Opportunities for Delta Reuse of Clean Material Dredged from San Francisco Bay

Phase II Report: Conceptual Design

Prepared For

The California Coastal Conservancy's
Dredged Material Reuse Program
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Executive Summary

Dredging in the San Francisco Bay Estuary will continue as long as the region remains a major shipping and recreational boating center, with large ships requiring deep channels to access port facilities, and smaller craft needing access to marinas. But dredging yields a tremendous volume of sediment requiring disposal, and traditional Bay or ocean dumping can be detrimental to the ecosystem. Upstream in the Delta there is a shortage of clean Bay dredged material to maintain levees and to restore degraded habitat, especially on severely subsided islands.

Is it feasible to simply shift disposal of these dredged spoils to the Delta for maintenance and reuse projects? Or does the salt in Bay sediment pose a major obstacle to Delta reuse of clean dredged materials from the Bay, a threat to Delta water quality, habitat and species?

This report identifies the challenges of dredged disposal reuse, and makes recommendations regarding its technical and economic feasibility. Salinity, costs and financing, legal and regulatory issues, engineering and design challenges and environmental impacts are all examined. The report identifies several potential salinity control strategies that are worthy of further investigation, and describes several levee demonstration projects that have used dredged material without revealing a significant salinity problem. The report outlines a conceptual design for a Delta restoration pilot project using dredged materials on Sherman Island, at the confluence of the Sacramento and San Joaquin river systems, near the most biologically productive part of the Estuary. This pilot project, if implemented, could yield valuable data.

The Long-Term Management Strategy (LTMS) interagency process is working to identify alternatives to the in-Bay disposal of dredged material, while the CALFED Bay-Delta Program is developing long-term levee protection plans and habitat restoration programs. The report recommends collaboration between LTMS and CALFED to investigate potential benefits of a broader habitat restoration and material rehandling project. If large scale Delta reuse is feasible, it could provide benefits to key target species, expand the tidal prism and increase residence time in the Delta, reduce agricultural drainage with a reduction in trihalomethane precursors, and strengthen the CALFED levee program while reducing the vulnerability of Delta islands to catastrophic failure.

The report finds that Delta reuse of clean Bay dredge materials could resolve some very complex problems in a cost-effective and environmentally beneficial way and recommends further investigation:

Conclusions

- There is a significant need for a program to maintain the integrity of Delta levees.
- An enormous volume of material will be required to maintain Delta levees, and existing in-Delta sources of material are inadequate to meet either habitat restoration or levee maintenance needs.
- Restoring extensive shallow-water or tidal-marsh habitat in the western or central Delta would have dramatic ecosystem benefits, with indirect benefits for Delta water diverters.
- Without an aggressive subsidence reversal strategy, much of the Delta, particularly the western and central Delta, cannot be restored to shallow-water or tidal-marsh habitat in the near future.
- LTMS goals regarding beneficial reuse of dredged materials are unlikely to be met over the next 50 years without significant Delta reuse of Bay material. Material targeted for ocean disposal by the LTMS could be redirected to reuse projects.
- The cost of Delta reuse appears to be comparable with other disposal options under consideration and in actual use.
- Salinity is the major constraint on the Delta reuse of materials dredged from the Bay. Several potential salinity control strategies are worthy of further investigation.
- Several levee demonstration projects using dredged material have been completed and have not revealed a significant salinity problem.

- State law does allow a thoughtful course of investigation into Delta reuse of Bay dredged material.
- A large-scale joint habitat restoration and rehandling project could be a cost-effective method of addressing a wide range of goals of the LTMS and CALFED, and a LTMS/CALFED partnership offers the potential for a broad range of funding partners to support Delta reuse.

Recommendations

1. CALFED and LTMS Joint Strategy. CALFED and LTMS policy-level decision-makers should discuss the potential for Delta reuse of Bay-dredged material, and develop a joint strategy to investigate and, as appropriate, implement such reuse.

2. Delta Habitat Restoration Pilot Project. As a part of its Ecosystem Restoration Program, CALFED should build on the apparent success of the Delta levee demonstration projects by designing and implementing a pilot project to investigate salinity-control strategies and other related issues.

3. CALFED Ecosystem Restoration Program. The Ecosystem Restoration Program effort should be revised to fund an investigation into the habitat restoration opportunities presented by Delta reuse of Bay material. CALFED restoration goals should be revised for the central and western Delta, and a recommendation regarding the acceptability of significant Delta reuse in the final Ecosystem Restoration Program Plan should be developed.

4. CALFED Levee Program. CALFED's Levee Program should be revised to include a careful review of the results of Delta demonstration projects using Bay materials. An investigation of additional issues raised by Delta reuse should be undertaken, and a conclusion reached regarding the acceptability of significant Delta reuse as a part of the levee plan.

5. Regional Water Quality Control Board Resources. Because both CALFED and LTMS are rapidly moving toward major decisions, they should investigate whether the Regional Board has adequate staff and other resources to study and resolve salinity and other water-quality issues raised by Delta reuse of Bay material. If required, additional resources should be provided immediately.

6. Ocean Disposal. LTMS agencies should consider the potential benefits of Delta reuse and potential demand for material in the Delta and evaluate the wisdom of the LTMS decision that 40 percent of Bay dredged material may be disposed at the deep-ocean disposal site.

7. Large-Scale Delta Reuse. Once a Delta habitat restoration demonstration project is undertaken, CALFED and LTMS should fully evaluate the feasibility and design of a large-scale Delta reuse project.

Sonoma Baylands: A Model Habitat Reuse Project

In the late 1800s a productive marshland located at the upper reaches of San Pablo Bay was diked and drained to create hay fields. This marshland was just one of many wetland areas to be transformed during the last one hundred and fifty years. Today nearly 90 percent of the San Francisco Bay's historic tidal marshes have been diked and drained for agriculture or filled for urban development.

One hundred years after this transformation from tidal marshland to hay field, the Bay Area has continued to change in many ways. In the 1980s, Port of Oakland officials proposed deepening its channels to accommodate larger ships. Originally, the U.S. Army Corps of Engineers expected to dredge the channels and dispose of the material in the Bay near Alcatraz Island or in the ocean, near Half Moon Bay. However, by 1988 both these solutions elicited fierce opposition from commercial and sport fishermen, environmentalists, and even Bay swimmers, who feared that water quality—crucial to a healthy ecosystem—would be adversely affected. Potential litigation threatened to halt dredging activities for years; the crisis seemed intractable. Meanwhile, environmentalists were seeking ways to protect sensitive lands in the rapidly urbanizing Bay Area. A 322-acre hay field on the edge of San Pablo Bay was a potential restoration site, but over the years it had subsided well below tidal-marsh elevations. A successful restoration would require an accumulation of up to seven and a half feet of "clean" mud before a new marsh could form. Left to natural sedimentation processes, this could take 50 years or more.

Figure 1. Sonoma Baylands Arial Photograph *Laurel Marcus*

The Port argued that dredging was needed immediately if it were to retain its share of the maritime market, generating revenues of more than $5 billion for the regional economy. The rapidly disappearing fringes of open land along the Bay's margins also needed to be preserved and restored for the benefit of both wildlife and future generations. To advance both these important objectives, a diverse and creative coalition with a new vision for the Bay was needed. Fortunately, that's exactly what happened. Environmentalists, fishermen, and the California Coastal Conservancy helped to convince the Port of Oakland, legislative leaders, and state and federal regulatory agencies of the potential joint benefits of a habitat-reuse project. The resulting Sonoma Baylands project combining tidal marsh restoration, seasonal wetland preservation, and an industrial-port dredging project-has been widely cited as a model for sustainable development and has opened the door to similar efforts nationwide. In the Bay Area, it has laid the groundwork for potential projects such as the Hamilton Field project. The Sonoma Baylands project has also helped to energize a larger movement to restore tens of thousands of acres of habitat around San Francisco Bay.

As you read this report, keep in mind our past challenges and successes. Today we are faced with another opportunity and challenge as we consider the need for Delta levee maintenance and habitat restoration and for disposal sites for material dredged from the Bay. Once again it will be critical for people with different ideas to and work together to find solutions to regional economic and environmental concerns. Dredged materials and water-quality issues are again on center stage. The ability to develop creative strategies to solve big problems is a hallmark of the Sonoma Baylands experience. It is worthwhile to recall how disparate members of the Bay Area community learned to work together to solve a Bay commercial problem while creating an innovative wetlands restoration project.

We need to change not only the way we address the Bay's complex restoration needs—no small task as we face unprecedented growth projections well into the next decade-but also the ways in which we work together to solve our mutual problems. It took a powerful and diverse collaboration built on cooperation and trust to accomplish the Sonoma Baylands project. This project has demonstrated that we can work together to solve significant local issues and that we do not have to choose between a healthy Bay and a healthy economy.

Introduction

LTMS and CALFED Background

The Long-Term Management Strategy (LTMS) and the CALFED Bay-Delta Program are both ambitious, long-term, state-federal planning efforts endeavoring to reduce the impact of human activities on the Bay-Delta Estuary. The LTMS is focused on dredging issues in the lower reaches of the Estuary. CALFED is engaged in a broader effort focused on ecosystem restoration, water quality, system vulnerability to natural disasters, and water-supply reliability.

Both these efforts address problems related to Bay dredged material. The LTMS is working to develop alternatives to in-Bay disposal of dredged material. Some of these alternative disposal strategies would promote the beneficial reuse of what has been considered merely waste material. The CALFED effort, on the other hand, is developing a Long-Term Levee Protection Plan and an Ecosystem Restoration Program, both of which may require substantial amounts of dredged material for full implementation to be possible. In part, CALFED is seeking in-fill material, and the LTMS is seeking a new home for unwanted dredged material. The juxtaposition of these two needs suggests the possibility of a LTMS/CALFED partnership that would investigate the potential benefits of reusing in the Delta clean material dredged lower in the Estuary.

Project Overview

This document, prepared for the Coastal Conservancy's Dredged Material Reuse Program and for submission to the CALFED Program, is the second phase of an effort to evaluate the potential for Delta reuse of clean dredged material from San Francisco Bay.

The first phase of this effort consisted of potential strategies to address concerns about the salinity of material dredged from the Bay. One of the primary obstacles to reusing this material in the Delta is the presence of salt in material dredged in the lower reaches of the Estuary. Importing substantial amounts of salt, along with Bay sediment, into the Delta could degrade water quality. This is a particular concern during dry years and periods when salinity can become a significant constraint on Delta agriculture, water-project exports, and environmental and fisheries protection.

Although there are many potential obstacles to such Delta reuse, such as cost, financing, engineering, air quality, and so forth, salinity has emerged as perhaps the most fundamental concern. In fact, concerns about salinity have prevented reusing Bay material in the Delta from being fully evaluated in either the LTMS or CALFED programs.

...CALFED is seeking sediment, and the LTMS is seeking a new home for unwanted sediment. The juxtaposition of these two needs suggests the possibility of a LTMS/CALFED partnership...

The narrow purpose of the first-phase document was to complete a reconnaissance-level effort to determine if there are any strategies worthy of further investigation with the potential to resolve these concerns about salinity. That effort concluded that there is a wide range of potential salinity-control strategies and that further investigation is indeed warranted.

This document updates the information in the first-phase document, addresses a broad range of issues related to potential Delta reuse, and identifies key issues that must be investigated to reach a final conclusion regarding the technical and economic feasibility of Delta reuse. A particular emphasis is the preparation of a conceptual design for a Delta reuse project. Phase three of this effort will involve increased work with stakeholders and decision makers to publicize the results of this work and to obtain support, for action recommendations and for further investigation.

The LTMS and the Department of Water Resources have focused more on opportunities for the Delta reuse of Bay material in levee maintenance than they have on habitat restoration. Therefore, although this document addresses both issues, it places greater emphasis on the latter. The Department of Water Resources' extensive work program regarding Delta reuse is discussed in section IV.

The Dredged Material Reuse Program (DMRP)

The DMRP was established through the LTMS as a forum to facilitate the development of alternative upland disposal and reuse sites for clean dredged materials as well as for materials unsuitable for aquatic disposal. This collaborative effort includes:

The Bay Planning Coalition
The California Coastal Conservancy
California Environmental Trust
The Port of Oakland
The San Francisco Bay Conservation and Development Commission
Save The Bay
U. S. Environmental Protection Agency
U. S. Army Corps of Engineers

II. Dredging and the Long-Term Management Strategy

According to the LTMS Preferred Alternative, two hundred million cubic yards of clean dredged material could be available for reuse during the coming fifty years.

Overview of Dredging in the San Francisco Bay
Each year, more than 4,000 commercial ocean-going vessels pass through the Estuary, carrying more than 50 million tons of cargo to and from ports and harbors stretching from Redwood City to Sacramento. The Estuary is home to more than 1,000 commercial fishing vessels and hosts more than thirty-three thousand recreational boats in more than 200 marinas. The Estuary has also been an important center for naval and other military operations.

To maintain these activities in an estuary with depths averaging less than twenty feet requires extensive dredging. Ocean-going, commercial, deep-draft vessels can draw 40 feet or more. Historically, dredging volumes in the Bay have ranged from two to ten million cubic yards (mcy) annually. However, the recent reduction of military activity in the Estuary has decreased the amount of dredging performed annually.

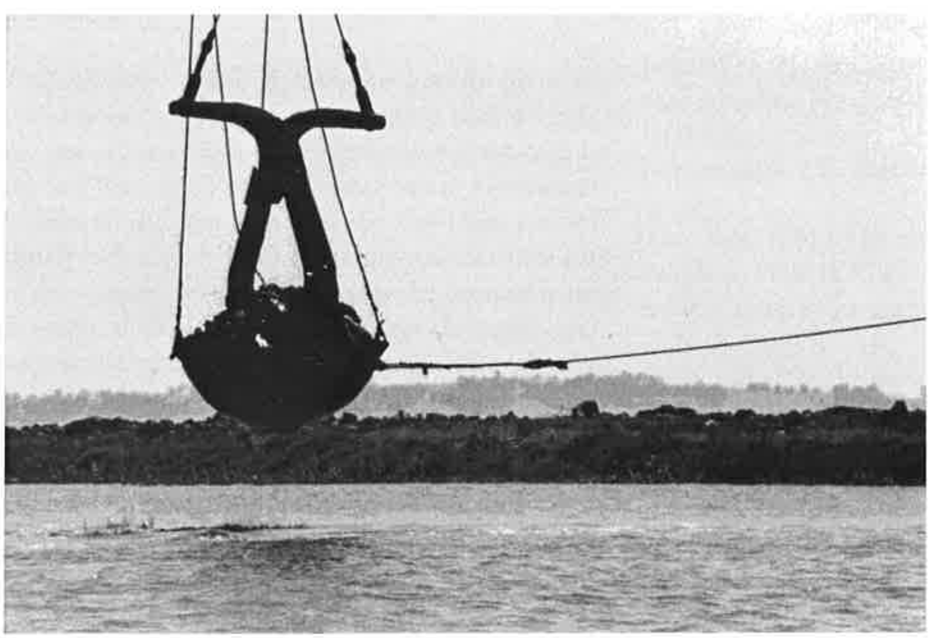


Figure 2. Dredging

The LTMS estimates that from 173.5 million to 296.5 mcy of material will be dredged from the Bay over the next 50 years.[1] These estimates do not include the current proposal for expanding the San Francisco International Airport. This proposed project alone could add many millions of cubic yards of dredged material to prepare the site for construction fill.

Generally, the reuse of Bay sediments is constrained by soil type and chemical concentration. The degree of potential contamination in Bay sediments varies dramatically depending on several factors: soil type, sediment depth, proximity to sources of contamination, and hydrology. A conservative estimate of total material available for beneficial Delta reuse should be based on the assumption that, due to a variety of possible concerns, reuse in the Delta would be limited to material that is suitable for unconfined aquatic disposal (or SUAD, in LTMS speak). For convenience, this report simply refers to SUAD material as "clean." The LTMS estimates that a minimum of 80 percent of Bay-dredged material is suitable for aquatic disposal.[2] Assuming the elimination of all non-SUAD materials, the amount of material potentially available for reuse over the LTMS planning horizon ranges from 138.8 to 237.2 mcy.

The LTMS Preferred Alternative
The LTMS final EIS/EIR and the final LTMS ROD call for 40 percent of all material dredged from the

The draft ERPP has been criticized for a number of reasons, including its lack of specific and aggressive restoration goals. The revised draft ERPP (with the same goals for the central and western Delta) was released in June. Conversations with CALFED staff indicates that there is still an opportunity to modify these regional goals.

The Recovery Plan for Native Resident Fishes of the Sacramento-San Joaquin Bay-Delta Estuary also recommends that Delta islands and islands in the Suisun Marsh be restored to provide habitat for fish spawning and rearing. The Comprehensive Conservation and Management Plan prepared by the San Francisco Estuary Project contains complementary recommendations regarding wetlands restoration and the preparation of regional wetlands management plans.

Table 1 - Selected Species That Would Benefit from Habitat Restoration in the Western and Central Delta

Species	Status
Delta smelt	TS, TF
Winter-run Chinook salmon	ES, EF
Spring-run Chinook salmon	P
Fall and late-fall Chinook salmon	P
Splittail	FT, C
Longfin smelt	
White sturgeon	
Green sturgeon	
Steelhead trout	
Striped bass	
Sacramento perch	
Sacramento blackfish	
Largemouth bass	
White catfish	
Sacramento squawfish	
Tule perch	
Threadfin shad	
Pacific herring	
Starry flounder	
Bay shrimp	
California black rail	TS
Suisun song sparrow	

Key

TS: Threatened under the California Endangered Species Act
TF: Threatened under the federal ESA
ES: Endangered under the California ESA
EF: Endangered under the federal ESA
C: Candidate for listing under the California ESA
P: Proposed for listing under the federal ESA

Source: CALFED Ecosystem Restoration Program Plan

Marine and estuarine species, which inhabit the lower, more saline reach of the Estuary, would also benefit from Delta habitat restoration. The destruction of habitat in the Estuary, the diversion of a large portion of natural fresh-water outflow, and the recent arrival of voracious non-native filter feeders (for example, *potamocurbula amurensis*) in the Estuary have led to depressed levels of phytoplankton in Suisun Bay, the western Delta, and in the Estuary. By increasing primary productivity, habitat restoration in the Delta would benefit species that do not, or at least rarely, occupy the Delta.[8]

It is important to note that Delta islands currently support wildlife and other environmental values. However, most of these islands are managed primarily for agriculture. Therefore, there is ample opportunity to protect and enhance existing natural resource values on these Delta islands as a part of a restoration program with an ambitious tidal wetland restoration component.

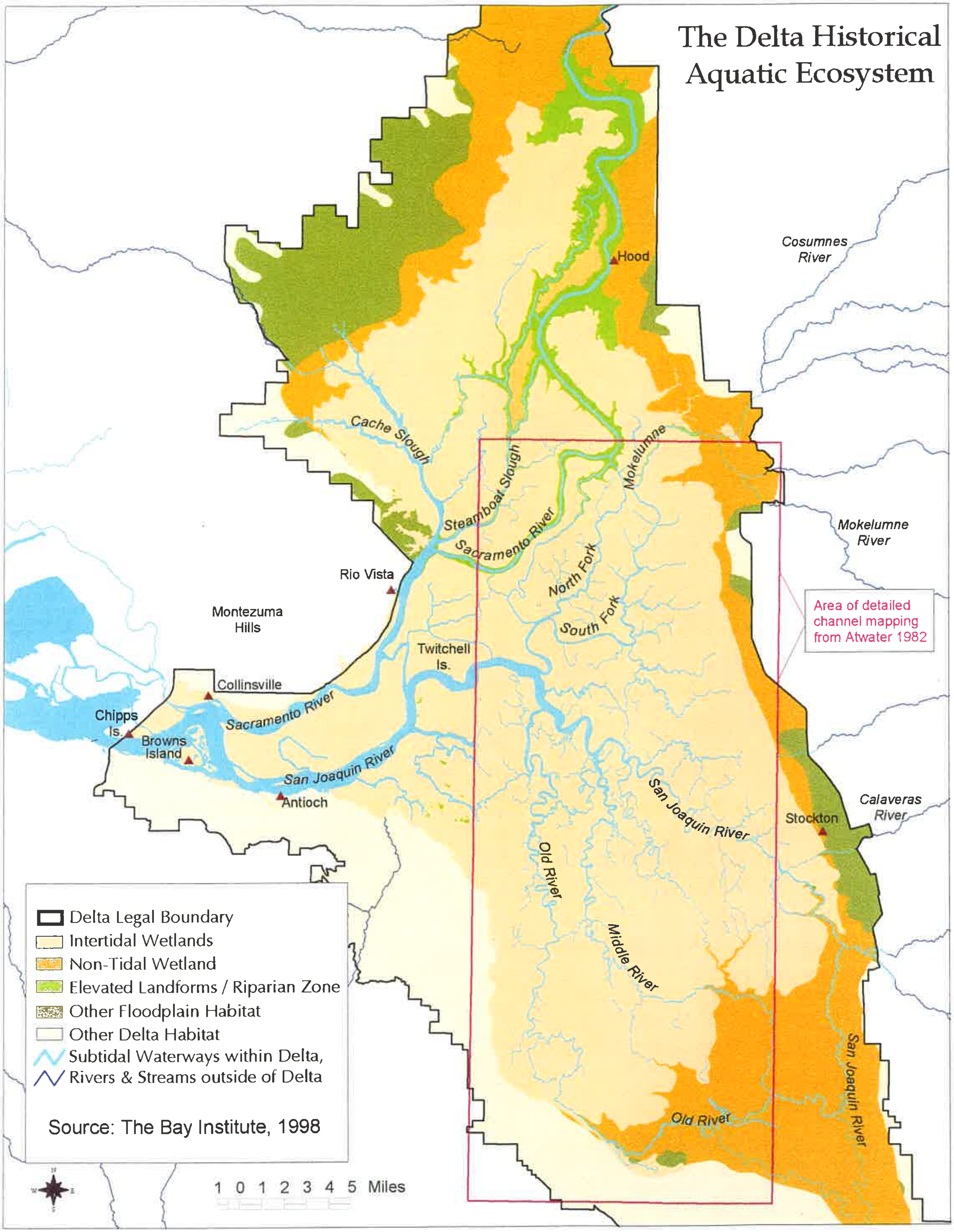
A wide variety of ecosystem restoration plans indicate that tidal habitat restoration in the western and central Delta is a key component of any systemwide restoration plan and offers the potential to benefit a broad range of species (see Table 1). However, the CALFED program contains surprisingly modest and ambiguous tidal habitat restoration goals for this region.

2. The Subsidence Constraint

The reason for CALFED's relatively modest shallow-water restoration goal for the western and central Delta and its ambiguity regarding Delta tidal wetland restoration goals is clear—the challenges presented by land subsidence.

The Dredging and Sediment Disposal section in the draft ERPP clearly endorses the concept of Delta reuse:

> Dredged material disposal would be environmentally sound and the use of nontoxic dredged material would be promoted as a resource for restoring tidal wetlands and other habitats, reversing Delta island subsidence, and improving dikes and levees.[9]



The Delta Historical Aquatic Ecosystem
Cosumnes River
Hood
Cache Slough
Steamboat Slough
Sacramento River
Mokelumne
Mokelumne River
North Fork
South Fork
Area of detailed channel mapping from Atwater 1982
Rio Vista
Montezuma Hills
Twitchell Is.
Collinsville
Chipps Is.
Browns Island
Sacramento River
San Joaquin River
Antioch
San Joaquin River
Stockton
Calaveras River
Old River
Middle River
Old River
San Joaquin River
Delta Legal Boundary
Intertidal Wetlands
Non-Tidal Wetland
Elevated Landforms / Riparian Zone
Other Floodplain Habitat
Other Delta Habitat
Subtidal Waterways within Delta,
Rivers & Streams outside of Delta
Source: The Bay Institute, 1998
1 0 1 2 3 4 5 Miles

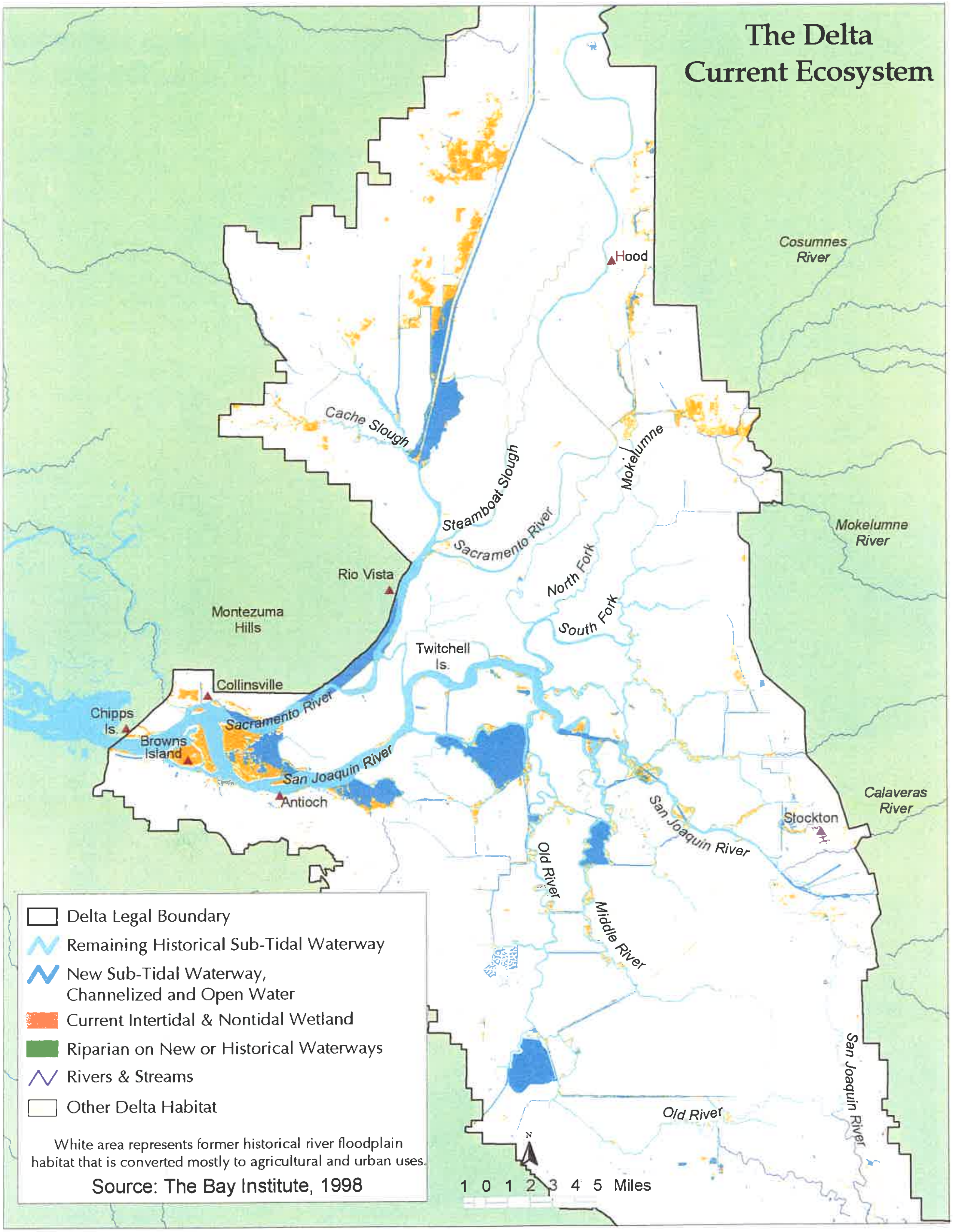
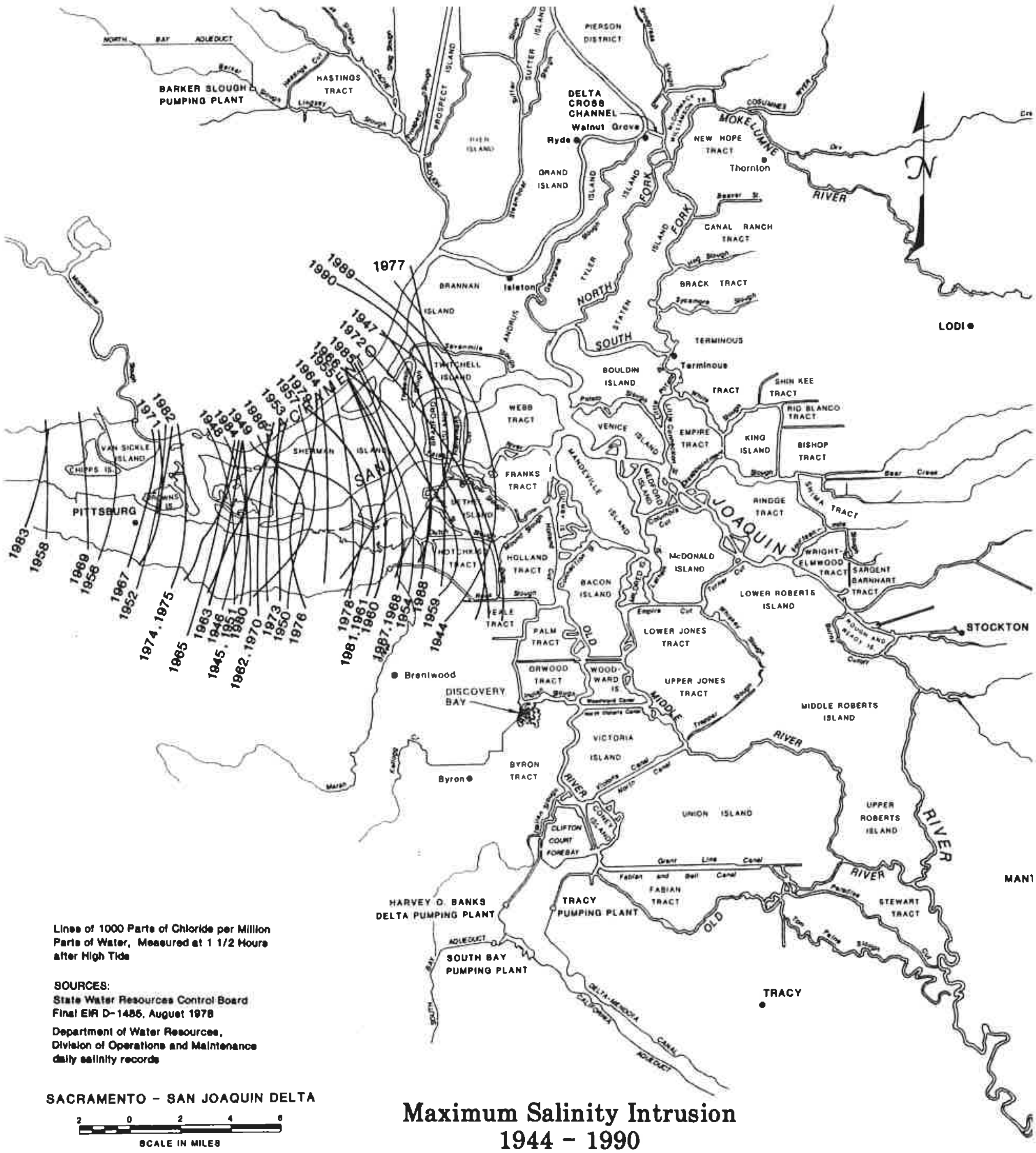

The Delta
Current Ecosystem
Hood
Cosumnes River
Cache Slough
Steamboat Slough
Mokelumne
Sacramento River
Mokelumne River
North Fork
South Fork
Rio Vista
Montezuma Hills
Twitchell Is.
Collinsville
Chipps Is.
Browns Island
Sacramento River
San Joaquin River
Antioch
Old River
San Joaquin River
Stockton
Calaveras River
Middle River
Old River
San Joaquin River
Delta Legal Boundary
Remaining Historical Sub-Tidal Waterway
New Sub-Tidal Waterway, Channelized and Open Water
Current Intertidal & Nontidal Wetland
Riparian on New or Historical Waterways
Rivers & Streams
Other Delta Habitat
White area represents former historical river floodplain habitat that is converted mostly to agricultural and urban uses.
Source: The Bay Institute, 1998
N
1 0 1 2 3 4 5 Miles

Figure 5. Maximum Salinity Intrusion 1944-1990



Source: Delta Atlas, Dept. of Water Resources approaches to reversing subsidence on Delta islands to facilitate habitat restoration. The first is using in-Delta materials, discussed below. The second is sediment augmentation through vegetation management, or bioaccretion. Some experiments have found that growing tules on Delta islands can reverse subsidence. Growing tules may allow subsidence to be reversed by one to two inches per year.[14] Using this approach, however, it could take at least 60 years to raise highly subsided islands to tidal-marsh elevations. The third possible approach is to import sediment from the Bay or elsewhere. Rice straw from the Sacramento Valley may be another possible source of material.

Care must be taken in designing and implementing any program using Bay or Delta fill material to raise the elevation of Delta islands. Raising bottom elevations in these islands will require phasing to prevent additional subsidence and lateral spreading. Past experiences with raising Delta levees indicate that careful monitoring during phased filling for habitat purposes could prevent subsidence and instability and protect the integrity of levees. Levee projects have been found to accommodate filling rates of up to three feet per month without creating subsidence or stability problems.[15]

...organic Delta soils make poor levees, inorganic mud, such as that found in the Bay, is ideal for levee construction.

