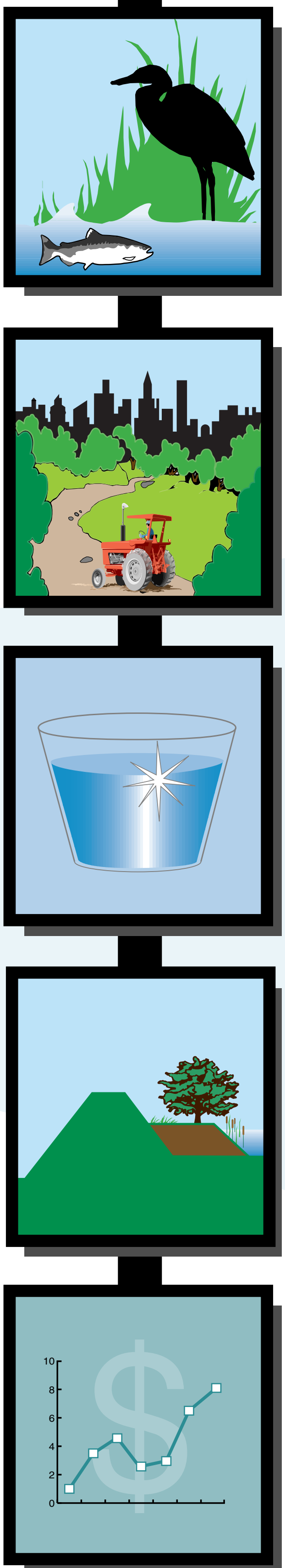
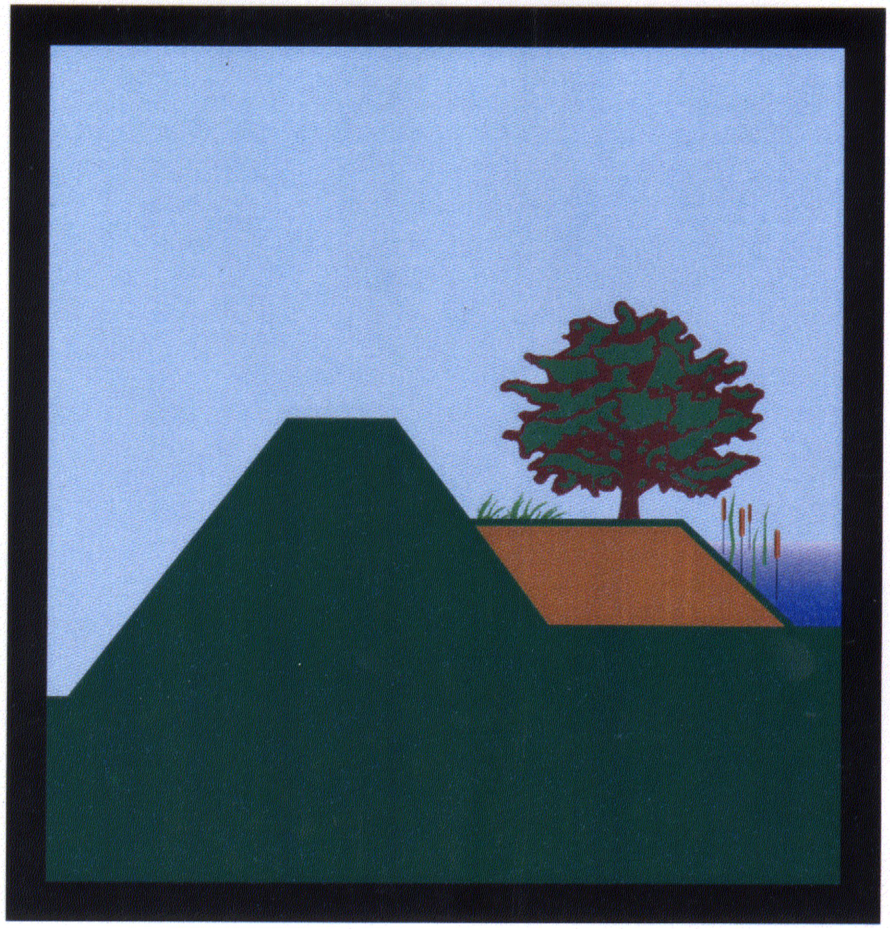


CALFED
BAY-DELTA
PROGRAM

Levee System Integrity Program Plan

Final Programmatic EIS/EIR Technical Appendix
July 2000



Levee System Integrity Program Plan
July 2000

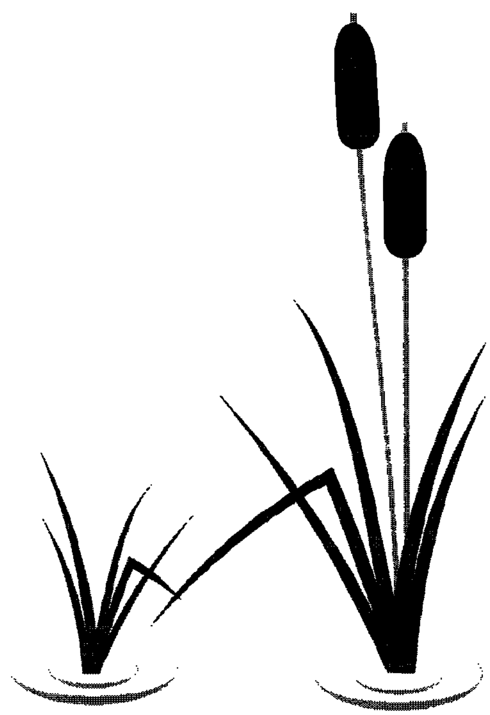
Reduce the risk to land use and associated economic activities, water supply, infrastructure, and ecosystem from catastrophic breaching of Delta levees

CALFED BAY-DELTA PROGRAM

FOREWORD

The Delta Levee System Integrity Program, like all components of the CALFED Bay-Delta Program (Program), is being developed and evaluated at a programmatic level. The Program is currently in what is referred to as Phase II, in which the CALFED agencies are developing a Preferred Program Alternative that will be subject to a comprehensive programmatic environmental review. This report describes both the long-term programmatic actions that are assessed in the June 1999 Draft Programmatic Environmental Impact Statement/ Environmental Impact Report (EIS/EIR), as well as certain more specific actions that may be carried out during implementation of the Program. The programmatic actions in a long-term program of this scope necessarily are described generally and without detailed site-specific information. More detailed information will be analyzed as the Program is refined in its next phase.

Implementation of Phase III is expected to begin in 2000, after the Programmatic EIS/EIR is finalized and adopted. Because of the size and complexity of the alternatives, the Program likely will be implemented over a period of 30 or more years. Program actions will be refined as implementation proceeds, initially focusing on the first 7 years (Stage 1). Subsequent site-specific proposals that involve potentially significant environmental impacts will require site-specific environmental review that tiers off the Programmatic EIS/EIR. Some actions, such as levee rehabilitation, also will be subject to permit approval from regulatory agencies.



EXECUTIVE SUMMARY

This Levee System Integrity Program Plan outlines a long-term strategy to reduce the risk to land use and associated economic activities, water supply, infrastructure, and ecosystem from catastrophic breaching of Delta levees. To achieve this and other CALFED objectives, in addition to meeting CALFED solution principles, Delta levees generally must remain in their current configuration.

The benefits of an improved Delta levee system include greater protection to Delta agricultural resources, municipalities, infrastructure, wildlife habitat, and water quality as well as navigation and conveyance benefits. The wide range of beneficiaries of the Delta Levee System Integrity Program (Levee Program) include Delta local agencies; landowners; farmers; boaters; wildlife; and operators of railroads, state highways, utilities, and water distribution facilities. Delta water users and exporters also benefit from increased protection to water quality. Federal interests benefit from improvements to conveyance, navigation, commerce, and the environment and from reduced flood damage.

> This document formulates an effective strategy to achieve the Levee System Integrity Program objective and is indeed necessary to facilitate all CALFED objectives. The Levee System Integrity Program Plan would be implemented over a period of 30 or more years and cost approximately $1.5 billion (1998 dollars).

Recognizing these potential benefits, state and local agencies formed a partnership to reconstruct Delta levees. This effort has resulted in a steady improvement in the Delta levee system. The success of the Delta in the 1997 and 1998 flood events illustrates the value of approximately $100 million of improvements made with Senate Bill (SB) 34 funds and over $10 million in emergency Public Law (PL) 84-99 work performed by the U.S. Army Corps of Engineers (Corps). These funds, in addition to local funds, have resulted in over $160 million in improvements to Delta levees since the SB 34 program's inception in 1988.

Over the past 10 years, staff from the California Department of Water Resources (DWR), California Department of Fish and Game (DFG), and many local agencies have worked together to successfully implement the existing levee program under SB 34 and Assembly Bill (AB) 360. In addition to managing over $100 million in levee funds, SB 34 and AB 360 program staff have developed and implemented three supply depots in the Delta for quick deployment of emergency materials, developed and began implementation of 32,000 lineal feet of new wildlife habitat, advanced subsidence control including new levee designs and monitoring techniques, coordinated beneficial reuse of dredged material projects, and continued to advance solutions to the numerous complexities related to flood control and habitat creation in the Delta's environmentally sensitive ecosystem. These efforts represent a positive first step in meeting the long-term CALFED objectives.

However, much more remains to be done, including:

- Improving levees to a higher standard,
- Developing adequate and reliable funding,
- Addressing permit and economic issues to enable expanded dredging and beneficial reuse of dredged material,
- Further improving existing emergency response capabilities,
- Reducing conflicts between levee maintenance and terrestrial and aquatic habitat resources on levees,
- Improving permit coordination,
- Incorporating subsidence control, and
- Continuing to quantify risks to levees and implementing appropriate risk management strategies.

CALFED provides a unique opportunity for federal, state, and local agencies to jointly address these needs. Existing Delta levee system problems and solution strategies proposed by CALFED are outlined below.

Many Delta levees do not provide a level of flood protection commensurate with the high value of beneficial uses they protect. As mandated by the California State Legislature and adopted by CALFED, the physical characteristics of the Delta should be preserved essentially in their present form. This is necessary to protect the beneficial uses of the Delta. The key to preserving the Delta's physical characteristics and to achieving CALFED's objectives is the levee system. Over the next 30 or more years, CALFED will invest billions of dollars in the Delta. The levees must protect this investment.

The existing levee program was intended to improve Delta levees up to the California/ Federal Emergency Management Agency (FEMA) Hazard Mitigation Plan (HMP) standard. As of January 1998, 36 of 62 (58%) Delta islands and tracts were in compliance with the HMP standard. This has resulted in a significant improvement in the ability to protect the beneficial uses of the Delta. However, as CALFED invests in the Delta, more is at risk. Therefore, CALFED has chosen to improve Delta levees to a higher level.

The CALFED Levee Program will institute a program that is cost-shared among the beneficial users, to reconstruct Delta levees to the Corps' PL 84-99 Delta Specific Standard. This action will increase levee reliability and reduce emergency repair costs. In addition, levee districts meeting this levee standard are eligible for federal emergency assistance under PL 84-99.

The CALFED Levee Program will institute a program that is cost-shared among the beneficial users, to reconstruct Delta levees to the Corps' PL 84-99 Delta Specific Standard.

The CALFED Levee Program also will continue the existing Special Flood Control Projects effort to provide additional flood protection for key Delta levees that protect public benefits of statewide significance.

Funding for levee work is insufficient, inconsistent, and often delayed. Under the existing State levee programs, local agencies finance projects in anticipation of reimbursements. The Delta Levees Maintenance Subventions Program (Subventions Program) annually distributes available state funds on an equal basis to all participants as approved by The Reclamation Board. Each fiscal year, districts are notified of the available funding but cannot be sure what their final reimbursement will be until all claims are received and processed. The Delta Levees Special Project Program (Special Projects Program) receives applications and enters into agreements with participants to fund specific projects. Projects eligible for funding must be in accordance with priorities approved by the California Water Commission. Once projects are deemed eligible, agreements are executed and districts can receive payments as work progresses. The lack of adequate and consistent appropriations in the Subventions and Special Projects Programs poses a challenge for local agencies to complete planned rehabilitation projects.

Under the existing State levee programs, local agencies finance projects in anticipation of reimbursements.

Many districts have experienced difficulty in rebounding from the long-term financial debt that was incurred while they waited for resolution of the 1980-1986 state and federal disaster assistance claims. The more recent 1995, 1997, and 1998 floods also have strained local financial resources. The overall financial health of these districts have significantly affected their ability to maintain their levee systems and limited their ability to upgrade their levees to a long-term levee standard. The Levee Program will secure federal cost sharing for Levee Program actions. The Corps' "Sacramento-San Joaquin Delta Special Study" could be used to establish a federal authority and subsequent federal funding. The Levee Program will establish consistent adequate funding for the Subventions and Special Projects Programs that will enable districts to plan and finance their work with greater certainty of reimbursement.

Dredging to increase channel capacity and to provide material for levee reconstruction, habitat restoration and creation, and subsidence control has been curtailed due to regulatory constraints, causing dredging equipment and trained manpower to leave the Delta. Regulatory agencies limit dredging in the Delta due to water quality and endangered species concerns. The dredged material can be relocated to suitable habitat development sites such as in-channel islands, waterside berms, or on-island areas, configured with different topographic features, and planted with selected vegetation to produce and/or improve diverse habitat types. Because insufficient data are available to quantify impacts and establish acceptable dredging criteria, the agencies regulate dredging activities more conservatively. Lack of a General Order for Waste Discharge Requirements (WDRs) complicates the permitting process.

Regulatory agencies limit dredging in the Delta due to water quality and endangered species concerns.

CALFED will work with the Regional Water Quality Control Board (RWQCB) and the Corps to develop a Regional Dredged Material Management Plan and General Order for WDRs.

Existing emergency response capabilities need to be continuously refined and funding increased. The existing emergency response system has significantly improved over the past several years. The State Office of Emergency Services (OES) continues to work with other emergency response organizations, including DWR, local Delta agencies, counties, FEMA, and the Corps to improve the emergency response system. However, the system is limited by insufficient dedicated Delta funding. Command and control procedures also need to be continuously refined using adaptive management principles.

CALFED plans to build on the existing emergency response system. CALFED's Emergency Response Subteam determined that an effective Delta levee emergency response program should be concentrated in seven areas:

- Funding;
- Response by state and federal agencies;
- Availability of flood fight resources;
- Integrated response;
- Clarification of regulatory procedures;
- Clarification of program eligibility, inspection, documentation, auditing, and reimbursement procedures; and
- Dispute resolution.

Levee reconstruction and maintenance sometimes conflicts with management of terrestrial and aquatic habitat resources on or around levees. In general, vegetation on levees results in more difficult levee maintenance. Stakeholders have voiced concern that activities to control levee and channel vegetation are often delayed because of potential impacts on endangered species habitat. Because levee districts often keep vegetation off of levee slopes to avoid the need to contend with endangered species requirements, potential opportunities for quality habitat are lost. Better strategies are needed to allow quality habitat to flourish on or around levees without hampering levee maintenance and construction.

In general, vegetation on levees results in more difficult levee maintenance.

CALFED will coordinate with state and local agencies to develop updated environmental baseline values. When reconstructing levees, mitigation and enhancement of existing habitat must be relocated outside the minimum section required for levee integrity (structural cross section) when possible. CALFED will work to establish a conservation strategy that encourages levee managers to allow critical habitat to grow on levees while giving assurances that levee managers will be able to maintain their levees.

Obtaining permits for levee work can be difficult and time consuming. Historically, obtaining permits for levee work has been difficult. In 1996, the California Department of Fish and Game (DFG) assumed a more active role in assisting levee districts with the regulatory process. This participation is a significant improvement and should continue. However, other regulatory agencies often lack sufficient resources to issue permits without delays. In addition, disagreements often exist between regulatory agencies with overlapping jurisdiction. A more efficient permit coordination process is needed.

Historically, obtaining permits for levee work has been difficult.

To ensure successful implementation of all CALFED programs, a coordinated permit process will be established. The process will anticipate the numerous permit requirements for actions approved as part of CALFED. Coordinated permitting will not relax permitting requirements but will include information sharing among regulatory agencies to coordinate the permitting process. The permit coordination process also would be designed to address broad issues in order to improve the efficiency of such processes as general and regional permits, mitigation banks, and habitat improvement areas.

Subsidence of portions of some Delta islands threatens levee integrity. Subsidence near some levees in the Delta may adversely affect levee integrity. The Subsidence Subteam considers that subsidence can be corrected and levee integrity assured. However, a grant program is recommended to develop new methods that are more effective and less intrusive to current land use.

Subsidence near some levees in the Delta may adversely affect levee integrity.

Seismic loading threatens Delta levees. Some CALFED stakeholders are concerned that earthquakes may pose a catastrophic threat to Delta levees, that seismic forces could cause multiple levee failures in a short time, and that such a catastrophe could overwhelm the current emergency response system.

CALFED agrees that earthquakes pose a potential threat. In addition, Delta levees are at risk from floods, seepage, subsidence, and other threats. To address this concern, CALFED has begun a risk assessment to quantify these risks and develop a risk management strategy.

Earthquakes pose a potential threat. In addition, Delta levees are at risk from floods, seepage, subsidence, and other threats.

Over the past year, the Seismic Risk Assessment Subteam quantified the seismic risk to Delta levees. CALFED is continuing its risk assessment of floods, seepage, subsidence, and other threats.

Several risk management options have been developed for inclusion in the CALFED Preferred Program Alternative. The available risk management options include, but are not limited to:

- Improving emergency response capabilities,
- Reducing the fragility of the levees,
- Improving through-Delta conveyance,
- Constructing an isolated facility,
- Developing storage south of the Delta,
- Releasing more water stored north of the Delta,
- Restoring tidal wetlands,
- Controlling and reversing island subsidence,
- Curtailing Delta diversions, and
- Continuing to monitor and analyze total risk.

The final Risk Management Plan may include a combination of these options.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

SECTION **PAGE**

TABLE OF CONTENTS (CONTINUED)

SECTION **PAGE**

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

CALFED staff sincerely appreciates the participation and significant contributions of all agency and stakeholders involved with the Levee System Integrity Program.

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GLOSSARY

The following terms are used in describing the Delta Levee System Integrity Program:

Action. A physical, operational, legal, or institutional change intended to maintain or achieve a desirable condition (target) of the Delta levee system.

Boil. A seepage exit point on the landside of the levee that is characterized by the rapid movement (boiling) of sand particles.

Channel islands. Small, unleveed land masses in Delta channels that typically provide quality wildlife habitat. Some islands are remnants of original Delta marsh lands, and others are the result of channel widening, levee construction, and dredged material disposal.

CMARP. Comprehensive Monitoring, Assessment, and Research Program.

Cut-off wall. An impermeable barrier constructed through the levee to interrupt (cut off) seepage through the levee or foundation. A slurry cut-off wall is a combination of soil, cement, and bentonite (a clay material) constructed inside a trench down the center of the levee. This trench must be sufficiently deep to cut off or reduce seepage through or under the levee.

Delta. The Sacramento-San Joaquin Delta as described in the California Water Code Section 12220.

Delta islands. Islands in the Sacramento-San Joaquin Delta protected by levees. The surface of the majority of islands are below sea level and provide many benefits, including agriculture, recreation, water quality, and habitat for fish and wildlife.

Drainage blanket. A layer of crushed or rounded gravel and coarse sand, usually encapsulated in a geotextile filter fabric, that is placed on the slope and landside toe of a levee to control seepage and piping. Drainage blankets usually are placed prior to the addition of a stability berm.

Erosion. Loss of levee material due to the effects of channel flows, tidal action, boat wakes, and wind-generated waves.

Ecosystem Restoration Program Plan. A comprehensive plan for restoration and management of the Bay-Delta ecosystem, including upstream tributaries and watersheds.

Freeboard. The vertical distance between the levee crest and the design water surface elevation.

Hydrostatic pressure. The pressure of water at a given depth resulting from the weight of the water above it.

Implementation objective. A description of what the program will strive to maintain or achieve for the Delta levee system that is not intended to change over the life of the program.

Levee crown. The highest, near-horizontal part of the levee between the water and landside slopes. The levee crest.

GLOSSARY (CONTINUED)

Liquefaction. A condition in which saturated silty sands or sandy silts have no shear strength. Liquefaction occurs often when loose soils are subjected to ground shaking during an earthquake.

Local agency. Any city, county, local agency, or other political subdivision of the state that is authorized to maintain project or non-project levees.

Non-project levee. A local flood control levee in the Delta that is not a project facility under the State Water Resources Law of 1945, as shown on page 38 of DWR's "Sacramento-San Joaquin Delta Atlas," dated 1993. (See Figure 3.)

Oxidation. The conversion of organic matter (such as peat) by bacteria to carbon dioxide. The conversion is directly related to aerobic soil bacteria.

Piping. Erosion of levee or foundation material at seepage exit points. The process carries away levee material, resulting in shorter seepage paths and accelerated internal erosion of the levee.

Primary zone. The Delta land and water area of primary state concern and statewide significance that is situated within the boundaries of the Delta but not within the urban limit line or sphere of influence line of any government's general plan or currently existing studies, as of January 1, 1992 (Delta Protection Act of 1992).

Project levee. A federal flood control levee, as shown on page 40 of DWR's "Sacramento-San Joaquin Delta Atlas," dated 1993, that is a project facility under the State Water Resources Law of 1945—if not less than a majority of the acreage under the jurisdiction of the local agency that maintains the levee is within the Primary zone of the Delta, as defined in the Public Resources Code (and above). (See Figure 2.)

Seepage. The movement of water through a porous material in response to a hydraulic gradient.

Seismicity. The frequency, intensity, and distribution of earthquake activity in an area.

Setback levee. A constructed embankment that is positioned some distance from the edge of the river or channel to prevent flooding and is not in contact with the original levee. Setback levees provide area for wildlife habitat to develop and for floodflow capacity.

Settlement. A downward movement of a surface as a result of underlying soil compression or consolidation caused by an increased load or the loss of underlying soil (foundation) support.

Slope protection. Various types of materials used to protect the levee surface and stream bank adjacent to the levee from erosion.

Stability berm. Earth fill usually placed against the levee landside slopes to act as a counterweight to prevent rotational slides.

Structural section. The minimum levee cross section required for levee integrity.

Subsidence. A decrease in ground surface elevation. Subsidence in the Delta is the result of a complex interaction of deep or large-scale processes and numerous shallow, near-surface causes. Subsidence is discussed in terms of levee subsidence or settlement and interior island subsidence.

Suisun Marsh islands. Islands in the Suisun Marsh protected by levees. The surface of the majority of islands are below sea level and provide many benefits, including recreation uses and habitat for fish and wildlife.

Target. A qualitative or quantitative statement of an implementation objective. Targets may vary as new information becomes available and according to Delta conveyance alternatives. Targets are to be set based on realistic expectations; must be balanced against other resource needs; and must be reasonable, affordable, cost effective, and practicably achievable.

Toe ditch. The open trench along the landside toe of the levee typically used to collect seepage water and distribute the water for agricultural purposes.

Toe drain. A trench along the landside toe of the levee designed to reduce saturation of the levee, control seepage, and help prevent boils. A toe drain is constructed by placing crushed rock in a trench at the landside toe of the levee. The rock is encapsulated in filter fabric that prevents levee and foundation soils from migrating into the rock.

LIST OF ACRONYMS

AB	Assembly Bill
Bay	San Francisco Bay
Base Levee Protection	Delta Levee Base Level Protection
BMPs	best management practices
Board	State Reclamation Board
CALFED	CALFED Bay-Delta Program
CMARP	Comprehensive Monitoring, Assessment, and Research Program
Corps	U.S. Army Corps of Engineers
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
Delta	Sacramento-San Joaquin legal Delta
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
EIS/EIR	Environmental Impact Statement/ Environmental Impact Report
Emergency Management Plan	Delta Levee Emergency Management and Response Plan
EOS	earth observation system
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Act
GIS	geographic information system
GPS	global position system
HMP	Hazard Mitigation Plan
LERRDs	lands, easements, rights of way, relocations, and disposal areas
Levee Program	Delta Levee System Integrity Program
LIG	Levee Implementation Group
LTMS	Long-Term Management Strategy
MOU	memorandum of understanding
OES	Office of Emergency Services
PL	Public Law
RWQCB	Regional Water Quality Control Board
SEMS	Standardized Emergency Management System
SB	Senate Bill
Special Projects	Special Delta Flood Protection Projects

LIST OF ACRONYMS (CONTINUED)

SRCD	Suisun Resource Conservation District
Subsidence Control	Delta Levee Subsidence Control Plan
Subventions Program	Delta Levee Maintenance Subventions Program
SWP	State Water Project
WDRs	Waste Discharge Requirements
ZOI	zone of influence

1. Introduction

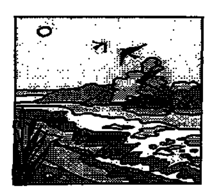
The Sacramento-San Joaquin Delta (Delta) is an area of regional and national importance. Delta levees are the most visible constructed features of the system. The levees are an integral part of the Delta landscape and are critical to preserving and improving the Delta's physical characteristics and processes, including definition of the Delta waterways and islands. To achieve objectives of the Delta Levee System Integrity Program (Levee Program) and other CALFED Bay-Delta Program (CALFED) objectives, in addition to meeting CALFED'S Solution Principles, the Delta levee system must remain generally in its current configuration.

Levees are critical to preserving and improving the Delta's physical characteristics and processes, including definition of the Delta waterways and islands. Many levees do not provide a level of flood protection commensurate with the high value of beneficial uses they protect.

Although the Delta levee system provides a broad array of benefits, many Delta levees do not provide a level of flood protection commensurate with the high value of beneficial uses they protect. The benefits of an improved Delta levee system include greater protection to Delta agricultural resources, municipalities, infrastructure, wildlife habitat, and water quality as well as navigation and conveyance benefits. The wide range of Levee Program beneficiaries include Delta local agencies; landowners; farmers; boaters; wildlife; and operators of railroads, state highways, utilities, and water distribution facilities. Delta water users and exporters also benefit from increased protection to water quality. The federal government benefits from improvements to navigation, commerce, conveyance, and the environment and from reduced flood damage.

The vulnerability of the Delta levee system to failure, especially during earthquakes or periods of high runoff, is a common concern. A levee failure in the central or western Delta would not only flood farmland and habitat but also could disrupt or interrupt water supply deliveries to urban and agricultural users, transportation, and the regional flow of goods and services. Even if the infra-structure and facilities survived the initial effects of inundation, long-term or permanent inundation would result in maintenance and repair being difficult, if not impossible. If a flooded island is not repaired and pumped out, the resulting body of open water may expose adjacent islands to increased wave action and additional subsurface seepage.

Of particular concern is the situation in which a levee fails in a dry or critically dry water year and one or more key western or central Delta island floods. Under these circumstances, inundation would allow salinity to intrude further upstream into the Delta. In-Delta and export water quality, along with the delicate balance of the brackish water habitat, would be negatively affected. The salinity intrusion could result in water supply interruption for in-Delta and export use by both urban and agricultural users, until the saltwater could be flushed from the Delta. In order to lower salinity in the Delta to acceptable levels and restore ecological balance, flushing flows would need to be released from upstream reservoirs. As



a result, water supplies in these reservoirs could be seriously depleted, and the ability to respond to other demands would be diminished.

The above hypothetical situation has a historical counterpart. In the early morning hours of a summer day in 1972, the southern levee protecting Andrus Island gave way. Rushing water poured through the initial break, quickly widened the opening to 300 feet, and eventually to 500 feet. Within 2 hours, Highway 12 was flooded and water began spilling over into the adjacent Brannan Island. During the next 2 days, Andrus and Brannan Islands were flooded with 164,000 acre-feet of water. Federal, state, and local emergency efforts failed to protect the town of Isleton. The water that flooded these islands was not winter floodwater from the major rivers that drain the watershed tributary to the Delta. Tributary inflow to the Delta at that time was mostly storage releases from federal and state reservoirs to supplement low summer unregulated flow. This controlled inflow was not sufficient to supply the sudden draft placed on the Delta's water supply by the levee break. Saline waters rushed in from Suisun Bay to meet the remaining draft, temporarily interrupting the controlled outflow that had been forming a hydraulic barrier to protect the Delta against salinity intrusion. Both the State Water Project (SWP) and federal Central Valley Project (CVP) immediately reduced exports and increased storage releases to restore the hydraulic barrier. In the western Delta, salinity began an immediate downward trend. But in the central and southern Delta, the flushing effect was less effective, and the saltwater needed to be removed by local and export pumping, causing adverse effects on agricultural and domestic water supplies. (California Department of Water Resources 1982, Bulle-tin 192-82.)

Local reclamation districts are concerned with the cost of maintaining and improving the levee and channel system. A complex array of agencies with planning, regulatory, and permitting authorities over levees makes rehabilitation and maintenance efforts difficult. Regulatory measures that protect endangered species or critical habitat sometimes conflict with and prolong levee rehabilitation and maintenance work, which can further increase the vulnerability of the system. CALFED's role is to reduce the existing conflicts between local agencies responsible for maintenance and regulatory agencies.

Regulatory measures that protect endangered species or critical habitat sometimes conflict with and prolong levee rehabilitation and maintenance work, which can further increase the vulnerability of the system.

1.1 DELTA AND LEVEE BACKGROUND INFORMATION

Prior to human intervention, the Delta consisted of low-lying vegetated wetlands separated by a complex of rivers, channels, and sloughs. Along the waterways were slightly higher over-bank deposits of coarser sediments, commonly referred to as "natural levees."

The Delta was reclaimed in two phases. During the first phase (1850-1880), reclamation projects were small-scale efforts using manpower and horsepower to build levees on top of existing natural levees. In the second phase (from 1880 to the early 1900s), levee building was more aggressive and was accomplished with powerful mechanical equipment. Currently, the Delta includes over 700,000 acres, with 700 miles of meandering waterways and approximately 1,100 miles of levees.

Currently, the Delta includes over 700,000 acres, with 700 miles of meandering waterways and approximately 1,100 miles of levees.

In the early 1900s, the Reclamation Board was created and Congress authorized the CVP. The State Water Resources Development Bond Act was approved in 1960, launching the SWP. SWP facilities include levees, control structures, channel improvements, and appurtenant facilities in the Delta that are used for water conservation, water supply, cross-

Delta water transfers, and flood and salinity controls. Also in 1960, the Sacramento River Flood Control Project was completed by the U.S. Army Corps of Engineers (Corps). This project incorporated and improved flood control for a portion of the Delta. In the 1970s, the California Legislature recognized that the Delta levee system benefits many segments and interests of the public and approved a plan to preserve the Delta levee system. In 1986, the CVP-SWP Coordinated Operation Agreement was initiated and the California Supreme Court confirmed the State Water Resources Control Board's authority and discretion over water rights and water quality issues in the Bay-Delta system, including jurisdiction over the federal CVP.

Since the late 1980s, a flurry of activity has shaped the future of the Delta. The Delta Flood Protection Act of 1988; Environmental Mitigation and Protection Requirements; the Delta Protection Act of 1992; the Central Valley Project Improvement Act (CVPIA); and the Safe, Clean, Reliable Water Supply Act were enacted. In 1994-1995, state and federal agencies entered into the historic Bay-Delta Accord, and the CALFED Bay-Delta Program "to fix the Delta" was initiated.

Table 1 (at the end of the report) provides a chronological summary of events important to the Delta.

1.2 CURRENT DEFICIENCIES - PROBLEM STATEMENTS

The State Reclamation Board (Board) and local agencies have been in partnership to reconstruct Delta levees for over 25 years. Although significant progress has been made in improving Delta levee integrity, several problems remain. If CALFED is to achieve its objectives, these problems must be addressed. This Levee System Integrity Program Plan develops strategies to address the following problems.

Although significant progress has been made in improving Delta levee integrity, several problems remain. If CALFED is to achieve its objectives, these problems must be addressed.

Many Delta levees do not provide a level of flood protection commensurate with the high value of beneficial uses they protect. The existing levee program was intended to improve Delta levees up to the California/Federal Emergency Management Agency (FEMA) Hazard Mitigation Plan (HMP) standard. As of January 1998, 36 of 62 (58%) Delta islands and tracts were in compliance with the HMP standard. Because the HMP standard will not assure success of CALFED objectives, a higher standard is needed.

Funding for levee work is insufficient, inconsistent, and often delayed. Under existing programs, local agencies must finance projects up-front and submit claims for reimbursement. Processing time for claims varies greatly as do reimbursement rates. Because funding is inconsistent, project planning by local agencies is difficult. The time lag from work completion to reimbursement poses financial difficulties for local agencies without the financial resources to provide up-front funds for an extended period. Even with reimbursements, many local districts cannot afford their share of costs under the current cost-sharing arrangements for levee work, without the additional financial burden of proposed levee upgrades.

Dredging to increase channel capacity and to provide material for levee reconstruction and subsidence control has been curtailed due to regulatory constraints, causing dredging equipment and trained manpower to leave the Delta. Regulatory agencies limit dredging in the Delta due to water quality and endangered species concerns. Because insufficient data are available to quantify impacts and establish acceptable dredging criteria, agencies regulate dredging activities more conservatively.

Existing emergency response capabilities need to be continuously refined and funding needs to be increased. The existing emergency response system has significantly improved over the past several years; however, the system is limited by insufficient dedicated Delta funding. In addition, improvements in command and control need to be continuously refined.

Levee reconstruction and maintenance sometimes conflicts with management of terrestrial and aquatic habitat resources on or around levees. In general, vegetation on levees results in levee maintenance being more difficult. Stakeholders have voiced concern that activities to control levee and channel vegetation sometimes are delayed because of potential impacts on endangered species habitat. Because local agencies often keep vegetation off of levee slopes to avoid the need to contend with endangered species requirements, potential opportunities for quality habitat are lost. Better strategies are needed to allow quality habitat to flourish on or around levees without hampering levee maintenance and construction.

Obtaining permits for levee work can be difficult and time consuming. Historically, obtaining permits for levee work has been difficult. In 1996, the California Department of Fish and Game (DFG) assumed a more active role in assisting local agencies with the regulatory process. This participation is a significant improvement and should continue. However, other regulatory agencies often lack sufficient resources to issue permits without delays. In addition, disagreements exist between regulatory agencies with overlapping jurisdiction. A more efficient permit coordination process is needed.

Subsidence of portions of some Delta islands threatens levee integrity. Subsidence near some levees in the Delta may adversely affect levee integrity.

Seismic loading threatens Delta levees. Earthquakes pose a catastrophic threat to Delta levees. Seismic forces can cause multiple levee failures in a short period. Such a catastrophe could overwhelm the current emergency response system.

1.3 VISION

The following is a vision of the future that represents successful implementation of the Levee Program along with other CALFED programs.

System-wide levee stability is improved because all levees meet or exceed the Corps' Public Law (PL) 84-99 Delta Specific Standard. The risk of catastrophic failure is significantly lower. The levees are well maintained and regularly inspected. A reliable and steady stream of funding allows for consistent construction and maintenance of Delta levees, creating an industry in the Delta. The increased availability of materials and equipment also aids emergency response capabilities.

A reliable and steady stream of funding allows for consistent construction and maintenance of Delta levees, creating an industry in the Delta. The increased availability of materials and equipment also aids emergency response capabilities.

There is little or no conflict with the ecosystem rehabilitation efforts, and for years there has been a net gain in critical habitat. Once threatened species now thrive, partially in response to levee-associated habitat improvements. Permitting new projects is obtained in weeks because of agency coordination and the availability of a Delta-wide comprehensive geographic information system (GIS) inventory, which facilitates evaluation of project-related impacts. Even with the addition of waterside habitats, the flood-carrying capacity of the system is better and hydraulic impacts upstream and downstream of the Delta have been beneficial.

Islands of particular state or national importance have been provided with increased flood protection and improvements to their seismic survivability resistance. The ongoing seismic and subsidence risk evaluations and monitoring continually provide feedback that improves levee design and reduces system vulnerability. Emergency response capabilities were improved early in the implementation phase and have proven their worth. The now rare isolated levee breach is closed in weeks, and the risk to water supply and water quality from multiple earthquake-induced failures has been reduced significantly as a result of seismic upgrades and improvements to emergency response capabilities.

1.4 MISSION

The CALFED mission is to develop a long-term comprehensive plan that will restore ecosystem health and improve water management for beneficial uses of the Bay-Delta system. CALFED fundamentally differs from previous efforts because the program seeks to concurrently address ecosystem restoration, water quality, water supply reliability, and levee and channel integrity. The geographic scope of the CALFED problem area consists of the legal Delta, Suisun Bay (extending to the Carquinez Strait), and the Suisun Marsh. The geographic scope of the CALFED solution area includes a much broader area that extends upstream and downstream of the Bay-Delta. The foundation of every CALFED alternative includes six common programs: Ecosystem Restoration, Water Use Efficiency, Water Quality, Water Transfers, Watershed Management, and Levee System Integrity. CALFED also includes two variable programs, Storage and Conveyance. Each of the individual common program elements is a major program on its own, and each element represents a significant investment in and improvement to the Bay-Delta system.

CALFED fundamentally differs from previous efforts because the program seeks to concurrently address ecosystem restoration, water quality, water supply reliability, and levee and channel integrity.

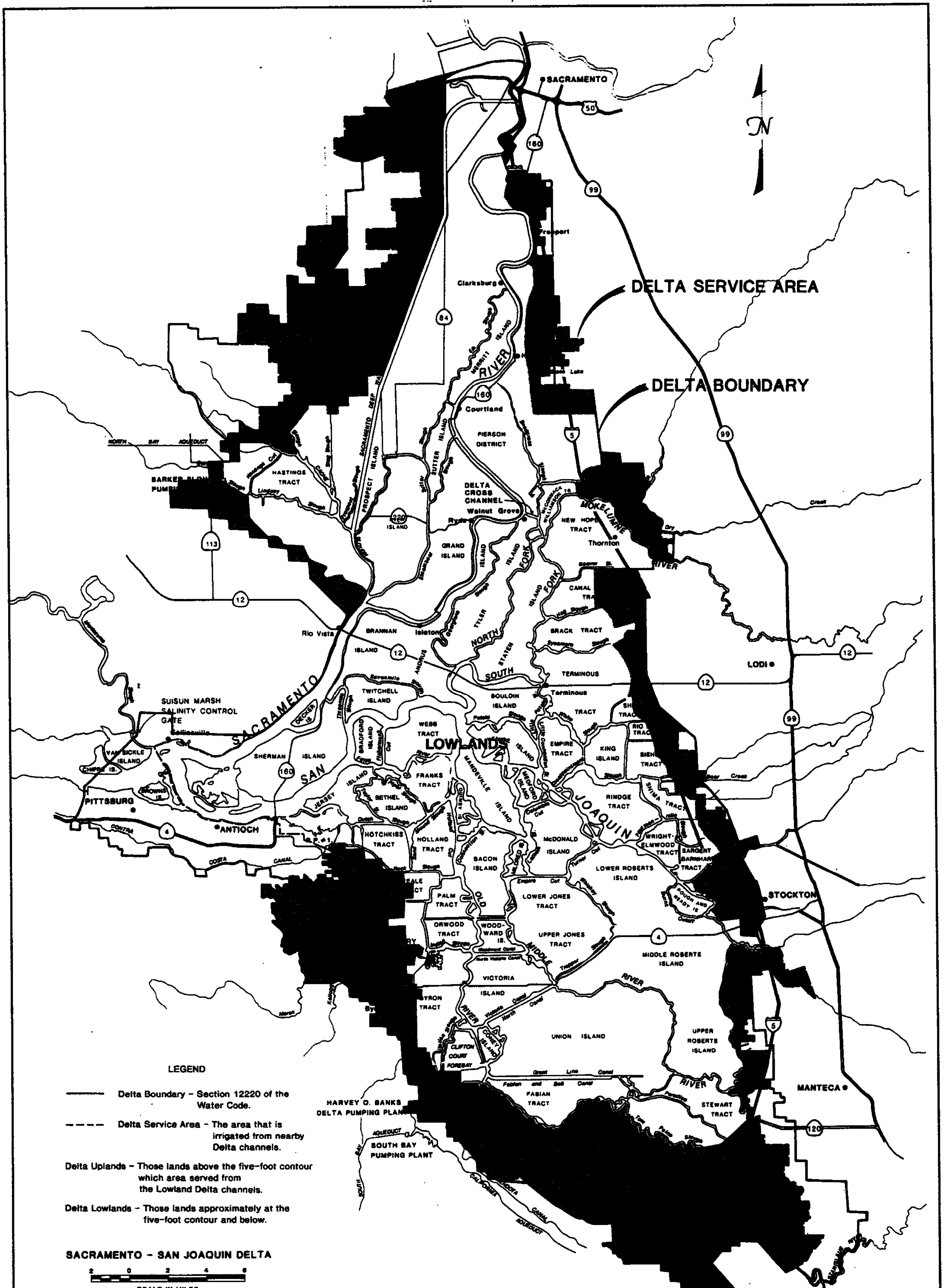
The overall Levee Program objective is to reduce the risk to land use and associated economic activities, water supply, infrastructure, and ecosystem from catastrophic breaching of Delta levees. Levee Program actions focus primarily on the legal Delta as defined in the Water Code and illustrated in Figure 1. The goal is to provide long-term protection for multiple Delta resources by maintaining and improving the integrity of the Delta levee system. In addition, the Levee Program aims to integrate ecosystem restoration and Delta conveyance actions with levee improvement activities. Improvements in the reliability of water quality will be a natural by-product of the program. Levee Program goals will be achieved through implementation of this Levee System Integrity Program Plan.

The goal is to provide long-term protection for multiple Delta resources by maintaining and improving the integrity of the Delta levee system. The Levee Program aims to integrate ecosystem restoration and Delta conveyance actions with levee improvement activities.

The specific elements of the Levee Program include the:

- Delta Levee Base Level Protection Plan,
- Delta Levee Special Improvement Projects,
- Delta Levee Subsidence Control Plan,
- Delta Levee Emergency Management and Response Plan, and
- Delta Levee Risk Assessment and Risk Management Strategy.

Figure 1



The Legal Delta

2. Program Elements

2.1 DELTA LEVEE BASE LEVEL PROTECTION PLAN

The goal of the Delta Levee Base Level Protection Plan (Base Level Protection) element is to improve all Delta levees to a uniform base level standard. This element is being developed and evaluated at a programmatic level. More focused analysis and documentation of specific targets and actions will occur in subsequent efforts.

The goal of the Delta Levee Base Level Protection Plan element is to improve all Delta levees to a uniform base level standard.

2.1.1 INTRODUCTION

The Delta Levee Maintenance Subventions Program was established in 1973 and amended by the Delta Flood Protection Act of 1988. The Delta Flood Protection Fund was created to provide for local assistance under the Delta Levee Maintenance Subventions Program (Subventions Program), and for Special Delta Flood Protection Projects (Special Projects). Currently, the Subventions Program and Special Projects are being carried forward under funding provided by the Safe, Clean, Reliable Water Supply Act, Division 24 of the California Water Code. Delta levee maintenance is described in the California Water Code, Division 6, Part 9 - Delta Levee Maintenance (commencing with Section 12980). (Refer to Appendix C for pertinent excerpts from the California Water Code.) It is the intent of the California Legislature that, to the extent allowed by existing requirements, levee rehabilitation will be consistent with CALFED's Delta ecosystem restoration strategy. (Refer to subsequent discussion of "Funding.")

