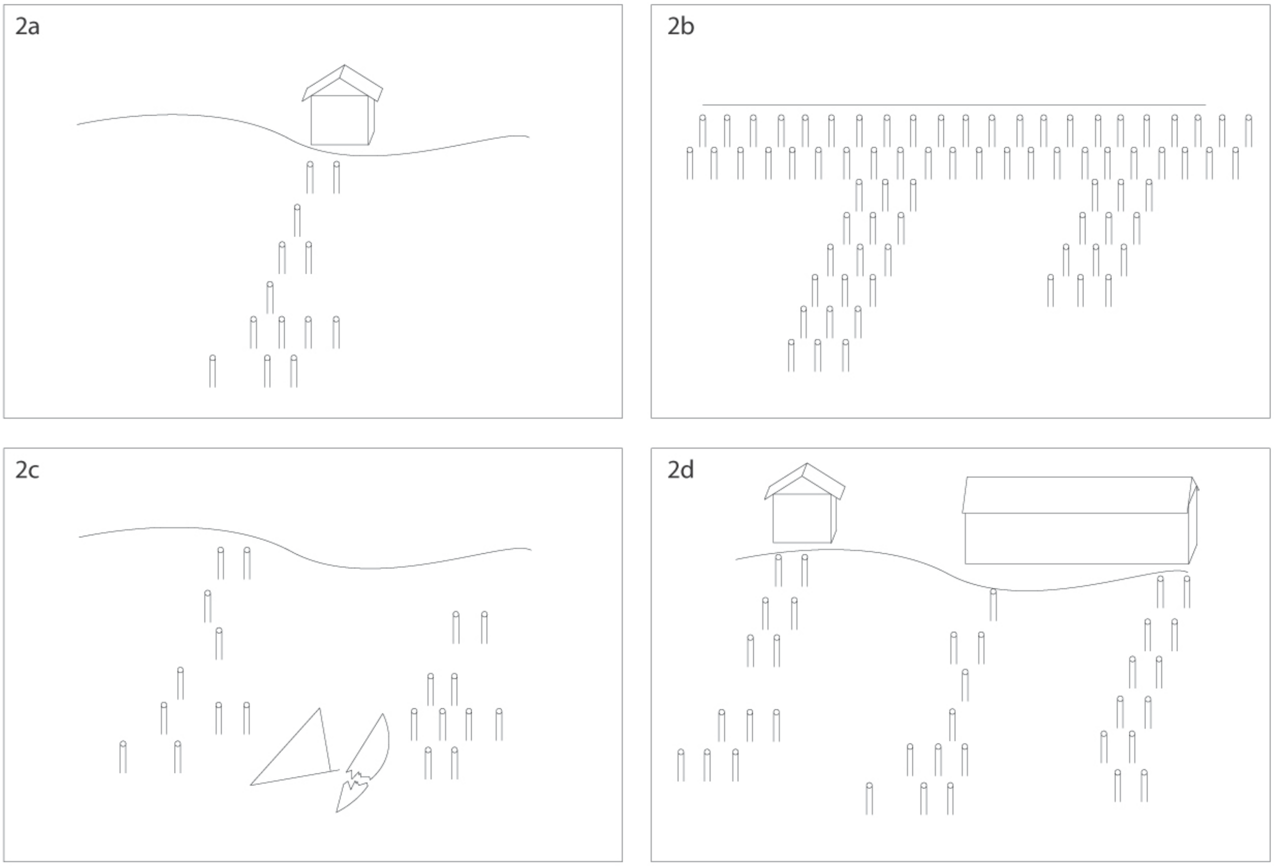

Figure 2. Many pilings may be ineligible for the National Register based on lack of integrity, since they are only remnants of a complete structure. However, a few scenarios exist in which pilings could be considered potentially significant (or where removal may be undesirable) in spite of compromised integrity. **2a**. Pilings are associated with a significant onshore structure. **2b**. Extensive piling complex retains the ability to convey the form, function, and association of the former, extremely notable structure. **2c**. Pilings mark the site of an archaeologically significant site (e.g., a shipwreck). **2d**. Pilings are an element in a multiple property district.

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APPENDIX C-2

Historical Significance of Creosoted Pilings: Case Studies

Erin Beller and Alec Norton

The following section contains examples of the type of research that could be conducted on a site-by-site basis to understand the history (and ultimately, assess the potential significance) of creosoted piling groups in the San Francisco Bay. The report structure is modeled after similar reports prepared by Maurice Major (Washington Department of Natural Resources) as part of a similar piling removal study in Washington state.

Three piling groups were chosen as case studies: the remains of a marina off the Tiburon Peninsula in Marin County, pilings associated with an abandoned quarry on the south side of Brooks Island in Contra Costa County, and pilings in the Carquinez Strait identified with the old Pacific Mail site in Benicia, Solano County.

Nothing was known about these piling groups when they were selected for further research. Piling groups of interest were identified from the GIS layer of mapped creosote piles. Sites were selected to represent a variety of Bay regions and piling complex forms. In addition, groups with multiple pilings were chosen (rather than one or two pilings, which have less likelihood of significance).

This research is preliminary, and is not meant to replace comprehensive, site-specific research on individual piling groups. It is also not designed to make assessments of historical significance. Instead, these case studies provide insight into the character of sites with abandoned piles in the Bay, and illustrate the quantity and type of information that may be available to a historical researcher.

CASE STUDY #1

El Campo, Tiburon Peninsula, Marin County

Location and Description

These pilings are located on the northeast side of the Tiburon Peninsula, between Paradise Beach County Park and the end of Seafirth Road. The site was historically known as El Campo, and is in unincorporated Marin County.

The pilings are divided into two groups. The first is a series of six rows of pilings perpendicular to the shore, with a set of 10 larger pilings perpendicular to the rows and on the seaward side. The structure is composed of about 250 pilings, with 8-20 in each row. South of this, the second group is an arc of about 40 sets of alternating single pilings and dolphins hugging the shoreline.

The pilings are remnants of a marina constructed in 1962 or 1963. The marina was built off a bulge of fill created around the same time the pilings were driven (Brady 1961a, 1963). Lines of piles driven for wave protection surround the inner piles composing the marina slips. The small arc is the remains of piles driven for a bulkhead that was abandoned before it was backfilled (Sayce pers. comm.).

History

The El Campo site (also known as Paradise Cove or Monticello Grove) was established July 18, 1891 by the San Francisco & North Pacific Railroad as a weekend recreational and picnicking resort far away from the crowds at more accessible beaches (Board of Railroad Commissioners 1892). El Campo was only accessible by SF&NP's private ferry, the Ukiah, which brought picnickers over from San Francisco on weekends during the "excursion season," starting April 1 (Rodgers 1895, *San Francisco Call* 1900).

Presumably the first wharf at El Campo was built in 1891; it is shown in an 1895 map as "El Campo Landing" (fig. 1). A new wharf was built in 1903 by the Hatch Brothers (*San Francisco Call* 1903). In 1909, a private property owner and the Monticello Steamboat Company (which had leased El Campo for picnicking) "filed petitions for privilege to maintain a wharf" at El Campo, after a scuffle between them over ownership and use of the existing wharf (*San Francisco Call* 1909). By 1916, all that remained of the original landings were "a few old pilings where the docks probably stood" (Clark 1916).

After the Panama Pacific Exposition in 1915, the Crowley Launch and Tugboat Company purchased El Campo, and ran boats that had been constructed for tours of the Bay for the Exposition to the site (Kortum and Baum 1967, Gilbertson 1992). They continued to do so until El Campo became accessible by car. This was likely in the late 1930s or early 1940s; a road is shown by 1942 (fig. 2).

The two structures related to the current complex of abandoned pilings were not constructed until 1962 or 1963. They are not present in oblique photographs taken from April 1959 to May 1962 (fig. 3; Brady 1959, 1961a, 1961b, 1962). They appear for the first time in a photograph from July 1963, constructed off a bulge of newly filled land (Brady 1963). Three gangways connect the fill to the marina, though one finger pier (the northernmost) appears unfinished (fig. 4; Polson pers. comm.). The gangways appear to be connected to a seawall, presumably related to the filled land though no longer visible. The piers are surrounded by larger piles in front and smaller ones to the side for wave protection; lagging connecting the piles is visible. The smaller arc of piles to the north is never shown filled.

The structures are present in photographs through March 1967 (Brady 1967). The next photograph, taken more than a year later in August 1968, shows the site completely abandoned, with much of the structure dismantled (fig. 5; Brady 1968). After 1968, the site looks much like it does presently (figs. 6 and 7), though the gangways and planking along the top of the abandoned bulkhead are visible at least through the early 1980s.

It is not known who built, owned, or operated the marina, nor why the site was abandoned after a relatively short time. Further research into the site would involve investigations into historical newspaper articles from the 1960s, research at the Marin County archives, and interviews with long-time residents. This may reveal more information about the former structures.

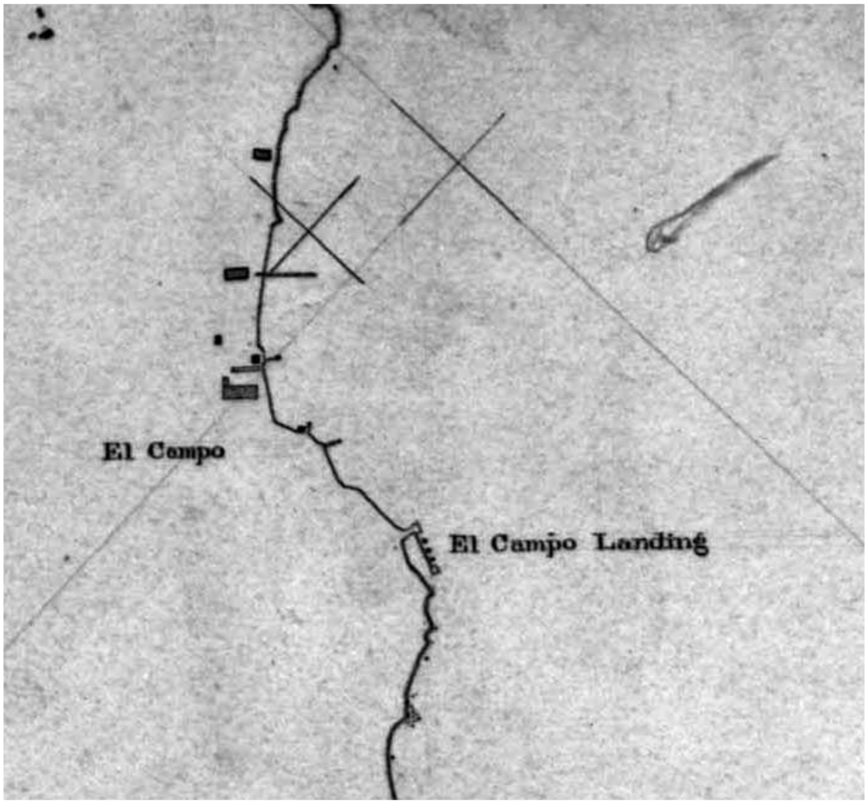

Figure 1. El Campo, 1895. This U.S. Coast and Geodetic Survey map shows the landing and some of the outbuildings associated with the El Campo resort. (Rodgers and Morse 1895)

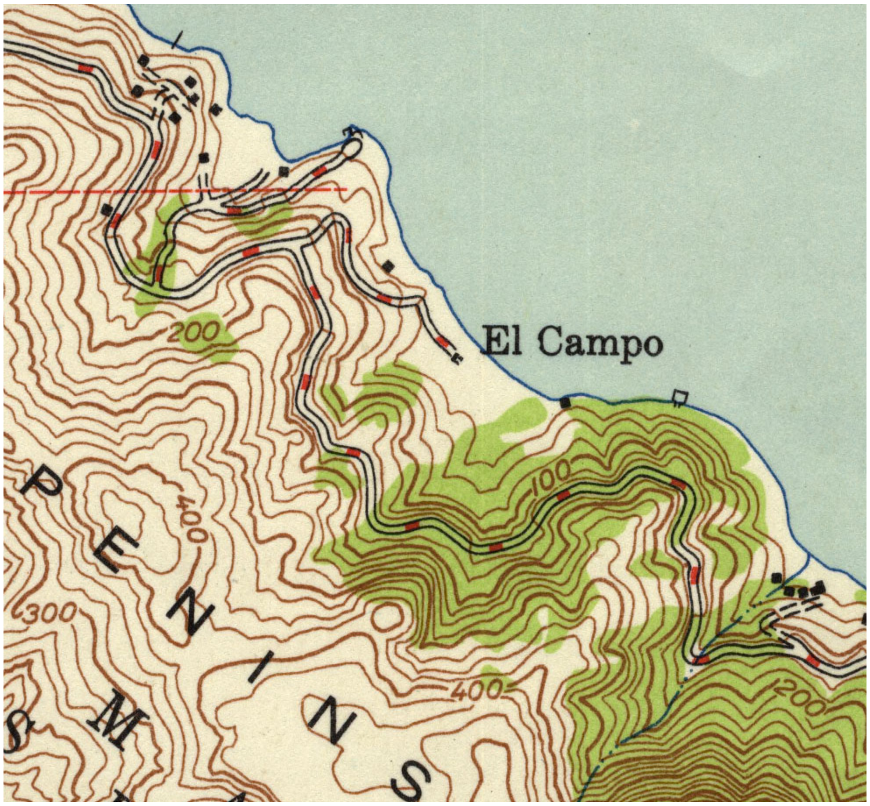

Figure 2. El Campo, 1947. No structures are present. A road, also shown on the 15' San Francisco quad in 1942, connects El Campo to Paradise Drive. (USGS 1947, courtesy of Earth Science and Map Library, UC Berkeley)

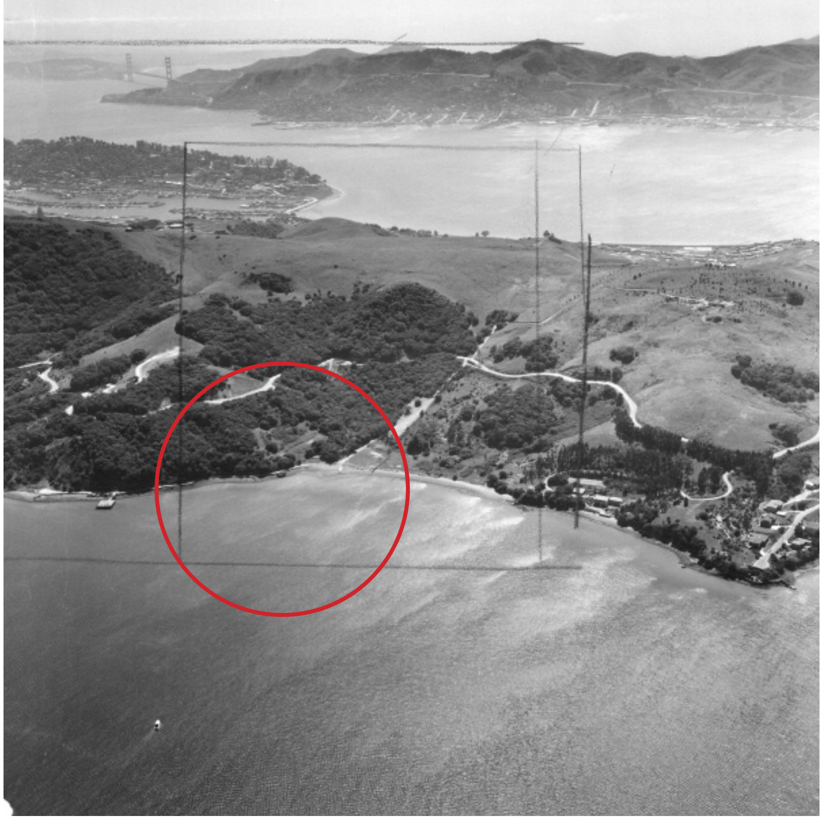

Figure 3. El Campo, 1959. Neither structure is present and no fill has been added. (Brady 1959, courtesy of Marin History Museum)

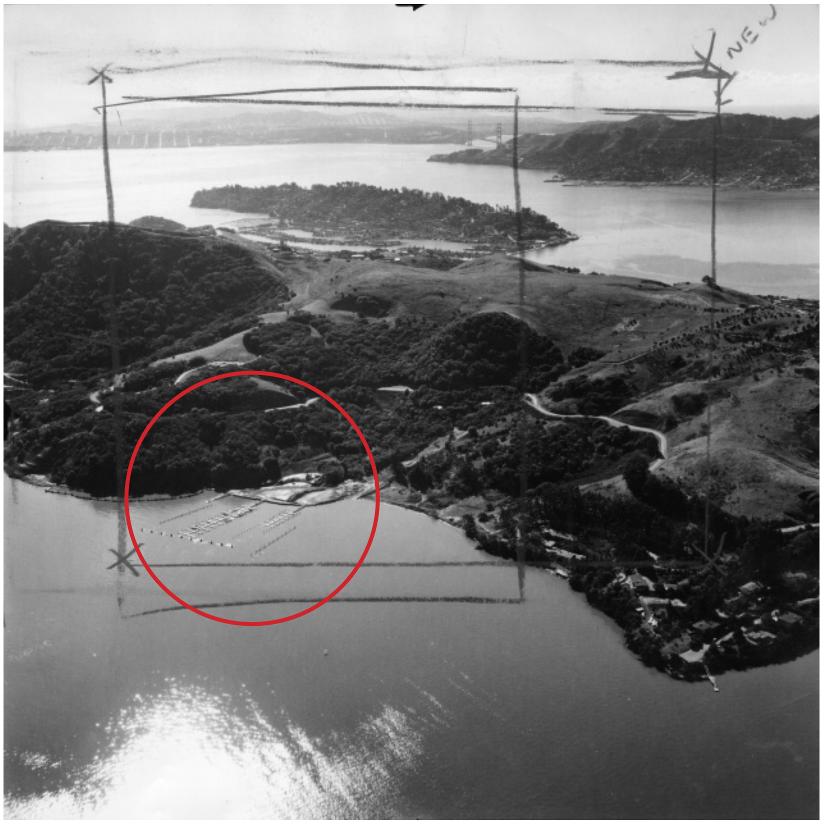

Figure 4. El Campo, 1966. The marina in use. Three gangways connect the bulge of fill to the marina, though only one pier looks fully in use. The bulkhead can be seen at left. (Brady 1966, courtesy of Marin History Museum)

Figure 5. El Campo, 1969. The marina was abandoned sometime between March 1967 and August 1968. Dividers between boat docks have been dismantled and very little remains of the site even in the late 1960s. Gangways can still be seen connecting the filled land to the marina. (Brady 1969, courtesy of Marin History Museum)

Figure 6. Abandoned bulkhead, 2008. (Courtesy of NOAA)

Figure 7. Abandoned bulkhead, 2008. (Courtesy of NOAA)

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CASE STUDY #2

Brooks Island, off Richmond Harbor, Contra Costa County

Location and Description

Brooks Island is located off the Richmond Inner Harbor, south of Point Potrero and west of Point Isabel. Groups of pilings extend off the northeast and southern shores of the island. The southern pilings are the focus of this case study.