5. Potential Capacity for Dredged Material

The amount of material that could be used to restore tidal habitat on western and central Delta islands is enormous. To illustrate, much of Sherman Island, has subsided more than fifteen feet. At 10,000 acres, or fifteen square miles, if dredged material were used to raise the elevation of the entire island (an unlikely approach), each three feet of subsidence reversal would require an additional 48.4 mcy of material. CALFED staff has indicated that, were it not for cost, CALFED's demand for material for habitat restoration would be practically limitless.[16]

Levee Integrity

1. An Overview

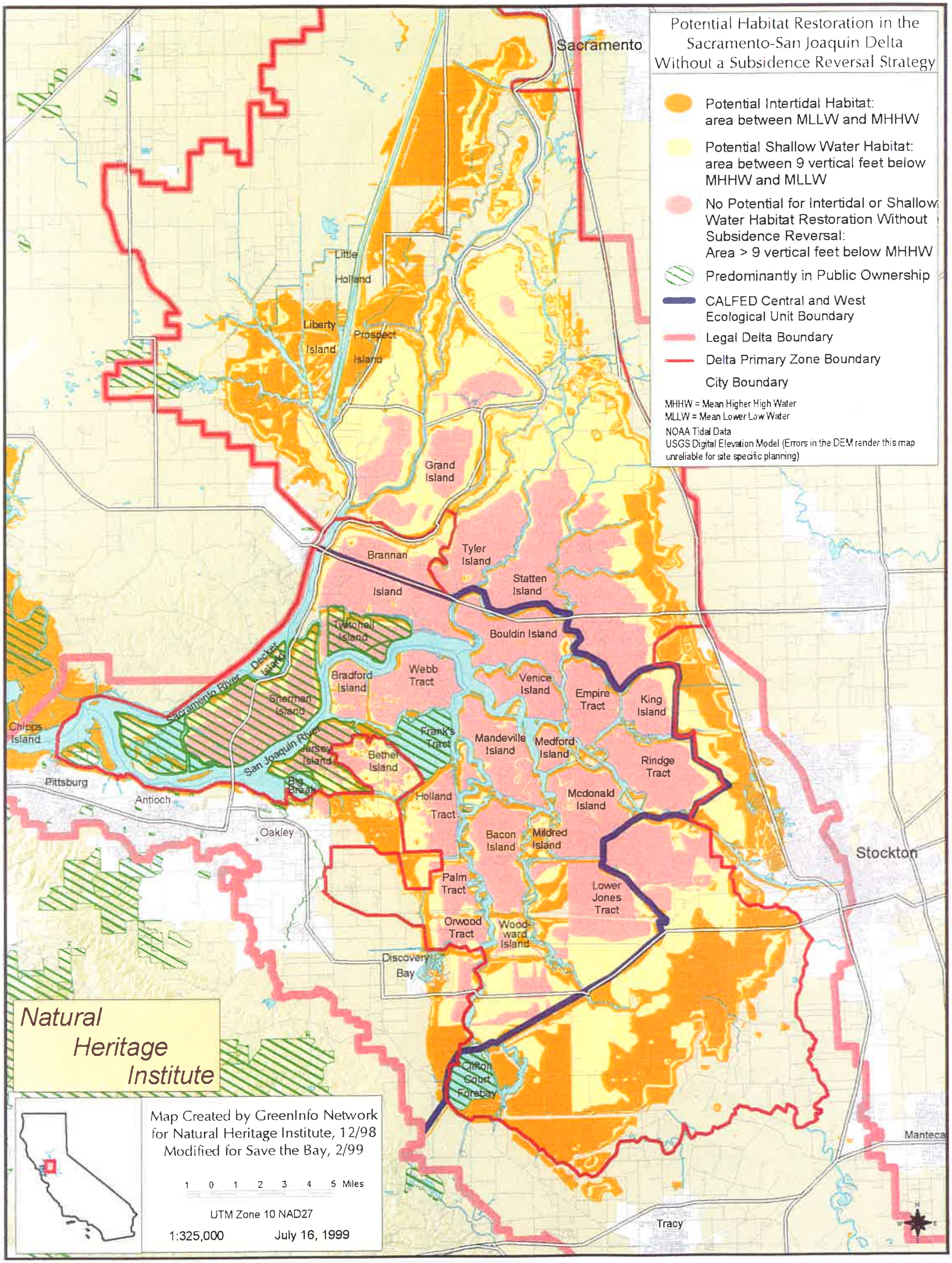
Over 1,100 miles of Delta levees protect a fragile network of increasingly subsided islands (see figures 8 and 9). These islands, totaling more than 700,000 acres, support important farming activities, thousands of residents, and important wildlife habitat. These islands also preserve the integrity of the Delta as the heart of California's plumbing system. Because two-thirds of the fresh water in the state arrives as precipitation north of the Delta and two thirds of the state's demand for water lies south of it, the Delta is California's switching yard for water. Every year millions of acre-feet of water are diverted from the Delta by state and federal water projects.

One of CALFED's major areas of focus is on maintaining the integrity of Delta islands. The failure of levees and the resultant flooding of Delta islands (as a result of earthquakes, levee subsidence, or inadequate maintenance), increases the tidal prism of the Delta. The water rushing into a flooded Delta island must come either from the rivers upstream or from the Bay downstream. During floods, there may be adequate fresh water in the Delta to repel saltwater intrusion. However, during periods of low flow, a levee failure could draw significant amounts of salt water into the Delta. A catastrophic failure could threaten Delta residents, power and transportation infrastructure, farmland, wildlife habitat, and the state's two largest water projects.

Many Delta island levees have failed, for a variety of reasons, during the past 150 years. At least 30 Delta islands and tracts have flooded between 1930 and 1991, seven in 1986 alone (see figures 10, 11 and 12). In addition, as the amount of water diverted in the Delta has increased, and as subsidence has worsened, the risk of levee failure has increased. In 1986, DWR began a much more ambitious program to address Delta levee stability. Of the approximately 1,100 miles of levees in the Delta, CALFED has found that 600 miles must be upgraded to meet current standards.[17]

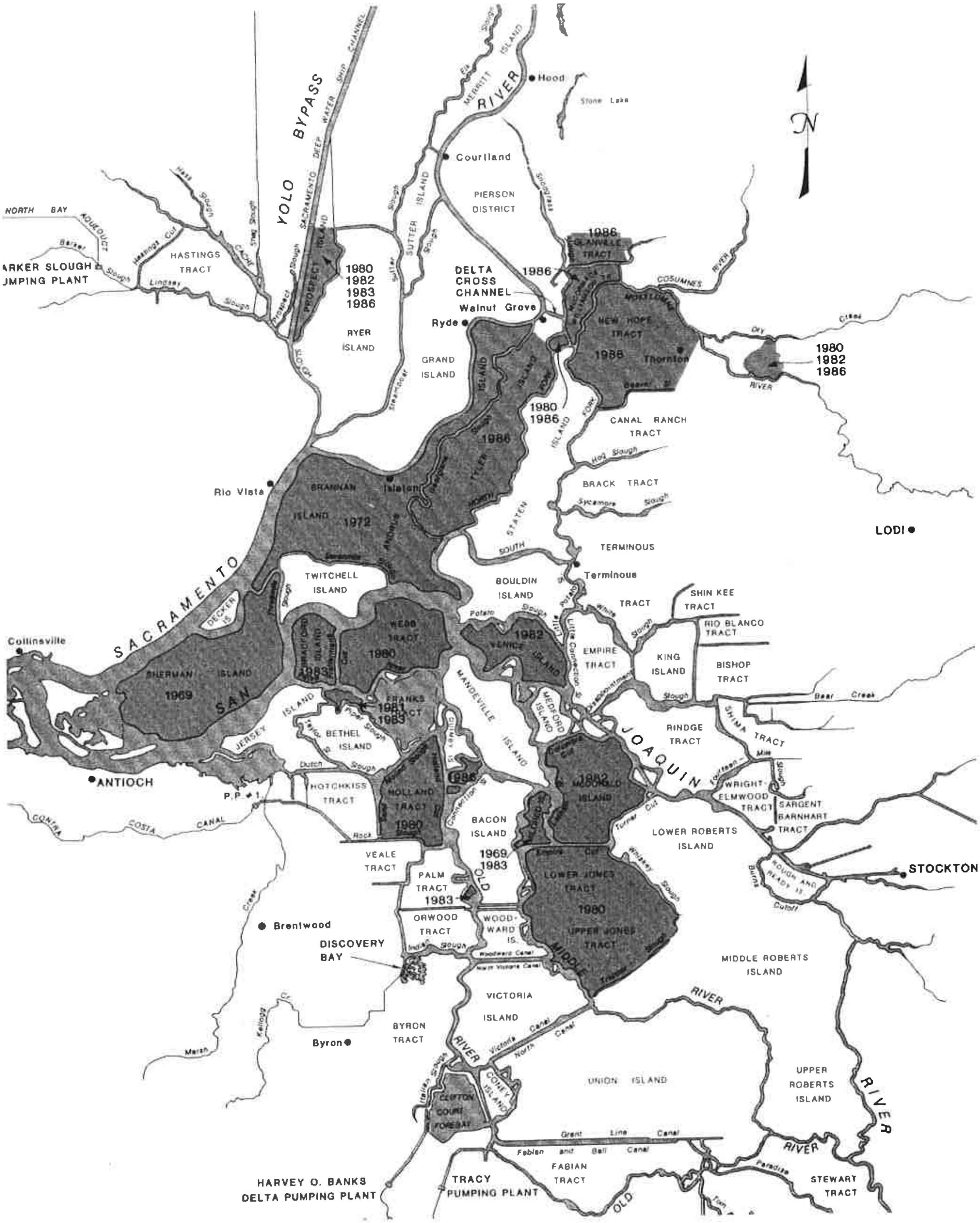
2. The Capacity for Material

CALFED has estimated that twenty-five mcy of material will be needed to strengthen and maintain Delta levees. It is possible that less material will be needed, since the CALFED levee program has not adequately considered that habitat restoration could take the form of removal or intentional breaching of levees. However, habitat restoration could also require additional sediment, as discussed above. In addition, alternatives such as setback levees, which would move levees and expand aquatic habitat, would require significant amounts of additional material.



Potential Habitat Restoration in the Sacramento-San Joaquin Delta Without a Subsidence Reversal Strategy
Potential Intertidal Habitat: area between MLLW and MHHW
Potential Shallow Water Habitat: area between 9 vertical feet below MHHW and MLLW
No Potential for Intertidal or Shallow Water Habitat Restoration Without Subsidence Reversal: Area > 9 vertical feet below MHHW
Predominantly in Public Ownership
CALFED Central and West Ecological Unit Boundary
Legal Delta Boundary
Delta Primary Zone Boundary
City Boundary
MHHW = Mean Higher High Water
MLLW = Mean Lower Low Water
NOAA Tidal Data
USGS Digital Elevation Model (Errors in the DEM render this map unreliable for site specific planning)
Sacramento
Little Holland
Liberty Island
Prospect Island
Grand Island
Brannan Island
Tyler Island
Statten Island
Twitchell Island
Bouldin Island
Decker Island
Sacramento River
Sherman Island
Bradford Island
Webb Tract
Venice Island
Empire Tract
King Island
Chipps Island
San Joaquin River
Jersey Island
Bethel Island
Frank's Tract
Mandeville Island
Medford Island
Rindge Tract
Big Break
Pittsburg
Antioch
Holland Tract
Mcdonald Island
Oakley
Bacon Island
Mildred Island
Stockton
Palm Tract
Lower Jones Tract
Orwood Tract
Woodward Island
Discovery Bay
Clifton Court Forebay
Manteca
Tracy
Natural Heritage Institute
Map Created by GreenInfo Network for Natural Heritage Institute, 12/98
Modified for Save the Bay, 2/99
1 0 1 2 3 4 5 Miles
UTM Zone 10 NAD27
1:325,000
July 16, 1999

Figure 11. Delta Islands Flooded Since 1980



Source: Delta Atlas, Dept. of Water Resources

Figure 12. Historic Inundation of Delta Islands

Area Flooded	Acres	Years
Andrus Is.	7,200	1902,1907,1909, 1972
Bacon Is	5,546	1938
Bethel Is.	3,400	1907,1908, 1909,1911
Big Break Is.	2,200	1927
Bishop Tract	2,100	1904
Bouldin Is.	5,600	1904,1907, 1908,1909
Brack Tract	2,500	1904
Bradford Is.	2,000	1950,1983
Brannan Is.	7,500	1902,1904, 1907,1909,1972
Byron Tract	6,100	1907
Cliftoncourt Tract	3,100	1901,1907
Coney Is.	900	1907
Dead Horse Is.	200	1950,1955,1958, 1980,1986,1997
Donlon Is.	3,000	1937
Edgerly Is.	150	1983
Empire Tract	3,500	1950,1955
Fabian Tract	6,200	1901,1906
Fay Is.	100	1983
Franks Tract	3,300	1907,1936,1938
Glanville Is.	N/A	1986,1997
Grand Is.	N/A	1955
Grizzly Is.	8,000	1983,1998
Holland Tract	4,100	1980
Ida Is.	100	1950,1955
Jersey Is.	3,400	1900,1904,1907, 1909
Little Franks Tract	350	1981,1982,1983
Little Mandeville Is.	200	1980,1994
Lower Jones Tract	5,700	1907,1980
Lower Roberts Is.	10,300	1906
Mandeville Is.	5,000	1938
McCormack-Williamson Tract	1,500	1938,1950,1955 1958,1964,1986 1997
McDonald Is.	5,800	1982
McMullin Ranch	N/A	1997
Medford Is.	1,100	1936,1983
Middle Roberts Is.	500	1938
Mildred Is.	900	1965,1969,1983
New Hope Tract	2,000-9,500	1900,1904,1907, 1928,1950,1955, 1986
Palm TRAC	2,300	1907
Paradise Junction	N/A	1997
Pescadero	3,000	1938,1950,1997
Prospect Is.	1,100	1980,1981,1982, 1983,1986,1995, 1997
Quimby Is.	700	1936,1938,1950, 1955
RD17	4,500-5,800	1901,1911,1950
RD 1007	3,000	1925
Rhode Is.	100	1938
River Junction	1997	
Ryer Is.	11,600	1904,1907
Sgt. Barhart Tract.	1,100	1904,1907
Sherman Is.	10,000	1904,1906,1909, 1937,1969
Shima	2,394	1983
Shin Kee Tract	700	1938,1958,1965, 1986
Staten Is.	8,700	1904,1907
Stewart Tract	3,900	1938,1950,1997
Terminous Tract	5,000-10,000	1907,1958
Twitchell Is.	3,400	1906,1907,1908
Tyler Is.	8,700	1904,1907,1986
Union Is.	24,000	1906
Upper Jones Tract	6,200-5,700	1906,1980
Upper Roberts Tract	500	1938
Van Sickle	N/A	1983,1998
Venice Is.	3,000	1904,1906,1907, 909,1932,1938, 1950,1982
Victoria Is.	7,000	1901,1907
Walthall	N/A	1997
Webb Tract	5,200	1950,1980
Wetherbee Lake	N/A	1997

Source: Dept. of Water Resources, Flood Protection and GIS Branch

Salinity aside, Bay material is highly suitable for Delta levee construction. Whereas organic Delta soils make poor levees, inorganic mud, such as that found in the Bay, is ideal for levee construction. Bay sand could also be useful in reinforcing the backs of levees and in levee seepage control features such as drain blankets.[18]

In-Delta Sources

There are four potential sources for in-Delta material for use in habitat restoration and levee maintenance. The first is in-Delta dredging, which produces an estimated 100,00 to 200,000 mcy per year, only some of which are currently reused in the Delta.[19] Using this source alone, it would require eleven to twenty-two years to meet CALFED's levee maintenance goals, without any reuse for habitat restoration. The second source is commercially available aggregate, a highly expensive option. The third source is material that could be excavated from existing Delta islands. However, given the fact that much of the material in the Delta is unsuitable for levee construction, and given the ongoing subsidence problem, the usefulness of this approach is limited.

Finally, CALFED has funded DWR to evaluate the feasibility of constructing sediment traps in the Delta. The wetlands on Delta islands formerly functioned as an enormous trap for sediment flowing into the Estuary. Delta leveeing has eliminated these traps, directing sediments downstream into the Bay. DWR staff is considering the possibility of constructing an artificial sediment trap in the western Delta to capture sediment before it reaches the more saline portion of the Estuary. This material would be pumped onto an island to be used there or elsewhere for habitat and levee maintenance. This idea is still in the conceptual stages.

CALFED is working to determine how much total material could be produced cost-effectively by using these four approaches. What is clear is that the demand for material far outweighs what's available in the Delta.

IV. The Status of Delta Reuse

Demonstration projects using clean Bay materials to maintain Delta levees have produced encouraging results, showing no significant water quality impacts. Given the interest in Delta habitat restoration and the shortage of dredged material in the Delta, Bay dredged material may play a greater role in future Delta habitat restoration projects.

The concept of using Bay-dredged material in the Delta is not new. Prior to the Sonoma Baylands project, for example, the Port of Oakland sought approval to take material from its 42-foot deepening project to Twitchell Island. Failure to obtain necessary permits killed this project and alienated Delta stakeholders and the Central Valley Regional Water Quality Control Board. As mentioned above, using Bay material in the Delta has also been discussed in both the LTMS and in CALFED. This section briefly reviews the status of efforts to evaluate this concept in these two forums and discusses related recent, current, and proposed projects.

CALFED Planning

CALFED recently paid for staff at the Central Valley RWQCB to begin work on a general permit for Delta habitat restoration using material dredged in the Delta. CALFED staff is also interested in pilot programs to learn more about the potential of using Bay-dredged material in the Delta for habitat restoration. As indicated above, the draft EIS/EIR discusses the potential of reversing subsidence in the Delta using Bay material. However, this potential has not yet been factored into the calculation of Delta restoration goals or into the development of CALFED early-implementation habitat restoration projects. At the moment, the CALFED ecosystem program has not developed a clear approach to evaluate and, as appropriate, implement such reuse.[20] CALFED has funded some monitoring work to investigate progress toward the restoration of habitat in the Delta, both at sites that have received Delta dredged material and at sites that have not. CALFED has chosen not to fund additional work in this area.[21]

Although staff for the CALFED Levee Program have indicated an interest in Delta reuse of Bay dredged material, they have indicated that, as a result of concerns from the Central Valley RWQCB and the Corps of Engineers, this work has not moved forward.[22] Several contacts indicated that because of inadequate resources and competing priorities, the Central Valley RWQCB has not allocated adequate staff resources to this issue.

> *...the time appears to be right for a Delta habitat demonstration project using Bay dredged material.*

LTMS, DWR, and Demonstration Projects.

In the past several years, the LTMS has moved from the concept to the reality of beneficial reuse. The Sonoma Baylands restoration project, using nearly three mcy of dredged material from the Port of Oakland to restore 322 acres of tidal marsh in San Pablo Bay, represented a major step. Work is now well under way to create a larger restoration project at Hamilton Field. Several other possible projects, including a private contained disposal and wetlands creation project called Montezuma Wetlands, are also under consideration. For the past decade, the Department of Water Resources has made a significant investment in Delta levee maintenance and in habitat restoration. That agency deserves much of the credit for developing demonstration projects and for providing answers to some of the questions regarding Delta reuse of Bay material.

1. Delta Levee Demonstration Projects

The LTMS has also taken several steps to evaluate the feasibility of Delta reuse of Bay material. Over the past ten years there have been four levee maintenance demonstration projects undertaken under the leadership of the Department of Water Resources and

LTMS agencies. The monitoring results from these projects have indicated no significant water-quality impacts.

- Sherman Island was the first island in the Delta to receive Bay dredged material for beneficial reuse. In 1990 the Department of Water Resources used 1,600 cy of dredged material from Suisun Slough to reinforce the levees on Sherman Island. Two years of monitoring required by the CVRWQCB indicated no soil contamination or adverse water-quality impacts.

- In 1992 Twitchell Island received 50,000 cy of Suisun Bay Channel-dredged material as a part of levee rehabilitation on that island. DWR monitoring on Twitchell Island has not indicated any significant water-quality impacts from increased salinity, although levee subsidence has been noted.[23] However, it is important to note that because the material used on Twitchell Island had been stockpiled on Simmons Island for several years, some of its salinity certainly leached out before it was used at Twitchell Island.

- The 1994 Jersey Island project was the most recent and largest Delta pilot project to date, receiving 80,000 cy of material dredged from Suisun Bay and New York Slough. The monitoring report was released in May 1997.[24] Despite the fact that this material was dredged high in the Estuary, it still contained an estimated 194,491 pounds of salt. The summary of monitoring results to date indicates that receiving water salt loadings did not appear to be significant and that water quality was at background levels. The report also stated that "due to an extremely wet rainy season and because of the low porosity and high permeability of sandy material, the salt impacts were relatively short term (only about one month)."

- Winter Island, which is just west of the legal boundary of the Delta, received 100,000 cy of Bay dredged material for levee restoration work in 1998. This project went so well that another 100,000 cy of Bay dredged material will be delivered to Winter Island in 1999.

2. Proposed Delta Habitat Restoration Projects Using Delta Dredged Material

Although there have been several levee pilot projects using Bay dredged material, this effort, as part of the DMRP, is the only step that the LTMS has undertaken to evaluate the potential of Delta reuse in habitat restoration. Below is a list of proposed Delta habitat projects that used or would use dredged material from the Delta. Although these projects have not addressed the issues related to the reuse of Bay material, they have demonstrated the value and feasibility of Delta habitat restoration.

- Staten Island project: In 1994, as part of a larger project to establish shaded riverine habitat, 25,000 cy of Delta dredged material was used to raise the elevation on the exterior side of the island to a level suitable for planting tules, cattails, willows, alders, and cottonwoods. In the future this site may be rehabilitated

Table 2 - Delta Levee Maintenance Projects Using Bay Dredged Material and Habitat Restoration Projects Using Delta Material.

Project Location	Year	Purpose	Material Source	Volume (CY)
Sherman Is.	1990	Levee	Suisun Bay	1,600
Twitchell Is.	1992	Levee	Suisun Bay	50,000
Jersey Is.	1994	Levee	Suisun Bay	80,000
Winter Is.	1998	Levee	Suisun Bay	100,000
Winter Is.	1999	Levee	Suisun Bay	100,000
Staten Is.	1994-N/A[29]	Habitat	Delta	25,000
Franks Tract	Proposed	Habitat	Delta	1,000,000
Bradford Is.	Proposed	Habitat	N/A	N/A
Sherman Is.	N/A	Habitat	Delta	25,000+
Twitchell Is.	1999	Habitat	Delta/Bay	N/A
Donlan Is.	1984	Habitat	Delta	525,000
Venice Cut Is.	1986	Habitat	Delta	604,500

using various techniques to reach a level that would support more woody vegetation.[25]

- Proposed Franks Tract Category III[26] Project: Franks Tract is a flooded island located in the central Delta. It is approximately 3,300 acres and is owned by the State of California and operated by the Department of Parks and Recreation. This proposed demonstration project, to be funded by CALFED, would use approximately one mcy of material to restore 42 acres of islands. This restored area would hopefully increase the fish and wildlife resources, provide effective wave barriers to help protect the levees of the adjacent islands, and expand recreational opportunities. If the demonstration project proves effective, the long-term plan is to restore 500 acres of the islands.

- Proposed Bradford Island project: DWR has investigated the opportunity to use dredged material to build up the northern half of Bradford Island. This project was deemed too expensive.[27]

- Sherman Island Category III project: The Sherman Island Berm Demonstration Project is a 2.2-acre island to be constructed in the San Joaquin River, near Sherman Island.[28] The island will be constructed on an unvegetated submerged sandy shoal using tubes of coir fabric that will be filled with 25,000 cy of a sand and slurry mixture. Once the perimeter is in place, the center area will be filled with soil and stabilized.

- Twitchell Island Category III project: The purpose of this $3.5 million project, slated to begin within the year, is to determine methods of reversing subsidence in the Delta. This project is funded jointly by the DWR and CALFED. In addition to growing tules to increase the organic composition of the island, a large quantity of additional sediment will be used. Where this sediment will come from has not yet been determined. It is possible that Bay dredged material will be used in part.[30]

- Donlan Island. In 1984, the Corps of Engineers used 525,000 cy of Delta dredged material from the Stockton ship channel to restore 58 acres of shallow-water habitat at Donlan Island, a flooded Delta island immediately downstream from Sherman Island.

- Venice Cut Island. In 1986, the Corps placed 604,500 cy of Delta dredged material in Venice Cut Island, another flooded Delta island, to create 23 acres of shallow-water habitat.

Given the encouraging results of the levee maintenance demonstration project using Bay dredged material, the interest in Delta habitat restoration, and the shortage of dredged material in the Delta, the time appears to be right for a Delta habitat demonstration project using Bay dredged material.

V. Salinity Concerns

Although salinity is currently an obstacle to the reuse of Bay dredged materials in the Delta, a variety of control strategies could be explored to reduce or mitigate salinity impacts.

Salinity is the major obstacle to the reuse of Bay dredged material in the Delta. Sediment from the Bay varies dramatically in type. In addition, the salinity gradient in the Estuary results in dramatic ranges in salinity in Bay sediments. However, all material dredged from the Bay retains some salt. Material reused in a pilot project on Jersey Island (discussed below) was found to range from " 10,000 to 17,000 milligrams per liter from Suisun Bay and 3,000 to 4,000 mg/l from New York Slough."[31] Material dredged lower in the Estuary has a correspondingly higher salinity level. In simple terms, if salinity in Bay muds ranged from 3,000 to 17,000 mg./l, then Delta reuse of one mcy of Bay material could result in the importation of 3,000 to 17,000 cy of salt.

How much salinity would be released in the Delta through levee maintenance and habitat restoration using Bay material is not clear. However, importing this saline material into the Delta raises concerns, because the Delta is already a salinity-impaired environment. The diversion of roughly half of the Estuary's natural inflow allows salt water to intrude into the Delta at certain times of the year, with deleterious impacts on the environment, Delta farming, and Delta export water quality. Reducing and managing this salinity intrusion is a major focus of the Bay-Delta Accord and the X2 standard discussed above.

Depending on the location of reuse in the Delta, salinity from Bay materials could also have a harmful effect on ongoing Delta agricultural practices. For years there has been controversy, particularly in the western and southern Delta, over the impacts of water project-caused salinity on agriculture. In fact, the Department of Water Resources purchase of western Delta islands has largely been driven by a desire to address these concerns.

The indiscriminate use of Bay dredged material in the Delta could increase salinity levels at times of the year when salinity standards control the operation of water projects, potentially requiring additional water releases from upstream reservoirs or reduced Delta exports to maintain required salinity levels. Such "losses" of water would be of great concern to water users who rely on Delta exports. Increases in delta salinity could also worsen drinking water quality for Delta exporters, particularly the Contra Costa Water District, which is the urban water district most reliant on Delta water.

Salinity could be a constraint on habitat restoration as well as on water quality. Highly saline material may or may not prove to be an appropriate substrate for the brackish to fresh-water vegetation that is needed to support healthy habitat in the Delta. A pilot Delta habitat restoration project using Bay material could reveal whether these impacts are significant.

Regulatory Constraints Regarding Salinity

1. Standard and Policy

Following the Bay-Delta Accord, the State Water Resources Control Board adopted water rights Decision 95-6, setting a revised salinity standard for the Estuary. When Decision 95-6 expired, it was replaced by Decision 98-9, which regulates both salinity and Delta exports. Requirements vary by year, type and actual conditions in the Delta. Setting this new standard required sixteen years of scientific research, litigation, federal legislation, and extensive stakeholder negotiations. Therefore, any action such as Delta reuse of Bay material that could complicate the implementation of this complex standard will be subject to close scrutiny.

The Central Valley Regional Water Quality Control Board staff has indicated that due to salinity concerns, the state's antidegradation policy prevents the large-scale importation of Bay dredged material to the Delta.

The state's antidegradation policy is contained in the Water Code:

> The Legislature further finds and declares that activities and factors which may affect the quality of the waters of the state shall be regulated to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible.
>
> The Legislature further finds and declares that the health, safety and welfare of the people of the state requires that there be a statewide program for the control of the quality of all the waters of the state; that the state must be prepared to exercise its full power and jurisdiction to protect the quality of waters in the state from degradation.[32]

The Central Valley and San Francisco Regional Water Quality Control Boards have overlapping jurisdiction over the dredging and importation of material from the Bay to the Delta. The boundary separating the two agencies is just west of Sherman Island. The antidegradation policies of these two regional boards follow:

> Implementation of this policy to prevent or minimize surface and groundwater degradation is a high priority for the Board. In nearly all cases, preventing pollution before it happens is much more cost-effective than cleaning up pollution after it has occurred.[33]
>
> The "Statement of Policy with Respect to Maintaining High Quality of Waters in California," known as the Antidegradation Policy, provides conditions under which a change in water quality is allowable. A change must:

- Be consistent with maximum benefit to the people of the state;
- Not unreasonably affect present and anticipated beneficial uses of water; and
- Not result in water quality less than that prescribed in water quality control plans or policies.[34]

2. Applying the Antidegradation Policy

In determining if the state's antidegradation policy prevents the reuse of dredged material from the Bay due to salinity concerns, several factors must be evaluated:

- How much material would be used?
- How much salinity would be contained in this material?
- How much salinity would be released, and when, if this material were used in the Delta?
- Could the release of this material violate standards in Decision 95-6?
- What impacts would the release of this salinity have on beneficial uses in the Estuary?
- Could these impacts be adequately mitigated?
- What public benefits would be derived from using these materials?

Potential salinity-control strategies are discussed below. However, two items should be noted here. First, the San Francisco Bay and Central Valley Regional Water Quality Control Boards have approved several Delta levee pilot projects (see table 2) that used dredged material from the Bay. In approving these projects and complying with the state's antidegradation policy, these Boards found that impacts from the projects would be minimal, that applicable salinity standards would not be violated, and that using this material would provide significant public benefits.

Second, a narrow interpretation of antidegradation could prohibit all tidal restoration in the Delta. Any restoration of diked islands, particularly in the western and central Delta would increase the tidal prism of the Delta and could increase the intrusion of salt water during times of low Delta outflow. Such a blanket prohibition of tidal-marsh restoration is clearly not in the public interest. To prevent this nonsensical outcome, the state and regional boards must consider the public benefits of restoration. These include ecosystem and fisheries benefits, water-quality filtration benefits provided by restored wetlands, and the prevention of catastrophic failure of Delta levees and the degradation of water quality that would ensue. In the case of much of the Delta, obtaining these benefits will only be possible by using material dredged from the Bay.

This review of the state's antidegradation policy and demonstration projects approved to date, reveals that there is no absolute prohibition regarding the reuse of Bay dredged material in the Delta for habitat restoration or levee maintenance. This review further suggests that a thoughtful course of investigation could allow the state and regional boards to weigh the environmental costs and benefits of such reuse.

Possible Salinity Control Strategies

One goal of this effort is to determine if potential control strategies exist that would reduce or mitigate salinity impacts caused by the importation of Bay dredged material to the Delta. This investigation has revealed several possible approaches:

1. ***Project Location.***

One method of reducing potential salinity impacts is to locate a Delta reuse project in the western Delta, closer to the Bay, in a region of higher salinity and farther from the state and federal water projects in the southern Delta.

2. ***Salinity Reduction***

Several strategies may be available to reduce the salinity of material taken to the Delta. The first would be to focus on Delta reuse of material dredged in the upper reach of the Bay. As indicated above, material dredged higher in the Bay system contains less salinity than material dredged in the central Bay.[35] An additional strategy could be to reuse sand, which retains less water, and therefore less salt, than Bay mud. On the other hand, given the impervious nature of Bay muds, it is possible that much of the their salinity would be sequestered in the Delta, as long as reuse sites were designed not be dispersive. Additional investigation into this issue will be required.

Levine-Fricke has proposed using a portion of their project site to "wash" material from the Bay to reduce salinity. If the project is approved, that material may be available for use in Delta habitat restoration or levee maintenance.

There are two alternate methods of placing material at sites in the Delta. The first is to use a clamshell crane. The second is to slurry dredged material with water and pump it onto Delta islands. Whereas the latter strategy would result in a greater release of saline material, placing material by clamshell would reduce salinity discharges.

3. ***Capping***

Capping provides another potential strategy to reduce the release of salinity from Bay dredged material reused in the Delta. Given the degree of subsidence in islands in the western and central Delta, it may be possible to place Bay dredged materials in the bottom of these islands and to cover them with low-salinity material. This low-salinity material could be provided from in-Delta sources, as discussed previously, or from implementing the salinity-reduction strategies described above.