Table 2 lists implementation objectives, targets, and actions associated with the Base Level Protection element.

2.1.2 SCOPE

Approximately 385 miles of project levees and 715 miles of non-project levees are located in the legal Delta (Figures 2 and 3). "Project levees" are levees that were improved or adopted as part of federal flood control projects. Most of the project levees are along the

Table 2. Implementation Objectives, Targets, and Actions Associated with the Delta Levee Base Level Protection Plan

Implementation Objective	Target	Action
Uniformly improve Delta levees	Improve Delta levee system stability to meet PL 84-99 criteria	Modify levee cross sections by raising levee height, widening levee crown, flattening levee slopes, or constructing stability berms
	Maintain Delta levees to the PL 84-99 standard	Develop a long-term maintenance plan
Establish a stable funding source	Provide necessary funding to improve and then maintain Delta levees to the PL 84-99 standard for the CALFED planning horizon	Prepare cost estimates
		Identify beneficiaries to provide equitable distribution of costs
		Develop funding sources
Coordinate the permitting process	Reduce the time required to acquire all necessary permits	Develop a uniform process to coordinate and approve all permits
		Provide regional mitigation banking
		Coordinate with the Ecosystem Restoration Program to provide an environmental enhancement component

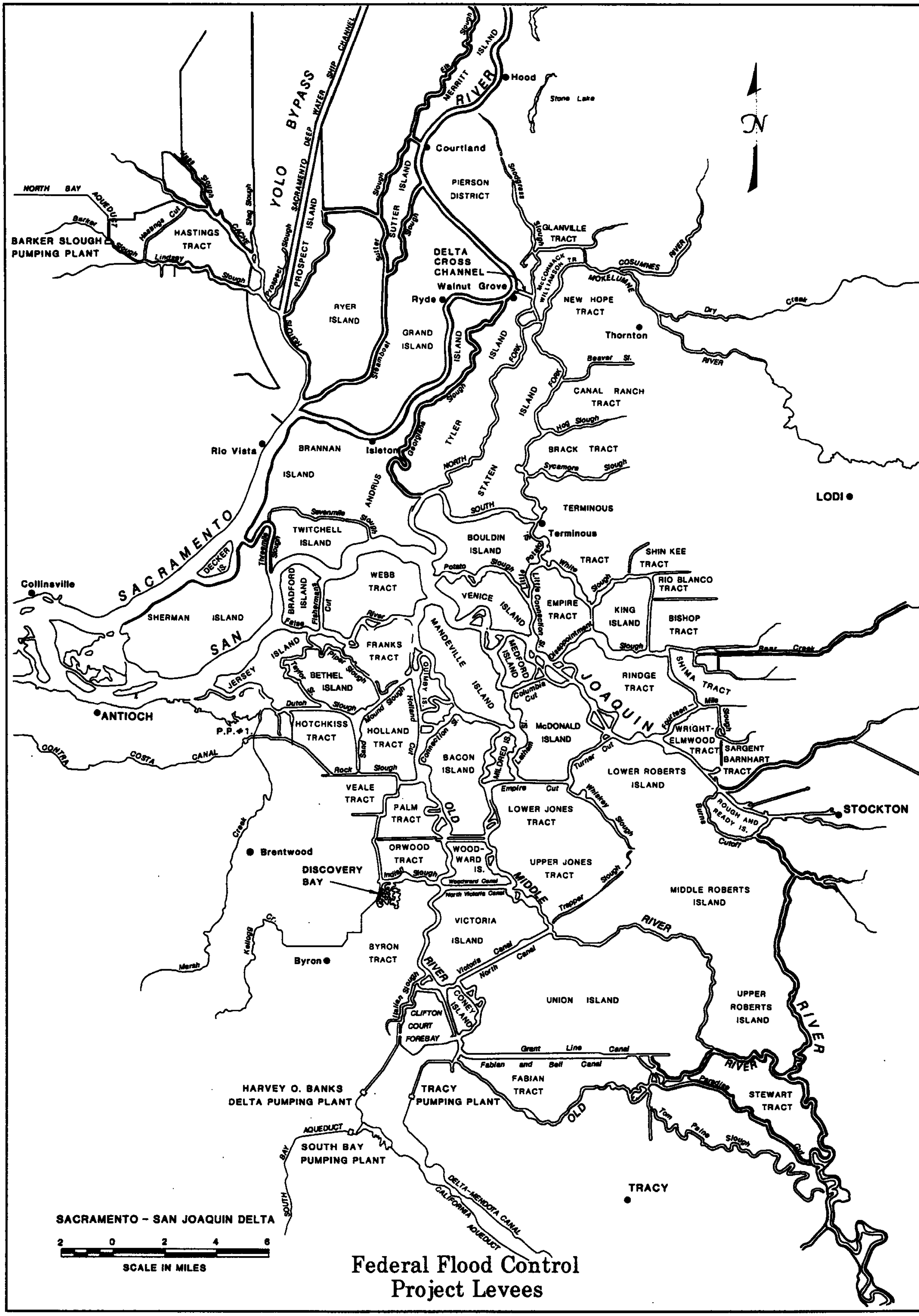
Sacramento and San Joaquin Rivers in the upper reaches of the Delta. (The California Water Code definition of "Project Levees" is provided in the glossary.) "Non-project levees" are all levees that are not project levees.

It is assumed that most of the project levees meet or exceed the PL 84-99 standard. The current (1998) cost estimate indicates that approximately 520 miles of levee will need to be rehabilitated and brought up to PL 84-99 standards. All 1,100 miles of levees should be routinely inspected and maintained. Table 3 (at the end of this report) includes an inventory of Delta levees that identifies project and non-project levees, responsible reclamation districts, and the existing levees considered up to the PL 84-99 standard.

Base level protection will be achieved through an extension of the existing Subventions Program defined in the California Water Code, commencing with Section 12980 (refer to Appendix C), except that CALFED recommends selection of the Corps' PL 84-99 Delta Specific Standard as the minimum base level standard. The Delta-specific criteria are contained in the Corps' document titled, "Guidelines For Rehabilitation of Non-Federal Levees in the Sacramento-San Joaquin Legal Delta" (1988). Constructing levees to the PL 84-99 criteria is a prerequisite for, but not a guarantee of, postflood disaster assistance. (Appendix A contains information on the PL 84-99 Delta Specific Standard.)

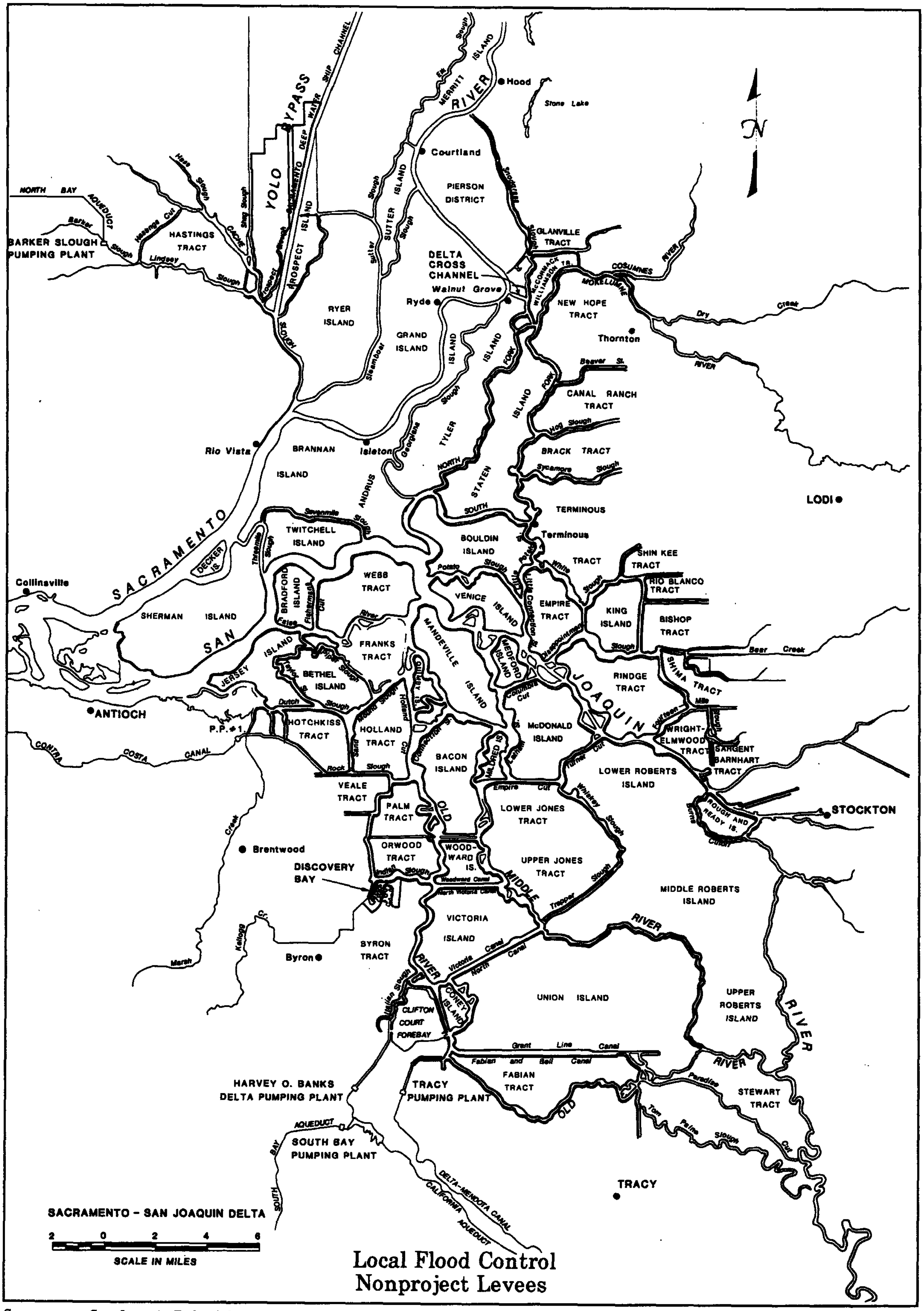
Figure 4 compares the PL 84-99 Delta Specific Standard to other levee standards.

Figure 2



SACRAMENTO - SAN JOAQUIN DELTA
SCALE IN MILES
Federal Flood Control Project Levees

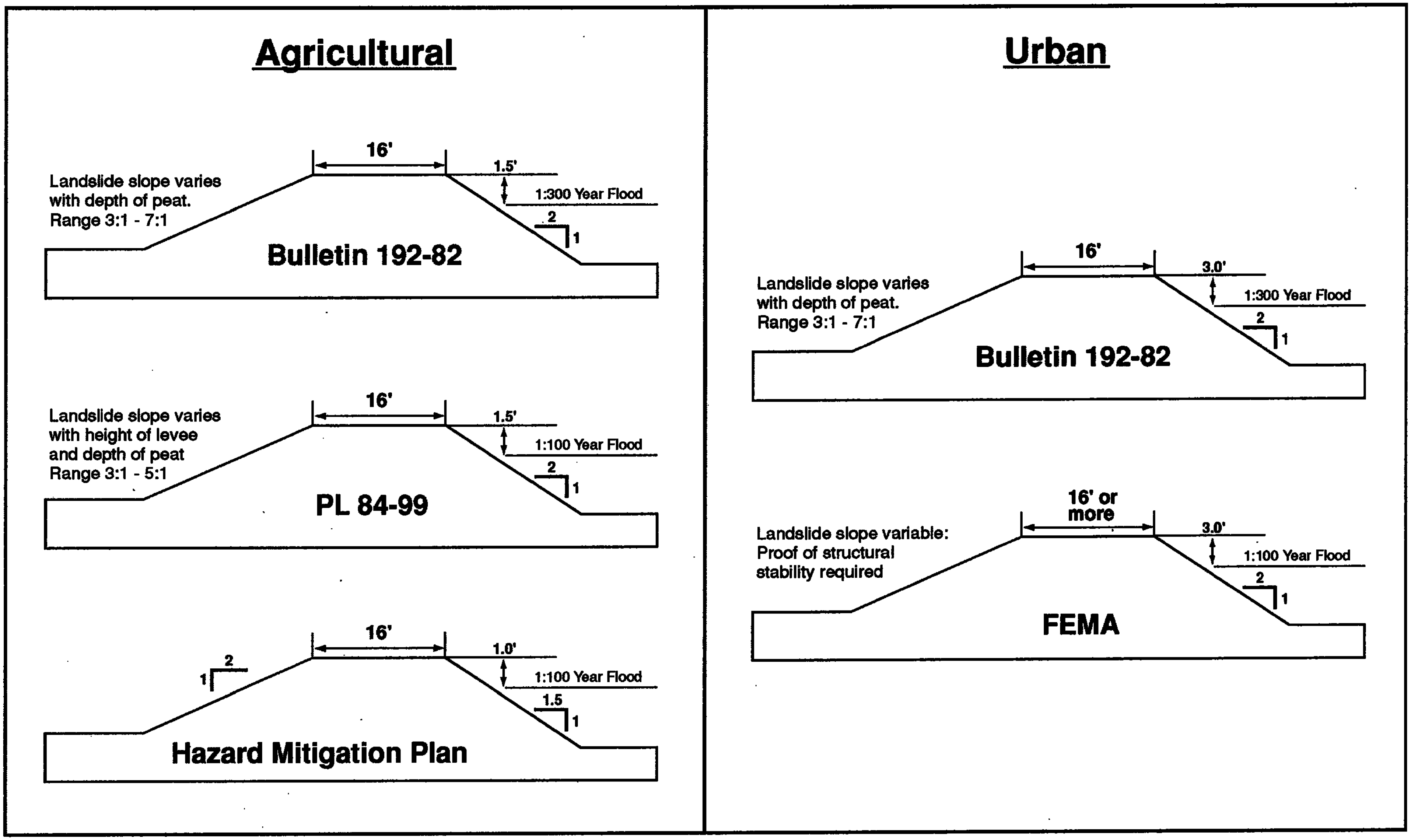
Figure 3



Local Flood Control Nonproject Levees

Figure 4

Levee Standards



2.1.3 CRITERIA AND PROJECT APPROVAL

The State Reclamation Board has jurisdiction over all levee rehabilitation and maintenance and will be the local sponsor as required. The Board is authorized to make such rules and regulations that are necessary to carry out its responsibilities, consistent with the California Water Code.

The State will approve plans and inspect work to ensure that levees are effectively rehabilitated and maintained. Under the current code, the California Department of Water Resources (DWR) is responsible for developing the maintenance and rehabilitation criteria for non-project levees. The criteria will vary as required to meet specific conditions, and will embody and implement the "Flood Hazard Mitigation Plan for the Sacramento-San Joaquin Delta" (most current version) and the "Vegetation Management Guidelines for Local Non-Project Delta Levees" (most current version). In addition, DWR's Bulletin 192, dated May 1975 and updated in 1982, will be used as the conceptual plan guiding the formulation of projects to preserve the integrity of the Delta levee system. The criteria developed by DWR will be submitted to the Board for approval. Prior to adoption of any criteria, the Board will hold public hearings and may revise the criteria as it determines necessary.

The current California Water Code does not address project levee design and maintenance criteria. It is anticipated that the Corps will continue to be responsible for the design of project levees. The State and local agencies will be responsible for maintaining the levees in accordance with the PL 84-99 standard and with guidelines provided in the Corps' "Standard Operation and Maintenance Manual" (most current version) and in each applicable supplement for individual project units.

DFG will make a written determination as part of its review and approval of a plan or project whether the proposed work is consistent with a net long-term habitat improvement program and whether the project would result in a net benefit for aquatic species in the Delta.

2.1.4 AGREEMENTS

Before any plan is approved, agreement entered into, or state and federal funds expended, the local agency will enter into an agreement with the Board. This agreement will indemnify and hold and save the State, the Board, DWR, and any other agency or department of the State and Federal Governments and their employees free from any and all liability for damages, except that caused by gross negligence, that may arise out of the approvals, agreements, inspections, or work performed. Upon approval of project plans by the Board, the local agencies will enter into an agreement with the Board to perform the maintenance and improvement work, including the annual maintenance work, specified in the plan. Also, the Board will act as the local sponsor to the Corps and give the Corps the same assurances.

2.1.5 PROJECT PRIORITY

Local agencies will prioritize projects based on their individual needs. If applications for funding in any year exceed the funds available, the Board will apportion the funds among those levees or levee segments that are identified by DWR as most critical and beneficial,

Local agencies will prioritize projects based on their individual needs.

considering the needs of flood control, water quality, recreation, navigation, habitat improvement, and fish and wildlife.

2.1.6 MAINTENANCE

There is a difference between the maintenance standard as defined by the California Water Code and the PL 84-99 maintenance standard. This difference in maintenance standards may result in greater habitat mitigation and enhancement requirements.

The PL 84-99 maintenance standards may result in greater habitat mitigation and enhancement requirements.

Local agencies will be responsible for maintaining project and non-project levees. Local agencies will be eligible for reimbursement upon submission to and approval by the Board of plans for the maintenance and improvement of the project and non-project levees, including plans for the annual maintenance of the levees in accordance with the criteria adopted by the Board. The plans will (1) include provisions to acquire easements along levees that allow for the control and reversal of subsidence in areas where DWR determines that such an easement is desirable to maintain structural stability of the levee, (2) include provisions for protection of the fish and wildlife habitat determined necessary by DFG and that will not reduce the integrity of the levee, and (3) take into account the most recently updated Delta Master Recreation Plan prepared by the Resources Agency.

2.1.7 OVERSIGHT AND INSPECTIONS

DWR will conduct at least one annual inspection of every levee for which maintenance or improvement costs have been paid to the local agencies. In addition, DWR will inspect non-project levees of local agencies to monitor and ascertain the degree of compliance with, or progress toward meeting, the approved and agreed on criteria and standard. Whenever an inspection reveals that the specified and agreed upon maintenance is not being performed, DWR may establish a maintenance area and thereafter annually maintain the non-project levee in accordance with the Board-approved plan.

DWR will conduct at least one annual inspection of every levee for which maintenance or improvement costs have been paid to the local agencies.

The Corps may inspect project levees. For non-project levees to become eligible for federal assistance under PL 84-99, a local agency must request and pass an Initial Eligibility Inspection by the Corps. The Corps will inspect the levee to assess the integrity and reliability of the levee. The inspection by the Corps consists of a structural and geotechnical analysis, a hydrologic and hydraulic evaluation, and an operation and maintenance determination.

2.1.8 EMERGENCY RESPONSE

Even with rehabilitation and active levee maintenance, the threat of levee failure will continue to exist. Emergency Management and Response, a critical element of the Levee System Integrity Program Plan, is discussed in a later section of this plan.

2.2 DELTA LEVEE SPECIAL IMPROVEMENT PROJECTS

The goal of the Delta Levee Special Improvement Projects (Special Improvement Projects) element is to provide additional flood protection separate from the Base Level Protection element for Delta islands that protects such public benefits as water quality, the ecosystem, life and personal property, agricultural production, cultural resources, recreation, and local and statewide infrastructure. This element is being developed and evaluated at a programmatic level. More focused analysis and documentation of specific targets and actions will occur in subsequent efforts.

The goal of the Delta Levee Special Improvement Projects element is to provide additional flood protection separate from the Base Level Protection element for Delta islands that protects such public benefits as water quality, the ecosystem, life and personal property, agricultural production, cultural resources, recreation, and local and statewide infrastructure.

2.2.1 INTRODUCTION

The Special Improvement Projects element of the Levee System Integrity Program Plan will be carried out through an extension of the existing Special Projects Program as defined in the California Water Code.

The Delta Flood Protection Act of 1988 created the Special Flood Control Project Program. The Delta Flood Protection Fund was created to provide for local assistance under the Delta Levee Maintenance Subventions Program (Subventions Program), and for Special Delta Flood Protection Projects (Special Projects). Currently, the Subventions Program and Special Projects are being carried forward under funding provided by the Safe, Clean, Reliable Water Supply Act, Division 24f the California Water Code. Special Projects are described in the California Water Code, Division 6, Part 4.8 - Delta Flood Protection, Chapter 2 - Special Flood Control Projects (commencing with Section 12310). Refer to Appendix C for pertinent excerpts from the California Water Code. It is the intent of the Legislature that, to the extent consistent with existing requirements, special projects will be consistent with the Delta ecosystem restoration strategy of the CALFED program.

Funding for the Special Improvement Projects is discussed later in this report. Table 4 lists implementation objectives, targets, and actions associated with the Special Improvement Projects elements.

2.2.2 SCOPE

DWR is responsible for the existing state Special Projects Program and would continue to develop and implement the Special Improvement Projects element of the Levee Program. The primary purpose of the existing and proposed programs is to protect discrete and identifiable public benefits, including public highways and roads, utility lines and conduits, urbanized areas, water quality, recreation, navigation, and fish and wildlife habitat. Special Improvement Projects include flood control projects for (1) all the Delta islands, but primarily the key eight western and central islands of Bethel, Bradford, Holland, Hotchkiss, Jersery, Sherman, Twitchel, and Webb; (2) the Towns of Thorton and Walnut Grove; and (3) approximately 12 (more like 18) miles of levees on the islands bordering northern Suisun Bay from Van Sickle Island to Montezuma Slough. The Special Improvement Projects Program also must provide for a net long-term habitat improvement.

The Special Improvement Projects Program also must provide for a net long-term habitat improvement.

Project plans may include, or be a combination of, the improvement, rehabilitation, or modification of existing levees, and the conveyance of interests in land to limit or to modify land management practices that negatively affect flood control facilities. Easements will be obtained for the control and reversal of subsidence in areas along the levees where DWR determines that such an easement is desirable to maintain the structural stability of the levee. Project plans must include provisions for the protection of fish and wildlife habitat determined necessary by DFG and that do not reduce the integrity of flood control works.

2.2.3 PROJECT PRIORITY

In accordance with the California Water Code (Section 12313), DWR is required to develop, in consultation with appropriate federal, state, and local agencies, a list of areas where flood control work is needed to protect public facilities or provide public benefits. Priority of projects is to be based on the importance or degree of public benefit needing protection and the need for flood protective work. The list is now subject to the approval of the California Water Commission.

However, for the CALFED Program to achieve its objectives, this authority must be coordinated with the CALFED Program. The following change in the Water Code is suggested:

- The Levee Implementation Group (LIG), as established by CALFED, will develop a priority list of Special Improvement Projects consistent with the CALFED objectives and the primary purpose of the Special Flood Control Projects authority. The LIG is comprised of CALFED agencies and stakeholders to provide a forum for stakeholder and science review and to coordinate Levee Program actions with all other CALFED actions.

- The priority list will be approved by the CALFED Policy Group (or new CALFED umbrella authority).

Special Improvement Projects could be prioritized based on a matrix of objectives and island attributes. Such a matrix was developed by DWR with input from CALFED's Levee and Channel Technical Team. Table 5 presents such a matrix. A more detailed "Special Projects Information Matrix" is presented in Appendix D. This information demonstrates the scope and complexity involved in objectively prioritizing islands and projects. The existing matrix of objectives and island attributes (see Table 5) and the more detailed Special Projects information matrix (see Appendix D) presented in this Levee System Integrity Program Plan, would supplement a new CALFED priority matrix developed to support the CALFED objectives. The matrix of objectives, attributes, and priorities should be evaluated regularly to adapt to the changing Delta environment.

Special Improvement Projects could be prioritized based on a matrix of objectives and island attributes.

Table 4. Implementation Objectives, Targets, and Actions Associated with the Delta Levee Special Improvement Projects

Implementation Objective	Target	Action
Enhance flood protection for key islands that provide statewide benefits to the ecosystem, water supply, water quality, economics, infrastructure, etc.	Improve levee stability in key Delta locations to a level commensurate with the benefits which the levees protect	Modify levee cross sections by raising levee height, widening levee crown, flattening levee slopes, and/or constructing stability berms in key Delta locations
	Maintain improved levees	Develop a long-term maintenance plan
Establish a stable funding source	Provide necessary funding to improve and then maintain key levees for the CALFED planning horizon	Prepare cost estimates
		Identify beneficiaries to provide equitable distribution of costs
		Develop funding sources
Coordinate the permitting process	Reduce the time required to acquire all necessary permits	Develop a uniform process to coordinate and approve all permits
		Provide regional mitigation banking
		Coordinate with the Ecosystem Restoration Program to provide an environmental enhancement component

2.2.4 Approval of Plans for Special Improvement Projects

Project plans will be developed by DWR in cooperation with the local agency, the public beneficiary, and DFG. Project plans will be subject to the approval of the appropriate local agency or agencies, and DFG. DFG will make a written determination as part of its review and approval of a plan or project whether the proposed expenditures are consistent with a net long-term habitat improvement program and would result in a net benefit for aquatic species in the Delta.

2.2.5 Execution of Plans

Special improvement projects will be undertaken and completed in accordance with the approved project plans. Project works may be undertaken by DWR or, at DWR's option, by the local agency pursuant to an agreement with DWR.

In addition to any obligations assumed under an agreement with DWR and to the extent consistent with that agreement, the local participating agency will (1) provide construction access to lands or rights-of-way that it owns or maintains for flood control purposes or for purposes that are compatible with the project's required use and necessary to complete the project; (2) maintain the completed project; (3) apply for federal disaster assistance, whenever eligible, under PL 93-288; (4) hold and save the State and its employees free from any and all liability for damages, except that caused by gross negligence, that may arise out

Table 5. Special Projects Matrix of Objectives and Attributes

Objective	Island Attribute
Life and personal property	Permanent population Towns Housing units Residential lands
Water quality	Long-term salinity intrusion induced Critical to water quality (Senate Bill 34) Island volume
Agricultural production	Total agricultural lands Value of damagable crops
Recreation	State or regional parks Recreation lands Recreation resorts/marinas
Cultural resources	Known prehistoric sites Potential historic sites
Ecosystems	Native vegetation Wetlands Riparian habitats Agricultural waterfowl habitats Known special-status plant occurrences Known special-status wildlife occurrences
Infrastructure of local concern	County roads Commercial lands Industrial lands Acreage protected per levee mile
Infrastructure of statewide concern	Federal and state highways Water supply conveyance Railroad mainlines Natural gas pipelines Natural gas fields and storage Power transmission lines
Adjacent island resources	Adjacent levees at risk Seepage risk

of the construction, operation, or maintenance of the project; (5) acquire easements; (6) comply with habitat mitigation and improvement requirements; and (7) use subsidence control alternatives.

2.2.6 MAINTENANCE

Prior to the adoption of any maintenance criteria, the Board will hold public hearings and revise the criteria as deemed necessary.

Completed special improvement projects will be maintained by the local cooperating agency pursuant to maintenance criteria adopted in accordance with Section 12984 of the California Water Code. This section requires DWR to develop and submit for approval by the Board, criteria for the maintenance and improvement of levees. The criteria will be adapted to meet specific conditions; be multipurpose; and include environmental considerations, when feasible. The non-project levee maintenance criteria will embody and implement the mitigation plan set forth in the "Flood Hazard Mitigation Plan for the Sacramento-San Joaquin Delta" and the "Vegetation Management Guidelines for Local Non-Project Delta Levees." Project levee and eligible non-project levee maintenance criteria also will comply with the PL 84-99 Delta Specific Standard, the Corps' "Standard Operation and Maintenance Manual," and each applicable supplemental agreement. PL 84-99 Levee Maintenance standards allow significantly less vegetation than the "Vegetation Management Guidelines for Local, Non-Project Delta Levees," that was approved for the HMP standard. Replacement of the HMP vegetation guidelines with the PL 84-99 vegetation standard on non-project levees likely will result in greater habitat mitigation and enhancement requirements through the AB 360 program. Prior to the adoption of any maintenance criteria, the Board will hold public hearings and revise the criteria as deemed necessary.

2.3 DELTA LEVEE SUBSIDENCE CONTROL PLAN

The goals of the Delta Levee Subsidence Control Plan (Subsidence Control) element are to reduce or eliminate the risk to levee integrity from subsidence and assist in the coordination of subsidence-related linkages with other CALFED programs. This element is being developed and evaluated at a programmatic level. Appendix E contains two subsidence reports developed by the Subsidence Subteam. One report discusses the effects of subsidence on levee integrity, presents a preliminary subsidence mitigation plan for levee integrity, and delineates target areas for subsidence control based on the best available information. The other report presents a broader perspective in an evaluation of subsidence as it affects all CALFED objectives.

The goals of the Delta Levee Subsidence Control Plan element are to reduce or eliminate the risk to levee integrity from subsidence and assist in the coordination of subsidence-related linkages with other CALFED programs.

2.3.1 INTRODUCTION

Subsidence issues, concerns, and solutions are addressed in both the Levee Program and the Ecosystem Restoration Program. The Levee System Integrity Program Plan focuses on subsidence that affects the levee system. Subsidence management is covered under the existing "Special Flood Control Project" portion of the California Water Code (refer to Appendix C).

2.3.2 BACKGROUND

Subsidence has substantially contributed to the Delta islands current condition of relatively tall levees that protect interiors below sea level. Recently, however, the importance of subsidence to levee stability has diminished. Land management and levee maintenance practices have improved, and subsidence rates have decreased. In addition, the Subsidence Subteam has determined that a zone of influence (ZOI) extends from the levee crest to some distance inland, beyond which subsidence will not affect levee integrity.

Subsidence has substantially contributed to the Delta islands current condition of relatively tall levees that protect interiors below sea level.

Although the ZOI for a reach of levee can be determined with site-specific data, the Subsidence Subteam has estimated the ZOI for planning purposes. Based on available information and engineering judgement, the ZOI is roughly estimated to range from 0 to 500 feet from the levee crest, depending on site-specific conditions. The Subsidence Control element addresses subsidence as it affects levee integrity within the ZOI adjacent to levees.

Table 6 lists implementation objectives, targets, and actions associated with the Subsidence Control element.

2.3.3 REMEDIAL ACTION AND PREVENTION

Potential levee settlement/subsidence mitigation actions that should be considered include:

- Geotechnical engineering principles and practices in conjunction with proven construction methods should be applied. Levee subsidence will continue as long as levee building and repair continue to add loads onto weak, compressible foundations.

- Seepage control, dewatering efforts, excavations, and land management activities near levees should be modified to minimize adverse impacts on levee integrity.

- Stability and drainage berms should be strategically located and sequentially constructed to minimize or prevent levee deformation.

- Land leveling and other ground surface modifications (for example, ditching) should be restricted within the ZOI. High groundwater levels and vegetative growth could be tolerated in some areas to accommodate measures aimed at reducing subsidence due to oxidation.

As long as subsidence is adequately managed within the ZOI, levee integrity should be unaffected. Subsidence control and monitoring are most important for the western and central Delta islands, where the depth of organic soils are the greatest and the organic content of the deposits are commonly high. Previous attempts at prioritizing areas and islands, based on depth of peat and organic matter content, provide a good starting point for the development of a subsidence monitoring, control, and prevention program.

Subsidence control and monitoring are most important for the western and central Delta islands, where the depth of organic soils are the greatest and the organic content of the deposits are commonly high.

The levees identified as target areas for subsidence remedial action and prevention would require screening and integration with other issues affecting levees, such as seismic stability requirements and Delta water operations. This integration would allow a better prioritization of future subsidence remediation of Delta levees.

2.3.4 CURRENT PROGRAM

The California Water Code's Special Flood Control Projects Program states that local agencies will acquire easements from the crown along levees for the control and reversal of subsidence in areas where DWR determines that such an easement is desirable to maintain structural stability of the levee. The easement would: (1) restrict the use of the land

Table 6. Implementation Objectives, Targets, and Actions Associated with the Delta Levee Subsidence Control Plan

Implementation Objective	Target	Action
Reduce the risk to levee integrity from subsidence	Reduce, eliminate, or reverse subsidence adjacent to affected levees	Implement current BMPs to correct subsidence effects on levees Fund grant projects to develop BMPs that address subsidence as it affects levee integrity
Improve the permitting process	Reduce the time required to acquire all necessary permits	Develop a uniform process to coordinate and approve all permits Provide regional mitigation banking Coordinate with the Ecosystem Restoration Program to provide an environmental enhancement component
Coordinate subsidence-related linkages with other CALFED programs	Develop and implement BMPs to facilitate CALFED objectives	Assist CMARP activities to quantify the effect and extent of inner-island subsidence and its linkages to all CALFED objectives

Notes:

BMPs = Best management practices.
CMARP = Comprehensive Monitoring, Assessment, and Research Program.

to open space uses, non-tillable crops, the propagation of wildlife habitat, and other compatible uses; (2) provide full access to the local agency for levee maintenance and improvement purposes; and (3) allow the owner to retain reasonable rights of ingress and egress, as well as reasonable rights of access to the waterways for water supply and drainage. In addition, the current program states that local agencies will use subsidence control alternatives, where appropriate, to reduce long-term maintenance and improvement costs.

2.3.5 PROPOSED PROGRAM

CALFED will implement a subsidence control and monitoring program. Subsidence control measures will be incorporated into base level and special improvement projects. Subsidence monitoring would begin with an evaluation of existing soils and their distribution in the Delta, and a determination of land surface elevation. Efforts would be directed to areas on and adjacent to the levees, within the ZOI. From a new, continually updated database, a target list of levees and islands being affected by subsidence could be maintained. Monitoring would allow subsidence control to be adaptively managed as levees are rehabilitated. This monitoring effort would be coordinated through CALFED's Comprehensive Monitoring, Assessment, and Research Program (CMARP).

Subsidence monitoring would begin with an evaluation of existing soils and their distribution in the Delta, and a determination of land surface elevation.

In addition, because the linkages of inner-island subsidence to CALFED objectives needs more study, the Levee Program recommends that CMARP quantify the extent and effect of inner-island subsidence. CALFED may implement grant projects to develop best management practices (BMPs) that restore interior island elevations.

The Levee Program recommends that CMARP quantify the extent and effect of inner-island subsidence.

2.4 DELTA LEVEE EMERGENCY MANAGEMENT AND RESPONSE PLAN

The goal of the Delta Levee Emergency Management and Response Plan (Emergency Management Plan) element is to enhance existing emergency management response capabilities in order to protect critical Delta resources and limit any interruption of services and supplies to 6 months or less in the event of a disaster. More focused analysis and documentation of specific targets and actions will occur in subsequent efforts.

The goal of the Delta Levee Emergency Management and Response Plan element is to enhance existing emergency management response capabilities in order to protect critical Delta resources and limit any interruption of services and supplies to 6 months or less in the event of a disaster.

2.4.1 INTRODUCTION

The existing emergency response capabilities need to be continuously refined, and funding needs to be increased. The Emergency Management Plan will build on existing state, federal, and local agency emergency management. It will propose specific actions that will improve response flexibility to ensure that appropriate resources are available and properly deployed, and provide for effective disaster recovery measures.

Table 7 lists implementation objectives, targets, and actions associated with the Emergency Management and Response Plan element.

2.4.2 BACKGROUND

The most recognizable threat to Delta islands and resources is inundation due to winter flood events. Other potential disasters that threaten these same resources include seismic events and levee failure during low-flow periods.

The most recogniz-able threat to Delta islands and resources is inundation due to winter flood events.

Current emergency response procedures could be streamlined to reduce delays in mobilizing resources. A quick response can prevent costly levee failures. In addition, the tendency to focus emergency response measures on those sites facing imminent failure can result in neglecting actions that could prevent threatened sites from escalating into emergencies.

2.4.3 CURRENT PROGRAM

The Governor's Office of Emergency Services (OES) coordinates state agency responses. When an incident appears to potentially exceed the resources of the local responsible agency, emergency personnel conduct on-site evaluations to determine what, if any, additional emergency support is warranted. Cities and counties can proclaim local disaster events and, in general, local or maintaining agencies are first in line for responsibility to address disaster events. Although certain agencies may have resources to provide initial emergency action, typically they cannot provide a sustained effort during a large disaster event. Most local agencies do not have the resources to address major disaster events, and existing agreements may provide a means for sharing additional resources from surrounding areas. The federal government provides financial assistance through FEMA under a presidential declaration of disaster; however, other federal agencies such as the Corps may provide assistance or resources under existing authorities.

Table 7. Implementation Objectives, Targets, and Actions Associated with the Delta Levee Emergency Management and Response Plan

Implementation Objective	Target	Action
Enhance emergency response capabilities and resource allocation	Develop the capability to efficiently respond to multiple concurrent levee breaks within the Delta and limit interruption of services to 6 months or less	Implement a comprehensive reconstruction, repair, and maintenance program for Delta levees
		Review, clarify, and refine command and control protocol; develop an Integrated Response Plan in conformance with SEMS/ICS
		Define agency responsibilities to ensure environmental compliance
		Purchase materials in advance and place in strategic locations
		Execute pre-negotiated contracts with contractors for forces and equipment to respond with short notice
		Clarify program eligibility, inspection, documentation, dispute resolution, auditing, and reimbursement procedures
Develop a stable funding source for emergency response	Provide funding for a well-defined Disaster Assistance Program	Prepare cost estimates
		Identify beneficiaries to provide equitable distribution of costs
		Develop funding sources

Notes:

ICS = Incident Command System.
SEMS = Standardized Emergency Management System.

The existing emergency management structure is designed to coordinate activities of multiple state, federal, and local agencies with varying responsibilities to provide emergency assistance in the event of a disaster. The Standardized Emergency Management System (SEMS) provides a framework for coordinating state and local government emergency response in California, using the Incident Command System (ICS) and mutual aid agreements. SEMS facilitates setting priorities, cooperation among agencies, and the efficient flow of resources and information.

2.4.4 PROPOSED PROGRAM

CALFED plans to build on the existing emergency response system. CALFED's Emergency Response Subteam determined that an effective Delta levee emergency response program should be concentrated in seven areas:

CALFED plans to build on the existing emergency response system.

- Funding;
- Response by state and federal agencies;
- Availability of flood fight resources;
- Integrated response;
- Clarification of regulatory procedures;
- Clarification of program eligibility, inspection, documentation, auditing, and reimbursement procedures; and
- Dispute resolution.

Funding

The vulnerability of the levee system can be reduced by implementing an integrated and comprehensive reconstruction, repair, and maintenance program for Delta levees and channels, as described and recommended under the Levee System Integrity Program. Implementation can be accomplished only by supplementing local funding capability through state and federal cost-sharing at adequate and consistent levels.

Response by State and Federal Agencies

- DWR's authority to respond should be clarified and expanded to include all instances where levees or other flood control structures are in danger of failure, regardless of whether the danger is due to storms, floods, earthquakes, rodents, vessel impacts, or any other cause. The funding for support of DWR's efforts should be ample and clearly committed for a comprehensive emergency response.

  The role of the Corps also should be clarified and confirmed, to eliminate delay in response and avoid any dispute concerning whether the local and state responses are sufficient.

- DWR should be given the mandate, authority, and funding to carry out the repair of damage to Delta non-project levees due to floods, storms, and levee failure incidents—including de-watering flooded areas. All FEMA and OES funds related to such work should go directly to DWR.

Availability of Flood Fight Resources

Specialized Equipment and Operators

A revitalized levee maintenance capability under the Levee System Integrity Program will establish a fleet of specialized equipment essential to a rapid emergency response but will not ensure its availability during emergencies that can widely range in geographic extent. Pre-emergency contracting for specialized equipment will secure the availability of the equipment and experienced operators and will establish the pricing for emergency services.

A revitalized levee maintenance capability under the Levee System Integrity Program will establish a fleet of specialized equipment essential to a rapid emergency response but will not ensure its availability during emergencies that can widely range in geographic extent.

Material Stockpiles

DWR (Central District) has established stockpiles for flood-fighting material (such as sandbags, plastic, stakes, light equipment, and pumps) at three locations in the north, south, and west Delta. The program should include assurance of a supply or stockpiling of sand, drain rock, and riprap.

Staffing for Emergency Assistance

Formalizing arrangements with the California Department of Forestry and Fire Prevention, as well as with the California Conservation Corps and the State Prison System, for emergency assistance should be considered.

Integrated Response

A detailed response plan should be developed for the Delta that would allow an immediate, simultaneous response to a serious incident by all levels of government within a single integrated organizational structure. The plan would identify common needs and functions of all agencies (for example, housing, food, transportation, supplies [including rock and sand], equipment, and contracted services) and would assign the most capable agency or jurisdiction to perform each action on behalf of all agencies. The detailed response plans would provide the basis for pre-identifying and assigning specific responsibilities for each agency, as well as the level of resources that the individual local agency would be expected to provide in response to the emergency. With detailed assignment of responsibilities, an organizational structure for the "area command" could be delineated to ensure that the "incident commands" were coordinated.

A detailed response plan should be developed for the Delta that would allow an immediate, simultaneous response to a serious incident by all levels of government within a single integrated organizational structure.

Clarification of Regulatory Procedures

Although both state and federal laws suspend environmental regulation during emergencies, some clarifications are desirable.

- A consistent definition of "emergency" should be developed for response and regulatory activities. It is especially important that the defined duration of the emergency be consistent for both purposes.

- Mitigation measures that are expected during post-emergency recovery work should be defined, to rapidly define and implement "appropriate" mitigation and to avoid unnecessary delays of post-emergency recovery work. Fish and Game Code Section 1600 outlines only general obligations.

Clarification of Program Eligibility, Inspection, Documentation, Auditing, and Reimbursement Procedures

The requirements of state and federal programs need to be standardized to be consistent with one another, be well communicated to the local agencies without delays, and avoid changes or re-interpretation during the reimbursement process.

Dispute Resolution

A binding arbitration procedure, conducted by knowledgeable but impartial arbiters, should be established. The procedure should encompass state and federal programs.

2.5 DELTA LEVEE RISK ASSESSMENT AND RISK MANAGEMENT STRATEGY

Delta levees and islands are at risk of failure from floods, seepage, subsidence, earthquakes, and other threats. A key management decision will be made at the end of Stage 1 implementation regarding the effectiveness of the CALFED Preferred Program Alternative. The following key levee-related question must be answered at the end of Stage 1: "Are the risks to export water supply from levee failure acceptable, or are other actions required?" To address these needs, CALFED will develop and implement an appropriate risk management strategy during Stage 1. The goal of the Delta Levee Risk Assessment and Risk Management Strategy is to quantify the risks to Delta levees, evaluate the consequences, and develop an appropriate risk management strategy.

The goal of the Delta Levee Risk Assessment and Risk Management Strategy element is to quantify the risks to Delta levees, evaluate the consequences, and develop an appropriate risk managements strategy.

2.5.1 INTRODUCTION

Many CALFED agencies and stakeholders have voiced concern over the need to quantify Delta levee risk, to determine the consequences of failure, and to implement an appropriate risk management strategy.

The greatest threat to Delta levees is overtopping and seepage during flood flows. Since their reclamation, numerous Delta islands have flooded at least once. Over the past 50 years, dozens of islands have flooded. Some islands have flooded many times. Some islands were never reclaimed. The vulnerability of the Delta levee system to failure during earthquakes is also a concern. Although levee failure from a seismic event has never been documented, the Delta has not experienced a significant seismic event since the levees reached their current size. The risk to Delta resources must be managed if the CALFED objectives are to be achieved. Appendix D lists the major resources in the Delta.

2.5.2 PAST AND PRESENT EFFORTS

Over the past 12 years, the existing Delta levee program has reduced the risk of flood and seepage by improving Delta levees.