Two groups of pilings extend off the southern shore. The eastern group consists of roughly 25 piles extending south with a 120 degree bend to the west. An old railroad track or conveyor belt runs to the shoreline at the base of this group of pilings. The western group consists of 5-6 piles extending to the southwest. Piles cover the gravel beach.

Modern aerial imagery reveals the remains of a quarry on the southern shore in the vicinity of the two groups of pilings. The footprint of a building is situated on the shore north of the eastern piling group. The southern end of Brooks Island also shows evidence of quarrying operations: the hillside is deeply carved out (fig. 1).

History

These pilings are the remains of two separate wharves that served as the loading point for rocks quarried from Brooks Island by a number of different operators between 1888 and 1939. Barges transported the quarried stone to Richmond, San Quentin and San Francisco.

The first wharf on the south side of Brooks Island was constructed sometime between 1888 and 1892. Until 1918 this was the only wharf on the south side. Quarrying operations were underway as early as 1888; in order to remove rocks from the island a wharf was likely constructed around the same time (*Daily Alta California* 1888a). An 1895 United States Coast and Geodetic Survey (USCGS) map depicts a wharf extending southeast off the southern shore of Brooks Island (fig. 2).

From 1895 until at least 1912 this wharf was used to load barges with quarried stone for transport to construction sites or a processing plant. It is not clear if the quarried stone was processed, and if so, whether it was processed on the island or at another site (Sayce pers. comm.). Rocks from the quarry were used at nearby sites: in 1888 the San Francisco Supply Company used 400 tons of rock from the “Sheep Island quarry” (Sheep Island was an early name for Brooks Island; Rego 1996a) in the construction of a Washington Street seawall (*Daily Alta California* 1888b). Similar reports suggest that rock from Brooks Island was used in construction on Treasure Island and for the “south cell block of the San Quentin penitentiary” (EBPRD 1976, McHugh 2002).

Sometime between 1912 and 1917 the quarry ceased operating. While Collier (1983) writes that in 1912 the “San Francisco Supply Company was operating the quarry on Brooks Island,” a 1917 USCGS map labels the quarry as “abandoned” (fig. 3). Presumably the wharf was also no longer in use, though it may have been modified for another use rather than completely abandoned.

The Healy-Tibbetts construction company purchased Brooks Island in 1918 and proceeded to build piers all over the island, including a second wharf on the south side, to the west of the original wharf (Collier 1969, 1983). Two wharves are visible and appear in good condition in 1939 (fig. 4).

As in the first quarrying phase, Healy-Tibbetts shipped rocks to off-island sites. The wharf footprint and the remnant structures on the island itself suggest that the quarry at this time operated on a fairly large scale: a rail car or a conveyor belt moved rocks to the wharves where they were loaded onto barges 150 to 200 feet long (Sayce pers. comm.). It's unclear where the rocks were taken once loaded onto the barges, but Healy-Tibbets owned a crushing plant at Winehaven near Richmond which could have been a destination (Jenkins 1951). While no documentation was found of specific uses for quarried rock during this era, Colliers (1969) wrote that the rock may have been used "in the construction of the Bay Bridge toll plaza, the Berkeley Yacht Harbor and aquatic park, highway roadbeds and waterfront structure bulkheads around the bay."

The quarry ceased operating in 1938 when it was sold to Mrs. Mabel Horton. The closing of the quarry likely marked the last time that the southern wharves were used. The following year a fire destroyed both wharves, leaving behind the piles seen today (figs. 5-6).

The quarry, structures, and wharves on the southern end of the island have been neglected since 1939, and the piers have been left to decay (figs. 6-8). Construction has been focused on the northern end of the Island: Bing Crosby and his Sheep Island Gun Club constructed a pier to the north, and the U.S. Army Corps of Engineers built a breakwater for the port of Richmond between 1924 and 1931 (Collier 1983). The Island received little attention until the opening of Brooks Island as part of the East Bay Regional Parks District in 1990 (Rego 1996b).

Figure 1. Brooks Island, 2009. The remains of two wharves are faintly visible at the bottom of the image (circled in red). The hillside has been carved out as a result of quarrying operations. (Courtesy of Bing Maps)

Figure 2. Brooks Island, 1895. Only one structure is present on the south side of the Island. (USCGS 1895, courtesy of IMC)

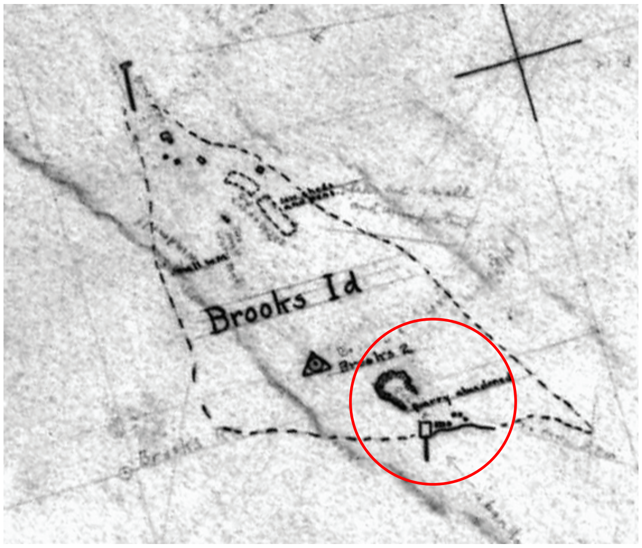

Figure 3. Brooks Island, 1917. One structure is present in the water to the south of the Island. The quarry is labeled "abandoned." (USCGS 1917, courtesy of IMC)

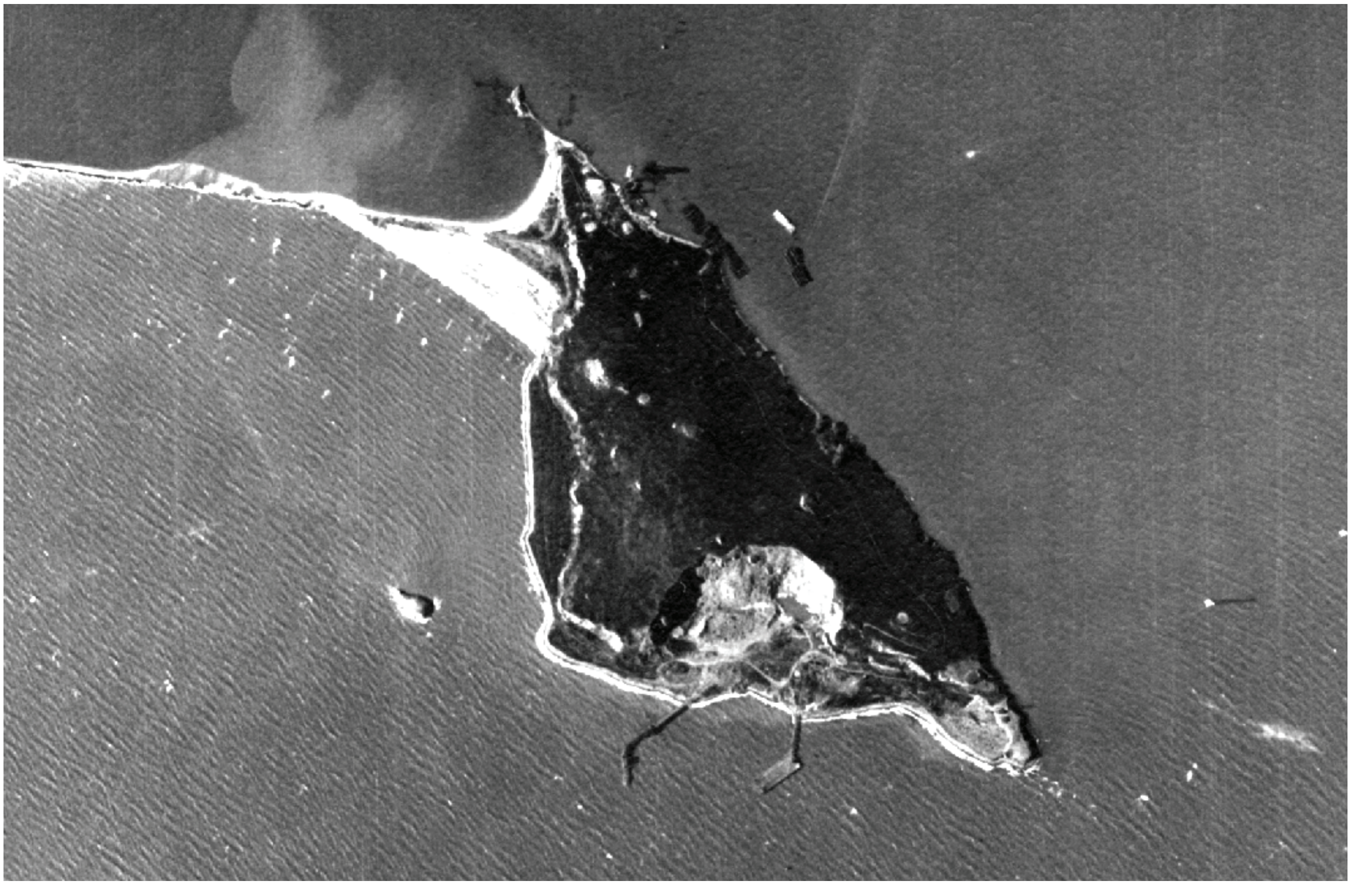

Figure 4. Brooks Island, 1939. A second wharf has appeared (at left) and the original wharf (at right) appears to have undergone significant changes. Both appear to be intact. (USDA 1939, courtesy Science and Engineering Library Map Room, UC Santa Cruz)

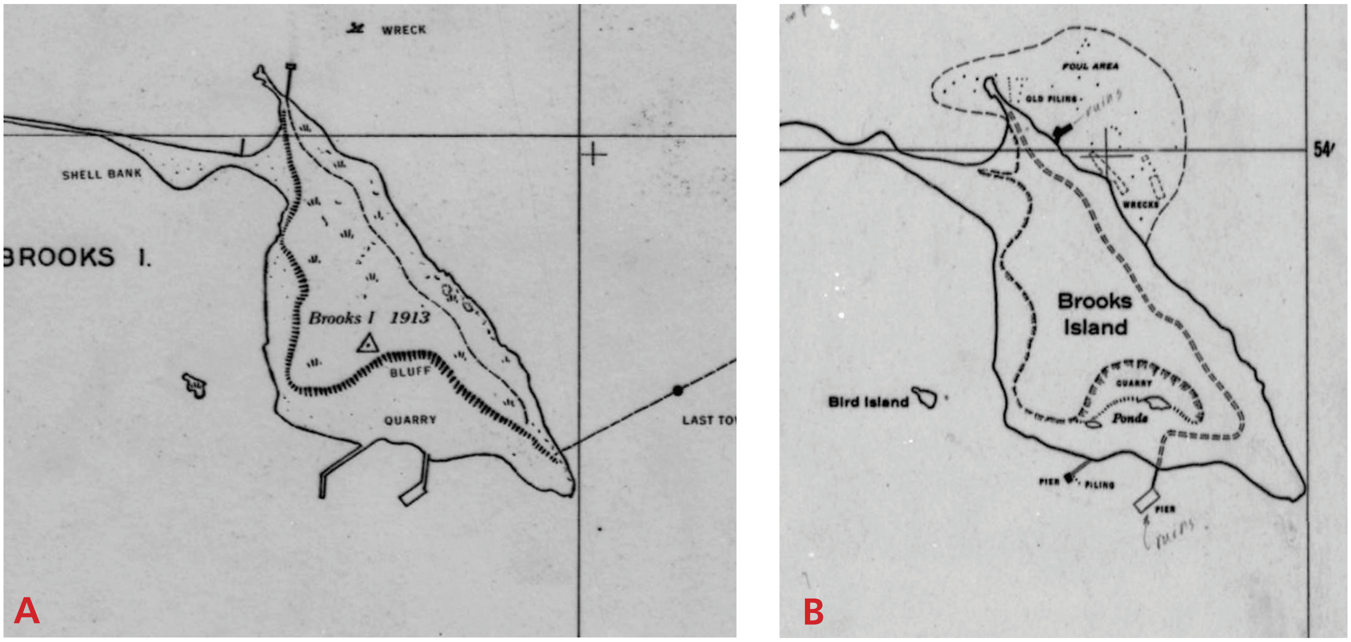

Figure 5. Brooks Island, 1939 and 1945.
A 1939 fire destroyed both wharves. Apparently intact in 1939 (A), the two wharves are still present in 1945 (B), but the wharf on the left has been truncated and is surrounded by piles. The wharf on the right is labeled "ruins." It appears to be connected to some sort of railway or road. (A: USCGS 1939, B: USCGS 1945. Courtesy of IMC)

Figure 6. Brooks Island, 1955. Two structures are still present, though both are in states of disrepair. (Sunderland ca. 1955, courtesy of the Richmond Museum of History)

Figure 7. Brooks Island, 1961. Looking west. The remnants of both structures are visible, and look similar to modern condition. (Unknown ca. 1955, courtesy of the Richmond Museum of History)

Figure 8. Brooks Island, ca. 1960. Looking west, the remains of the western wharf are visible. (Unknown ca. 1960, courtesy of The Bancroft Library, UC Berkeley)

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CASE STUDY #3

Seventh Street wharf, Benicia, CA

Location and Description

The pilings of interest are located south of the city of Benicia, along the north side of the Carquinez Strait. They are roughly between Sixth and Seventh streets in Benicia, along the western edge of the auto off-loading area and to the east of a constructed inlet (fig. 1).

The piling group consists of approximately 18 piles organized in rows of three extending to the southwest. A fenced in complex and two dilapidated buildings lie to the north. The larger building is the original brick foundry built by the Pacific Mail Steamship Company in the 1850s (Rohrs n.d.).

History

The pilings are possibly the remains of an early wharf that linked the industrial buildings north of the area to the waterway (fig. 2). No information has been found linking the remaining pilings to a particular era of construction or specific company. However, it is clear that the waterfront and land in the immediate vicinity of these pilings played a central role in international shipping in the 19th century and in the rise of Benicia as an industrial city.

The Pacific Mail Steamship Company, the Benicia Agricultural Works, and the Yuba Manufacturing Company occupied this area in succession from 1850 to 1973. Pacific Mail moved to Benicia in 1850, building the first wharf in this location in 1853 (Dillon 1980). Along with the wharf, Pacific Mail built repair shops dedicated to maintaining their fleet of steamers. These structures were part of the "first large industrial enterprise in California" (Kemble 1957). Munro-Fraser (1879) described the property and activities of Pacific Mail at Benicia: "two buildings of large dimensions, used as a foundry and machine shop. Here they repair and coal their steamers, besides doing an immense amount of work for other parties." The wharf also played a role in international shipping, since Pacific Mail transported goods between the Isthmus of Panama and California (Cohen 1996). We have not found any historical source depicting this wharf during the time of Pacific Mail.