The Delta levee program itself could provide a source of capping material. The construction of levees on Delta peat soils can lead to dramatic subsidence, caused by compaction and lateral movement. For example, when DWR constructed a setback levee on virgin peat soils on Twitchell Island, an initial placement of four feet of fill led to four feet of compaction.[36] To reduce the subsidence of Delta levees, engineers have occasionally excavated peat spoils to replace them with material less susceptible to compaction and lateral movement. The Contra Costa Water District, for example, relocated

Figure 13. Delta Tidal Marsh Restoration Using Capped Bay Dredged Material

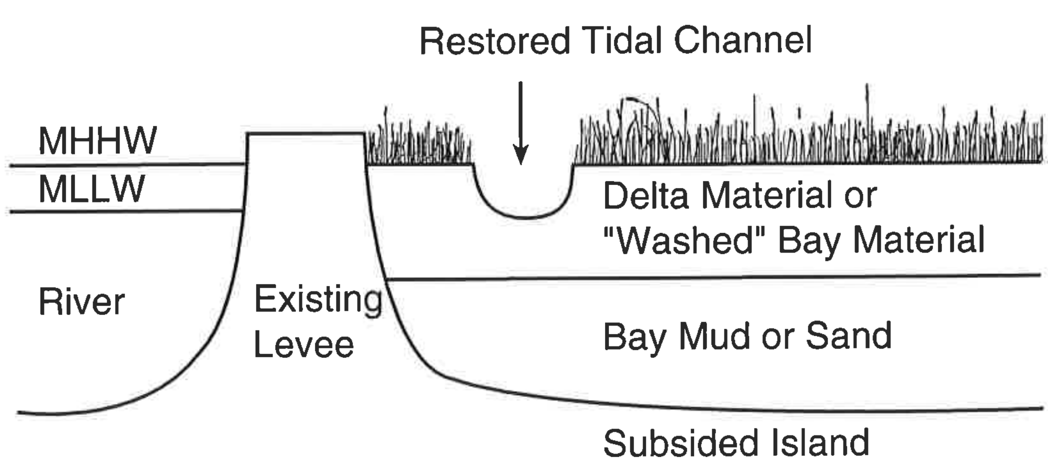
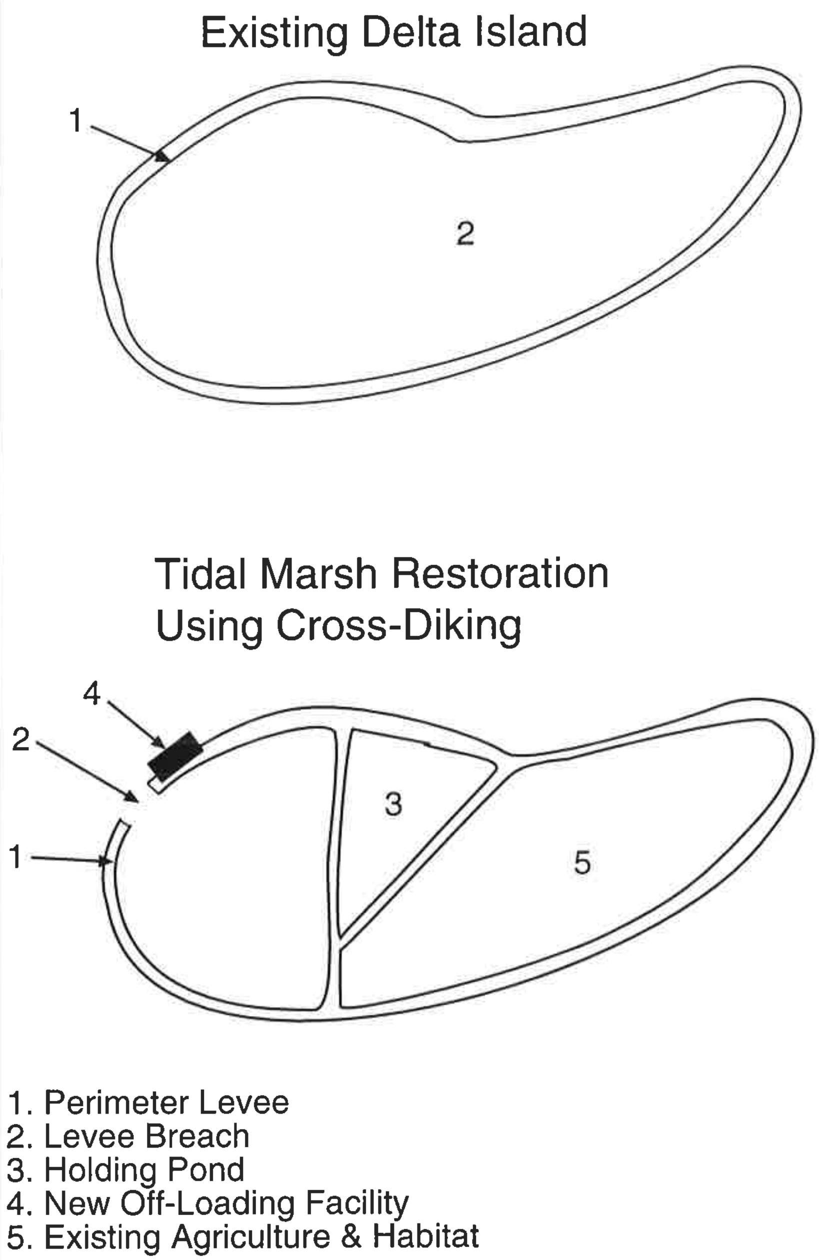


Figure 14. Tidal Marsh Restoration Using Cross-Diking and a Holding Pond



approximately 150,000 cy of peat soils as part of a levee project. As a part of another levee project, eight to ten feet of peat soils were excavated.[37] If such excavation were performed as part of a larger levee program, these peat soils could be used as capping material and as substrate for wetland vegetation.

Capping could allow Delta island levees to be breached, restoring tidal action while reducing the release of salinity (see figure 13). Special attention should be paid to the design of such a project to prevent material from being released into the environment through new slough channels in the restored marsh or through the levee breaches. In addition, the placement of heavy material on peat soils must be carefully planned to prevent additional subsidence or the undermining and failure of perimeter levees, since such failures could release additional saline material into the environment.

Seepage through levees could also release salinity from a capped Delta island. However, seepage through well-constructed levees in the other direction—from the rivers to the interior of Delta islands—is relatively small.

Capping contaminated materials in the aquatic environment has been attempted in different parts of the country, with mixed results. However, no examples could be found of the capping of saline material in a fresh or brackish water environment.

Capping may not address all potential salinity pathways, since salinity could also move through the Delta's high groundwater table. Additional investigation is required to determine the effectiveness of capping as a salinity-control strategy.

4. Timing of Disposal and Release of Saline Runoff

There are three possible strategies to time the release of saline discharges in the Delta to reduce salinity impacts.

First, during high freshwater outflow events, salinity in the Delta is dramatically reduced. If Bay material could be placed in the Delta at such times, it could significantly mitigate short-term salinity impacts. It may also be possible to build mud—or plastic-lined holding ponds as a component of a restoration site to hold saline runoff during placement in Delta islands (see figure 14). This saline water could be held on site and released during times of high outflow. Some Delta islands have soils that are more suitable to serving as the foundation for the cross dikes that would be required to implement this strategy.

Second, saline water could be discharged during the ebb tide. In the western Delta, ebb tides would rapidly carry saline water into Suisun Bay, where it would be diluted, reducing potential the effects of salinity in the Delta.

Third, during high-flow winter outflow events, when salinity is reduced, it may be possible to flood Delta reuse cells, releasing salinity in Bay material in those facilities. At these times, salinity could be be washed from the surface of Bay muds and then discharged.

5. Selective Levee Application

The release of salinity could also be reduced through using Bay dredged materials on the top and on the inboard side of levees. This Delta salinity control strategy is discussed in the LTMS Final EIS/EIR. Material applied in these areas is not subject to irrigation or tidal action. Salinity would most likely be released from these areas during storms. There is a high probability that such storms would correspond to a high outflow event, when salinity is reduced. It may also be possible to adjust the operations of drainage pumps in Delta islands, which use Bay dredged material to release saline runoff during high outflow events.[38]

6. Open Water Disposal

Some of the above approaches require the rehandling of dredged material-pumping, washing, placing material with clamshells, and so on. However, if approaches can be found that control salinity and other impacts, material from the Bay could be placed in the Delta without rehandling. These approaches could allow barges carrying Bay material to "bottom-dump" to raise the elevation of existing deep-water habitat (a CALFED goal). It could also allow existing Delta islands to be partially or entirely flooded, allowing barges to enter and bottom dump material directly inside these islands. If such open-water disposal proves possible, it could significantly reduce the cost of restoration. Such open-water disposal has been done with Delta material at Donlan Island and is being contemplated for use at Franks Tract.

VI. Other Environmental Issues

Projects using Bay dredged materials in the Delta must be carefully designed to avoid or fully mitigate adverse effects on Delta natural resources.

In addition to the salinity issues discussed above, Delta reuse raises other potential environmental concerns, some of which will be discussed in this section.

Air Quality

The barging of material from the Bay to the Delta could have effects on air quality, in comparison with the disposal of this material at sites nearer to the central Bay. There are two primary ways in which this conceptual design could have air-quality impacts: transportation and dust.

Transportation

Several activities during the construction and operation of a Delta reuse project could have adverse air-quality impacts. These include site preparation, transportation, material placement, and rehandling. However, the primary cause of adverse effects on air quality would be from the diesel exhaust generated during the transportation of dredged material to the site (see figure 15). The LTMS EIS/R summarizes potential impacts on habitat restoration and levee maintenance from pollutants, including ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, and PM10.[39] Of these, ozone impacts present the greatest concern, since the Bay Area is out of compliance with the ozone standard. The remaining air-quality impacts all appear to be within regulatory requirements. The LTMS environmental document also concludes that the air-quality impacts of using dredged material for habitat restoration and levee maintenance would be insignificant.[40]

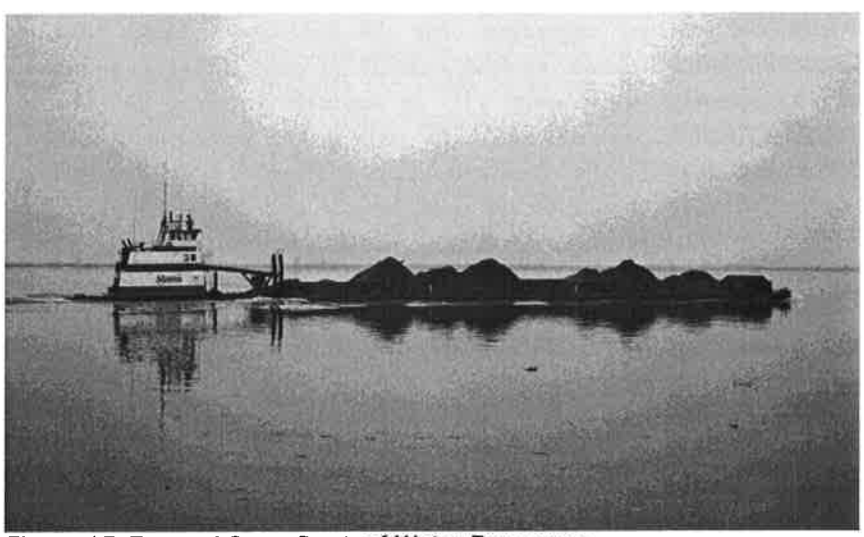


Figure 15. Tug and Scow *Dept. of Water Resources*

The effects of moving 5.2 mcy of dredged material from the Port of Oakland to the Montezuma Wetlands was also studied in the -50 ft. Dredge Project EIS/R.[41] Material would be removed from the inner and outer harbors using two clamshell dredges, loaded onto 5,000 cy scows, and towed by tug nearly to the Delta. Emissions from the dredges, tugboats, tender boats, and survey boats were all considered. The conclusion was that emissions from these temporary construction activities would cause an adverse, but not significant, air-quality impact under the BAAQMD CEQA Guidelines.

It is worth noting that transporting material to the Delta could result in lower emissions than disposal at the deep-ocean disposal site, which is located 50 miles from San Francisco. Average transport distance to the ocean site would be 71 nautical miles, significantly greater than distances to the Delta.[42] However, existing air quality in the Sacramento Metropolitan Air Quality Management District and the San Joaquin Valley United Air Pollution Control District is substantially poorer than that at the ocean site. In addition, the Clean Air Act only regulates air-quality discharges within three miles of the shoreline. Thus, most ocean disposal air discharges are sub-

Figure 17.
Arial Photograph of Sherman Island
Dept. of Water Resources

tion in this location provides significant habitat benefits, particularly during dry years.

- The site has excellent deep-water access. Little, if any, dredging would be required.
- Material from the Bay has been taken to this site for levee maintenance. And the site is near the location of Department of Water Resources' rehandling facility for Sherman Island levee maintenance.
- Given the extent of subsidence on Sherman Island, habitat restoration is not possible in the near future without the importation of fill material. This depth also provides maximum capacity for dredged material.
- The site is adjacent to existing habitat, particularly the Sherman Island Waterfowl Management Area and Donlan Island.
- The site is already in public ownership. The Department of Water Resources has purchased almost the entire island over the past five years.
- There are relatively few land-use conflicts in the area (in the highly urban Bay Area).
- Using the existing levee on Mayberry Slough as a containment levee for the habitat restoration unit would reduce levee-construction costs. DWR has already constructed a partial containment levee in this vicinity.

This site is discussed briefly in the 1995 LTMS upland analysis.[56] That document proposed the 1,400-acre River Islands Land Company parcel as a possible restoration site. The capacity of this site, as discussed in this document is 27 mcy, if filled to +three NGVD, comparable to the capacity estimated in this conceptual design. Concerns about this site and alternative sites are discussed later in this section.

Given the proposal (put forth below) that dredging contractors place dredged material on the site, minimal onshore facilities would be required. A few pilings would be necessary. Contractors placing material on the site would require access to the power lines that cross Sherman Island. Given the number of times the site would be used over the life of the project, possibly by different contractors, it may be appropriate to install a permanent power line to the site.

1. The Rehandling Unit

For several years, the Department of Water Resources has been operating a facility of Sherman Island to rehandle dredged material for reinforcing that Islands levees. DWR has also planned two possible permanent facilities on Sherman Island to facilitate rehandling for levee reuse purposes. They would be constructed on parcels of 78 and 340 acres. An LTMS analysis concluded, however, that the 78-acre parcel would probably be too small to serve as a viable large-scale rehandling site.[57] A previous LTMS report also presented a conceptual plan for a 400-acre rehandling facility.[58] Because these reports have been prepared for the LTMS and because of the significant experience in using Bay material for Delta levee maintenance in recent years, the conceptual design discussion for this unit is relatively brief.

This conceptual rehandling unit is divided into three 100-acre cells. This design provides flexibility in operating the site and increases the throughput of material by allowing one cell to be filled while another is being harvested. Assuming that these cells are filled to a maximum depth of three feet, to ensure that the material would dry rapidly, the site would have a capacity of approximately 1,000,000 cy. This capacity reflects the fact that fine-grained sediments retain water when they are placed by slurrying. This initial bulking can be as much as 40 percent, decreasing the capacity of the site.[59] The actual capacity of the rehandling site would be somewhat greater than this conservative estimate, because sand, the preferred material for levee maintenance, is subject to less initial bulking. A complete cycle of placement, drying, and harvesting would take approximately two years.

Given the size of the habitat and the rehandling units, we assume that the majority of material will be placed in the site hydraulically. However, small projects could be placed in the cells by clamshell. We do not propose to install a permanent pumping facility on the site, but rather that dredging contractors place the material in the site. Maintaining continuity of responsibility for placement would reduce potential expensive delays that could result from breakage of a dedicated pumping facility.

Given a three-foot fill depth, the levees for the rehandling cells could be relatively small (eight feet or less). However, given the variation in subsidence on the site, the actual height of the levees will depend on final design.

After initial placement, material would dry for approximately six months before it could be harvested. Material would be rehandled and transferred onto scows or trucks for Delta levee maintenance;. Highway 160 would provide access for trucks. This design assumes that the vast majority of material would be rehandled either on the island or by scow. Therefore, we have not evaluated potential transportation impacts on Highway 160.

2. The Habitat Restoration Unit

The habitat restoration unit is designed to be 1,200 acres in size. As with the rehandling site, we anticipate that most of the material will be placed hydraulically. The site is designed as a single cell. After the placement of material, the original levee would be breached in one or more locations, allowing the reestablishment of native tules and other wetland vegetation. This conceptual design does not include a detailed proposed habitat design (see the additional issues section).

The capacity of the site is determined by the amount of material required to restore the site to tidal-marsh elevations. This portion of Sherman Island is subsided up to -fifteen feet NGVD. Most tidal-marsh restoration projects have a final design elevation of approximately +two feet NGVD. Some projects, such as Sonoma Baylands, intentionally "undershoot" the final design elevation to allow sedimentation and other natural processes to reach the final elevation and shape the restored wetlands. (Sonoma Baylands was filled to zero feet NGVD, for example.) Therefore, the final capacity of the site would be a function of site design, subsidence, desired elevation types, and the approach to restoration (that is, conservative or filling to the desired final elevation). Given the high degree of subsidence, a 1,200-acre site in this location would have a significant capacity. Assuming a conservative twelve feet of fill, restoring a 1,200-acre site on Sherman Island to tule marsh elevation would require 23 mcy of material. This estimate is conservative, because aggressively dried fine-grained material can shrink by up to 30 percent.[60]

Given the capacity of the site, it is nearly certain that it would be filled in phases—a strategy that would also provide an opportunity to reduce costs. An initial eight-foot levee would be constructed from native material or from the rehandling site, which could be constructed first. The habitat restoration site would then be filled with three to four feet of material. After that material had dried, it could be used to construct a higher levee on the perimeter of the site. This approach would reduce the total amount of material that would be moved to build the final levee (see figure 18). These levees could be protected from erosion by adding rock to their slopes, by flattening their slopes, or by designing the restored riparian and wetland habitat. The exterior of these levees would also be hydroseeded to reduce erosion.

The existing levees on the San Joaquin River and along Mayberry Sough, on the interior of the Island, surround the habitat-restoration site on three sides, further reducing levee-construction costs. The new perimeter levee would be relatively short (see detail on figure 18). It is also possible that it could incorporate an existing DWR levee near this location.[61]

CALFED has actively supported restoration efforts in both the Delta and the Bay, including the Hamilton Field restoration site. However, from the perspective of CALFED, in comparison with Hamilton Field, this project offers several potential advantages. This conceptual design would:

- Provide benefits to key target species, such as the Delta smelt.
- Allow a dramatic expansion in tidal wetland restoration opportunities in CALFED's primary area of focus-the Delta.
- Reduce conflicts with water projects by providing dry year benefits for fisheries.
- Reduce the vulnerability of Delta islands to catastrophic failure, thus protecting water quality for Delta water users.
- Reduce conflicts with Delta farmers by directing some habitat restoration effort to land already in public ownership and by strengthening the CALFED levee program.
- Reduce agricultural drainage as a result of habitat restoration, including reducing the loading of trihalomethane precursors in the Delta.
- Expand the tidal prism and increase residence time in the Delta, a key factor in ecosystem restoration
- Cap existing sediments, which could reduce the potential for the release of mercury from sediments contaminated by mining, a potential problem that has led some scientists to raise serious concerns about Delta restoration.[62]

The potential for habitat restoration using dredged material on Sherman Island was addressed very briefly in the 1995 LTMS Reuse/Upland Analysis. That study concluded that, "There is a high potential for smaller (smaller than the entire island) tidal wetland restoration projects on Sherman Island especially on the southern and northern portion of the Island."[63]

3. Salinity Control

This conceptual design incorporates several of the measures discussed in section V to reduce potential salinity impacts.

First, this project is located in the western Delta, in substantial part to reduce potential effects of salinity.

Second, in the habitat restoration unit, saline material from the lower Estuary could be capped with less saline material than it would from higher in the Estuary. Material from the Suisun Bay or the Delta could be used as capping material. A three-foot cap could substantially reduce the discharge of salinity when the site is restored to tidal action. An added benefit of such capping is that it would reduce the overall cost of the project: Material dredged from the upper reach of the Estuary would cost substantially less to transport to the site than material from the Central Bay (see figure 19). These savings could come to as much as two to three dollars per cy. The cost estimate below assumes that the final three feet of material in the habitat restoration unit will come from a source with less saline higher in the Estuary. It is important to note, however, that some of the material dredged in the upper Estuary is sand, which makes both a poor substrate for habitat restoration and a poor capping material for containing salinity. Care would need to be taken in designing a project that uses capping as a salinity-control strategy and in selecting appropriate capping material.

Third, material from some small projects could be placed on the site by clamshell (see figure 20). The multiple-cell design would allow runoff from such small projects to be directed to other cells on the site, to be released when salinity is minimal.

Fourth, discharges of saline water from hydraulic pumping could be timed to reduce impacts. Hydraulic placement requires dredged muds to be slurried at a four-to-one ratio of water to sediment (see figure 21). As a result, hydraulic placement generates a quantity of runoff water four times the amount of material placed on the site. Bay dredged material would be slurried using Delta water. The extent to which such slurrying would allow salinity in Bay sediment to enter the water column has not been determined. However, the runoff water would certainly be higher in salinity than Delta water.

If the site were filled at a rate of 8,000 cy per day (during a large dredging project), hydraulic placement would generate 7.3 million gallons of water per day. Even with a multiple-cell design, it would not be possible to retain all the runoff from a large dredging project for discharge during the wet season. Therefore, runoff from large projects would be discharged within a day or two of placement. Salinity impacts could be reduced by placing the discharge point as far to the west as possible (a deep-water outfall could be added) and by timing discharge to coincide with the outgoing tide. Given Sherman Island's location, runoff discharged during ebb tide would rapidly be carried to Suisun Bay and diluted, thus minimizing the impacts of salinity the Delta. Regional Board staff has indicated that discharges of saline water in this location and during the ebb tide "would not be as problematic as for other areas in the Delta."[64] Additional modeling should be undertaken to determine what effect such discharges would have on the location of X2.

Figure 18. Phased Levee Construction in Habitat Restoration Project

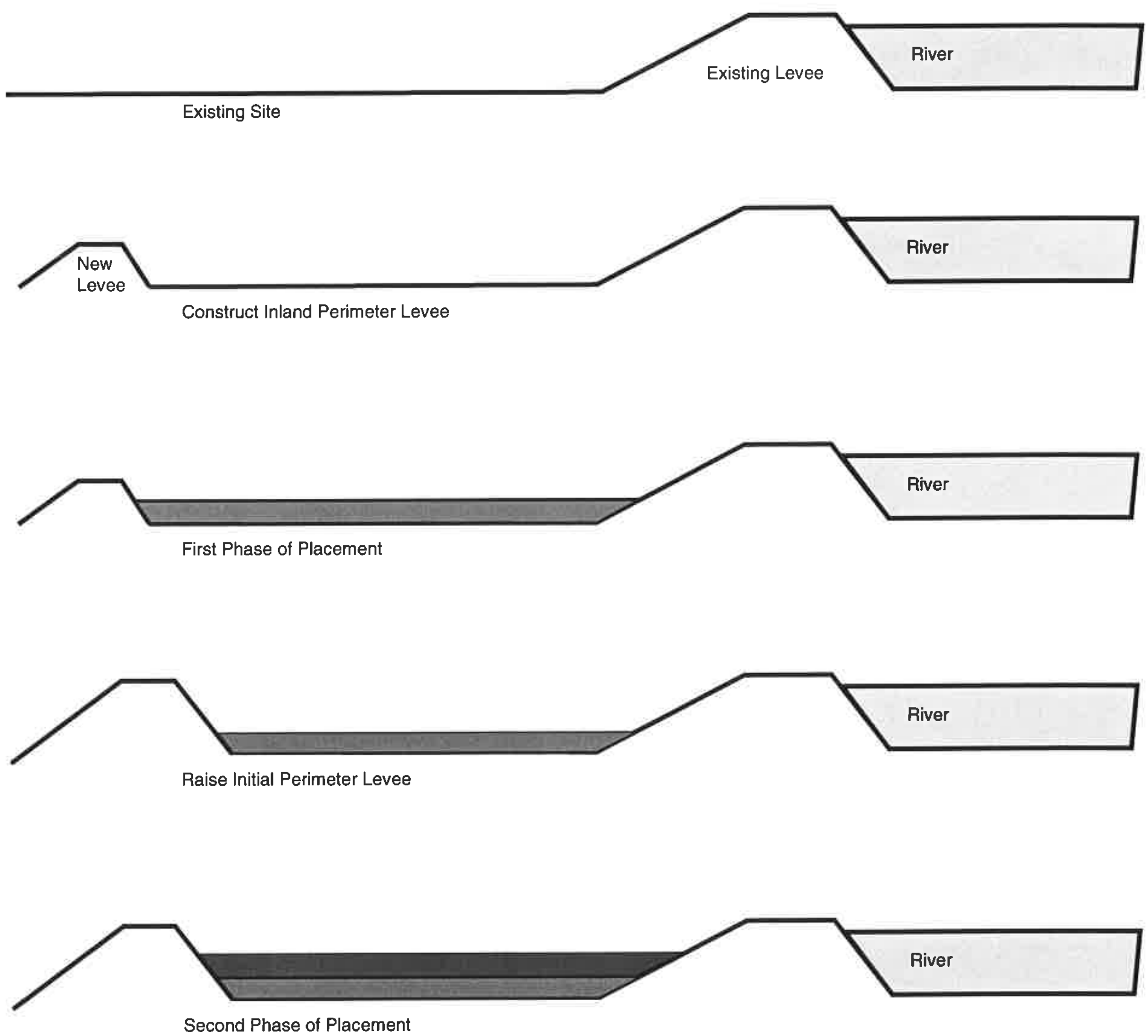
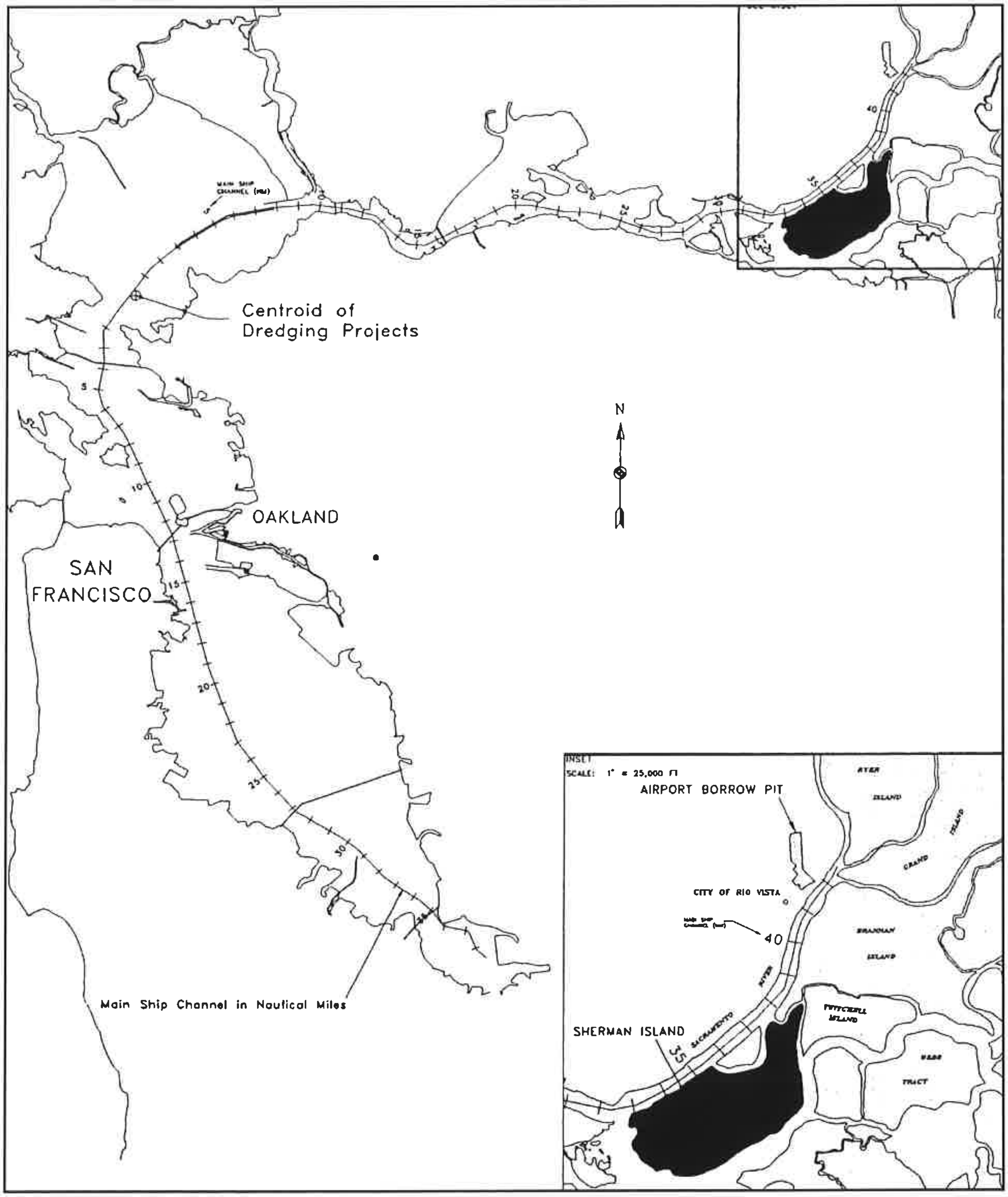


Figure 19. The Bay Dredging Centroid and Distances to the Western Delta



Source: Gahagan & Bryant Associates

Figure 20 Clamshell Offloading *DWR*

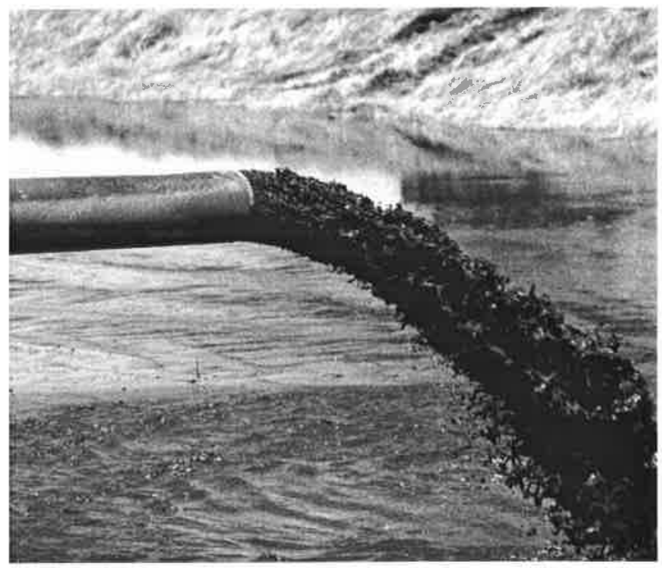


Figure 21. Hydraulic Placement *DWR*

It may also be possible to coincide the time of material placement with high winter flows, a time of year when salinity in the Delta is less of a constraining factor.

Fifth, it may be possible to flush salts out of the site during the winter. During high outflow events, when the location of X2 is not a concern, the rehandling cells could be flooded with low-salinity water. When this water is discharged, it would remove some of the salinity in the near-surface sediment. Over the course of a winter, several flushing cycles may be possible. Although such flushing is unlikely to be needed in the initial stages of filling the habitat restoration unit, flushing could be of value in reducing salinity as the restoration site approaches final design elevations.

In section X, we recommend that the potential of salinity and of the effectiveness of the potential salinity-control measures discussed here and in section V be carefully evaluated.

Cost Estimates and Financing

1. Cost Estimates

DWR is planning to expand the existing dredged material rehandling facility on Sherman Island. We have not been able to obtain cost estimates for this facility. However, we assume that economies of scale should lower the unit cost of material from the rehandling unit in comparison with the reuse projects to date (See section VII). The cost estimates below are for the habitat restoration unit of the conceptual design. Cost estimates for this conceptual design were developed from information drawn from a variety of sources.

While this conceptual design is an ambitious project requiring substantial resources, these costs must be evaluated in the following context. They:

- may be overly conservative, given the potential for economies of scale for a project of this size. The final $5.00 cy cost for Sonoma Baylands, for example, was far below the Corps of Engineers initial estimate of $9.10, in addition to site costs.
- are similar to Hamilton Field, the total cost of which could exceed $150 million (see cost estimates, below).
- are roughly comparable to the Hamilton Field restoration project and deep-ocean disposal on a unit-cost basis. The LTMS EIS/EIR calls for 40 percent of Bay dredged material to be disposed at the deep ocean site.
- would be incurred over several years and might not be completed within the seven-year horizon of CALFED's Stage 1.
- could be partially offset by a reduction in costs for CALFED's levee maintenance program.
- represent a cost-effective project, with multiple beneficiaries, which would address the goals of both the LTMS and the CALFED programs.

Financing

Financing a project of this scope will require broad support and multiple funding sources. Fortunately, such a Delta reuse project could be a high priority for both CALFED and LTMS, providing a unique funding opportunity. Section VIII discusses potential financing sources in detail. Clearly, if Delta reuse proves to be viable and to provide significant benefits for both the LTMS and CALFED stakeholder and agency communities, there is a large and diverse set of potential funding sources to support an ambitious reuse program.

Additional Issues, Assumptions, and Alternative Approaches

Preparing the final design for a Delta reuse site will require a number of additional issues to be addressed. Although these issues are important, they are not addressed in this conceptual design since they have minimal impact on the cost estimates and scoping level analysis in this document. Some of these issues are dis-

Table 3 - Estimated Costs for Conceptual Delta Habitat Restoration Unit

	Cost (in millions)
Transportation 17.0 mcy, 35 miles from the dredging centroid (at$.09/cy/mile)	$53.55
Transportation 6.0 mcy, 10 miles from the Delta	5.40
Levees 5,000 lineal feet of levees in 3 phases (at $3.00 per cy)	1.00
Miscellaneous site preparation	0.50
Hydraulic placement 23 mcy ($4.00 per cy)	92.00
Subtotal	152.45
Administration and Management (20 percent)	30.49
Subtotal	182.94
Contingency (20 percent)	36.59
Total	**$219.53**

Average cost per cy (assuming a 23-mcy capacity) = $9.54 per cy cussed below to assist in the further design of a Delta reuse site. In addition, we have made many assumptions about the design of this project. Below we discuss some alternative approaches that could lead to a different final design.

1. Site Ownership and Operation

There are a number of options for site ownership and operation. The Department of Water Resources owns the site, making that agency an obvious candidate to own and operate this project. In addition, DWR operates an existing rehandling site on the island and has proposed the construction and operation of a permanent Delta reuse site. The Corps or local Delta Reclamation Districts may be interested in operating a rehandling site. However, these agencies would be inappropriate as long-term owners of the habitat restoration unit. The Department of Fish and Game would be particularly appropriate as a long-term owner of this unit. In addition, several other CALFED agencies should be involved in design and could be possible owners. Finally, CALFED may lead to the creation of a new habitat-restoration entity, which could be an appropriate operator and owner of a Delta reuse site.

2. Permits and Monitoring

We believe that the evaluation of potential salinity impacts should be addressed through the LTMS and CALFED processes and should not be considered a cost for this particular project. However, the project will require a waste discharge permit from the Central Valley Regional Water Quality Control Board. This conceptual design has not addressed all the permits necessary for such a reuse project or the extensive water quality, biological, physical, and other monitoring that would be required. These costs would be included in the contingency line item in the budget for the conceptual project.

3. Management and Administration

The project sponsor may or may not be the actual owner and operator of the site. A number of LTMS and CALFED agencies and stakeholder groups may participate in the planning and management of a Delta reuse site.

4. Final Habitat Design and Site Elevations

The Sherman Island habitat restoration site could be designed to include a wide range of habitats (for example, deep water, dead-end sloughs, mudflats, riparian habitat, tule marsh, habitat islands, and upland habitat). On the Sonoma Baylands site, peninsulas were constructed to reduce wind fetch and to assist in natural sedimentation. The same approach may be necessary for a larger site on windy Sherman Island. Final habitat goals for the site, the design of channels, islands, peninsulas, and final elevations and the restoration method (conservative or filling to final desired habitat elevations) should all be developed through broad agency, scientific, and public involvement. Final design should include many of those who have participated in the CALFED Ecosystem Restoration Program and the Bay habitat goals efforts. Final design will, of course, affect the capacity of the site. However, we have made simple assumptions about subsidence and capacity to develop rough estimates of capacity and cost.