Over the past 12 years, the existing Delta levee program has reduced the risk of flood and seepage by improving Delta levees.

Research and demonstration projects are being conducted to quantify the effects of subsidence and determine how to reduce its threat to Delta levees.

In the late 1980s, DWR's Division of Engineering embarked on a long-term seismic stability evaluation of Delta levees. Strong-motion accelerometers were installed at several sites in the Delta. Field and laboratory testing is being done to better determine the static and dynamic properties of organic soils and to better determine their liquefaction potential. The potential activity of the Coast Range/Sierra Nevada Boundary Zone is being evaluated. In 1992, DWR published a report titled, "Seismic Stability Evaluation of the Sacramento-San Joaquin Delta Levees - Volume I." DWR's seismic investigation is being continued. DWR continues to collect data from their seismic monitoring instruments, and continues field and laboratory testing. These data will be published in future reports.

In 1998, a Seismic Vulnerability Subteam began a seismic risk assessment of Delta levees. The sub-team was comprised of a group of experts in the fields of seismology and geotechnical engineering. The assessment identifies the risk to Delta resources during catastrophic seismic events and comments on the general feasibility of various actions to reduce exposure to the risk. The Seismic Vulnerability Subteam's report, "Seismic Vulnerability of the Sacramento-San Joaquin Delta Levees," dated April 2000, is included in Appendix G of this document.

"... A significant seismic risk is present; however, improved prepared-ness can reduce the potential damage."

2.5.3 PROPOSED RISK ASSESSMENT

As part of CALFED's Stage 1 actions, CALFED staff will work with stakeholders, the public, and state and federal agencies to develop and implement a Delta Levee Risk Assessment and Risk Management Strategy. CALFED will incorporate the findings from the Seismic Vulnerability Subteam's assessment into an overall risk assessment. Once the risk to Delta levees is quantified and the consequences are evaluated, CALFED will develop and implement an appropriate risk management strategy.

CALFED staff will work with stake-holders, the public, and state and federal agencies to develop and implement a Delta Levee Risk Assessment and Risk Management Strategy.

Several risk management options have been developed for inclusion in the CALFED Preferred Program Alternative. The available risk management options include, but are not limited to:

- Improving emergency response capabilities,
- Reducing the fragility of the levees,
- Improving through-Delta conveyance,
- Constructing an isolated facility,
- Developing storage south of the Delta,
- Releasing more water stored north of the Delta,
- Restoring tidal wetlands,
- Controlling and reversing island subsidence,
- Curtailing Delta diversions, and
- Continuing to monitor and analyze total risk.

The final Risk Management Plan will include a combination of these options and others identified as a result of the risk assessment.

Table 8 lists implementation objectives, targets, and actions associated with the Delta Levee Risk Assessment and Risk Management Strategy Element.

Table 8. Implementation Objectives, Targets, and Actions Associated with the Delta Levee Risk Assessment and Risk Management Strategy Element

Implementation Objective	Target	Action
Prepare a Delta Levee Risk Assessment and Risk Management Strategy	Document findings in a report to CALFED	Assemble a Levee Risk Assessment Team Quantify risks to Delta levees from earthquakes, overtopping, seepage, and subsidence Quantify the consequences to resources at risk Develop potential risk management strategies that are consistent with CALFED's Preferred Program Alternative; coordinate with CALFED program managers, agencies, and stakeholders; develop viable funding methodologies Make recommendations to CALFED on specific risk management actions and funding methodologies
Implement appropriate risk management strategies	Integrate risk management strategies into CALFED's Preferred Program Alternative	CALFED to take appropriate action on selected risk management actions

3. Sea-Level Rise

3.1 INTRODUCTION

Most researchers agree that sea level is currently rising and has been since the end of the last ice age about 17,000 years ago (Scientific American August 1998). The evidence for rising sea levels comes from direct measurements of the ocean water column, the geologic record, changes in the earth's angular momentum, and melting glaciers. Thermal expansion of ocean water due to increased surface warming and an increased water supply from glacial melt are the two main causes of increased sea level.

Tectonic sinking and human-induced sinking of the ground (for example, by hydrocarbon extraction, ground water pumping, or settlement of Delta levees) also may cause relative sea-level rise. When combined with rising sea levels due to climatic and oceanic factors, a total sea-level rise may be obtained for any given area where measurements are available.

Only the long-term rise in sea levels due to fresh-water influx from melting glaciers and oceanic thermal expansion factors are considered here. Site-specific amounts of total sea-level rise may be calculated as needed and are beyond the scope of this work.

Since near the beginning of this century, the rate of sea-level rise has been from about 1 to 3 millimeters per year (mm/yr). If the sea level continues to rise at the present rate, low-lying beaches, wetlands, and critical infrastructure such as levees will become further inundated and threatened by increased water surface levels, wave erosion, and associated problems. Since much of the Bay-Delta system is at or near sea level, it is likely to be directly affected by rising sea levels. Levee height determinations may need to be increased to prevent levee overtopping and subsequent levee failure.

If sea level continues to rise at the present rate, low-lying beaches, wetlands, and critical infrastructure such as levees will become further inundated and threatened by increased water surface levels, wave erosion, and associated problems.

3.2 ATMOSPHERIC WARMING AND SEA-LEVEL RISE

One of the major causes of rising sea levels is an increase in atmospheric temperatures. Increasing atmospheric temperatures heat ocean waters and cause them to rise by thermal expansion. Warmer temperatures also are responsible for the increase in melting of terrestrial and oceanic glaciers. Average atmospheric temperatures have risen about 1 degree Fahrenheit (0.6 degree Celsius) since the turn of the century (Titus and Narayanan, EPA 1996). Warming trends are not the same on all continents and in all oceans, but rather are an average of global climate trends. Local climates may actually be cooling, as discussed by the National Oceanic and Atmospheric Agency (NOAA) at **http://www.ncdc.noaa.gov/ol/climate/globalwarming.html#Q1**. Many climate experts believe that the overall warming trend is a result of an increase of anthropogenic carbon dioxide and other so-called "greenhouse gasses."

One of the major causes of rising sea levels is an increase in atmospheric temperatures.

There is considerable debate on the effects of greenhouse gases. For example, Curt Suplee at **http://www.Globalwarming.org** reports that increases in carbon dioxide concentrations may actually follow warming trends. However, the uncertainty of the cause of warming is high, and much more research is needed to resolve the issue. While earth-based instruments show a distinct warming trend, space-based measurements of atmospheric temperatures over the past decade or so show no such trend and instead show a small cooling trend in some cases. However, it is also possible that the climate system does not react instantly to increases in greenhouse gases. The effects of the input of such gases to the atmosphere may not be linear and possibly may not be felt until a future time. This view is detailed at **http://www.artsci.wustl.edu/~rjniemie/hewterm.html.**

Research into atmospheric warming is continuing. Instruments such as those aboard the currently planned CloudSat satellite will better enable scientists to determine whether the atmosphere is getting warmer (Space News May 1999).

3.2.1 MELTING GLACIERS AND SEA-LEVEL RISE

Besides thermal warming of ocean waters, the other major input to sea-level rise is glacial melt water. While no glaciers are present in the project area and no volumes have been estimated, relatively rapidly melting glaciers are a current phenomena in many other places. Terrestrial glaciers are melting at a seemingly accelerated pace throughout the world. The web sites referencing this melting are:

Besides thermal warming of ocean waters, the other major input to sea-level rise is glacial melt water.

- **http://www.tv.cbc.ca/national/pgminfo/glacier/index.html** shows photographs of the retreating Athabascan Glacier.
- **http://www.enn.com/enn-news-archive/1998/05/052798/glacier.asp** gives a discussion of the melting of glaciers at various locations.
- **http://www.greenpeace.org/~climate/database/records/zgpz0212.html** shows the amount of glacial retreat at various locations.
- **http://spacelink.nasa.gov/NASA.News/NASA.News.Releases/Previous.News.Releases/99.News.Releases/99-03.News.Releases/99-03-04.Greenland.Glaciers.Shrinking** reports the unexpected recent change in the Greenland Ice Sheet.

Continued measurements over the next decade will expand the amount of factual information concerning glacial melting. This would be especially important in the case of a possible breakup and melting of very large glaciers, for example, on Greenland or in the Antarctic ice system.

The April 1999 Scientific American reports that the glaciers of Glacier National Park in Montana will run dry within the next 50 years. For comparison, about 6% of the world's ice is contained in mountain glaciers. The Antarctica and Greenland Ice Sheets contain about

90% of the world's fresh water. Melting of the ice sheets could sharply accelerate sea-level rise. Photographs showing the breakup of the Larsen Ice Shelf in the Antarctic can be found at **http://www-nsidc.colorado.edu/NSIDC/ICESHELVES/ lars_wilk_news**. The rapid retreat of summer sea ice in the Beaufort Sea north of Alaska is detailed in the February 1999 Science News.

3.2.2 MEASURING THE AMOUNT OF SEA-LEVEL RISE

Measuring sea-level rise is complex. Seaborne measurements over the last 100-150 years indicate that globally, the sea level has been rising at the rate of about 2 mm/yr. This amount will vary with location. The global average from tide gage records (Gornitz 1994) is from about 1 to 3 mm/yr.

Tide gages provide the most direct measurements of sea-level rise; however, tide gages usually are placed on piers near a geodetic benchmark. Some serious problems are associated with tide gage measurements. Local movements caused by postglacial rebound or subsidence greatly modifies the rate of relative sea-level rise or lowering, as may be the case. Tide gages also must be resurveyed periodically to correct for changes in gage platform mountings. The length of record is important, with 50 years of record probably being the minimum length for accurate measures. A detailed discussion of tide gage measurement accuracy can be found at **http://www.agu.org/revgeophys/dougla01/ node3.html#SECTION00030000000000000000**.

Tide gages provide the most direct measurements of sea-level rise; however, tide gages usually are placed on piers near a geodetic benchmark.

Modern electronic measurements such as GPS- (global position system-) based measures, and laser and satellite altimetry offer the most consistent and accurate methods available to measure sea-level fluctuations. Problems with these techniques can occur from various kinds of instrument noise and interference, but they can be resolved. Over time, these techniques will provide very accurate measures of sea surface changes. Since electronic techniques are relatively new, they do not offer the history of measurements provided by tide gage data. Nevertheless, when combined with computer models over the next decade, the measurements should provide good baseline sea-level data and better insight to sea-level changes over time.

Plans now call for launching a series of earth observation system (EOS) observatories. LandSat 7 was launched in April 1999, with more instruments scheduled to be placed in orbit steadily through 1999 and the coming years. European Space Agency and Japanese platforms also will be launched. Measurements will extend beyond the first decade of the 21st century, providing 10- to 15-year data sets. Scientists believe they can obtain important insights into how the earth system collectively works and provide a quantitative basis for 10- to 100-year predictions of global change. See NASA Facts Online at **http://pao.gsfc. nasa.gov/gsfc/service/gallery/fact_sheets/earthsci/eosund.htm** for discussion. Mission descriptions and launch schedules may be linked at **http://www.earth.nasa.gov/missions/ index.html**.

Current space-based projections of short-term sea levels have been made with some accuracy in the case of the 1997 El Niño and 1998 La Niña events. The TOPEX-Poseiden home page at **http://topex-www.jpl.nasa.gov** links to color plots of sea-level heights determined from satellite altimetry.

Not all researchers agree on the amount that sea level might rise over a given time span or in a geographic location. For this report, a survey was made of nine current sea-level rise projections. The average of these projections shows that the global sea level could rise about 3.4 inches over the next 50 years, not including additional rise caused by increased warming. (If the sea level continued to rise at the rate of about 1.8 mm/yr for the next 50 years, by 2050 the ocean would have risen on average 3.4 inches.) This rate of sea-level rise is close to historical average rates of rise and varies with location.

The average rate above does not include a possible increased rate of rise due to increased climate warming and resultant thermal expansion. The trend of warming and sea-level rise is predicted by many to be non-linear in the next century. When increased rates of warming are included, the average of surveyed projections of sea-level rise shows that global sea level could rise 7.2 inches by 2050 and 17.2 inches by 2100.

Predictions of sea-level rise are based on historical data, satellite and GPS measurements, seaborne measures, and mathematical models. It is important to note that future trends in sea-level rise may not be linear. Sea-level observations and models are being calibrated as techniques and technologies improve over time. The U.S. Environmental Protection Agency (EPA) is at the forefront of research on global warming and sea-level rise. The EPA has included recent global warming projections in their model; results show that by 2050, global sea levels might be expected to rise 5.9 inches. The same models show that by 2100, sea levels might rise by about 13.4 inches. These results may be viewed at **http://www.epa.gov/docs/oppeoee1/globalwarming/reports/pubs/sealevel/probofsea/index.html#toc.**

Predictions of sea-level rise are based on historical data, satellite and GPS measurements, seaborne measures, and mathematical models.

3.2.3 Effects on the Bay-Delta System

Ground elevations in the Bay-Delta system vary from at or near sea level in the San Francisco Bay area to 10 feet and more in the Sacramento area. The effects of a rising sea level on inland areas will be in direct proportion to the amount of ocean rise. Effects will scale down to very little in the far northeast and southeast reaches of the Delta, where tide effects are diminished along with increasing river and waterway elevations.

Ground elevations in the Bay-Delta system vary from at or near sea level in the San Francisco Bay area to 10 feet and more in the Sacramento area. The effects of a rising sea level on inland areas will be in direct proportion to the amount of ocean rise.

Climate warming does not appear to be occurring as fast as predicted in the late 1980s and early 1990s. In 1996, the EPA published "The Probability of Sea Level Rise," which lowered the climatic warming projections and published a set of tables to be used in the projection of sea-level rise numbers at various locations in the coastal United States. The average rate of rise for the San Francisco Bay Area is given as 1.3 mm/yr. This average alone would result in a rate of rise of 2.6 inches in 50 years. An additional component of sea-level rise due to increased warming is given as 3.9 inches (10 cm) by 2050. Combining these terms gives a total projected EPA sea-level rise of 6.5 inches by 2050 for the San Francisco Bay Area. The EPA method is found at **http://www.epa.gov/docs/oppeoee1/globalwarming/reports/pubs/sealevel/probofsea/Chpt9.pdf.**

This projection is for the average trend and warming only, and does not contain a component for the addition of water from melting glaciers. The EPA report does contain discussion and diagnosis-level quantities for a Greenland contribution.

Other agencies in the Bay-Delta area have considered the possible effects of sea-level rise. For example, the Bay Area Conservation and Development Commission (BCDC) in 1987 commissioned the report, "Sea Level Rise Predictions and Implications for San Francisco Bay."

The report is detailed and provides total sea-level rise projections for 2006 and 2036. Sea-level rise projections due to thermal expansion were based on a 1.8-mm/yr average taken linearly over the period of interest. This Bay Area rate was higher than the century-long average global sea-level rise of 1.2-mm/yr cited in the report. For comparison, the EPA uses 1.3 mm/yr for the Bay Area, not including the warming component. The BCDC used only average rates and did not consider a warming component in its projections, relying on a long period of record at the Presidio gage.

Based on a continuous record since 1855 at the Presidio, the rate of rise was 0.0039 ft/yr, or 1.2 mm/yr. During the most recent 19-year tide period (1967-1985), the rate was estimated at 0.0072 ft/yr, or 1.8 mm/yr. The greater rate in this period of measure was in part caused by inclusion of the 1983 El Niño event. Even without the El Niño component, however, the rate was 0.0059 ft/yr, or 1.5 mm/yr. The rate of sea-level rise appears to be increasing over time. These rates give a projected 3.5-inch rise over a 50-year period with no El Niño component, and a 4.3-inch rise over 50 years including the El Niño component. The rate with the El Niño component was used as a working average in the BCDC report. Table 9 compares the rates discussed.

Considering the projections of sea-level rise in Table 9, it is estimated that sea level will rise from 3 to 6 inches near the Golden Gate Bridge by 2050. Using the upper end of this range, the effects on the Bay-Delta system might range from 6 inches of increased water surface elevation near the Golden Gate Bridge, to 4 inches of rise in the area of Venice Island in the mid-Delta, to no rise at the "H" Street Bridge in Sacramento. Again, these figures are based on the upper end of the range, or 6 inches of rise by 2050 near the Golden Gate Bridge. If the lower end of the range is assumed (3 inches of rise by 2050 near the Golden Gate Bridge), these projections would be half at all locations. The far right column of Table 10 shows the estimated upper end of the projected sea-level rise by location.

Considering the projections of sea-level rise in Table 9, it is estimated that sea level will rise from 3 to 6 inches near the Golden Gate Bridge by 2050.

3.2.4 EFFECTS ON DELTA LEVEES

Projected sea-level changes must be considered in meeting the PL 84-99 levee standard.

A major goal of the Long-Term Levee Protection Plan is to reconstruct and maintain all Delta levees to the PL 84-99 standard. This standard is based on the Corps' Delta-specific 100-year flood elevation. This standard is affected by the elevation of sea level. If this goal is to be achieved, therefore, projected sea-level changes must be considered.

Table 10 shows changes in the amount of projected sea-level rise with tide gage location.

3.3 CONCLUSIONS AND RECOMMENDATIONS

Local land settlement, expansion of ocean water, and the addition of water through glacial melting cause sea levels to rise. Increased atmospheric temperatures, measured over the past century, are causing thermal expansion of ocean water.

Local land settlement, expansion of ocean water, and the addition of water through glacial melting cause sea levels to rise. Increased atmospheric temperatures, measured over the past century, are causing thermal expansion of ocean water. Although glaciers are melting and

Table 9. Amount of Projected Sea-Level Rise: A Comparison of Historical Average and Projected Increased Warming-Induced Sea-Level Rise Components and Totals

Location and Component of Projection	Average Rate/Year (mm)	Number of Years	Average Rise Component	Projected Warming Component	Sea-Level Rise (mm)	Sea-Level Rise (inches)
Bay Area						
EPA historical average	1.3	50	65	0	65	2.6
EPA projected warming component	-	50	0	100	100	3.9
EPA average + warming component	-	50	65	165	165	6.5
BCDC historical average	2.2	50	109	0	109	4.3
Global						
Other agencies historical average	1.8	50	88	0	88	3.4
Other agencies average + warming component	-	50	-	-	183	7.2
Other agencies average + warming component	-	100	-	-	437	17.2
EPA average + warming component	-	100	-	-	340	13.4

Notes:

Various other investigative agencies report different amounts of sea-level rise. The amounts have been averaged. EPA amounts are lower than other agency amounts due to decreased amounts of projected global warming.

BCDC = Bay Area Conservation and Development Commission
EPA = U.S. Environmental Protection Agency
mm = millimeters

receding worldwide, the contribution of glacial-melt water to sea-level rise has not been well quantified. The increase in temperatures has not been conclusively linked to the increase in anthropogenic greenhouse gases. The research into global greenhouse warming is continuing. Current measures and computer models already have lowered warming projections made in the late 1980s and early 1990s.

The methods used to measure sea-level rise have traditionally been land-based. As more space-based instruments are used in the coming decade, the accuracy of sea-level measurements will increase. A series of sophisticated space-based instruments soon will be placed into orbit for the purpose of measuring and understanding the complex interactions of the climate systems of the earth. Understanding these systems will have a direct bearing on civil works programs such as the Levee System Integrity Program Plan.

Current measures and computer models already have lowered warming projections made in the late 1980s and early 1990s. As more space-based instruments are used in the coming decade, the accuracy of sea-level measurements will increase.

Table 10. Amount of Projected Sea-Level Rise at Bay Area and Delta Tide Gage Stations

Tide Gage Station Location	Approximate Daily Tide Fluctuation (feet)	Tide Decrease Factor	Adjusted Sea-Level Rise (feet)	Adjusted Sea-Level Rise (Estimated Upper End) (inches)
Golden Gate	5.8	1.1	0.5	6
Martinez	5.6	1.0	0.5	6
Rio Vista	4.8	0.9	0.4	5
Roaring River	4.4	0.8	0.4	5
Mallard Island	5.1	0.9	0.5	6
Antioch	4.3	0.8	0.4	5
Tracy	3.0	0.5	0.3	3
Venice Island	3.8	0.7	0.3	4
Freeport	1.7	0.3	0.2	2
Thornton	1.5	0.3	0.1	2
"I" Street Bridge	1.1	0.2	0.1	1
"H" Street Bridge	0.0	0.0	0.0	0

It is recommended that a 3- to 6-inch sea-level rise be assumed for a 50-year planning horizon for the San Francisco Bay Area. The assumed sea-level rise will decrease to 0 in the far northeast and southeast reaches (see Table 10) of the Delta, where tide effects are eliminated by increasing river and waterway elevations. For comparison, the Corps' New Orleans District (Britsch, personal communication May 1999) is using about 6 inches per year for projected sea-level rise due to thermal expansion. As more accurate sea-level rise projections become available, CALFED will make adjustments accordingly.

It is recommended that a 3- to 6-inch sea-level rise be assumed for a 50-year planning horizon for the San Francisco Bay Area.

4. Ecosystem Restoration Program/Levee Program Coordination

Levee maintenance activities sometimes conflict with management of terrestrial and aquatic habitat resources on or around levees. For instance, vegetation provides valuable habitat but can complicate levee maintenance activities. A common stakeholder concern is that actions to control levee and channel vegetation are often delayed or precluded because of potential impacts on endangered species. Although in some cases vegetation may provide erosion control benefits, in general, vegetation on levees is not desirable for maintenance and emergency response purposes. Bare levees are easier to inspect. Vegetation may conceal evidence of instability, erosion damage, and burrow holes. In addition, the vegetation may provide shelter for, and foster the establishment of, burrowing animals. Deep-rooting plants may threaten the integrity of the structural cross section. When deep-rooting plants are pulled away by wave action or high winds, they can leave gaping holes in levee cross sections, leading to failure of the levee. Although vegetation on levees is not precluded by OES or FEMA, vegetation may hamper flood fighting by impeding the application of sand bags or plastic membrane to levees. Vegetation on levees may make use of some levee maintenance equipment difficult or impossible; therefore, vegetated levees may require more labor-intensive levee maintenance activities. The application of riprap or other erosion protection materials may require clearing established vegetation.

Levee maintenance activities sometimes conflict with management of terrestrial and aquatic habitat resources on or around levees.

The value of riparian habitat as a critical resource for many fish and wildlife species must be respected; however, many issues regarding vegetation on levees require resolution. Sometimes when vegetation on the levee is feasible or even desirable for erosion control, local agencies maintain unvegetated levee slopes in order to avoid the need to contend with endangered species requirements. This conflict contributes to reducing the environmental quality in the Delta.

4.1 CURRENT PROGRAM

This section discusses actions in the existing Subventions Program to address potential conflicts between environmental restoration and levee maintenance efforts. Actions have been taken to ensure that levee maintenance and reconstruction does not work against efforts to protect and establish fish and wildlife habitat in the Delta. The existing Delta Levee Subventions Program established by Senate Bill (SB) 34 and amended by SB 1065 contained a requirement that levee maintenance result in "no net habitat loss." The Program was further amended by AB 360, which established that levee maintenance work funded under the Delta Levee Subventions Program must result in net habitat **improvement**. A memorandum of understanding (MOU) has been negotiated among DWR, the Board, The Resources Agency, and DFG. DWR and DFG have developed mechanisms to implement the habitat requirements of the Subventions Program, including collecting data to create an environ-mental database using GIS technology, identifying sites for habitat restoration, and coordinat-ing with local agencies to develop methods to document restoration efforts.

In addition, California Water Code Section 12300 requires that projects funded under the Delta Levee Subventions and Special Projects Programs, currently administered by DWR, be consistent with CALFED's Delta ecosystem restoration strategy. DWR and DFG have coordinated with the near-term Restoration Coordination Program (Category III) and have championed several Category III projects furthering levee and habitat restoration coordination.

4.2 PROPOSED PROGRAM

This section presents the Levee Program's strategy to address conflicts between the Levee Program and the Ecosystem Restoration Program. The Levee Program will build on the success of existing programs, such as the AB 360 program, in developing methods for successful levee and ecosystem coordination. Levee Program and Ecosystem Restoration Program staff are working in close coordination to develop additional strategies that will minimize conflicts between goals of the two programs. Program staff jointly developed cross sections that would minimize potential conflicts. Figure 5 (at the end of the report) illustrates possible strategies for levee and habitat improvements. Figures 6a through 6e (at the end of the report) depict the strategies selected for future analysis and development. Additional guidelines to successfully integrate habitat and levee integrity concerns are discussed below.

Levee Program and Ecosystem Restoration Program staff are working in close coordination to develop additional strategies that will minimize conflicts between goals of the two programs.

In general, it is desirable to provide separation of the habitat from the levee cross section. An existing environmental baseline must be set, and all existing habitat required to meet AB360 habitat goals should be relocated off the levee structural cross section where possible. Other vegetation on the levees must not impinge on the structural levee section. The structural section is the minimum section required for levee integrity; therefore, additional material must be placed above and beyond the levee structural section to accommodate vegetation. For instance, deep-rooting plants should not be allowed on levee sections unless the levee is larger than the required stable cross section. Also, the use of setback levees to create new riparian and wetland habitat in areas underlain with peat is not recommended because of the high cost of building new levees on peat. Peat is generally weak and highly compressible; therefore, levees built on peat will subside substantially and may require many years to stabilize. Instead, maximum use will be made of in-channel islands and waterside berms for

The use of setback levees to create new riparian and wetland habitat in areas underlain with peat is not recommended because of the high cost of building new levees on peat.

such opportunities. Setback levees could be considered along the edges of the Delta where mineral soil or thin, shallow peat layers are found.

The Levee Program seeks to minimize habitat-related conflicts with local maintenance agencies. Levee Program staff are working with Ecosystem Restoration Program staff and regulatory agency staff to determine whether a tool similar to the safe harbor policy as written in draft federal regulations can be developed as part of the CALFED conservation strategy. The AB 360 program has in place some "sustainable yield" routine maintenance agreements that implement "safe-harbor"-type provisions, and the Levee Program will seek broader application of these types of principles. Also, the inclusion of multi-use improvements, such as access roads or staging areas for local agencies on the levee sections, will be encouraged where feasible. These improvements will provide local agencies incentives to allow some vegetation growth on their levees. This coordination could benefit both levee maintenance efforts and habitat development.

CALFED Levee Program and Ecosystem Restoration Program staff coordinate with DFG staff, who have identified many potential restoration sites in the Delta. In addition, the Levee Program is working to coordinate the selection of Ecosystem Restoration Program levee habitat restoration sites with local residents who have greatest knowledge of the Delta terrain. A small task force, including representatives of North, Central, and South Delta Water Agencies; the Delta Protection Commission; and the National Heritage Institute assembled to identify attractive sites for habitat restoration. Their efforts resulted in a report titled, "Alternative Proposals for CALFED Ecosystem Restoration Program in the Delta." Appendix H, "Proposals for Ecosystem Restoration," presents this report in which possible Ecosystem Restoration Program/Levee Program coordination sites are identified.

In addition, the Levee Program made a public outreach effort, soliciting input from local landowners and reclamation districts in identifying desirable sites for Ecosystem Restoration Program/Levee Program coordination. Letters were sent to all Delta local agencies describing the program goals and asking for recommended locations to create the desired habitats along the levees. The Levee Program received several responses from local agencies. These responses included a proposal to use the dredger cut along the San Joaquin River reach on Webb Tract and to consider the levee on the southern edge of Faye Island for habitat development. The Levee Program and Ecosystem Restoration Program will consider the use of these sites, as well as the sites recommended by the task force for Levee Program/Ecosystem Restoration Program coordination.

The Levee Program made a public outreach effort, soliciting input from local landowners and reclamation districts in identifying desirable sites for Ecosystem Restoration Program/Levee Program coordination.

5. Permit Coordination

To ensure successful implementation of all CALFED programs, a coordinated permit process is being established. The process will anticipate the numerous permit requirements for actions approved as part of CALFED. Coordinated permitting will not result in relaxation of permitting requirements but will facilitate information sharing among regulatory agencies to refine the permitting process. The permit coordination framework also would be designed to address broad issues in order to improve the efficiency of such processes as general and regional permits, mitigation banks, and enhancement sites.

Coordinated permitting will not result in relaxation of permitting requirements but will facilitate information sharing among regulatory agencies to refine the permitting process.

Permit coordination for the Levee Program will be addressed under the umbrella of the CALFED permit coordination program. CALFED has attempted to incorporate broad stakeholder and agency input into development of that program. For example, the Levees and Channels Technical Team, a team of agency staff and stakeholders that provides technical input to the Levee Program, contributed to developing the program concerning current levee maintenance issues.

Table11 identifies the Levee Program permit coordination issues that will be included in the overall CALFED coordinated permit process.

In addition to providing input for the development of the coordinated permit process, the Levee Program seeks to resolve existing permit issues, where possible. A current issue of concern is dredge permitting. The ability to dredge is important because dredging maintains channel capacity for water supply and flood control, and dredged material is reused for levee construction as well as to create shallow-water habitat. Historically, the process of obtaining permits for levee and channel work has been problematic. A lack of staff resources has hindered the Regional Water Quality Control Board (RWQCB) in processing dredging permits. Processing times for individual dredge permits are long, sometimes over 1 year. Issuance of a general order for dredging by the RWQCB would greatly expedite the dredge permit process. The RWQCB has been unable to process a general order for dredging, which requires an EIR, due to lack of RWQCB resources as well as lack of scientific information. This lack of scientific information also causes the RWQCB to issue individual permits more conservatively (with greater restrictions).

The ability to dredge is important because dredging maintains channel capacity for water supply and flood control, and dredged material is reused for levee construction as well as to create shallow-water habitat.

The Levee Program and CALFED upper management are developing an administrative plan for CALFED to obtain a general order for WDRs that would apply to dredging and sediment reuse in the Delta for all CALFED implementation actions. Where possible, the Levee Program will promote opportunities for investigations, directed by federal and state water quality decision makers such as the RWQCB, that will provide scientific background for establishing guidelines by which maintaining agencies can dredge Delta channels. An

Table 11. Delta Levee Program Permit Coordination Issues

Areas of Concern

- Work windows for in-channel work developed by U.S. Fish and Wildlife Service and National Marine Fisheries Service (NMFS) as part of Section 7 federal involvement restrict and affect the maintenance of levees.
- Lack of real-time data prevents permit agencies from granting variances for work within the windows.
- The federal government (U.S. Environmental Protection Agency in coordination with the U.S. Army Corps of Engineers) recently released the "Inland Waters Testing Manual," which presents testing methodologies for in-water dredged material disposal. If the federal testing standards differ from the state standards, costs may increase due to additional testing requirements.
- The Regional Board requires testing of materials to be dredged, but a general order has not yet been issued. Uncertainty and lack of scientific information on applicable standards exist.
- The term "net habitat enhancement" as required by Assembly Bill 360 needs to be clearly defined.
- A clear definition of "impacting activities" is needed, and these activities need to be classified according to the level of impact (for example, minimal or substantial).
- Lack of agency staffing and frequent regulatory agency staff turnover hinder permit processing.
- Trust and team building are needed in permit coordination.
- The process of Endangered Species Act consultation is uncertain, including lack of NMFS/CALFED coordination, lack of established monitoring protocols, and potential impacts caused by monitoring.
- A suite of designs for allowable in-water work and monitoring is needed.
- Upper management support and oversight of the program are needed.

Avenues for Better Permit Coordination

- Memoranda of Understanding are desirable, such as the one between the State Lands Commission and local agencies that allows the districts to conduct dredging to obtain materials for levee maintenance under certain conditions.
- Multi-year and programmatic agreements are desirable.
- A system of centralized permit tracking is needed, including follow through for permit actions.

example of this is a current near-term ecosystem (Category III) focused grant for research that will address sediment toxicity.

The Levee Program has provided input and coordinated with members of the Delta Levees and Habitat Advisory Committee, DFG, and the near-term ecosystem restoration program in the design of this research project that will provide much-needed information regarding sediment toxicity and develop a comprehensive strategy for Delta sediments. Also, the Levee Program seeks to incorporate monitoring for sediment toxicity and sediment characterization into the CMARP (see later discussion under "Monitoring and Research").

6. Linkages

Many issues and concerns overlap between the Levee Program and other CALFED components, and between the Levee Program and ongoing programs of other agencies. The Levee Program strives to identify all possible connections and areas of overlap, to coordinate with other programs to the maximum possible extent for mutual benefit, and to ensure that Levee Program objectives do not conflict with other programs.

One issue of concern to the Levee Program, as well as to numerous agencies and stakeholders, is the need for a well-maintained common datum in the Delta.

One issue of concern to the Levee Program, as well as to numerous agencies and stakeholders, is the need for a well-maintained common datum in the Delta. A group composed of the U.S. Geological Survey, National Geodetic Survey, U.S. Bureau of Reclamation, DWR, and others recently completed efforts to establish a set of elevations in the Delta consistent with the National Vertical Datum (NAVD88) geodetic network for vertical control. The network consists of 100 benchmarks spaced at approximately 7 kilometers. The Levee Program is seeking ways to support tie-in to the common datum by Levee Program participants, as well as by agencies and other Delta interests.

Many linkages exist between the Levee Program and the Ecosystem Restoration Program. As discussed earlier, the Levee Program seeks to reduce the conflict between protection of wildlife habitat that occurs on levees and maintenance of the levees to prevent their failure. The Levee Program and the Ecosystem Restoration Program have collaborated extensively to develop strategies in order to minimize potential conflicts and to identify key areas where Ecosystem Restoration Program/Levee Program efforts can be coordinated. (For a detailed discussion of this issue, refer to the earlier section, "Ecosystem Restoration Program/Levee Program Coordination".) Another area of overlap between the Levee Program and the Ecosystem Restoration Program concerns efforts to reduce or reverse subsidence and actions to restore habitat. Both the Delta ecosystem and levee system stability can benefit from reducing land surface subsidence adjacent to levees. The creation of shallow-wetland habitat serves to reduce or reverse subsidence.

Dredge permitting is a common area of concern for several CALFED programs.

Dredge permitting is a common area of concern for the Levee Program, the Ecosystem Restoration Program, and the Water Storage and Conveyance Program. Dredge permitting issues addressed by the Levee Program (as discussed in detail in the "Permit Coordination" section) also affect the Ecosystem Restoration Program. The Ecosystem Restoration Program will require dredge permits in order to use dredged materials to create shallow-water habitat. Thus, the Levee Program's efforts to resolve dredge permitting issues also will benefit the Ecosystem Restoration Program.

Water quality and water supply reliability are closely tied to the integrity of the levee system. The consequences of a levee breach to water quality and water supply reliability can be catastrophic. Improvements to levee system integrity provided in the Levee Program also serve to provide better protection for water quality and water supply reliability. The Emergency Management and Response element of the Levee Program also will serve to better protect water quality and water supply reliability in the event of a levee breach by providing for a more immediate and organized response. An area of common concern for the Levee Program and Water Quality Program is toxicity of sediments and water quality impacts from dredging. Research advocated by the Levee Program to resolve dredge permitting issues also will provide useful information for the Water Quality program.

The consequences of a levee breach to water quality and water supply reliability can be catastrophic.

There are many significant linkages between levee system integrity and water storage and conveyance. Reservoir storage and levees function as a system with regard to flood control. CALFED proposals for setback levees are included in the Ecosystem Restoration Program and Water Storage and Conveyance Program. Hydraulic impacts on levees caused by construction of setback levees and other storage and conveyance modifications, such as changed operation of flow control structures, will be examined. The hydraulic impacts of levee maintenance and construction work included in the Levee Program will be examined on a project-specific basis. As with the Ecosystem Restoration Program and Water Quality Program, dredge permitting issues resolved by the Levee Program would benefit the Water Storage and Conveyance Program. The Water Storage and Conveyance Program will require dredge permits for dredging to increase channel capacities for conveyance and flood control. Thus, the Levee Program's efforts to resolve dredge permitting issue will also benefit the Water Storage and Conveyance Program.

Reservoir storage and levees function as a system with regard to flood control.

Levee system integrity also is linked to watershed management. Many proposed watershed management actions may reduce the risk of levee failures by moving the timing, variability, and duration of floodplain inundation and water table elevation closer to an undisturbed condition through meadow restoration and wetland development.

Many proposed watershed management actions may reduce the risk of levee failures by moving the timing, variability, and duration of floodplain inundation and water table elevation closer to an undisturbed condition through meadow restoration and wetland development.

In addition to coordination with other CALFED programs, the Levee Program is working in conjunction with efforts outside CALFED, where feasible. The Levee Program is working in coordination with the Corps on a "Delta Special Study" that will address rehabilitation and improvement of levees in the Delta. These coordination efforts could develop into a long-term Delta levee reconstruction program, with cost-sharing agreements among the Corps, State, and local agencies.

CALFED also is coordinating with the Corps and the Board in their efforts on the "Sacramento-San Joaquin River Basins Comprehensive Flood Control Study" currently under way. Because the comprehensive flood control study area includes major tributaries into the Delta, CALFED actions need to be compatible with all comprehensive study actions.

The Levee Program has been communicating with representatives of the Long-Term Management Strategy (LTMS) Program to identify areas where coordination between the programs would be beneficial. The LTMS Program was launched in the Bay area to identify technically feasible and environmentally acceptable dredging and disposal options, and to develop a research program leading to a long-term management plan for dredging and disposal in the Bay Area. Information sharing between the two programs is beneficial in that the programs face many similar regulatory issues. In addition, many areas of technical information overlap, although the usefulness of the LTMS Program data to CALFED is limited by the greater salinity of the LTMS program environment. The Levee Program also has considered the use of dredged materials from the LTMS Program for levee construction and subsidence control.

7. Adaptive Management

Adaptive management is a fundamental concept of CALFED. For the Levee Program, adaptive management is in part a philosophical approach toward implementing some Levee Program actions in that it acknowledges that a better understanding of Levee Program issues is needed to succeed in program implementation. Adaptive management is also a structured decision-making process that includes monitoring, research, staged implementation of the program; a feedback process to integrate knowledge gained from monitoring and research; and the flexibility to change the program in response to new information. Under adaptive management, actions are designed, at least in part, to provide new information about the system. Areas where the adaptive management approach will be especially useful in Levee Program implementation include seismic risk assessment, subsidence, and levee and ecosystem restoration coordination. All of these issues are components of the CMARP (refer to later discussion of the CMARP under "Monitoring and Research").

A better understanding of Levee Program issues is needed to succeed in program implementation.

Adaptive management also may be relevant in institutional arrangements and funding scenarios for levee construction and maintenance. For example, the Levee Program will use information gained from observing the successes and shortcomings of the current Delta Levee Subventions and Special Projects Programs to develop funding and administrative scenarios for levee maintenance and construction covered under the Levee Program. As conditions change in the Delta and more is learned about the system and how it responds to program actions, these actions may be adjusted to ensure that Levee Program objectives are met and the solution is durable.

8. Monitoring and Research

Monitoring and research are key inputs to CALFED's adaptive management process. Monitoring gauges the success of individual Levee Program actions and provides feedback necessary for successful Levee Program implementation. Research also will provide information necessary for successful Levee Program implementation. Levee Program monitoring and research will be developed largely within the context of the CMARP, which is developing a comprehensive monitoring, assessment, and research program for CALFED as a whole. A panel of experts with a collective technical experience representative of all the different elements of the Levee Program has convened to develop the Levee Program component of the CMARP. Levee program monitoring and research under the CMARP will address monitoring for levee cross section compliance, subsidence, seismic activity, and success of environmental mitigation, as well as research on sediment toxicity and characterization. The CMARP will coordinate with existing programs such as the San Francisco Estuary Institute, Interagency Ecological Program, and LTMS to avoid duplication in developing research and monitoring efforts, and to build on existing monitoring and research programs where possible (for a more complete discussion of the CMARP effort, see the CMARP document).

Levee Program monitoring and research will be developed largely within the context of the CMARP.

In addition, the Levee Program is coordinating with the current near-term ecosystem (Category III) focused grant for research that will address sediment toxicity. The Levee Program has provided input and coordinated with members of the Delta Levees and Habitat Advisory Committee, DFG, and the near-term ecosystem restoration program in the design of this research project that will provide much needed information regarding sediment toxicity and develop a Comprehensive Strategy for Delta sediments.

9. Cost Estimate

The following preliminary costs include estimates for all elements of the Levee System Integrity Program Plan. (Refer to the "Funding" section and Appendix B, "Cost Estimate Backup and Report" for additional information.)

9.1 DELTA LEVEE BASE LEVEL PROTECTION PLAN

This estimate is for the total cost to rehabilitate and maintain project and non-project levees in the legal Delta up to the PL 84-99 standard. The estimate assumes that major rehabilitation or reconstruction work will be performed on approximately 520 of the 1,100 miles of levee in the Delta. The remaining levees are assumed to meet or exceed the PL 84-99 standard. Seismic stability upgrades are not included in the Base Level Protection Plan, although some minor reduction in levee fragility is expected. The estimate includes costs for engineering planning and design; geotechnical analyses; construction inspection; contract administration; obtaining environmental permits and dealing with regulatory requirements; funding for the CMARP-related costs; erosion protection; environmental mitigation; maintenance; an overall contingency; and lands, easements, rights of way, relocations, and disposal areas (LERRDS).

The estimate assumes that major rehabilitation or reconstruction work will be performed on approximately 520 of the 1,100 miles of levee in the Delta.

Because unit costs of Delta levee work vary substantially, a low and high cost estimate were provided to evaluate projects. The preliminary cost estimate to achieve the base level protection ranges from $600 to $1,300 million.

9.1.1 ASSUMPTIONS:

The estimate assumes that:

- A majority of the design, construction, and right-of-way acquisition will be accomplished with local resources.

- Local borrow is readily available on the islands and beneficial reuse of dredged materials will be maximized where economically feasible.

9.2 DELTA LEVEE SPECIAL IMPROVEMENT PROJECTS

The preliminary cost estimate to add Special Improvement Projects is $360 million. The estimate is based on DWR Central District's request for approximately $12 to $15 million a year to support Special Projects. Central District has been requested to provide additional information on scope, schedule, and costs. Special Improvement Projects could include seismic stability upgrades to selected levees.

Special Improvement Projects could include seismic stability upgrades to selected levees.

9.2.1 ASSUMPTIONS:

The estimate assumes that:

- Special improvement projects will enhance the base level flood control improvements.
- A majority of the design, construction, and right-of-way acquisition will be accomplished with local resources.
- Local borrow is readily available on the islands.
- Beneficial reuse of dredged materials will be maximized.

9.3 DELTA LEVEE SUBSIDENCE CONTROL

The primary cost estimate for subsidence control and management is $70 million.

9.3.1 ASSUMPTIONS:

The estimate assumes that:

- Subsidence projects will be directed at control and management of subsidence as it affects levee system integrity.
- Subsidence control measures will be incorporated with base level and Special Improvement Projects to upgrade levees.
- A majority of the design, construction, and right-of-way acquisition will be accomplished with local resources.
- Local borrow is readily available on the islands.

- Beneficial reuse of dredged materials will be maximized where economically feasible.

9.4 DELTA LEVEE EMERGENCY MANAGEMENT AND RESPONSE PLAN

The preliminary cost estimate for the Emergency Management and Response element is $68 million.

9.4.1 ASSUMPTIONS:

The estimate assumes that:

- Emergency management and response will be accomplished through existing programs.
- A $10 million emergency response fund will be established and maintained.

The estimate assumes that emergency management and response will be accomplished through existing programs.