Baker and Hamilton (which later became the Benicia Agricultural Works) purchased the Pacific Mail property, including its docks, in 1879 (Dillon 1980, Wassman and Bussinger 2004). They produced plows and used the wharf as a warehouse and docking and loading area (Wassman and Bussinger 2004; figs. 3 and 4). Maps produced through the 1880s and 1890s clearly show this first wharf, bending to the southwest across tidal marsh (Bache 1883, USGS 1898; fig. 5). The Benicia Agricultural Works appears to have maintained the original wharf through 1913 (fig.6).

In 1914 the Yuba Manufacturing Company purchased the plant, warehouse and wharf. Yuba manufactured plows, tractors, marine engines, dredges, and howitzers during World War II before closing down in 1973 (Wassman and Bussinger 2004). Yuba also appears to have found an alternative shipping method, perhaps by railroad, because by 1928 the old wharf no longer appears in aerial photography (fig. 7). By 1942, a portion of the tidal marsh was filled in, although the roadway linking the factories to the waterfront remained (fig. 8).

It seems likely that Yuba either removed the wharf and warehouse, or allowed them to decay. There is little evidence of what happened to the wharf after 1942. However, one map from the late 1940s reveals pilings that appear to be the footprint of the old wharf (Colbert 1948; fig. 9). They are in the correct location and are organized in a narrow line running parallel to the shore, reflecting the position and shape of the original wharf. Yuba Manufacturing Company closed down in 1973.

There is not enough evidence to determine whether these pilings represent a remaining portion of the old wharf associated with Pacific Mail and the Benicia Agricultural Works, or some newer construction not discovered through our preliminary research. Though the orientation of the pilings in modern imagery appears to differ from the orientation of the old wharf, it is possible that the pilings may represent a small portion of the original wharf. While the pilings may be associated with an undocumented structure in the area that postdates the original wharf site, there is little evidence of activity along the waterfront in this location since 1913. Further research is necessary to document the association of these pilings.

Figure 1. Seventh Street Pilings, looking south, 2009. The pilings are located south of Benicia, west of the auto-off-loading area and east of a constructed inlet. The remains of the Yuba Manufacturing Co. (bottom left) and the pilings (circled) can be seen. (Courtesy of Bing Maps)

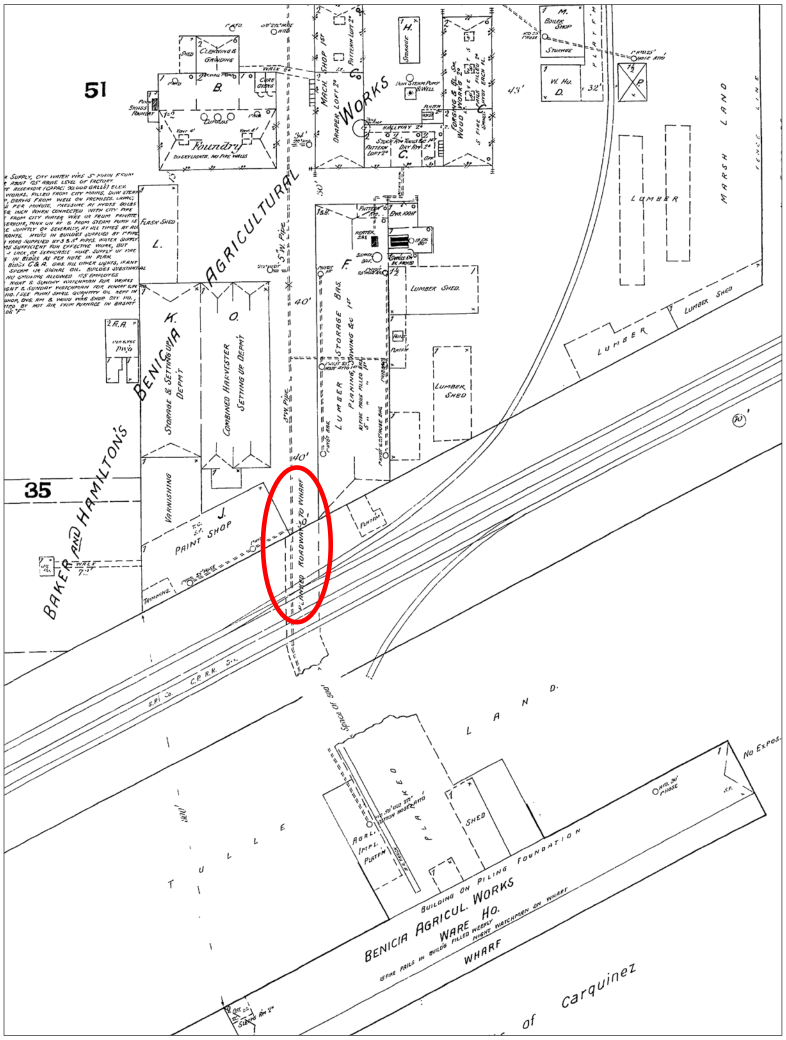

Figure 2. Benicia Agricultural Works structures, 1891. A “planked roadway to wharf” (circled) is shown connecting Benicia Agricultural Works’ wharf to the buildings clustered to the north. The Pacific Mail foundry (top left) still stands today. (Sanborn-Perris Map Co. 1891, courtesy of Earth Sciences and Map Library, UC Berkeley)

Figure 3. Benicia Agricultural Works and wharf, ca. 1881. The long structure on the left is the wharf constructed by Pacific Mail and purchased by Baker and Hamilton (later the Benicia Agricultural Works) in 1879. (Wassman and Bussinger 2004, courtesy of the Benicia Historical Museum)

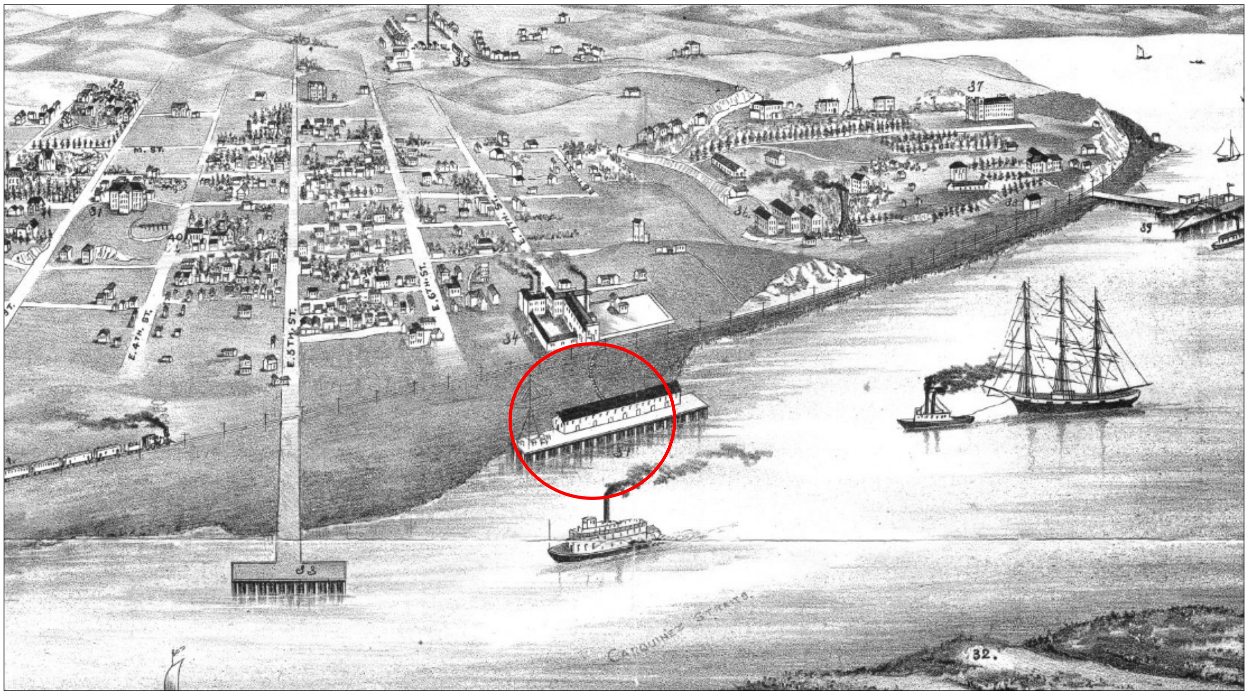

Figure 4. Birdseye view of the City of Benicia, 1885. Another view of the Benicia Agricultural Works wharf and warehouse (circled). (Courtesy of the California State Library)

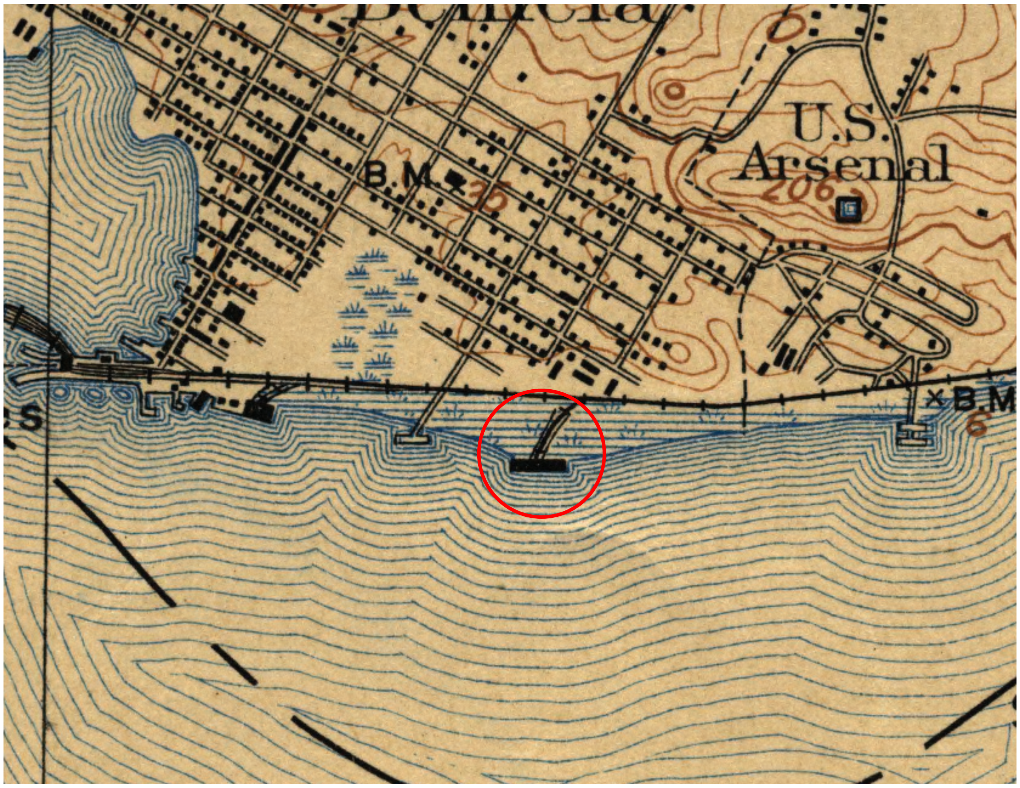

Figure 5. Benicia Agricultural Works wharf, 1898. The Benicia Agricultural Works wharf is still present in 1898. (USGS 1898, courtesy of Earth Sciences and Map Library, UC Berkeley)

Figure 6. Benicia Agricultural Works wharf, 1913. In 1913 the wharf is still the same shape as in previous decades; few changes have apparently been made to the initial wharf since the 1880s. (Sanborn Map Company 1913, courtesy of Earth Sciences and Map Library, UC Berkeley)

Figure 7. Yuba Manufacturing Company, 1928-9. The Yuba Manufacturing Company purchased the east Benicia property in 1914; it appears that shortly thereafter they stopped using the wharf. By 1928 there is no structure visible at the location of the former Pacific Mail and Benicia Agricultural Works wharf. (Unknown 1928-9, courtesy of Earth Sciences and Map Library, UC Berkeley)

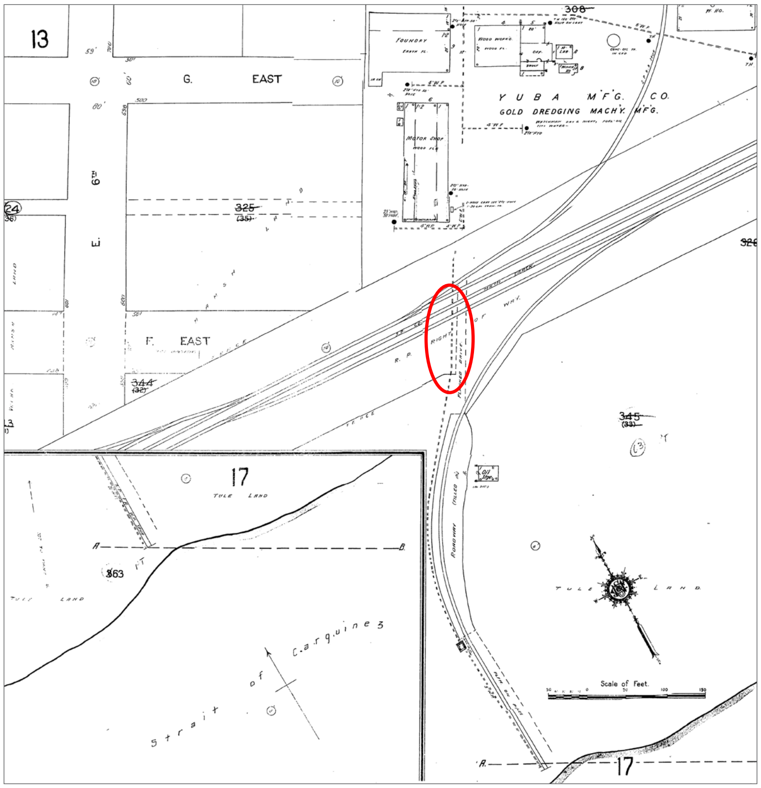

Figure 8. Yuba Manufacturing Company, 1942. A road still links the buildings to the Strait (as in figure 2), but a wharf is no longer present. In addition, while the road was constructed on a platform in 1891, in 1942 it is described as running on top of "filled land" (circled). The previous location of the wharf is at the bottom right of the image. (Sanborn Map Company 1942, courtesy of Earth Sciences and Map Library, UC Berkeley)

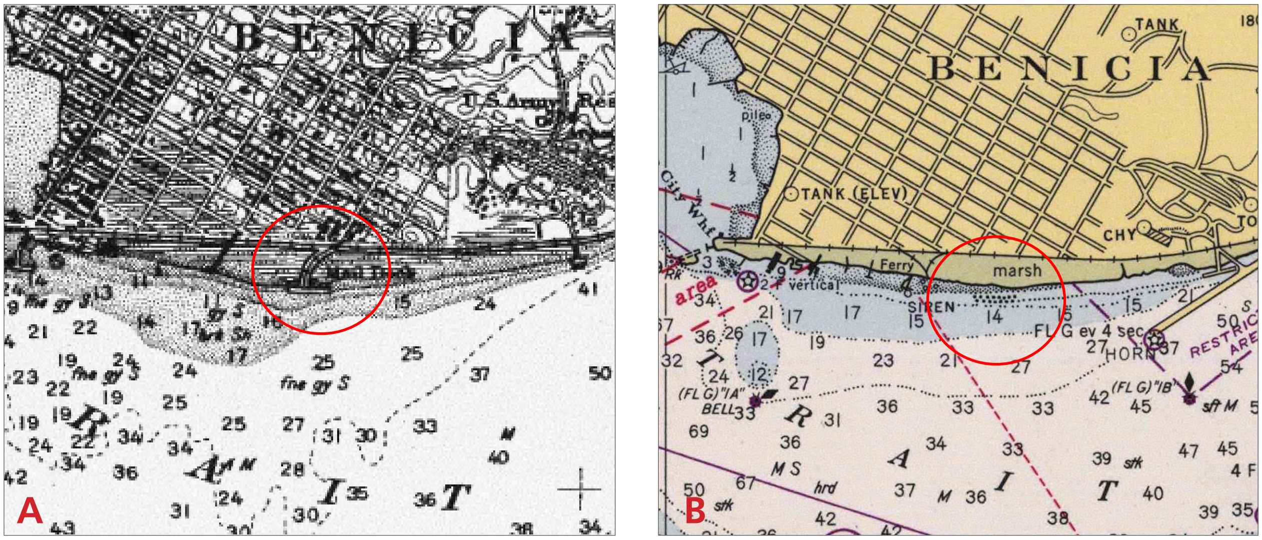

Figure 9. Benicia Agricultural Works wharf, 1910 and 1948. A 1910 coast survey map shows the shape and structure of the wharf at the end of Seventh street and labels it a "mail dock" (A). The 1948 resurvey shows a group of pilings in the same position and are oriented in a similar manner as the 1910 wharf (B). (Jones 1910 and Colbert 1948, courtesy of NOAA)

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REMOVAL OF CREOSOTE-TREATED PILINGS AND STRUCTURES FROM SAN FRANCISCO BAY

ACTION PLAN

ERIC POLSON

Appendix D of
Removal of Creosote-Treated Pilings and Structures
from San Francisco Bay

Prepared by

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Executive Summary

Marine equipment including barges with cable cranes or hydraulic excavators is typically used to remove piles by pulling the pile vertically out of the sediment. This equipment may also be used with a vibratory hammer that aids in removing the pile. Large marine equipment typically needs at least 6 feet of water and smaller marine equipment typically needs at least 3 feet of water to operate effectively.