5. Appropriate Substrate

Delta tule marshes evolved during a period of rising sea level and consist primarily of peat-decayed organic material-although there are some mineral soils on Delta islands. Dredged material consists of a variety of types, from fine silts to coarse sand. Some of this sediment is low in organic material. Also, much of the material in the upper reach of the Estuary is sand (the first material to settle out of rivers entering the Estuary), which is not ideal substrate for wetland vegetation. One possible strategy to address this issue, which has been used elsewhere, is to augment sediments with organic material. For example, peat could be placed on top of dredged material in the habitat restoration unit. This material could come from elsewhere in the Delta or could be excavated from the restoration site itself and stockpiled. Rice straw is another possible source of organic material. (Rice straw burning is currently being phased out, and rice farmers are actively investigating alternative uses of this material.) In fact, CALFED recently decided not to fund a proposal to bring rice straw to the Delta for this purpose. The need for such augmentation can be better determined through the design process. The approach to filling the site (conservative or aggressive) may also affect the need for substrate augmentation.

6. Delta Sediment Traps

Prior to diking, Delta islands served as enormous sediment traps. However, upstream dams have robbed the system of sediment from the upper watersheds. The diking of Delta islands also reduced in-Delta sedimentation. As a result, there is a shortage of in-Delta material for habitat restoration and levee maintenance. To address this issue, CALFED staff has considered constructing sediment traps in the Delta. These traps would most likely consist of islands, or portions of islands, that would be breached to collect sediment as river flows pass through the Delta. Another option would be to use siphons to flood Delta islands to remove sediment. This sediment could be used to restore habitat in the sediment trap site or to provide material for levee maintenance and habitat restoration elsewhere in the Delta. Delta sediment traps are still in the conceptual stage, and the potential effects of removing sediment from the Bay have not been addressed (particularly since marshes in some parts of the Bay are eroding). However, if proven to be feasible, such sediment traps could be jointly managed with this conceptual plan for a Delta rehandling and habitat restoration site.

7. Location of the Reuse Project

The site selected for this conceptual design raises some potentially serious issues that must be considered in selecting a final site for a reuse project:

- There is a 35-foot high-pressure transcontinental natural gas main in the vicinity of the project. Investigations by the Corps have indicated that no overburden could be placed within the right of way.[65]
- The site may conflict with existing high-tension power lines.
- There may be conflicting uses along the levee in this area. Although DWR has purchased virtually the entire site, approximately 100 acres remain in private ownership. Care should be taken in designing a final site to reduce impacts and potential costs related to these uses.
- This site contains deep peat soils (up to 30 to 40 ft.[66]), which raise issues concerning the stability of containment levees and the habitat restoration unit.

Further, although the high degree of subsidence on Sherman Island presents an advantage to the LTMS, this advantage may be a disadvantage to habitat. Because of the extent of subsidence, placing material on this site would result in less habitat acreage than if the same volume of material were placed on a site with less subsidence. If the salinity problem can be overcome, it may be possible to locate reuse projects on less subsided sites in the Delta with the potential for a significant increase in habitat restoration. Likewise, it may be possible to design a tidal wetland restoration project downstream, on Winter Island or in the diked areas of Suisun Marsh.

Finally, though we have selected the southwest corner of Sherman Island for a variety of reasons discussed above, a more complete investigation may reveal better locations on the Island for this project. One possible alternative location is discussed in the 1995 LTMS upland analysis.[67] The northern tip of Sherman Island may also have potential as a habitat restoration site. This site, however, is east of that selected for our conceptual design, thus increasing potential salinity impacts. Locating a project on the northwest corner of the site was rejected due to conflicts with land uses along Sherman Island road.

In the design of a Delta reuse project, care must be taken to minimize, avoid, and mitigate impacts on existing natural resources. However, these impacts must be evaluated in light of the potential environmental benefits of Delta habitat restoration.

Phasing of Levee Construction

Another key feature of this conceptual design is the plan to fill the habitat restoration unit over the course of several years. Given the capacity of the site, it is highly unlikely that it could be filled rapidly. This design reduces levee construction costs in comparison with the cost of building the perimeter levee for the habitat restoration unit to final height at the beginning of the project. This design would also allow material in the habitat unit to dry to a much greater extent, which would increase the stability of the site and reduce the potential for salinity discharges, either due to levee failure or to the release of unconsolidated material that would result from a rapid filling of the site. However, if a particularly large dredging project were planned, it might be cost effective to construct a containment levee to final height in a single phase. Such an approach would reduce the capacity of the site, because slurried material, if retained in a saturated state, can occupy 120 percent of the initial volume.[68]

Wildlife and Habitat Impacts

Sherman Island has been aggressively farmed for over 50 years. However, in recent years, some of the land on the island has been fallow, which may have allowed populations of native vegetation and wildlife to increase. One rare plant species—Mason's lilaeopsis—has been observed on the site, and habitat exists for California hibiscus, a "candidate" species are present on the site. However, the hibiscus habitat is on the exterior of the levee and two of the three sightings of Mason's lilaeopsis were on the exterior of the levee. Therefore, carefully designed restoration might benefit these species. We were not able to determine if a jurisdictional determination has been performed for Sherman Island. However, the Negative Declaration for the Sherman Island Wildlife Management plan suggests that Section 404 permit issues should be manageable.

Nine bird species of concern have been recorded on the site. Habitat exists for endangered bird species on the island, but none were observed. Several of these species would benefit from habitat restoration. However, special care must be taken to avoid impacts to species of concern that are dependent on terrestrial habitat, such as the burrowing owl. (No evidence of burrowing owl nesting has been discovered, but nesting habitat is present on the Island.) There has been one sighting of the giant garter snake near the site for this proposed conceptual design.[69]

In the design of a Delta reuse project, care must be taken to minimize, avoid, and mitigate impacts on existing natural resources. However, these impacts must be evaluated in light of the potential environmental benefits of Delta habitat restoration.

VIII. Costs and Financing

Large-scale Delta reuse of dredged material will require substantial financial resources, however there are a wide variety of potential funding sources for Delta habitat restoration.

Disposal Cost Estimates

The cost of dredged material disposal can be broken down into fixed costs and variable—or quantity dependent—costs. Fixed costs are set expenses determined by project design and do not vary greatly with quantities dredged, including the expenses of equipment mobilization/demobilization, planning, design, engineering, and initial construction costs. Variable costs fluctuate with the quantity of material and include transportation, off-loading the material at the disposal site, and rehandling. Disposal costs do not include the cost of dredging itself, as these costs are unchanged by the selection of disposal sites.

The fixed costs for the designated in-Bay and ocean disposal sites are, in general, much lower than those for upland sites. The designated in-Bay sites have been in operation for several years, and the planning, design, engineering, and initial construction expenses no longer factor into current disposal costs.

Transportation costs are largely dependent upon the quantity of material and the distance between dredging and disposal sites. Ocean disposal can include an additional cost, because the tugs and scows for ocean disposal must be suitable for operation in the open ocean. The choice of a disposal site is dictated by the dredging location, type of material, quality of material, quantity of material, quantity of material recently disposed at possible disposal sites, commitments to a particular site, and other factors.

The cost of disposal, exclusive of dredging, at current in-Bay disposal sites is between \$4 and \$6 per cy, while the cost for ocean disposal at the designated Deep Ocean Disposal Site (SF-DODS) is between \$6 and \$8 per cy70 (see table 1). The cost for upland disposal of dredged material for restoration purposes is between \$7 and \$16 per cy.71 Existing estimates for the cost of Delta Island disposal of Bay dredged material for levee maintenance purposes is between \$12 and \$15 per cy. The Delta Island costs are taken from projects to date, which have been relatively small in scale. Larger Delta reuse projects could lower these costs through economies of scale. We have been unable to locate cost estimates for Delta habitat restoration using Bay dredged material (see cost estimates in section VII).

...one of the strengths of the Delta reuse concept is that the broad array of potential beneficiaries presents a wide range of possible funding sources.

The economies of scale of larger projects reduce the unit costs, since fixed costs remain relatively constant. This cost reduction can be dramatic. In the case of the Sherman Island project, an initial bid from the Manson Construction and Engineering Company to move 10,000 cy of dredged material was for \$10.44. When the project was reduced to a 1,600-cy project, the cost per cy rose approximately 25 percent.[72] Disposal at the Hamilton Army Airfield restoration site, which would accommodate 10.2 mcy of material, is between \$7.4 and \$11.3 per cy. The disposal cost at the Montezuma site (\$7 to \$10 per cy without the tipping fee), which is approximately the same distance from the centroid of the Bay as many of the western Delta islands, shows that moving a greater quantity of material can reduce the cost to a value comparable with dumping at designated sites, such as the deep-ocean disposal site.

Reducing the distance between dredging and disposal site can lower transportation costs. Suisun Bay is the closest part of the Bay to the Delta. 200,000 cy of material are dredged from Suisun Bay Channel and New York Slough annually.[73] Historically, this material has been deposited in the Suisun Bay or Carquinez Straight designated disposal sites. If material from the Suisun Bay were used in the Delta,

Table 4 - Dredged Material Disposal Options

Disposal Site	Implementation Costs (million dollars)[74]	Disposal Cost[75] (dollars per cy)	Site Capacity
Alcatraz (SF-11)	0	4	4.0 mcy/yr
Carquinez Strait (SF-9)	0	5-6	2-3.0 mcy/yr
San Pablo Bay (SF-10)	0	4-5	500,000 cy/yr
Suisun Bay (SF-16)	0	5.5	200,000 cy/yr
SF Deep Ocean Disposal Site (SF-DODS)	5	6-8	4.8 mcy/yr
Hamilton Army Airfield (HAAF)	55	7.4-11.3	10.2 mcy
Mare Island	0.4	7	12.0 mcy
Montezuma	To be borne by project applicant	16[76]	17.0 mcy
Sonoma Baylands	7.6	5	Completed
Winter Island Levee Maintenance	1.7	15[77]	100,000 cy/yr
Sherman Island Levee Maintenance	Considered in the disposal cost	12-13[78]	N/A
Jersey Island Levee Maintenance	Considered in the disposal cost	15[79]	N/A
Twitchell Island Levee Maintenance	0.083	9.72[80]	N/A
Sherman Island Conceptual Design Estimated Cost for Habitat Restoration	Considered in the disposal cost	9.74	10 mcy

transportation costs, and thus disposal costs, could be reduced.

Potential Funding Partners

Large-scale Delta reuse of dredged material will require substantial financial resources. However, one of the strengths of the Delta reuse concept is that the broad array of potential beneficiaries presents a wide range of possible funding sources. These funding sources generally fall into three categories: funds that are available for dredging projects, habitat restoration projects, and levee maintenance projects. Some of these potential sources are discussed briefly below.

Dredging

The Corps of Engineers annual national operations and maintenance budget, which supports dredging around the nation, is approximately $1.9 billion per year. The San Francisco District's annual dredging budget is approximately $10 million. Congress is currently considering a Water Resources Development Act, which is the primary federal funding vehicle for dredging projects. Future WRDA reauthorizations would be likely sources of funding for reuse projects.

Local agencies (ports, marinas, flood control districts, and so on) pay a substantial share of the cost of Corps dredging projects and bear the entire cost of non-Corps projects. The Port of Oakland, for example, plans to pay $124 million toward the cost of the Port's proposed $254 million project to deepen channels to 50 feet.

Habitat Restoration

There are a wide variety of potential funding sources for Delta habitat restoration. The largest single potential source of funding for habitat restoration is the CALFED Bay-Delta Program. CALFED is currently preparing a financing plan for its preferred alternative. The draft finance plan indicates that the CALFED ecosystem restoration program (which does not yet include adequate Delta restoration measures) will cost $910 million during the first seven years. The draft plan indicates that funding for the implementation of the CALFED program will come from a variety of possible sources:

- General obligation bonds
- Water and power revenue bonds
- State and federal appropriations
- Private financing
- Broad-based water diversion fees

At least under some conditions, all these sources could make appropriate funding partners for a Delta reuse program. The scale of habitat restoration funds potentially available through CALFED is significant. For example:

Proposition 204: The Clean, Safe and Reliable Drinking Water Act was passed by California voters in 1996. Among other provisions, it provided $540 million for habitat restoration. Of this amount, $150 million was available immediately upon passage. $390 million will be released only when the CALFED program has adopted a final preferred alternative and upon a finding by the Secretary of Resources that the program is being implemented appropriately.

The Bay-Delta Act: Also in 1996, Congress authorized $430 million in federal funding for Bay-Delta habitat restoration through the Bay-Delta Act. At the end of the fiscal year 2000, this three-year authorization will expire, by which time approximately half of the authorized amount will have been appropriated. It is not yet clear if this authorization will be extended or if there will be a separate authorization for the implementation of the CALFED preferred alternative. However, it is clear that when interests in California unify around the need for restoration of the Bay-Delta ecosystem, the state's congressional delegation is capable of securing substantial federal funding.

Central Valley Project Improvement Act: The CVPIA was passed in 1992 and calls for the Department of Interior to develop and implement a program that would double the population of anadromous fish in the Central Valley. One of the primary tools provided by Congress to accomplish the "doubling goal" is the CVP Restoration Fund. The Fund receives up to $50 million per year in contributions from CVP water and power customers. Given the potential benefits to anadromous fish, Delta habitat restoration projects are eligible for funds from the Restoration Fund.

Other Potential Federal Funding[81]

Water Resources Development Act of 1992: This act provides funds, approximately $6 million in fiscal year 1998, for the USACE to provide specialized services to operate and manage natural resources and recreational facilities at Army Corps water resource development projects as part of the Challenge Cost Share Program. Section 204 of the WRDA (Beneficial Uses of Dredged Materials) provides additional funds for the USACE to aid state and local communities in protection, restoration, and creation of habitats in connection with dredging operations. Because of the nature of Delta island restoration projects, and the possible role of the USACE in these projects, they can be eligible for funds from the WRDA of 1992. The Sonoma Baylands project received approximately $2 million in funding from Section 204.[82]

Water Resources Development Act of 1996: Section 206 of the WRDA of 1996 (Aquatic Ecosystem Restoration) provides funds to pay for USACE services to implement aquatic ecosystem restoration projects to improve environmental quality. The Study and Project Specific Programs of the Civil Works Environmental Program (SPSPCWEP) provides hundreds of millions of dollars annually in USACE services to support restoration activities within study and project specific appropriations of the Civil Works Environmental Activities. Because of the nature of Delta island restoration projects, and the possible role of the USACE in these projects, they can be eligible for funds from Section 206 and the SPSPCWEP of the WRDA of 1996. The Hamilton Army Airfield project is likely to benefit from the WRDA. The federal share of the $55.1 million implementation cost for Hamilton will be 75 percent, or $41.37 million.[83]

Department of Agriculture Appropriations Act of 1997: This act, through the Watershed and Air

Management Cost Share Program, calls for the Forest Service to share the cost of grants to evaluate, protect, and restore water, soil, and air resources.

Watershed Protection and Flood Prevention Act: The WPFPA provides over $100 million for the Natural Resources Conservation Service to provide technical and financial assistance to improve watershed areas.

Wetlands Reserve Program: The WRP provides, through the NRCS, direct funds to protect and restore wetlands, riparian and buffer areas. This program focuses completely on restoration and protection.

Anadromous Fish Conservation Act: With an annual budget of $2 million, this Act calls for the National Oceanic and Atmospheric Administration and the Fish and Wildlife Service to provide grants to states for conserving and enhancing fish stocks. Given the potential benefits to anadromous fish, Delta habitat restoration projects are eligible for funds from this act.

Water Resources Development Act of 1974: The WRDA of 1974 provides several million dollars ($3 million in fiscal year 1998) worth of USACE services to states and territories through the Planning Assistance to States Program to plan for the development, conservation, and utilization of water and related land resources.

Water Resources Development Act of 1986: Section 1135 of the WRDA of 1986 provides funds to pay for the USACE services in modifying existing project facilities and areas to achieve ecosystem restoration.

Wetlands Protection Development Grant: The WPDG, under the Clean Water Act, provides grant funds, $15 million annually between fiscal years 1996 and 1998, to develop and enhance existing wetlands programs. Wetland restoration is a significant part of the program.

Challenge Grant Cost Share Program: The Fish and Wildlife Service provides the CGCSP grant money to manage, enhance, and restore fish and wildlife resources. In previous years habitat restoration accounted for a large portion of the projects supported by the grant.

Endangered Species Conservation Fund: The Fish and Wildlife Service provides the ESCF grant money to projects that develop programs for the conservation of endangered species. Given the potential benefits to endangered species that use the Delta, Delta habitat restoration projects should be eligible for ESCF grants.

Levee Maintenance

The CALFED draft finance plan indicates that CALFED's levee maintenance program will require $264 million during its first seven years. Many of the funding sources discussed above would also be appropriate for levee maintenance projects.

Water Resources Development Acts of 1974 and 1992: See the discussion above regarding habitat restoration.

SB34-The Delta Flood Protection Act of 1988: This act amended the Delta Levee Maintenance Subvention Program, established in 1973, to provide state financial assistance to local districts for maintaining and improving nonproject Delta levees. The term "nonproject" is used to distinguish the levees from the "project" levees, which are part of federal flood-control projects. Local agencies will be eligible for reimbursement upon submission to and approval by the Reclamation Board of plans for the maintenance and improvement of the nonproject levees. This Bill expired on January 1, 1999.

AB 360: The Assembly Bill revised the provisions for the Delta Levee Maintenance Subvention Program, to extend the existence of the fund until July 1, 2006. AB 360 appropriated $6 million annually for local assistance under the DLMSP and the administration thereof.

IX. Institutional Challenges and Opportunities

The Army Corps of Engineers, The United States Environmental Protection Agency and the Bay Conservation and Development Commission should work together to establish policies for dredge material rehandling in the Delta, with a consistent set of principles, permit procedures, and criteria to evaluate projects. The biggest challenge will be to bring together all of the different requirements and make them consistent with one another, without losing important economic or environmental protections.

In the past, dredged Bay material has been viewed as a waste requiring disposal rather than a resource with potential for reuse. The policy of Bay Area agencies working with dredged material is to change this view, but some agencies have not implemented such a shift in policy.

As with other development projects, each reuse project must be examined on a case by case basis. The concerns of nearby citizens and communities about potential environmental impacts need to be addressed sensitively. In addition, there are challenging legal and institutional issues to overcome. Depending on the location and type of project, 10 to 15 different planning and regulatory agencies could be involved on the federal, state, regional and local level, which may result in conflicting guidance and responsibility. However, identifying these potential obstacles in the early stages would greatly reduce uncertainty and time delays associated with regulatory compliance and permit processing.

The United States Environmental Protection Agency

The EPA's mission is to protect human health and safeguard the natural environment. The EPA is responsible for enforcing the National Environmental Policy Act (NEPA) and the Clean Water Act, with the authority to determine the particular waste category and issue waste discharge permits.

The United States Army Corps of Engineers

The Army Corps shares joint authority with the US EPA for enforcing section 404 of the Clean Water Act.

The US Fish and Wildlife Service

This agency has jurisdiction for all listed species under the federal Endangered Species Act. For any reuse project it would be prudent to conduct an early assessment of species listed as endangered or threatened, under consideration for listing, considered jeopardized, or are being petitioned to be listed. The US Fish and Wildlife Service is also responsible for the Fish and Wildlife Service Coordination Act, a consultation statute which requires agencies that impact fish and wildlife to talk to the US Fish and Wildlife Service.

The National Marine Fisheries Service (NMFS)

The NMFS would play a role if any of the proposed facilities have the potential to affect anadromous species.

California Department of Fish and Game

The Department of Fish and Game enforces the California Endangered Species Act, which is very similar to the federal Endangered Species Act, but there could be overlapping issues.

Regional Water Resources Control Board(s)

The Regional Boards have delegated authority from the US EPA to interpret the Clean Water Act and play a role in permitting.

Dredge Material Management Office (DMMO)

Agencies with responsibilities for dredging have assembled a "Dredge Material Management Office" that may facilitate permitting for these types of facilities. Further exploration is needed to determine how the DMMO would be able to assist in eliminating complex agency jurisdictional issues, and facilitating dredging permit processing.

State Lands Commission (SLC)

This Commission has a public trust responsibility for the State's tidal and submerged lands and is likely to play an important role in this kind of activity in the Delta.

Integrated Waste Management Board (IWMB)

Involvement of the IWMB depends upon the assessment of sediment quality and how the material load is actually defined.

The Delta Protection Commission (DPC)

Although the DPC does not have permanent authority, it is responsible for planning in the Delta. Projects in the Delta should be consistent with the DPC's Resources Management Plan.

Local Issues and Regulations

Under California law, land use policy is made at the local level. Local governments have final authority over areas outside of the Bay zone or Delta levees, unless they fall into categories regulated by the Army Corps of Engineers. It will be essential to determine how the local General Plans and zoning ordinances treat proposed project sites. Although general plans and zoning ordinances can be changed, the project uses must conform.

CALFED

Although CALFED has no regulatory or permitting authority, it has political sanction to do restoration and water resource planning for the entire state—and most significantly for the Bay and Delta. CALFED has created an important precedent by establishing a forum where agencies can come to some agreement about how to work together. CALFED could help reduce conflicting and overlapping jurisdictions by convening the relevant agencies.

Conclusion

State and federal laws do allow pursuit of large-scale beneficial reuse of Bay dredged material in the Delta. However, overlapping agency jurisdictions could deter beneficial projects unless agencies cooperate closely with each other.

X. Conclusions and Recommendations

Conclusions

- There is a significant need for a program to maintain the integrity of Delta levees.
- An enormous volume of material will be required to maintain Delta levees, and existing in-Delta sources of material are inadequate to meet either habitat restoration or levee maintenance needs.
- Restoring extensive shallow-water or tidal-marsh habitat in the western or central Delta would have dramatic ecosystem benefits, with indirect benefits for Delta water diverters.
- Without an aggressive subsidence reversal strategy, much of the Delta, particularly the western and central Delta, cannot be restored to shallow-water or tidal-marsh habitat in the near future.
- LTMS goals regarding beneficial reuse of dredged materials are unlikely to be met over the next 50 years without significant Delta reuse of Bay material. Material targeted for ocean disposal by the LTMS could be redirected to reuse projects.
- The cost of Delta reuse appears to be comparable with other disposal options under consideration and in actual use.
- Salinity is the major constraint on the Delta reuse of materials dredged from the Bay. Several potential salinity control strategies are worthy of further investigation.
- Several levee demonstration projects using dredged material have been completed and have not revealed a significant salinity problem.
- State law does allow a thoughtful course of investigation into Delta reuse of Bay dredged material.
- A large-scale joint habitat restoration and rehandling project could be a cost-effective method of addressing a wide range of goals of the LTMS and CALFED, and an LTMS/CALFED partnership offers the potential for a broad range of funding partners to support Delta reuse.

Recommendations

1. CALFED and LTMS Joint Strategy. CALFED and LTMS policy-level decision-makers should discuss the potential for Delta reuse of Bay dredged material, and develop a joint strategy to investigate and, as appropriate, implement such reuse.

2. Delta Habitat Restoration Pilot Project. As a part of its Ecosystem Restoration Program, CALFED should build on the apparent success of the Delta levee demonstration projects by designing and implementing a pilot project to investigate salinity-control strategies and other related issues.

3. CALFED Ecosystem Restoration Program. The Ecosystem Restoration Program effort should be revised to fund an investigation into the habitat restoration opportunities presented by Delta reuse of Bay material. CALFED restoration goals should be revised for the central and western Delta, and a recommendation regarding the acceptability of significant Delta reuse in the final Ecosystem Restoration Program Plan should be developed.

4. CALFED Levee Program. CALFED's Levee Program should be revised to include a careful review of the results of Delta demonstration projects using Bay materials. An investigation of additional issues raised by Delta reuse should be undertaken, and a conclusion reached regarding the acceptability of significant Delta reuse as a part of the levee plan.

5. Regional Water Quality Control Board Resources. Because both CALFED and LTMS are rapidly moving toward major decisions, they should investigate whether the Regional Board has adequate staff and other resources to study and resolve salinity and other water-quality issues raised by Delta reuse of Bay material. If required, additional resources should be provided immediately.

6. Ocean Disposal. LTMS agencies should consider the potential benefits of Delta reuse and potential demand for material in the Delta and evaluate the wisdom of the LTMS decision that 40 percent of Bay dredged material may be disposed at the deep-ocean disposal site.

7. Large-Scale Delta Reuse. Once a Delta habitat restoration demonstration project is undertaken, CALFED and LTMS should fully evaluate the feasibility and design of a large-scale Delta reuse project.

XI. Contacts

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XII. References

Berger, John. *Restoring the Earth*. New York: Doubleday, 1987.

CALFED. March 1998. *Draft Bay-Delta Program Ecosystem Restoration Program Plan,* vols. I and II, Programmatic EIS/EIS.

CALFED. June 1999. *Revised Draft Bay-Delta Program Ecosystem Restoration Program Plan,* vols. I and II, Programmatic EIS/EIS.

CALFED. June 1999. *Revised Draft Ecosystem Restoration Program Plan*, vols. I and II.

CALFED. October 1998. *Staff draft Long-Term Levee Protection Plan.*

CALFED. June 1999. *Revised Draft Long-Term Levee Protection Plan.*

California Department of Water Resources and the U. S. Bureau of Reclamation for the U. S. Fish and Wildlife Service. August, 1994. *Effects of the Central Valley Project and the State Water Project on Delta Smelt and Sacramento Splittail.*

California Department of Water Resources. July 1988. *West Delta Water Management Program.*

California Department of Water Resources. *Sacramento-San Joaquin Delta Atlas.*

California State Lands Commission. May 1991. *Delta-Estuary California's Inland Coast: A Public Trust Report*

California Regional Water Quality Control Board, San Francisco Bay Region. *Basin Plan San Francisco Bay Region.*

California Regional Water Quality Control, Central Valley Region. 1998. *Board Basin Plan: Central Valley Bay Region.*

California Water Code. Section 1300.

Enright, Chris Kate Le, Kamyar Guivetichi, DWR. Fall 1998. *Progress in Modeling Salinity Impacts of Suisun Marsh Levee Breaches*, newsletter, Interagency Ecological Program for the Sacramento-San Joaquin Estuary, vol. 11.

Environmental Defense Fund and the Bay Institute of San Francisco. June 1996. *Restoration of the San Francisco Bay-Delta-River System: Choosing Indicators of Ecological Integrity.*

Gahagan & Bryant Associates, Inc. December 1995. *Long-Term Management Strategy, Work Element E, Reuse/Upland Site Analysis and Documentation,* vol. I. Submitted to U.S. Army Corps of Engineers, San Francisco District.

Gahagan & Bryant Associates, Inc. December 1995. *Long-Term Management Strategy, Work Element E, Reuse/Upland Site Analysis and Documentation*, volume II. Submitted to U.S. Army Corps of Engineers, San Francisco District.

Gahagan & Bryant Associates, Inc. February 1998. *Summary Report, Mare Island Dredge Ponds Feasibility Study, revised final* vol. I. Prepared for City of Vallejo, Mare Island Conversion Division.

Jones & Stokes Associates, Inc. December 1998. *Hamilton Army Airfield Wetland Restoration Feasibility Study*, volume I. Prepared for the U.S. Army Corps of Engineers and the California State Coastal Conservancy.

Long-Term Management Strategy. December 1995. *Reuse/Upland Site Ranking, Analysis and Documentation.*

Long-Term Management Strategy, Appendix A: General Engineering Considerations.

Natural Heritage Institute. October, 1998. *An Environmentally Optimal Alternative for the Bay-Delta: A Response to the CALFED Program.*

Philip Williams & Associates. July, 1998. *Learning Laboratory for Restoring Subsided Lands in the Delta: Phase I Restoration Design Component.*

Restore America's Estuaries. 1998. *Funding for Habitat Restoration Projects: A Citizens Guide.*

San Francisco Bay Conservation and Development Commission. June 1999. *LTMS Dredging and Disposal Road Map.*

San Francisco Estuary Project. 1993. *Comprehensive Conservation and Management Plan.*

San Francisco Estuary Project. 1993. *Managing Freshwater Discharge to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary: The Scientific Basis for an Estuarine Standard.*

San Francisco Estuary Project. March 1992. *Status and Trends Report on Aquatic Resources in the San Francisco Estuary.*

San Francisco Estuary Project. March 1990. *Status and Trends Report on Dredging and Waterway Modification in the San Francisco Estuary.*

San Francisco Estuary Project. January 1992. *Status and Trends Report on Wildlife of the San Francisco Estuary.*

Steinhart, Peter. *California's Wild Heritage: Threatened and Endangered Animals in the Golden State.* California Department of Fish and Game, California Academy of Sciences, Sierra Club Books. 1990.

U.S. Army Corps of Engineers for the San Francisco Bay Regional Water Quality Control board. May 1997. *Final Lessons Learned from the Jersey Island Demonstration Project.*

U.S. Army Corps of Engineers, U.S. EPA, et al. October 1998. *Long-Term Management Strategy (LTMS) for the Placement of Dredged Material in the San Francisco Bay Region.* Final PEIS/PEIR.

U.S. Army Corps of Engineers, U.S. EPA, et al. April 1996. *Long-Term Management Strategy (LTMS) for the Placement of Dredged Material in the San Francisco Bay Region.* Draft PEIS/PEIR

U.S. Army Corps of Engineers. 1989. *Long-Term Monitoring of Eleven Corps of Engineers Habitat Development Field Sites Built of Dredged Material,* 1975-1987. Dredging Operations Technical Support Program, Technical Report D-89-1.

U.S. Army Corps of Engineers, U.S. EPA, et al. July 1995. LTMS *Status Report: Accomplishments and Tasks Ahead.*

U.S. Army Corps of Engineers and Solano County. July 1998. *Montezuma Wetlands Project,* final EIS/EIR.

U.S. Army Corps of Engineers, U.S. EPA, et al. October 1998. Long-Term Management Strategy (LTMS) for the Placement of Dredged Material in the San Francisco Bay Region, final PEIS/PEIR, vol. I.

U.S. Environmental Protection Agency. June 1994. *Draft Inland Testing Manual.*

U.S. Environmental Protection Agency. August 1993. *Final Environmental Impact Statement for Designation of a Deep Water Ocean Dredged Material Disposal Site off San Francisco, California.*

U.S. Fish and Wildlife Service. December 1995. *Draft Anadromous Fish Restoration Plan.*

U.S. Fish and Wildlife Service, and U.S. EPA. September, 1989. *The Ecology of the Sacramento-San Joaquin Delta: A Community Profile.*

U.S. Fish and Wildlife Service. 1996. *Recovery Plan for Native Resident Fishes of the Sacramento-Dean Joaquin Bay-Delta Estuary.*

U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers. *Design and Biological Monitoring of Wetland and Riparian Habitats Created with Dredged Materials.* Deep Water Ship Channel Monitoring Program.

U.S. National Marine Fisheries Service. August 1997. *Proposed Recovery Plan for the Sacramento River Winter-Run Chinook Salmon.*

Woodward-Clyde. April 1998. *Draft Hamilton Wetlands Conceptual Restoration Plan.* Prepared for the State Coastal Conservancy and the City of Novato.

XIII. End notes

1. LTMS Final EIS/EIR., p. 3-15.
2. Ibid., p. 3-63.
3. Ibid., p. 5-28
4. Ibid., p. 4-118
5. Curt Schmutte, personal communication
6. Managing Freshwater Discharge to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, p. 9
7. CALFED Revised Draft ERPP, vol.1., p. 89
8. CALFED Draft ERPP, vol. 1., p. 175
9. CALFED Draft ERPP, vol. 1., p. 286
10. CALFED Draft ERPP, vol. 1., p. 81
11. CALFED Draft ERPP, June 1999, vol. 2., p. 89
12. CALFED Draft ERPP, vol.. 2., p. 50
13. Long-Term Monitoring of Eleven Corps of Engineers Habitat Development Field Sites Built of Dredged Material, 1974-1987.
14. Curt Schmutte, personal communication
15. Chris Neudeck, personal conversation
16. Dick Daniel, personal conversation
17. CALFED levee program, staff draft, 1998., p. 5
18. Chris Neudeck, Curt Schmutte, personal conversation
19. Rob Cooke, personal conversation
20. Dick Daniel, personal communication
21. Betty Andrews, personal communication
22. Rob Cooke, personal communication
23. CALFED Final EIS/R., pp. 4-129
24. Final Lessons Learned from the Jersey Island Demonstration Project., p. 25
25. DWR website
26. Category III projects are partially funded by CALFED under the commitment of the Bay-Delta Accord
27. Curt Schmutte, personal communication
28. DWR website
29. In the future addition restoration might be done.
30. Bill Heyenbruch, personal communication
31. Final Lessens Learned from the Jersey Island Demonstration Project, p. 20
32. California Water Code, Section 13000
33. CVRWQCB Basin Plan, pp. IV-15.00
34. SFRWQCB Basin Plan, Section 5
35. LTMS Final EIS/R., pp. 4-118
36. Curt Schmutte, personal conversation
37. Chris Neudeck, personal conversation
38. Chris Neudeck, personal conversation
39. LTMS FEIS/R., pp. 4-172
40. LTMS FEIS/R., pp. 6-28
41. Port of Oakland, FEIS/EIR.
42. LTMS FEIS/R, pp. 6-23
43. Personal communication with Kathy Broderick
44. LTMS FEIS/R, pp. 6-27
45. Personal communication with Margit Aramburu
46. Sam Luoma, USGS, personal communication

47. LTMS report, Appendix A: General Engineering Considerations, p. A-9.
48. LTMS FEIS/R, pp. 3-69.
49. LTMS report, Appendix A: General Engineering Considerations, p. A-8.
50. Ecosystem Restoration Program Plan PEIS/R, p. 1
51. Delta Estuary, California's Inland Coast, p. 85
52. Initial Study and Negative Declaration for Proposed Sherman Island, Wildlife Management Plan, p. 19. Delta Atlas website.
53. Delta Estuary, California's Inland Coast, p. 82
54. Delta Estuary, California's Inland Coast, p. 82
55. Delta Estuary, California's Inland Coast, p. 84
56. Ibid., p. A-17.
57. LTMS Reuse/Upland Site Analysis, Appendix A, p. A-18
58. Ogden Beeman & Associates, Inc. October 1990
59. Appendix A, LTMS Report, p. A-4
60. Appendix A, LTMS Report, p. A-9
61. Curt Schmutte, personal communication
62. Sam Luoma, personal communication
63. LTMS Reuse/Upland Site Analysis, Appendix A, p. A-20.
64. Ibid., p. A-10
65. Ibid., p. A-9
66. Delta Atlas, p. 26
67. Ibid., p. A-17
68. Appendix A, LTMS Report, p. A-9
69. Negative Declaration for the Sherman Island Wildlife Management plan, pp. 15-19.
70. Designated site disposal costs are from the LTMS Dredging and Disposal Road Map, 1999.
71. LTMS Dredging and Disposal Road Map, 1999
72. Communication with Len Cordoza. This cost includes the $6-$9 per cy tipping fee.
73. Includes off-loading costs.
74. From 1600 cy levee restoration project conducted in 1990.
75. From 70,000 cy levee restoration project conducted in 1994. Does not include engineering/construction and monitoring costs.
76. From 75,000 cy levee restoration project conducted in 1992. The material was taken from Simmons Island.
77. Manson Construction and Engineering Company letter to Department of the Army, San Francisco Dist., Corps of Engineers, 1990.
78. Bill Heyenbruch, personal communication.
79. Implementation costs listed are for site preparation and are additive to the disposal costs.
80. Implementation and disposal costs for non-Delta projects are from LTMS Dredging and Disposal Road Map, 1999, unless otherwise noted.
81. Restore America's Estuaries. Funding for Habitat Restoration Projects: A Citizens Guide, 1998.
82. The U.S. Arm Corps of Engineers has not completed the cost analysis as of the date of this report.
83. Hamilton Army Airfield Wetland Restoration Feasibility Study, pp. 5-88.