9.5 DELTA LEVEE SEISMIC RISK ASSESSMENT

The preliminary cost estimate for continuing the Seismic Risk Assessment element is $5 million.

9.5.1 ASSUMPTIONS:

The estimate assumes that:

DWR will continue to lead the evaluation of seismic risk.

- Projects and research will include updates to area seismicity, evaluation of ground motion response, determination of soil parameters, and continuous site monitoring.

DWR will continue to lead the evaluation of seismic risk.

10. Funding

The Levee Program funding model must be consistent with the CALFED benefits-based approach to funding. The benefits of improved Delta levee system integrity include greater protection to Delta agricultural resources, municipalities, infrastructure, wildlife habitat, and water quality as well as navigation and flood control benefits. A funding model that includes federal, state, and local contributions allows costs to be shared by all beneficiaries.

A funding model that includes federal, state, and local contributions allows costs to be shared by all beneficiaries.

The proposed funding provisions outlined herein are those recommended to CALFED by the CALFED Levees and Channels Technical Team. CALFED staff will use this recommendation to prepare a benefits-based funding recommendation for approval by the CALFED Policy Group.

The Levee System Integrity Program Plan will be implemented over a period of 30 years or more, at an estimated cost of $1.5 billion (1998 $). This cost is based on the detailed cost estimate for the Base Level Protection Element provided in Appendix B, "Cost Estimate Backup and Report," and cost estimates for all program elements discussed in the "Cost Estimate" section. Based on the current estimate, the funding in 1998 dollars will be approximately distributed as follows:

Base Level Protection	$1,000 million
Special Improvements Projects	360 million
Subsidence Control	70 million
Emergency Management and Response	68 million
Seismic Risk Assessment	$ 5 million
	$1,503 million

This funding does not include any funds required to implement the CMARP Program. The following problems related to funding the existing levee program will be addressed by the Levee Program:

Reliable near- and long-term funding is paramount to the success of the Levee Program.

- Funding for levee work is insufficient and inconsistent. Reimbursement to local agencies often is delayed, made at an insufficient rate, or not made at all—leaving bank loans, engineers, and contractors unpaid.

- Many local agencies cannot afford their share of costs under the current cost-sharing arrangements for levee work, much less the additional financial burden of proposed levee upgrades.

Reliable near- and long-term funding is paramount to the success of the Levee Program. Lack of adequate funding for levee maintenance and construction will impede the success of the Base Level Protection Plan and other elements of the Levee Program. For example, the success of the emergency response component of the program partially depends on the existence of an industry in the Delta to provide needed equipment for emergency response. It is assumed that continued funding for the Levee Program will recreate such an industry in the Delta so that these resources will be readily available when needed.

The Levee Program will obtain long-term federal and state funding authority, and develop appropriate cost-sharing scenarios between state, federal, and other interests. In developing funding models, the Levee Program will build on the strengths of, and seek continuity with, existing funding programs such as the Subventions Program and Special Projects Program. In addition, the Levee Program will seek to resolve problems in current funding strategies and identify mechanisms that best secure long-term funding.

Under the existing state levee programs, local agencies have financed projects in anticipation of reimbursements. The Subventions Program annually administers available funds, distributing funds on an equal basis to all participants in accordance with funding priorities approved by the Board. Each fiscal year, local agencies are notified of the available funding but cannot be sure what their final reimbursement will be until all claims are received and processed.

The uncertainty and time lag from work performance to reimbursement poses financial difficulties for many local agencies, as most districts lack the financial resources to provide funds up-front for an extended period. In some cases, the agencies incur high debt service charges or must delay payments to contractors. Consequently, contractors' reluctance to perform levee work drives up costs.

The uncertainty and time lag from work performance to reimbursement poses financial difficulties for many local agencies, as most districts lack the financial resources to provide funds up-front for an extended period.

The Special Projects Program receives applications and enters into agreements with participants to fund specific projects. Projects eligible for funding must be in accordance with priorities approved by the California Water Commission. Once projects are deemed eligible, agreements are executed and local agencies can receive timely payments as work progresses. The lack of adequate and consistent appropriations in the Subventions and Special Projects Programs poses a challenge for local agencies to complete planned maintenance and rehabilitation projects.

Additionally, many districts have experienced difficulty in rebounding from the long-term financial debt that was incurred while they waited for resolution of the 1980-1986 state and federal disaster assistance claims. The more recent 1995, 1997, and 1998 floods also have strained local financial resources. The overall financial health of these local agencies has significantly affected their ability to maintain their levee systems and limited their ability to upgrade their levees to a long-term levee standard.

Any of these funding issues can deter performance of adequate levee work. Therefore, the Levee Program will seek a means to provide up-front state and federal contributions for levee work. Adequate funding will enable districts to plan and finance their work with greater certainty of reimbursement. The Levee Program will work in conjunction with other programs to negotiate mutually beneficial funding arrangements. For instance, California Water Code Section 12995 indicates a federal interest in Delta levee rehabilitation due to benefits to navigation, commerce, and the environment and increased flood control.

The Levee Program will seek a means to provide up-front state and federal contributions for levee work.

The following principles also will guide development of Levee Program funding:

- Local agencies will provide LERRDS. Use of local sources is cost effective and allows maintenance work to proceed more smoothly. Local agencies will continue to ensure that costs are distributed equitably among their members.
- The Ecosystem Restoration Program will provide funds for net habitat enhancement requirements under current statutes, and the Levee Program will fund all mitigation necessary for levee construction.
- Funds for any necessary mitigation for levee construction work are included in the overall cost for the Levee Program. Federal, state, and local cost-sharing percentages include mitigation costs.
- The Levee Program will pursue long-term authority for state and federal funding for these cost-sharing scenarios. This will involve amending the sections of the California Water Code that pertain to Delta levee maintenance and construction funding. The Levee Program also will seek a mechanism to provide up-front funding to the local agencies.

10.1 DELTA LEVEE BASE LEVEL PROTECTION PLAN FUNDING

10.1.1 CURRENT FUNDING PROVISIONS

As discussed earlier, current programs that fund levee maintenance and construction often are insufficient or inconsistent. Many Delta interests cannot afford their share of costs under the current programs, much less the additional financial burden of proposed levee upgrades. Problems with current funding provisions are discussed under "Delta Levee System Integrity–Problem Statements."

> Many Delta interests cannot afford their share of costs under the current programs, much less the additional financial burden of proposed levee upgrades.

Levee work is currently funded up front by the local agencies and reimbursed up to 75% by the State through DWR under the Subventions Program. California Water Code Section 12300 authorizes $6 million a year to be appropriated to the Delta Flood Protection Fund from the California Water Fund for the Subventions Program until July 1, 2006. Historically, less has been appropriated yearly. No funds are currently appropriated for the program past June 30, 1999.

10.1.2 PROPOSED FUNDING PROVISIONS

The Base Level Protection element will incorporate the levees currently covered under the existing Subventions Program. Proposed cost sharing for the Base Level Component will be 65% federal/ 25% state/ and 10% local for construction to PL 84-99. Local agencies can contribute LERRDs toward their 10% share. Planning costs will be cost shared at 50% federal/ 25% state/ 25% local. Funding for maintenance will be provided 100% by the local agencies up to $1,000 per mile of levee improvement. Costs above $1,000 per mile of levee improvement will be cost-shared 65% federal/ 25% state/ and 10% local, and will be considered reconstruction. Summaries of cost sharing and approximate state, federal, and local dollar contributions for the Base Level Protection element are included in Tables 12 and 13.

Table 12. Proposed Levee Program 7-Year Cost Sharing

	Base Level Protection Plan Funding/Year[a]				Special Projects Funding/Year[c]				Emergency Response[d]				
Year(s)	Fed	State	User[b]	Sub-total	Fed	State	User[b]	Sub-total	Fed	State	User[b]	Sub-total	Total Funding
1	5	3	2	10	7	5	0	12	5	5	1	11	33
2	6	3	2	11	7	5	0	12	1	1	1	3	26
RAMP 3	7	4	2	13	7	5	0	12	1	1	1	3	28
RAMP 4	9	5	3	17	7	5	0	12	1	1	1	3	32
RAMP 5	11	5	4	20	7	5	0	12	1	1	1	3	35
↓ 6	22	11	7	40	7	5	0	12	1	1	1	3	55
7	22	11	7	40	7	5	0	12	1	1	1	3	55
Totals	**82**	**42**	**27**	**151**	**49**	**35**	**0**	**84**	**11**	**11**	**7**	**29**	**264**

Notes:

Funding in millions (1998 $). Totals are rounded to the nearest million.

[a] Includes subsidence control funding.
[b] User to provide lands, easements, rights-of-way, relocations, and disposal areas.
[c] Includes Levee Risk Assessment.
[d] Includes $10 million first-year start-up costs.

10.2 DELTA LEVEE SPECIAL IMPROVEMENT PROJECT FUNDING

10.2.1 CURRENT FUNDING PROVISIONS

Problems with current funding provisions are similar to those described for the Base Level Protection element.

Cost-sharing percentages under the existing Special Projects Program vary from 75 to 100% state funds, depending on "ability-to-pay" analysis completed for each participating local agency. Although no federal cost-sharing agreements exist for the Special Projects Program, the California Water Code encourages DWR to seek cost sharing with, or financial assistance from, federal agencies with programs applicable to or an interest in flood protection projects. California Water Code Section 12300 authorizes $6 million a year to be appropriated to the Delta Flood Protection Fund from the California Water Fund for the Special Projects Program until July 1, 2006. Historically, less has been appropriated yearly. As with the Base Level Protection element, no funds are currently appropriated for the program past June 30, 1999.

Table 13. Levee System Integrity Program Proposed Cost Sharing

Program Action	Federal	State	User [a]
Base Level Protection and Subsidence Control			
Planning [b]	50%	25%	25%
Construction [c]	65%	25%	10%
Maintenance [d]	0%	0%	All costs (up to $1,000/mile)
Special Improvement Projects			
Planning [b]	50%	50%	To be determined
Construction [c]	65%	35%	To be determined
Maintenance [d]	0%	100%	To be determined
Emergency Management and Response			
First response	0%	0%	100% (exhaust resources)
Secondary response	50%	50%	LERRDs

Notes:

LERRD = Lands, easements, right-of-way, relocations, and disposal areas.

[a] Subject to an "ability to pay analysis."
[b] Planning includes feasibility studies, environmental documentation, and obtaining permits.
[c] Construction is defined as eligible levee work above $1,000/mile.
[d] Maintenance includes routine preventative actions up to $1,000/mile.

10.2.2 PROPOSED FUNDING PROVISIONS

The Special Improvements Project element will adopt the goals of the existing Special Projects Program. Funding for this element of the Levee Program will be cost shared at 65% federal/ 35% state. The State will seek a local cost-sharing partner. If a local cost-sharing partner is found, the cost-sharing will be the same as that for the Base Level Protection Element. Summaries of cost sharing and approximate state, federal, and local dollar contributions for the Special Projects Program are shown in Tables 12 and 13.

10.3 DELTA LEVEE SUBSIDENCE CONTROL PLAN FUNDING

10.3.1 CURRENT FUNDING PROVISIONS

No existing formal separate program provides funding for subsidence; however, subsidence research currently is funded under the existing Special Projects Program.

10.3.2 PROPOSED FUNDING PROVISIONS

Funding for the Subsidence Control element of the Levee Program will be cost shared at 65% federal/ 25% state/ and 10% local. Local agencies will contribute necessary LERRDS in addition to the 10% share. Summaries of cost sharing and approximate state, federal, and local dollar contributions for the Subsidence Control Program are shown in Tables 12 and 13.

10.4 DELTA LEVEE EMERGENCY MANAGEMENT AND RESPONSE PLAN FUNDING

10.4.1 CURRENT FUNDING PROVISIONS

No existing formal program provides funding for initial emergency response, which is provided by local resources. The State provides assistance and funding when local resources are exhausted. If the governor declares an emergency and requests emergency assistance, federally funded emergency assistance is provided.

No existing formal program provides funding for initial emergency response, which is provided by local resources.

10.4.2 PROPOSED FUNDING PROVISIONS

Funds for the Emergency Management and Response element will be provided 100% by local interests for initial response. After local resources have been exhausted, secondary response funds will be cost shared at 50% federal/50% state. After the established State funds are exhausted, funding will be 100% federal. First-year start-up costs to establish a $10 million Emergency Response Fund will be cost shared at 50% federal/50% state. After the Emergency Response Fund is exhausted, the Federal Government will provide funds through the Corps. Local agencies will contribute any necessary LERRDS. Summaries of cost-sharing and approximate state, federal, and user dollar contributions for the Emergency response element are shown in Tables 12 and 13. The user contribution assumes that the annual initial response is $1 million.

10.5 DELTA LEVEE RISK ASSESSMENT FUNDING

10.5.1 CURRENT FUNDING PROVISIONS

DWR currently funds a Seismic Stability Evaluation for Delta levees.

10.5.2 PROPOSED FUNDING PROVISIONS

CALFED has expanded the scope of this element to include all major risks, not only seismic risks. CALFED will use existing planning funds to develop this Risk Assessment and Risk Management Strategy, which is considered a necessary part of CALFED's overall program development.

CALFED has expanded the scope of this element to include all major risks, not only seismic risks.

11. Stakeholder/Science Review

Implementation of the Levee Program will require regular input from stakeholders, the technical community, and the public. A Levee Program Coordination Group would be formed at the beginning of Stage 1 implementation to coordinate technical and non-technical issues between the CALFED Advisory Council and the CALFED Policy Group. The Group would also coordinate levee actions with all other CALFED actions. The composition of the Group is illustrated in Table 14.

Implementation of the Levee Program will require regular input from stakeholders, the technical community, and the public.

Table 14. Composition and Roles of the Levee Program Coordination Group

CALFED Staff/Agency/Stakeholder	Role
Staff	
Levee Program	Chair meetings, coordinate: funding, permits, policy, project priorities, conflict resolution, and project performance; report to Policy Group
Ecosystem Restoration Program	Coordinate Ecosystem Restoration Program actions with levee and conveyance actions
Conveyance	Coordinate conveyance actions with Levee and Ecosystem Restoration Program actions
Comprehensive Monitoring, Assessment, and Research Program (CMARP)	Coordinate CMARP levee actions with other CMARP actions
Agency	
California Department of Fish and Game (DFG)	Coordinate DFG permits and levee maintenance agreements
U.S. Fish and Wildlife Service (USFWS)	Coordinate USFWS permits and levee maintenance agreements

Table 14. Composition and Roles of the Levee Program Coordination Group (continued)

CALFED Staff/Agency/Stakeholder	Role
Agency (continued)	
National Marine Fisheries Service (NMFS)	Coordinate NMFS permits
Central Valley Regional Water Quality Control Board (CVRWQCB)	Coordinate water quality certification for dredging and water-side work
California Department of Water Resources (DWR)	Represent the Reclamation Board, coordinate Levee Program administration
DWR	Coordinate Comprehensive Study
DWR	Represent DWR, coordinate emergency response actions
U.S. Army Corps of Engineers (Corps)	Represent the Corps on non-regulatory implementation issues
Corps	Coordinate Comprehensive Study
Corps	Coordinate Corps permits for dredging, beneficial reuse, and levee work
Delta Protection Commission (DPC)	Coordinate Levee Program actions with DPC Delta Resources Management Plan
Stakeholder	
Environmental	Coordinate Levee Program actions with environmental interests concerns
Water exporters - State Water Project (SWP)	Coordinate Levee Program actions with SWP contractors concerns
Water exporters - Central Valley Project (CVP)	Coordinate Levee Program actions with CVP contractors concerns
Delta interests - North Delta Water Agency (NDWA)	Coordinate Levee Program actions with in-Delta water user concerns
Delta interests - Central Delta Water Agency (CDWA)	Coordinate Levee Program actions with in-Delta water user concerns
Delta interests - South Delta Water Agency (SDWA)	Coordinate Levee Program actions with in-Delta water user concerns

12. Implementation Strategy

The Levee Program objective is to reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees. The vulnerability of the levee system to both static and dynamic failure can be reduced by implementing an integrated and comprehensive management program for levees.

The vulnerability of the levee system to both static and dynamic failure can be reduced by implementing an integrated and comprehensive management program for levees.

Implementation objectives, targets, and actions for the individual Levee Program elements are presented in Tables 2, 4, 6, 7, and 8.

Staged implementation and staged decision making will be part of the implementation strategy as they support the adaptive management process (refer to the discussion under "Adaptive Management"). The program will be implemented in stages according to major program milestones. Stage 1 is 7 years long, will start in 2000, and includes the following actions:

1. Develop and implement an outreach, coordination, and partnering program with local landowners, including individuals, local agencies, resource conservation districts, water authorities, irrigation districts, farm bureaus, and other local agencies to ensure local participation in planning design, implementation, and management of levee projects. (Year 1.)

2. Obtain short-term federal and state funding authority as a bridge between the existing Delta Flood Protection Authority (AB 360) and long-term levee funding. (Years 1-5.)

3. Obtain long-term federal and state funding authority (e.g., the Corps' current "Delta Special Study" could develop into a long-term Delta levee reconstruction program and the State would be the local cost-sharing partner). (Years 1-7.)

4. Conduct project level environmental documentation and obtain appropriate permits for each bundle (package) of Stage 1 actions. (Years 1-7.)

5. Implement demonstration projects for levee designs that minimize the need for continuous disruption of habitat from levee maintenance and minimize the need for ongoing mitigation from disrupted habitat. (Years 1-7.)

6. Coordinate Delta levee improvements with ecosystem restoration improvements (e.g., coordinate improvements, modify maintenance manuals as appropriate to accommodate Ecosystem Restoration Program actions near levees, and separately

track levee mitigation costs and Ecosystem Restoration Program costs). (Years 1-7.)

7. Fund levee improvements up to the PL 84-99 standard, approximately $151 million ($71 million during Years 1-5 and $80 million during Years 6-7) in Stage 1 (e.g., proportionally distribute available funds to entities making application for cost sharing of Delta levee improvements). (Years 1-7.)

8. Further improve levees with significant statewide benefits, approximately $84 million ($60 million during years 1-5 and $24 million during Years 6-7) in Stage 1 (e.g., improve levees with statewide benefits to ecosystem, water supply, economy, water quality, and infrastructure). (Years 1-7.)

9. Coordinate Delta levee improvements with Stage 1 water conveyance improvements and with potential conveyance improvements in subsequent stages. (Years 1-7.)

10. Enhance existing emergency response plans, approximately $29 million in Stage 1 (e.g., establish a $10 million revolving fund, continue to refine command and control protocol, stockpile flood-fighting supplies, establish pre-negotiated contracts for flood-fighting and recovery operations, and outline environmental considerations during an emergency). (Years 1-7.)

11. Implement current BMPs to correct subsidence effects on levees. Develop and implement BMPs to facilitate CALFED objectives. Assist CMARP activities to quantify the effect and extent of inner-island subsidence and its linkages to all CALFED objectives. (Years 1-7.)

12. Complete total risk assessment for Delta levees and develop and begin implementation of risk management options as appropriate to mitigate potential consequences. (Years 1-7.) Available CALFED risk management options may include:

    - Improving emergency response capabilities,
    - Developing storage south of the Delta,
    - Reducing the fragility of the levees,
    - Improving through-Delta conveyance,
    - Releasing more water stored north of the Delta,
    - Restoring tidal wetlands,
    - Controlling and reversing island subsidence,
    - Curtailing Delta diversions,
    - Continuing to monitor and analyze total risk, and
    - Constructing an isolated facility.

Knowledge gained from monitoring and research will be incorporated into staged implementation and decision making through a feedback process as part of adaptive management. The CMARP will play a key role in the adaptive management approach to Levee Program implementation.

Knowledge gained from monitoring and research will be incorporated into staged implementation and decision making through a feedback process as part of adaptive management.

Other key points for Levee Program implementation include:

- The Levee Program will need to coordinate and provide a reliable funding source for the planning, regulatory, and permitting processes that affect the levee system.

- The Levee Program will be built on a foundation of existing state, federal, and local laws and agency programs. The Levee Program will supplement and improve these existing programs, eliminate deficiencies, and enhance opportunities to improve levee system integrity.

- In keeping with CALFED's commitment to concurrently make broad improvements in many areas, every effort will be made to integrate Levee Program actions in such a way as to provide opportunities for resolution of multiple problems in the Delta and to coordinate Levee Program actions with other CALFED actions. Levee improvements will be coordinated with ecosystem restoration and conveyance improvements to protect existing Delta characteristics and processes.

Every effort will be made to integrate Levee Program actions in such a way as to provide opportunities for resolution of multiple problems in the Delta and to coordinate Levee Program actions with other CALFED actions.

- The Levee Program will seek to reduce conflicts where possible.

- Implementation of Stage 1 actions is contingent on successful completion of appropriate environmental documentation.

13. Suisun Marsh Levee System

CALFED has added the Suisun Marsh levee system to the Levee Program to achieve ecosystem quality, water supply reliability, and water quality objectives. Efforts to clarify linkages of these actions to the CALFED objectives are ongoing and will be completed during early Stage 1 as listed in the CALFED Implementation Plan.

Ensuring the integrity of the exterior levees in the Suisun Marsh is critical to sustaining seasonal wetland values provided by the marsh's managed wetlands. Improved levees would ensure that conversion to tidal wetlands will not be due to levee failure but instead will be planned with consideration of landowner support Ecosystem Restoration Program targets, regional wetland goals, endangered species recovery plans, and Delta water quality objectives.

Continued management of the Suisun Marsh for waterfowl and recreational activities is threatened by periodic flooding and the problem of maintaining a proper salt balance.

13.1 INTRODUCTION

The Suisun Marsh consists of approximately 57,000 acres of marshland and 27,000 acres of bays and waterways. Waterways include a network of tidal sloughs, principally tributaries of Suisun and Montezuma Sloughs, together with many drainage sloughs. Major streams carrying runoff from surrounding hills and floodplains include Green Valley, Suisun, Ledgewood, Laurel, McCoy, Union, and Denverton Creeks.

The Suisun Marsh is one of the few major marshes remaining in California and furnishes habitat for a variety of plants and animals. The Suisun Marsh serves as a principal waterfowl wintering area and also is highly valued for fishing and recreation. Despite reclamation improvements in the late 1800s and early 1900s, agricultural development in the Suisun Marsh has been largely unsuccessful due to poor drainage and salt accumulation in the soil. Limited cattle production and dry farming of grain crops occurs today where suitable soils exist. For the most part, however, the marshlands have been converted to private duck clubs and state wildlife management areas. Continued management of the Suisun Marsh for waterfowl and recreational activities is threatened by periodic flooding and the problem of maintaining a proper salt balance.

The Suisun Marsh is an area of regional and national importance, providing a broad array of benefits that include recreation use and fish and wildlife habitat. The Suisun Marsh's approximately 229 miles of exterior levees are an integral part of its landscape and are key to preserving the Suisun Marsh's physical characteristics and processes.

The focus of the Suisun Marsh component of the Levee Program is to provide long-term protection for multiple Suisun Marsh resources by maintaining and improving the integrity of the Suisun Marsh levee system. The Suisun Marsh component of the Levee Program focuses on the legally defined Suisun Marsh.

13.2 BACKGROUND INFORMATION

Most of the Suisun Marsh land surface elevations are below sea level. Suisun Marsh levees are vulnerable to failure, especially during floods, because of poor levee construction and inadequate maintenance.

Most of the Suisun Marsh land surface elevations are below sea level. Suisun Marsh levees are vulnerable to failure, especially during floods, because of poor levee construction and inadequate maintenance.

A chronological summary of reclamation and water management activities that influenced the current Suisun Marsh is provided in Table 15. AB 360 currently includes only selected exterior levees in the Suisun Marsh.

Inundation of one or more islands in the Suisun Marsh can disrupt wildlife habitat and other land uses either permanently or until repairs can be made. Inundation of roads, electric power lines, telephone lines, gas mains, and other infrastructure can cause lengthy delays in service. Several Suisun Marsh roads run along levees that are vulnerable to collapse due to erosion or overtopping. If a flooded island is not repaired and drained, the resulting large body of open water can expose adjacent islands to increased wave action and additional seepage.

Table 15. Chronological Summary of Events Important to the Suisun Marsh

Time	Event
1850s	Settlers began to build low sod levees to "reclaim" tidal wetlands in the Suisun Marsh for agricultural uses.
1860s	Levee construction increased and over 20 reclamation districts were formed in the Suisun Marsh.
1930	By this date, approximately 44,600 acres of tidal wetlands had been converted to commercial agricultural purposes in the Suisun Marsh.
1950s	By this date, the majority of the diked lands in the Suisun Marsh had been converted from agriculture to seasonal managed wetlands and duck clubs.
1972	Passage of the Federal Coastal Zone Management Act.
1977	Passage of the Suisun Marsh Preservation Act triggered a series of actions to more aggressively protect the Suisun Marsh and its fish and wildlife values.

Preliminary modeling studies of the Suisun Marsh indicate that levee failure in the Suisun Marsh may affect western Delta channel water quality. Modeling studies currently are being refined.

13.3 COST ESTIMATE

Most of the Suisun Marsh lies at a level near or below mean tide elevation. To protect marshland from uncontrolled tidal inundation and flooding, levees have been added over the years to supplement the natural levees throughout the Suisun Marsh. Approximately 90% of the marshland now is enclosed by a system of low levees, ranging in height from 4 to 8 feet above ground level. This system of levees is critical to the management of water quality and waterfowl habitat in the Suisun Marsh.

Approximately 90% of the marshland now is enclosed by a system of low levees, ranging in height from 4 to 8 feet above ground level. This system of levees is critical to the management of water quality and waterfowl habitat in the Suisun Marsh.

To prepare estimates, the levee classification strategy developed by Ramlit (1983) was used. This report is entitled "Suisun Marsh Levee Evaluation" and was submitted to the Corps, San Francisco District in February 1983. The levee types and classes used in the following discussion are based on the Ramlit evaluation. Levees were identified according to adjacent waterways and grouped in the following classes:

- Class I. Nine exterior levees protecting all islands and along primary sloughs (Montezuma, Suisun, and Nurse).
- Class II. Exterior levees along all secondary sloughs (Goodyear, Cordelia, and Hill).
- Class III. Dead-end sloughs (Wells, Sheldrake, and Boynton).

Levees also were classified based on the extent of the repairs that would be needed to bring them to Suisun Resource Conservation District (SRCD) standards. Type A levees required the most significant reconstruction effort and could entail the use of imported fill and phased construction. Type D levees would require only limited amounts of repair. Approximately one-third of the Suisun Marsh levees were classified as Type A levees.

The following preliminary cost estimates are for the Suisun Marsh Levee Base Level Protection Plan and the Suisun Marsh Levee Special Improvement Projects Plan without Ecosystem Restoration Program Plan actions.

The estimate is for the total cost to reconstruct Class I A, B, C, and D, and Class II A and B levees in the Suisun Marsh up to the SRCD standard. This estimate assumes work will be performed on approximately 155 of the 229 miles of levee in the Suisun Marsh. The estimate includes costs for design, construction, and LERRDS.

The cost estimate assumes work will be performed on approximately 155 of the 229 miles of levee in the Suisun Marsh.

Methods to prepare the cost estimates focused primarily on the unit costs estimated by Ramlit (1983). Those costs were updated using indices from the Engineering News Record to account for inflation and construction cost increases. Tables 17 and 18 in the Ramlit evaluation were used to calculate the cost estimates for the Suisun Marsh Levee Base Level Protection Plan and Suisun Marsh Levee Special Improvement Projects Plan.

A summary of rehabilitation costs by general waterway classes is given in Table 17. Levees along Class I waterways represent the bulk of the total estimated repair cost (71%). Repair costs for levees on Class II and III waterways amount respectively to 18% to 11% of the total.

Table18 provides a breakdown of estimated costs according to the five general levee types. The percentage of total rehabilitation costs attributable to each levee type are as follows: Type A - 36%; Type B - 8%; Type C - 50%; and Type D - 6%.

The preliminary cost estimate for rehabilitating 155 miles of levees in the Suisun Marsh is estimated at $60 million (all costs are at March 1998 price level).

13.4 ANNUAL MAINTENANCE

The preliminary cost estimate for annual maintenance costs for the 229 miles of exterior levees was computed at approximately $350,000.

13.5 ASSUMPTIONS

The estimate assumes that:

- Quantities are based on a "typical" levee section for existing levees and proposed levee improvement cross sections.
- A majority of the design, construction, and right-of-way acquisition will be accomplished with local resources.
- Beneficial reuse of dredged materials will be maximized.

These estimates are preliminary, and are being developed and evaluated at a programmatic level. CALFED staff is continuing to refine these costs. More focused analysis and detailed estimates will occur in subsequent refinement efforts.

These estimates are preliminary, and are being developed and evaluated at a programmatic level.

13.6 FUNDING

Under the proposed program for the Suisun Marsh, funding would be provided and equitably distributed to federal and state governments, and participating local agencies or public wetland managers such as DFG.

FIGURES

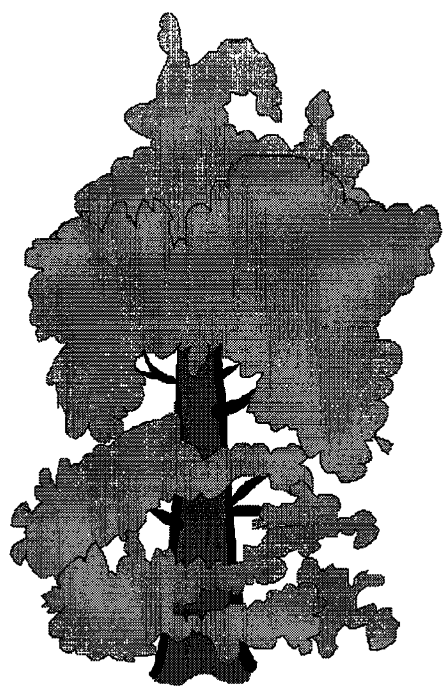


Figure 5

Possible Strategies for Levee and Habitat Improvements

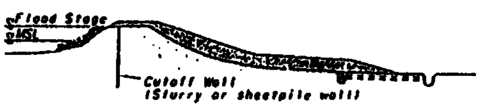
LEVEE IMPROVEMENT EXAMPLES	PURPOSE	APPLICABLE AREAS	POSITIVES	NEGATIVES
 A. Placement of Fill on Levee Crown and Landside Slope in Firm Mineral Soil Foundation Areas	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path.	Firm foundation areas, generally located in outer fringes of Delta and on old stream channels filled with mineral soils.	a. Levee structural stability is improved. b. Levee improvements stay within general footprint of existing levee and drain ditch. c. Relatively easily maintained as a flood control levee. d. Provides small increase in seismic stability.	a. Requires import of mineral soil. b. Represents a significant cost. c. Provides no environmental enhancement. d. Provides no significant increase in seismic stability. e. Addition of fill may result in short-term instability and/or cracking if levee/foundation system is weak.
 B. Placement of Fill on Levee Crown and Landside Slope, Together with Landside Berm in Soft Foundation Areas	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path. o Placement of berm accounts for soft foundation.	Most areas of Delta, but especially applicable in areas where soft foundation material exists.	a. Levee structural stability is improved. b. Relatively easily maintained as a flood control levee. c. Provides limited increase in seismic stability.	a. Requires significant import of mineral soil. b. Represents a significant cost. c. Provides no environmental enhancement. d. Provides only slight increase in seismic stability. e. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. f. Seepage system may need to be modified. g. Infringes on inboard farm land or habitat areas.
 C. Placement of Fill on Levee Crown, on Landside Slope, and in Landside Berm in Soft Foundation Areas - Together with Seepage Cutoff Wall (Slurry or Sheetpile Wall)	o Increases freeboard and flood protection. o Increases landside slope stability. o Significantly lengthens seepage path, stops concentrated seepage areas. o Placement of berm accounts for soft foundation.	Areas of the Delta where both soft foundation materials and significant, concentrated seepage problems exist.	a. Levee structural stability is improved. b. Provides significant improvement in control of seepage problems in levee. c. Relatively easily maintained as a flood control levee. d. May provide moderate improvement in seismic stability of levee if water levels inboard of cutoff wall are greatly reduced within levee (reduces amount of possible liquefaction).	a. Requires significant import of mineral soil. b. Placement of fill represents a significant cost. c. Construction of cutoff wall represents a major cost. d. Provides no environmental enhancement. e. Levee and foundation may still be unstable during earthquake loading. f. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. g. Construction of cutoff wall may result in hydraulic fracturing and/or levee cracking if not carried out carefully. h. Lowered ground water inboard of wall may result in differential settlement and cracking. i. Seepage system may need to be modified.

Figure 5 cont.

Possible Strategies for Levee and Habitat Improvements

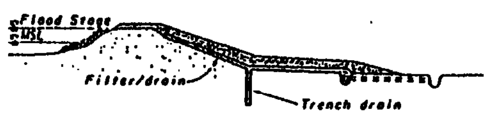
LEVEE IMPROVEMENT EXAMPLES	PURPOSE	APPLICABLE AREAS	POSITIVES	NEGATIVES
 D. Placement of Fill on Levee Crown, on Landside Slope, and in Landside Berm in <u>Soft</u> Foundation Areas - Together with <u>Filter/Drain System</u> on Landside Slope.	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path, stabilizes concentrated leaks and prevents piping erosion. o Placement of berm accounts for soft foundation.	Areas of the Delta where both soft foundation materials and significant, concentrated seepage or settlement and cracking problems exist.	a. Levee structural stability is improved. b. Provides significant improvement in control of seepage problems in levee. c. May prevent piping erosion associated with both flood events and moderate earthquake-induced settlement and cracking.	a. Requires significant import of mineral soil. b. Placement of fill represents a significant cost. c. Construction of filter/drain represents additional cost. d. Provides no environmental enhancement. e. Levee and foundation may still be unstable during earthquake loading. f. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. g. Seepage system may need to be modified. h. Seepage and filter/drain system may need to be maintained. i. Infringes on inboard farm land or habitat areas.
 E. Placement of Fill on Levee Crown, on Landside Slope, and in Landside Berm in <u>Soft</u> Foundation Areas - Together with <u>Filter/Drain System</u> on Landside Slope and Toe Drain	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path, stabilizes concentrated leaks and prevents piping erosion through both levee and foundation. o Placement of berm accounts for soft foundation.	Areas of the Delta where both soft foundation materials and significant, concentrated seepage or settlement and cracking problems exist. Particularly suited where piping erosion problems exist within levee foundation.	a. Levee structural stability is improved. b. Provides significant improvement in control of seepage problems in levee <u>and foundation</u>. c. May prevent piping erosion associated with both flood events and moderate earth quake-induced settlement and cracking.	a. Requires significant import of mineral soil. b. Placement of fill represents a significant cost. c. Construction of filter/drain on both slope and in trench represents additional cost. d. Provides no environmental enhancement. e. Levee and foundation may still be unstable during earthquake loading. f. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. g. Construction of drain trench may cause levee distress or seepage problems if not carried out carefully. h. Seepage system may need to be modified. i. Seepage and filter/drain system may need to be maintained. j. Infringes on inboard farm land or habitat areas.

Figure 5 cont.

Possible Strategies for Levee and Habitat Improvements

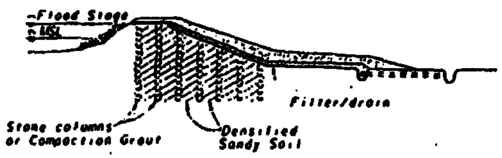
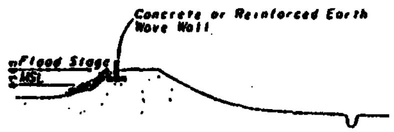
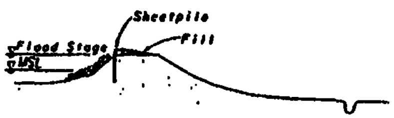
LEVEE IMPROVEMENT EXAMPLES	PURPOSE	APPLICABLE AREAS	POSITIVES	NEGATIVES
 F. Placement of Fill on Levee Crown, on Landside Slope, and in Landside Berm in Soft Foundation Areas - Together with Filter/Drain System on Landside Slope. Densification of Levee and Foundation Soils Using Vibroreplacment (Stone Columns) or Compaction Grouting.	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path, stabilizes concentrated leaks and prevents piping erosion through levee. o Placement of berm accounts for soft foundation. o Densification of levee and foundation soils prevents/limits earthquake-induced liquefaction.	Areas of the Delta where both soft foundation materials and liquefiable materials exist within levee and/or levee foundation.	a. Levee structural stability is improved. b. Provides significant improvement in control of seepage problems in levee. c. Densification reduces amount of slumping and cracking which may occur during an earthquake. Filter/drain may prevent piping erosion following an earthquake (and flood events).	a. Requires significant import of mineral soil. b. Placement of fill represents a significant cost. c. Construction of filter/drain represents additional cost. d. Densification represents a major cost. e. Provides no environmental enhancement. f. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. g. Densification construction may cause levee distress or seepage problems if not carried out carefully. h. Seepage system may need to be modified. i. Seepage and filter/drain system may need to be maintained. j. Infringes on inboard farm land or habitat areas.
 G. Construction of Concrete Wave Wall on Levee Crown	o Provides wave protection during high tides and flood events (Probably only an interim measure).	Areas of the Delta where levee freeboard is of immediate concern.	a. Provides wave protection. b. Relatively inexpensive. c. Can be constructed relatively quickly.	a. Provides no significant improvement in: - overall freeboard. - structural stability. - seepage control. - piping erosion. - seismic stability. b. Provides no environmental enhancement.
 H. Construction of Sheetpile Wave Wall on Levee Crown	o Provides wave protection during high tides and flood events (Probably only an interim measure).	Areas of the Delta where levee freeboard is of immediate concern.	a. Provides wave protection. b. Relatively inexpensive. c. Can be constructed relatively quickly.	a. Provides no significant improvement in: - overall freeboard. - structural stability. - seepage control. - piping erosion. - seismic stability. b. Requires limited import of fill. c. Provides no environmental enhancement. d. Installation of sheetpile wall may result in cracking of levee if not carried out with care.

Figure 5 cont.

Possible Strategies for Levee and Habitat Improvements

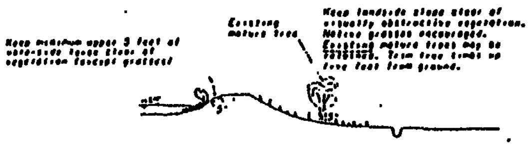
LEVEE IMPROVEMENT EXAMPLES	PURPOSE	APPLICABLE AREAS	POSITIVES	NEGATIVES
 I. Maintenance of Vegetation on Existing Levee Slopes	o Provides reasonable on-site growth and regrowth of vegetation while maintaining safety, access, and inspectability of levees.	Most areas in the Delta, but impact on levee stability must be first evaluated on a site by site basis. Waterside vegetation must be integrated with wave protection systems such as riprap to prevent major levee erosion.	a. Limited waterside vegetation provides some riparian and shaded aquatic habitat. b. Limited waterside vegetation provides some wave protection for levee. c. Grass vegetation provides erosion control for surface runoff. d. Preservation of existing trees provides valuable riparian habitat.	a. If Engineer's guidance not followed and vegetation becomes overgrown, then: - Vegetation limits access for inspection, maintenance, and flood fighting. - Vegetation encourages burrowing rodents. - Downing of trees during storms causes damage to levees due to fallen root balls pulling out chunks of the levee. - Tree roots can also eventually provide a seepage path through levee when they decay. b. Cannot be implemented on Federal levees. c. Because levees require continual maintenance and remediation, some developed habitats need to be covered over with stabilizing berms.
 J. Placement of Fill on Levee Crown and Landside Slope, Together with Landside Berm in Soft Foundation Areas. Creation of Waterside Berm at Mean Sea Level to Create Waterside Wetland Habitat.	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path. o Placement of berm accounts for soft foundation. o Provides Waterside Wetland Habitat.	Areas of Delta where soft foundation material exists and where waterside slope is not steep (deep). Cannot be used where channel capacity is severely limited.	a. Levee structural stability is improved. b. Relatively easily maintained as a flood control levee. c. Provides limited increase in seismic stability. d. Provides valuable Waterside Wetland Habitat (Waterside fill may limit seepage and improve waterside slope stability).	a. Requires major import of mineral soil. b. Placement of landside fill represents a significant cost. c. Placement of waterside fill represents a significant cost. d. Provides only limited increase in seismic stability. e. Limits channel capacity. f. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. g. Dredging may be needed on waterside. h. Seepage system may need to be modified.
 K. Placement of Fill on Levee Crown and Landside Slope, Together with Landside Berm in Soft Foundation Areas. Creation of Waterside Berm above Mean Sea Level to Create Waterside Riparian Habitat.	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path. o Placement of berm accounts for soft foundation. o Provides Waterside Riparian Habitat.	Areas of Delta where soft foundation material exists, and where waterside slope is not steep (deep). Cannot be used where channel capacity is severely limited.	a. Levee structural stability is improved. b. Relatively easily maintained as a flood control levee. c. Provides limited increase in seismic stability. d. Provides valuable Waterside Riparian Habitat (Waterside fill may limit seepage and improve waterside slope stability).	a. Requires major import of mineral soil. b. Placement of landside fill represents a significant cost. c. Placement of waterside fill represents a significant cost. d. Provides only limited increase in seismic stability. e. Limits channel capacity. f. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. g. Dredging may be needed on waterside. h. Seepage system may need to be modified.

Figure 5 cont.

Possible Strategies for Levee and Habitat Improvements

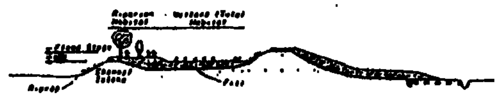
LEVEE IMPROVEMENT EXAMPLES	PURPOSE	APPLICABLE AREAS	POSITIVES	NEGATIVES
 L. Placement of Fill on Levee Crown and Landside Slope, Together with Landside Berm in Soft Foundation Areas. Placement of Fill between Channel Island and Levee to Create Waterside Wetland and Riparian Habitat.	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path. o Placement of berm accounts for soft foundation. o Provides Waterside Riparian and Wetland Habitat.	Areas of Delta where soft foundation material exists, and where channel islands and channel between island levee is not too deep. Cannot be used where channel capacity is severely limited.	a. Levee structural stability is improved. b. Relatively easily maintained as a flood control levee. c. Provides limited increase in seismic stability. d. Provides valuable Waterside Riparian and Wetland Habitat (Waterside fill may limit seepage and improve waterside slope stability).	a. Requires major import of mineral soil. b. Placement of landside fill represents a significant cost. c. Placement of waterside fill represents a significant cost. d. Provides only limited increase in seismic stability. e. Limits channel capacity. f. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. g. Dredging may be needed on waterside. h. Seepage system may need to be modified. i. Channel island requires protection.
 M. Placement of Fill on Levee Crown and Landside Slope, Together with Landside Berm in Soft Foundation Areas. Placement of Sand Beach on Waterside Slope to Create Recreation Area.	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path. o Placement of berm accounts for soft foundation. o Provides Recreation Area.	Areas of Delta where soft foundation material exists, and where waterside slope is not too steep (deep). Cannot be used where channel capacity is severely limited.	a. Levee structural stability is improved. b. Relatively easily maintained as a flood control levee. c. Provides limited increase in seismic stability. d. Provides valuable Waterside Recreation Area. (Waterside fill may limit seepage and improve waterside slope stability.)	a. Requires major import of mineral soil. b. Placement of landside fill represents a significant cost. c. Placement of waterside sandy fill represents a significant cost. d. Provides only limited increase in seismic stability. e. Limits channel capacity. f. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. g. Dredging may be needed on waterside. h. Seepage system may need to be modified. i. Beach area requires maintenance.
 N. Partial Setback of Levee to Create Waterside Riparian Habitat, Placement of Fill on Levee Crown and Landside Slope. Slope, Together with Landside Berm in Soft Foundation Areas.	o Increases freeboard and flood protection. o Increases overall slope stability. o Lengthens seepage path. o Placement of berm accounts for soft foundation. o Provides Waterside Riparian Habitat.	All areas of Delta, but especially applicable in areas where soft foundation material exists.	a. Levee structural stability is improved. b. Relatively easily maintained as a flood control levee. c. Provides limited increase in seismic stability. d. Lengthens seepage path.	a. Requires significant import of mineral soil. b. Fill placement and cost associated with levee setback greater than simply raising levee crown and adding berm. c. Provides only limited increase in seismic stability. d. Addition of fill likely to result in short-term instability and/or cracking if staged-construction is not used. e. Seepage system may need to be modified. f. Infringes on inboard farm land or habitat areas.