Land based cranes can only cost effectively reach a maximum of 150 feet from stable shore to remove piles. Excavators can only effectively reach a maximum of 30 to 40 feet.

Removal methods include direct pulling, pulling with vibratory hammer assisting, snapping by pulling sideways and cutting by divers or equipment. Vibratory pulling is considered the preferable, cleanest and most cost effective method for complete pile removal and snapping is the easiest and least expensive method of partial removal. Cutting typically also requires sediment removal by jetting has turbidity impacts and is usually more expensive than snapping.

Complete pile removal should be used in all areas that will be dredged in the future and in areas that may erode in the future exposing remnant piles left by snapping or cutting. Partial removal by snapping is likely the most cost effective method in areas that will not be dredged or scour and reduces the disposal costs by removing only part of the piles. If snapping or cutting is used removal to about 2 feet below the mud line should be required.

Storage of creosote piles for drying to reduce disposal costs may be practical in areas distant from commercial and residential areas. Odors and runoff may be issues for storage. Reduced disposal costs from drying may be offset by extra storage, handling or transportation costs.

In the Bay area creosote piles are typically disposed in Class 2 landfills as non-hazardous wastes. The costs average $40-$60 per ton currently. Residual liability for landfill disposal may stay with the generator forever and may be a future risk management issue.

Transportation of piles to disposal and reuse locations is typically by on highway truck. Marine transport combined with truck is also common. Rail transportation may be cost effective when available at the removal and disposal sites.

Reuse opportunities for used creosote piles appear to be limited to small volumes and may have some impacts in both marine and upland areas. Reuse options should be reviewed as an environmental policy decision. Some creosote wastes can be burned in electrical cogeneration plants however current opportunities appear limited by other sources of supply. One portable cogeneration plant that could burn creosote piles is currently under development and may be able to operate at the removal site.

Permitting creosote pile removal projects will likely require permits from the Corps of Engineers, BCDC and possibly State Lands Commission. Water Quality Certification or Waste Discharge Requirements from the San Francisco Bay Regional Water Quality Control Board will be required. Coordination with NOAA Fisheries, US Fish and Wildlife Service and California Department of Fish and Game will be required for most if not all projects. The cost and time required for permitting pile removal projects will encourage large projects or groups of smaller projects.

Regulatory and resource agencies are mixed on allowing creosote pile removal projects to occur outside the current Dredging and Dredged Material Disposal Work Windows in the Bay. Allowing pile removal projects outside the current Work Windows could significantly lower project costs. Work outside the current Work Windows is less likely in high value habitats and spawning areas.

Enforcement of historic regulatory permit conditions requiring abandoned piles to be removed by the original or current owners is unlikely for all regulatory agencies and therefore is probably not a significant source of funding for pile removal projects.

Research and investigation will likely be required to determine pile ownership for permitting and implementing pile removal projects.

Removal of creosote treated wood debris from shorelines, tidal wetlands and mudflats is possible and may be very cost effective if implemented by well coordinated volunteer efforts and nonprofit organizations.

The San Francisco District Corps of Engineers removes about 800 tons of creosote treated wood wastes per year from the Bay through the Debris Collection and Control Mission. The Corps may be able to help nonprofit and volunteer organizations dispose of limited quantities of creosote treated wood wasted.

1 Action Plan

1.1 Removal Techniques and Costs

1.1.1 Marine Equipment and Techniques Used in Pile Removal

Marine Equipment

The typical equipment used in marine pile removal includes barge fitted with cable cranes, hydraulic cranes or excavators. The barges are moved from site to site with tug boats. Moving barges within a work site is done with winches and cables attached to anchors or by tug boat. The barge holds itself in position during operations with winch lines and anchors or with spuds. Spuds are usually steel piles that are raised and lowered by the crane or with winches. A typical operation would include a crane barge, a tug, a flat deck barge to hold the removed piles and debris and one or more smaller craft to move workers, supplies, anchors and other equipment.

Pile Removal Techniques

Pile removal techniques typically include vertical pulling, vibratory extraction, horizontal snapping and breaking techniques, cutting, hydraulic jetting and combinations of these methods. Pulling and vibratory extraction are techniques for complete removal of the piling and snapping, breaking and cutting are techniques for partial removal of the pile.

Vertical pulling involves gripping the pile with a chain, cable or collar and pulling up vertically with a cable or hydraulic crane. Vertical pulling is typically more difficult and slower without a vibratory hammer and also may result on more sediment being removed or disturbed than with vibratory extraction. In general a larger more powerful crane or excavator is required to remove piles by pulling than pulling combined with vibratory extraction.

Vibratory extraction involves attaching a vibratory hammer to the pile and pulling vertically with a crane or excavator. The vibratory hammer serves to break the seal or suction between the pile and the sediment holding the pile in place. This technique is generally preferred by regulators due to potential lower impacts, is usually quicker than just pulling and may result in lower disposal and handling costs due to less sediment attached to the removed pile.

Horizontal snapping or breaking typically involves pushing or pulling the pile laterally to break the pile off near the mud line. This is a quick method and therefore typically less costly. This method also removes significantly less of the pile than pulling or vibratory extraction and therefore significantly reduces handling and disposal costs relative to complete removal. Most regulators want piles to be removed 2 feet below the mud line. Snapping typically breaks the pile at the weakest point near the mud line which is typically 1-3 feet below the mud line. This technique can leave part of the pile above mud line particularly if the pile is highly degraded. Snapping may result in more sunk or floating broken debris than pulling or cutting especially for degraded piles.

Cutting typically involves having a diver cut the pile at or below the mud line with a hydraulic or pneumatic chain saw or using hydraulic shears mounted on an excavator to cut the pile. To achieve the typical permit conditions of removal 2 feet below the mud line cutting is frequently combined with hydraulic jetting or some other form of minor dredging.

Hydraulic jetting typically uses a high pressure water hose to blow the sediment away from the base of the pile and is typically combined with snapping or cutting operations especially when removal below the existing mud line is required. Jetting is frequently done by a diver or could be done with a jetting head mounted on an excavator or crane. Jetting is typically combined with other methods and is not used alone due to efficiency and impacts. Jetting mobilizes sediment directly adjacent to the pile that is typically contaminated with creosote and also has increased turbidity impacts relative to other methods.

Relative Benefits of Complete Extraction Verses Snapping, Breaking or Cutting
The primary considerations for complete extraction verses partial removal include future uses of the site, navigational hazards, environmental impacts and costs.

If the site will or may be dredged in the future complete extraction is the best option and will likely be the most cost effective option if future projects costs are also considered. Pile debris in clamshell dredged materials is very difficult and expensive to handle and should not be disposed in the aquatic environment. Pile debris in hydraulically dredged material is also difficult, adds to costs and equipment damage claims and will result in creosote contaminated debris in the dredged material disposal or beneficial reuse site. Hopper dredging operations have similar problems with equipment damage and the contaminated debris will be left at the site or transferred to the disposal site or water column.

If the removal project is in an area that may naturally scour or deepen the remaining pile portions could become a navigation hazard in the future and could result in future creosote exposure in the water or benthic community.

Partial removal by snapping or breaking is likely the most cost effective method of removal and also results in lower pile debris handling and disposal costs. However, this method may result in some broken creosote contaminated debris floating, on the bottom or in the water column. Floating booms can capture most surface debris and divers can do some bottom cleaning. However bottom cleaning with divers is not efficient in turbid waters and is labor intensive and expensive. Snapping can be followed with “sweeping” the bottom with a clamshell bucket or excavator to find pile fragments and then attempt removal. Snapping methods may have slightly higher impacts and are less controlled than extraction. However the lower overall project cost due to higher production and less disposal volume may make snapping a preferable method in areas that will not be dredged in the future when viewed from the larger perspective of gaining the greatest reduction in continued aquatic impacts with the available funding.

Cutting or shearing has the advantage of lower debris handling and disposal costs due to partial removal. Both cutting and shearing do result in some fragments lost to the local environment however the volume may be less than for snapping. If hydraulic jetting is used in conjunction with cutting and shearing there are turbidity impacts.

Removal Method Summary

Considering the factors above pulling piles for complete removal should be used if future dredging or dock construction is likely in an area. If there is a significant potential for future natural deepening and the related navigation hazards from exposed pile stubs complete removal should also be considered or required. Cutting and shearing are likely more cost effective if dredging or deepening is not likely to occur in a project area. Snapping is likely the least expensive pile removal method. Jetting and cutting may have the highest environmental impacts of all methods discussed method.

The decision on removal method should also consider the funds available for creosote pile removal and what method will result in the largest amount of creosote treated timber removed from the most important habitats. Creosote piling remaining in the sediment below the active benthic community layer and in an anoxic environment will likely have significantly lower bioavailability than creosote pilings in the water column that are not removed due to lack of funding.

For sensitive habitat areas complete removal by pulling or snapping should be the preferable methods due to the impacts of jetting prior to cutting. For eel grass bed areas it would be important to require that the equipment work at the highest practical tides, not allow equipment to set on the bottom and attempt to limit propeller damage to the eel grass.

1.1.2 Water Depth Constraints for Marine Equipment

The typical large marine equipment used to remove piles and demolish marine structures usually have a draft of 6 feet or more and can only work efficiently in areas with bottom elevations of -6 feet Mean Lower Low Water (MLLW). This equipment may be able to operate relatively efficiently in areas as shallow as -3 feet MLLW if a significant portion of the work area has at least -6 feet MLLW. Areas with eel grass or other sensitive bottom habitats where the equipment should not touch the bottom or permits require a specific equipment clearance from the bottom will increase the water depth required for efficient operations. Large marine equipment typically is used for constructing and maintaining large deep draft commercial ports and harbors.

The typical small marine equipment used to remove piles and structures usually have a draft of about 3 feet and can only work efficiently in areas with bottom elevations of -3 feet Mean Lower Low Water (MLLW). This equipment may be able to operate relatively efficiently in areas as shallow as 0 feet MLLW if a significant portion of the work area has at least -3 feet MLLW. Areas with eel grass or other sensitive bottom habitats where the equipment should not touch the bottom or permits require a specific equipment clearance from the bottom increase the required water depth for efficient operations. Small marine equipment typically is used for constructing and maintaining small craft marinas and shallow draft harbors.

1.1.3 Land Based Equipment Constraints and Considerations

In some areas piling clusters may be close enough to shore for removal with land based heavy equipment such as cable cranes and hydraulic excavators. The removal equipment and techniques used are similar as discussed above for marine equipment.

All land based equipment reach distances discussed below are the distance from stable ground. If the equipment is working on unstable fills, tidal wetlands or mudflats the reach distances are reduced, ground stabilization (such as crane mats) are required and the costs rise significantly.

Large hydraulic excavators can reach a maximum of 30 to 50 feet and typically have an efficient reach for piling removal of 15 to 35 feet. Long reach excavators may have a reach of about 60 feet however they are not typically suitable for pile removal work.

Large cable cranes can have a maximum reach of up to 250 feet however most are not capable of pile removal work at that reach. The maximum effective reach for cost effective pile removal work is likely less than 150 feet.

Land based equipment may be efficient and appropriate for very near shore pile removal, near shore pile removal in very shallow areas or areas with sensitive bottom habitats and pile removal in tidal marsh areas. However most piling clusters will not be able to be completely removed with land based equipment due to limited maximum and cost effective reach distances. Projects requiring both land based and marine based equipment will have higher equipment costs and higher mobilization and demobilization costs. The relationship between cost and reach length are not linear. Longer reaches have substantially higher costs.

1.1.4 Seasonal Timing Considerations for Pile Removal Projects

The regional marine equipment fleet in the Bay area is currently severely constrained by the current regional work windows (see Appendix D1) for dredging and dredged material disposal, pile driving and other marine construction. The economic result of the work windows is that this large expensive equipment sits idle many months of the year while the ownership and maintenance costs are relatively fixed. The crews for this equipment are also impacted by periods of no work and some companies have problems finding or keeping qualified crews. During the work windows crews and equipment may be overloaded and work to many hours. This can lead to crew burnout, higher cost due to overtime and equipment problems related to lack of maintenance time.

Some large marine contractors are able to transport their equipment to other areas of the west coast and increase the effective utilization for the equipment and crews. Smaller marine contractor's equipment is typically too big to truck and to small to go to sea so they sit idle portions of the year.

All contractors who were contacted during this study indicated that if pile removal projects could work outside of the current dredging windows that projects costs would be lower and the crews would have better lives. Therefore it is strongly suggested that pile removal projects be planned, permitted and contracted to allow work outside the current work windows to the maximum extent possible.

Contract performance periods are also an important issue. Typical dredging projects have fairly short performance periods due to navigation needs and work windows. If pile removal projects are set up with long performance periods the contractors will be able to use those projects to fill in between other projects and this will result in lower bid costs. This factor is especially important for smaller projects or projects that include multiple smaller project sites distant from each other.

1.1.5 Marine Equipment Considerations and Costs

Estimating costs for pile removal projects is difficult without having a clearly defined project including the specific permit requirements, project timing relative to work windows, site specific factors such as water depth, pile numbers and length, the disposal site location and other site specific factors. It is suggested that future studies define three conceptual site specific projects, one large project, one small project and one project that includes multiple small project sites.

Contractors are also careful about discussing cost since they all compete with each other on a competitive bid basis and need specific project requirements to give any realistic estimate. Pile removal costs were discussed with many small and large contractors during this study effort. To avoid the contractors concerns over competition and to avoid the appearance of favoring or recommending any specific contractor(s) individual names and company affiliations are not used in this report.

Contractors cost are based on equipment costs, labor costs, fuel costs and well as company overhead, profit and bonding. Fuel cost has been highly variable in the last few years. The amount of other projects available before and after the bid opening date also affects prices based on competition.

The funding sources for a project and the contracting agency also have distinct effects on project bid costs. Federal and State funded projects typically require compliance with regionally adjusted wage standards that are similar to union wage rates. Privately funded projects may not have these requirements and therefore may favor non-union contractors.

Mobilization to and demobilization from a jobsite would typically take at least 1 day each for projects located in most regions of the Bay. The costs to mobilize and demobilize a large marine crane barge and related equipment would likely be in the range of $14,000 $20,000. Smaller equipment could possibly be 50% to 60% of that cost. The message here is that small projects will pay a premium due to a higher percentage of mobilization and demobilization costs. Therefore it is recommended that small projects be grouped into larger projects to reduce the effect of mobilization and demobilization costs.

The basic cost of a fully manned crane barge is on the order of $500 to $1,200 per hour depending on the size, related equipment and required labor rates. The number of piles that a rig can remove and hour is highly variable depending on site conditions and permit requirements. The point is that projects need to be well planned and permitted to keep cost as low as possible.

One contractor that specializes in marine demolition, uses modern methods and equipment, with a seasoned crew and a shallow draft barge that could work in most areas of the Bay estimated that his company could complete a medium to large project (think 500 to 1,000 piles) for about $300 per pile including all transportation and disposal costs. This cost is for complete extraction not cutting the piles below the mud line. This type of cost is just one example. Actual contract costs will vary significantly based on project specific details. This cost does not include the cost of project planning, permitting, contract administration or contract inspection.

The Port of San Francisco applied for Federal stimulus funds earlier this year to help fund a large pier and dock removal program. This project included removal of approximately 473,000 square feet of piers and wharves, many in degraded condition that were constructed with creosote timbers and supported by 7,390 creosote piles. The estimated total cost for demolition and disposal on this project was $8.1 million (about $17.00 per square foot). This cost was for removal 2 feet below the mud line not for complete pile extraction. This cost did not include the planning, engineering, design and permitting costs.

The important messages about cost are that marine demolition and creosote waste disposal are expensive. Therefore to effectively use any funds available and get the largest environmental benefit projects need to be grouped into economic units for planning, permitting, design, administration and contracting.

1.1.6 Best Management Practices for Pile Removal

The Washington Department of Natural Resources as part of the Puget Sound Initiative developed Best Management Practices (BMP) for Derelict Creosote Piling Removal (see Appendix D2). The important points covered by this BMP include:

- vibratory extraction is preferred over direct (vertical) pulling, cutting and other methods;
- complete removal is preferred over partial removal;

- Piles that can not be removed should be cut at least 1 foot below the mud line;
- sediment disturbance should be minimized;
- no barge grounding over eel grass beds;
- all piles, mud and related debris need to be placed in a primary containment on-deck after removal;
- all piles, mud and debris are disposed at the proper landfill;
- floating boom with absorbent pads is required to capture debris;
- project oversight by the State included turbidity testing

Many of these BMP are applicable to San Francisco Bay region and are very similar to conditions for creosote pile removal contained in a September 2009 permit modification issued by BCDC for removal of a fuel pier.

It is recommended that future studies include development of BMPs specifically for San Francisco Bay and/or sub-regions of the Bay. This could be done as part of developing one or more pilot projects. Development of these region/area specific BMPs should be coordinated with all the regulatory and resource agencies and should include considerations for specific valuable habitats such as eel grass beds, tidal wetlands and Pacific Herring spawning areas.