REPORT

on

SAND MINING

in

SAN FRANCISCO BAY

prepared for
Tidewater Sand & Gravel Co.

prepared by
MEC Analytical Systems, Inc.
and
M. H. Cheney, Consulting Civil Engineer

November 1990

SAND MINING REPORT

CONTENTS

I. SAN FRANCISCO BAY AREA SAND MARKET

Sand is used in the Bay Area as a construction material in concrete, asphalt, road and foundation bases and in drainage structures. Sand sources include submerged, naturally replenishing mining sites in central Bay and in the Delta and surface mining sites at Scott's Valley (Santa Cruz mountains), Manteca and Dillon Beach.

Truck accessible sand distribution points for mined submerged sands include Oakland (High Street on the Estuary), San Francisco (pier 94), Martinez, Rio Vista, Petaluma, Redwood City, Collinsville and Petaluma. Truck accessible sand distribution points for surface sand sources are at the mine sites.

Almost all of the sand used in the central Bay area is distributed from the Oakland and San Francisco distribution points. All of the sand that moves through these two points is mined from the central Bay sand shoals off Pt. Knox, Alcatraz and the Presidio. The locations of these shoals are shown on the enclosed map.

The total amount of sand mined from the central Bay shoals averages about 900,000 cy annually. This amount is far in excess of all other production sources around the Bay combined. Exact records from most of the other sources are not available due to their proprietary nature.

The central Bay sand shoals are leased from the State; payments to the State amount to about $480,000 annually. The value of the sand produced from these shoals, FOB at the distribution point, amounts to approximately $4,200,000 annually.

If the central Bay shoals were taken out of production, the 900,000 cy of annual demand they serve would have to be supplied from the other area sand sources. Trucking costs from these sources to the indicated distribution points have been determined as follow in terms of dollars/ton:

SOURCE	DISTRIBUTION POINT	ADDED COST
Rio Vista	Oakland	7.50
Manteca	Oakland	9.00
Dillon Beach	San Francisco	5.65
Scott's Valley	Oakland	7.70
Scott's Valley	San Francisco	8.50

The economic impact of substituting other sand sources for central Bay sources would be to increase the cost of sand (if divided equally among other sources) supplied to the central

Bay area by about $12 million annually. In addition, the State would lose lease revenue, non-replenishing sand sources would be depleted more quickly and truck traffic, supplanting barge movements of sand, would increase significantly.

II. SAND MINING OPERATIONS

Sand is mined from the central Bay shoals using a specially built hopper dredge. The dredge is contained in a barge which is pushed by a tug (see photos 1 & 2). The barge is 230' long by 55' wide; the tug and barge unit together is about 300' in length. Capacity of the barge is 2,500 cy.

For sand nining operations, the barge is positioned at one of the shoals, her drag head is lowered to the sand and a sand/water mixture is pumped on board at an average composition of about 15% sand to 85% water by volume. Normally, the tug will orient the dredge into the prevailing tidal current and remain relatively stationary during loading operations. Generally, sand from the shoals will flow over the bottom to the draghead and be pumped up on board. Any fish or other animals that might be pumped up with the sand are caught at a grate and channeled back into the Bay. It is quite rare to see any fish or shellfish come up, although the dredge crew did see a salmon once come up only to swim away once it was diverted overboard.

As the barge is filled with sand, excess water begins to be returned to the Bay. There are two outlets for overflow water, one at each side of the stern end of the barge, just ahead of the tug (see photos 1 & 2). The rate of discharge of overflow water averages about 16,000 GPM and the average time of discharge is about 2.8 hours.

A trailing plume is visible behind the barge during flood and ebb tides and a more localized plume can be seen during slack tide. The plume is caused by the discharge of a portion of the "fine" materials (silts & clays) that are mixed with the sand in the shoals. There are from 2 to 4% fines in the sand shoals where the sand is mined; when the sand is checked at the distribution points, it has from 1/2 to 1% fines content. The difference in fines content from shoal to distribution point is washed overboard from the dredge with the overflow water and it is this content, along with aeration bubbles, dissolved materials and plankton that define the plume which is visible around the dredge while it is loading sand.

After the barge is loaded, it returns to either the San Francisco or Oakland distribution points and is offloaded by conveyor belts into storage piles for distribution by trucks.

Permits issued by the regulatory agencies to conduct sand mining in the central Bay preclude sand mining on the weekends. On the average, a little over one dredging episode per 24 hour weekday occurs at the central Bay shoals. This frequency of delivery corresponds closely to demand from the San Francisco and Oakland distribution points since there is very little (maximum 3 day) stockpiling at either point.

III. ENVIRONMENTAL IMPACTS OF SAND MINING IN CENTRAL BAY

There are two main impacts of sand mining in central Bay: (1) bottmon impacts and (2) water column impacts from the discharge plume. These impacts are examined in detail in the appendices to this report. Appendix I contains a report prepared by MEC Analytical Systems that examines sand mining in central Bay specifically; the remaining appendices contain exerpts from pertinent research work about dredging and turbidity impacts.

The MEC report concludes, on the basis of extensive field and laboratory testing, that the sand mining operation has no signigicant impacts on the Bay environment. The reports in the remaining appendices indicate, based on MEC's characterization of the plume, that the operation could not possibly have any impact on fishery resources.


CENTRAL BAY SAND SHOALS
STATUTE MILES
1 0 1 2
January 8, 1990
SAN FRANCISCO BAY
RICHMOND
Albany
BERKELEY
Emeryville
Richmond Inner Harbor
Pt Isabel
Fleming Pt
San Pablo Ave
University Ave
Berkeley Pier (abandoned)
Southampton Shoal
GENERAL ANCH
Treasure Island
Yerba Buena Island
LIMITED TRAFFIC AREA (see note)
Cable and Pipeline Area
Oakland Outer Harbor
SAN FRANCISCO-OAKLAND BAY BRIDGE
RACCOON STRAIT
Angel I
Pt Simpton
Pt Blunt
Bluff Pt
Tiburon
TIBURON PEN
PT. KNOX SHOAL
Richardson Bay
Alcatraz I
ALCATRAZ SHOAL
PRESIDIO SHOAL
Sausalito
North Pt
Rincon Pt
STORM WARNINGS
CLOCK TR
Van Ness Ave
SAN FRANCISCO
Lime Pt
Pt Diablo
Fort Pt
GOLDEN GATE
Wreckage
CAUTION
The currents are variable and uncertain, tide rips, swirls, or eddies may occur in the Golden Gate and as far eastward as Alcatraz Island and Raccoon Strait.
Marin Peninsula

APPENDIX I

ENVIRONMENTAL EFFECTS OF SAND MINING AT POINT KNOX SHOAL

MEC Analytical Systems, Inc.

ENVIRONMENTAL EFFECTS OF SAND MINING AT POINT KNOX SHOAL

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October 2, 1990

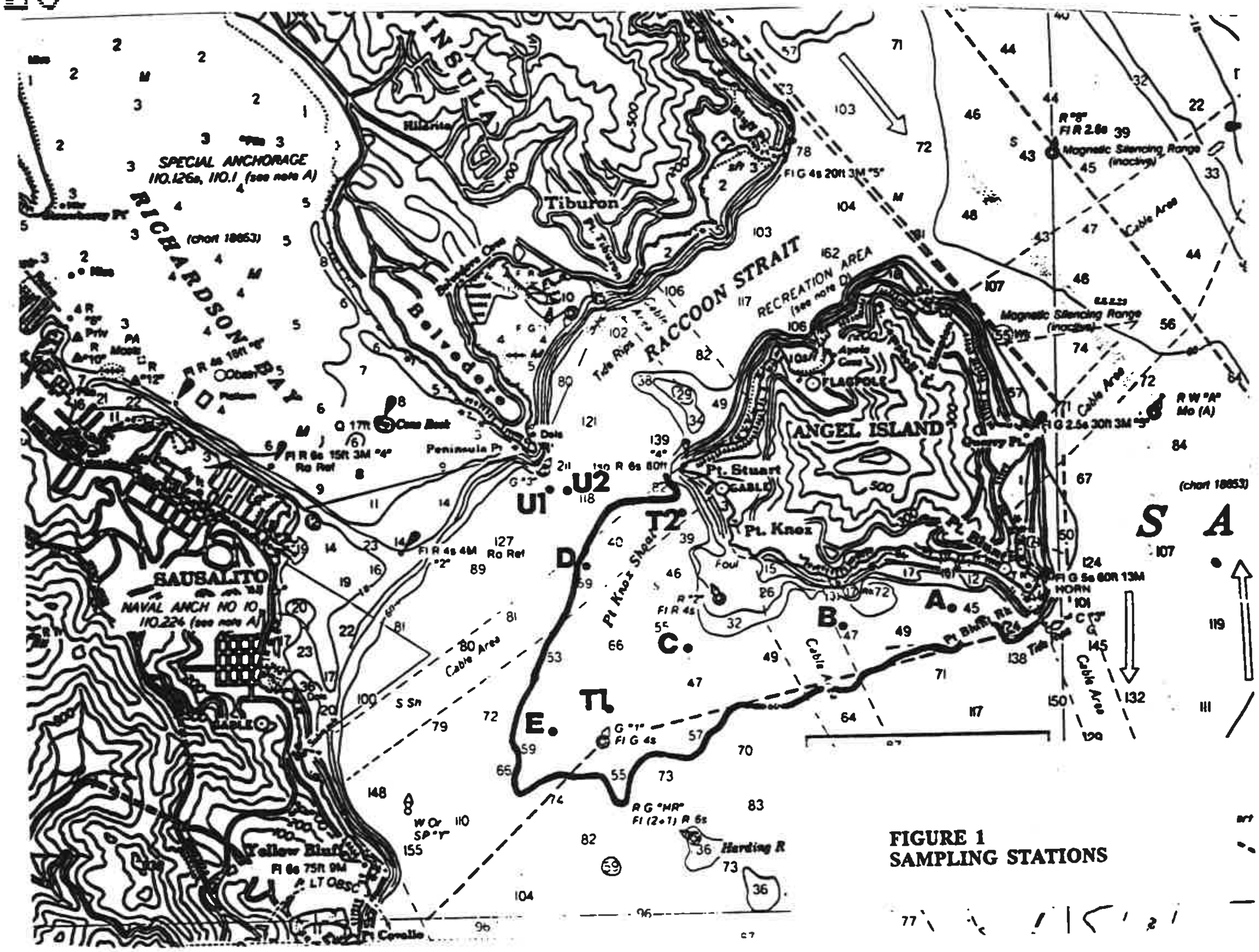

FIGURE 1
SAMPLING STATIONS

MEC ANALYTICAL SYSTEMS, INC.

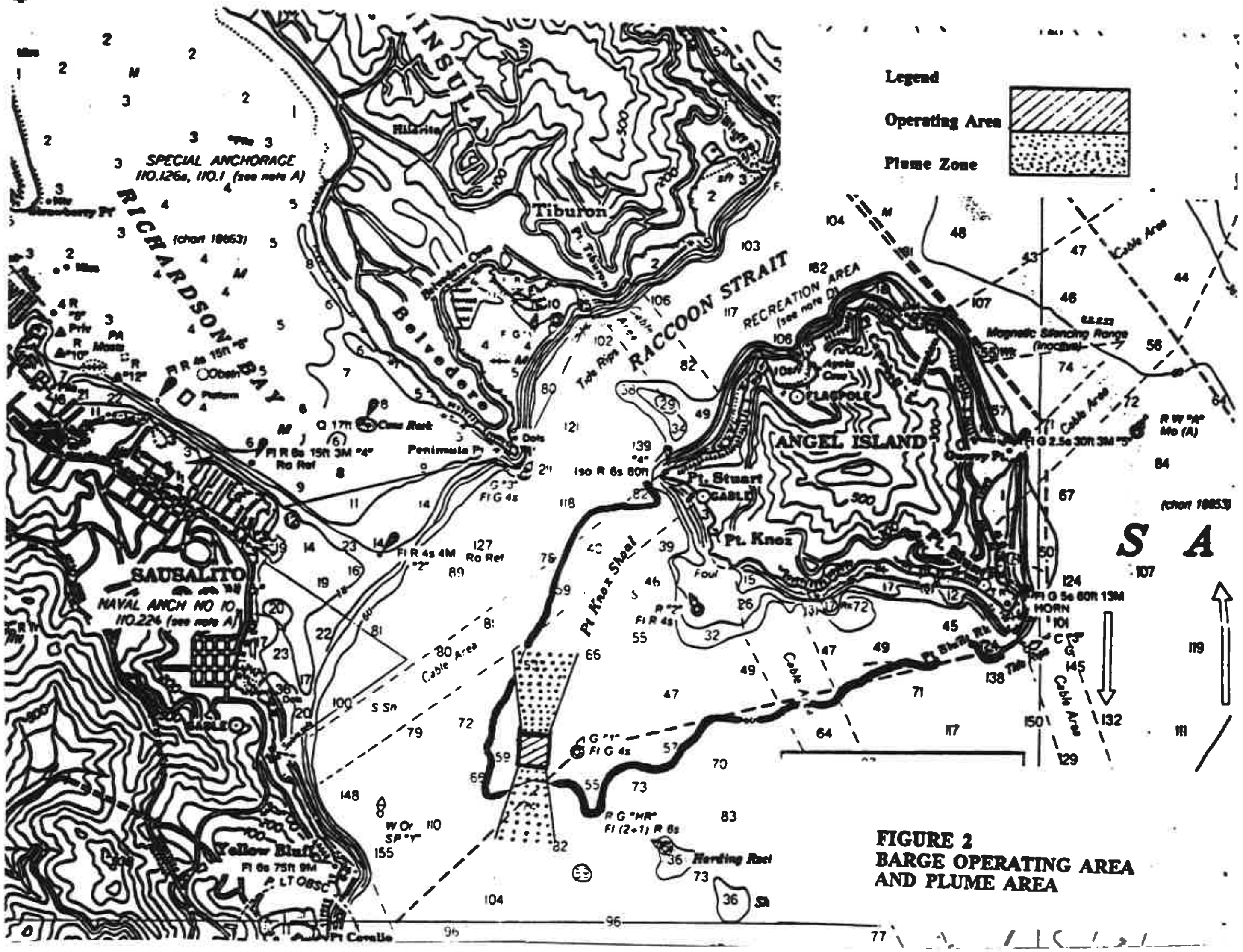

FIGURE 2
BARGE OPERATING AREA
AND PLUME AREA

five foot increments, and weighted to provide depth measurements. The water samples were continuously pumped from depth through a manifold where oxygen and temperature were measured. A valve in the manifold permitted water sampling into sample bottles for total sulfides and suspended solids. Samples to be tested for dissolved sulfides were initially fixed with zinc acetate and preserved with NaOH as recommended in Standard Methods. Levels were analyzed using a Hach DR 2000 spectrophotometer.

Oxygen measurements were taken using a YSI model 57 Oxygen Meter placed in line, within the manifold. Readings were taken and recorded on data sheets. Temperatures were read directly from the oxygen probe (temperature setting).

Three different approaches to the plume were used.

Test 1: Water samples were taken at five foot vertical intervals starting immediately astern of the tug. This test attempted to assess the vertical distribution of the plume to a depth of 50 feet (Figures 3 and 4).

Test 2: Water samples were taken at four points across the plume at various distances from the barge. Figures 5 and 6 show how the cross-sectioned samples were taken. The water sample was taken from a depth of 20 feet. The sampling stations were defined as starboard outside (SO), starboard inside (SI), port outside (PO), and port inside (PI). Four cross sections were run at distances of 50 yards to 800 yards from the barge. On two occasions we used aircraft spotters to ensure that we were either within the plume or outside of it as appropriate. The data from these tests are included in this report. The inside and outside plume values are averaged for each cross-section for presentation.

Test 3: Water samples were taken from a set depth of 20 feet (defined on the fathometer as the zone of maximum turbidity) starting up current of the barge and at two minute intervals as the research vessel moved from unaffected into plume-affected water using the tidal currents. This test was run for 24 minutes and normally the research vessel was at least 800 yards astern of the barge at the end of the sampling cycle (Figures 7 and 8). Sampling was carried out in the midline of the plume.

Ebb tide monitoring In order to examine background water quality conditions in the Racoon Strait, a sampling program was carried out at a single station during a high velocity

MEC ANALYTICAL SYSTEMS, INC.

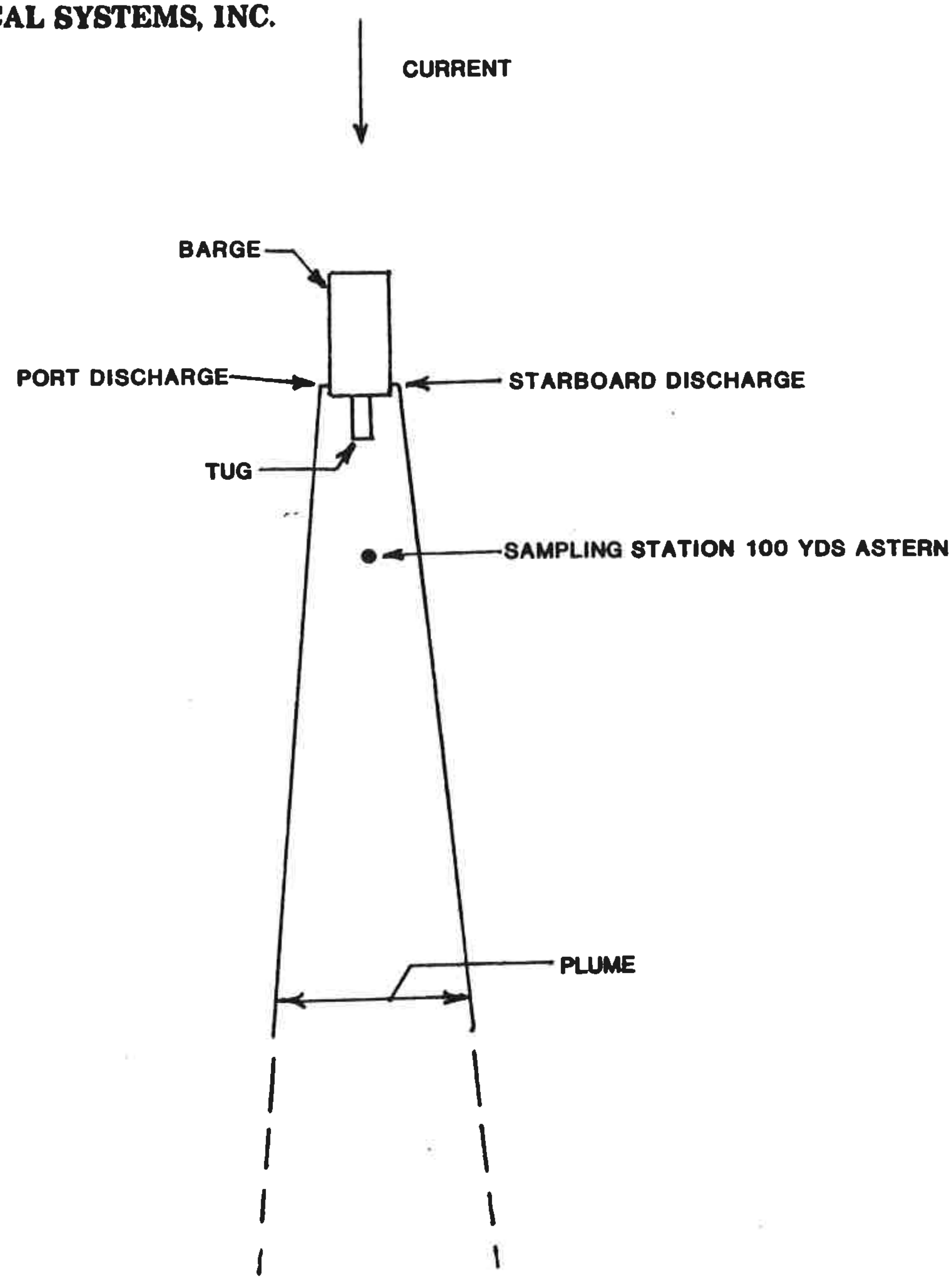

FIGURE 3
Plan View Test 1
Vertical Profile

Sample depth = 5' increments
(0' to 50')

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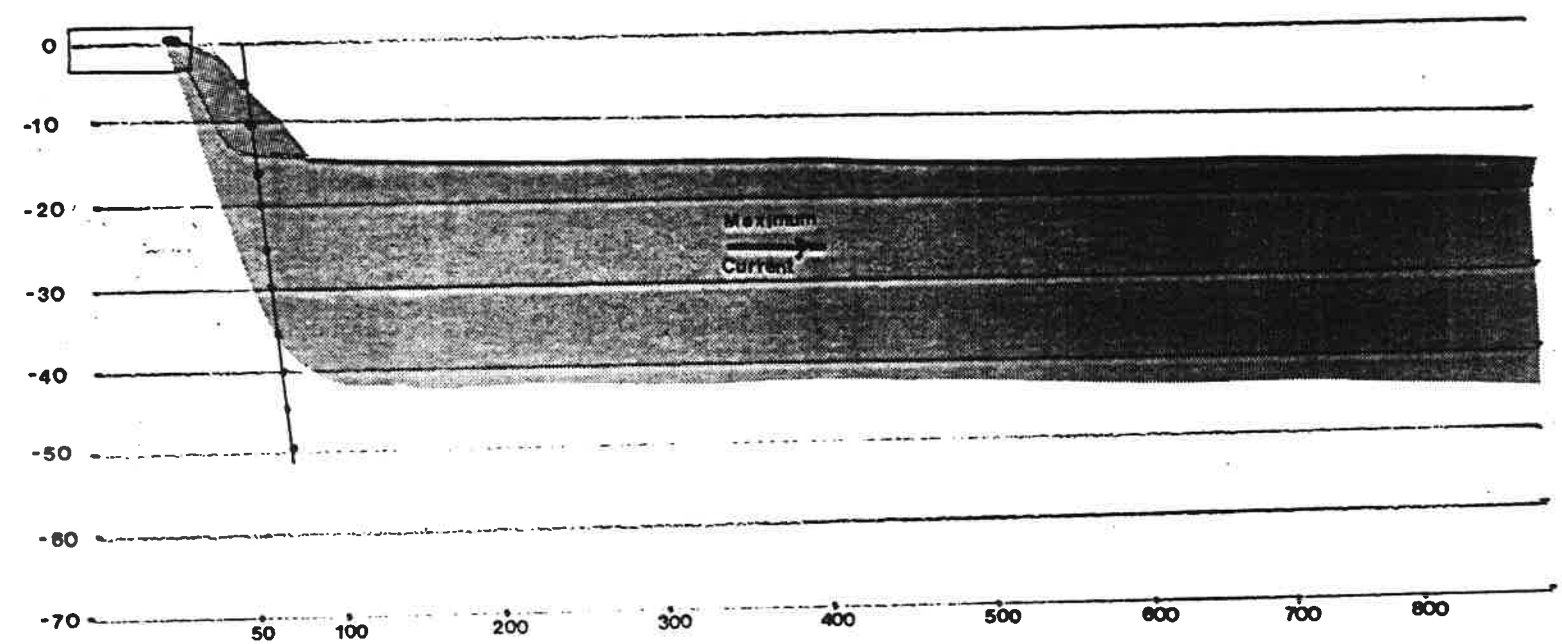

FIGURE 4
Elevation - Test 1
Vertical Profile
Sampling Depth = 5' increments
(0 - 50')

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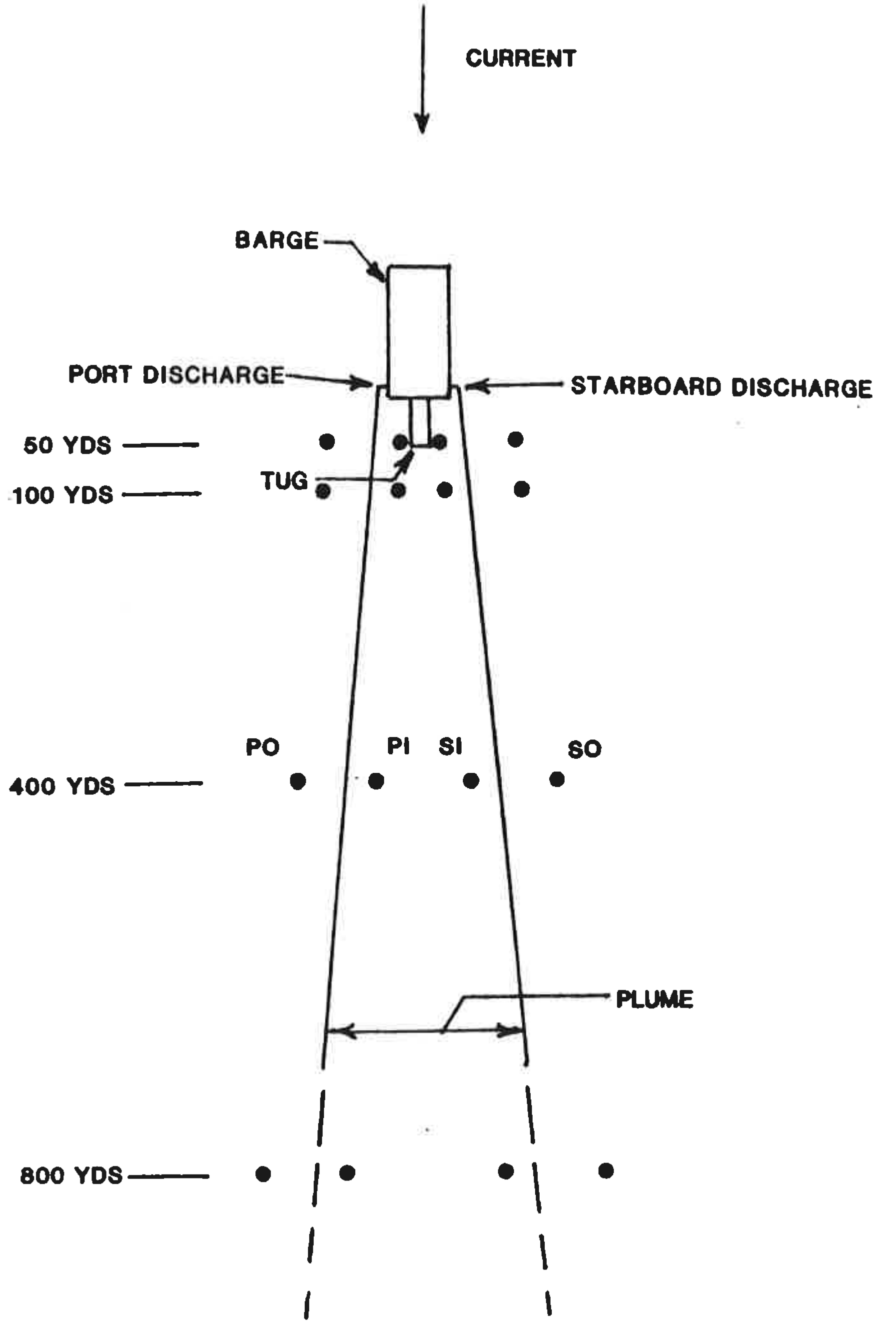

FIGURE 5
Plan View Test 2
Cross-sectional analysis

Sample depth = 20'

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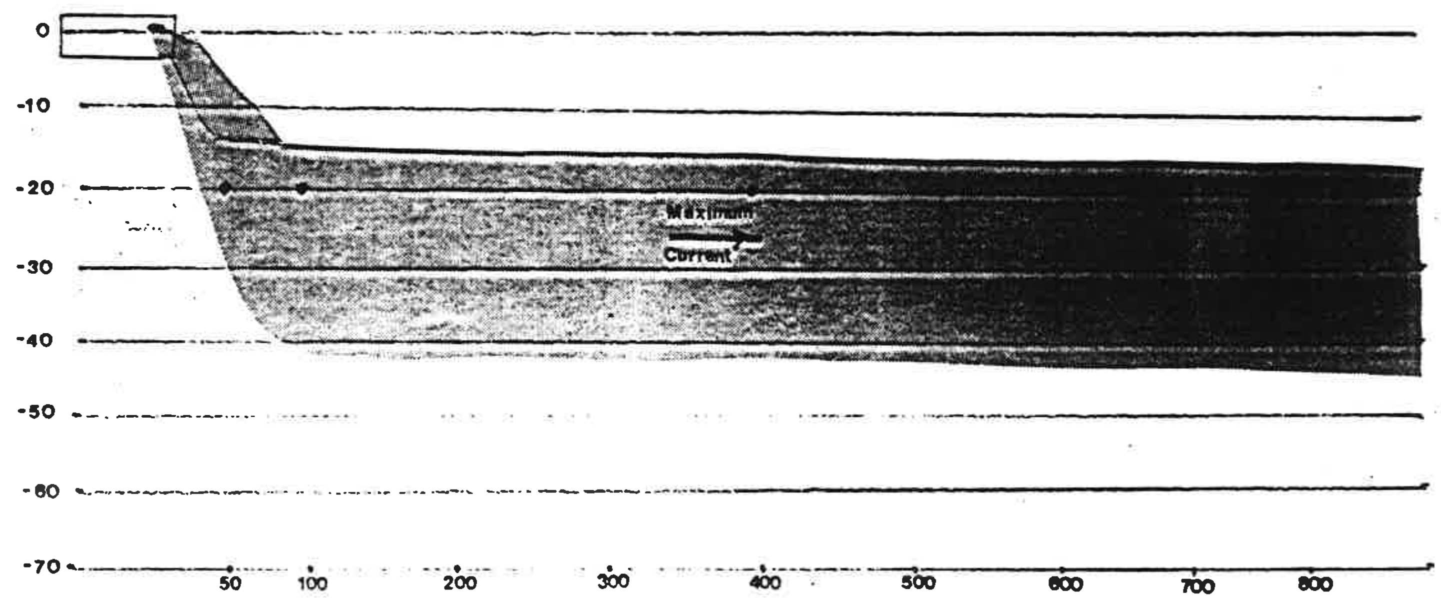

FIGURE 6
Elevation - Test 2
Cross-sectional analysis
Sampling Depth = 20'

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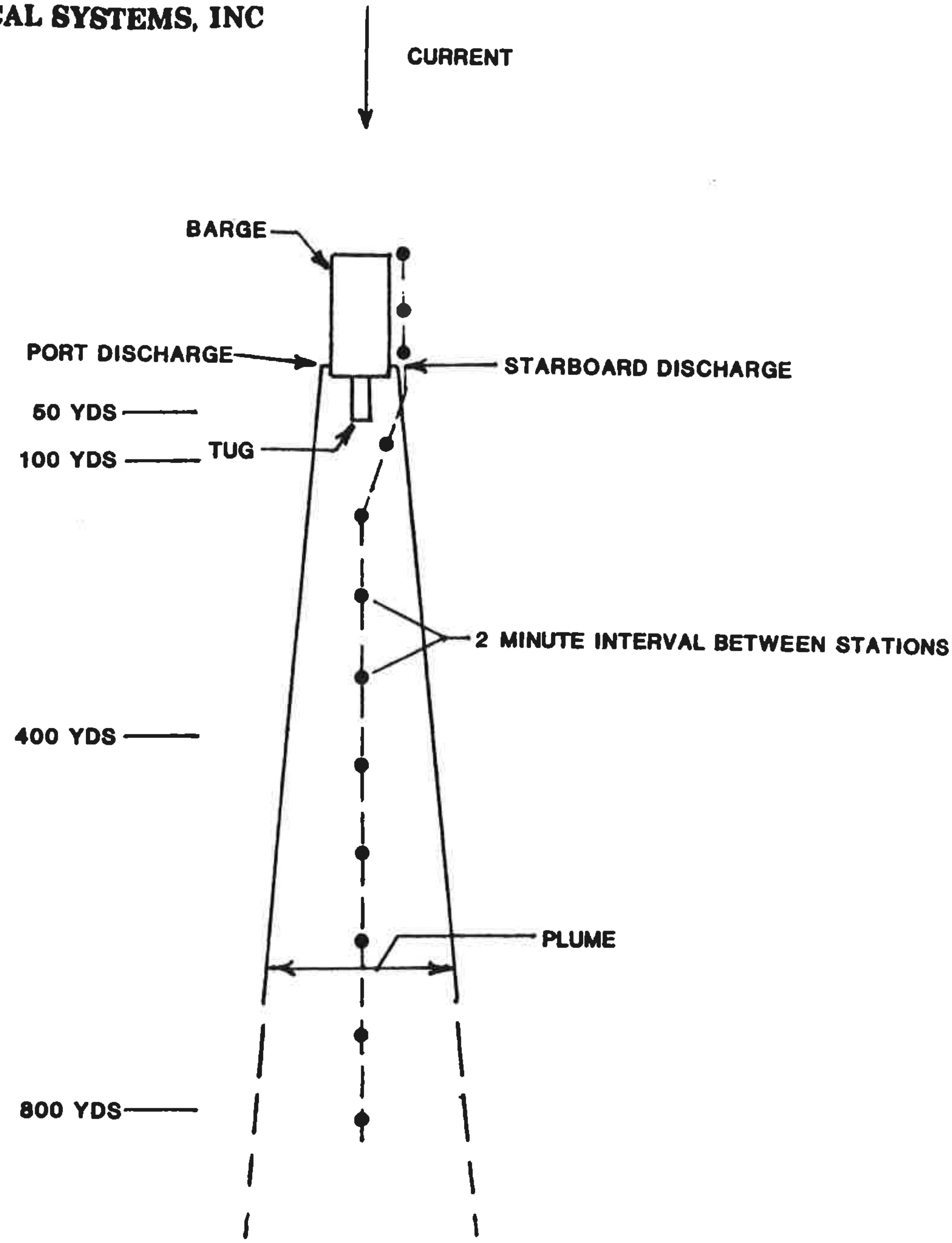

FIGURE 7
Plan View Test 3
Longitudinal analysis

Sample depth = 20'

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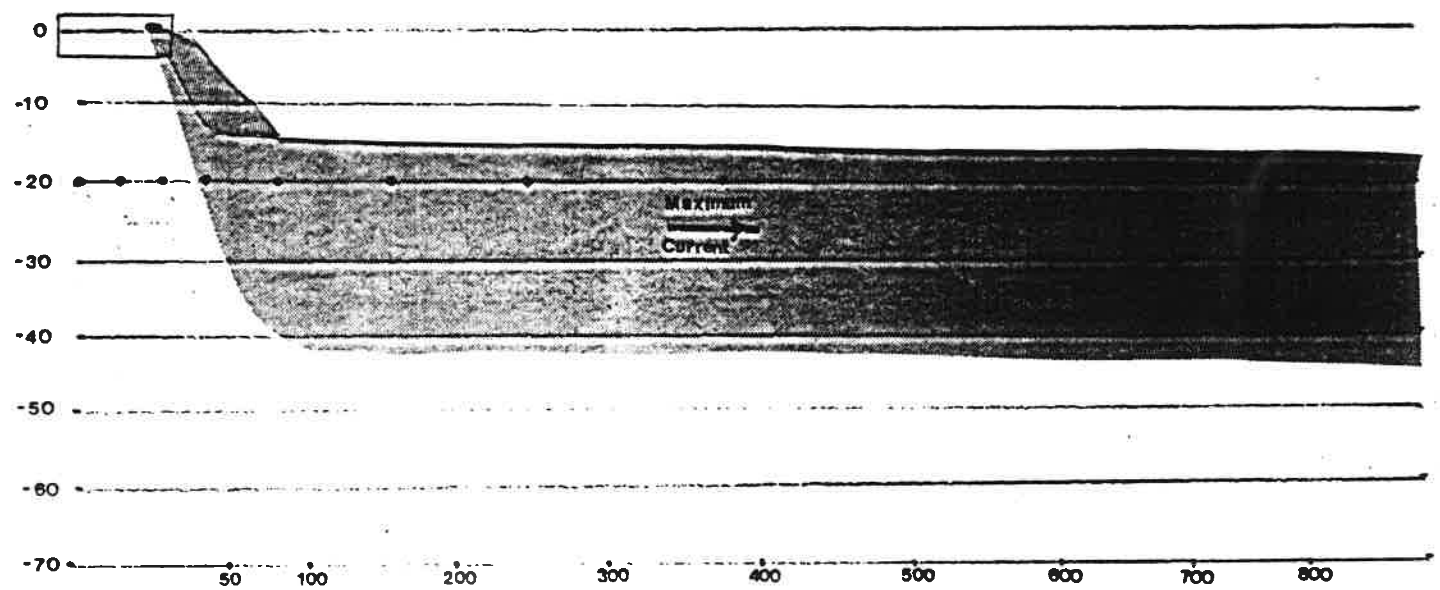

FIGURE 8
Elevation - Test 3
Longitudinal analysis
Sampling Depth = 20'

ebb tide exchange. The research vessel anchored northwest of the green # 1 buoy (Station T-1) (Figure 1) and sampled at half hour intervals as the tidal front moved south down Raccoon Strait toward the Golden Gate Bridge. Water samples were taken in front of the ebb front, at the ebb tide interface, and at timed intervals after the interface had passed the anchor location. A second station (T-2) (Figure 1) was also sampled. This sample set was taken as a water column sampling immediately prior to the passing of an ebb tide front. The water quality conditions of that sample would be reflective of water conditions at slack tide.