Figure 5 cont.

Possible Strategies for Levee and Habitat Improvements

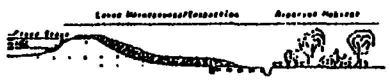
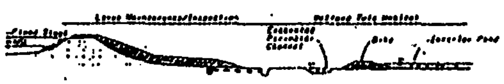
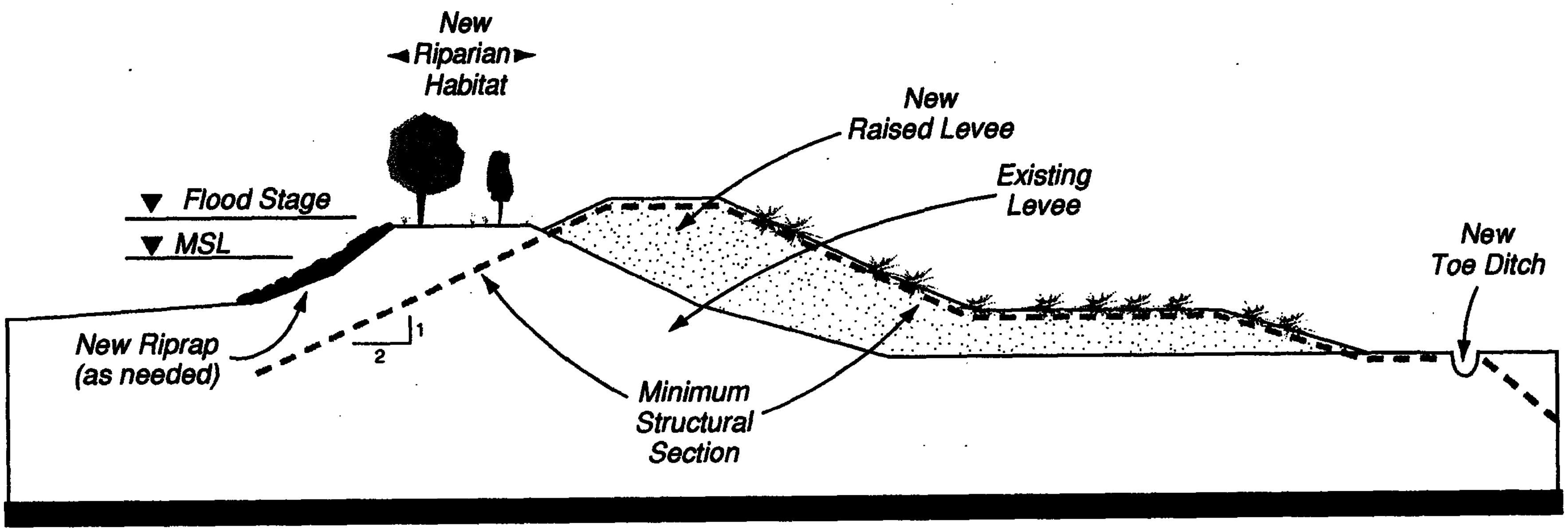
LEVEE IMPROVEMENT EXAMPLES	PURPOSE	APPLICABLE AREAS	POSITIVES	NEGATIVES
 O. Complete Setback of Levee to Improve Channel Capacity, Improve Levee Structural Stability and Provide Waterside Wetland Habitat.	o Increases channel capacity. o Improves levee stability. o Provides Waterside Wetland Habitat.	Many areas of Delta, but possibly not in areas where very thick layers of soft foundation material may make creation of new setback levees infeasible.	a. Increases channel capacity and improves flood control. b. New levee would be an engineered fill and would not liquefy during seismic events. c. Provides Waterside Wetland Habitat.	a. Requires major import of mineral soil. b. Fill placement and cost associated with levee setback greater than simply raising levee crown and adding berm. c. Foundation liquefaction could still cause failure during future earthquake. d. New levee fill likely to result in short-term instability and/or cracking if staged-construction is not used. This could temporarily make new levee less reliable than existing levee. e. Significantly infringes on inboard farm land or habitat areas.
 P. Placement of Fill on Levee Crown and Landslide Slope, Together with Landside Berm in Soft Foundation Areas. Creation of Landside Riparian Habitat.	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path. o Placement of berm accounts for soft foundation. o Provides Landside Riparian Habitat.	All areas of Delta, but especially applicable in areas where soft foundation material exists.	a. Levee structural stability is improved. b. Relatively easily maintained as a flood control levee. c. Provides limited increase in seismic stability. d. Provides Landside Riparian Habitat. e. Reduces subsidence near levee by not tilling land in habitat area.	a. Requires significant import of mineral soil. b. Represents a significant cost. c. Provides only slight increase in seismic stability. d. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. e. Seepage system may need to be modified. f. Significantly infringes on inboard farm land and requires some land to be taken out of agricultural production.
 Q. Placement of Fill on Levee Crown and Landslide Slope, Together with Landside Berm in Soft Foundation Areas. Creation of Inboard Ponds and Water filled Perimeter Ditches for Landside Wetland Habitat.	o Increases freeboard and flood protection. o Increases landside slope stability. o Lengthens seepage path. o Placement of berm accounts for soft foundation. o Provides Landside Wetland Habitat.	All areas of Delta, but especially applicable in areas where soft foundation material exists and significant inland subsidence is occurring.	a. Levee structural stability is improved. b. Relatively easily maintained as a flood control levee. c. Provides limited increase in seismic stability. d. Provides Landside Wetland Habitat. e. Reduces subsidence near levee by keeping organic soils saturated.	a. Requires significant import of mineral soil. b. Represents a significant cost. c. Provides only slight increase in seismic stability. d. Addition of fill may result in short-term instability and/or cracking if staged-construction is not used. e. Seepage system may need to be modified. f. Significantly infringes on inboard farm land and requires some land to be taken out of agricultural production. g. Inland pond and dike systems require maintenance.

Figure 6a

Selected Strategy for Levee and Habitat Improvements



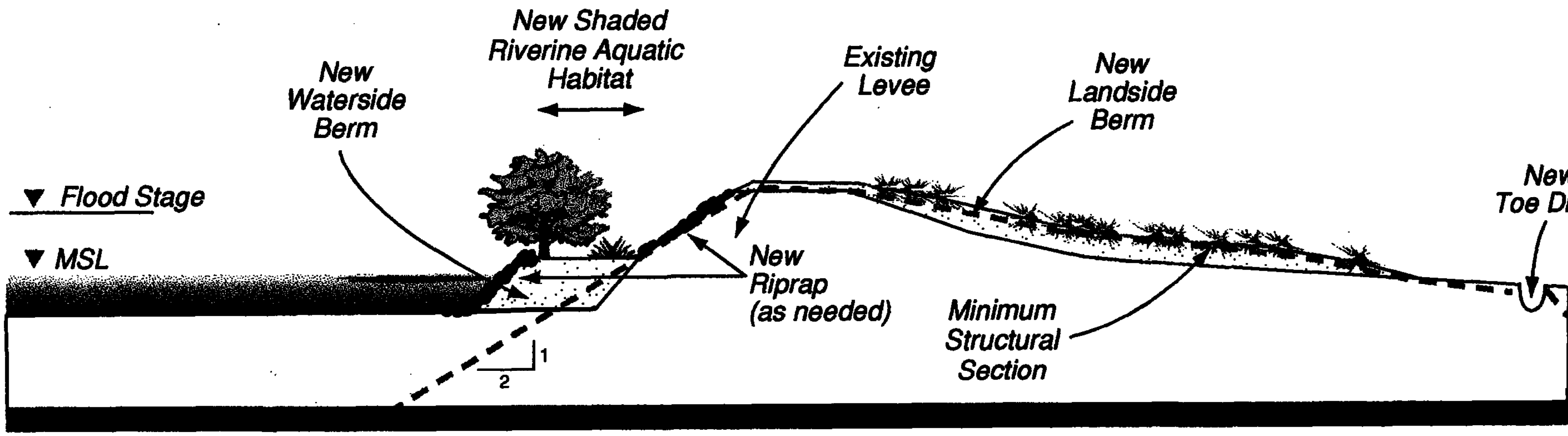
Raised Levee with New Riparian Habitat

not to scale

CALFED BAY-DELTA PROGRAM

Figure 6b

Selected Strategy for Levee and Habitat Improvements



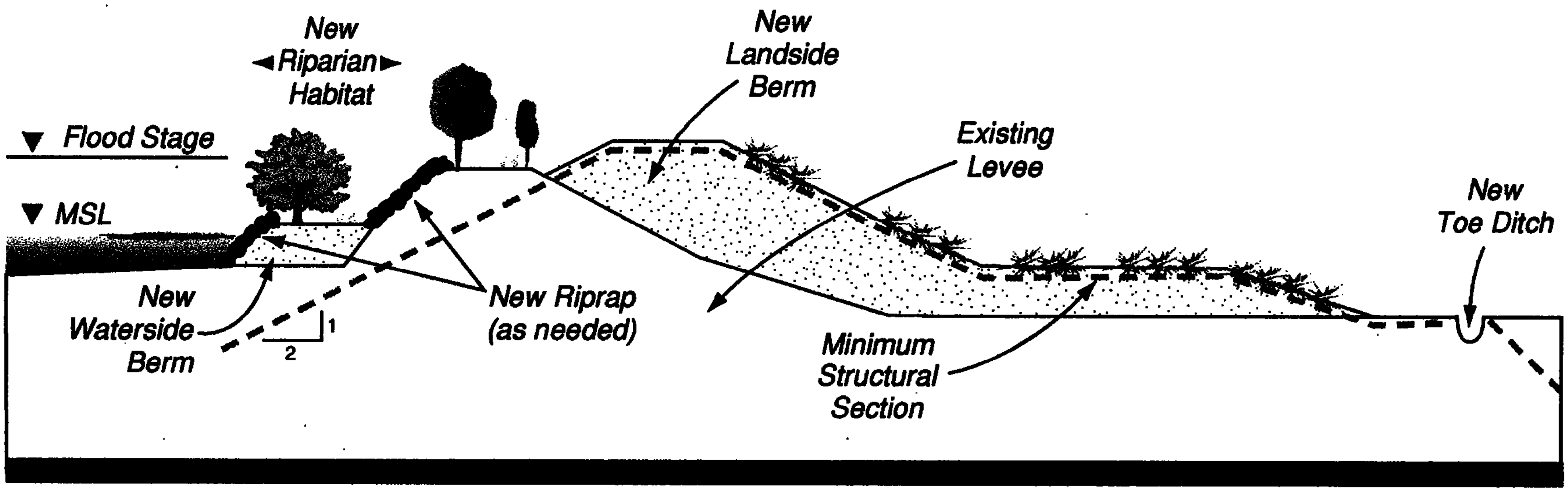
Levee Enlargement, Waterside Berm with New (SRA) Habitat

not to scale

CALFED BAY-DELTA PROGRAM

Figure 6c

Selected Strategy for Levee and Habitat Improvements



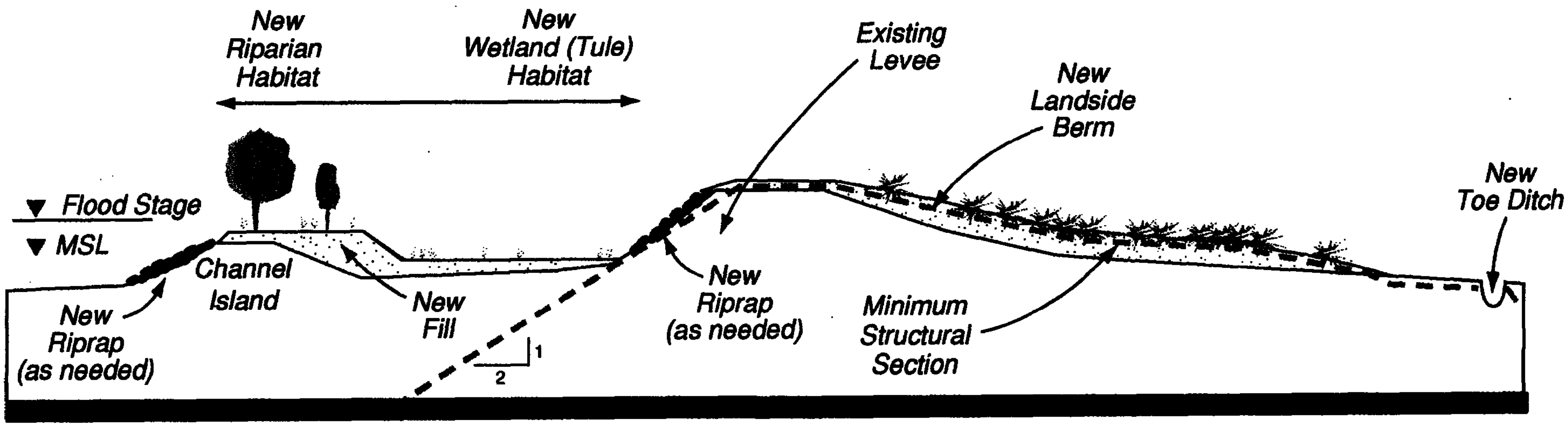
Raised Levee with New Riparian Wetland Habitat

not to scale

CALFED BAY-DELTA PROGRAM

Figure 6d

Selected Strategy for Levee and Habitat Improvements



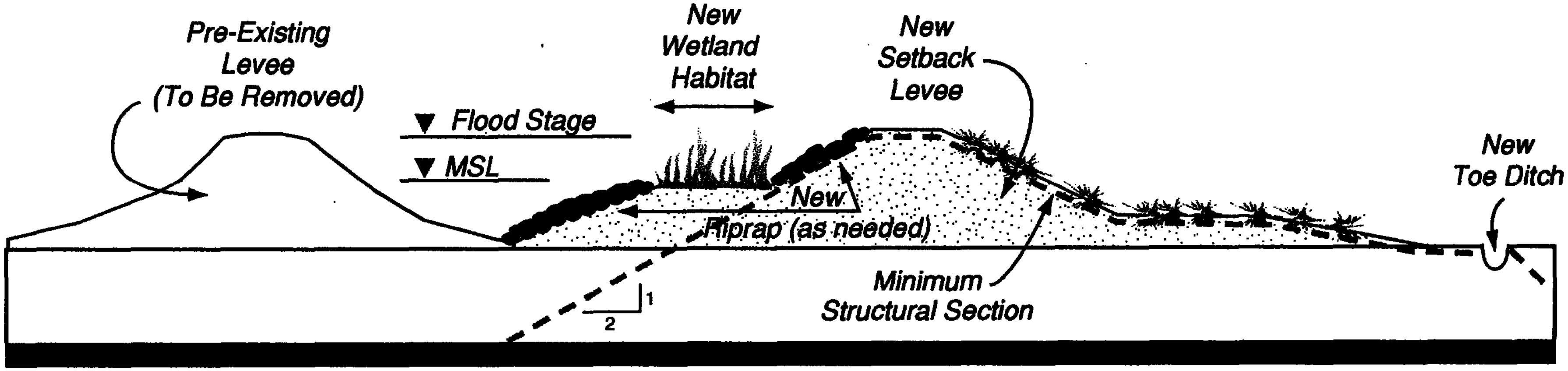
Levee Enlargement, Waterside Berm with New Riparian Habitat

not to scale

CALFED BAY-DELTA PROGRAM

Figure 6e

Selected Strategy for Levee and Habitat Improvements



Setback Levee with Habitat Improvements

not to scale

TABLES

Table 1. Chronological Summary of Events Important to the Delta

Year	Activity
The following reclamation, water management, and legislative activities greatly influenced and shaped the current Delta system of waterways and islands:	
1849	Settlers began arriving in the Delta to farm its rich soils. The majority of the Delta was marsh land prior to subsequent reclamation and conversion to agricultural lands.
1850	Congress passed the Federal Swamp and Overflow Act, which provided for the title of wetlands to be transferred from the federal government to the states.
1861	The California Legislature authorized the State Reclamation District Act. As a result of state and federal legislation, swamp and overflow land was sold and reclaimed for agricultural use by construction of levees. The Delta was transformed from a large tidal marsh to a system of improved channels and levees by the early 1900s.
1880	By now most of the Delta has been reclaimed.
1884	Discharge of hydraulic mining debris into California rivers declared illegal.
1902	Congress passed the Reclamation Act for development of irrigated lands in the western United States.
1911	The Reclamation Board was created by the California Legislature.
1933	Congress authorized the Central Valley Water Project (CVP). The Stockton Deep Water Ship Channel, which extends from the confluence of the Sacramento and San Joaquin Rivers to the City of Stockton, was completed.
1940	The Contra Costa Canal, which exports water from the south Delta to the Bay Area, was completed. This was the first unit of the CVP that used existing channels to convey water through the Delta for export.
1944	Shasta Dam and Reservoir, a key feature of the CVP used to capture and store water, was completed. This project provided additional water to Delta channels during low-flow periods.
1951	The Delta-Mendota Canal, which exports water from the Delta via the Tracy Pumping Plant to the San-Joaquin Valley, was completed. This unit of the CVP increases exports from the Delta. The Delta Cross Channel, which aids transfer of water from the Sacramento River across the Delta to the Tracy Pumping Plant, was completed.
1959	The Delta Protection Act was enacted by the California Legislature to protect, conserve, develop, control, and use the waters of the Delta for the public good.
1960	Voters approved the State Water Resources Development Bond Act (also known as the Burns-Porter Act) to help finance the initial facilities of the State Water Project (SWP). These facilities included master levees, control structures, channel improvements, and appurtenant facilities in the Delta that are used for water conservation, water supply in the Delta, transferring water across the Delta, and flood and salinity control. The Sacramento River Flood Control Project, authorized by Congress, was completed by the U.S. Army Corps of Engineers. This project incorporated and improved certain Delta levees to provide improved flood control for a portion of the Delta. These levees are commonly referred to as "project" levees.

Table 1. Chronological Summary of Events Important to the Delta (Continued)

Year	Activity
1963	The Sacramento Deep Water Ship Channel, which extends from the confluence of the Sacramento and San Joaquin Rivers, was completed.
1967	Oroville Dam and Reservoir, which provides increased channel flows during low-flow periods, was completed. This is a key feature of the SWP and includes the Feather River Fish Hatchery to replace spawning areas lost as a result of the dam.
	The first stage of the Harvey O. Banks Delta Pumping Plant, another unit of the SWP, was completed along with the John E. Skinner Fish Facility. Diversions began from the Delta to the California and South Bay Aqueducts of the SWP.
	Construction of Clifton Court Forebay located in the south Delta began. This unit of the SWP facilitates export of water from the Delta.
1971	The State Water Resources Control Board adopted Delta Water Rights Decision 1379, establishing Delta water quality standards to be met by the CVP and SWP.
1973	The California Legislature recognized that the Delta levee system benefits many segments and interests of the public and approved a plan to preserve the Delta levee system. The Delta Levee Maintenance Subvention Program (Senate Bill [SB] 541) was enacted to provide state funding and technical assistance for maintenance and rehabilitation of non-project Delta levees.
1976	The California Legislature adopted a conceptual plan for improvement of Delta levees (the Nejedly-Mobley Delta Levees Act). The plan for improvement of the Delta levees, as set forth in California Department of Water Resources (DWR) Bulletin No. 192, dated May 1975, was approved as the conceptual plan to guide the formulation of projects in order to preserve the integrity of the Delta levee system.
1986	Congress passed the DWR and U.S. Bureau of Reclamation historic accord, the CVP-SWP Coordinated Operation Agreement.
	The California Supreme Court confirmed the State Water Resources Control Board's broad authority and discretion over water rights and water quality issues in the Bay/Delta system, including jurisdiction over the federal CVP.
1988	Barker Slough Pumping Plant, which provides water from the northwest Delta for the North Bay aqueduct, was completed.
	Suisun Marsh salinity control gates, which aid in controlling water quality in the marsh for protection of waterfowl, were completed.
	SB 34, the Delta Flood Protection Act of 1988, was enacted, creating the Special Flood Control Project Program for eight islands in the western Delta and the towns of Thorton and Walnut Grove. This act amended the Delta Levee Maintenance Subventions Program and established a special account in the California Water Fund for appropriation by the Legislature for mitigation activities.
1991	Environmental Mitigation and Protection Requirements (SB 1065 and Assembly Bill [AB] 360) were enacted, amending the Delta Flood Protection Act of 1988. Sections were added to the California Water Code to establish coordination between the Resources Agency, DWR, the Reclamation Board, and the Department of Fish and Game to ensure that flood protection activities resulted in no net loss of riparian, wildlife, or fishery habitat.

Table 1. Chronological Summary of Events Important to the Delta (Continued)

Year	Activity
1992	The Delta Protection Act of 1992 established the Delta Protection Commission. The Commission has developed a regional, comprehensive long-term resources management plan for the Delta to protect, maintain, and, where possible, enhance and restore the overall quality of the Delta environment. The act acknowledges that agricultural land in the Delta is of significant value, including its function of providing open space and habitat for waterfowl using the Pacific Flyway. All local general plans for areas in a designated Primary zone and within the boundaries of the Delta are required to be consistent with the Delta Protection Commission regional plan.
	Congress passed the Central Valley Project Improvement Act (Public Law [PL] 102-575).
1994	State and federal agencies and representatives signed the Bay-Delta Accord.
1995	The CALFED Bay-Delta Program was initiated.
1996	Proposition 204, the Safe, Clean, Reliable Water Supply Act was approved by the voters to fund a variety of Delta improvements and local programs that were designed to address California water needs, including Delta levee system improvements.

Table 3. Delta Levee Inventory

No.	Reclamation District	Island/Reclamation District	Total Levee Miles [a]	Total Project Levee Miles [b]	Total Non-Project Levee Miles [c]	Total Non-Project Levee Miles up to PL 84-99 Standard	Total Flooded/ Other Levee Miles [d]	Total Eligible Levee Miles [e]
1	556	Andrus, Upper; RD 556	11.7	11.2	0.5	0	0	0.5
2	2028	Bacon; RD 2028	14.3	0	14.3	0	0	14.3
3		Bear Creek	2.5	2.5	0	0	0	0
4		Bethany	5.2	0	5.2	0	5.2	0
5		Bethel Island MID	11.5	0	11.5	0	0	11.5
6	2042	Bishop; RD 2042	7.8	0	7.8	7.8	0	0
7		Bishop East	0.6	0	0.6	0.6	0	0
8	2121	Bixler; RD 2121	6.2	0	6.2	6.2	0	0
9	404	Boggs Dist; RD 404	5.3	4.1	1.2	1.2	0	0
10		Borrow Pond Area	2	0	2	0	2	0
11	756	Bouldin; RD 756	18	0	18	0	0	18
12	2033	Brack; RD 2033	10.8	0	10.8	0	0	10.8
13		Browns Island (T)	0	0	0	0	0	0
14	2059	Bradford; RD 2059	7.4	0	7.4	7.4	0	0
15	2067/317/407	Bran.-Andrus LMD	29.4	19.3	10.1	0	0	10.1
16	800	Byron; RD 800	19.3	0	19.3	19.3	0	0
17	2098	Cache Haas; RD 2098	12.1	12.1	0	0	0	0
18	2086	Canal Ranch; RD 2086	9.6	0	9.6	0	0	9.6
19		Chipps Island	2.6	0	2.6	0	2.6	0
20		Clifton Court (F)	9.2	0	9.2	0	9.2	0
21		Collinsville	1.1	0	1.1	0	1.1	0
22	2117	Coney; RD 2117	5.4	0	5.4	0	0	5.4
23	2111	Deadhorse; RD 2111	2.6	0	2.6	0	0	2.6
24		Delta Mendota	2.1	0	2.1	0	2.1	0
25		Decker	4.1	0	4.1	0	4.1	0
26		Drexler	4	0	4	0	0	4
27	536/2084	Egbert; RDs 536 and 2084	10.6	10.6	0	0	0	0
28	813	Ehrheart; RD 813	4.7	0	4.7	0	4.7	0
29	2029	Empire; RD 2029	10.5	0	10.5	0	0	10.5

Table 3. Delta Levee Inventory (Continued)

No.	Reclamation District	Island/Reclamation District	Total Levee Miles [a]	Total Project Levee Miles [b]	Total Non-Project Levee Miles [c]	Total Non-Project Levee Miles up to PL 84-99 Standard	Total Flooded/ Other Levee Miles [d]	Total Eligible Levee Miles [e]
30	773	Fabian; RD 773	18.8	0	18.8	0	0	18.8
31	2113	Fay; RD 2113	1.6	0	1.6	0	0	1.6
32		Frank, Little (F)	3.5	0	3.5	0	3.5	0
33	1002	Glanville; RD 1002	13	0	13	0	0	13
34	765	Glide; RD 765	1.7	1.7	0	0	0	0
35	3	Grand; RD 3	28.8	28.8	0	0	0	0
36	2126	Harbor Cove (Atlas); RD 2126	1.9	0	1.9	0	0	1.9
37	1609	Harveys; RD 1609	12.4	0	12.4	0	12.4	0
38	2060	Hastings; RD 2060	16	16	0	0	0	0
39	2025	Holland; RD 2025	11	0	11	0	0	11
40	999	Holland Land; RD 999	33.4	33.4	0	0	0	0
41	2116	Holt Station; RD 2116	0.4	0	0.4	0.4	0	0
42	799	Hotchkiss; RD 799	6.3	0	6.3	0	0	6.3
43	830	Jersey; RD 830	15.6	0	15.6	0	0	15.6
44	2038	Jones, Lower; RD 2038	9	0	9	0	0	9
45	2039	Jones, Upper; RD 2039	9.3	0	9.3	0	0	9.3
46	2085	Kasson; RD 2085	6.2	6.2	0	0	0	0
47		Kimball Island	1.9	0	1.9	0	1.9	0
48	2044	King; RD 2044	9.1	0	9.1	0	0	9.1
49	369	Libby McNeil; RD 369	1.9	0.8	1.1	0	0	1.1
50	2093	Liberty; RD 2093	14.5	0	14.5	0	14.5	0
51	307	Lisbon; RD 307	6.6	6.6	0	0	0	0
52	2118	Little Mandeville (F); RD 2118	4.5	0	4.5	0	4.5	0
53		Los Medanos	5.6	0	5.6	0	5.6	0
54		Maintenance Area 9	19.6	19.6	0	0	0	0
55	2027	Mandeville; RD 2027	14.3	0	14.3	0	0	14.3
56	2110	McCormack-Williamson; RD 2110	8.8	0	8.8	0	8.8	0
57	2075	McMullin; RD 2075	7.5	7.5	0	0	0	0
58	2030	McDonald; RD 2030	13.7	0	13.7	0	0	13.7

Table 3. Delta Levee Inventory (Continued)

No.	Reclamation District	Island/Reclamation District	Total Levee Miles [a]	Total Project Levee Miles [b]	Total Non-Project Levee Miles [c]	Total Non-Project Levee Miles up to PL 84-99 Standard	Total Flooded/ Other Levee Miles [d]	Total Eligible Levee Miles [e]
59	2041	Medford; RD 2041	5.9	0	5.9	0	0	5.9
60	150	Merritt; RD 150	18.1	18.1	0	0	0	0
61	2021	Mildred (F); RD 2021*	7.3	0	7.3	0	7.3	0
62		Montezuma Flats	1.9	0	1.9	0	0	0
63		Montezuma Island	0.4	0	0.4	0	0.4	0
64	2107	Mossdale 2; RD 2107	4.2	4.2	0	0	0	0
65	1007	Naglee Burke; RD 1007	8.3	0	8.3	0	0	8.3
66	348	New Hope; RD 348	18.6	0	18.6	0	0	18.6
67		Oakley	6.7	0	6.7	0	6.7	0
68	2024	Orwood; RD 2024	6.3	0	6.3	0	0	6.3
69	2036	Palm; RD 2036	7.5	0	7.5	0	0	7.5
70	2095	Paradise; RD 2095	4.9	4.9	0	0	0	0
71	2058	Pescadero; RD 2058	9.2	6.7	2.5	0	0	2.5
72	2104	Peters; RD 2104	8.4	8.4	0	0	0	0
73	551	Pierson; RD 551	14	6.8	7.2	7.2	0	0
74	1667	Prospect; RD 1667 (F)	10	2.9	7.1	0	7.1	0
75	2090	Quimby; RD 2090	7	0	7	0	0	7
76	755	Randall; RD 755	1.9	1.9	0	0	0	0
77	2037	Rindge; RD 2037	15.8	0	15.8	0	0	15.8
78	2114	Rio Blanco; RD 2114	4.2	0	4.2	0	0	4.2
79	2064	River Junction; RD 2064	11.9	11.9	0	0	0	0
80	684	Roberts, Lower; RD 684	16	0	16	0	0	16
81	524	Roberts, Middle; RD 524	12.7	6.1	6.6	0	0	6.6
82	544	Roberts, Upper; RD 544	15	10.6	4.4	0	0	4.4
83		Rough and Ready*	5.5	0	5.5	0	5.5	0
84	501	Ryer; RD 501	20.6	20.6	0	0	0	0
85		Sacramento Deepwater	26	0	26	0	26	0
86	2074	Sargent Barnhart; RD 2074	6	1.5	4.5	4.5	0	0
87	341	Sherman; RD 341	18.5	9.7	8.8	0	0	8.8

Table 3. Delta Levee Inventory (Continued)

No.	Reclamation District	Island/Reclamation District	Total Levee Miles [a]	Total Project Levee Miles [b]	Total Non-Project Levee Miles [c]	Total Non-Project Levee Miles up to PL 84-99 Standard	Total Flooded/ Other Levee Miles [d]	Total Eligible Levee Miles [e]
88		Sherman West (F)	5.5	0	5.5	0	5.5	0
89	2115	Shima; RD 2115	6.6	0	6.6	0	0	6.6
90		Shin Kee	3.6	0	3.6	0	0	3.6
91		SJCFCD Five Mile Slough	1.4	0	1.4	1.4	0	0
92		SJCFCD Fourteen Mile Slough	2	0	2	2	0	0
93		SJCFCD Mosher Slough	4.1	0	4.1	4.1	0	0
94	17	San Joaquin River; RD 17	16.2	16.2	0	0	0	0
95	1614	Smith Tract; RD 1614	2.8	0	2.8	2.8	0	0
96	1608	Lincoln Village West	4.3	0	4.3	4.3	0	0
97		Spinner Island	0.8	0	0.8	0	0.8	0
98	2089	Stark; RD 2089	3.5	2.8	0.7	0.7	0	0
99	38	Staten; RD 38	25.4	0	25.4	0	0	25.4
100	2062	Stewart; RD 2062	12.3	12.3	0	0	0	0
101	349	Sutter; RD 349	12.5	12.5	0	0	0	0
102	548	Terminous; RD 548	21	0	21	0	0	21
103	2108	Tinsley; RD 2108	0	0	0	0	0	0
104	1601	Twitchell; RD 1601	12	2.5	9.5	0	0	9.5
105	563	Tyler; RD 563	22.9	12.2	10.7	0	0	10.7
106	1	Union, East; RD 1	14	1	13	0	0	13
107	2	Union, West; RD 2	16.2	0	16.2	0	0	16.2
108	1607	Van Sickle; RD 1607	3.8	0	3.8	0	3.8	0
109	2065	Veale; RD 2065	5.1	0	5.1	0	0	5.1
110	2023	Venice; RD 2023	12.3	0	12.3	0	0	12.3
111	2040	Victoria; RD 2040	15.1	0	15.1	0	0	15.1
112	554	Walnut Grove; RD 554	4.9	1	3.9	3.9	0	0
113	2094	Walthall; RD 2094	3.3	3.3	0	0	0	0
114	2026	Webb; RD 2026	12.9	0	12.9	0	0	12.9
115	828	Weber; RD 828	1.7	0	1.7	1.7	0	0
116		West Island	3	0	3	0	3	0

Table 3. Delta Levee Inventory (Continued)

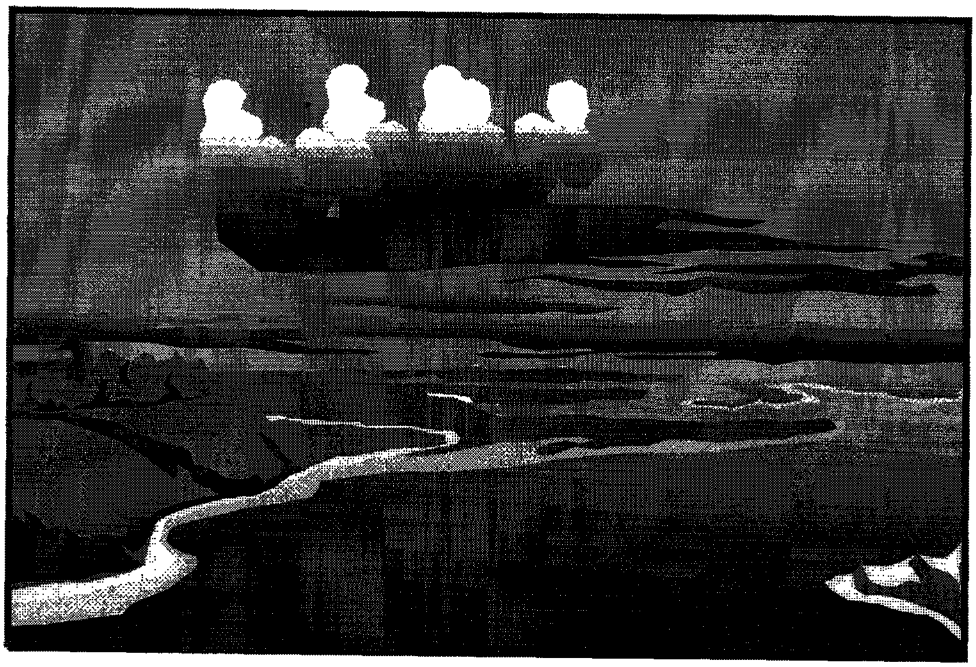
No.	Reclamation District	Island/Reclamation District	Total Levee Miles [a]	Total Project Levee Miles [b]	Total Non-Project Levee Miles [c]	Total Non-Project Levee Miles up to PL 84-99 Standard	Total Flooded/ Other Levee Miles [d]	Total Eligible Levee Miles [e]
117	900	West Sacramento; RD 900	13.6	13.6	0	0	0	0
118	2096	Wetherbee; RD 2096	0.2	0.2	0	0	0	0
119	2122	Winter; RD 2122	4.8	0	4.8	0	0	4.8
120	2072	Woodward; RD 2072	8.8	0	8.8	0	0	8.8
121	2119	Wright-Elmwood; RD 2119	7.1	0	7.1	0	0	7.1
122	2068	Yolano; RD 2068	8.7	8.7	0	0	0	0
123		Yolo Bypass Unit 4	3.6	3.6	0	0	0	0
		Total Miles	**1,116**	**384.6**	**731.7**	**75.5**	**148.3**	**506.0**

NOTES:

From Corps' 1993 System Final Report - Lower Sacramento.
Includes Corps' estimate for project levee repairs.
Discrepancies in the Delta levee inventory and the cost estimate are being investigated.

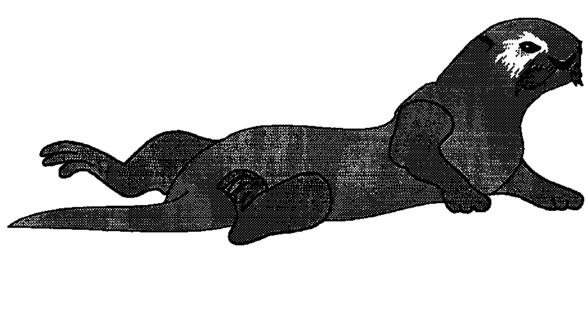
[a] Total Levee Miles - Length of levees in the legal Delta.
[b] Total Project Levee Miles - Length of federal project levees.
[c] Total Non-Project Levee Miles - Non-project levees included in the Subventions Program. Includes Direct Agreement levees.
[d] Total Flooded Levees - Islands or tracts that are permanently flooded or tidal and the levees are not being maintained. Other Levees - Non-Project levees maintained and operated by either a private entity or the Corps, U.S. Bureau of Reclamation, Navy, or DWR.
[e] Total Eligible Levee Miles - Non-project levees that are not up to PL 84-99 standards and are not flooded or maintained by a private or federal entity.

APPENDICES

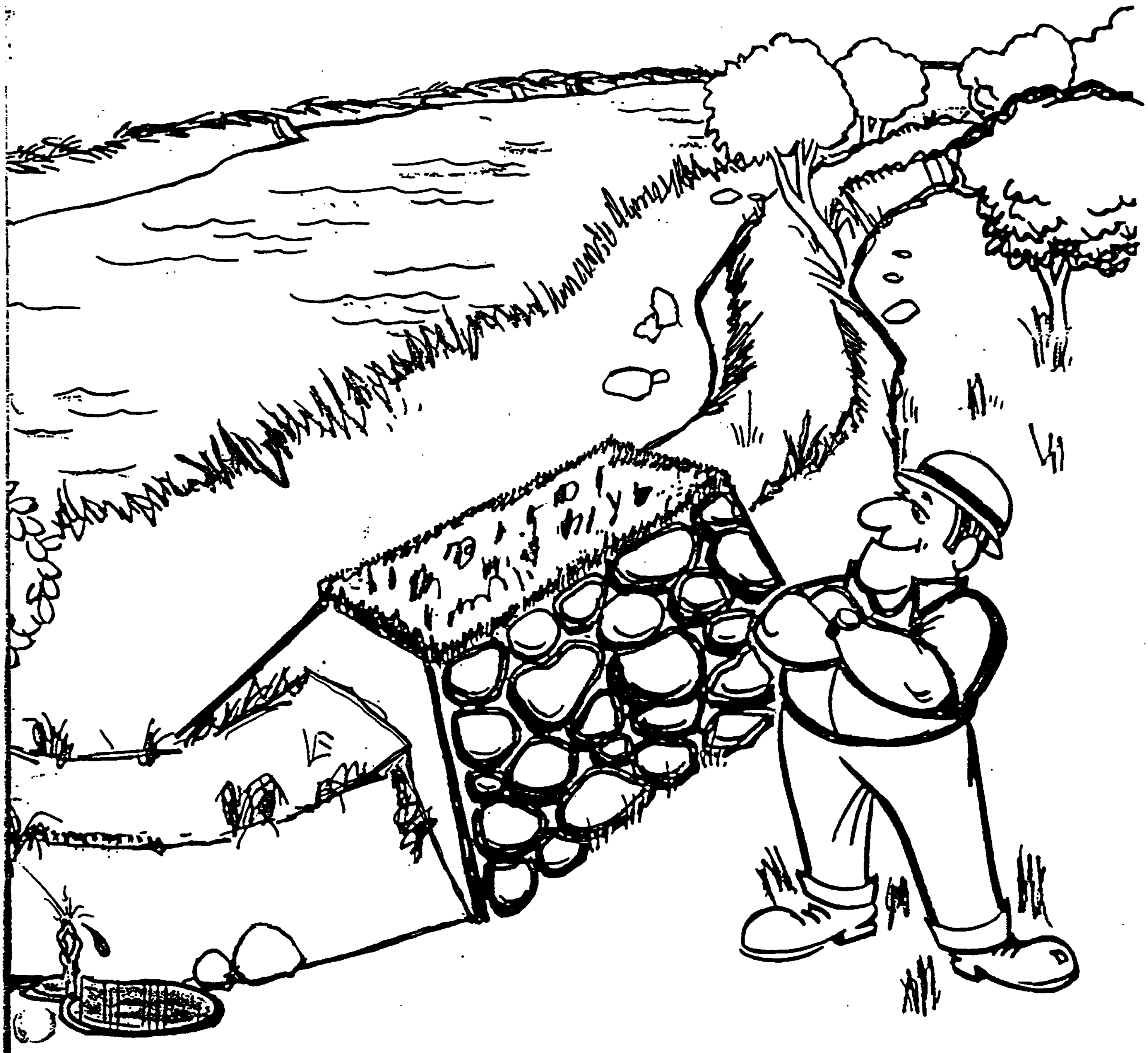


APPENDIX A

PL 84-99 DELTA SPECIFIC STANDARD AND PL 84-99 OVERVIEW



GUIDELINES FOR REHABILITATION OF NON-FEDERAL LEVEES IN THE SACRAMENTO-SAN JOAQUIN LEGAL DELTA



DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
WASHINGTON, D.C. 20314-1000

REPLY TO
ATTENTION OF:

24 MAR 1988

CECW-OE-D

MEMORANDUM FOR: Commander, South Pacific Division

SUBJECT: Non-Federal Levee Rehabilitation in the Sacramento-San Joaquin Legal Delta under the Provisions of PL 84-99, as amended

1. Reference: Memorandum with enclosures, CESPD-CO-E, 30 November 1987, sab.

2. The proposed eligibility guidelines are approved subject to the following conditions:

a. The PL 84-99 rating guide dated 2 December 1987, which superseded the 30 June 1987 version, will be used in the final eligibility guidelines.

b. General dewatering of inundated tracts as a result of levee failure will not be considered as eligible work under Corps rehabilitation project as it is rightfully a non-federal responsibility. Costs associated with dewatering the immediate construction area for the purpose of levee embankment repair is eligible for consideration.

3. Implementation of the new guidelines must always focus on our common objective to ensure consistent application of the emergency authority to all eligible applicants where the Federal interest and flood protection are of paramount concern. This position must be clearly transmitted to all interested parties.

FOR THE COMMANDER:

JOHN P. ELMORE
Chief, Operations and Readiness Division
Directorate of Civil Works

DEPARTMENT OF THE ARMY
SOUTH PACIFIC DIVISION, CORPS OF ENGINEERS
630 Sansome Street Room 720
San Francisco, California 94111-2206

REPLY TO
ATTENTION OF:

CESPD-CO-E

30 Nov 87
~~24 Sept~~ 1987

MEMORANDUM FOR: Commander, HQUSACE, ATTN: DAEN-CWO-EO, 20 Mass. Ave, N.W. Wash D.C., 20314-1000

SUBJECT: Non-Federal Levee Rehabilitation in the Sacramento-San Joaquin Legal Delta under the Provisions of PL 84-99, as amended.