1.2 Disposal and Reuse Options and Costs for Creosote Piles and Timbers

1.2.1 Storage and Drying of Creosote Piles

Most contractors indicated that pile removal projects would require an on-land storage area adjacent to a dock or seawall with sufficient water depth (typically 3 to 6 feet or more at MLLW). Typically a minimum of 1 acre is needed for sorting, cutting, temporary stockpiling and loading trucks and debris boxes even for smaller projects. This on-land area should be as close as possible to the pile removal area for cost efficient operations. Many local contractors do have base yards that could be used for this activity however transit to/from these base yards typically increase costs and may reduce production rates for projects. All on-land storage areas require large truck access for pile removal and disposal.

The standard permit conditions for recent Bay area pile removal projects typically require primary containment of the piles, related debris and sediment. The Washington State BMP for pile removal and disposal also require a primary containment for temporary storage areas. Typically the water associated with removal operations and rainfall on the storage area is allowed to run back into the adjacent waters.

Drying of creosote treated wood waste could reduce pile disposal costs since disposal costs are typically by weight. Several contractors have indicated that drying removed piles has been problematic in most areas due to odor complaints relative to creosote, mud and marine growth on the piles. Any planned drying operations would need to consider nearby residents, businesses, recreational areas and habitats as well as seasonal timing of drying operations. With the typical Bay area weather patterns piles could dry significantly during one dry season (late spring, summer and early fall). Little effective drying would likely occur during the wet season (late fall, winter and early spring). Pile disposal costs saved by drying operations may be reduced or eliminated by double handling costs, local impacts/complaints, seasonal timing and storage area costs. Drying operations should be evaluated on a case by case basis for environmental acceptability and cost effectiveness.

Long term storage of removed creosote pilings prior to disposal does not appear to have any significant cost benefits and may have adverse air quality and storm water impacts.

Temporary pile storage locations and costs will require evaluation on a project by project basis relative to accessibility, distance from project, current adjacent land use and related storage impacts and costs.

1.2.2 Disposal of Creosote Piles and Timbers

Contacts and research indicate that most creosote piles and timbers removed in the Bay area are currently sent to nearby landfills. Several regional landfills including Vasco Road Landfill in Livermore, Keller Canyon Sanitary Landfill in Pittsburg and Potrero Hills Landfill in Suisun do accept various types of creosote treated wood waste. Also several waste management companies offer debris box services for creosote treated wood waste.

In California Landfills are typically identified as Class I, Class II or Class III landfills. Class I landfills typically accept hazardous and toxic wastes, Class II landfills typically accept some hazardous and all inert wastes and Class III landfills typically accept primarily inert wastes. Since a specific set of waste acceptance criteria is typically developed for each individual landfill material acceptance standards may vary widely for landfills within a Class. In general creosote treated wood is accepted at most Class II landfills and some Class III landfills. Due to cost creosote treated wood is typically not disposed at Class I landfills.

Disposal rates vary among the landfills contacted from about $40 to $60 per ton. Most landfills indicated that rates were somewhat negotiable for larger volumes. All the landfills indicated they would accept mud, concrete, asphalt, metal and related debris attached to or associated with the creosote treated wood waste. However most landfills also indicated that free water or liquid was not acceptable with creosote treated wood waste. Several landfills indicated that they require non-hazardous waste manifest for creosote treated wood waste. The non-hazardous waste manifest basically documents ownership of the waste to the generator forever. There is a potential that future liability for the disposed waste could fall back on the owner. Therefore this may be a risk management issue for government agencies and individually involved in pile removal projects.

Various contacts indicated that they used waste management companies for disposal of creosote treated wood waste. Typically these companies deliver a debris box to the project site and haul the full boxes to a landfill. Typically these companies have a franchised area of service in a specific county or portion of a county. Costs vary by area and company. Bay Cities Refuse serves areas of southern Marin County and currently charges about $1,100 per 42 cubic yard debris box.

Debris box type services have the benefit of providing the primary containment typically required by permits and BMP's. These boxes also have a known fixed cost per volume that is not dependent on weight therefore drying of piles is not required. Additionally the removal contractor does not need to have trucks or a trucking sub-contractor.

A direct comparison of cost between landfill charges per ton and debris box services by the cubic yard is difficult due to many factors including the relative quantities of saturated piles/timbers verses dry materials from above the waterline and the amount of empty volume in the "full" debris box. Some of the contractors contacted found it more cost effective to provide all handling and trucking and pay by the ton and others preferred the debris box concept.

1.2.3 Transportation of Creosote Pile

The conceptual transportation options include road and highway transportation, rail transportation, marine transportation and multi-modal transportation (a combination of highway, rail and marine transport).

All pile removal and disposal operations in the Bay area that were investigated appear to only use road and highway transport to disposal and reuse locations due to cost, access and logistics considerations. On-highway trucking of piles to local landfills typically has the advantage of being very flexible, requiring a minimum of land based storage and access space and require less coordination and timing considerations than rail transport.

Rail transportation could be economically feasible if relatively large pile removal projects happened to be adjacent to rail facilities and utilized a disposal or re-use option that also had rail access. Previous LTMS studies looked at out of state disposal of contaminated dredged materials via rail. At that time the economics were not favorable due to transportation costs and double handling costs except for potentially large volumes of sediment that required placement in a Class I landfill. The basic factor involved in these types of materials was saving the significant in-state generator fees by sending the Class I waste out of California. Since creosote treated wood waste are typically accepted at Class II landfills locally rail transportation is likely only a cost effective option for a few large projects that have direct access to rail loading without trucking to rail and the resulting double handling. In projects where a large number of piles will be barged to large storage areas or contractor's yards that happen to have rail access and sent to landfills with rail access then rail transportation may be a cost effective option. Evaluation of rail options would need to be done on a project by project basis.

Barge transportation is used in many pile removal operations in the Bay area and barge and truck transportation is the typical multi-modal transport used in the area. Large pier and dock renovation projects typically included the contractor removing and disposing of all creosote treated wood wastes. In several of these projects the contractor transported the piles to their local yards by barge for stockpiling, handling and disposal. Most of these projects used trucking to deliver the piles to the disposal or reuse site.

At many of the pile removal projects at refineries the contracts did not include transport and removal of the pilings and the refinery handled final disposal operations.

As indicated above multi-modal transportation is typically more costly than single mode transport due to the cost of repeatedly loading, unloading and handling of the pilings.

The specific transportation technique(s) most suitable and cost effective for specific pile removal projects will need to be assessed on a project by project basis and is highly dependent on site access, storage, permit conditions and disposal or reuse options.

1.2.4 Reuse Options for Creosote Piles

Reuse of creosote treated piles could conceptually include reuse as marine pilings after encapsulation, marine reuse in above the waterline applications, use as fuel in cogeneration plants and a wide variety of non-marine reuses. Cogeneration plants in this case are plants that burn waste products of various types generate electricity for on-site uses or for commercial resale.

A few years ago a Bay area marine contractor was able to save significant disposal costs by giving away a significant number of sound creosote pilings to an out of state contractor. This option is unlikely to exist now or in the future for any significant number of pilings due to increasingly stringent regulations in other adjacent states.

Reuse as marine pilings after encapsulation may be an option only for pilings and timbers that are sound and in good condition. Since this study is primarily focused on the removal of older abandoned pilings it is unlikely that a significant fraction of the pilings removed would be completely sound and in good condition over the entire length of the pile. However, the lower portions of long pilings that have continuously been in an anoxic environment (likely 3 feet or more below the lowest mud line over the installed life) would likely be sound and in good reusable condition.

Sound portions of removed piles may be suitable for reuse in the Bay area after encapsulation in shallow water projects such as small craft marinas, small recreational fishing piers in shallow water and related uses. Obviously this type of reuse would require finding a willing party to buy or take the reusable piles sections for free. This type of reuse could significantly reduce pile disposal costs for some projects.

If willing parties are available, cost effective reuse would be heavily dependent on rehandling, storage and encapsulation costs and the inherent local demand for short pilings. It is suggested that a regional policy decision be made on this type of reuse. Obviously to spend public or private funds to remove creosote related contamination from the Bay and then reuse these pilings in a manner that could potentially introduce the same contamination in the future would be unwise.

Reuse of creosoted treated pilings at cogeneration plants that can burn these wastes in a controlled and environmentally acceptable fashion and generate electricity is potentially a very good reuse. Various sources have indicated that the rail road industry uses this reuse option extensively for old rail road ties and other creosote wastes. Unfortunately it seems that the cogeneration plants within economic trucking distances from the Bay have all the supply from the rail road industry that they are able to use. One local marine contractor has repeatedly and unsuccessfully tried to develop this reuse option over much of the last decade.

In general transport to distant cogeneration plants via on-highway truck would likely be both economically infeasible and environmentally unwise. There is a potential that cooperative efforts with the rail road industry could be a viable alternative for regional or distant cogeneration reuse.

One interesting cogeneration technology currently under development is a modular portable plant that can be moved to a site with on highway trucks. This plant may not generate significant power for commercial resale or on-site uses. The concept of this plant is to eliminate waste products without disposal in landfills and avoid the cost and potential long term liability for waste generators associated with landfill placement of hazardous or non-hazardous wastes. Conceptually this system would grind and burn wet creosote piles in a controlled system that generates electricity. Most of the electricity produced would be used internally by the operation. Technically this system is a fluidized bed combustion chamber and the system uses hot air to drive an electrical generator with a turbine.

The remaining questions currently under investigation about this system are can this system burn creosote wastes in an urban area within the emission standards required and the cost of this type of operation relative to current landfill costs. Conceptually this system could provide on-site elimination of creosote pile wastes without any additional surface transportation or disposal costs and eliminate the impacts associated with transportation and the long term liability associated with disposal. As indicated above the economics of this system are currently under study and no specific information is currently available to compare the cost of this system with current transportation and disposal costs. The contact for this system is Perry McLain, pmclain@pacbell.net.

Other potential land based re-uses include selling or giving the piles to the landscape industry, fencing contractors, ranchers or other land based industries. This option is likely limited to a few hundred piles per year based on information provided by regional contractors. In any case it is unlikely that the thousands of piles generated by large removal projects could be sold or given away in a timely fashion for these types of uses. Additionally, reuse of these piles on land will likely have impact to air quality and soil quality. It is suggested that a policy type decision be made relative to sending creosote treated piles to land based reuses.

1.3 Creosote Pile Encapsulation Techniques

Encapsulation techniques are methods for covering piles in place without the need to remove or replace the pile. These techniques are used for exposed piles and piles under docks. Many types of encapsulation methods for marine piles are available including non-structural encapsulation that reduces or eliminates pile degradation from marine organisms and/or isolates contaminates from the aquatic environment and structural encapsulation that restores and preserves the structural strength of degraded piles.

A few of the available methods include liquid coatings that harden in place in the marine environment, plastic sheeting to wrap piles, fiber glass and other synthetic structural overlays that are assembled over the pile in-situ and sealed with epoxy, grouts and other materials, various fabrics that are used to contain cement, grout or similar products applied around the in-situ piles and many more concepts.

For this project study encapsulation techniques may be appropriate for creosote piles that are still in active use, abandoned piles with historical significance, abandoned piles in habitats to sensitive to disturb, abandoned piles in locations where they are difficult or not cost effective to remove and possibly as a cost affective alternative (long term or short term) to removal in general.

Regional contractors and port authorities have recently used wrapping with 60 mil thick Ultra High Molecular Weight Polyethylene and securing with stainless steel nails and structural fiberglass bolt on overlays that are sealed with epoxy and filled with grout.

Future study efforts should focus on specific potential project sites and the specific types of encapsulation techniques that would be appropriate or superior for the potential needs discussed above. In particular an encapsulation material that provided a superior exterior surface for Pacific Herring spawning may be important for specific areas in the Bay. Additionally study efforts should also evaluate cost effective encapsulation techniques for high value habitat areas such as eel grass beds and tidal wetlands where pile removal is desired and the impacts of pile removal are not acceptable.

1.4 Permitting and Ownership Issues

1.4.1 General Permitting and Inter-Agency Coordination

Summary

The approach to this section was to contact staff at the regulatory and resource agencies and discuss the range of pile removal projects envisioned by this study. In general most regulatory and resource agency staff were positive about pile removal projects.

Permitting pile removal projects will likely be easier and quicker than permitting for dredging projects. Regulatory and resource agency staff had mixed viewpoints on the difficulty of gaining regulatory approval for working outside the current Bay regional work windows for dredging in specific areas and related to specific threatened or endangered species and the related habitat areas.

US Army Corps of Engineers Permit Requirements

Jane Hicks, Chief of the Regulatory Branch was contacted relative to pile removal project permitting. Jane indicated that a Corps permit would be required for any pile removal project. The type of permit required would by evaluated on a project by project basis and large, complex projects could require an individual permit. Project permitting requirements would depend on the project size and the nature and type of adjacent habitats. No general conclusions about the specific permit path could be drawn based only on project size without considering project by project habitat impacts and concerns.

Several Corps Nationwide Permits (NWP) may be applicable to projects that include creosote pile removal as a part of habitat or cleanup projects including NWP 27 Aquatic Habitat Restoration, Establishment and Enhancement Activities and NWP 38 Cleanup of Hazardous and Toxic Wastes. In addition several other NWP may be applicable for projects removing creosote piles during the maintenance and repair of existing permitted structures including NWP 3 Maintenance and NWP 28 Modifications to Existing Marinas. The current Corps Nationwide Permits were authorized on March 19, 2007 and expire on March 18, 2012.

Many creosote pile removal projects may fall under a simplified permit procedure called a Letter of Permission (LOP). General LOP guidance provided by the Corps was reviewed and it appears that “minor” work for demolition of structures may be permitted under LOP procedure “B” if the project removes pilings completely or remove piles 2 feet below the mud line and no debris are allowed to enter the waterway. Procedure “B” requires only after-the-fact notification to the other regulatory and resource agencies and also requires notification of US Geologic Survey, US Coast Guard and the US Navy. In practical application the Corps will likely request or require that the applicant coordinate in advance with other regulatory and resource agencies on any significant pile removal project.

LOP procedure “A” may be applicable to pile removal projects that are not considered “minor” in procedure “B” above. Procedure A requires coordination in advance with all applicable regulatory and resource agencies and possibly adjacent landowners, allows a 30 day comment period and requires confirmation that BCDC has or will approve the project and that the SFBRWQCB has issued or will waive water quality certification.

An LOP under procedure “A” or “B” will likely be a significantly faster route to project approval than an individual permit for many projects. Further coordination with the Corps to define “minor work” relative to LOP’s for regional pile removal projects is recommended in future study efforts as part of a comprehensive coordination with all regulatory and resource agencies for general, pilot or specific pile removal projects.

San Francisco Bay Conservation and Development Commission Permit Requirements

Staff contacts at the San Francisco Bay Conservation and Development Commission (BCDC) included Bob Batha, Brenda Goeden and Carolynn Box. BCDC staff indicated that removing piles from the Bay was removal of Bay fill and did not necessarily require a BCDC permit action. BCDC staff did indicate that related impacts (such as dredging or contaminated sediment movement) related to pile removal projects would likely require a BCDC permit. In general BCDC would want to review all pile removal projects to insure compliance with the Bay Plan and applicable rules and regulations and some type of permit or approval will likely be required for most projects.

The specific permit required could vary from a region wide permit to individual permit depending on the scope and specific activities in individual projects. BCDC staff indicated that for most pile removal projects the highest level of permit required would likely be a minor permit that may take from 1.5 to 3 months to complete.

BCDC staff indicated that the timing of pile removal projects relative to endangered species windows would be based on approval by or consultation with CDF&G, USF&WS and NOAA Fisheries and that they preferred the work occur within the existing regional work windows if possible.

BCDC staff prefers that piles be pulled out completely where possible. If complete removal is not possible pilings are typically required to be cut 2 feet below the current bottom. BCDC staff is aware that cutting below the bottom typically requires jetting or other sediment movement techniques.

A recent BCDC permit amendment (Oct. 2009) issued for the removal of a 114,000 square foot dock that included removing a total of about 440 piles including 180 creosote treated piles was reviewed. This permit required a two-day test removal to assess the success of complete pile removal by vibratory hammer. Additional conditions included a floating surface boom to contain floating debris, keeping removal equipment out of the water when possible, primary containment for piles and related sediment and debris, slowly lifting piles through the water column, allowed no sediment removal from extracted piles, and required disposal of all creosote piles, sediment and related debris at an authorized upland disposal site. This permit also required the submission of 12 specific work plans and 5 of the plans were specifically related to debris, waste and spill prevention. These plans required a 90 day review by BCDC staff. The work window for this project located in Carquinez Strait was from June 15th to October 31st.

San Francisco Bay Regional Water Quality Control Board Permit Requirements

Elisabeth Christian of the SFBRWQCB staff indicated that Water Quality Certification for all creosote pile removal projects would likely be required and that no general permits are applicable to pile removal projects. Projects would be evaluated on a project by project basis by the individual staff covering the county where the project is located. Permit fees and timeframes would vary by project size, impacts and related details. Elisabeth was open to considering pile removal work outside of the current dredging windows if the projects had limited or no impacts. Pile removal projects that involved significant impacts or dredging volumes could require Waste Discharge Requirements.