<u>Upwelling areas</u> Areas of tidal current upwelling, often visible from the air can contribute to the suspended solids loading in waters of Raccoon Strait. In order to examine water quality conditions in the upwelling zones, water sampling of the water column was carried out at stations U-1 and U-2 (Figure 1). These upwelling areas were spotted from the air and the sampling vessel was directed into place. Water samples were taken at ten foot depth intervals. At station U-1, water samples were taken inside and outside of the upwelling. At Station U-2, samples were only taken inside the upwelling. Two major areas of tidal upwelling were at the mouth of Richardson Bay and off the tip of Belvedere Island. The upwellings appear to be strongly influenced by bottom and shoreline topography.

<u>Trawl surveys</u> The Department of Fish and Game requested a preliminary assessment of transitory species on the Pt. Knox Shoals. It was proposed that trawling using a 16 foot experimental, 1/4" fine mesh trawl be conducted at the five sampling stations. Due to bottom topography and current speeds only three stations were sampled using the fine mesh trawl. Sampling took place on August 1, 1990. The trawls were conducted as two five minute hauls along each sampling transect, totaling six trawls (Figure 9).

<u>Literature survey</u> It was proposed that the literature regarding the effects of particulates in fish gills be reviewed to place observed levels in context of their potential to cause harm to gill epithelium. The Department of Fish and Game requested that the literature review be expanded to include crustaceans. This portion is currently underway and is not included in this report.

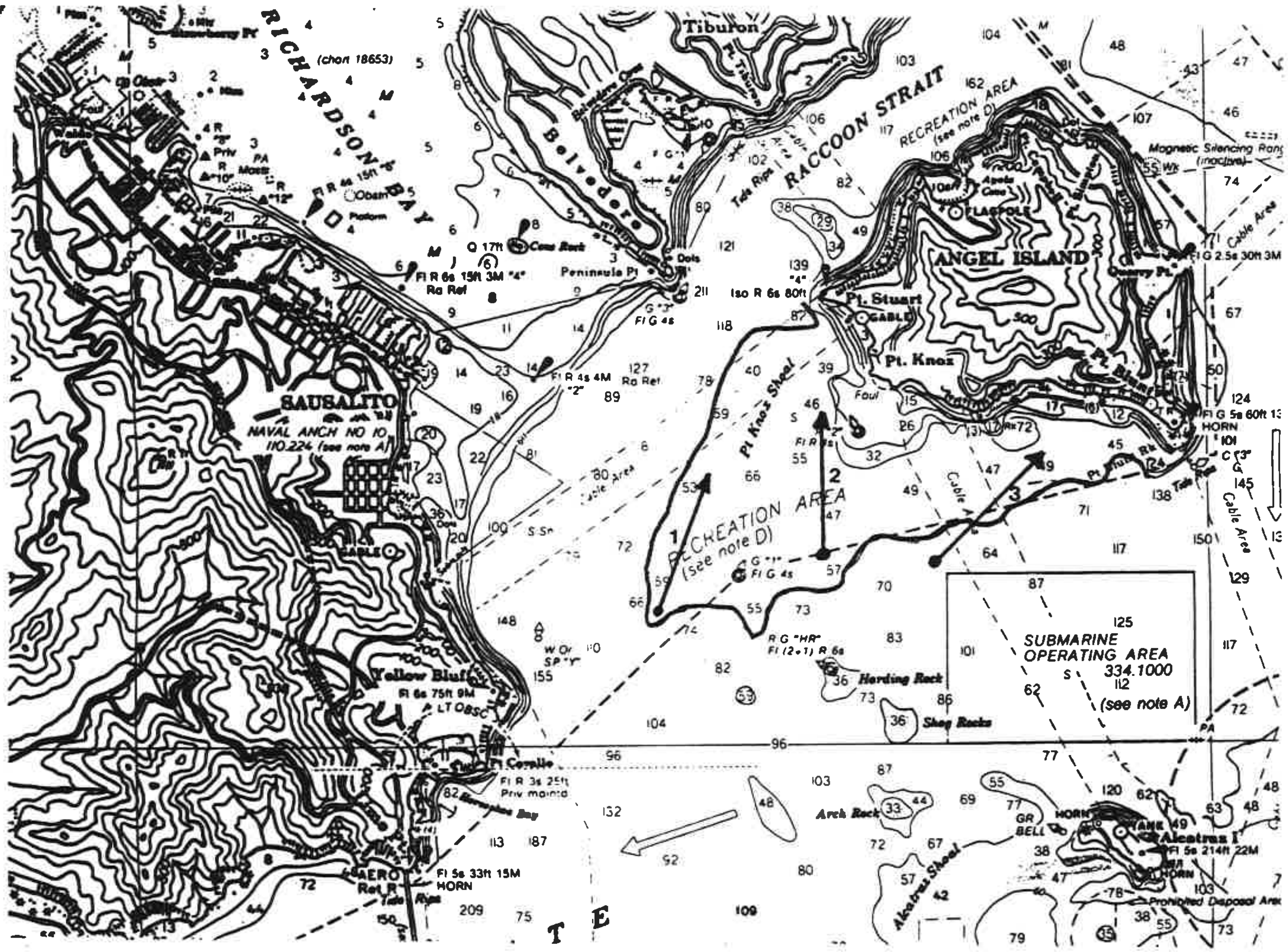

FIGURE 9
Trawling Stations
Pt. Knox Shoals

2.0
METHODS/ RESULTS

2.1 BENTHIC SAMPLING

Bottom samples were taken at sites A through E (Figure 1) with an eight liter benthic grab taking a 900 cm^2 surface samples. Two 0.25 liter samples were taken from each grab for enumeration and identification of benthic organisms, and grain-size analysis. The sample designated for enumeration and identification was completely sorted and counted. The grain-size analysis for each station is shown in Table 1.

The results of the benthic enumeration is shown in Table 2. The numbers determined from the direct counts were converted to the number of organisms per m^2. The subsample equaled 27 cm^2 in area, the conversion was then made to estimate the number of organisms per m^2.

2.2 PLANKTON SAMPLING

Plankton tows on two different days were made using fine mesh plankton net in the plume for 10 minutes each time. The samples were sorted, identified, and counted using a $^1/_8$ split to reduce counting time. Species numbers were corrected for the split and reported as #/filtered m^3. The results of the two tows are shown in Table 3.

Barge overflow water was sampled by taking a 20 liter grab water sample 15 minutes from the overflow and screening the water through a 0.5 mm screen. Organisms and material retained were collected, placed in containers, and preserved. Identification to the lowest taxa was carried out. The results of this analysis is shown in Table 4.

TABLE 1

GRAIN-SIZE ANALYSIS OF SEDIMENTS AT FIVE STATIONS ON PT. KNOX SHOALS AND FROM A SINGLE SEDIMENT SAMPLE FROM THE BARGE STATION

%	A	B	C	D	E	Barge
Gravel	2.28	0.007	2.41	0.043	0.199	0
Sand	94.23	85.68	93.52	98.94	61.54	99.77
Silt	0.99	5.07	1.86	0.75	20.17	0.23
Clay	2.49	9.23	2.13	0.27	18.09	0

TABLE 2

RESULTS OF BENTHIC ANALYSIS AT STATIONS A-E, POINT KNOX SHOALS (number of individuals counted)

Taxon	A	B	C	D	E
Polychaetes	5		2	9	2
Crustaceans					
Barnacles					14
Isopods	1				
Mollusc					
Gastropods	1				
Clams		1		3	
Nematodes	26	5		2	8
Misc. Taxa					
Hydroids	1		1		1
Bryozoans		1			
Encrusting form	1				
Total	37	7	3	14	25
#/cm^2	1.3	0.24	0.1	0.49	0.88
Est. #/m^2	13000	2400	1000	4900	8800

TABLE 3

ORGANISMS COUNTED AND IDENTIFIED IN PLANKTON TOWS THROUGH THE PLUME

	Tow 1	Tow 2
Polychaete	6	6
Copepods	700	824
Mysids	53	96
Barnacle larvae	242	76
Other crustaceans	29	3
Nematodes	9	5
Invertebrate eggs	6	3
Miscellaneous taxa	9	6
Echinoderms		
Cnideria		
Chaetognaths		
Totals	1054	1019
Planktonic	1039	1008
Benthic	15	11

	Tow 1	Tow 2
The estimated total based upon $^1/_8$ split	8432	8152
Estimate of #/m^3 of filtered volume (6.96 m^3 filtered volume)	1211	1171

TABLE 4

ANALYSIS OF BARGE OVERFLOW WATER AND IDENTIFICATION OF ORGANISMS

	Organism				
Time (min)	**Crustaceans**	**Polychaete**	**Hydroid**	**Nematode**	**Unidentified**
0	1				
15	1	1	2		
30					1
45	2		1		
60	8	1	1		
75	6	1			
90	2				
105	4				
120	Sample Lost				
135	1				
150	7				
165	13	2	1	1	

The crustaceans identified included cumaceans, copepods barnacles, tanaeids, amphipods, ostracods, and caprellids.

2.3 Water Quality Analysis of The Plume

Test 1 Vertical Profile

In Test 1 (vertical profiles) samples were taken on May 17, June 1, June 11, and June 14, 1990. Two ebb and two flood tides were assessed. Table 5 shows the oxygen levels by depth; Table 6, the dissolved sulfides; and Table 7, the suspended particulates. Temperatures were taken and were found to have no vertical stratification due to the high tidal current velocities (15 ± 0.5°C).

No significant decrease in dissolved oxygen levels were observed in the plume. The variation from the surface to 50' was less than 0.3 mg/L. The plume area, generally from -20' to -40' in depth did not appear to have depressed oxygen levels.

Dissolved sulfides were not found at significant levels in in samples taken during this study. The highest value observed was 0.023 mg/L. These concentrations would have no significant toxic or sublethal effect on aquatic organisms.

The levels of suspended particulates in the plume were variable and did not appear to correlate with the visible plume. Suspended levels varied from 5 mg/L to 121 mg/L. The highest average level (69.7 mg/L) was observed on May 22, 1990; lowest levels (9.7 mg/L), on June 14, 1990.

Secchi disk readings were taken in the plume on June 11, and 14, 1990. Table 8 shows a substantially reduced transparency inside the area of the plume. The water is colored, but when analyzed for suspended particulates, no significant mass is present. The Secchi disk transparency is a function of the reflection of light from the water's surface and is influenced by the absorption characteristics of the water and its dissolved and particulate matter. Color in the plume may be derived more from small amounts of dissolved clay, rather than larger particulates. This appears to be consistent with the performance of the plume, as it stays in a laminar configuration at 20’ to 40’ and does not appear to settle out of suspension.

TABLE 5

TEST 1
SUMMARY OF OXYGEN CONCENTRATIONS (mg/L)
DIRECTLY IN THE DREDGE PLUME
BY DEPTH

Date	**5/17/90**	**6/1/90**	**6/11/90**	**6/14/90**	**6/14/90**
Tide	**Ebb**	**Flood**	**Flood**	**Ebb**	**Ebb**
Depth					
5	7.4	6.8	6.1	6.6	6.2
10	7.4	6.9	6.1	6.6	6.2
15	7.4	6.7	6.4	6.4	6.3
20	7.2	6.4	6.4	6.6	6.2
25	7.3	6.6	6.1	6.5	6.3
30	7.4	6.7	6.1	6.4	6.2
35	7.4	6.6	6.3	6.5	6.2
40	7.2	6.6	6.5	6.5	6.4
45	7.3	6.6	6.7	6.5	6.3
50	7.1	6.5	6.4	6.4	6.4
*Temperature					
Min	15.4	15.5	15.5	16.0	16.0
Max	15.6	15.6	15.6	16.1	16.1

*The extreme tidal currents completely mixed the water column and no temperature stratification was observed.

TABLE 6

TEST 1
SUMMARY OF DISSOLVED SULFIDES (mg/L)
BY DEPTH

Date	5/17	5/22	6/11	6/11	6/14	6/14
Tide	Ebb	Ebb	Flood	Flood	Ebb	Ebb
Depth						
5	0.008	0.01	0.021	0.021	0.009	0.001
10	0.013	0.013	0.016	0.023	0.007	0.001
15	0.016	0.008	0.019	0.022	0.005	0.001
20	0.001	0.004	0.019	0.019	0.002	0.001
25	0.013	0.010	0.018	0.019	0.002	0.001
30	0.014	0.013	0.017	0.020	0.003	0.001
35	0.002	0.014	0.016	0.018	0.004	0.001
40	0.013	0.018	0.019	0.018	0.002	0.001
45	0.015	0.012	0.020	0.018	0.001	0.001
50	0.004	0.003	0.021	0.017	0.001	0.001
Temperatures						
Min	15.4	15.5	15.5	15.5	16.0	16.0
Max	15.6	15.6	15.6	15.6	16.1	16.1

TABLE 7

TEST 1
SUMMARY OF SUSPENDED SOLIDS (mg/L)
BY DEPTH

Date	**5/17**	**5/22**	**6/11**	**6/11**	**6/14**	**6/14**
Tide	**Ebb**	**Ebb**	**Flood**	**Flood**	**Ebb**	**Ebb**
Depth						
5	35	121	15	11	25	10
10	43	40	10	18	15	7
15	53	45	10	18	9	12
20	34	58	11	21	23	10
25	41	62	13	15	12	10
30	37	65	22	12	10	9
40	40	67	22	20	11	6
45	40	99	11	17	5	11
50	43	71	13	27	13	13
	40.6	69.7	14	17.6	13.6	9.7
Temperatures						
Min	15.4	15.5	15.5	15.5	16.0	16.0
Max	15.6	15.6	15.6	15.6	16.1	16.1

TABLE 8

SECCHI DISK READINGS

Date: 6/11
Tide: Flood

Location		Secchi depth
Pt. Knox buoy - Red # 2		3.5'
Next to barge - out of plume		4.0'
Port of barge - out of plume		5.0'
Astern	Port plume	2.0'
	Starboard plume	2.0'
Starboard plume (inside)		1.5'
Starboard plume (outside)		5.0'

Date: 6/14
Tide: Ebb

Location		Secchi depth
Port side	Outside of plume	4.0'
	Inside of plume	2.0'
Starboard	Outside of plume	4.0'
	Inside of plume	2.0'

All plume readings were taken within 50 meters of the stern of the tug.

Test 2 Cross-section analysis

Table 9 summarizes Test 2 water quality parameters taken across the plume at varying distances from the barge. Oxygen levels did not vary significantly, and in a number of cases was higher inside the plume than outside. This is probably the result of aeration by the prop of the tug during disposal.

No significant increase in dissolved sulfides was observed. However particulates, between 50 and 400 yards, did increase over values seen outside the plume. These observed values are still very low and are generally comparable to background levels observed during a tidal exchange (Table 11) and in upwelling areas (Table 12).

Test 3 Longitudinal analysis

Table 10 summarizes the water quality parameters taken during Test 3 on a longitudinal gradient along the long axis of the plume. Dissolved oxygen and sulfide levels were not significantly reduced in the plume. Suspended particulate levels did increase slightly at the point of discharge, but rapidly reduced to background levels.

2.4 Ebb Tide Monitoring

Table 11 summarizes the results of a timed sampling program at one point as an ebb tide front moved through Raccoon Straits and across Pt. Knox Shoals. The initial sample (Time 0) was taken prior to the ebb front passing the sampling location.

Average oxygen concentrations did not vary significantly throughout the test run, ranging from 5.6 mg/L to 6.5 mg/L. Oxygen levels at 50' were generally the lowest observed with the lowest value being 5.6 mg/L at 240 minutes after the passage of the tidal front. This would correspond to 3.5 hours after the ebb tide front had passed and may be reflective of material moving downcurrent behind the front.

Particulate levels did not change significantly until 120 to 150 minutes when high surface and bottom levels were observed. These levels were generally higher than levels found in the plume. A single sample set was taken at T-2, immediately prior to an ebb front.

TABLE 9

TEST 2
SUMMARY OF AVERAGE WATER QUALITY PARAMETERS INSIDE AND OUTSIDE OF THE PLUME AT VARYING DISTANCES DOWN CURRENT FROM THE BARGE

Date: 5/17
Tide: Ebb
Depth 20'

	O_2		Dissolved Sulfides		Suspended Particulates	
Distance (m)	**Out**	**In**	**Out**	**In**	**Out**	**In**
50	6.85	7.2	0.0145	0.018	38.5	30.0
100	6.6	6.6	0.0115	0.011	26.5	35.0
400	6.95	7.4	0.0095	0.0085	32.0	37.5
800	7.15	6.8	0.013	0.013	36.5	43.0

Date: 5/22
Tide: Ebb
Depth 20'

	O_2		Dissolved Sulfides		Suspended Particulates	
Distance (m)	**Out**	**In**	**Out**	**In**	**Out**	**In**
50	NT	NT	0.0155	0.0175	40.0	70.0
100	NT	NT	0.017	0.018	65.0	85.5
400	NT	NT	0.0145	0.019	79.5	52.0
800	NT	NT	0.015	0.013	92.0	87.0
	Meter malfunction					

Date: 6/11
Tide: Flood
Depth 20'

	O_2		Dissolved Sulfides		Suspended Particulates	
Distance (m)	**Out**	**In**	**Out**	**In**	**Out**	**In**
50	6.7	7.0	0.003	0.002	11.5	32
100	6.9	6.8	0.012	0.001	19	26
400	6.8	7.0	0.0015	0.003	8.5	16
800	6.85	6.75	0.001	0.001	17.5	23

TABLE 9 (Cont'd)

TEST 2
SUMMARY OF AVERAGE WATER QUALITY PARAMETERS INSIDE AND OUTSIDE OF THE PLUME AT VARYING DISTANCES DOWNCURRENT FROM THE BARGE

Date: 6/14
Tide: Ebb
Depth 20'

	O_2		Dissolved Sulfides		Suspended Particulates	
Distance (m)	**Out**	**In**	**Out**	**In**	**Out**	**In**
50	6.9	6.85	0.0055	0.006	13	12
100	6.85	7.0	0.0045	0.005	13	19
400	6.8	6.85	0.002	0.003	15.5	24
700	6.95	6.9	0.001	0.002	12	17.5

Distance is estimated in meters from the stern of the tug.

TABLE 10

TEST 3
SUMMARY OF WATER QUALITY PARAMETERS FROM A 20' DEPTH AT TIME INTERVALS

Date: 5/17

Tide: Ebb

Minutes	Distance (m)	D.O	Dissolved Sulfides	Suspended Particulates
0	+100	NT	0.002	70
2	+50	7.0	0.007	55
4	+25	7.0	.010	70
6	0	7.3	0.004	90
8	-50	7.4	0.006	47
10	-100	7.3	0.006	73
12	-200	7.2	0.003	54
14	-300	7.2	0.010	54
16	-400	7.3	0.011	51
18	-500	7.2	0.010	50
20	-600	7.0	0.014	62
22	-700	6.8	0.011	77
24	-800	6.7	0.013	42

Distance is estimated in meters from the stern of the tug.

+ = up current

- = down current

TABLE 10 (Con'd)

TEST 3
SUMMARY OF WATER QUALITY PARAMETERS FROM A 20' DEPTH AT TIME INTERVALS

Date: **5/22**
Tide: **Ebb**

Minutes	Distance (m)	D.O*	Dissolved Sulfides	Suspended Particulates
0	+100		0.015	49
2	0		0.002	90
4	-100		0.003	29
6	-200		0.007	41
8	-300		0.002	57
10	-400		0.005	24
12	-500		0.006	18
14	-600		0.006	20
16	-700		0.005	30
18	-800		0.007	59
20	-900		0.004	64
22	-1000		0.003	49
24	-1200		0.004	55

*D.O. meter malfunctioned.

TABLE 10 (Con'd)

TEST 3
SUMMARY OF WATER QUALITY PARAMETERS FROM A 20' DEPTH AT TIME INTERVALS

Date: 6/11
Tide: Flood

Minutes	Distance (m)	D.O	Dissolved Sulfides	Suspended Particulates
0	+100	6.6	0.017	17
2	+50	6.5	0.020	12
4	+25	6.4	0.019	16
6	0	6.4	0.018	16
8	-100	6.4	0.025	19
10	-200	6.2	0.025	31
12	-300	6.3	0.021	58
14	-400	6.6	0.020	40
16	-500	6.4	0.018	100
18	-600	6.2	0.017	27
20	-700	6.4	0.025	22
22	-800	6.6	0.022	16
24	-900	6.7	0.019	40

TABLE 10 (Con'd)

TEST 3
SUMMARY OF WATER QUALITY PARAMETERS
FROM A 20' DEPTH AT TIME INTERVALS

Date: 6/14

Tide: Ebb

Minutes	Distance (m)	D.O	Dissolved Sulfides	Suspended Particulates
0	+100	6.3	0.003	14
2	+50	6.4	0.005	13
4	+25	6.1	0.007	7
6	0	6.1	0.004	10
8	-50	5.9	0.005	13
10	-100	6.6	0.002	13
12	-200	6.4	0.007	18
14	-300	6.4	0.006	19
16	-400	6.3	0.006	16
18	-500	6.6	0.006	8
20	-600	6.8	0.002	13
22	-700	6.7	0.001	8
24	-800	6.9	0.002	14

TABLE 11

SUMMARY OF WATER QUALITY PARAMETERS DURING AN EBB TIDE EXCHANGE 5/28/90

Station T-1 Time (minutes)	Depth (ft)	DO	Total Suspended Solids (mg/L)
0	10	NT	42
	20	6.8	49
	30	6.7	42
	40	6.6	71
	50	6.0	50
	Mean	6.5	50.8
30 Ebb tide front	10	6.6	34
	20	6.7	45
	30	6.6	25
	40	6.5	78
	50	6.0	56
	Mean	6.5	47.6
60	10	6.7	50
	20	6.8	62
	30	6.5	46
	40	6.4	38
	50	6.0	33
	Mean	6.5	45.8
90	10	6.7	52
	20	6.6	45
	30	6.7	62
	40	6.6	46
	50	6.5	30
	Mean	6.6	47.0
120	10	6.3	87
	20	6.1	46
	30	6.5	41
	40	6.6	50
	50	6.6	51
	Mean	6.4	55.0
150	10	6.6	46
	20	6.7	64
	30	6.6	61
	40	6.5	71
	50	6.4	104
	Mean	6.6	69.2

TABLE 11 (Cont'd)

SUMMARY OF WATER QUALITY PARAMETERS
DURING AN EBB TIDE EXCHANGE
5/28/90

Time (minutes)	Depth (ft)	DO	Total Suspended Solids (mg/L)
180	10	-	56
	20	6.5	43
	30	6.3	46
	40	6.2	48
	50	6.0	32
	Mean	6.3	45.0
210	10	6.4	41
	20	6.4	89
	30	6.3	66
	40	6.4	43
	50	6.4	58
	Mean	6.4	59.4
240	10	6.4	8
	20	6.4	< 1
	30	6.3	44
	40	6.2	79
	50	5.6	30
	Mean	6.2	40.3
270	10	6.4	21
	20	6.6	7
	30	6.5	16
	40	6.2	18
	50	6.2	14
	Mean	6.4	15.2
Station T-2 6/14/90			
	Surface	6.1	7
	10	6.1	11
	20	6.3	5
	30	5.9	12
	40	6.1	14
	50	6.7	38
	Mean	6.2	14.5

TABLE 12

SUMMARY OF WATER QUALITY PARAMETERS FOR TWO UPWELLING AREAS (U-1 AND U-2)

Site	O_2		Dissolved Sulfides		Suspended Particulates	
U-1	**Out**	**In**	**Out**	**In**	**Out**	**In**
Surface	6.65	6.7	0.0035	0.0045	6.5	29.5
10	6.6	6.85	0.0035	0.005	8.5	41.5
20	6.45	6.75	0.0055	0.0045	10	40.5
30	6.45	6.8	0.0045	0.002	8.5	36
40	6.15	6.8	0.0025	0.0025	14.5	43
50	6.5	6.8	0.004	0.003	16.5	35.5
U-2						
Surface	6.4		0.0045		19	
10	6.25		0.005		25.5	
20	6.1		0.0055		34	
30	6.3		0.004		36.5	
40	6.15		0.004		57.5	
50	6.05		0.005		54	

2.5 Upwelling Analyses

Two areas of upwelling created by tidal currents were assessed on June 14, 1990. A plane spotted areas off Belvedere and near midchannel of Raccoon Straits. Water samples were taken from both inside and outside the upwelling at U-1 and inside at U-2. The results of the water sampling are shown on Table 12.

There was an observed drop in oxygen levels between the outside and inside of the upwelling area. Differences between depth values range from 0.25 to 0.65 mg/L. These values were generally higher than observed within the plume. No differences were noted for sulfides.

Suspended particulate levels were also higher within the upwelling than outside of its influence. The values in the upwelling were generally similar to values observed in the area of the plume. A high degree of variability in suspended particulates is apparent in the Strait during tidal exchanges.

2.6 Trawling Results

A total of six trawls were conducted at Pt. Knox Shoal using a 16' experimental otter trawl with 1/4" mesh. Three areas were assessed using duplicate trawls per area. Area 1 was the site of the sand mining operation; Area 2 was approximately 90 meters east of Area 1; and Area 3 was approximately 1500 meters east of Area 2.

All trawls were taken with the tide and were approximately 1500 meters in length.

The results of the trawling are presented in Table 13.

TABLE 13

RESULTS OF OTTER TRAWL SAMPLING

	Site 1		Site 2		Site 3	
Trawl	1	2	1	2	1	2
Northern Anchovy						
1	3.5"	5.25"	3.25"			
2	2.5"	3.25"				
3	4.5"					
4	3.0"					
5	3.75"					
Midshipman						
1		7.25"				
Crangon shrimp						
1		2.0"				
Ctenophores	X	X	X			
Debris	X	X	X	X		

3.0 DISCUSSION

The results of the benthic studies from the five stations appear to be consistent with organism density data in a recent NOAA report (1989). Number of organisms per m^2 at Yerba Buena Island ranged from 2600 to 7400; at Vallejo, 6000 to 13000; and in San Pablo Bay, from 38,000 to 40000. The grain-size at the three sites were significantly different than the PT. Knox sites with high percentages of silt and clay.

The data from this study, while consistent, appears to be on the lower end of the observed values. If the nematodes (meiofauna) are excluded, the densities drop dramatically. The taxa from these five locations are primarily polychaetes, a few crustaceans (primarily barnacles), minimal numbers of mollusks and the nematodes. Miscellaneous taxa (hydroids, bryozoans) are also present.

Based upon these preliminary data, the Pt. Knox Shoals supports an apparent low diversity, low density infaunal assemblage.

The analysis of water quality parameters in the plume, upwelling areas and in open water does not support the contention of significant water quality degradation from the disposal of fines from the sand mining.

Oxygen levels and dissolved sulfides were not affected by the disposal of this material. Suspended particulates did increase slightly when directly compared to open water areas, however these values were generally within the overall background levels observed during normal tidal exchanges.

The coloration of the water in the plume influence zone does not appear to be from high levels of suspended materials. It is possible that dissolved clay particles may provide the discoloration. Secchi readings did show a significant drop in transparency in the plume area and could be explained by dissolved material.

The plume formation was similar each time we sampled. A high level of surface coloration was noted immediately behind the barge. As the plume spread with the current, the zone appeared to drop to between 20' and 40'. This zone also appeared to be in the area of highest current speed. The vertical settling velocity of the particulates was overridden by the horizontal velocity of the tidal flow. The 20' to 40' band was observed for up to 1000 meters from the barge, at which point it started to dissipate.

The sand mining operation on Pt. Knox Shoals takes place in a relatively small area shown in Figure 2. Benthic infaunal density at the major operational site is moderate to low. The plume is influenced by high current speeds and does not appear to have a significant effect on water quality, other than to discolor the water. Suspended solids levels are low overall in the area and should not constitute a significant hazard to aquatic organisms.

4.0 REFERENCES

Long, E.R. and M. F. Buckman. 1989. An Evaluation of Candidate Measures of Biological Effects for the National Status and Trends Program. NOAA Technical Memo NOS OMA 45. April 1989

Plumb, R.H., Jr. 1981. Procedure for handling and chemical analysis of sediment and water samples. Technical Report EPA/CE-81-1, Vicksburg, MS: U.S. Environmental Protection Agency/U.S. Army Corps of Engineers Technical Committee on criteria for dredged and fill material, U.S. Army Waterways Experimental Station. 471 pages.

APPENDIX II

Laboratory tests

ToxScan Inc.

42 Hangar Way
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FAX (408) 724-3188

SUMMARY OF TIER 2 BULK SEDIMENT CHEMICAL ANALYSES

Project: Tidewater Sand and Gravel
Sample ID: Main Pump Discharge

ANALYTE	CONCENTRATION	DETECTION LIMIT*
Percent Solids (wet)	91%	--
Metals (mg/kg dry)		
Cadmium	ND	0.1
Chromium	120	0.1
Copper	8.1	0.1
Lead	2.1	0.1
Mercury	ND	0.02
Nickel	79	0.1
Silver	0.92	0.1
Selenium	ND	0.1
Zinc	27	2.0
Nonmetals (mg/kg dry)		
Arsenic	1.2	0.1
Cyanide	ND	0.02
Total Sulfides	ND	0.1
Water Soluble Sulfides	ND	0.1
Pesticides (ug/kg dry)		
Aldrin	ND	0.5
Chlordane and Related Compounds	ND	5.0
Dieldrin	ND	0.5
4,4'-DDT	ND	1.0
4,4'-DDE	ND	0.5
4,4'-DDD	ND	1.0
Endrin	ND	0.5
Endosulfan I	ND	2.0
Endosulfan II	ND	0.5
Endosulfan Sulphate	ND	10.0
Hexachlorocyclohexane Isomers	ND	0.5-1.0
Toxaphene	ND	30.0

* Detection Limits are wet weight.
ND = None Detected

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SUMMARY OF TIER 2 BULK SEDIMENT CHEMICAL ANALYSES, continued

Project: Tidewater Sand and Gravel
Sample ID: Main Pump Discharge

ANALYTE	CONCENTRATION	DETECTION LIMIT*
Oil and Grease (mg/kg dry)		
Oil and Grease	ND	20
Organotin Compounds (ug/kg dry)		
Monobutyltin	ND	1.0
Dibutyltin	ND	1.0
Tributyltin	ND	1.0
Phenolic Compounds (ug/kg dry)		
Total Phenols	ND	20-100
Total Chlorinated Phenols	ND	20-100
Pentachlorophenol	ND	100
Phenol	ND	20
2,4-dichlorophenol	ND	20
2,4-dimethylphenol	ND	100
Polychlorinated Biphenyls-PCBs (ug/kg dry)		
Total PCBs	ND	20.0
Arochlor 1242	ND	20.0
Arochlor 1254	ND	20.0
Arochlor 1260	ND	20.0

* Detection Limits are wet weight.