1. The Corps position on rehabilitation of non-Federal levees within the Sacramento-San Joaquin Delta was defined in a February 1980 PL 84-99 policy statement by Commander, HQUSACE, Lieutenant General John W. Morris. General Morris stated that since non-Federal Delta levees were built for tidal and not flood control they could not be rehabilitated under PL 84-99 authority. Director of Civil Works Major General John F. Wall reviewed this policy in May of 1984 and added that if local interests upgraded these tidal levees to meet appropriate flood control standards they may be considered for rehabilitation assistance. General Wall also stated that SPD may have to develop Delta exclusive standards for any levee upgrade by locals.

2. Based on the above policy guidance Sacramento District has developed Delta exclusive standards (Encl 3) for non-Federal levees to qualify for rehabilitation under PL-84-99. I concur with the District's proposal with the following stipulations:

a. It is agreed to view FEMA's short-term hazard mitigation plan for the Delta (valid through 1991) as the interim Federal guideline for Delta levees. These guidelines would apply to eligibility for Federal assistance under PL 93-288 only.

b. The long-term solution to eligibility to Corps emergency assistance in the Delta will be based on eligibility guidelines for rehabilitation under PL 84-99 as coordinated between the State and Corps. This is consistent with FEMA's expectations.

c. The Corps accepts the established State standards for level of protection and freeboard in the Delta (State long-term subvention program as expressed in State Pub 192.82.) However, geotech standards must also be addressed to establish eligibility for Corps rehabilitation assistance. The geotech/stability screening process developed by SPK will be proposed to the State for their consideration. An option must be included for levee sponsors to do their own analysis to reclaima if desired.

d. SPK's proposed definition of a flood event in the Delta appears reasonable for eligibility purposes, provided it is understood that the Division Commander retains the purogative to judge individual events based on specific H&H data.

3. This document is forwarded for your review and comment. A formal presentation on the proposal will be given to your staff if so requested.

4. References:

a. MSG, DAEN-CWO-E, 271415 Feb 80, Subject: PL 84-99 Authority. (Encl 1 - Morris Policy on Delta)

b. First Endorsement, DAEN-CWO-EO, 1 May 84, Subject: Sacramento San Joaquin Delta, California. (Encl 2 - Wall Policy on Delta)

/s/

Enclosures (3)

PATRICK J. KELLY
Brigadier General, U.S. Army
Commanding

CESPD-CO-E (CECW-OE-D/24 Mar 88) 1st End B. Edmisten/dah/556-3108
SUBJECT: Non-Federal Levee Rehabilitation in the Sacramento-San Joaquin Legal Delta under the Provisions of PL 84-99, as amended

DA, South Pacific Division, Corps of Engineers, 630 Sansome Street, Room 720, San Francisco, CA 94111-2206 13 April 1988

FOR: Sacramento District Emergency Management (CESPK-EM)

The proposed eligibility guidelines are approved subject to conditions stated in basic memorandum and those conditions listed in paragraph 2 of CESPD-CO-E Memorandum of 30 November 1987, same subject.

FOR THE COMMANDER:

DAVID L. FULTON, Chief
Construction-Operations Division

CESPK-EM (500) 4 September 1987

MEMORANDUM FOR: Commander, South Pacific Division

SUBJECT: Non-Federal Levee Rehabilitation in the Sacramento-San Joaquin Legal Delta under the Provisions of PL 84-99, as amended

1. Reference:

a. Letter, SPKEM, 1 May 1987.

b. Joint SPD/SPK Meeting, 2 September 1987.

c. DRAFT - Guidelines for Rehabilitation of non-Federal Levees in the Sacramento-San Joaquin Legal Delta, CA, 3 September 1987 (encl 1).

2. Purpose.

a. The purpose of this letter is to change the recommendations submitted by Reference 1.a. The changes are to those items discussed at the joint meeting (Reference 1.b.).

b. This letter also requests your approval to implement the subject guidelines.

3. General.

a. The Chief of Engineers and the South Pacific Division Engineer tasked the Sacramento District Engineer to develop Delta-exclusive standards for non-Federal levee upgrade, by local interests, to appropriate flood control standards that will result in their being eligible for consideration for repair under PL 84-99, as amended. The Delta-exclusive standards supplement the National Guidelines (33 CFR203) issued 16 July 1986.

b. The recommended guidelines are Delta-specific and they are not intended to establish design standards for the 537 miles of non-Federal levees in the Sacramento-San Joaquin legal Delta, but to provide uniform procedures to be used by the Corps of Engineers in determining eligibility under PL 84-99, as amended. These Delta-specific guidelines supplement the National Guidelines.

c. The National Guidelines provide a maintenance inspection rating guide that is meant to be used for all non-Federal levees. That document plus the supplemental guidelines (recommended herein) and all existing PL 84-99 criteria will be used to qualify the non-Federal levees in the Sacramento-San Joaquin Delta for rehabilitation assistance.

4. Recommendations - Supplemental to the National Guidelines.

a. Non-Federal Levee Guidelines for structures in the Legal Delta to be considered flood control structures eligible to qualify for post-flood rehabilitation under PL 84-99, as amended, are as follows:

(1) 1.5 feet of freeboard above the 100-year flood stage for all islands/tracts.

(2) The 100-year flood stages are those stages developed by the Sacramento District for FEMA that are being used in their Flood Hazard Mitigation Plan, Sacramento-San Joaquin Delta, Disaster Declaration FEMA-758-DR-CA, 1986.

(3) The levee will have a 16-foot crown width with an all-weather patrol road.

(4) The minimum water side slope of the levee will be 1V:2H.

(5) The minimum land side slope of the levee will vary with the levee height and depth of peat (see encl 1). The levee stability charts were computed using an idealized levee section with 5 zones of materials and using a safety factor of 1.25. Public agencies whose levees do not fit into these guidelines may submit data/information prepared by an engineer registered in the fields of geotechnical, soils or civil that demonstrates their levees meet or exceed a 1.25 factor of safety.

(6) A levee toe drain will be located 30 feet landward from the landside levee toe.

b. The California State Water Code Section 12200 (dated 1959) has defined the boundary of the Delta and it is recommended that the Corps of Engineers adopt this boundary of the Delta for the purposes of administering the provisions of PL 84-99, as amended.

c. When any one of the following conditions is met, a determination will be made by the Sacramento District Engineer and concurred in by the South Pacific Division Engineer, for post-flood rehabilitation of non-Federal levees in the legal Delta.

(1) Antioch tidal gauge equals or exceeds 6.0 feet (1929 National Geodetic Vertical Datum) NGVD (about 25-year frequency), plus the combined flow in the Sacramento River and Yolo Bypass equals or exceeds 320,000 cfs (about 10-year frequency flow) at the latitude of the city of Sacramento, or

(2) Antioch tidal gauge equals or exceeds 6.0 feet NGVD (about 25-year frequency), plus the flows in the San Joaquin River at Vernalis equals or exceeds 28,000 cfs (about 10-year frequency rain flood), and the stage on the Mokelumne River at New Hope Landing equals or exceeds 11 feet NGVD (about 10-year frequency stage), or

(3) Antioch tidal gauge equals or exceeds 6.0 feet NGVD (about a 25-year frequency), plus the flow of any other river/stream into the legal Delta exceeds a 10-year frequency.

5. Subsequent to your approval to implement the subject Delta-specific guidelines, we have arranged to meet informally with FEMA, State OES, State DWR and State Reclamation Board officials to solicit their views. The meeting will be held at the Sacramento District office, Room No. 6543, on 30 September 1987 at 1300 hours.

Encl

WAYNE J. SCHOLL
COL, CE
Commanding

DG
GARRETT/pk/
2539
JLC
CZARZASTY
SCHOLL
9/4

CF (w/encl):
CESPD-CO-E (6)
CESPK-ED
CESPK-PD
CESPK-CO
CESPK-EM (4)

cc:
Exec RF
EMD RF

CESPK-EM 3 September 1987

GUIDELINES FOR REHABILITATION OF NON-FEDERAL LEVEES IN THE SACRAMENTO-SAN JOAQUIN LEGAL DELTA, CA

1. In 1980, the Corps of Engineers stopped all rehabilitation assistance to non-Federal levees in Sacramento-San Joaquin Legal Delta under PL 84-99 until such time that the non-Federal levees could be considered flood-control levees that provide a dependable adequate degree of protection. Subsequently, the Corps of Engineers developed National Guidelines that were finalized and published in the Federal Register Vol. 48, No. 246, dated July 16, 1986. Those guidelines are supplemented by additional guidelines, contained in this document, that are specific to the Delta. The boundaries of the legal Delta are defined in the State of California Water Code Section 12200 dated 1959. All non-Federal levees in the legal Delta will be evaluated for eligibility for rehabilitation under the provisions of PL 84-99, as amended, when they meet the guidance provided herein.

2. Summary of changes to PL 84-99, as amended. These changes prescribe a set of minimum guidelines that non-Federal flood control projects must meet to be eligible for

consideration for rehabilitation under the provisions of PL 84-99. These guidelines address both maintenance and engineering criteria and revise the existing cost-sharing formula for non-Federal projects. The changes also include a requirement that all applications for rehabilitation of non-Federal projects have a public agency sponsor. The new cost-sharing requirements, effective immediately, establish an 80% Federal-20% non-Federal distribution of the construction cost of the rehabilitation of non-Federal flood control projects. Evaluations for eligibility, investigation of flood damages, engineering and rehabilitation design costs are borne by the Corps of Engineers.

3. The National Guidance for the technical and maintenance evaluation of non-Federal flood control facilities is attached as Appendix A.

4. The Delta-specific guidelines are supplemental to the National Guidelines and are as follows:

a. 1.5 feet of freeboard above the 100-year flood stage for all islands/tracts.

b. The 100-year flood stages are shown on Appendix B. These are the same 100-year flood stages used for the Flood Hazard Mitigation Plan, Sacramento-San Joaquin Delta, Disaster Declaration FEMA-758-DR-CA, 1986.

c. The levee will have a 16-foot crown width with an all-weather patrol road.

d. The minimum water side slope of the levee will be 1V:2H.

e. The minimum land side slope of the levee will vary with the levee height and depth of peat (see Appendix D). The levee stability charts were computed using an idealized levee section with 5 zones of materials and using a safety factor of 1.25. Public agencies whose levees do not fit into these guidelines may submit data/information prepared by a registered engineer (geotechnical, soils, civil) that demonstrates their levees meet or exceed a 1.25 factor of safety.

f. A levee toe drain will be located 30 feet landward from the landside levee toe.

5. Public agencies may request an evaluation of their non-Federal levee system by providing the following information to U.S. Army Corps of Engineers, ATTN: Emergency Management Division, 650 Capitol Mall, Sacramento, CA 95814-4794.

a. Name of Island/Tract, point of contact, telephone number and address.

b. Furnish centerline profile and cross-sections of the levee at a minimum of 1,000 feet intervals.

c. If applicable, certification data of a 1.25 factor of safety.

6. When any one of the following conditions is met, a determination will be made by the Sacramento District Engineer and concurred in by the South Pacific Division Engineer for post-flood rehabilitation of non-Federal levees in the legal Delta.

a. Antioch tidal gauge equals or exceeds 6.0 feet (1929 National Geodetic Vertical Datum) NGVD (about 25-year frequency), plus the combined flow in the Sacramento River and Yolo Bypass equals or exceeds 320,000 cfs (about 10-year frequency flow) at the latitude of the city of Sacramento or

b. Antioch tidal gauge equals or exceeds 6.0 feet NGVD (about 25-year frequency), plus the flows in the San Joaquin River at Vernalis equals or exceeds 28,000 cfs (about 10-year frequency rain flood), and the stage on the Mokelumne River at New Hope Landing equals or exceeds 11 feet NGVD (about 10-year frequency stage), or

c. Antioch tidal gauge equals or exceeds 6.0 feet NGVD (about a 25-year frequency), plus the flow of any river/stream into the legal Delta exceeds a 10-year frequency.

Atchs

APPENDICES

Appendix	Description
A	Levee Rating Guide
B	Map of 100-year Flood Stages in the Delta
C	Peat Thickness Map
D	Minimum Landside Levee Configuration

Rating codes:	
	A- Acceptable Performance Level
	M- Minimally Acceptable Performance Level
	U- Unacceptable Performance Level

ITEM	RATING GUIDE		
1.	**Level of Protection**	A-	The designed section is for an exceedance frequency greater than 10% chance (10 yr.) with minimum freeboard of 2 feet.
		M-	The designed section is for an exceedance frequency between 20% to 10% chance (5-10 yr) with minimum freeboard of 1 foot.
		U-	The designed section is less than the minimum required for an M rating.
2.	**Erosion Control**	A-	Erosion protection in active areas is capable of handling the designed flow velocity for the level of protection for the entire FCW.
		M-	Erosion protection is capable of handling the designed flow velocity for the level of protection for 75% or more of the FCW.
		U-	Erosion protection measures protects less than 75% of the FCW; or if erosion protection was not provided and there is evidence indicating a need for erosion protection.
3.	**Embankment**	A-	Fill material for embankment is suitable to prevent slides and seepage for the existing side slopes. Fill material is uniform and adequately compacted through the entire FCW.
		M-	Material is adequate and suitable to prevent major slides and capable of handling localized seepage for the existing side slopes. Fill material is uniform and adequately compacted in 75% or more of the FCW.
		U-	Material is unsuitable and likely to cause numerous slides and allow excessive uncontrolled seepage. Fill material is not uniform, or there is no compaction and evidence indicates a need for compaction.
4.	**Foundation**	A-	Foundation materials will not cause piping, sand boils, seepage, or settlements which reduce the level of protection.
		M-	Foundation materials may show signs of excessive seepage, minor sand boils, and localized settlements.
		U-	Foundation materials are unsuitable and likely to cause excessive uncontrolled seepage, sand boils, and piping.

Figure E-2. Engineering Guide

5.	**Structures**	A- Structures are capable of performing their design functions and show no signs of failure.
		M- Structures are performing their design functions but show signs of overtopping and bypassing flows.
		U- Structures are not performing their design functions or show signs of structural failure.

Figure E-2. Engineering Guide (Cont'd)

E-5. Maintenance Compliance Guide. This guide (Figure E-3) is used to assign a rating for maintenance compliance during the Initial Eligibility Inspection and the Continuing Eligibility Inspection. The evaluation should reflect the level of maintenance required to insure the intended degree of flood protection and actions required by the owner/sponsor for a FCW to remain eligible for the rehabilitation program under PL 84-99.

Rating codes:

A- Acceptable Performance Level
M- Minimally Acceptable Performance Level
U- Unacceptable Performance Level

ITEM	RATING GUIDE		
1.	**Depressions**	A-	Minimal depressions or potholes; proper drainage.
		M-	Some depressions that will not pond water.
		U-	Depressions 6" vertical or greater which endangers the integrity of the levee.
2.	**Erosion**	A-	No erosion observed.
		M-	LEVEES: Erosion of levee crown or slopes that will not interrupt inspection or maintenance access. OTHER: Erosion gullies less than 6 inches deep or deviation of 1 foot from designed grade or section.
		U-	LEVEE: Erosion of levee crown or slopes that has interrupted inspection or maintenance access. OTHER: Erosion gullies greater than 6 inches or deviation of 1 foot or more from designed grade or section.
3.	**Slope Stability**	A-	No slides present, or erosion of slopes more than 4" deep.
		M-	Minor superficial sliding that with deferred repair does not pose an immediate threat to FCW integrity. No displacement or bulges.
		U-	Evidence of deep seated sliding (2 ft. vertical or greater) requiring repairs to re-establish FCW integrity.
4.	**Cracking**	A-	No cracks in transverse or longitudinal direction observed in the FCW.
		M-	Longitudinal cracks are no longer than the levee height. No displacement and bulging. No transverse cracks observed.
		U-	Longitudinal cracks are greater than levee height with some bulging observed. Transverse cracks are evident.

Figure E-3. Maintenance Compliance Guide

5.	**Animal Burrows**	A- Continuous animal burrow control program that eliminates any active burrowing in a short period of time. M- Animal burrows present that will not result in seepage or slope stability problems. U- Animal burrows present that would result in possible seepage or slope stability problems.
6.	**Unwanted Levee Growth**	A- No large brush or trees exist in the FCW. Grass cover well maintained. CHANNELS: Channel capacity for designed flows is not affected. M- Minimal tree (2" diameter or smaller) and brush cover present that will not threaten FCW integrity. (NOTE: Trees that have been cut and removed from levees should have their roots excavated and the cavity filled and compacted with impervious material). CHANNELS: Channel capacity for designed flows is not adversely affected. U- Tree, weed and brush cover exists in the FCW requiring removal to re-establish or ascertain FCW integrity. (NOTE: If significant growth on levees exists, prohibiting rating of other levee inspection items, then the inspection should be ended until this item is corrected.) CHANNEL: Channel obstructions have impaired the floodway capacity and hydraulic effectiveness.
7.	**Encroachments**	A- No trash, debris, excavations, structures, or other obstructions present. M- Trash, debris, excavations, structures, or other obstructions present or inappropriate activities occurring that will not inhibit operations and maintenance performance. U- Trash, debris, excavations, structures or other obstructions present or inappropriate activities that would inhibit operations and maintenance performance.
8.	**Riprap/Revetment**	A- Existing protection works which is properly maintained and undamaged. M- No scouring activity that could undercut banks, erode embankments, or restrict desired channel flow. U- Meandering and/or scour activity that is undercutting banks, eroding embankments (such as levees), or impairs channel flows by causing turbulence, meandering or shoaling.

Figure E-3. Maintenance Compliance Guide (Cont'd)

9.	**Stability of Concrete Structures**	**A-** Tilting, sliding or settling of structures, that has been secured which preserves the integrity or performance. **M-** Uncorrected sliding or settlement of structures of a magnitude that doesn't affect performance. **U-** Tilting or settlement of structures that has resulted with a threat to the structure's integrity and performance.
10.	**Concrete Surfaces**	**A-** Negligible spalling or scaling. No cracks present that are not controlled by reinforcing steel or that cause integrity deterioration or result in inadequate structure performance. **M-** Spalling, scaling and cracking present but immediate integrity or performance of structure not threatened. **U-** Surface deterioration or deep, controlled cracks present that result in an unreliable structure.
11.	**Structural Foundations**	**A-** No scouring or undermining near the structures. **M-** Scouring near the footing of the structure but not close enough to impact structure stability during the next flood event. **U-** Scouring or undermining at the foundation which has impacted structure integrity.
12.	**Culverts**	**A-** [a] No breaks, holes, cracks in the culvert that would result in any significant water leakage. No surface distress that could result in permanent damage. [b] Negligible debris or silt blocking culvert section. None or minimal debris or sediment present which has negligible effect on operations of the culvert. **M-** [a] Culvert integrity not threatened by spalls, scales or surface rusting. Cracks are present but resulting leakage is not impacting the structure. [b] Debris or sediment present, which is proposed to be removed prior to the next flood event, that minimally affects the operations of the culvert. **U-** [a] Culvert has deterioration such as surface distress and/or has significant leakage in quantity or degree to threaten integrity. [b] Accumulated debris or settlement which has not been annually removed and severely affects the operations of the culvert.

Figure E-3. Maintenance Compliance Guide (Cont'd)

13.	Gates	A-	Gates open easily and close to a tight seal. Materials do not have permanent corrosion damage and appear to have historically been maintained adequately.
		M-	Gates operate but leak when closed, however, leakage quantity is not a threat to performance. All appurtenances of the facility are in satisfactory condition.
		U-	Gates leak significantly when closed or don't operate. Gates and appurtenances have damages which threaten integrity and/or appear not to have been maintained adequately.
14.	Closure Structures	A-	Closure structure in good repair. Placing equipment readily available at all times.
		U-	Closure structure in poor condition. Parts missing. Placing equipment may not be available within normal warning time.
15.	Pumps and Motors	A-	All pumps and motors are operational. Preventive maintenance is occurring and system is periodically subject to performance testing.
		M-	All pumps are operational and minor discrepancies are such that pumps could be expected to perform through the next projected period of usage.
		U-	Pumps are not operational, or noted discrepancies have not been corrected.
16.	Power	A-	Adequate, reliable, and enough capacity to meet demands.
		U-	Power source not considered reliable to sustain operations during flood condition.
17.	Pump Control System	A-	Operational and maintained free of damage, corrosion or other debris.
		M-	Operational with minor discrepancies.
		U-	Not operational, or uncorrected noted discrepancies.
18.	Metallic items	A-	All metal parts in a plant/building protected from permanent damage from corrosion. Trash racks free from damage/debris and are capable of being cleared, if required, during operation. Gates operable.
		M-	Corrosion on metal parts appears maintainable. Trash racks free from damage and minimum debris present, and capable of being cleared before next flood event or during operation. Gates operable.
		U-	Metal parts need replacement. Trash racks damaged, have accumulated debris that have not been cleared annually or cannot be cleared during operation.

Figure E-3. Maintenance Compliance Guide (Cont'd)

19.	Sumps	A- Clear of debris and obstructions, and mechanisms are in place to maintain this condition during operation.
		M- Clear of large debris and minor obstructions present and mechanisms are in place to deter further accumulation during operation.
		U- Large debris or major obstructions present in sump or no mechanism exists to prevent debris accumulation during operation.

Figure E-3. Maintenance Compliance Guide (Cont'd)

Figure I-2

MINIMUM ELIGIBILITY INSPECTION DATA

1. **SPONSOR/OWNER INFORMATION**

   Name of Applicant/Requestor
   Levee Location, River, stream, river mile and bank
   City, County, State
   Name, Address, Phone, point of contact.
   POC phone of both Levee Owner and Sponsor.

2. **INTRODUCTION**

   Should list authority for inspection (e.g., PL 84-99), purpose and scope of the inspection.

32. **PROJECT INFORMATION**

   a. Identification:

   Project ID number
   River Basin and levee or drainage district
   Previous repair history such as costs, dates and by whom
   River or Creek bank and mile.

   b. Classification:

   Project purpose (flood control, land reclamation, etc.)
   Type levee (primary, secondary, setback, etc.)
   Complete/incomplete/operational/abandoned, etc.

   c. Economic Protection Provided:

   Total area protected
   Land usage and Percent
   Cropping pattern
   Value of property protected
   Facilities protected
   Historic flood damages, cite year and amount
   Frequency of event.

   d. Design Data:

   Height: top width
   Riverward and landward side slopes
   Estimated level of protection (percentage)
   Overtopping elevation
   Gage data if available
   Type of levee construction material
   Erosion protection
   Interior Drainage

4. **FIELD INSPECTION DATA (Based on Rating Guide)**

   Identify inspection team
   Summary of results of observations

5. **EVALUATION**

   a. Structural and Geotechnical:

   General Description of levee embankment features
   Foundation condition
   Stability and Seepage

   b. Hydrology and Hydraulics:

   Level of protection
   Erosion Protection

   c. Comments on Operation and Maintenance:

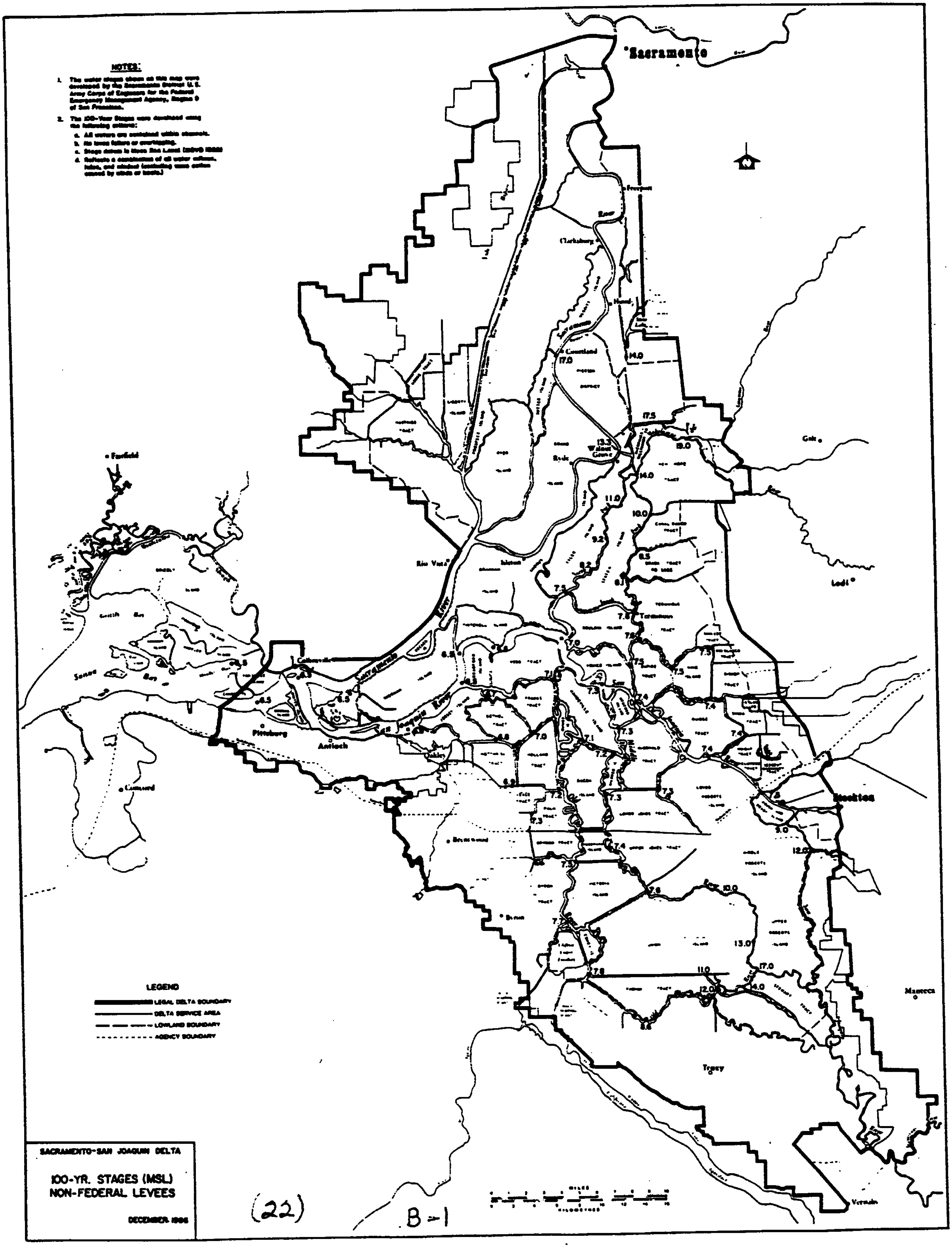
6. **RECOMMENDATIONS**

7. **LIST OF ATTACHMENTS:**

8. **SIGNATURES:**

   Report should be signed by a representative of each discipline.

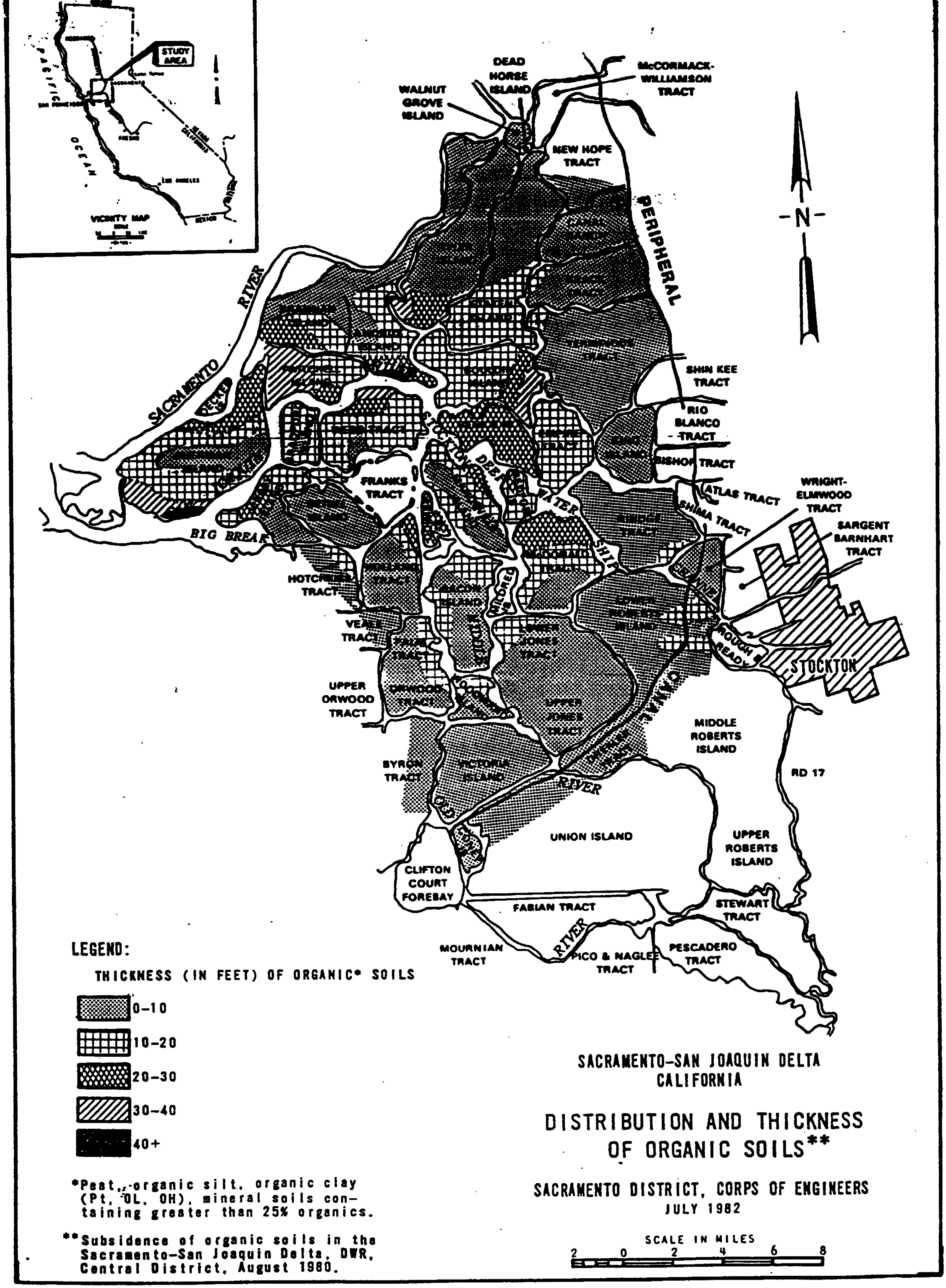
9. Each division/district shall develop a standard form (approved as required by local Information Management element) for use in documenting these inspections.

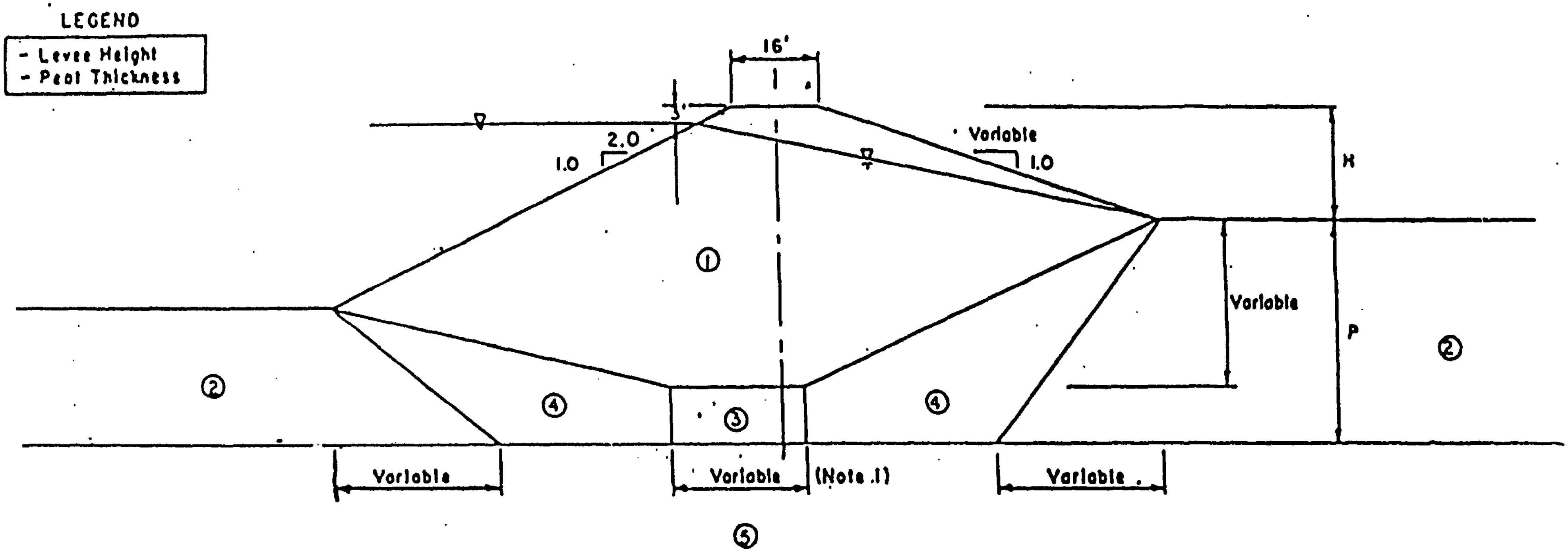


SACRAMENTO-SAN JOAQUIN DELTA

100-YR. STAGES (MSL)
NON-FEDERAL LEVEES

DECEMBER 1986


STUDY AREA
PACIFIC
OCEAN
VICINITY MAP
DEAD HORSE ISLAND
McCORMACK-WILLIAMSON TRACT
WALNUT GROVE ISLAND
NEW HOPE TRACT
-N-
PERIPHERAL
SACRAMENTO
RIVER
SHIN KEE TRACT
RIO BLANCO TRACT
BISHOP TRACT
FRANKS TRACT
DEEP WATER SHIP
ATLAS TRACT
WRIGHT-ELMWOOD TRACT
SHIMA TRACT
SARGENT BARNHART TRACT
BIG BREAK
VEALE TRACT
UPPER ORWOOD TRACT
STOCKTON
MIDDLE ROBERTS ISLAND
RD 17
BYRON TRACT
RIVER
UNION ISLAND
UPPER ROBERTS ISLAND
CLIFTON COURT FOREBAY
FABIAN TRACT
STEWART TRACT
MOURNIAN TRACT
RIVER
PICO & NAGLEE TRACT
PESCADERO TRACT
LEGEND:
THICKNESS (IN FEET) OF ORGANIC* SOILS
0-10
10-20
20-30
30-40
40+
*Peat, organic silt, organic clay (Pt, OL, OH), mineral soils containing greater than 25% organics.
**Subsidence of organic soils in the Sacramento-San Joaquin Delta, DWR, Central District, August 1980.
SACRAMENTO-SAN JOAQUIN DELTA
CALIFORNIA
DISTRIBUTION AND THICKNESS
OF ORGANIC SOILS**
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
JULY 1982
SCALE IN MILES
2 0 2 4 6 8



Zone	Material	Moist Wt (PCF)	Sat Wt (PCF)	Strength c (PCF)	Strength φ (Deg)
1	Levee Fill - Clay, Sand Peat, Silt	115	120	0	33
2	Foundation - Unconsolidated Peat & Clayey Peat	77	77	100	18
3	Foundation - Consolidated Peats & Clayey Peats	85	85	200	27
4	Foundation - Partially Consolidated Peats & Clayey Peats	85	85	150	25
5	Foudation - Clayey Sand, Firm Sand & Silty Sand	127	135	0	35

NOTES:

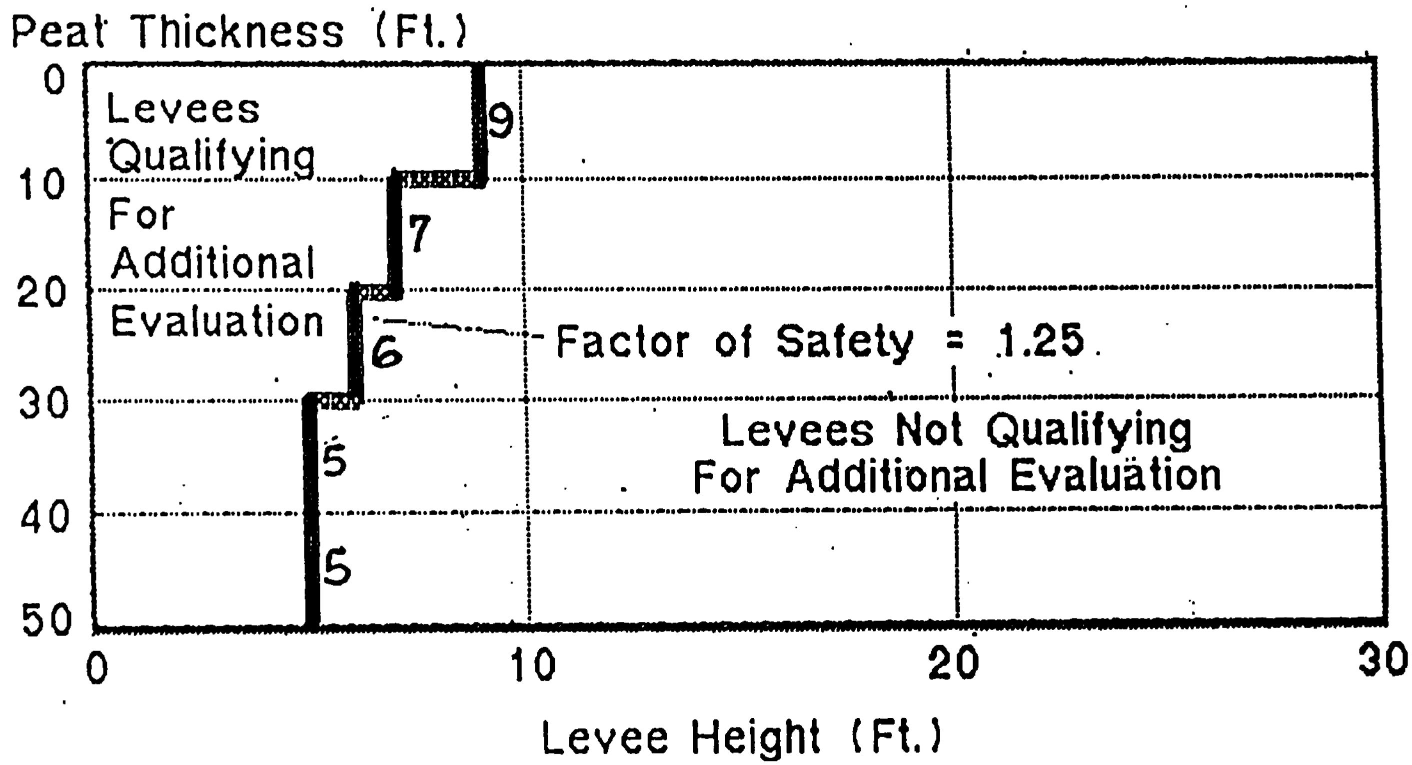
1. Dimensions noted as variable, change as a function of levee height and peat depth.
2. References a & d.
3. No distinction is made between peat, organic silt, organic clay, and mineral soil containing greater than 25% organics.