California State Lands Commission Coordination Requirements

Donn Oetzel a public lands management specialist at State Lands Commission (SLC) was contacted relative to the coordination required for creosote pile removal projects. Donn indicated that SLC interest in pile removal projects would include protecting California's legal interests, CEQA compliance and that such projects would likely require a title search.

Protecting the legal interests of California would be a factor if the project is on land owned by the State. A title search by SCL staff would typically be required to determine if the land involved was State owned and if that land had been leased by the SLC to any public agency or private entity. For land owned by the State and not leased the SLC would need to insure the project did not damage the land and would typically require financial liability and insurance coverage for contractors. For State land leased to others SLC would likely require permission from the lessee for pile removal projects.

SLC would need to insure CEQA compliance for pile removal projects and Donn indicated that CEQA compliance would typically be handled by other State permitting agencies.

Donn was unsure if a specific type of action or permit would be required by the SLC for pile removal and indicated that it was good to remove abandoned piles and that liability and removal methodology that protected State land were the important points. It is recommended that future study efforts include two site specific pilot projects, one on State land and one on leased State land. This approach would help define the processes, timeframes and costs associated with SLC approval of creosote pile removal projects.

NOAA Fisheries Coordination Requirements

David Woodbury a fisheries biologist with NOAA Fisheries was contacted relative to potential creosote pile removal projects. David supports creosote pile removal projects and has visited pile removal projects in progress. David was open to considering pile removal projects outside the typical dredging windows and may support pile removal during Pacific herring closures for dredging due to the potential adverse effects of herring spawning on creosote treated piles. David indicated that he was familiar with and supportive of the pile removal BMP's developed during the Puget Sound Initiative and that he would like to see a Bay area industry conference on pile removal techniques. David indicated that normal NOAA consultation on permits issued by other agencies would be required for pile removal projects and also indicated that future Green sturgeon windows could affect pile removal projects.

Comments received on the draft report from Korie Schaeffer of NOAA Fisheries indicated that the consultations required for creosote pile removal projects would include Section 7 consultation relative to the Endangered Species Act (ESA), Essential Fish Habitat (EFH) consultation relative to the Magnuson Stevens Fishery Conservation and Management Act and Fish and Wildlife Conservation Act (FWCA). These consultations are triggered by a federal action such a Corp permit or authorization relative to the Clean Water Act or the Rivers and Harbors Act.

California Department of Fish and Game Coordination Requirements

Contacts with CDF&G included Vicki Frye, George Isaac and Scott Wilson. Vicki covers most areas of the North Bay, George covers most areas of the central and south Bay and Scott covers Carquines Strait and Suisun Bay. Information has been received from Vicki and George to date. Numerous attempts to contact Scott Wilson were not successful.

In general consultation or coordination with CDF&G will be required for all pile removal projects. Any projects that are in a stream or river will also likely require a Streambed Alteration Agreement issued by Scott Wilson or other staff from CDF&G Region 3 office in Yountville California.

Vicky Frye recommended complete pile removal by vibratory extraction where possible and removal at 2 feet below the mud line in cases where vibratory extraction was not possible. Vicky did not want removal work done during Pacific Herring season in herring spawning areas. Vicki also indicated that areas of eel grass would require protection from vessels sitting aground, propeller damage or propeller scour. Vicki did not necessarily see significant issues for other state listed species from pile removal operations in general, however each project would require a specific CDF&G review based on area, scope and project specific plans and requirements.

George Isaac indicated that a project by project evaluation was needed and the Pacific Herring was a significant concern. George also indicated specific concern for the protection of eel grass areas and that if dredging was involved the work would need to be completed within the existing work windows.

U.S. Fish and Wildlife Service Coordination Requirements

As part a of any federal permits issued for creosote pile removal projects coordination with U.S. Fish and Wildlife Service will be required for listed threatened or endangered species as part of section 7 consultation under the ESA. This coordination is typically initiated by the permitting agency and may include additional effort by the permit applicant. This coordination may add significant time to permit processing due to U.S. Fish and Wildlife Service staff workloads and response times.

Unfortunately staff from the U.S. Fish and Wildlife Service has not responded to repeated contacts. Therefore no specific staff opinions are available at this time. It is recommended that future study efforts include additional efforts to engage U.S. Fish and Wildlife Service staff.

1.4.2 Seasonal Timing Considerations for Pile Removal Projects

As discussed in the Removal Techniques and Cost section the regional marine fleet is relatively confined by maintenance dredging and disposal work windows in the Bay area. These windows are provided in Attachment A. One focus of this report is to assess if creosote pile removal operations would be allowed outside the existing work windows. As discussed earlier in this section individual regulatory and resource agency staff had mixed viewpoints on allowing pile removal operations outside the existing work windows. Given the mixed viewpoints it is likely that most or all pile removal projects would require multiple resource agency consultations for work outside these windows. Additionally, all projects including work areas containing eel grass beds or in or near tidal wetlands habitat would require multiple resource agency consultations all year. These consultations will increase the time and cost to permit pile removal project.

As plans for specific creosote pile removal projects or focused areas for pile removal projects are developed in future study efforts further coordination with regulatory and resource agency staff is recommended as a potential means to define when and where the existing work windows may be relaxed based on Bay sub-regions, specific valuable habitat types, pile removal BMPs and other factors. This effort could help save permitting time and expense involved in a project by project approach to work windows.

1.4.3 Potential Enforcement of Historic Permit Conditions for Pile Removal

Summary

Discussions with staff from the Corps, BCDC, SFBRWQCB and SLC have indicated that it is unlikely that any of these agencies would be able to substantially enforce conditions in historic permits that require the removal of abandoned piles. The limited staff resources and current enforcement case load combined with the significant level of research needed to find and evaluate historic permits and locate potentially responsible parties (PRPs) makes it unlikely to highly unlikely that regulatory agency enforcement actions would result in PRP funding of a significant number of creosote pile removal projects.

US Army Corps of Engineers

Corps of Engineers Regulatory branch staff indicated that permits issued prior to 1993 are not available in a searchable database. Therefore, it is assumed that most abandoned piles would require the hand search of microfiche files or stored paper documents. The Corps typically requires a FOIA request for permit documents and does not have staff resources available to assist search efforts. There has been some Corps enforcement activity related to navigation hazards from abandoned pilings in the Bay however it is not frequent. Enforcement of Corps permit conditions requiring pile removal on a case by case basis would require the local Corps staff to get senior staff approval and to convince the US Attorney of a compelling reason for legal action. Given the staff availability and the resources required it currently appears highly unlikely that enforcement of Corps permit conditions would be a viable option for most abandoned pile complexes.

San Francisco Bay Conservation and Development Commission

BCDC began regulating activities in the Bay on September 17, 1965, therefore pile placement prior to this date are not covered by BCDC permits. In the early years of BCDC regulation permits were typically light on enforcement provisions that would give BCDC the ability to require pile removal. Searching BCDC records for historic permits that may require pile removal is not an activity that BCDC currently has staffing resources to assist with. BCDC's ability to enforce specific permit conditions for piling removal would need to be evaluated on a permit by permit basis. In general the current staff resources available for enforcement are very limited and that staff has a significant existing workload. Therefore, it appears unlikely that BCDC would be able to provide significant assistance in enforcing pile removal requirements in historic permits even if other resources were able to complete the significant research required to locate and evaluate specific permits.

San Francisco Bay Regional Water Quality Control Board

The SFBRWQCB started issuing permits in the 1980's and only permits and actions after the mid 1990's are in a searchable database that requires a known board order number to search. As with most other regulatory agencies, staff resources are not available to research and initiate a significant number of enforcement actions without compelling environments impacts.

SFBRWQCB staff indicated that it was possible that enforcement action could be taken under an Abatement Order or Cleanup Order type process if a strong case was made that abandoned piles were causing a significant threat to the waters of the state. The initial indication from SFBRWQCB management was that they wanted to see the final report from this study to consider the conclusions and recommendations. Potential future support for enforcement actions would be based on measurable impacts, benefits, costs and feasibility and would also require the support of executive management.

California State Lands Commission

State Lands Commission staff indicated that even if the permits or leases that SLC may have historically granted for pilings included conditions requiring removal upon expiration or abandonment that it is unlikely that the SLC would be able to effectively enforce any such provisions. SLC staff indicated that lease conditions vary, removal may not be required in leases and that many historic leases may have under funded bonds for pile removal. Additionally, the significant staff resources required to research historic leases, find PRP's and bring legal action are not available.

1.4.4 Potential Need for Legal Analysis of Pile Ownership

As discussed in Section 1.4.1 above a SLC title search on the area included in a pile removal project should establish the current or historic owner(s) of the structures. In the case of private lands the county property records may also need to be searched. After the initial search the current landowner could be contacted about approving, accomplishing or assisting with pile removal in that area. In some cases the land owners or lessee my not be available to respond or may choose not to respond. At that point it may be necessary to establish a legal analysis or action to determine what permissions or authorizations are required or recommended to proceed with a removal project. Typically BCDC and other regulatory agencies are not able to issue permits without the permitee demonstrating legal authority/approval for the proposed actions on private or public lands.

1.5 Removal of Creosote-treated Debris from Intertidal Areas

Much of the shoreline of San Francisco, San Pablo and Suisun Bays has trash and debris accumulated from land based and water based human activities. Some of this debris is creosote treated wood debris. Tidal wetlands in San Pablo Bay and many other areas typically contain significant amounts of creosote wood debris. Mudflat edges may also contain this type of debris. This material is typically not highly visible in tidal wetlands due to vegetation such as pickle weed. Some of this debris is mobilized from mudflats and tidal wetlands during extreme tides and storms and washed against levees or above the normal high water line. Once deposited on the levee side slope or above normal tidal levels this creosote debris may be removed with hand labor or relatively small equipment typically at low cost relative to removing in place piles and other marine structures with heavy land and marine equipment. The concept is that this creosote treated wood debris may be cost effectively removed by volunteer or small contracted efforts when and where opportune thereby removing potential contaminant loads from these productive wetland and mudflat habitats. Beyond the contamination impacts this debris may also damage vegetation and levee erosion protection when mobile during waves and storms. A few notable concentration points for this type of debris are the north levee of the Sonoma Baylands Project along the eastern Bay front levee at Hamilton Wetlands Restoration Project and many areas of the Richmond and Carquinez Strait shoreline.

1.5.1 Conceptual Non-Profit and Volunteer Efforts

The conceptual model for using non-profit and volunteer groups is to develop a brief training guide that organizations can use to guide staff and volunteers in the importance of and techniques for removal and disposal of creosote treated wood debris from the intertidal and shore areas. Even a small group of 4 to 6 active and fit individuals using hand tools, pickup trucks and small trailers could easily remove smaller sized debris that weigh up to 50 to 200 pound and are a maximum of 6 to 12 feet in length. The basic items needed to support a volunteer project would include basic safety training, basic supervision and encouragement by an experienced non-profit staff or volunteer, debris containment materials and equipment and an easily implemented disposal option at no cost to the volunteers.

1.5.2 Conceptual Small Contracted Efforts

The conceptual model for using small contracted efforts is to identify areas of concentrated creosote treated wood debris or debris that is larger than hand crews can effectively remove and package these areas with a standard set of basic plans and specifications for debris removal. In this case the "contactor" could be a non-profit or for-profit entity. Many small projects are (or were) funded by government agencies granting funds for a fixed scope of work to a non-profit organization that do the work with staff or volunteers or contract with for-profit contractors to complete the work.

The equipment used could include a relatively small crane truck for debris within about 50 feet of a suitable road. Small loaders or excavators could also be used in areas where some vegetation impacts are acceptable. Costs for this type of operation could likely be reduced by setting a relatively long schedule for the work enabling the contractor to use these small projects as fill in work for crews that are not fully booked on other projects.

1.5.3 Potential Cooperation with San Francisco District Corps of Engineers Debris Collection Mission

The San Francisco District Corps of Engineers has a debris collection and control mission based out of docks in Sausalito near the Bay Model. The main effort is accomplished by the "Raccoon" a modified landing craft that travels about the bay collecting debris and trash. This debris is stored near the docks and hauled to appropriate disposal sites as needed.

Mike Dillabough with the Corps San Francisco District indicated that about 60% of the material cleaned from the Bay is creosote treated wood debris. The Corps typically stores creosote treated material in a large debris box and contracts with a service to transport the full box to an appropriate landfill. Hank Mackner of the Corps indicated that the current flat rate transport and disposal cost is about $900 for a 42 cubic yard debris box. The Corps estimates that the debris collection mission disposes about 800 tons per year of creosote treated wood waste.

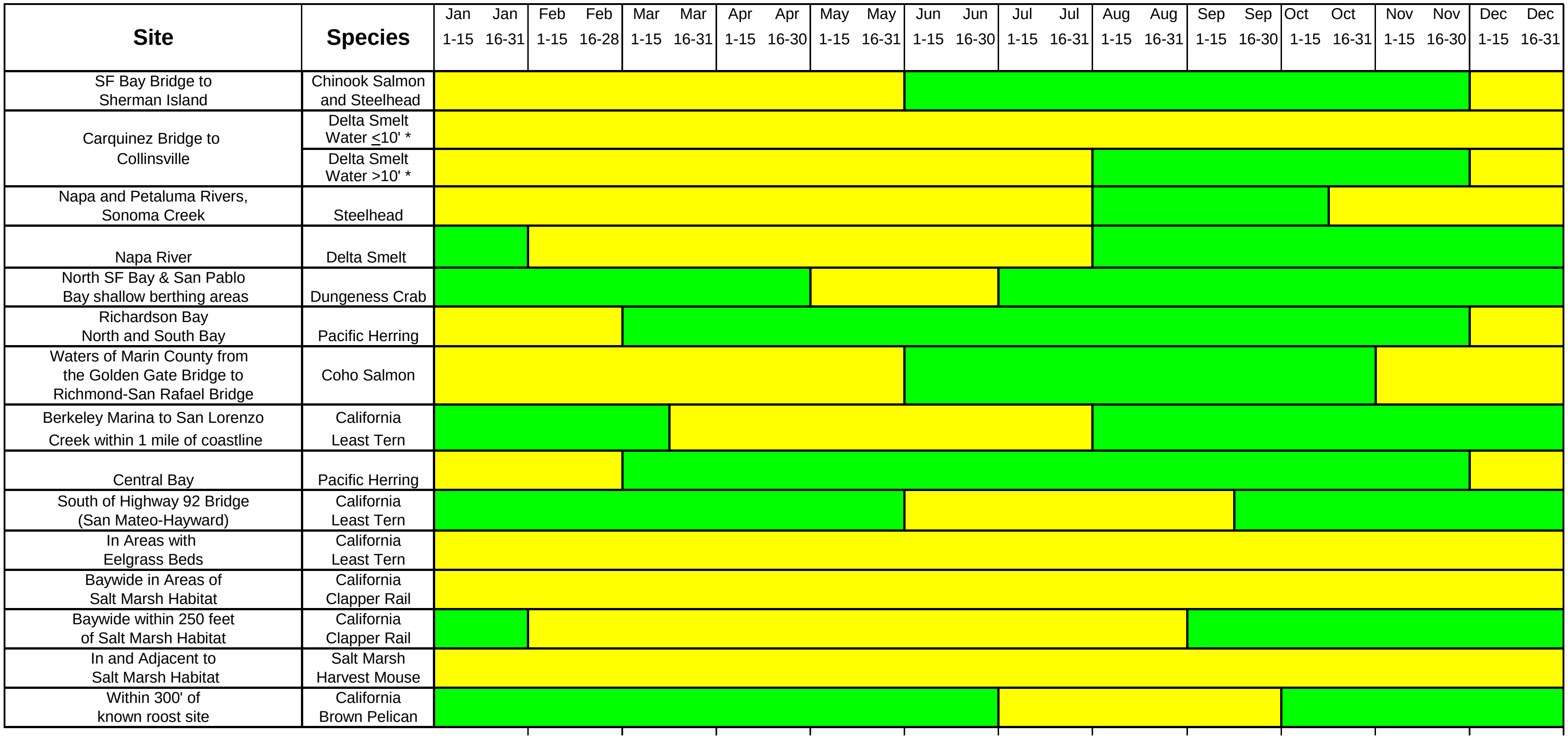
Mr. Dillabough indicated that the Corps may be willing to cooperate with well coordinated volunteer or non-profit efforts and receive creosote treated wood wastes for drying and disposal. Future study efforts should include coordination with Corps management including the Chief of Operations and Readiness and Office of Council to determine the extent of cooperation possible and the amount of creosote treated wastes that could be accepted based on budget constraints and project scheduling.

1.5.4 Potential Cooperative Public Outreach Efforts

In general the Coastal Cleanup Day and other such events do an excellent job of getting the general public to volunteer once or twice a year to clean up on-shore and near shore debris. A simple outreach and education program to and through these existing organized efforts may help increase the amount of treated wood debris that is collected by these volunteers. Most basic volunteers will only be able to safely handle small individual pieces of treated wood that weigh less than 50 pounds. The concept is to develop brief information that is written in plan language and explains why it is important to remove this creosote treated debris and how it should be safely handled and disposed.