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SUMMARY OF TIER 2 BULK SEDIMENT CHEMICAL ANALYSES, continued

Project: Tidewater Sand and Gravel
Sample ID: Main Pump Discharge

ANALYTE	CONCENTRATION	DETECTION LIMIT*
Polynuclear Aromatic Hydrocarbons (PAHs) (ug/kg dry)		
Acenaphthene	ND	20
Acenaphthylene	ND	20
Anthracene	ND	20
Benzo(a)anthracene	ND	20
Benzo(a)pyrene	ND	20
Benzo(g,h,i)perylene	ND	20
Benzo(k)fluoranthene	ND	20
Benzo(b)fluoranthene	ND	20
Chrysene	ND	20
Dibenzo(a,h)anthracene	ND	20
Fluoranthene	ND	20
Fluorene	ND	20
Indeno(1,2,3,-c,d)pyrene	ND	20
Naphthalene	ND	20
Phenanthrene	ND	20
Pyrene	ND	20
Total PAHs	ND	20
Phthalates (ug/kg dry)		
Total Phthalates	26	10
Total Organic Carbon (mg/kg dry)	440	1000

* Detection Limits are wet weight.

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PARTICLE SIZE DETERMINATION

Tidewater Sand and Gravel
4501 Tidewater Ave.
Oakland, CA. 94601

12-14-89

MATERIAL:sand and gravel
ID -04
ID TOXSCAN 5176
1 of 1

SIZE INTERVAL Phi	mm	INTERVAL WT	INTERVAL %	CUMULATIVE %
<-5	>32	0.00	0.0	0.0
-4	32-16	0.00	0.0	0.0
-3	16- 8	0.00	0.0	0.0
-2	8- 4	53.60	51.6	51.6
-1	4- 2	23.57	22.7	74.3
0	2- 1	14.55	14.0	88.3
1	1-0.5	8.98	8.6	97.0
2	0.5-0.25	2.40	2.3	99.3
3	0.25-0.125	0.70	0.7	100.0
4	0.125-0.062	0.03	0.03	100.0
5	0.062-0.031	0.00	**********	************
6	0.031-0.016	0.00	**********	************
7	0.016-0.008	0.00	**********	************
8	0.008-0.004	0.00	**********	************
9	0.004-0.002	0.00	**********	************
>9	< 0.002	0.00	**********	************

total wt	coarse wt	fine wt
103.83	103.83	0.00

Laboratory Director

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QA\QC FOR PROJECT # 5176

ELEMENT	SPIKE AMOUNT ug/ml	% RECOVERY OF SPIKE
ARSENIC	0.28	74.00
CADMIUM	0.28	77.00
CHROMIUM	1.43	98.00
COPPER	1.43	112.00
LEAD	1.43	109.00
MERCURY	0.14	86.00
NICKEL	1.43	94.00
SELENIUM	0.14	70.00
SILVER	0.28	105.00
ZINC	2.85	113.00

	SRM VALUE FOUND ug/g	CERTIFIED SRM VALUE ug/g	
ARSENIC	9.10	11.60	1.30
CADMIUM	0.39	0.36	0.07
CHROMIUM	73.00	76.00	3.00
COPPER	16.00	18.00	3.00
LEAD	21.00	28.20	1.80
MERCURY	0.07	0.06	0.01
NICKEL	25.00	32.00	3.00
ZINC	123.00	138.00	6.00

SRM = National Bureau of Standards
Estaurine Sediment , #1646

GRAIN SIZE DISTRIBUTION
(MECHANICAL ANALYSIS)

ROJECT TIDEWATER PROJECT NO. 1551-800 DATE 12/26/89

BORING ______ DEPTH (FEET) ______ TESTED BY OT

AMPLE DESCRIPTION GRAY SAND & GRAVEL

OISTURE CONTENT DETERMINATION:

ARE NO. ______ gms

TARE + WET SOIL ______ gms

ARE + DRY SOIL ______ gms

WT. OF TARE ______ gms

. OF MOISTURE ______ gms

WT. OF DRY SOIL ______ gms

MOISTURE CONTENT ______ (%)

WET WT. TOTAL SAMPLE ______ GMS

DRY WT. TOTAL SAMPLE:

$= \frac{\text{WET WT. TOTAL SAMPLE}}{1 + \text{MOISTURE CONTENT}} =$ ______ gms

SIEVE SIZE U.S. STANDARD)	PARTICLE DIAMETER IN.	PARTICLE DIAMETER MM.	WEIGHT RETAINED (GMS)	ACCUM. WT. RET. (GMS)	PERCENT RETAINED	PERCENT PASSING
5"	----					
3"	3.0	76.2				
1 1/2"	1.5	38.1		0		100
3/4"	0.742	18.85		33.8	2.7	97.3
3/8"	0.371	9.42		52.8	4.2	95.8
# 4	0.185	4.699		207.9	16.5	83.5
# 8	0.093	2.362		424.9	33.7	66.3
# 16	0.046	1.168		630.7	50.0	50.0
# 30	0.0232	0.589		799.2	63.3	36.7
# 50	0.0116	0.295		968.2	76.8	23.2
# 100	0.0058	0.147		1199.4	95.1	4.9
# 200	0.0029	0.074		1232.8	97.8	2.2
# 270	0.0021	0.053				
PAN						
T. WASHED THRU #200						
TOTAL						

WEIGHT WASHED THROUGH #200:

. OF PAN B

WT. PAN + DRY SOIL 1485.3

. OF PAN 224.3

WT. OF DRY SOIL 1261.0

APPENDIX III

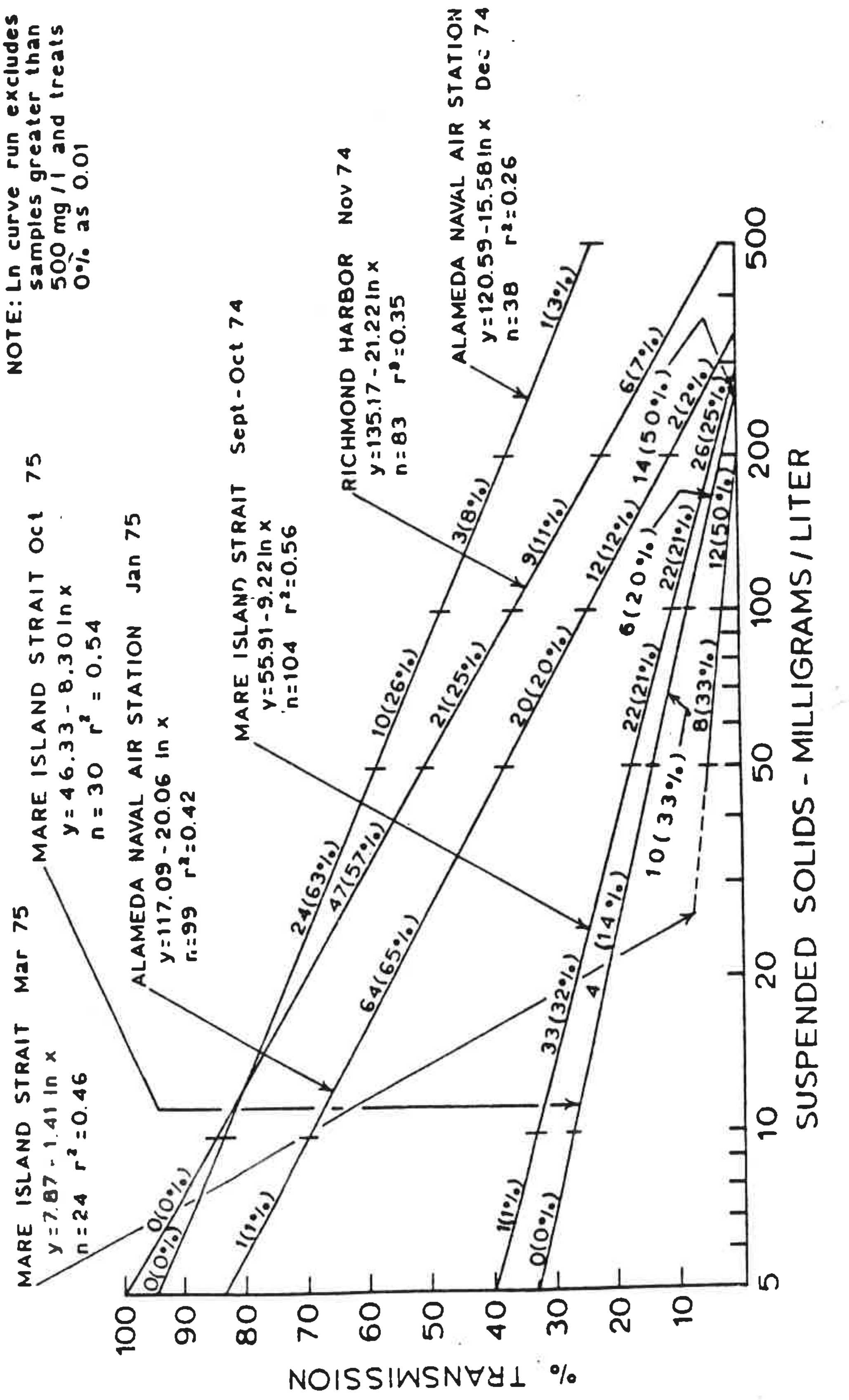
Excerpts from:

Supplemental EIS
Oakland Harbor
Deep draft navigation improvements
March 1988
U. S. Army Corps of Engineers
San Francisco District

processes. The total quantity of material in solution and the amount of particulate matter in suspension at any given time is highly variable and is greatly influenced by the dynamics of San Francisco Bay. Because many factors can affect turbidity, measurements of turbidity in San Francisco Bay do not accurately define the level of suspended sediment present in Bay waters. Correlation between suspended particulate or suspended sediments and light transmission can be established for a specific location for a limited time period by calibrating simultaneous measurements of both and extrapolating relationship curves.

Measurement of light transmission and suspended solids was undertaken as part of the Dredge Disposal Study, San Francisco Bay and Estuary by the U.S. Army Corps of Engineers (USACE), San Francisco District (USACE, 1976). Transmission measurements and suspended solids measurements of water samples collected in situ were correlated to enable curve generation. Results are shown in Figure 3-7. The interdependence of turbidity and suspended solids was highly variable over time and location within the Bay. Examination of the generated curves clearly establishes the inefficacy of measuring turbidity or light transmission and drawing conclusions regarding suspended particulate levels in San Francisco Bay. Conclusions concerning suspended sediment loading based on turbidity are even less sound as suspended sediments are a subset of suspended solids. To assess turbidity and suspended sediment levels in San Francisco Bay it is essential to understand the ocean, waste, and surface runoff waters entering the Bay and the water properties, circulation, and mixing of the diverse components. An overview of circulation and mixing in San Francisco Bay is presented in Conomos, 1977. A brief description of tides and currents in San Francisco Bay is presented in section 3.3.2. Suspended particulate and suspended sediment loading of Bay waters are presented below:

Riverine inflow, mostly from the Sacramento-San Joaquin River Delta contributes 8.3 million m^3 (10.5 million yd^3) of largely lithogenous suspended sediments to the Bay annually, mostly in the winter and spring. An estimated 130 million m^3 (170 million yd^3) of sediments are resuspended annually from the shallow areas of the Bay by wind generated waves. Wind generated resuspension of sediments is most prevalent during prolonged periods of strong northwest winds in summer. Riverine inflow also carries large quantities of biogenous matter, particularly plant fragments (detritus) and freshwater phytoplankton. Warmer temperatures, increased insolation, and heightened mixing in summer months induce huge increases in the planktonic population. Late summer concentrations of phytoplankton and zooplankton in the turbidity maximum range up to 30 percent of suspended particulate matter, up from typical winter concentrations of 3 percent (Conomos and Peterson, 1973). Ocean waters that mix with the Bay waters can also contribute suspended particulate matter. An estimated 5 percent of Bay water is replaced by "new" ocean water in an average tidal cycle during the summer and over 15 percent of Bay water can be replaced in



% TRANSMISSION Vs SUSPENDED SOLIDS

FIGURE 3.7

winter months (Parker, 1972). From March to as late as September, northerly winds along the California coast generate periods of upwelling that produce episodic blooms of netplankton (Malone, 1971). Maxima of planktonic diatoms in the Central Bay often result from these offshore blooms during the upwelling period (Cloern, 1979).

As shown above, suspended sediments in San Francisco Bay contribute to the suspended particulate loading of the Bay and the suspended particles augment turbidity in San Francisco Bay. Dredged sediment disposal, in turn, is a small addition to the total suspended sediment regime of the Bay. The total annual quantity of dredged material disposed at aquatic sites within the Bay is a distant third in quantity behind natural resuspension of sediments by wind generated waves and riverine sediment inflow and is quite small in comparison (Table 3.D). Further, only part of the dredged material disposed at aquatic sites is dispersed and contributes to the Bay's suspended sediment regime. Determining the amount of sediments suspended and recirculated in the Bay from dredged material disposal at the Alcatraz site requires an understanding of the physical discharge and descent of dredged material and the mixing characteristics of the site.

Fall of dredged material through the water column and distribution on the Bay floor occurs in three distinct phases: convective descent, dynamic collapse, and passive transport. Density differential between released dredged material and the water at the receiving site enables convective descent of the dredge material to the Bay floor. Average descent velocity at the site has been measured at 1.2 m/s (3.8 ft/s). The mass of material moving downward conveys lighter particles to the bottom simultaneously. The dynamic collapse phase begins when the mass of material impacts the bottom and vertical momentum is translated to horizontal spreading. Examination of the area immediately after impact and initial settling of typical Bay mud reveals a central deposit of relatively cohesive, high density sediments surrounded by soft, low density, high water content material that behaves like a viscous fluid (SAIC, 1987c). The passive transport phase begins when erosion, gravity induced flow, or a combination of both, act to remove the material from the site.

Release of dredged material from a hopper dredge in October 1986 was monitored to determine the movement and persistence of turbidity or suspended material (SAIC, 1987a, SAIC, 1987b). The longest period of time that an elevated suspended sediment level was detectable above background levels in the vicinity of the site extended up to fifteen minutes. The maximum suspended sediment load of six monitored plumes (two coincident with strong ebb currents, two during periods of strong flood currents, and two simultaneous with slack water), reached about 60 mg/l near the surface and 120 mg/l near the bottom. Suspended sediment levels dropped to less than 40 mg/l very rapidly.

Table 3.D: ESTIMATED SUSPENDED PARTICULATE LOADING TO SAN FRANCISCO BAY WATERS[a]

Volume (m^3)[b]	Source
130,000,000	wind/wave resuspension
8,000,000	riverine inflow
unknown	netplankton[c]
2,800,000	dispersion from Alcatraz dredged material disposal site
2,010,000	Bay basin surface runoff[d]
994,000	dispersion from San Pablo Bay dredged material disposal sites
443,000	net erosion from South Bay[e]
174,000	point sources[f]
157,000	aerial[g]

a) annual figures irrespective of residence time.
b) volumes calculated with specific gravity value of 2.65 and saturated density of 1.3 g/cc.
c) 3% to 30% of suspended matter in turbidity maximum is living or detrital biogenous matter (Conomos and Peterson, 1977)
d) (Russel, 1982)
e) (Conomos, 1977)
f) Municipal and industrial wastewater discharges (Russel, 1982; Miller, 1986.)
g) inputs directly to surface of Bay, includes precipitation and dustfall (Russel, 1982; Miller 1986)

All plumes tracked east-west and material did not disperse significantly in a north-south direction. Calculations based on volume and suspended solids concentration measurements of the respective plumes, indicate that about ten percent of the material disperses in the water column during the convective descent and dynamic collapse phases. It is important to note that that the contribution of this suspended dredged material to the overall suspended sediment load of the water column at the site is minuscule. Assuming a 4000 m^3 disposal load, with an average sediment density of 1300 g/l, and the ten percent dispersed over an area of 1 km^2 25 m deep, the increase in suspended sediment for that volume is 0.02 mg/l. Ambient concentrations at the site can be as low as 12 to 15 mg/l near the end of a flood tide in summer when the site is dominated by relatively clear coastal waters, or up to 30 to 50 mg/l at the end of an ebb tide when the site is dominated by the sediment laden waters of San Pablo and Suisun Bays.

Dredged material retained at the site, based on monthly bathymetric surveys and logs of disposal quantities, is calculated to be 20 percent within 305 m (1000 ft) of site center and 30 percent within a 610 m (2000 ft) radius of site center. An additional 5-10 percent (7.5% is used for subsequent calculations) is estimated to have been deposited in the bathymetric depression on the east and south perimeter of the site, through gravity induced flow of the fluid fraction of material deposited during the dynamic collapse phase. The distribution of the viscous fluid mud in the vicinity of the disposal site is presented in SAIC, 1987a and SAIC, 1987b.

It follows that slightly more than half (52.5%) of the total material discharged at the site is resuspended and transported from the vicinity after initial deposition by the strong currents. The erosional capacity of the site for the high water content, fluid material (1.3 g/cc or less) is much higher than the amount of material deposited (Teeter, 1987). Combined with the ten percent lost to the water column during the convective descent phase, approximately five-eighths (62.5%) of the material discharged at the site is dispersed and transported from the site. In light of the above, it can be estimated that for an average year, five-eighths (62.5%) of the 3.8 million m^3 (5.0 million yd^3) of dredged material discharged at the site, or 2.8 million m^3 (3.7 million yd^3) is added to the Bay's suspended sediment regime by disposal of dredged material at the Alcatraz site (see Table 3.D).

The turbidity attributable to the additional sediments resuspended by dredged material disposal at Alcatraz is minor. The overall concentration of suspended sediments measured between July 1986 and February 1987 in the vicinity of the Alcatraz Disposal Site was dependent on the stage of the tide. Greatest concentrations occurred after slack low water and the lowest concentrations were observed immediately after slack high water. The influence of tidal circulation in the Bay, transporting sediment laden waters from the shallow areas of the Bay and Delta, and relatively clear waters from the Golden Gate and beyond, back and forth across the disposal site, as overwhelmingly the most important factor affecting suspended sediment load. If resuspension of sediments from the substrate was a major contributing factor to the sediment load and turbidity in the vicinity of the disposal site, then the amount of suspended sediment would be relative to tidal velocity and not tidal stage.

The oscillating flow of sediment laden waters from upstream in the Bay system and the less turbid waters from beyond the Golden Gate across the Central Bay has been widely observed (Carlson and McCulloch, 1974; Winzler and Kelly, 1985; SAIC, 1987c). A significant portion of the estimated 130 million m^3 (170 million yd^3) of sediments resuspended annually by wind generated waves can be transported miles to the ocean or miles upstream during a typical tidal excursion. In the summer months, when riverine inflow is the low and prevailing winds from the west or northwest are augmented by daily pressure gradient induced movement of air due to solar heating of air masses in the interior valley, the interface between sediment laden waters and the relative clean ocean waters is readily visible at the Bay's surface. The migration of the interface back and forth through the Central Bay can be observed from boats and planes, from elevated topographic locations around the Central Bay, and from bridges or even offices buildings in San Francisco.

Historically, most Corps of Engineers dredging in San Francisco Bay has been undertaken with hopper dredges which produce a slurried disposal material. The substitution of clamshell dredging with barge transport for a significant portion of hopper dredging in San Francisco Bay and the evolution of larger clamshell equipment have resulted in denser, more consolidated material being discharged at the site and larger loads of dredged material per discharge event. Increased density and increased volume of material per discharge event both contribute to material retention at the site and will hasten eventual filling of the site to its capacity. To reduce dredged material retention at the site, the San Francisco District of the Corps of Engineers proposed a slurry requirement on dredging in 1986. The slurry requirement was not effectively applied until mid-1987 and never became truly operational. Clamshell dredging equipment could not produce a slurry without extensive modification of plant equipment and/or methods of operation. It has been alleged that this partially implemented requirement to slurry dredged material has contributed significantly to turbidity levels in San Francisco Bay during 1986 and 1987 and that high turbidity levels adversely affected selected fisheries in the Bay during the same period.

The first comments related to increased turbidity levels in San Francisco Bay attributed to dredged material disposal practices were advanced by representatives of clamshell dredging industry in July and August 1987 (Dredged Material Management Advisory Steering Committee Meetings #3 and #4, July 29, 1987 and August 18, 1987). Representatives of the charter boat sportsfishing industry followed with charges of unexpected "muddy water" and the sudden disappearance of Striped bass from the Central Bay in September, 1987 (Dredged

Material Management Advisory Steering Committee Meeting #5, September 11, 1987). California Department of Fish and Game (CDFG) accessed Secchi disc data from three Central Bay stations for a seven year period from 1980 through October, 1987 and "partyboat" catch log data for the same years (CDFG, unpublished data, 1987). At first glance, these data may lend to the plausibility of the charges advanced by the clamshell dredgers and sportsfishermen However, any objective examination of the data clearly shows that the charges are not credible.

First, there is no correlation between level of dredged material disposal at the Alcatraz site and turbidity in the Central Bay as measured by the Secchi discs. In fact, the May-October period with the highest turbidity coincided with the lowest level of dredged material disposal activity of several years. The highest annual turbidity was present in 1983, a fact not reported by CDFG, and dredging activity was below the seven year average. Dredged material disposal in 1987 was highest of several years, yet turbidity levels measured by Secchi disc were third highest of the seven year period, below turbidity levels in 1983 and 1986. In perspective, turbidity and suspended solids monitoring at the Alcatraz site during dredged material disposal, has shown that turbidity levels at the site are influenced more by tidal oscillation of waters of varying sediment load from beyond the site than the perturbations due to dredged material disposal.

Secondly, the correlation between the Secchi disc turbidity data and sportfishing catch reports is tenuous at best. Sportfishing log reports indicated above-average fishing in 1983, yet the highest levels of turbidity were indicated by the Secchi disc data for the same time period. Reports of the worst sportfishing in the seven year period occurred in 1987, but again, turbidity levels were only the third highest of the seven year period. Fishing success was better in 1986 than 1987, but turbidity was higher in 1986 versus 1987. Sportfishing boats leaving Central Bay in September, 1987, due to poor Striped bass fishing (alleged to be caused by elevated turbidity in Central Bay) moved to the more turbid waters of San Pablo Bay and Suisun Bay and were reported locally as catching the legal limits on numerous occasions. No mention of the typical variation in distribution of fish or presence and availability of food source as a result of salinity or temperature is furnished by CDFG, although these inconspicuous factors could contribute to "poor fishing conditions" in a particular geographic area. If Striped bass were being caught in more turbid waters, it is illogical to charge that too much turbidity was the driving influence in their migrating from the Central Bay. A historical, but much less exiguous, data set for California Department of Fish and Game block 488, North San Francisco Bay (section of Bay north of the San Francisco-Oakland Bay Bridge, south of the Richmond-San Rafael Bridge, and east of the Golden Gate) summarizes party boats logs collected over a twenty year period and summarizes the block as follows:

"The North Bay (Block 488) has been good on occasion but is highly variable. In 1944 this block accounted for 23 percent of all party boat days, in 1948 a mere one percent...Fishing is best during the summer months and almost at a standstill from September through April..."(Skinner, 1962).

It is misleading to attribute alleged September 1987 declines in the Striped bass fishery in the Central Bay to purported high turbidity in light of the above twenty years of data and events of 1987. It is even less valid to link the reputed declines in selected fisheries to dredged material disposal because of the poor correlation between turbidity measurements and disposal activity. Finally, it is highly questionable that an analysis of turbidity levels can be based on an exiguous set of Secchi disc data. The Secchi disc is a white, circular disc that is lowered into the water until it just disappears from sight. The measurement of Secchi depth is very subjective, and due to a number of extraneous influences (surface waves, atmospheric variations such as haze and clouds, and visual acuity of the observer), is little more than a qualitative estimate of water clarity (Stern and Stickle, 1978). Additionally, Secchi depth readings taken monthly, cannot gauge temporal changes such as turbidity from tidal oscillation or wind wave resuspension and limited geographic data sets cannot detect systemic changes.

There is no scientific data that supports the recent allegations of turbidity induced reduction in fisheries or of the dredged material disposal connection with purported high Central Bay turbidities. Alternately, there has been a study of disposal operations that demonstrates the short duration, limited extent increase of suspended sediments and turbidity in the immediate vicinity of the Alcatraz disposal site attributable to dredged material disposal, and that documents the back and forth, oscillation of sediment laden waters from the shallow areas of the Bay and relatively clean waters from the near ocean, across the disposal site that dominates turbidity and suspended sediment levels at the site.

3.3.5 Water Quality. The water quality in the Central Bay region is dominated by oceanic conditions. Semi-diurnal tidal exchange through the Golden Gate causes mixing of Bay and Pacific Ocean water twice daily. This oceanic modulation is illustrated by the stability of Central Bay water characteristics. Comparison of water parameter data including salinity, temperature, pH, dissolved oxygen, suspended solids and transparency between 1960-1964 and 1970-1970 for Central Bay indicate little change in its chemical and physical makeup (USACE, 1976, Appendix C).

Observations in the field and laboratory indicate that upon addition of organic-sulfide rich dredged material to the water column, the dissolved oxygen immediately drops to a lower level, more so than with sandy sediments (USACE, 1976, Appendix C; Chen et al. 1976). This reduction in the dissolved oxygen concentrations is a function of the level of oxygen-consuming materials in the sediments. The levels in navigation channel sediments are not typically sufficient

APPENDIX IV

Excerpts from:

Technical Report DS-78-5
Synthesis of research results
Dredged Material Research Program
August 1978
U. S. Army Corps of Engineers
Waterways Experiment Station

PART III: SEDIMENT SUSPENSIONS

Review of Research

Fluid muds

30. Open-water disposal of hydraulically dredged fine-grained dredged material with high water content can create fluid mud. Very little background information is available concerning the occurrence and effects of fluid muds. There is no generally accepted definition of fluid mud; Nichols, Thompson, and Faas[6] arbitrarily assign concentrations of greater than 10 g/ℓ suspended sediment to the fluid mud category. The impact of this phenomenon has been researched in DMRP Work Unit 1D12 by Diaz and Boesch,[4] who measured species diversity and populations in a predredging and postdisposal survey at a number of stations in the James River, Virginia. After dredging and disposal of the material in the river, several stations were found to be covered with up to 1.6 m of fluid muds. Different species varied in their responses to the environmental perturbation caused by the fluid mud. Insect larvae were most sensitive, being extensively lost from the environment. The more resilient species, particularly the oligochaetes, were only slightly affected. Recolonization of the substrate provided by the consolidating fluid mud took only 3 months due to the general resilience of the indigenous species and the naturally unstable physical conditions of the ecosystem studied. This recovery was monitored in late summer and early fall months. Recolonization, reproduction, and growth probably vary throughout the year, and the results obtained cannot be accepted as universal for the system unless studies are carried out during different seasons.

Turbidity

31. Habitat disruption or burial of organisms can be considered local in effect. Short of burial in compacted or fluid sediments, living organisms are exposed to varying levels of turbidity in water induced by dredging and disposal. The term turbidity properly refers to optical properties of water having to do with light adsorption and scatter, but

turbidity is commonly attributed to suspended sediments alone. It is used in this sense to refer to a broad spectrum of conditions, varying from what can essentially be considered a highly fluid mud, having several grams of particulates per litre, to particle suspensions of a few milligrams per litre, which appear clear to the eye.

32. Most ecosystems experience varying natural ranges of turbidity, to which resident fauna and flora are adapted. Conceptualized impacts of excessive turbidity include interference with filter-feeding activities of invertebrates, irritation and clogging of the gills in fishes, and interference with plant photosynthesis due to shading effects. The effects of turbidity and suspended sediments on the aquatic environment are the subjects of Work Unit 1D01.[8] This literature review points out that while water-column turbidity created by dredging or disposal is seldom an ecological problem, it is often a very real aesthetic problem.

33. Peddicord et al.[9] investigated the effects of graded suspensions of bentonite clay on several sensitive species of fish and invertebrate organisms in the laboratory. The material chosen was a potential irritant due to small particle size and jagged particle surfaces and also was similar in mineralogy and particle size to naturally occurring San Francisco Bay sediments. Research was designed to determine lethal concentrations of sediments for test organisms for periods up to 240 hr. In addition to varying concentrations of suspended solids, tests were carried out at temperatures of 10° and 18°C and under conditions of reduced dissolved oxygen. Results showed that mussels, shrimp, a polychaete species, an amphipod species, shiner perch, striped bass, and an isopod species were tolerant of suspended sediment loads much in excess of the few hundred milligrams per litre generally expected[17] in the water column during major dredging operations in San Francisco Bay. Organisms normally associated with mud environments were more highly tolerant of sediment loading in the water than organisms not closely associated with muddy habitats. Suspended sediment tolerance generally decreases with increasing temperature or decreasing dissolved oxygen, and the combination of summer temperature and low dissolved oxygen is particularly adverse.

34. Studies in DMRP Work Unit 1D09[11] used harbor sediments chosen for physical similarity to bentonite, in order to assay for impacts due to chemical properties of the sediments in suspension. Measurements were carried out using sediments from relatively uncontaminated reaches of San Francisco Bay and compared with measurements on more highly contaminated Bay sediments. Organism responses did not differ greatly between pure mineral suspensions and uncontaminated natural sediments. In many cases, lethal effects were more marked with the contaminated sediments. The most sensitive species tested, striped bass, Morone saxatilis, survived only a few hours at levels of 0.5 g/ℓ of contaminated sediments, a condition probably representing a worst case of turbidity generation associated with a dredging operation. Such conditions are very unlikely to occur in the field, where motile organisms may escape turbidity maxima, and where water currents disperse sediments as they settle out of the water column.

35. Chemical analyses of several species for heavy metals, pesticides and polychlorinated biphenyls (PCB's) indicated uptake of several contaminants, but none were accumulated to levels which appeared to be sufficient to influence the survival of the exposed organisms.[11] Difficulties in interpreting such chemical data argued for developing assays which evaluate total toxicity of a sediment regardless of specific toxicants. Various concentrations of contaminated sediment suspensions from the Duwamish Waterway in Seattle, Washington, were used by LeGore and DesVoigne[25] in 96-hr static bioassays. They were unable to demonstrate lethal or sublethal toxic effects in threespine sticklebacks and coho salmon fry.

36. Studies on physical impact of sediment suspensions suggest, in summary, that there is probably no significant impact of uncontaminated or lightly contaminated suspended particulate matter on a broad variety of organisms. When exposed to suspended sediment levels of several grams per litre for periods of days, the impacts may be significant, particularly if the muds are chemically contaminated (see Prater and Anderson[26] and Part IV of this report).

37. Studies of mortality do not completely determine the potential biological impact of suspended particulate matter on organisms. Studies by Sherk, O'Connor and Neumann[27] have shown numerous sublethal alterations in tissue morphology and physiology of test species exposed to suspensions of particulate matter representative of levels of turbidity potentially induced by dredging and disposal. The changes recorded were natural reactions to turbidity stress and it is not known to what extent they influence the fitness of the organisms tested. Indeed, such reactions are probably naturally evolved physiological defense mechanisms to natural turbidity stress. Peddicord and McFarland[11] noted mortalities and deformities in commercial crabs (Cancer magister) after several days in 9 g/ℓ of contaminated harbor sediments. Mortality occurred only when the crabs underwent molting. Such laboratory results, although of interest in the general field of environmental research, might be predicted to occur as a result of dredging and disposal only when fluid mud made possible the exposure times and concentrations necessary to cause such effects.

Conclusions and Interpretations

38. Research results show that only concentrations of suspended sediment on the order of grams per litre maintained for days cause mortality in test animals and that contamination of the sediments increases the possibility of damage to organisms. The literature shows that in some cases dredging-induced turbidity may have effects on local community functions such as photosynthesis, but that these effects are transitory.[28] Coralline reefs might be permanently impacted by temporary high suspended sediment concentrations.

39. More serious than normal turbidity is the extreme sediment suspension near the bottom known as fluid mud or flocculent layer formation. Fluid muds present an extreme stress to bottom environments, as they are usually low in dissolved oxygen and persist for weeks or more before they are sufficiently consolidated to provide a solid foothold for bottom organisms. Fluid muds can have direct deleterious effects

on adult macrofauna, as well as indirect effects where they form a blanket over fish spawning grounds and bottom areas critical in the juvenile life stages of aquatic organisms.

Applications and Regulation

40. Sediment suspensions associated with dredging and disposal are unavoidable. Mitigating measures should be employed where there are reasonable indications that aesthetically or environmentally objectionable sediment suspensions are likely to result. These measures are best applied to each dredging and disposal operation by considering the general characteristics of the local environment during the development of the work plans. The synthesis report on Task 6C[7] discusses alternative operational practices which minimize turbidity at the expense of increasing the thickness of fluid mud layers which may be created, or vice versa. That is, pipeline configurations which minimize water-column turbidity tend to produce fluid mud layers of maximum thickness and minimum areal coverage, while configurations producing maximum turbidity tend to produce fluid mud layers of minimum thickness and maximum areal extent.

41. The Task 1D work units showed that water-column turbidity is generally an aesthetic rather than an ecological problem and fluid mud has the potential for definite environmental impact. Therefore, in most cases the basic environmental question in selecting pipeline discharge configurations is whether fluid mud depth should be maximized over a small area, or minimized but cover a larger area. Although such a decision must be made locally after considering the unique characteristics of each case, indications are that a thick mound covering a relatively small area might be desirable in many cases. This would impact the smallest portion of the benthic habitat and organisms.