Minimum Levee Geometry
Sacramento - San Joaquin Delta

GENERALIZED LEVEE SECTION & DESIGN PARAMETERS

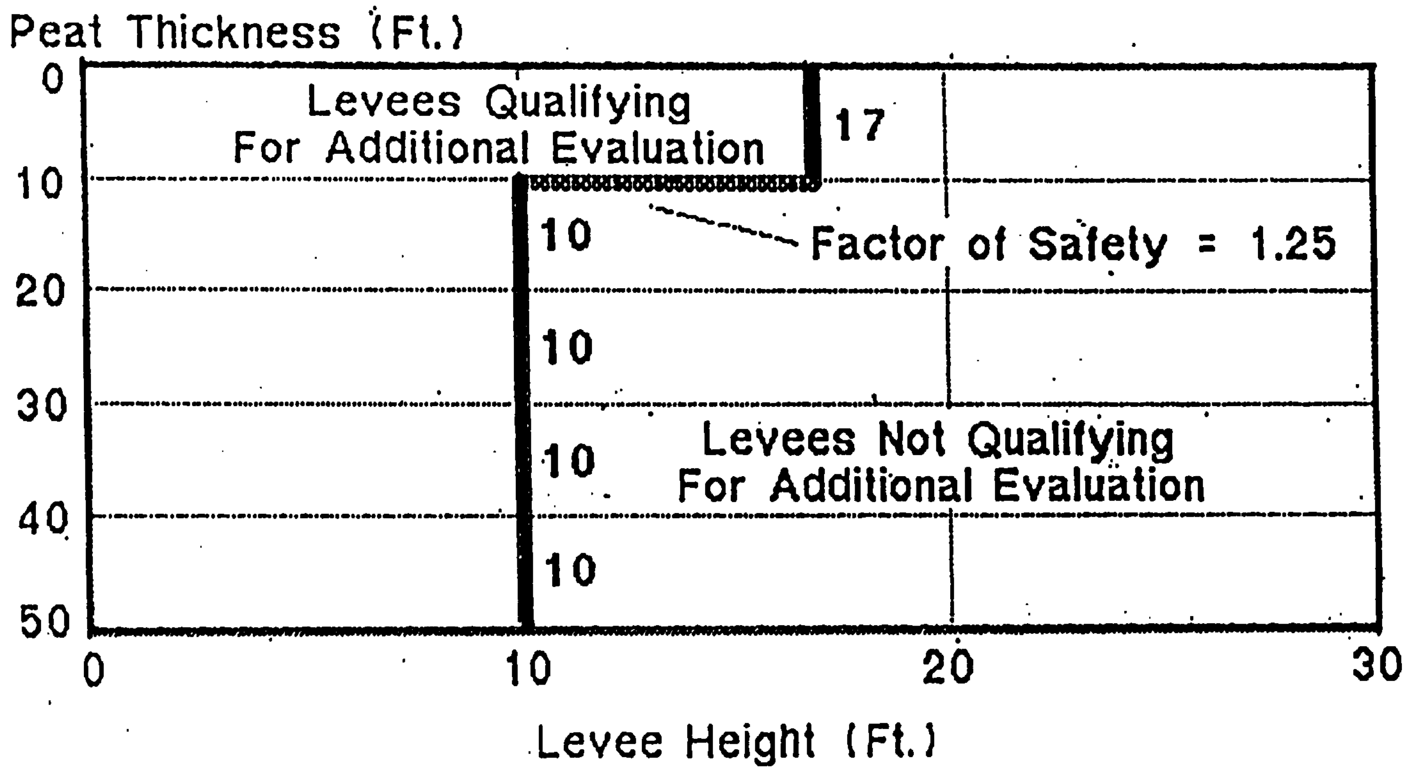
Sacramento-San Joaquin Legal Delta
PL84-99
Agricultural and Urban Island Stability

1(V) ON 2(H) LANDSIDE SLOPE



Sacramento-San Joaquin Legal Delta
PL84-99
Agricultural and Urban Island Stability

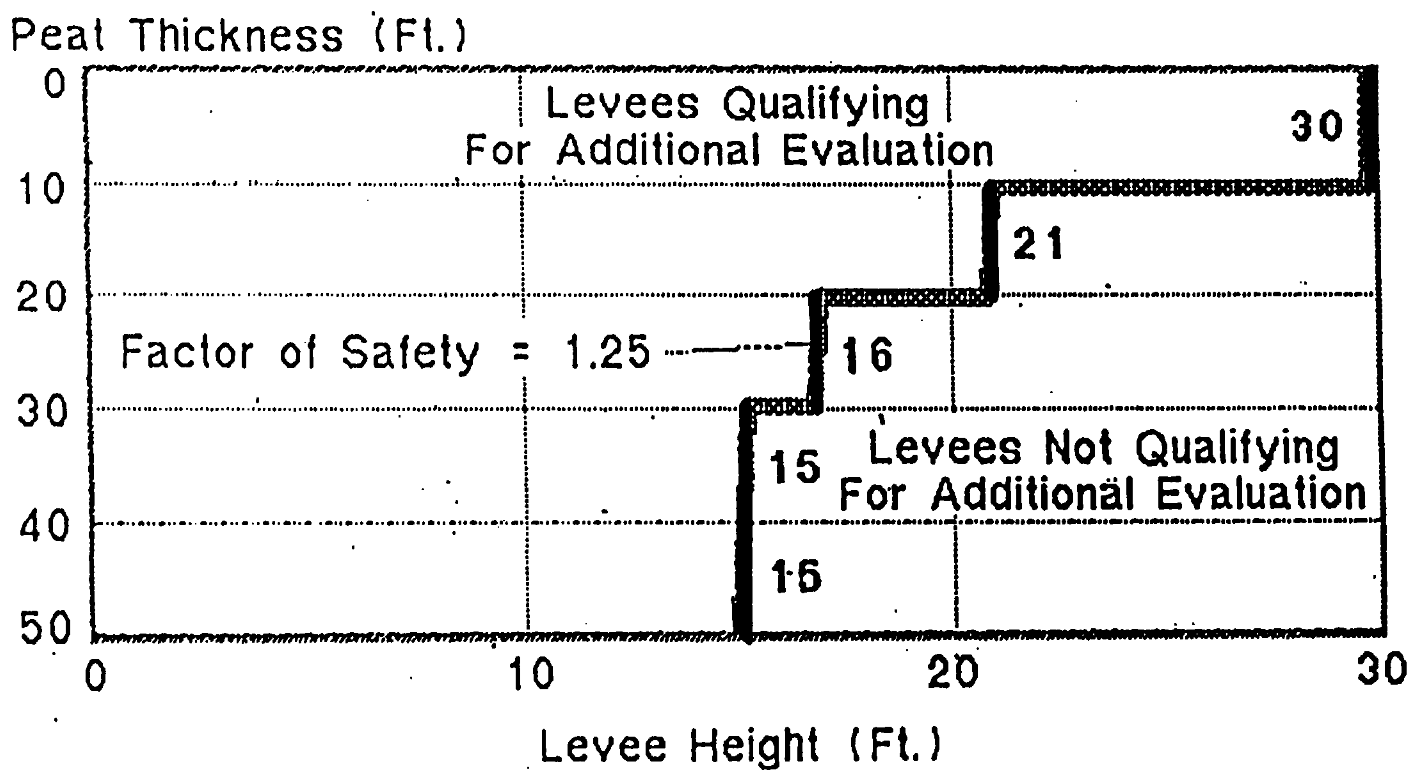
1(V) ON 3(H) LANDSIDE SLOPE



D-3

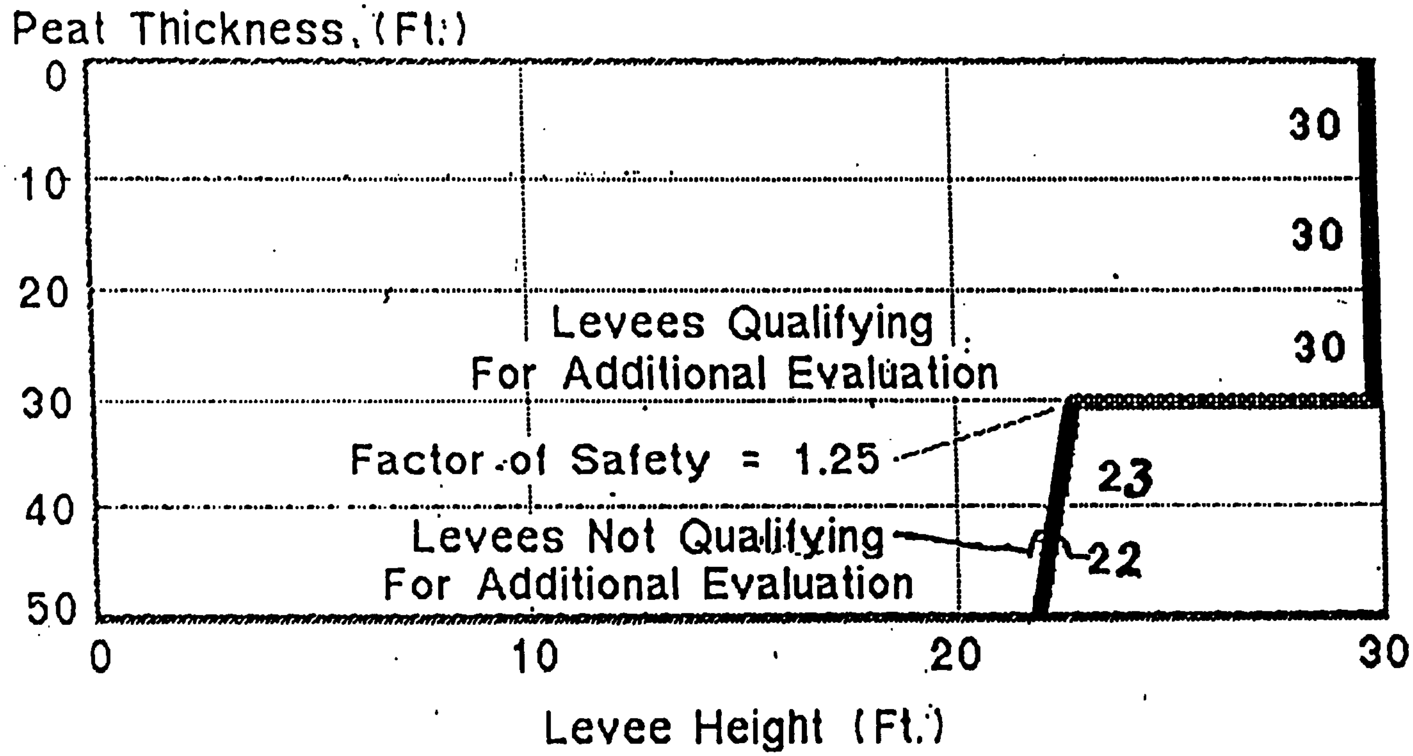
Sacramento-San Joaquin Legal Delta
PL84-99
Agricultural and Urban Island Stability

1(V) ON 4(H) LANDSIDE SLOPE



Sacramento-San Joaquin Legal Delta
PL84-99
Agricultural and Urban Island Stability

1(V) ON 5(H) LANDSLIDE SLOPE



US ARMY CORPS OF ENGINEERS

DISASTER ASSISTANCE OVERVIEW

The US Army Corps of Engineers is a major Army command with a broad set of missions and capabilities. One of its missions is to provide assistance, within its authorities, when natural disasters or other emergencies occur.

Emergency preparedness and response is primarily a state and local responsibility. However, in instances when the nature of the disaster exceeds the capabilities of state and local interests, the Corps of Engineers may provide help to save human life, prevent immediate human suffering, or mitigate property damage.

The authority for the Corps of Engineers to provide such assistance is Public Law (PL) 84-99. Under this law, the Corps of Engineers is authorized to provide assistance under the following six programs:

1. Disaster Preparedness
2. Advance Measures
3. Emergency Operations
4. Rehabilitation and Inspection of Flood Control Works
5. Emergency Water
6. Hazard Mitigation

Each program is described in greater detail in the subsequent paragraphs.

1. Disaster Preparedness. State and local governments are responsible for natural disaster emergency preparedness, including training and stockpiling of flood fight supplies. The role of the US Army Corps of Engineers is to supplement maximum efforts of the state and local authorities during a natural disaster emergency. The Corps of Engineers provides the following assistance to the state and local communities:

a. Provides personnel to assist communities with public information programs for awareness and knowledge of natural disaster hazards.

b. When requested by state and local officials, the Corps will participate in natural disaster emergency seminars or exercises.

c. Provide technical assistance for development of emergency plans at the state and local level.

d. Inspection of flood control works constructed or repaired by the Corps of Engineers, and advisement to local sponsors of needed maintenance.

e. Upon request, inspection of non-federal flood control works. This is covered more thoroughly under Rehabilitation of Flood Control Works.

2. Advance Measures. Advance measures consist of actvities performed prior to a flood event, including flood fighting actions, to protect against loss of life and damages to urban and/or public facilities. The threat must be of a nature that if no action is not immediately taken, damages will be incurred. The following criteria must be met for Corps assistance:

a. An imminent threat of unusual flooding must exist to justify assistance. The threat must be established by either the National Weather Service (NWS) forecast or by Corps determination of unusual flooding from adverse conditions.

b. Assistance will be in support of state and local on going or planned efforts. All activities will be coordinated with the State Office of Emergency Operations or equivalent. Local and state interests must commit available resources.

c. A written request is required from the state governor or designated representative.

d. Requested assistance must be technically feasible and have a economically justifiable cost benefit ratio.

e. Assistance will be temporary in nature, designed to effectively deal with the specific threat, and capable of construction in time to prevent projected damages.

f. These projects must have a Public Sponsor.

g. Assistance is terminated when the imminent flood threat ends.

h. Assistance may be in the form of Technical or Direct assistance.

i. Technical assistance consists of technical review, advice, and/or recommendations to state and local agencies before, during and/or after a flood event. The following are examples of technical assistance support:

- Provide personnel to inspect existing flood control works to identify potential problems and solutions, to evaluate conditions to determine additional flood control protection requirements, and to recommend the most expedient construction methods.

- Provide hydraulic, hydrologic, and/or geotechnical analysis.

- Provide information, readily available at Corps districts, to local entities for use in the preparation of local evacuation and/or contingency flood plans.

j. Direct assistance provided by the Corps to supplement state and local resources may include:

- Flood fight materials such as sandbags, plastic sheeting, lumber, stone, pumps etc.

- Corps equipment if available

- Emergency contracting

k. The types of emergency work the Corps can provide are:

- Emergency work on Federal and Non-Federal Flood Control Works by strengthening or temporary raising to prevent structural failure or overtopping.

- Construction of temporary flood control levees to protect life and improved property.

- Removal of channel obstructions to allow the passing of predicted flood flows. Obstructions may be snags/logs or debris jams, or sand and gravel bars restricting hydraulic capacity.

- Relieve the threat of dam failures by dewatering, controlled breaching, or strengthing.

3. Emergency Operations. The Corps of Engineers may provide emergency assistance for flood and post flood response to save lives and protect improved property, such as public facilities/services and residential/commercial developments. This assistance will supplement state and local efforts. State and local entities must commit all available resources, i.e., manpower, supplies, equipment, funds, etc. Assistance to individual homeowners, businesses (to include agricultural property) is not permitted.

a. Corps assistance during flood fight operations will be of a temporary nature to meet the immediate threat and is not intended to provide permanent solutions to flood problems.

b. Emergency assistance must be requested by the state governor or his/her designated representative for flood and post flood response.

c. The Corps flood fight assistance may be in the form of technical or direct assistance.

- Technical Assistance for any disaster consists of providing review and recommendations in support of state and local efforts. Examples of technical assistance are:

(1) Providing experienced personnel at the

disaster site to give guidance on flood fight techniques and emergency construction methods.

(2) Providing personnel to inspect existing flood protection projects and/or structurally threatened dams to identify problem areas and recommended corrective measures.

(3) Providng hydraulic or hydrologic analysis, geotechnical evaluations, topography and stream data, maps, and historic flood or storm information.

- <u>Direct Assistance</u> may include but is not limited to the following:

(1) Purchase of flood fight materials to support on-going state and local efforts. These materials include sandbags, sand, plastic sheeting, lumber, etc. Government supplies may be furnished only if local resources are exhausted or will be exhausted. Unused materials will be returned, replaced in kind, or reimbursement made to the Corps of Engineers.

(2) Assist in search and rescue operations. The Corps may use its resources in such operations.

(3) Corps may direct flood fight operations upon request of an appropriate state or local official. <u>However</u>, legal responsibility remains with the requesting official.

(4) Emergency contracting will be available to hire equipment and operators. Emergency work includes construction of temporary levees, the emergency repair, strengthening, or temporary raising of levees or other flood control works, or removal of stream obstructions.

d. Flood response assistance will end when the flood waters recede to bankfull conditions.

e. The authority for the Corps of Engineers to perform post flood response was enacted by the US Congress under Section 917 of the Water Resources Act of 1986. The intent of this authority is to allow Corps assistance prior to a Presidential Declaration made under authority of the <u>Stafford Act</u>. Corps assistance will be limited to major floods/coastal storms resulting in life threatening situations. Response is limited to lifesaving actions and protection of public facilities/services and residential/commercial developments. Assistance to individual homeowners and businesses (to include agricultural property) <u>is not</u> permitted.

- A written request from the governor to the appropriate district commander will be provided concurrently with or immediately after the governor's request to FEMA for a Preliminary Damage Assessment (PDA).

- This request must indicate that recovery work is beyond the capability of the state, identify specific damage locations, and detail specific requirements for Corps of Engineers assistance.

- Corps assistance is limited to a maximum of 10 days from the receipt date of the governor's request for assistance.

- No work, including contract work, shall be performed after the 10 day period expires. Post response assistance may be technical or direct assistance. Direct assistance activities include:

(1) Clearance of debris necessary to reopen critical transportation routes.

(2) Restoration of critical transportation routes or public ervices or facilities.

(3) Other assistance required to prevent loss of life or public property as determined by the division or district commander.

4. Rehabilitation and Inspection Program (RIP). The RIP is the Corps of Engineers program that implements the provisions of Public Law 84-99 regarding inspection and rehabilitation of Non-Federal flood control works and the rehabilitation of Federal flood control works. Rehabilitation assistance is limited to eligible Non-Federal and Federally authorized flood control projects. The Non-Federal Flood Control Works Rehabilitation Program is described on pages 7 thru 10 and Exhibit A and B. Structures that are not eligible for assistance are:

a. Structures built for channel alignment, navigation, recreation, fish and wildlife, land reclamation, drainage, or to protect against land erosion are not flood control works.

b. Bank protection works, river control structures, or other non-flood control projects constructed by the Corps.

c. Structures damaged by non-flood disasters such as earthquakes or volvanic eruptions are not authorized assistance. If a potential flood threat exists due to damage caused by a non-flood disaster, Corps of Engineers Headquarters may grant exceptions on a case by case basis to allow rehabilitation.

d. Those flood control works constructed, operated and maintained by the Corps or other Federal agencies are not eligible for inclusion into the RIP and not eligible for rehabilitation assistance. Those flood control works constructed, modified, or repaired with financial assistance from other Federal agencies (e.g., Bureau of Reclamation, Natural Resources Conservation Service) are not eligible for assistance, unless exceptions are granted by Corps of Engineers Headquarters.

e. The project Public Sponsor must furnish items of cooperation and assurance prior to any construction work:

(1) Provide without cost to the United States all lands, easements, barrow lands, and rights-of-way necessary.

(2) Hold and save the United States free from damages due to the work, exclusive of damages due to negligence of the United States or its contractor.

(3) Maintain and operate, in a manner satisfactory to the Chief of Engineers, the entire project after completion.

5. Emergency Water Assistance. The Corps may provide potable water to any community confronted with water supply problems associated with a contaminated water source or drought conditions. The supply problems must present a substantial threat to the public health and welfare of the inhabitants in the area. The intent of the assistance is to meet minimum public health, safety, and welfare requirements. This assistance will supplement state and local relief efforts to supply water for public health and welfare.

a. Written request required from the state governor or authorized representative.

b. Contamination, whether deliberate, accidental, or natural will be be established by one or more of the following:

(1) Maximum established contaminant levels pursuant to the Safe Drinking Water Act are exceeded.

(2) Water supply identified as source of illness by state or Federal public health official.

(3) Emergency situation has either resulted in contaminants entering the source or has made equipment inoperable to remove the contaminants.

c. Assistance provided for transportation of bulk water by certified vehicle, small diameter pipeline, purchase of bottled water, or installation of temporary filtration units. Must be cost effective and meet the need. Also, construction of wells by competitive bid contract.

d. Assistance provided for 30 days. Extensions granted with adequate justification and explanation.

e. A drought distressed area is one that the Assistant Secretary of the Army determines to have an inadequate supply which is causing, or is likely to cause, substantial threat to public health and welfare of the area including threat of damage or loss of property.

6. Hazard Mitigation. The Corps of Engineers supports and is a member of the FEMA Hazard Mitigation Team.

PUBLIC LAW 84-99 AS AMENDED
Non-Federal Flood Control Works Rehabilitation Program

A. General Policy

The Corps of Engineers has authority, under PL 84-99, to repair flood control projects which are damaged by flood. Flood control projects constructed by non-Federal interests may be eligible for this disaster recovery assistance provided that certain criteria for eligibility and local cooperation are met. For example, a project constructed by non-Federal interests must meet established Corps quidelines to establish its structural integrity for flood control purposes. The policy is consistent with policy and procedures established by other Federal agencies for disaster assistance. The policy will help insure that the intent of Executive Order 11988 is met.

B. Policy Background

In July 1986, the Corps of Engineers revised and standardized the PL84-99 levee rehabilitation program for structures not originally constructed by a Federal agency. The program revisions were intended to provide uniformity throughout the Corps in establishing requirements for state and local participation associated with rehabilitation assistance. The revisions culminated in focusing on development of uniform eligibility quidelines and requirements for public sponsorship and local cooperation, to include cost sharing. The revisions will provide for greater participation by concerned state and local agencies in the Corps non-Federal flood control project rehabilitation program. Also, project sponsors are given the same eligibility requirements nationwide, for promoting local attention on disaster preparedness and promoting improved levee design and maintenance, and encourage sound floodplain management practices.

C. Policy Coordination Between Corps and NCRS

In 1986, the Corps and Soil Conservation Service (NCRS) signed a Memorandum of Agreement which outlined how the two agencies would delineate responsibility for repair of levees. The agencies agreed in general principle that the delineation would be based upon the area of geoghraphical contributing drainage. The Corps would be responsible for repairing levees with drainage areas of 400 square miles or greater with the NCRS responsible drainage areas less than 400 square miles. Corps policy for the repair of levees in the Corps geographic areas requires that levee sponsors be active participants in the Corps PL84-99 non-Federal levee rehabilitation program at the time of the disaster event to be considered eligible for rehabilitation assistance. Sponsors or private owners that **have not** applied for the Corps program and are in the NCRS's area of responsibility should seek assistance under NCRS's Emergency Watershed Program.

D. <u>Corps PL84-99 Non-Federal FCW Rehabilitation Program</u>

1. To become eligible for assistance, several steps **must** be taken. One very important step the levee owner must take is to acquire public sponsorship for the flood control structure. The public sponsor will request the Initial Levee Eligibility Inspection on behalf of the levee owner. The sponsor will sign the Project Cooperation Agreement with the Federal Government in the event rehabilitation work will be authorized on the levee. A public sponsor must be a financially, viable identity capable of fulfilling operations and maintenance requirements and ensuring proper stewardship of the Federal investment. The sponsor must be one of the following:

* state chartered organization such as a levee board, reclamation board, flood control district, etc.
* a legal subdivision of a state or a county government
* a local unit of government
* a qualified Indian tribe or tribal organization

2. Another step in the eligibility process is the eligibility inspection. This inspection will be conducted by the Corps to assess the integrity and reliability of your flood control works. The eligibility inspection will consist of:

* structural and geotechnical analysis
* hydrologic and hydraulic evaluation
* operation and maintenance determinations

The eligibility inspection will be conducted using a rating quide which provides the inspector with a consistent and accurate system of inspection. An inspection checklist, based upon the quidelines, will be filled out at the conclusion of the field inspection. A copy of this checklist will be provided to the sponsor on site for his records and a copy retained in the Corps files. At the conclusion of the eligibility determination process, the sponsor and owner will receive written notification of the overall condition of the levee. The levee will be rated as one of the following:

* Acceptable - no work required
* Minimally Acceptable - deficient conditions exist which should be improved
* Unacceptable - the levee is ineligible for rehabilitation assistance under PL84-99 unless corrective action is taken and the levee is reinspected before any request for assistance is accepted.

If an unacceptable rating is given, a recommendation for corrective action will be made by the Corps of Engineers. If the levee sponsor does not comply with the recommendation and the levee **is not** upgraded to at least the Minimally Acceptable level, the Corps **will not** perform repair work in the event of damage resulting from a flood. The sponsor should complete the recommended upgrade work as soon as possible. If the levee is upgraded to at least the Minimum Acceptable level, the sponsor **must** notify the Corps that the corrective work has been completed. The levee will be reinspected and reinstated in the program as an active levee. An Unacceptable rated levee is carried as an inactive levee until corrective work is accomplished.

The Corps will conduct Continuing Eligibility Inspections utilizing the Maintenance Compliance Guide for all flood control works that are in an "active" eligibility status. These subsequent inspections will be for the purpose of detecting significant changes to the levee from the Initial Inspection which impact the integrity of the levee. A rating in accordance with the rating guidelines will be given for each inspection and will be performed at least once every two years. If the levee receives an unacceptable rating on these inspection, the levee will be put in an "inactive" status until the corrective work is accomplished and the sponsor requests the Corps to perform a re inspection.

E. Criteria for Corps Assistance

The following criteria must be met for the Corps to repair Federal and non-Federal flood control works.

* The Corps will repair federal levees and flood control works at 100% cost to the federal government. A federal levee or federal flood control works is authorized, constructed by the Corps, and operated and maintained by a local sponsor.
* Requests for Corps assistance in repairing non federal flood control works must:
    * Be in an "active" status under the PL84-99 FCW rehabilitation program.
    * Be from the public sponsor.
    * Be economically justified (have a favorable cost benefit ratio of at least 1:1).
    * Be cost shared 80% federal and 20% public sponsor.
    * Provide required level of flood protection.
    * Adhere to environmental laws, policies and regulations.
    * Meet the rehabilitation engineering and maintenance guidelines prior to the flood event.
    * Restore flood control Works (FCW) to original pre-flood conditions.

Attached Exhibit A contains the Eligibility Rating Guidelines, Policy Summary, and the Project Cooperation Agreement. The rating guidelines **are not** intended as an absolute standard, nor are they intended to establish design standards for non-Federal flood control works. The guidelines are used to establish uniform procedures in assigning rating codes to the flood control works.

F. Sacramento-San Joaquin Delta Specific Guidelines

1. In 1987, the Corps implemented additional eligibility guidelines specifically for the legal delta, as defined by the California State Water Code Section 12200, dated 1959. The Delta-exclusive quidelines supplement the National Guidelines described in paragraphs D and E.

2. The minimum quidelines that must be met for the flood control works to be eligible for PL84-99 rehabilitation consideration are as follows:

* 1.5 feet of levee freeboard above the 100 year flood stage for all islands/tracts. These are the same 100 year flood stages used for the Flood Hazard Mitigation Plan, Sacramento-San Joaquin Delta, Disaster Declaration FEMA-758-DR-CA, 1986.
* The levee will have a 16 foot crown width with an all weather patrol road.
* A levee toe drain will be located 30 feet landward from the land side levee toe.
* The minimum water side slope of the levee will be 1V:2H.
* The minimum land side slope of the levee will vary with the levee height and the depth of peat. The levee stability charts in attached Exhibit B were computed using an idealized levee section with 5 zones of materials and using a safety factor of 1.25. Public sponsors whose levees do not fit into these guidelines may submit data/information prepared by a registered engineer (geotechnical, soils, civil) that demonstrates their levees meet or exceed a 1.25 factor of safety. A delta peat thickness map is included in Exhibit B.

3. Public sponsors may request an evaluation of their non-Federal flood control works system by providing the following information to U.S. Army Corps of Engineers, ATTN: Construction-Operations Division, Readiness Branch, 1325 J Street, Sacramento, CA 95814-2922. The telephone number is (916) 557-6911 or 557-6913.

Rating codes:

A- Acceptable Performance Level
M- Minimally Acceptable Performance Level
U- Unacceptable Performance Level

ITEM	RATING GUIDE		
1.	**Level of Protection**	A-	The designed section is for an exceedance frequency greater than 10% chance (10 yr.) with minimum freeboard of 2 feet.
		M-	The designed section is for an exceedance frequency between 20% to 10% chance (5-10 yr) with minimum freeboard of 1 foot.
		U-	The designed section is less than the minimum required for an M rating.
2.	**Erosion Control**	A-	Erosion protection in active areas is capable of handling the designed flow velocity for the level of protection for the entire FCW.
		M-	Erosion protection is capable of handling the designed flow velocity for the level of protection for 75% or more of the FCW.
		U-	Erosion protection measures protects less than 75% of the FCW; or if erosion protection was not provided and there is evidence indicating a need for erosion protection.
3.	**Embankment**	A-	Fill material for embankment is suitable to prevent slides and seepage for the existing side slopes. Fill material is uniform and adequately compacted through the entire FCW.
		M-	Material is adequate and suitable to prevent major slides and capable of handling localized seepage for the existing side slopes. Fill material is uniform and adequately compacted in 75% or more of the FCW.
		U-	Material is unsuitable and likely to cause numerous slides and allow excessive uncontrolled seepage. Fill material is not uniform, or there is no compaction and evidence indicates a need for compaction.
4.	**Foundation**	A-	Foundation materials will not cause piping, sand boils, seepage, or settlements which reduce the level of protection.
		M-	Foundation materials may show signs of excessive seepage, minor sand boils, and localized settlements.
		U-	Foundation materials are unsuitable and likely to cause excessive uncontrolled seepage, sand boils, and piping.

Figure E-2. Engineering Guide

5.	Structures	A-	Structures are capable of performing their design functions and show no signs of failure.
		M-	Structures are performing their design functions but show signs of overtopping and bypassing flows.
		U-	Structures are not performing their design functions or show signs of structural failure.

Figure E-2. Engineering Guide (Cont'd)

TABLE E-2
Cross Section Template Data

Levee Material	Maximum Riverward Side-Slope	Maximum Landward Side-Slope	Maximum Height	Top Width
Clay	1V on 2 1/2H	1V on 2 1/2H	12 Feet	10 Ft
Sand	1V on 3H	1V on 4H	15 Feet	10 Ft

Table E-2 used as a quide for the evaluation of slope stability.

E-5. Maintenance Compliance Guide. This guide (Figure E-3) is used to assign a rating for maintenance compliance during the Initial Eligibility Inspection and the Continuing Eligibility Inspection. The evaluation should reflect the level of maintenance required to insure the intended degree of flood protection and actions required by the [redacted]/sponsor for a FCW to remain eligible for the rehabilitation program under PL 84-99.

Rating codes:

A- Acceptable Performance Level
M- Minimally Acceptable Performance Level
U- Unacceptable Performance Level

ITEM		RATING GUIDE	
1.	**Depressions**	A-	Minimal depressions or potholes; proper drainage.
		M-	Some depressions that will not pond water.
		U-	Depressions 6" vertical or greater which endangers the integrity of the levee.
2.	**Erosion**	A-	No erosion observed.
		M-	LEVEES: Erosion of levee crown or slopes that will not interrupt inspection or maintenance access. OTHER: Erosion gullies less than 6 inches deep or deviation of 1 foot from designed grade or section.
		U-	LEVEE: Erosion of levee crown or slopes that has interrupted inspection or maintenance access. OTHER: Erosion gullies greater than 6 inches or deviation of 1 foot or more from designed grade or section.
3.	**Slope Stability**	A-	No slides present, or erosion of slopes more than 4" deep.
		M-	Minor superficial sliding that with deferred repair does not pose an immediate threat to FCW integrity. No displacement or bulges.
		U-	Evidence of deep seated sliding (2 ft. vertical or greater) requiring repairs to re-establish FCW integrity.
4.	**Cracking**	A-	No cracks in transverse or longitudinal direction observed in the FCW.
		M-	Longitudinal cracks are no longer than the levee height. No displacement and bulging. No transverse cracks observed.
		U-	Longitudinal cracks are greater than levee height with some bulging observed. Transverse cracks are evident.

Figure E-3. Maintenance Compliance Guide

5.	**Animal Burrows**	A- Continuous animal burrow control program that eliminates any active burrowing in a short period of time. M- Animal burrows present that will not result in seepage or slope stability problems. U- Animal burrows present that would result in possible seepage or slope stability problems.
6.	**Unwanted Levee Growth**	A- No large brush or trees exist in the FCW. Grass cover well maintained. CHANNELS: Channel capacity for designed flows is not affected. M- Minimal tree (2" diameter or smaller) and brush cover present that will not threaten FCW integrity. (NOTE: Trees that have been cut and removed from levees should have their roots excavated and the cavity filled and compacted with impervious material). CHANNELS: Channel capacity for designed flows is not adversely affected. U- Tree, weed and brush cover exists in the FCW requiring removal to re-establish or ascertain FCW integrity. (NOTE: If significant growth on levees exists, prohibiting rating of other levee inspection items, then the inspection should be ended until this item is corrected.) CHANNEL: Channel obstructions have impaired the floodway capacity and hydraulic effectiveness.
7.	**Encroachments**	A- No trash, debris, excavations, structures, or other obstructions present. M- Trash, debris, excavations, structures, or other obstructions present or inappropriate activities occurring that will not inhibit operations and maintenance performance. U- Trash, debris, excavations, structures or other obstructions present or inappropriate activities that would inhibit operations and maintenance performance.
8.	**Riprap/Revetment**	A- Existing protection works which is properly maintained and undamaged. M- No scouring activity that could undercut banks, erode embankments, or restrict desired channel flow. U- Meandering and/or scour activity that is undercutting banks, eroding embankments (such as levees), or impairs channel flows by causing turbulence, meandering or shoaling.

Figure E-3. Maintenance Compliance Guide (Cont'd)

9.	**Stability of Concrete Structures**	**A-** Tilting, sliding or settling of structures, that has been secured which preserves the integrity or performance.
		M- Uncorrected sliding or settlement of structures of a magnitude that doesn't affect performance.
		U- Tilting or settlement of structures that has resulted with a threat to the structure's integrity and performance.
10.	Concrete Surfaces	**A-** Negligible spalling or scaling. No cracks present that are not controlled by reinforcing steel or that cause integrity deterioration or result in inadequate structure performance.
		M- Spalling, scaling and cracking present but immediate integrity or performance of structure not threatened.
		U- Surface deterioration or deep, controlled cracks present that result in an unreliable structure.
11.	**Structural Foundations**	**A-** No scouring or undermining near the structures.
		M- Scouring near the footing of the structure but not close enough to impact structure stability during the next flood event.
		U- Scouring or undermining at the foundation which has impacted structure integrity.
12.	**Culverts**	**A-** [a] No breaks, holes, cracks in the culvert that would result in any significant water leakage. No surface distress that could result in permanent damage. [b] Negligible debris or silt blocking culvert section. None or minimal debris or sediment present which has negligible effect on operations of the culvert.
		M- [a] Culvert integrity not threatened by spalls, scales or surface rusting. Cracks are present but resulting leakage is not impacting the structure. [b] Debris or sediment present, which is proposed to be removed prior to the next flood event, that minimally affects the operations of the culvert.
		U- [a] Culvert has deterioration such as surface distress and/or has significant leakage in quantity or degree to threaten integrity. [b] Accumulated debris or settlement which has not been annually removed and severely affects the operations of the culvert.

Figure E-3. Maintenance Compliance Guide (Cont'd)

13.	**Gates**	A-	Gates open easily and close to a tight seal. Materials do not have permanent corrosion damage and appear to have historically been maintained adequately.
		M-	Gates operate but leak when closed, however, leakage quantity is not a threat to performance. All appurtenances of the facility are in satisfactory condition.
		U-	Gates leak significantly when closed or don't operate. Gates and appurtenances have damages which threaten integrity and/or appear not to have been maintained adequately.
14.	**Closure Structures**	A-	Closure structure in good repair. Placing equipment readily available at all times.
		U-	Closure structure in poor condition. Parts missing. Placing equipment may not be available within normal warning time.
15.	**Pumps and Motors**	A-	All pumps and motors are operational. Preventive maintenance is occurring and system is periodically subject to performance testing.
		M-	All pumps are operational and minor discrepancies are such that pumps could be expected to perform through the next projected period of usage.
		U-	Pumps are not operational, or noted discrepancies have not been corrected.
16.	**Power**	A-	Adequate, reliable, and enough capacity to meet demands.
		U-	Power source not considered reliable to sustain operations during flood condition.
17.	**Pump Control System**	A-	Operational and maintained free of damage, corrosion or other debris.
		M-	Operational with minor discrepancies.
		U-	Not operational, or uncorrected noted discrepancies.
18.	**Metallic items**	A-	All metal parts in a plant/building protected from permanent damage from corrosion. Trash racks free from damage/debris and are capable of being cleared, if required, during operation. Gates operable.
		M-	Corrosion on metal parts appears maintainable. Trash racks free from damage and minimum debris present, and capable of being cleared before next flood event or during operation. Gates operable.
		U-	Metal parts need replacement. Trash racks damaged, have accumulated debris that have not been cleared annually or cannot be cleared during operation.

Figure E-3. Maintenance Compliance Guide (Cont'd)

19.	**Sumps**	**A-**	**Clear of debris and obstructions, and mechanisms are in place to maintain this condition during operation.**
		M-	**Clear of large debris and minor obstructions present and mechanisms are in place to deter further accumulation during operation.**
		U-	**Large debris or major obstructions present in sump or no mechanism exists to prevent debris accumulation during operation.**

Figure E-3. Maintenance Compliance Guide (Cont'd)

PUMP STATION MAINTENANCE INSPECTION GUIDE

RATED ITEM	A	M	U	EVALUATION
SECTION I				*FOR USE DURING INITIAL ELIGIBILITY INSPECTION ONLY*
1. Pump Station Size				Pump station has adequate capacity (considering pumping capacity, ponding areas, etc.) to handle expected inflow volumes. (A or U.)
SECTION II				*FOR USE DURING ALL PUMP STATION INSPECTIONS*
2. O&M Manual				O&M Manual is present and adequately covers all pertinent areas. (A or U.)
3. Operating Log				Pump Station Operating Log is present and being used. (A or U.)
4. Annual Inspection				Annual inspection is being performed by the local sponsor. (A or U.)
5. Plant Building				A Plant building is in good structural condition. No apparent major cracks in concrete, no subsidence, roof is not leaking, etc. Intake louvers clean, clear of debris. Exhaust fans operational and maintained. Safe working environment. M Spalling and cracking are present, or minimal subsidence is evident, or roof leaks, or other conditions are present that need repair but do not threaten the structural integrity or stability of the building. U Any condition that does not meet at least Minimum Acceptable standards.
6. Pumps				A All pumps are operational. Preventive maintenance and lubrication are being performed. System is periodically subjected to performance testing. No evidence of unusual sounds, cavitation, or vibration. M All pumps are operational and deficiencies/minor discrepancies are such that pumps could be expected to perform through the next expected period of usage. U One or more primary pumps are not operational, or noted discrepancies have not been corrected.
7. Motors, Engines, and Gear Reducers				A All items are operational. Preventive maintenance and lubrication being performed. System is periodically subjected to performance testing. Instrumentation, alarms, and auto shutdowns operational. M All systems are operational and deficiencies/minor discrepancies are such that pumps could be expected to perform through the next expected period of usage. U One or more primary motors are not operational, or noted discrepancies have not been corrected.
8. Trash Rakes				A Drive chain, bearings, gear reducers, and other components are in good operating condition and properly maintained. M Drive chain, bearings, gear reducers, and other components are capable of performing as designed through the next flood event. U Proper operation would be inhibited during the next flood event.
9. Other Metallic Items				A All metal parts in plant/building are protected from permanent damage by corrosion. Equipment anchors show no rust or deterioration. M Corrosion on metallic parts (except equipment anchors) appears maintainable. U Any condition that does not meet at least Minimum Acceptable standards.
10 Insulation Megger Testing				A Results of megger test show that insulation meets manufacturer's or industry standard. Test not more than 24 months old. M Results of megger test show that insulation resistance is lower than manufacturer's or industry standard, but can be corrected with proper application of heat. U Insulation resistance is low enough to cause the equipment to not be able to meet its design standard of operation.
11 Backup Power				A Adequate, reliable, and enough capacity to meet demands. Required backup generators are on hand and deemed reliable. Backup units are properly sized, operational, periodically exercised, and maintained in accordance with operating manual. U Power source not considered reliable to sustain operations during flood condition.

ENCL 2

PUMP STATION MAINTENANCE INSPECTION GUIDE

RATED ITEM	A	M	U	EVALUATION
12 Pump Control System				A Operational and maintained free of damage, corrosion, or other debris. M Operational with minor discrepancies. U Not operational, or uncorrected discrepancies noted from previous inspections.
13 Sumps				A Clear of debris and obstructions. Mechanisms are in place to maintain this condition during operations. M Clear of large debris, minor obstructions present. Mechanisms are in place to deter any further accumulation during operation. Sump will function as intended. U Large debris or major obstructions present, or no mechanism exists to prevent debris accumulation during operation.
14 Intake/Discharge Gates.				Functional. Electric operators maintained. (A or U.)
15 Cranes				Operational. Inspected and load tested in accordance with OSHA requirements. (A or U.)
16 Telephone Communications				Telephone communication is available in the pump station. Alternatively, two-way radio, cellular telephone, or similar device is available, or, access to a telephone is within a reasonable driving distance. (A or U.)
17 Safety				No exhaust leaks in building. Fuel storage/distribution meets state/local requirement. Fire extinguishers on hand, of sufficient quantity, and properly charged. Safety hardware installed. Required safety items (e.g., aural protectors) used. (A or U.)
18 Remarks.				Continued on separate sheet: Yes ____ No ____

GENERAL INSTRUCTIONS

1. All items on this guide must be addressed and a rating given.
2. The lowest single rating given will determine the overall rating for the pump station.
3. A non-Federal pump station located behind a Federal levee will be treated as a separate FCW, and will not be incorporated into the Federal levee project.
4. Additional areas for inspection will be incorporated by the inspector into this guide if the layout or physical characteristics of the pump station warrant this. Appropriate entries will be made in the REMARKS block.
5. Rating Codes:
   - A - Acceptable
   - M - Minimally Acceptable
   - U - Unacceptable

SPECIFIC INSTRUCTIONS

SECTION I. Pump station must have primary purpose of flood control, not interior drainage. District will determine, based on appropriate study, if adequate capacity exists. Lack of adequate capacity mandates a determination of Unacceptable.

AGREEMENT BETWEEN
THE UNITED STATES OF AMERICA
and

____

FOR REHABILITATION OF FLOOD CONTROL WORKS
or
FEDERALLY AUTHORIZED HURRICANE OR SHORE PROTECTIVE STRUCTURES

THIS AGREEMENT, entered into this __________ day of ____________________, 19________, by and between THE UNITED STATES OF AMERICA (hereinafter called the "Government") represented by Commander, U.S. Army Corps of Engineers, ____, executing this agreement, and ____ ______________________________________, (hereinafter called the "Sponsor");

WITNESSETH THAT:

WHEREAS, Public Law 99, 84th Congress, approved 28 June 1955, authorized the Chief of Engineers in the repair or restoration of any flood control works threatened or destroyed by recent floods, including the strengthening, raising, extending, or other modification thereof as may be necessary at the discretion of the Chief of Engineers for the adequate functioning of the work for flood control; in the repair and restoration of any federally authorized hurricane and shore protective structures damaged or destroyed by wind, wave, or water action of other than an ordinary nature when in the discretion of the Chief of Engineers such repairs and restoration are warranted for the adequate functioning of the structure; and

WHEREAS, the Sponsor has requested in writing, assistance in the repair or restoration of the flood control work or federally authorized hurricane or shore protective structure damaged as described by the written request for assistance, and the Sponsor qualifies for assistance in accordance with the established policies of the U.S. Army Corps of Engineers.

NOW, THEREFORE, the parties agree as follows:

1. The Government will perform the work described in its scope of work which is made part of this agreement.

2. The Sponsor agrees, that in consideration of the Government providing assistance, to fulfill the requirement of non-Federal cooperation required by the U.S. Army Corps of Engineers regulations, to wit:

a. Provide without cost to the Government all lands, easements and rights-of-ways necessary for the repair and restoration of the flood control works, and for the use of borrow area and/or spoil areas. This provision will also include the access to and from the flood control works or structures, the borrow sites, and spoil areas.

b. Hold and save the Government free from damages due to the repair or restoration work, except damages due to the fault or negligence of the Government or its contractors.

Figure C-2. Sample C&P Agreement For Rehabilitation

c. Be familiar with the policies and procedures of the U.S. Army Corps of Engineers Inspection Program, participate in the program's periodic inspection, and maintain without cost to the Government the flood control work in a manner satisfactory to the Government and in accordance with the prescribed regulation of the Inspection Program.

d. Give the Government a right to enter, at reasonable times and in a reasonable manner, upon land which the Sponsor owns or controls, for access to the flood control works or structures for the purpose of inspection.

3. The Sponsor further agrees to: (Add as applicable)

a. Contribute, as the sponsor's cost share, the amount and method of contribution as specified in the attachment Sponsor's Cost Share Estimate and Method of Contribution.

b.

4. This agreements remains in effect indefinitely. Termination of this agreement will be automatic when the Sponsor is removed from the U.S. Army Corps of Engineers Inspection Program due to the Sponsor's non compliance with the policies and procedures of the Inspection Program.

5. ATTACHMENTS:

a. Exhibit A - Written request for assistance from the Sponsor.
b. Exhibit B - Government Scope of Work.
c. Exhibit C - Sponsor Cost Share Estimate and Method of Contribution.