Appendix D

Appendix D1



Site	Species	Jan 1-15	Jan 16-31	Feb 1-15	Feb 16-28	Mar 1-15	Mar 16-31	Apr 1-15	Apr 16-30	May 1-15	May 16-31	Jun 1-15	Jun 16-30	Jul 1-15	Jul 16-31	Aug 1-15	Aug 16-31	Sep 1-15	Sep 16-30	Oct 1-15	Oct 16-31	Nov 1-15	Nov 16-30	Dec 1-15	Dec 16-31
SF Bay Bridge to Sherman Island	Chinook Salmon and Steelhead	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨
Carquinez Bridge to Collinsville	Delta Smelt Water ≤10' *	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
	Delta Smelt Water >10' *	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨
Napa and Petaluma Rivers, Sonoma Creek	Steelhead	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟨
Napa River	Delta Smelt	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
North SF Bay & San Pablo Bay shallow berthing areas	Dungeness Crab	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Richardson Bay North and South Bay	Pacific Herring	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨
Waters of Marin County from the Golden Gate Bridge to Richmond-San Rafael Bridge	Coho Salmon	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨
Berkeley Marina to San Lorenzo Creek within 1 mile of coastline	California Least Tern	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Central Bay	Pacific Herring	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨
South of Highway 92 Bridge (San Mateo-Hayward)	California Least Tern	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩
In Areas with Eelgrass Beds	California Least Tern	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Baywide in Areas of Salt Marsh Habitat	California Clapper Rail	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Baywide within 250 feet of Salt Marsh Habitat	California Clapper Rail	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
In and Adjacent to Salt Marsh Habitat	Salt Marsh Harvest Mouse	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Within 300' of known roost site	California Brown Pelican	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩

For more detailed information, see Appendix F of the LTMS Management Plan or the LTMS EIR/EIS.
* Depths are represented in MLLW, and are project depth, not including over dredge allowance
**This chart is for operations and maintenance dredging of existing navigational facilities. Other species may be affected by work in other areas.

🟩 **WORK WINDOW**

🟨 **CONSULTATION REQUIRED**

Summary of Disposal Work Windows

Location & Designation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bar Channel (SF-8)	▨	▨	▨	▨	▨	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Carquinez (SF-9)	▨	▨	▨	▨	▨	🟩	🟩	🟩	🟩	🟩	🟩	🟩
San Pablo (SF-10)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	🟩	🟩
Alcatraz (SF-11)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	🟩	🟩
Suisun (SF-16)	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Beneficial Reuse Sites	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨

Disposal Work Windows

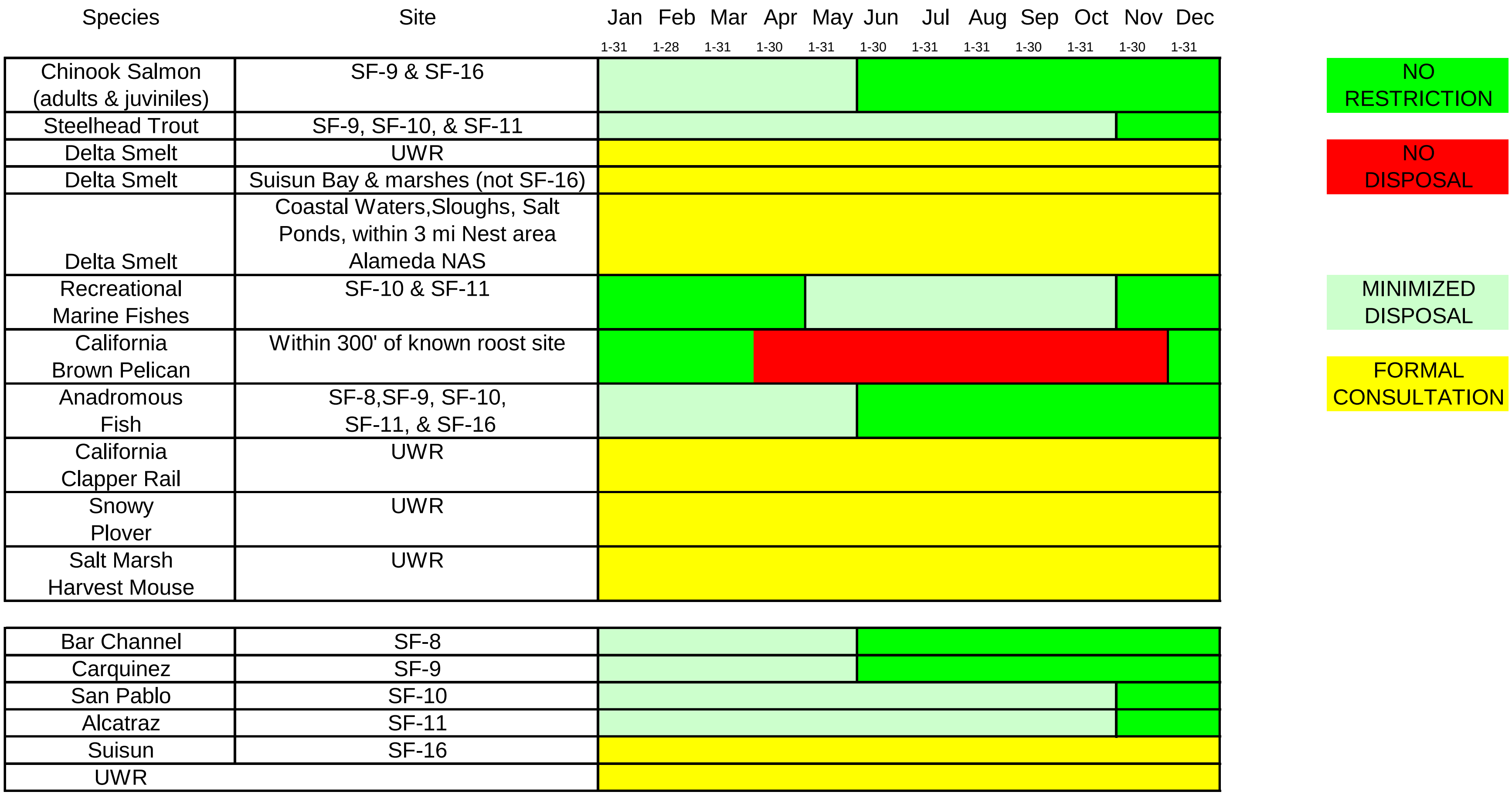
Species	Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook Salmon	SF-9 & SF-16	▨	▨	▨	▨	▨	🟩	🟩	🟩	🟩	🟩	🟩	▨
Steelhead Trout	SF-9, SF-10, & SF-11	▨	▨	▨	▨	▨	▨	🟩	🟩	🟩	🟩	🟩	▨
Recreational Marine Fishes	SF-10 & SF-11	🟩	🟩	🟩	🟩	▨	▨	▨	▨	▨	▨	🟩	🟩
California Brown Pelican	Within 300' of known roost site	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟩	🟩	🟩	🟩
California Clapper Rail,	Beneficial Reuse Site	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Snowy Plover,		🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Salt Marsh Harvest Mouse,		🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Delta Smelt		🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Delta Smelt	Suisun Bay & marshes (not SF-16)	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Least Tern	All eelgrass beds, or within 3 miles of nesting area at Alameda Naval Air Station	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨

(For more information, see Appendix F or the LTMS EIS/EIR)

🟩 **WORK WINDOW**

▨ **MINIMIZED DISPOSAL**

🟨 **CONSULTATION REQUIRED**



Species	Site	Jan 1-31	Feb 1-28	Mar 1-31	Apr 1-30	May 1-31	Jun 1-30	Jul 1-31	Aug 1-31	Sep 1-30	Oct 1-31	Nov 1-30	Dec 1-31
Chinook Salmon (adults & juviniles)	SF-9 & SF-16	▨	▨	▨	▨	▨	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Steelhead Trout	SF-9, SF-10, & SF-11	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	🟩	🟩
Delta Smelt	UWR	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Delta Smelt	Suisun Bay & marshes (not SF-16)	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Delta Smelt	Coastal Waters,Sloughs, Salt Ponds, within 3 mi Nest area Alameda NAS	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Recreational Marine Fishes	SF-10 & SF-11	🟩	🟩	🟩	🟩	▨	▨	▨	▨	▨	▨	🟩	🟩
California Brown Pelican	Within 300' of known roost site	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩
Anadromous Fish	SF-8,SF-9, SF-10, SF-11, & SF-16	▨	▨	▨	▨	▨	🟩	🟩	🟩	🟩	🟩	🟩	🟩
California Clapper Rail	UWR	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Snowy Plover	UWR	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Salt Marsh Harvest Mouse	UWR	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨

Bar Channel	SF-8	▨	▨	▨	▨	▨	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Carquinez	SF-9	▨	▨	▨	▨	▨	🟩	🟩	🟩	🟩	🟩	🟩	🟩
San Pablo	SF-10	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	🟩	🟩
Alcatraz	SF-11	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	🟩	🟩
Suisun	SF-16	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
UWR		🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨

🟩 NO RESTRICTION

🟥 NO DISPOSAL

▨ MINIMIZED DISPOSAL

🟨 FORMAL CONSULTATION

Source of Information: Appendix J of LTMS ROD (Jul 99)

Appendix D1

Washington Department of Natural Resources

Puget Sound Initiative – Derelict Creosote Piling Removal

Best Management Practices

For Pile Removal & Disposal

The following Best Management Practices (BMPs) are adapted from EPA guidance (2005), Washington State Department of Transportation (WSDOT) methods and conservation activities as included in Joint Aquatic Resources Protection Application (JARPA) 2005, and Washington State Department of Resources (WADNR) "Standard Practice for the Use and Removal of Treated Wood and Pilings on and from State-Owned Aquatic Lands" 2005.

The purpose of these BMPs is to control turbidity and sediments re-entering the water column during pile removal, and prescribe debris capture and disposal of removed piles and debris.

BMP 1. Pile removal

A. Vibratory extraction

1) This is the preferred method of pile removal.

2) The vibratory hammer is a large mechanical device (5-16 tons) that is suspended from a crane by a cable. The hammer is activated to loosen the piling by vibrating as the piling is pulled up. The hammer is shut off when the end of the piling reaches the mudline. Vibratory extraction takes approximately 15 to 30 minutes per piling depending on piling length and sediment condition.

3) Crane operator shall be trained to remove pile slowly. This will minimize turbidity in the water column as well as sediment disturbance.

4) Operator will "Wake up" pile to break up bond with sediment.
- Vibrating breaks the skin friction bond between pile and soil.
- Bond breaking avoids pulling out a large block of soil – possibly breaking off the pile in the process.

- Usually there is little or no sediment attached to the skin of the pile during withdrawal. In some cases material may be attached to the pile tip, in line with the pile.

B. Direct Pull

1) This method is optional if the contractor determines it to be appropriate for the substrate type and structural integrity of the piling.

2) Pilings are wrapped with a choker cable or chain that is attached at the top to a crane. The crane pulls the piling directly upward, removing the piling from the sediment.

C. Clamshell Removal

1) Broken and damaged pilings that cannot be removed by either the vibratory hammer or direct pull shall be removed with either a clamshell bucket or environmental clamshell.

2) A clamshell is a hinged steel apparatus that operates like a set of steel jaws. The bucket is lowered from a crane and the jaws grasp the piling stub as the crane pulls up.

3) The size of the clamshell bucket will be minimized to reduce turbidity during piling removal.

4) The clamshell bucket will be emptied of material onto a contained area on the barge before it is lowered into the water.

D. Cutting

1) Is required if the pile breaks off at or near the existing substrate and cannot be removed using a clamshell bucket.

2) Prior to commencement of the work the contractor will assess the condition of the pilings. Contractors will create a log outlining the location and number of pilings that need to be cut or broken off and have this log available to the agencies upon request.

3) Washington State Department of Fish and Wildlife (WDFW) will be consulted to determine if this is the preferred option at any specific site.

4) Every attempt will be made to completely remove the piling in its entirety before cutting. If a pile is broken or breaks above the mudline during extraction, one of the methods listed below should be used to cut the pile.

a. A chain should be used, if practical, to attempt to entirely remove the broken pile. (BMP 1-C)

b. If the entire pile cannot be removed, the pile should be cut at or below the mudline by using a pneumatic underwater chainsaw. Project-specific requirements for cutoff will be set by the project manager in consultation with WDFW and Washington Department of Ecology considering the mudline elevation and the presence of contaminants in the sediment. Generally, in subtidal areas with contaminated sediments, pilings should be cut off at the mudline to minimize disturbance of the sediment. In dry, intertidal areas, piling should be cut off at least 1 foot below the mudline. In uncontaminated, subtidal areas, piling should be cut off at least 1 foot below the mudline.

c. Piles shall be cut off at lowest practical tide condition and at slack water. This is intended to reduce turbidity due to reduced flow and short water column through which pile must be withdrawn.

d. In deep subtidal areas, if the piling is broken off below mudline greater than 1 foot, the piling may remain. In intertidal and shallow subtidal areas, seasonal raising and lowering of the beach could expose the pilings above the mudline and leach out PAH’s or other contaminants. In this case, the piling should be cut off at least two feet below the mudline if it is accidentally broken off during removal.

e. Depending on future use, the removal contractor will provide the location of the broken pile using GPS. This will be necessary as part of debris characterization should future dredging be a possibility in the area of piling removal.

BMP 2. Barge operations, work surface, containment

A. Barge grounding will not be permitted within project areas over eelgrass beds.

B. Work surface on barge deck or pier shall include a containment basin for pile and any sediment removed during pulling.

1) Containment basin may be constructed of durable plastic sheeting with sidewalls supported by hay bales or support structure to contain all sediment. Water run off can return to the waterway.

2) Work surface on barge deck and adjacent pier shall be cleaned by disposing of sediment or other residues along with cut off piling as described in BMP #3.C below.

3) Containment basin shall be removed and disposed in accordance with BMP #3.C below or in another manner complying with applicable federal and state regulations.

4) Upon removal from substrate the pile shall be moved expeditiously from the water into the containment basin. The pile shall not be shaken, hosed-off, left hanging to drip or any other action intended to clean or remove adhering material from the pile.

BMP 3. Disposal of piling, sediment and construction residue

A. Pulled pile shall be placed in a containment basin to capture any adhering sediment. This should be done immediately after the pile is initially removed from the water.

1) Utilize basin set up on the barge deck or adjacent pier

2) Basin may be made of hay bales and durable plastic sheeting.

B. Piling shall be cut into 4’ lengths with standard chainsaw.
1) All sawdust and cuttings shall be contained in the container.

C. Cut up piling, sediments, construction residue and plastic sheeting from containment basin shall be packed into container. For disposal, ship to Rabanco/Regional Disposal Subtitle D Landfill in Roosevelt, Washington.

BMP 4. Debris capture in water

A. A floating surface boom shall be installed to capture floating surface debris. Debris will be collected and disposed of along with cut off piling as described in BMP #3.C above.

B. The floating surface boom shall be equipped with absorbent pads to contain any oil sheens. Absorbent pads will be disposed as described in BMP #3.C above.

BMP 5. Resuspension/Turbidity

A. Crane operator shall be trained to remove pile from sediment slowly.

B. Work shall be done in low water and low current, to the extent possible.

C. Removed piles shall be placed in a containment facility.

D. Sediments spilled on work surfaces shall be contained and disposed of with the pile debris at permitted upland disposal site.

E. Holes remaining after piling removal shall not be filled.

BMP 6. project oversight

A. WADNR will have a project manager or other assigned personnel on site. Oversight responsibilities will include, but are not limited to the following:

  1) Water quality monitoring to ensure turbidity levels remain within required parameters.

  2) Ensure contractor follows BMPs

  3) Ensure contractor is in compliance with contract and permit requirements

  4) Ensure correct structures are removed

  5) Maintain contact with regulatory agencies should issues or emergencies arise

Artificial Structure in San Francisco Bay

Aroon Melwani
San Francisco Estuary Institute

Appendix E of
Removal of Creosote-Treated Pilings and Structures
from San Francisco Bay

Prepared by

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Eric Polson,[c] and Robin Grossinger[b]

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1. The Broader Picture: Artificial Structure in San Francisco Bay

1.1 Introduction

1.1.1 Overview of Habitat Structure in San Francisco Bay

Human activities have radically modified the vertical structure present in San Francisco Bay (the Bay). Natural hard substrates including boulders, fallen tree branches, rock face outcrops, and low relief rock have become rare throughout much of the Bay having been removed or modified by the U.S. Army Corps of Engineers to minimize navigation hazards (Goals Project, 2000). As a result, natural hard bottom habitats are considered a scarce resource in the Bay, and artificial substrates are the more common habitat types (Appendix 1). Artificial structures, such as breakwaters, rip rap, and sea walls, have been put in place to stabilize the shoreline for development and to control erosion of the Bay. However, there are growing concerns that these hard structures used to armor the Bay may actually be contributing to coastal erosion by inhibiting natural shoreline processes and restricting available habitat. Consequently, San Francisco Bay is currently habitat limited for many of the biotic species that rely on hard structure for survival. However, there have been few local studies conducted to evaluate the potential benefits and adverse effects of artificial structure in San Francisco Bay. In the section below, some of the important factors affecting local biota are reviewed, drawing on evidence from the predominant artificial habitat types in the Bay.