42. Measures to minimize water-column turbidity should especially be taken where dredging is required in clear water areas, in particular coral reefs, where dredging could potentially create enough turbidity to kill the local reef system. Peddicord et al.[9] suggested that, in certain instances, dredging and disposal schedules could be made to coincide

APPENDIX V

Excerpts from:

Technical Report D-88-
Seasonal restrictions on dredging
and disposal operations (Feb. 1988)
Mark LaSalle
U. S. Army Corps of Engineers
Waterways Experiment Station

Effects of Dredging/Disposal Operations on Fishes

General comments

In the opinion of most fisheries biologists, the ultimate survival and strength of a given year class of fishes are largely determined by events which occur during egg and larval developmental stages. The relative success or failure of transitions through "critical" phases, such as at the time of first extrogenous feeding (i.e. deriving nutrition from planktonic prey rather than yolk reserves) or during metamorphosis from larval to juvenile form, can be influenced by extant environmental conditions. In comparison with juvenile and adult fishes, egg and larval stages seem generally more sensitive to stress of whatever origin (Rosenthal and Alderdice 1976). Also, because of their dependence on local hydrodynamic conditions for transport into and out of project areas and limited or nonexistent escape capabilities, egg and larval stages have been asserted to be more susceptible to the effects of unfavorable environmental conditions than motile juvenile and adult life history stages (Auld and Schubel, 1978). As a result, resource agency concerns over potential detrimental effects of dredging and disposal operations have focused on how environmental alterations affect egg and larval stages of marine and estuarine species. In addition, concerns regarding anadromous fishes involve: a) the supposition that turbidity fields constitute a barrier to migration of adult and juvenile fishes, and b) a concern about entrainment of eggs, larvae and juveniles by hydraulic dredges.

Two basic reproductive patterns occur among fishes, which are important considerations in relation to dredging operations. Many coastal or estuarine-dependent species produce pelagic (free floating, unattached or in gelatinous masses) eggs which, depending on their specific gravities, may occur at various levels in the water column from surface to bottom. Potential impacts on pelagic eggs may therefore be related to both spatial distributions of suspended sediments and duration of exposure to specific concentrations. Numerous other fish species produce demersal, non-buoyant eggs which may adhere to substrates at the spawning site and remain in place for short to extended periods prior to larval hatching and release. In addition to the problem of exposure duration, demersal eggs may be subject to burial by accumulated deposited sediments and/or entrainment by suction dredges.

Suspended sediments

The causal factors by which suspended sediments affect eggs and larval fishes are complex and little understood. Cairns (1968) provided a detailed summary of these factors which include: direct mechanical abrasion of egg and larval surficial membranes, reduction of available light in the water column, and sorption of contaminants carried by the sediments. Indirect effects of elevated suspended sediments may also be of consequence. Examples include interference with feeding behavior of visually oriented larvae, or delayed development resulting in asynchronous occurrences of larvae and their prey. At present, however, reliable information which either lends credence to or disputes these possibilities is not available. Very little is known of the importance of synergistic effects resulting from combinations of causal factors, or how physical features of the suspended particles such as size or angularity contribute to the effects observed. Stresses caused by chemical, physical, or biological conditions may be manifested in chronic rather than acute biological responses (Sherk 1972) further complicating the determination of detrimental effects.

Given the above complexities, it is difficult to draw clear conclusions from published studies on effects of suspended sediments on fish eggs and larvae. Because they do not produce accurate quantitative mortality estimates, information critical to assessing project impacts (Dovel 1970), field studies have yielded largely inconclusive results (e.g., Flemer et al. 1967). The dual constraints of logistics and the inability of field designs to isolate effects of experimental factors have relegated meaningful studies to the laboratory.

A meaningful summary of laboratory results is hindered by the lack of standardization in experimental protocol (e.g., selection of test concentrations, exposure durations, or suspensions of natural vs. processed sediments) and equipment used to maintain sediments in suspension. A review of studies evaluating suspended sediment effects on fish eggs and larvae is provided by Schubel, Williams, and Wise (1977). A number of pertinent references on this issue are products of investigations in the upper Chesapeake Bay system, particularly in connection with striped bass spawning grounds in the vicinity of the Chesapeake and Delaware Canal (Schubel and Wang 1973; Auld and Schubel 1978; Priest 1981; Morgan, Rasin, and Noe 1983). Table 6, although not a comprehensive compilation, represents a sample of the results of relevant investigations.

Laboratory studies have focused on three aspects of responses of fish eggs and larvae to elevated suspended concentrations. Effects have been demonstrated at various levels of suspended sediment concentrations in terms of a) percent successful hatch of eggs, b) time elapsed between fertilization and hatching, and c) percent survival of larvae after known durations of exposure. For example, Schubel, Williams, and Wise (1977) concluded that

Table 6

Results of Experimental Determinations of Effects of Suspended Sediments on Various Life History Stages of Fishes (Modified From Priest 1981)

Species	Stage	Sus. Sed. Conc. (mg/1)	Exposure Duration	Type of Sediment	Degree of Effect	Reference
Yellow Perch	eggs	500	not stated	natural	no significant effect on hatching success; some delay in time to hatching noted in samples at ~ 100 mg/1 (for all species)	Schubel and Wang (1973)
White Perch	"	"	"	"		
Striped Bass	"	"	"	"		
Alewife	"	"	"	"		
Striped Bass	"	"	"	"		
White Perch	"	50-5,250	"	" (fine)	no significant effect on hatching success; difinite delay in development at ≥ 1,500 mg/1	Morgan, Rasin, and Noe (1983)
Striped Bass	"	20-2,300	"	" (fine)	no significant effect on hatching success; definite delay in development at ≥ 1,300 mg/1	
Blueback Herring	"	50-5,000	not stated	"	no significant effect on hatching success at all test concs.	Auld and Schubel (1978)
Alewife	"	"	"	(fine)		
American Shad	"	"	"	"	"	
Yellow Perch	"	"	"	"	"	
White Perch	"	"	"	"	significant effect on hatching success at 1,000 mg/1, but not at lower concs.	
Striped Bass	"	"	"	"		
White Perch	larvae	1,626-5,380	24-48 hrs	"	15-49% mortality	Morgan, Rasin, and Noe (1983)
Striped Bass	"	1,557-5,210	"	"	20-57% mortality	
Yellow Perch	"	50-1,000	4 days	natural	survival significantly reduced at ≥ 500 mg/1	Auld and Schubel (1978)
Striped Bass	"	"	2-3 days	"	"	
Alewife	"	"	4 days	"	survival significantly reduced at ≥ 100 mg/1	

(Continued)

Table 6 (Concluded)

Species	Stage	Sus. Sed. Conc. (mg/1)	Exposure Duration	Type of Sediment	Degree of Effect	Reference
Spot	adult	13,090	24 hrs	artificial	LC_{10}	Sherk, O'Connor, and Neumann (1975)
"	"	68,750	"	natural	"	
Striped Killifish	"	23,770	"	artificial	"	
"	"	97,200	"	natural	"	
Mummichog	"	24,470	"	artificial	"	
Atlantic Silverside	"	580	"	"	"	
Bay Anchovy	"	2,310	"	"	"	
White Perch	"	9,970	"	natural	"	
"	"	3,050	"	artificial	"	
Striped Bass	subadult	4,000	21 days	natural	"	Peddicord and McFarland (1978) /Rogers (1969)
Cunner	adult	133,000	12 hrs	" (silt)	median tolerance limit	
"	"	100,000	24 hrs	"	"	
"	"	72,000	48 hrs	"	"	
Mummichog	"	300,000	24 hrs	"	no mortality	
Sheepshead minnow	"	"	"	"	< 30 percent mortality	
Cunner	"	100,000	"	"	median tolerance limit	
Stickleback	"	52,000	"	"	"	

striped bass eggs (semi-buoyant) can tolerate very high suspended sediment levels ($\geq$1,000 mg/l) for periods of many hours. There is some indication that larval stages may be more sensitive to elevated suspended sediment concentrations than are eggs of the same species. For example, Auld and Schubel (1978) reported that striped bass, yellow perch, and American shad larvae were less tolerant than eggs of these respective species at equivalent experimental suspended sediment concentrations. This trend may be attributable to loss of protection provided by the chorion (outer egg membrane) upon hatch of the larvae (Boehlert 1984). Additionally, many fish larvae are highly dependent on the epidermis as a respiratory surface. Adhesion of sediment particles to the epidermis may exert a smothering effect, although adhesion was noted by Boehlert (1984) only at concentrations above 1,000 mg/l, which is well above that found in dredging operations. Priest (1981) critically reviewed the literature pertaining to effects of total suspended solids on fish eggs. He concluded that for the four species considered, the only effect caused by the highest levels of suspended solids expected at a dredging operation was a slight delay in time to hatching. Lethal concentrations sufficient to produce a 50 percent mortality in laboratory experiments of larvae of the studied species were far in excess of levels characteristic of dredging operations.

Mechanical abrasion has been identified by Cairns (1968) as an important suspended sediment effect, yet little attention has been given to differential effects of sediments of different particle characteristics. The premise here is that delicate surficial membranes such as gills or the epidermis of larval fishes are particularly susceptible to abrasive damage. Several lines of evidence support this view. Rogers (1969) reported that processed sediments (highly angular incinerator residues) were much more toxic to experimental fishes than naturally weathered estuarine sediments. Coarse sediments were also shown to exert greater detrimental effects on fish survival rates than fine sediments of equal concentration. Boehlert (1984) compared the effects of natural, weathered estuarine sediments to those of sharp, angular Mt. St. Helens volcanic ash on yolk sac larvae of Pacific herring (Clupea harengus pallasi). Severe abrasion and puncture damage of larval epidermal membranes were observed via light and electron microscopy at volcanic ash concentrations of 1,000 mg/l, whereas comparable effects were evident for natural sediments only at concentrations at or above 4,000 mg/l (all larvae exposed to experimental concentrations for 24 hr). Although larvae did not show significant mortality at any experimental concentration (up to 8,000 mg/l), observed effects could represent sublethal stress which may contribute to later mortality.

Although juvenile forms might be suspected to be somewhat less tolerant of elevated suspended sediment concentrations than adults, the literature is sparse and incomplete on the direct physical effects of elevated suspended sediment concentrations on juvenile stages. Wallen (1951) exposed both adults and juveniles of a number of freshwater fish species to a wide range of silt-clay suspensions, all of which were well above concentrations found under typical dredging conditions. While results for juveniles were not presented separately, he concluded that, "direct effects of turbidity due to montmorillonite (hydrous aluminum silicate) type silt-clay is not a lethal condition and seldom produced observable symptoms in juvenile or adult fishes." Sherk et al. (1975), working with juvenile Atlantic menhaden determined that a lethal concentration producing 10% mortality (LC_{10} value) of

1,540 mg/1 was obtained after a 24 hour exposure to Fuller's earth (a combination of clay and silicious material). Jeane and Pine (1975) compared the effects of elevated turbidities at dredging sites characterized by suspension of fine versus coarse sediments through _in situ_ bioassays using juvenile chinook salmon. No significant mortality as observed among juveniles exposed tp fine sediment suspensions. Exposure to coarse sediments led to mortalities, but these were greater at stations away from the actual dredge site. This led the authors to suggest that toxic contaminants or some other artifact confounded the results.

Determination of direct physical effects of elevated suspended sediment concentrations on adult fishes lends itself to both field and laboratory examination. As a result, a considerable body of relevant literature exists (Table 6). Interpretation of this literature, however, is limited by the lack of standardization among experiments and differing experimental protocols. The most widely used approach employs basic bioassays in which fishes are exposed to incremental concentrations of suspended sediments until some lethal concentration is determined, generally that which produces a ten or fifty percent mortality (LC_{10} or LC_{50}) after a specified period (e.g., Sherk, O'Conner, and Neumann 1975; O'Conner, Neumann, and Sherk 1976; Peddicord and McFarland 1978). Another common approach is to measure threshold concentrations of suspended sediments above which a given species is adversely affected.

A widely referenced study on sixteen species of freshwater fishes (Wallen 1951) found lethal turbidity thresholds to be equal to or greater than 16,500 mg/1 following exposure durations of at least 3.5 days and up to 17 days.

Behavioral signs of stress for most species were not apparent at suspended sediment concentrations under 20,000 mg/l. Peddicord and McFarland (1978) determined that rainbow trout showed no significant mortality after 22 days at concentrations below 2,000 mg/l, and 95 percent survival occurred at concentrations approaching 4,300 mg/l. Although under less controlled conditions, other studies have exposed caged specimens to in situ levels of suspended and deposited sediments at actual dredge sites (Ingle 1952; Ritchie 1970) reporting little or no detrimental effects.

Several workers have employed histological preparations of gill tissues to demonstrate effects of elevated suspended sediments. Ritchie (1970) found no evidence of gill pathology in specimens of eleven estuarine fish species prior to and after exposure to dredging conditions. Sherk, O'Conner, and Neumann (1975), however, found disrupted gill tissue and increased mucus production in white perch exposed to sublethal suspended sediment concentrations (650 mg/l).

Conclusions and recommendations. Although the data on tolerances of egg and larval stages of fishes are currently inadequate to enable dredging management decisions to be made completely without risk, some generalizations can be made. Based on studies conducted to date (Table 6), eggs and larvae of estuarine dependent species appear to be very tolerant of elevated suspended sediment concentrations. In all probability eggs and larvae of fishes that utilize naturally turbid habitats as spawning and nursery grounds are adapted to and highly tolerant of elevated suspended sediment concentrations. Such conditions would not be expected to prevail at an operating dredge site for sufficient lengths of time to merit special concern, however, disposal operations may be of such duration to cause concern. These investigators suggested that a conservative "safe" level at which no impact would be anticipated would be 500 mg/l. A strong case can be presented that a 1,000 mg/l limit within a 500 m buffer zone surrounding a dredge would be acceptable with little or no risk.

Insufficient evidence is at hand upon which to base assertions that dredging operations involving uncontaminated sediments pose either significant or insignificant physical threats to juvenile fishes. Much additional work on determinations of juvenile stage tolerances to suspended sediments at concentrations comparable to actual dredging conditions needs to be performed. Based on what ~~little~~ information is available, however, we find no indication that dredging operations pose unacceptable risks to juveniles of target species if due consideration is given to project-specific variables such as scale and location. Restrictions based on seasonal aspects alone appear unjustifiable.

As was the case for eggs and larvae of estuarine fishes, a great deal of evidence supports the fact that adult and juvenile stages are moderately to extremely tolerant of elevated suspended sediment concentrations. Given that the levels of suspended sediment surrounding a dredging activity seldom exceed 1,000 mg/l, and that this level is confined to a relatively small area immediately surrounding the dredge site, there appears to be no justification to predict significant dredge-induced physical effects on adult estuarine fishes. Additionally, there is no justification to suspect that these highly mobile organisms would be subjected to dredge-produced elevated suspended sediment levels for sufficient periods of time to incur even sublethal adverse effects. Exceptions would involve dredging operations handling contaminated sediments, or sediments consisting primarily of highly angular particles.

Because the presence of unweathered, angular, or otherwise "anomalous" particles would in all probability lower threshold concentrations of suspended sediments required to elicit adverse effects, appropriate restrictions and restraints should be considered.

Data on average, minimum, and especially maximum concentrations that occur in a water body, such as presented by Schubel, Williams, and Wise (1977) for the Chesapeake and Delaware Canal, should be employed in dredging management decisions wherever these data are available. Comparison of the typical amounts of suspended sediments generated by dredging operations with known background levels would allow an informed estimate of the additive concentrations to be expected. Examination of the data presented in Table 6 would then provide a basis for relating expected suspended sediment concentrations in the field to objective estimates of fish tolerances.

APPENDIX VI

Excerpts from:

Main Report
Dredge Disposal Study
San Francisco Bay and Estuary
February 1977
U. S. Army Corps of Engineers
San Francisco District

SUSPENDED SOLIDS LOADING

During the periods when sediments are excavated or disposed, a fraction of the sediment is lost to the water column. To ascertain the extent of the adverse effects on San Francisco Bay species a laboratory study was conducted (Appendix G). This research evaluated the impact of the presence of fine mineral particles in the water column on Bay macrofauna. A unique facility providing large aquaria with open, once-through flow of water with desired suspended solids concentrations was employed. Two types of commercially processed clay minerals were used as the experimental material. Initial screening was performed with kaolin, a uniform, low-abrasion particle. Eighteen species of fish and invertebrates were subjected to elevated concentrations of this material to determine their sensitivity. The most sensitive organisms were selected for more intensive study using bentonite clay. This clay is significantly more abrasive or injurious than kaolin because of its size (smaller) and jagged, irregular surfaces. In addition the material showed a high similarity with the fine sediment dredged in north Bay both in size distribution and mineralogy. Subsequent studies with bay mud have shown that the effects of suspended bentonite and natural sediments under comparable conditions are approximately the same (13).

The bentonite experiments were conducted in a stepwise manner beginning with studies of the lethal effect of bentonite at two temperatures (10°C and 18°C). This was followed by a set of tests on the effects of suspended bentonite at two reduced dissolved oxygen levels (2 ppm and 5 ppm) while temperature was held constant. Finally a multi-factor experiment was conducted in which suspended bentonite, temperature and dissolved oxygen were varied simultaneously. Each experiment was run for approximately ten days.

Based on the results of the kaolin tests, six species were selected for the more intensive bentonite experiments. The organisms chosen were: the bay mussel, Mytilus edulis; the polychaete Neanthes succinea; sand shrimp, Crangon nigricauda; the amphipod Anisogammarus confervicolus; the shiner perch, Cymatogaster aggregata; and striped bass, Morone saxatilis. When A. confervicolus could not be found in sufficient numbers, it was replaced in the dissolved oxygen and multifactor experiments by the isopod Synidotea laticauda. The English sole, Parophrys vetulus, was included in the temperature experiment but was replaced in the remaining experiments by M. saxatilis. These species are widely distributed in the Bay and are of considerable ecological importance. Taxonomically none are related at the level of Order and most represent even more widely separated groups. The results of the multifactor experiments are shown in Figures 25 to 29 for all species except the polychaete N. succinea. The experiments with N. succinea showed no correlation of increasing suspended solids concentration with mortality. Control mortalities were fairly high, and while more deaths occurred in the test aquaria, they followed no discernible pattern.

The lethal concentration of suspended bentonite for 2-3 centimeter bay mussels, Mytilus edulis, was much lower than that for large mussels (10 cm). Survival was greater at saturated dissolved oxygen than at 5 ppm or 2 ppm, but little difference was apparent between the reduced levels. The short-term oxygen consumption of M. edulis in suspensions of bentonite was inversely correlated with concentration.

Under conditions of low temperature and saturated dissolved oxygen, survival of 3-5 centimeter sand shrimp, Crangon nigricauda, was high, even in high concentrations of suspended bentonite. Survival was lower at summer temperature, even at saturated oxygen levels. Decrease in dissolved oxygen from saturation to 5 ppm dramatically reduced the tolerance to suspended bentonite.

The isopod Synidotea laticauda suffered few mortalities in the experiments. The plots of survival versus exposure time showed no striking differences in effects of the various conditions except that survival was lowest at 44 grams per liter, 5 ppm dissolved oxygen and 18°C. An analysis of variance confirmed that none of the experimental variables had a statistically significant effect on the length of survival.

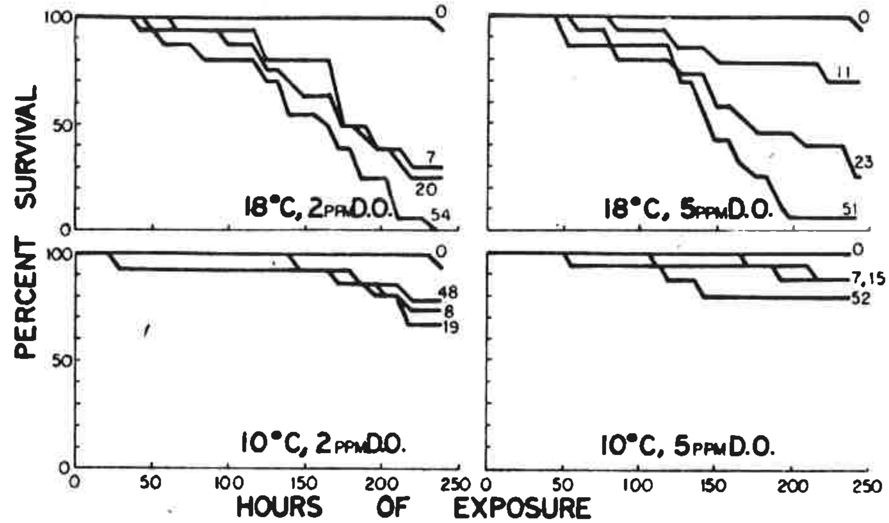


FIGURE 25 SURVIVAL - *MYTILUS EDULIS* WITH BENTONITE, GM/L

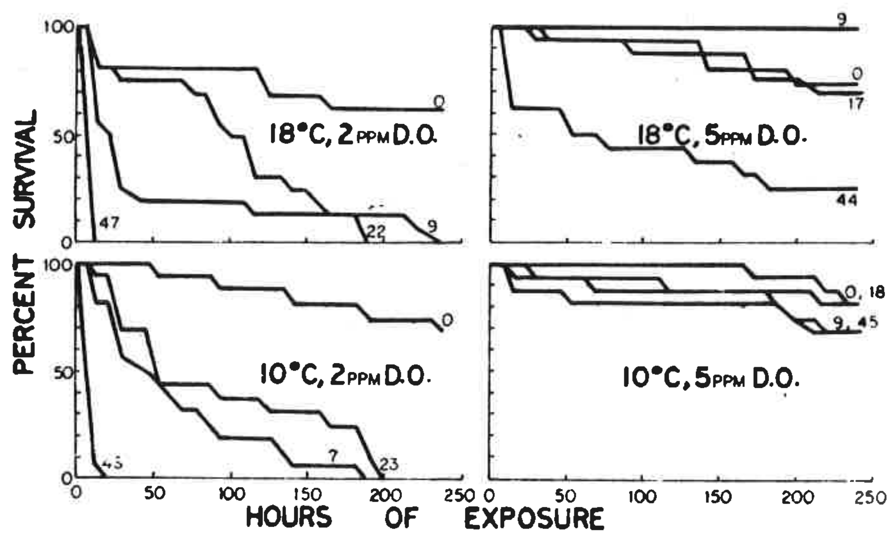


FIGURE 26 SURVIVAL - *CRANGON NIGRICAUDA* WITH BENTONITE, GM/L

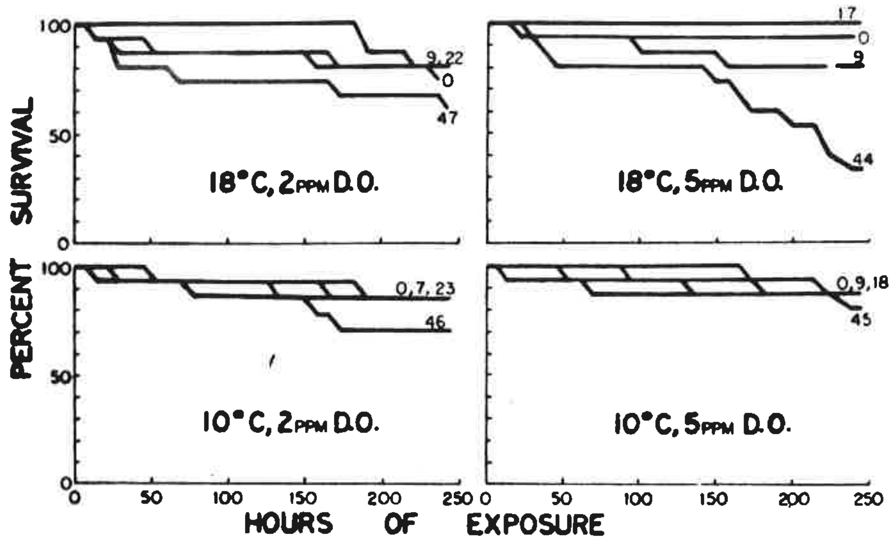


FIGURE 27 SURVIVAL - *SYNIDOTEA LATICAUDA* WITH BENTONITE, GM/L

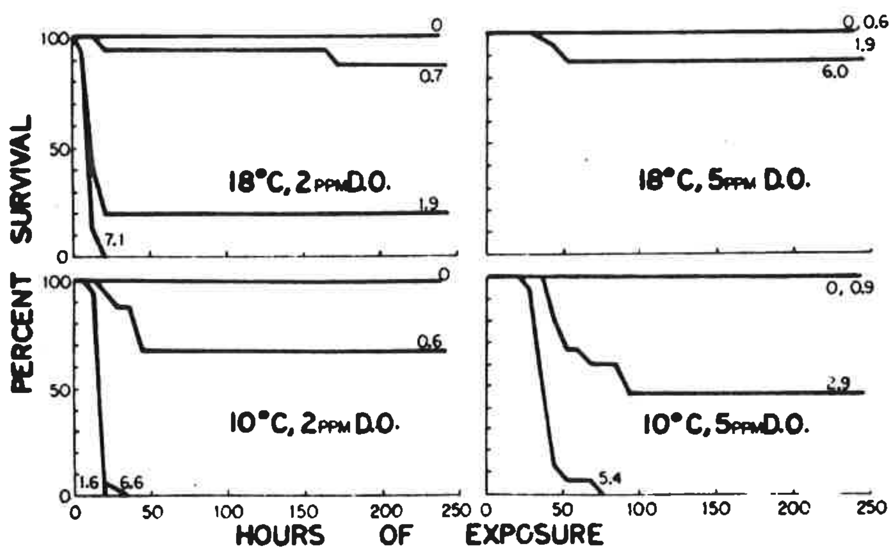


FIGURE 28 SURVIVAL - *MORONE SAXATILIS* WITH BENTONITE, GM/L

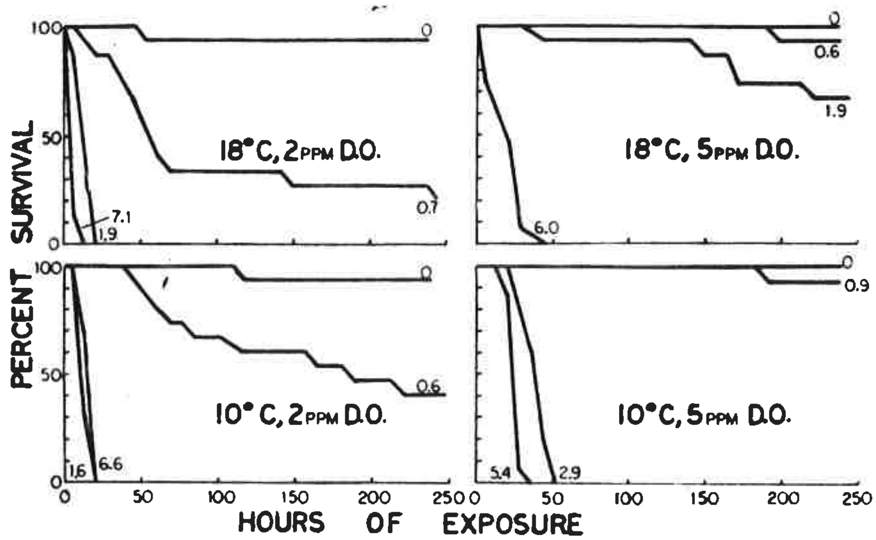


FIGURE 29 SURVIVAL - *CYMATOGASTER AGGREGATA* WITH BENTONITE, GM/L

The fingerling striped bass, *Morone saxatilis*, were killed at lower suspended bentonite concentrations than any of the invertebrates tested. Survival varied inversely with suspended bentonite concentration and directly with dissolved oxygen and temperature. These factors were shown to interact in a complex, non-additive manner to reduce survival.

The most sensitive of the test organisms to suspended bentonite were 6-8 centimeter shiner perch, *Cymatogaster aggregata*. As with *M. saxatilis*, increasing suspended bentonite concentration and decreasing dissolved oxygen and temperature combined in a complex manner to reduce survival. The slightly lower mortality of both species of fish at higher temperature was in contrast to all the invertebrates.

In general tolerance to suspended bentonite seemed to be correlated with the normal habitat of the organisms, but no phylogenetic correlations were apparent. No species living primarily in close association with mud bottoms was found to be sensitive. All sensitive test species were either invertebrates occurring predominantly on sandy bottoms or in fouling communities, or fish not intimately associated with the bottom. Many tolerant species also were found from these habitats.

Direct application of the laboratory results to dredging and disposal activities is not possible. During field operations, elevated suspended solids concentrations exist in the water column for periods of minutes, not days. The solids concentration is intermittently increased with the periodicity dependent on the project and the type of equipment, although a hydraulic cutterhead with aquatic disposal could approach the continuous loading condition generated in the laboratory. This type of operation is extremely uncommon in the Bay. More commonly, Bay operations are performed by the hopper dredge or clamshell dredge with barge disposal.

The hopper dredge disturbs a project area for approximately twenty minutes of a one hour cycle-time. During this time various areas are discontinuously subjected to resuspended sediments generated by draghead benthal disruption and overflow. At the bottom, solids concentrations of about two grams per liter are created for several minutes before redeposition occurs. In the upper water column loadings of approximately a half gram per liter are initially produced and elevated levels (0.2 gm/l) can exist for ten to twenty minutes. The remainder of the hour while the dredge is out of the area in transit to and from the disposal site, the suspended solids concentration is at or near ambient levels.

The suspended solids loading created by the clamshell dredge in a project area is in about the same range as that created by the hopper dredge. However since the dredge does not work with the same degree of mobility as the hopper dredge, the elevated solids levels will exist for longer durations at a specific locale. Depending on the rate of forward dredge movement, durations may vary from several hours to a day.

During release of a slurry from either a hopper dredge or barge, a bottom density flow can occur. The suspended solids concentration near the bottom may pulse at ten to twenty grams per liter for approximately fifteen minutes with the succeeding reduction to background levels requiring an additional fifteen minutes. The minimum time cycle for disposal is about one hour.

Assuming that these suspended solids concentrations are sustained continuously instead of intermittently and temperature and dissolved oxygen levels are at their most stressful condition for the respective test organism, indirect application of the laboratory study showed it would be several hours before the first death. Since these conditions are not maintained in the field, the data implies that these species, and by inference all the species tested, would be able to survive the suspended solids concentrations generated by Bay dredging and disposal activities, although individuals may be killed.

Although organisms may be able to survive the initial impacts of bottom disturbance and associated high suspended solids concentrations, there is a potential for secondary adverse phenomena following the direct interaction between the equipment and the sediment. In the channel, further biological stress may result if a fluff layer is created.

This layer may cause problems by subjecting non-motile species to long periods of high suspended solids and low dissolved oxygen. Filter feeders may have their gills clogged, and epibenthic species may fatigue from having to swim for long periods until consolidation of the sediment occurs. In the disposal area high density mud flows may follow impact of the released material with the bottom. These mud flows typically have suspended solids concentrations greater than ten grams per liter and extremely low dissolved oxygen levels. The period of time necessary for consolidation varies from hours to days, thus creating a period in which the environment would be extremely stressful for benthic and epibenthic organisms.

The potential of impacts from high suspended solids concentrations might be reduced by limiting operations to winter periods. The results of the laboratory study indicated that the biological effects of suspended solids would be less severe in winter than in summer (App. G). The typically higher dissolved oxygen levels would increase the survival ability of all species studied. Low temperatures would increase the suspended solids tolerance of the invertebrates, but slightly decrease that of the fish. However, this slight reduction would likely be offset by the increased tolerance at high dissolved oxygen levels. In winter there would also be fewer actively reproducing adults and fewer larvae and immature stages present, which may or may not be more sensitive to lower suspended solids concentrations than the adults studied during these laboratory experiments.

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January 6, 1991

Mr. Jim Peterson
Tidewater Sand and Gravel Co.
4501 Tidewater Ave.
Oakland, California 94601

Dear Mr. Peterson;

After our recent meeting with BCDC, Fish and Game, Corps of Engineers and others, it was felt that the colored water plume discharged by the mining barge had not been adequately described. Several questions were raised regarding the nature of the material making up the plume, and some proposed methods for its evaluation were discussed. Based upon the questions raised, it was decided to assess the material using the following plan.

1.) Collect water directly from the overflow and from another site unaffected by the discharge for use as a background control. A sample of the overflow water was delivered to MEC on December 27, 1990, and a sample of water was taken at the north end of Raccoon Strait during an ebb tide on the same day. These samples were immediately sent to Quality Assurance Laboratory in San Diego for analysis.

2.) It was requested that the water samples be analyzed for the following constituents: total suspended particulates(TSS); total organic carbon (TOC); aluminum (Al) and silicates (as Si) using standard methods.

3.) The suspended particulates were analyzed using unfiltered samples; while the TOC was analyzed on filtered as well as unfiltered samples. This was done to determine if the suspended load did in fact have elevated levels of organic material as suggested in the interagency meeting and it these levels differed from background levels.

4.) The analysis of aluminum and silica was carried out on the filtrate generated by the TOC analysis. Water was filtered at 0.45 µ to remove all but the smallest particulates, and the filtrate was then analyzed for aluminum and silica. If our argument was correct and the material in the plume was a fine clay particulate, this analysis should establish the presence or absence of clay, which is predominantly aluminum silicate.

The results of the water analysis are as follows:

Sample	TOC (unfilt)	TOC (filt)	TSS	Al	Si
Overflow	2.3	4.6	2050	3240	439
Ambient	4.4	3.5	215	396	246

Values for TOC and TSS are in mg/l; Al and Si are in mg/kg

The observed values for Total Organic Carbon are low for both the filtered and unfiltered samples and appear to suggest that no significant organic material is present in the overflow material when compared to ambient water.

The total suspended particulates were high in the overflow water as was expected, but were also higher than previously documented for the ambient water. The ambient water was taken however from a different location than in the previous test. The overflow water suspended particulates appear to be diluted quickly by approximately 100:1 close to the point of discharge if the previous sample TSS levels are accepted, and would only require a 10:1 dilution to match the background water levels for this study.

The analysis of aluminum and silica appear to substantiate the dominating presence of clay in the particulate load from the overflow water when compared to background water. As was originally proposed, the plume appears to composed of fine clay particles based upon this test. The particles are extremely fine and the currents in the area cause the plume to extend in the 20' to 40' zone.

I believe that this information as well as the previous data should provide the agencies with sufficient information concerning the composition of the plume and its potential impact on the area.

I have enjoyed working with you and your staff and have appreciated the effort everyone made to assist us in this test program. I look forward to the completion of this program. If you have any questions please feel free to call me.

Sincerely:

Kurt F. Kline Ph.D.
Vice-President
MEC Analytical Systems, Inc.