1.1.2 Benefits and Adverse Effects of Artificial Substrates

Artificial substrates play a critical role by providing essential habitat for biota at multiple trophic levels, including barnacles, oysters, fish, and mammals (Thompson et al. 2007). Docks and pier pilings occur throughout a significant portion of San Francisco Bay and have been shown to provide vertical structure for hundreds of invertebrate species. A 2004 survey conducted by the San Francisco Estuary Institute identified 294 invertebrate species from eleven dock and pier piling sites in the Bay, including numerous exotic species (Cohen and Chapman, 2005). Artificial structures in the Bay also provide habitat for fish and birds, including some species of special concern. During November – March, schools of Pacific herring (*Clupea pallasii*) enter San Francisco Bay to spawn, depositing eggs onto submerged aquatic vegetation (such as native eelgrass, *Zostera marina*) and any suitable hard bottom substrate within their salinity range (Moyle 2002). Vines et al. (2000) noted that in urbanized estuaries such as San Francisco Bay, natural spawning substrates for herring have declined, and artificial habitats are frequently used instead (Spratt 1981, Watters et al. 2004). In the northern Central Bay, one of the few areas of dense natural structure still present, the predominant spawning vegetation is eelgrass and red algae (Watters et al. 2004). In contrast, the majority of the nearshore area of the Bay has been armored with hard substrates such as seawalls, which do not provide suitable spawning substrate, and thus there is concern for the future populations of some fish species, such as Pacific herring and green sturgeon.

Piscivorous birds also frequently forage over hard substrates in the Bay. Weeden (2007) identified 18 distinct bird species on the San Francisco pier pilings and wharves during a recent breeding season. These included double crested cormorant, great blue heron, snowy egret, Caspian tern, and western grebe. Many fish species that are prey for birds are commonly found in association with artificial structures (Clynick 2008), likely in search of food or cover. Fish commonly found near or in the fouling growth on floating docks and pilings of San Francisco Bay include Bay pipefish (*Syngnathus leptorhynchus*), Pacific herring (*C. pallasii*), rockfish (*Sebastes spp.*), and shiner surfperch (*Cymatogaster aggregata*) (Moyle 2002). Subsequently, fish assemblages attracted to hard substrate become prey for larger biota, such as harbor seals and sea lions. Many haul-out sites for harbor seals are found near to subtidal hard substrate, including Castro Rocks and Angel Island (Goals Project 2000). The strong connection between artificial substrates and natural food web dynamics in San Francisco Bay suggests the need to restore and enhance such habitats in the Bay.

Despite the benefits of increasing essential habitat and foraging area, there are a number of negative impacts associated with the presence of artificial compared to natural substrate. Numerous studies conducted around piers and docks have found reduced density, growth, and biomass of submerged aquatic plants due to light limitation from shading (Burdick and Short, 1999; Shafer, 1999), and shifts in the biotic community towards more shade tolerant species (Glassby 1999). Studies of dock design have shown that wider piers and those closer to the surface may further increase the shading footprint, resulting in direct impacts to biota (Burdick and Short, 1999). Submerged aquatic flora such as *Z. marina* has been shown to be particularly susceptible to shading. Eelgrass beds are one of the most important natural habitat types currently present in the Bay. Eelgrass and other submerged macrophytes help to stabilize soft sediments, reduce turbidity, provide habitat, and absorb wave energy. Subtidal vegetation also serves as critical nursery habitat, by providing biota with camouflage and structural refuge from predators. However, in San Francisco Bay as well as other estuaries in the United States, eelgrass is thought to be in severe decline compared to historic levels. Furthermore, the density and abundance of the existing beds are quite variable (Merkel & Associates 2004), suggesting they may be under significant stress. Eelgrass growth and extent throughout the world has been found to be reduced during turbid water column conditions (Zimmerman et al., 1991). This is of special concern in a highly turbid, light limited environment such as San Francisco Bay. Low light levels may be the factor that most limits the extent of growth (e.g. Shafer, 1999). A study by Burdick and Short (1999) in two Massachusetts estuaries showed that docks placed higher over the water surface produced more diffuse shadow footprints, which resulted in greater light reaching sediments and biota under the dock. No net eelgrass growth was evident when surface irradiance was less than 10%, which supported results from eelgrass beds in other estuaries of the United States. Such influences are evident locally, as the largest eelgrass beds in San Francisco Bay are present in the Central Bay, which has the clearest water of any region of the Bay.

Artificial structures built or placed along the shoreline have also been shown to significantly alter water flows and patterns of sediment erosion and deposition. The presence of pier pilings and other artificial structures can disrupt currents and induce sediment scour in their immediate vicinity. Modifications to the flow of water have the potential to also increase deposition of sediments depending on the conditions and structural type. Other activities, such as floats or boats associated with piers, that disturb the bottom at low tides can also cause scour or erosion by suspending sediments in the water column. Therefore, indirect impacts of artificial structure can also impact near-shore habitats (Burdick and Short, 1999). Of greatest concern are areas of San Francisco Bay where natural substrates have been removed and replaced with hard artificial substrate. Given that much of the Bay is in a state of constant erosion, bulkheads and riprap put in place to reduce erosion can work to amplify the erosive effect by further increasing wave reflection. These artificial modifications of the shoreline often cause a decrease in the width of the near-shore environment and increase water depth, processes that can contribute to erosion, often causing a cascading effect of hardening down the shoreline (Davis et al. 2002). The cumulative impacts include permanent removal of sediment from the littoral system, and loss of intertidal and beach zones. Armor has been used to replace shoreline vegetation in many areas of San Francisco Bay, which may be reducing water filtration and habitat functions in such areas. These structures, especially bulkheads and seawalls, also steepen shorelines, reducing or removing altogether valuable shallow-water nursery and refuge habitat for many estuarine species.

Modifications to the shoreline have particular implications in view of future changes to the morphology of San Francisco Bay as a result of climate change and sea level rise. In addition to the increases in water temperature, climate change researchers currently predict a sea level rise up to five feet in the next 100 years (CNRA, 2009). This global increase may reveal significant effects to San Francisco Bay where more than 200 miles of low lying land exist around the Bay (CNRA, 2009). The continual steepening of the Bay shoreline by the presence of sheer vertical structures could result in higher storm surge intensity and frequency. As a result, there is a significant concern for increased erosion and scour of the shoreline as a result of rising sea levels, which may further reduce wetland and intertidal habitats. Restoring tidal wetland area around the Bay could play a key role in San Francisco Bay’s climate change adaption strategy (CNRA, 2009). Tidal wetlands have the advantage of being able to naturally buffer shorelines from storm surge, as well as to help alleviate the impacts of climate change by sequestering carbon. However, with much of the Bay’s landscape currently armored with hard artificial structures, there is limited space along the shoreline available for marsh migration.

1.2 Living Shoreline Restoration in San Francisco Bay

Techniques for incorporating natural habitat into shoreline stabilization design, as an alternative to hard artificial structures, have existed for some time. Implementation of such techniques has been ever increasing on the East Coast, particularly in areas at risk from coastal erosion and loss of wetland habitat. Restoration scientists in Chesapeake Bay were the first to implement these techniques, coining the phrase “Living Shoreline” (Smith, 2006). The term defines shoreline restoration methods that use natural habitat to protect shorelines from erosion and habitat loss, thereby increasing habitable areas for riverine, coastal, or estuarine species.

Examples of natural substrate used in living shorelines include emergent marsh, submerged aquatic vegetation, riparian vegetation, and oyster shell. These types of non-structural habitat types can be used either individually or in combination to control erosion of the shoreline and stabilize critical habitat (Smith, 2006). Natural habitat can also be combined with hard artificial structure to form a “hybrid” design. Hybrid designs are used to support and enhance natural habitat restoration or creation, and thus share similar ecosystem functions with the non-structural types. These benefits include providing space and structure for local species, wave attenuation, and improving water quality through a reduction in suspended sediments. Both non-structural and hybrid types can be used in a variety of low to medium energy environments, and thus have wide applications. In higher energy environments, living shoreline designs often utilize rock offshore of the restoration site as breakwaters or sills. These breakwaters are often constructed of limestone, granite, or rock that is seeded with ancient oyster shell. The harder substrate acts to buffer the shoreline and create habitat between the existing shoreline and the added rock. Sills or breakwaters placed parallel to the shore are effective at dampening wave energy, thereby creating marsh or beach habitat for local flora and fauna. Shorelines with vegetated marsh have been shown to sustain much higher abundance and diversity of benthic macrofauna, as well as higher abundance of juvenile and predatory fish, compared to shorelines hardened with bulkheads or groins (Seitz et al. 2006). Therefore, the potential exists for living shorelines to link habitat functions across multiple spatial scales, such as between marshes, benthic fauna, and predator abundance, as would occur in a natural shoreline setting. However, higher abundances may not correlate with changes in local populations, but more likely a reflection in an increase in habitat suitability for certain species (Barwick et al. 2004). As with all habitat restoration techniques, a good understanding of the local subtidal foodweb is required *a priori* to facilitate appropriate habitat modifications to effectively enhance the natural functionality of the area to be restored. Ultimately, living shorelines are designed to limit the need for structural erosion control at the interface been the riparian and wetland/intertidal zones, thereby allowing natural physical processes to be maintained. Shoreline systems are dynamic by nature and the potential exists for appropriate shoreline stabilization techniques to function as part of the natural system not independent of it.

1.3 Case Studies of Habitat Restoration

Living shoreline projects have been implemented successfully for over two decades by NOAA and other researchers in a variety of settings in the Pacific Northwest, East Coast, and Gulf of Mexico. In San Francisco Bay, a recent pilot study has also been initiated. Case studies describing three techniques for habitat restoration are reviewed below to provide context for future restoration opportunities in the Bay.

1.3.1 Living Shoreline Restoration

The NOAA Restoration Portal summarizes numerous studies that have been conducted in the past 10 years or more in conjunction with the NOAA Habitat Program (https://habitat.noaa.gov/restoration/). One of these projects described below was selected as a living shoreline case study:

North Carolina has undergone significant habitat loss in the past 30 years. Approximately 30 miles of wetland area has been lost each year from impacts related to new development along the coastline (Titus et al. 1991). At the North Carolina Maritime Museum (NCMM) in Beaufort, North Carolina, concerns for further erosion of the marsh shoreline led officials to seek modifications to the deteriorating shoreline protection. The project involved removal of a steel sheet pile bulkhead and construction of a “hybrid” living shoreline. The design consisted of three stone sills in the shallow subtidal environment, and subsequent planting of smooth cordgrass and saltmeadow cordgrass by volunteers. There were no obvious tradeoffs associated with implementing this design, except that the original erosion control measures had to be removed prior to construction of the living shoreline. Due to the involvement of the local community in its construction, continued monitoring by volunteers allowed NCMM to monitor the success of the restoration for a few years following the construction. Monitoring data indicated that the sill structures were successful at reducing wave impact onto the marsh and shoreline, which allowed for re-colonization by native marsh. After three years, one of the three areas of restored marsh had equivalent stem densities of *Spartina alterniflora* relative to a nearby natural fringing marsh (Currin et al. 2007). Further, the mean number of fish and invertebrates sampled were also comparable between the natural and restored marshes. Continued monitoring of the restoration site after construction provided valuable information for the success of the project and due to the proximity to the NCMM, the opportunity for continued visitor education. This project was completed in 2001 and was one of thirty funded by the North Carolina Coastal Federation to demonstrate the use of natural alternatives to bulkheads on the coastline. Many of the projects proved successful, in part due to the help of local communities in the restoration and the cost-effectiveness of the living shoreline designs.

1.3.2 Artificial Structure Redesign

The Clinton Ferry Terminal in Puget Sound was subject to one of the first large scale ferry terminal redesign projects on the West Coast that integrated habitat considerations into its construction. In 1994, the Washington State Department of Transportation partnered with scientists from the University of Washington and Battelle Laboratories to develop a new dock design that would minimize impact to eelgrass and surrounding habitat (http://www.wsdot.wa.gov/ferries/your_wsf/corporate_communications/clinton_enviro/). The final permitted design significantly reduced the potential impact to 10,000 square feet of eelgrass habitat in the area. The terminal expansion project engineers employed a variety of techniques to enhance light penetration below the docks and reduce erosion from propeller wash. The redesign included installation of glass blocks in the passenger walkway to increase light penetration, extension of the terminal further offshore and narrowing of the terminal to reduce the shading footprint, artificial breakwater reef construction, and planting of native eelgrass beds. As a result of these efforts, more than 14,000 square feet of eelgrass were transplanted, including areas directly under the ferry terminal. The project resulted in a significant expansion of eelgrass beds around the Clinton Terminal and increased the density of eelgrass compared to before construction began. Battelle Laboratories and University of Washington have continued the research of eelgrass beds in Puget Sound by extensively mapping submerged aquatic vegetation throughout the estuary. These data are being used to mitigate future impacts to eelgrass and other juvenile salmon habitat caused by expansion of commercial docks throughout Puget Sound. Since the Clinton Terminal Study, a number of techniques to counteract the adverse effects of artificial dock structures have built upon that initial work. These include the use of grating, glass blocks, sun tunnels, and applying reflective material on the underside of docks (Kelty and Bliven, 2003). These designs have proven effective in redesigns of numerous large ferry docks in Washington State (Williams et al. 2003). In San Francisco Bay, an assessment of the effects of dock structures on Bay organisms has yet to be performed.

1.3.3 Oyster Reef and Eelgrass Restoration

Living shoreline projects have yet to be implemented on a broad scale in San Francisco Bay. In 2005, a pilot study that integrated techniques commonly used in hybrid shoreline designs was initiated at a subtidal site located off the Marin Rod and Gun Club in North San Francisco Bay. The project involved construction of reef mounds made of Pacific oyster shell and restoration of native eelgrass beds. Both types of structure were placed from intertidal to subtidal depths. During 2005 - 2009, more than 100,000 native oysters have colonized the artificial reefs and more than 10,000 shoots of new eelgrass have persisted (R. Abbott, Environ, Pers. Comm.). Consistent with the living shoreline successes on the East Coast, this project has indicated the benefits of integrating site design with both natural and artificial habitat considerations. However, the project has yet to show results related to shoreline stabilization as has been a frequent goal of the living shorelines in other areas.

Since implementation of the project, the restoration site has provided benefits to many local species. In addition to the oyster and eelgrass colonization, herring and gobies have been found to spawn on the ancient oyster shell used to construct the reef, and sturgeon and steelhead trout have been detected foraging on the reef for up to four hours at a time (R. Abbott, Environ, Pers. Comm). In comparison to the control plots, where no eelgrass or reef mounds were present, fish tended to spend longer times over the reef structures, suggesting that the design was successful at providing functional benefits, such as cover, camouflage, or food resources for local species.

1.4 Conclusions

Future opportunities to incorporate living shoreline approaches into the management of the Bay shoreline may gather impetus as climate change adaptation strategies continue to be developed. Living shorelines have already been recommended as a component of the California Climate Change Adaptation Strategy (CNRA, 2009). However, given that living shoreline methods have yet to be attempted in San Francisco Bay, future shoreline modifications of the Bay seeking to incorporate techniques described in this chapter will therefore need to conduct extensive pilot study before proceeding on a broad scale. Such studies will need to evaluate the benefits and tradeoffs to current shoreline erosion strategies. Important considerations when evaluating potential sites for restoration in the Bay will include: a) the scale of application; b) resource suitability; and c) overall cost of construction and monitoring. The oyster reef and eelgrass habitat restoration techniques that are currently being piloted on a small scale in the North Bay may provide a reasonable starting point. However, their utility for shoreline stabilization has yet to be shown. Shoreline stabilization techniques incorporating natural habitat have proved successful in other parts of the country providing some evidence for their potential applications to the Bay, but need to be demonstrated locally. A future living shoreline pilot study in San Francisco Bay should consider including the following elements:

- Shoreline stabilization techniques
- Protection and enhancement of native eelgrass habitat and shellfish beds
- Collection of baseline information on aquatic habitats and biota
- Support sufficient light intensity for plant photosynthesis, fish recruitment, and growth
- Minimize shading effects and scouring
- Document success through continued monitoring of water quality, habitat variables, and flora/fauna recruitment
- Stakeholder involvement

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Appendix 1. List of Artificial Substrate Types Known to Occur in San Francisco Bay

Substrate Type
Breakwaters
Buoys
Duck blinds
Floating docks (private, public, and fishing docks)
Jetties
Moorings and anchors
Outfall structures (power plants and water treatment plants)
Pacific oyster shell (dead, clean shells used in restoration projects)
Piers and wharfs
Pilings (marinas, ports, vehicle bridges, foot bridges, fishing piers, private docks, and public docks)
Pipelines and cables
Rip rap (shoreline stabilization and debris)
Sea walls (wood and concrete)
Shipwrecks (exposed and sunken)
Watercrafts (personal and commercial)