6. IN WITNESS WHEREOF, the parties hereto have executed this agreement of the day and year first above written.

THE UNITED STATES OF AMERICA SPONSOR

____________________ (Signature) ____________________

____________________ (Name) ____________________

____________________ (Title) ____________________

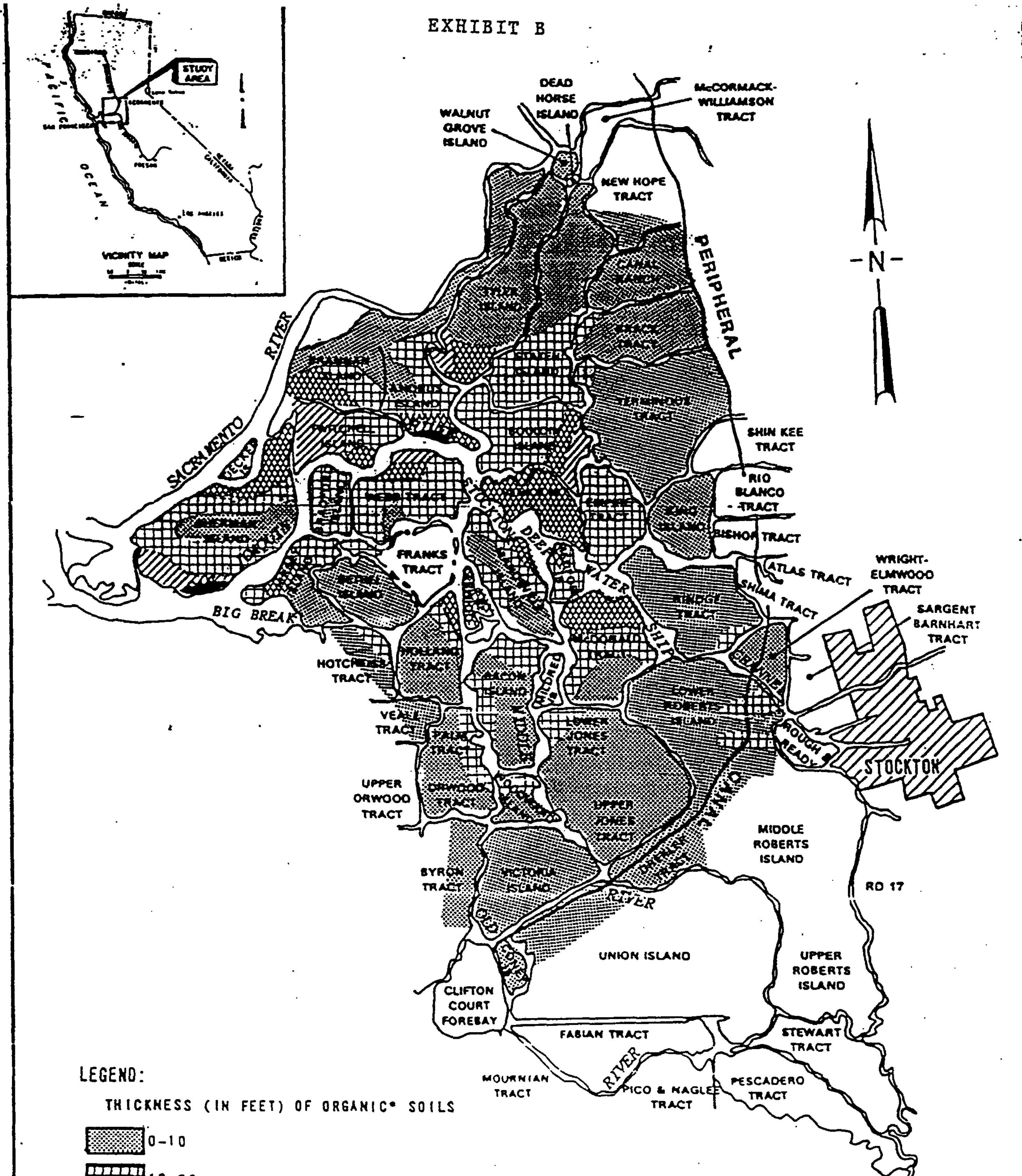
Address:

____________________ ____________________

____________________ ____________________

Figure C-2. Sample C&P Agreement For Rehabilitation (Cont'd)

EXHIBIT B



LEGEND:

THICKNESS (IN FEET) OF ORGANIC* SOILS

- 0-10
- 10-20
- 20-30
- 30-40
- 40+

*Peat, organic silt, organic clay (Pt, OL, OH), mineral soils containing greater than 25% organics.

**Subsidence of organic soils in the Sacramento-San Joaquin Delta, DWR, Central District, August 1980.

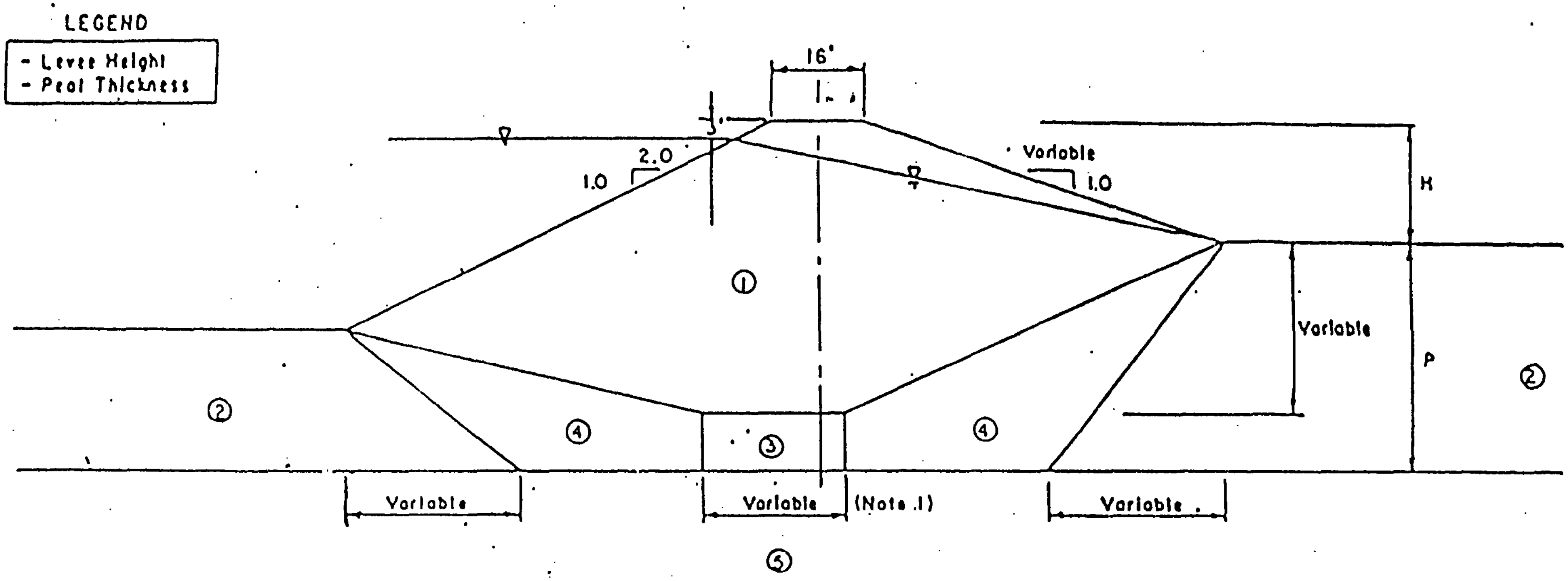
SACRAMENTO-SAN JOAQUIN DELTA
CALIFORNIA

DISTRIBUTION AND THICKNESS OF ORGANIC SOILS**

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
JULY 1982

SCALE IN MILES
2 0 2 4 6 8

EXHIBIT B



Zone	Material	Moist Wt (PCF)	Sat Wt (PCF)	Strength c (PCF)	φ (Deg)
1	Levee Fill - Clay, Sand Peat, Silt	115	120	0	33
2	Foundation - Unconsolidated Peat & Clayey Peat	77	77	100	18
3	Foundation - Consolidated Peats & Clayey Peats	.85	85	200	27
4	Foundation - Partially Consolidated Peats & Clayey Peats	85	85	150	25
5	Foudation - Clayey Sand, Firm Sand & Silty Sand	127	135	0	35

NOTES:

1. Dimensions noted as variable, change as a function of levee height and peat depth.
2. References a & d.
3. No distinction is made between peat, organic silt, organic clay, and mineral soil, containing greater than 25% organics.

Minimum Levee Geometry
Sacramento - San Joaquin Delta

GENERALIZED LEVEE SECTION & DESIGN PARAMETERS

Sacramento-San Joaquin Legal Delta
PL84-99
Agricultural and Urban Island Stability

1(V) ON 2(H) LANDSIDE SLOPE

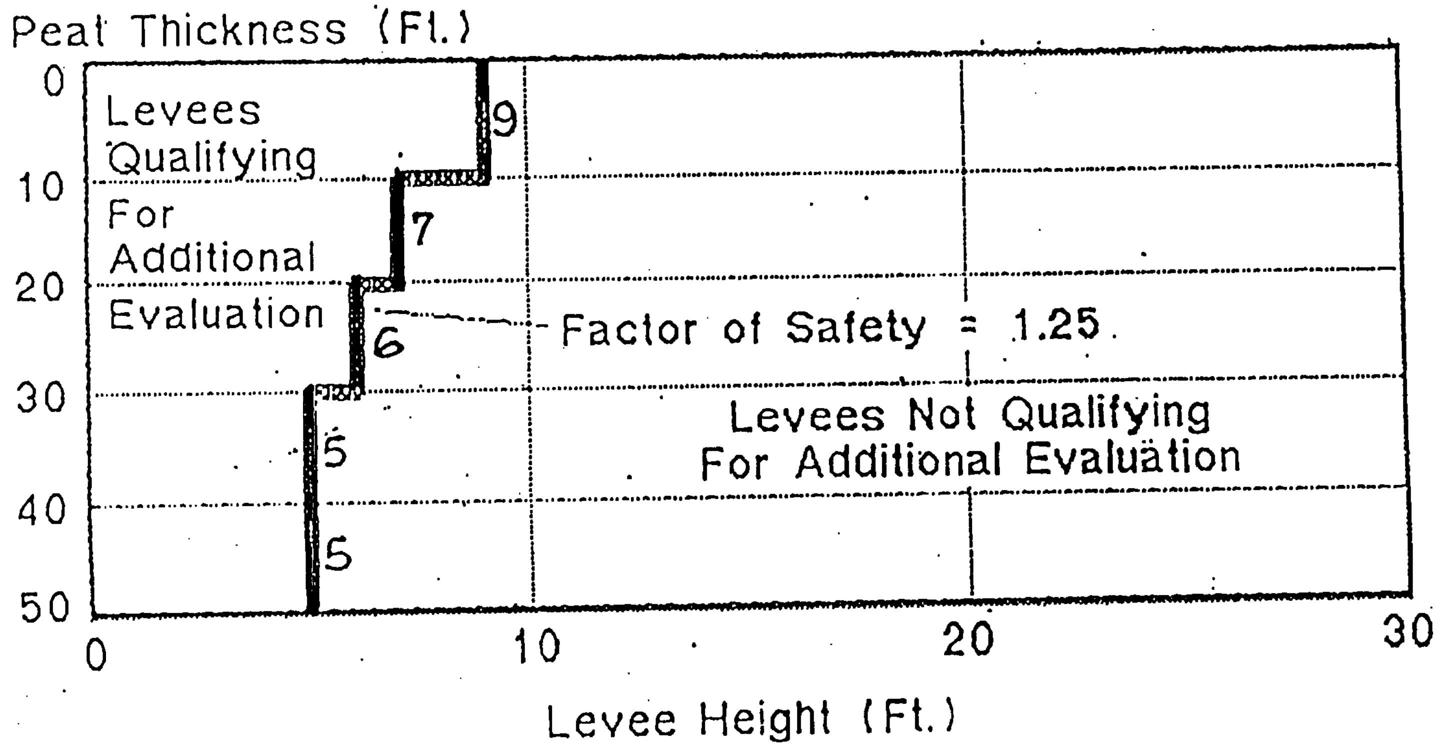
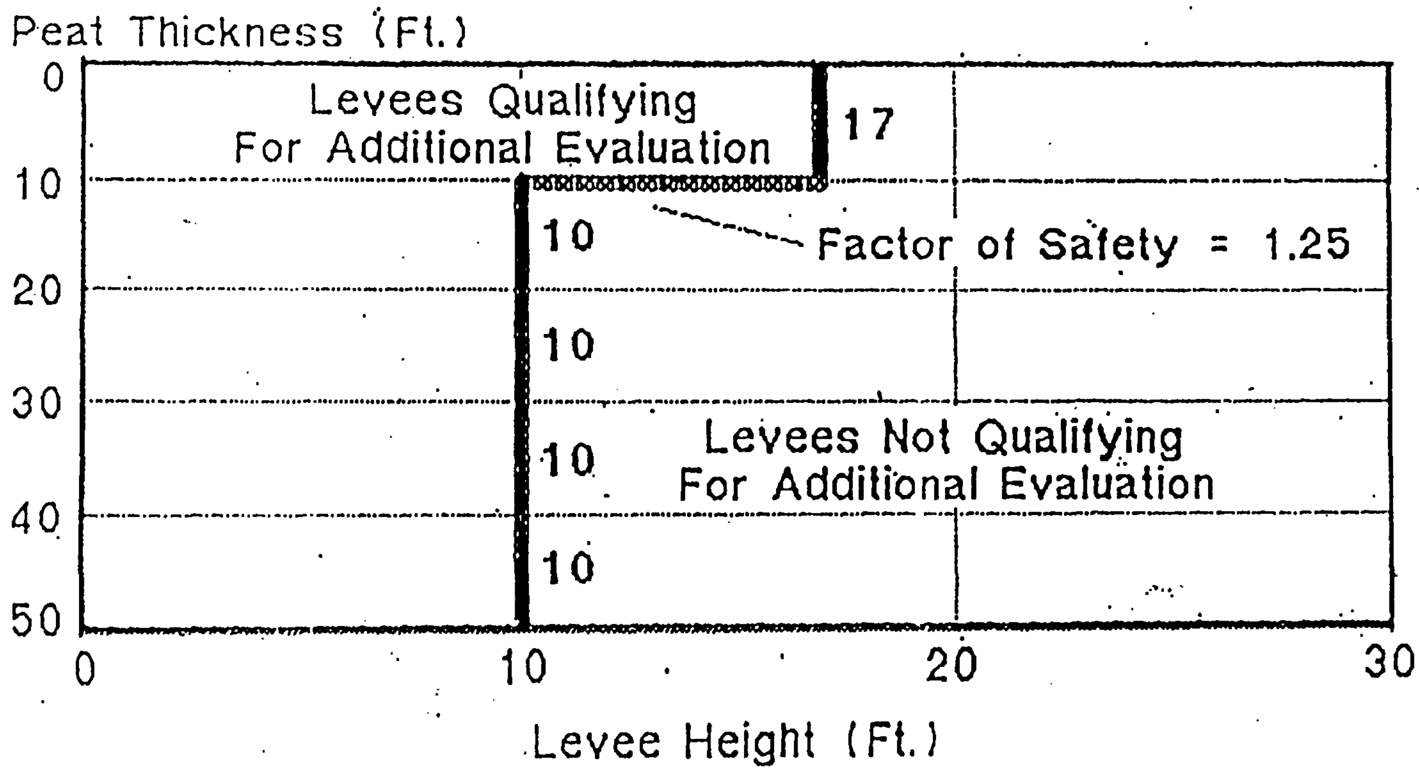


EXHIBIT B

Sacramento-San Joaquin Legal Delta
PL84-99
Agricultural and Urban Island Stability

1(V) ON 3(H) LANDSIDE SLOPE



D-3

EXHIBIT B

Sacramento-San Joaquin Legal Delta
PL84-99
Agricultural and Urban Island Stability

1(V) ON 4(H) LANDSIDE SLOPE

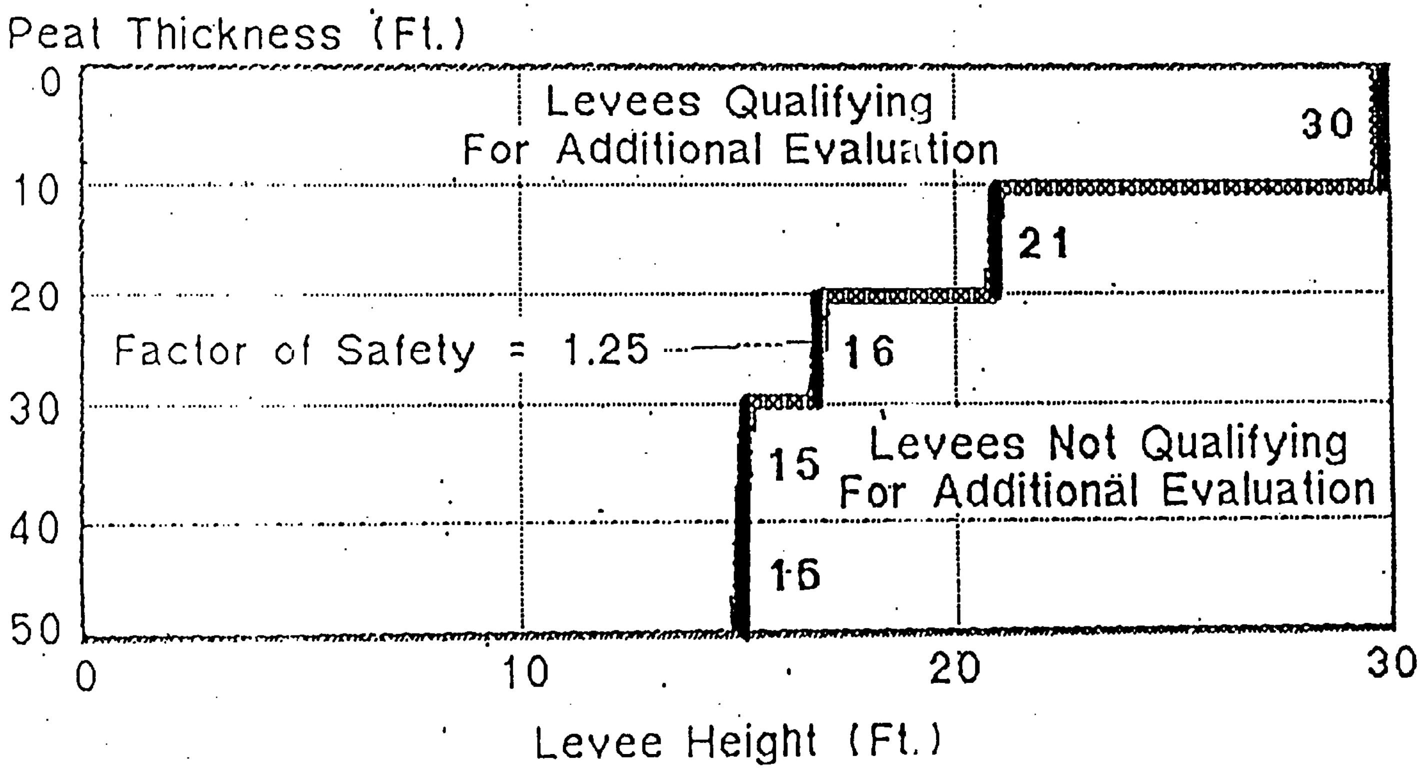


EXHIBIT B

Sacramento-San Joaquin Legal Delta
PL84-99
Agricultural and Urban Island Stability

1(V) ON 5(H) LANDSLIDE SLOPE

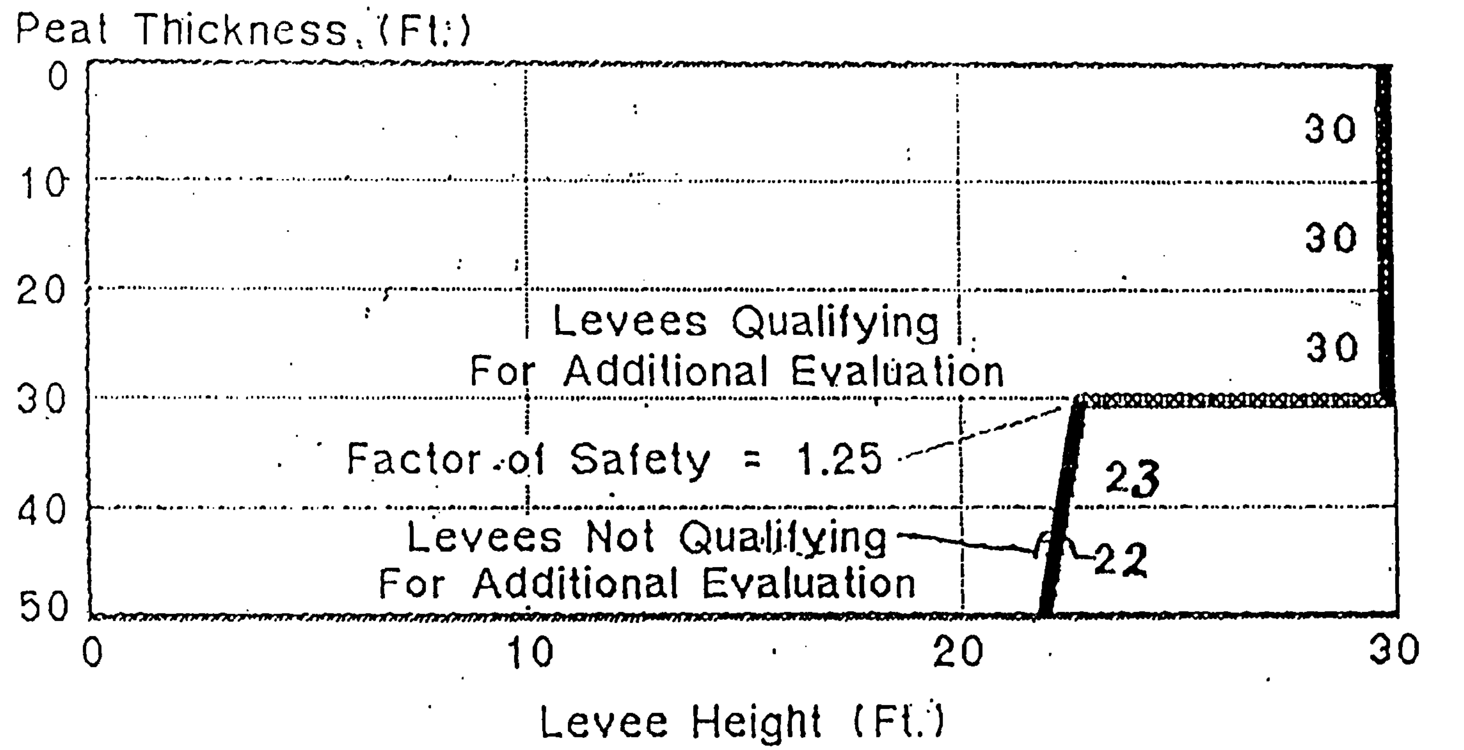


EXHIBIT B

APPENDIX B
PUBLIC LAW 84-99 AS AMENDED

33 U.S.C 701n. Flood Emergency preparation; authorized expenditures

(a)(1) There is authorized an emergency fund to be expended in preparation for emergency response to any natural disaster, in flood fighting and rescue operations, or in the repair or restoration of any flood control work threatened or destroyed by flood, including the strengthening, raising, extending, or other modification thereof as may be necessary in the discretion of the Chief of Engineers for the adequate functioning of the work for flood control; in the emergency protection of federally authorized hurricane or shore protection being threatened when in the discretion of the Chief of Engineers such protection is warranted to protect against imminent and substantial loss to life and property; in the repair and restoration of any federally authorized hurricane or shore protective structures damaged or destroyed by wind, wave, or water action of other than an ordinary nature when in the discretion of the Chief of Engineers such repair and restoration is warranted for the adequate functioning of the structure for hurricane or shore protection. The emergency fund may also be expended for emergency dredging for restoration of authorized project depths for Federal navigable channels and waterways made necessary by flood, drought, earhtquake, or other natural disasters. In any case in which the Chief of Engineers is otherwise performing work under this section in an area for which the Governor of the affected State has requested a determination that an emergency exists or a declaration that a major disaster exists under the Disaster Relief and Emergency Assistance Act of 1974, the Chief of Engineers is further authorized to perform on public and private lands and waters for a period of ten days following the governor's request any emergency work made necessary by such emergency or disaster which is essential for the preservation of life and property, including, but not limited to, channel clearance, emergency shore protection, clearance and removal of debris and wreckage endangering public health and safety, and temporary restoration of essential public facilities and services. The Chief of Engineers, in the exercise of his discretion, is further authorized to provide emergency supplies of clean water, on such terms as he determines to be advisable, to any locality which he finds is confronted with a source of contaminated water causing or likely to cause a substantial threat to the public health and welfare of the inhabitants of the locality. The appropriation of such moneys for the initial establishment of this fund and for its replenishment on an annual basis is authorized: Provided, that pending the appropriation of sums to such emergency fund, the Secretary of the Army may allot, from existing flood control appropriations, such sums as may be necessary for the immediate prosecution of the work herein authorized, such appropriations to be reimbursed from the appropriation herein authorized when made. The Chief of Engineers is authorized, in the prosecution of work in connection with rescue operations, or conducting other flood emergency work, to acquire on a rental basis such motor vehicles, including passenger cars and buses, as in his discretion are deemed necessary.

(2) In preparing a cost and benefit feasibility assessment for any emergency project described in paragraph (1), the Chief of Engineers shall consider the benefits to be gained by such project for the protection of-

"(A) residential establishments;

"(B) commercial establishments, including the protection of inventory; and

"(C) agricultural establishments, including the protection of crops."

"(b)(1) The Secretary, upon a written request for assistance under this paragraph made by any farmer, rancher, or political subdivision within a distressed area, and after determination by the Secretary that (A) as a result of the drought such farmer, rancher, or political subdivision has an inadequate supply of water, (B) an adequate supply of water can be made available to such farmer, rancher, or political subdivision through the construction of a well, and (C) as a result of the drought such well could not be constructed by a private business, the Secretary, subject to paragraph (3) of this subsection, may enter into an agreement with such farmer, rancher, or political subdivision for the construction of such well.

"(2) The Secretary, upon a written request for assistance under this paragraph made by any farmer, rancher, or political subdivision within a distressed area, and after a determination by the Secretary that as a result of the drought such farmer, rancher, or political subdivision has an inadequate supply of water and water cannot be obtained by such farmer, rancher, or political subdivision, the Secretary may transport water to such farmer, rancher, or political subdivision by methods which include, but are not limited to, small-diameter emergency water lines and tank trucks, until such time as the Secretary determines that an adequate supply of water is available to such farmer, rancher, or political subdivision.

"(3)(A) Any agreement entered into by the Secretary pursuant to paragraph (1) of this subsection shall require the farmer, rancher, or political subdivision for whom the well is constructed to pay to the United States the reasonable cost of such construction, with interest, over such number of years, not to exceed thirty, as the Secretary deems appropriate. The rate of interest shall be that rate which the Secretary determines would apply if the amount to be repaid was a loan made pursuant to Section 7(b)(2) of the Small Business Act.

"(B) The Secretary shall not construct any well pursuant to this subsection unless the farmer, rancher, or political subdivision for whom the well is being constructed has obtained, prior to construction, all necessary state and local permits.

"(4) The Federal share for the transportation of water pursuant to paragraph (2) of this subsection shall be 100 per centum.

"(5) For purposes of this subsection-

"(A) the term 'construction' includes construction, reconstruction, or repair;

"(B) the term 'distressed area' means an area which the Secretary determines due to drought conditions has an inadequate water supply which is causing, or is likely to cause, a substantial threat to the health and welfare of the inhabitants of the area including threat of damage or loss of property;

"(C) the term 'political subdivision' means a city, town, borough, county, parish, district, association, or other public body created by or pursuant to state law and having jurisdiction over the water supply of such public body;

"(D) the term 'reasonable cost' means the lesser of (i) the cost to the Secretary of constructing a well pursuant to this subsection exclusive of the cost of transporting equipment used in the construction of wells, or (ii) the cost to a private business of constructing such well;

"(E) the term 'Secretary' means the Secretary of the Army, acting through the Chief of Engineers; and

"(F) the term 'state' means a state, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American samoa, and the Trust Territory of the Pacific Islands."

Historical Note

Codification. The Department of War was designated the Department of the Army, and the title of the Secretary of War was changed to Secretary of the Army by Section 205(a) of Act July 26, 1947, c. 343, Title II, 61 State. 501. Section 205(a) of Act July 26, 1947, was repealed by Section 53 of Act August 10, 1956, c. 1041. 70A Stat. 641. Section 1 of Act August 10, 1956, enacted "Title 10, Armed Forces", which in Sections 3011-3013 continued the military Department of the Army under the administrative supervision of a Secretary of the Army.

1990 - Section 302 of the Water Resources Development Act of 1990 (PL 101-640) amends PL 84-99 by striking "flood emergency preparation" and adding "preparation for emergency response to any natural disaster." It also authorizes the use of the emergency fund for emergency dredging for restoration of authorized project depths for Federal navigable channels and waterways made necessary by flood, drought, earthquake, or other natural disaster.

1987 - Section 9 of the Farm Disaster Assistance Act of 1987 (PL 100-45) amends PL 84-99 by requiring the Corps of Engineers to consider benefits to residential establishments, commercial establishments and agricultural establishments in preparing a benefit-cost analysis for any emergency project.

1986 - Section 917 of the Water Resources Development Act of 1986 (PL 99-662) amends PL 84-99 by removing the word "drinking" in each place it appears. It also authorizes the Chief of Engineers performing emergency work in a disaster area to perform emergency work on public and private lands and waters for a period of ten days following a Governor's request for assistance.

1977 - Amendment: PL 95-51 approved 20 June 1977, added subsection (b) giving the Secretary the authority to construct wells and transport water during drought situations.

1974 - Amendment: PL 93-251 deleted the specified amount of the emergency fund, and authorized the emergency provision of clean drinking water to any locality confronted with a contaminated source.

1962 - Amendment: PL 87-874 authorized expenditures from the emergency fund for the protection of federally authorized hurricane or shore protection being threatened when such is warranted to protect against imminent and substantial loss to life and property, and for the repair and restoration of any such federally authorized hurricane or shore protective structure damaged or destroyed by wind or water action of an extraordinary nature when such is warranted for the adequate functioning of the structure for hurricane or shore protection.

1955 - Amendment: Act June 28, 1955, PL 84-99, authorized expenditure for flood emergency preparation and eliminated the requirement of maintenance of flood control works threatened by flood.

1950 - Amendment: Act May 17, 1950, expanded scope of work considered under emergency repairs to flood control structures and increased the appropriation from $2,000,000 to $15,000,000.

1948 - Amendment: Act June 30, 1948, added provisions relating to the strengthening, extending, or modification of flood control work.

1946 - Amendment: Act July 24, 1946, increased authorization from $1,000,000 to $2,000,000.

1941 - Section 5 of the Flood Control Act of August 18, 1941 (PL 77-228) established the authority for the expenditure of not more than $1,000,000 per year for rescue or in the repair or maintenance of any flood-control work threatened or destroyed by flood.

APPENDIX B

COST ESTIMATE BACKUP AND REPORT

NOTE:

Appendix B contains a summary of the Cost Estimate. The complete cost estimate and all the backup data are available under separate cover. The backup data include levee cross-section data in AUTOCAD format. The cross-sections are available on CD. To obtain the complete cost estimate and all the backup data, contact CALFED's Project Manager for the Levee System Integrity Program.

CALFED LEVEE REHABILITATION STUDY

INTRODUCTION

CALFED has chosen the levee standards established for the Delta under Public Law 84-99 (PL-99) as the minimum level of protection for system integrity. This study inventories the levees within the legal Delta not meeting the PL-99 standard and estimates quantities and costs required to rehabilitate these levees.

SCOPE OF STUDY

The study includes three main components: *an inventory of the levees not meeting the PL-99 standard*, *quantity and cost estimates to meet the standard*, and *an evaluation and estimated cost for the associated land, easements, rights of way, relocations and disposal (LERRD's) required to perform the levee rehabilitation.*

Generally, the levees not meeting the PL-99 standard consist of the non-project levees in the Delta (Figure 1). Unless there was specific knowledge of site conditions, project levees were assumed to meet the PL-99 standard. The inventory attempts to identify a complete listing of levee districts and associated levee miles not meeting the standard. In addition, the inventory identifies levees which meet the geometric standard but experience significant seepage during high water.

Quantity and cost estimates were based on a comparison of the design levee standard geometry as set forth in PL-99, to the existing levee configuration. Data used for these levee rehabilitation cost estimates included actual levee data from 60% of the existing non-project levee districts, representing 69% of the total mileage of substandard levees. The results of the estimates using actual data were then used to extrapolate the same information for islands where actual data was not available (Figure 2).

Finally, the study evaluated an estimated cost for the LERRD's associated with the levee rehabilitation. Generally, the required levee improvements extend from the levee toe landward into existing private property. In addition, the levee improvements impact existing infrastructure which must be evaluated and costs estimated for work to move or replace the infrastructure. Components of this infrastructure include pumps and siphons, utility lines and poles, seepage and irrigation ditches and buildings. The LERRD's also include easement acquisition for the additional levee section. The results of this study are summarized on Table 1.

STUDY DETAILS

The study estimates the quantity and cost required to obtain the PL-99 standards for 55 islands or levee districts totaling 521.2 miles of levee. Improvement costs, based on fill and roadway estimates, were used to project other costs associated with levee projects such as engineering, environmental and regulatory. Described below are details regarding the components of the cost estimates.

Fill Quantity Estimates

The basis for establishing fill quantity required to meet the PL-99 standards is establishment of the standard levee section for a particular levee in the Delta. PL-99 simplifies its standard by requiring freeboard of 1.5' above the 100-year flood elevation, a 16' wide crown, a 2 (horizontal)-to-1 (vertical) waterside slope and a variable landside slope based on the levee height and estimated depth of organic material in the foundation. This varying landside slope ranges between 3:1 to 5:1 (Figure 3). Organic material depths were taken from the Department of Water Resources' map entitled, "Organic Isopach Map", October 18, 1976. Flood elevations were from the Corps of Engineers' report entitled, "Sacramento/San Joaquin Delta California Special Study Documentation Report", dated March 1993. Levee heights were computed from actual levee survey data.

Fifty-five of the Delta islands were found to not meet the PL-99 standards. Actual survey data from 32 of these islands was used for the cost estimates. These 32 islands represent 352 miles or 68% of the 521.2 miles of levee providing less than PL-99 level of protection. These survey data were obtained directly from the districts. At a minimum, cross sections were taken at 1,000' intervals. Using this data and superimposing the required PL-99 standard yields the "neat" fill requirements at each section. The average end method was then used to estimate the fill along the levee between each cross section.

The "neat" fill estimates were the basis for the Delta levee rehabilitation. The "neat" fill estimates were increased by 100% to account for losses associated with this type of work. Losses amounting to 150% of the "neat" fill requirement were applied where the levee still appears to be experiencing significant foundation consolidation. Islands where this is occurring include Sherman, Twitchell, Empire, Bouldin, Tyler and Webb Tract. Much of the loss associated with levee rehabilitation on Delta islands is attributable to consolidation of organic material, consolidation of loosely compacted fill and accuracy of this survey data. Estimated fill based on the above factors is shown on Table 1.

The rehabilitated levee section will require replacement of existing access ramps. These ramps require approximately 1,000 cubic yards (cy) of fill material. Where the number of ramps was known, the corresponding additional fill material was added to the cross-section quantity estimates. Where the number of ramps was not known, an average of three ramps per levee mile was used to estimate the fill requirement needed for replacement of access ramps.

Detailed survey cross-sections were not obtained for 23 levee districts. The fill requirements to meet the PL-99 standard were extrapolated based on values estimated using detailed information. Five categories of fill requirement ranging from 5,000 cy to 100,000 cy per mile were used. Based on knowledge of the 23 districts, each was assigned the category which most nearly represented its need for levee material.

Roadway Quantity Estimates

When raising and widening a levee, the gravel roadway is destroyed. Therefore, quantity estimates were made to replace the roadway under the CALFED system integrity program. Gravel was assumed to be 6-inches by 16-feet for the general levee section. For levees which currently support a county road, the roadway was designed as 6-inches by 24-feet of gravel subgrade covered by a 20 foot wide triple chip seal.

Cost Estimates

Based on fill and roadway quantity estimates, cost estimates were calculated using high and low unit prices from actual Delta levee projects. Delta levee work experiences a great variance in cost due to factors such as proximity to borrow material, accessibility of the project, condition of access roads and workload of local contractors. It is anticipated that a program as extensive as the CALFED will generate new markets which don't currently exist, thus keeping the levee costs to a minimum. For the sake of this study, the improvement costs were left to range between low and high.

Additional Costs

Levee improvement includes an array of costs to account for services required to plan and construct a project. Based as a percentage of the subtotal of the fill and roadway cost estimates, the following costs were included:

- Engineering Planning and Design: $10,000 + 5% to $10,000 + 8%
- Geotechnical Analysis: 5% to 8%
- Construction Inspection and Contract Administration: 5% to 8%
- Environmental and Regulatory: 5% to 8%
- CMARP: 1%
- Erosion Protection for Newly Placed Fill: 8%
- Environmental Mitigation: 15%
- Ongoing Repair: 25%
- Overall Contingency to Account for Unforeseen Costs: 20%

Seepage Repair

Although most federally reconstructed project levees in the Delta meet or exceed the PL-99 geometric standard, there are several locations where the sand composition of the levees causes a threat of seepage and piping of material during high water. This seepage could lead to a reduction in the factor of safety, diminishing the level of protection. The bulk of these levees are located along the San Joaquin River Channel upstream of Stockton. Several areas have also been noted along the Sacramento River and Georgian Slough. The total mileage where this type of repair is required was estimated based on accounts during the January 1997 floods. Cost estimates to repair this type of problem were based on costs estimated by the Corps of Engineers to repair levees along the San Joaquin River at Reclamation District No. 17 (Figure 4). It was assumed 33% of a district's levee system, where seepage has been a problem, would have to be repaired. Table 2 summarizes seepage repair estimates.

Lands, Easements, Rights of Way, Relocations and Disposal (LERRD'S)

The third component of the study was to evaluate the cost of LERRD's resulting from the CALFED System Integrity Program. As described above, a rehabilitation as extensive as CALFED's program will impact existing infrastructure. Widening of the levees will encroach upon existing private property (Figure 5). Therefore, cost estimates were made to acquire easements for the existing land required due to the levee rehabilitation, and to move or replace existing infrastructure. This infrastructure includes irrigation and drainage pipes and pumping plants, power poles, homes and ditches. These estimates were based on recent experience of a similar type project performed on the levees surrounding the Stockton Metropolitan Area (Table 3).

Summary

Based on the above, the total costs of the levee rehabilitation program is estimated to range from $613 million to $1.28 billion. The range is based on the uncertainty regarding location and cost of levee fill material. The breakdown for the costs, as shown on Tables 1-3, is as follows:

	Low	High
PL-99 Improvement Cost	$ 356,970,324	$ 1,023,686,285
Seepage Repair	$ 164,229,790	$ 164,229,790
LERRD's	$ 92,028,000	$ 92,028,000
	$ 613,228,114	$ 1,279,944,075

These costs include acquisition of easements over 3,419 acres for the PL-99 improvement and 1,209 acres for the seepage repair.

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Sacramento-San Joaquin Delta, California

Levee Rehabilitation Study

District Number		Reclamation District	Levee Miles Project	Levee Miles Non-Project	Levee Miles Total	Total Fill Volume (yd³)	Estimated PL-99 Improvement Cost Low	Estimated PL-99 Improvement Cost High
556	1	Andrus Island, Upper	11.2	0.6	11.8	30,000	$517,290	$1,408,450
2126	1	Atlas Tract	0.0	1.9	1.9	57,000	$927,394	$2,631,111
2028		Bacon Island	0.0	14.3	14.3	1,420,443	$20,712,541	$60,697,769
	2	Bear Creek	46.5	0.0	46.5	0	$0	$0
	2	Bethany			0.0	0	$0	$0
		Bethel Island MID	0.0	11.5	11.5	230,634	$4,188,633	$11,473,059
2042	2	Bishop Tract	0.0	5.8	5.8	0	$0	$0
	2	Bishop Tract, East			0.0	0	$0	$0
2121	2	Bixler	0.0	2.3	2.3	0	$0	$0
404	2	Boggs (Moss) Tract	4.0	1.2	5.2	0	$0	$0
	2	Borrow Pond Area			0.0	0	$0	$0
756		Bouldin Island	0.0	18.0	18.0	2,454,122	$33,917,002	$101,465,550
2033		Brack Tract	0.0	10.8	10.8	246,291	$4,162,288	$11,645,933
2059		Bradford Island	0.0	7.4	7.4	797,028	$11,222,624	$33,430,057
317, 407 & 2067		Brannan-Andrus LMD	19.3	10.1	29.4	1,260,711	$19,147,841	$54,942,188
	2	Browns Island			0.0	0	$0	$0
800	2	Byron Tract	0.0	9.7	9.7	0	$0	$0
2098	2	Cache Haas	12.1	0.0	12.1	0	$0	$0
2086		Canal Ranch	0.0	7.5	7.5	511,350	$7,374,253	$21,731,317
	2	Chipps Island			0.0	0	$0	$0
	2	Clifton Court			0.0	0	$0	$0
	2	Collinsville			0.0	0	$0	$0
2117		Coney Island	0.0	5.4	5.4	37,477	$1,004,522	$2,428,368
2111	1	Dead Horse Island	0.0	2.6	2.6	13,258	$384,338	$915,177
	2	Decker			0.0	0	$0	$0
	2	Delta-Mendota			0.0	0	$0	$0
	1	Drexler Island	0.0	4.0	4.0	20,000	$614,178	$1,495,435
536	2	Egbert Tract	14.0	0.0	14.0	0	$0	$0
813	2	Ehrheart	2.0	6.0	8.0	0	$0	$0
2029		Empire Tract	0.0	10.5	10.5	1,093,053	$15,737,352	$46,227,173
773	1	Fabian Tract	0.0	18.8	18.8	188,000	$4,541,103	$11,439,905
2113	1	Fay Island	0.0	1.6	1.6	8,026	$240,435	$569,585
1002	1	Glanville Tract	0.0	13.0	13.0	65,099	$2,335,317	$5,292,676
765	2	Glide	1.7	4.0	5.7	0	$0	$0
3	2	Grand Island	29.0	0.0	29.0	0	$0	$0
1609	2	Harveys			0.0	0	$0	$0
2060	2	Hastings Tract	16.0	0.0	16.0	0	$0	$0
999	2	Holland Land	27.0	5.8	32.8	0	$0	$0
2025		Holland Tract	0.0	10.9	10.9	182,612	$3,816,975	$9,912,258
2116	2	Holt Station	0.0	0.4	0.4	0	$0	$0
799	1	Hotchkiss Tract	0.0	6.3	6.3	121,248	$2,371,992	$6,406,959
830	1	Jersey Island	0.0	15.6	15.6	468,000	$7,527,319	$21,485,215
2038		Jones Tract, Lower	0.0	8.8	8.8	173,847	$3,283,897	$8,908,588
2039		Jones Tract, Upper	0.0	9.3	9.3	32,586	$866,491	$2,142,417
2085	2	Kasson	6.2		6.2	0	$0	$0
	2	Kimball Island			0.0	0	$0	$0
2044		King Island	0.0	9.0	9.0	276,103	$4,483,102	$12,688,246
369	1	Libby McNeil	1.0	0.7	1.7	66,000	$981,195	$2,864,665
2093	2	Liberty Island	0.0	20.5	20.5	0	$0	$0
1608	2	Lincoln Village West	0.0	4.0	4.0	0	$0	$0
307	2	Lisbon	7.8	5.2	13.0	0	$0	$0
2084	2	Little Egbert Tract	0.0	7.0	7.0	0	$0	$0
	2	Little Franks Tract			0.0	0	$0	$0
2118	1	Little Mandeville	0.0	4.5	4.5	450,000	$6,348,833	$18,876,664
	2	Los Medanos			0.0	0	$0	$0
	2	Maintenance Area 9	19.6	0.0	19.6	0	$0	$0
2027		Mandeville Island	0.0	14.3	14.3	502,358	$7,789,541	$22,407,366
2110	1	McCormack-Williamson Tract	0.0	8.8	8.8	525,000	$7,696,924	$22,600,613
2030		McDonald Island	0.0	13.7	13.7	98,170	$2,482,325	$6,316,103
2075	2	McMullin	7.4	0.0	7.4	0	$0	$0
2041		Medford Island	0.0	5.9	5.9	453,667	$6,494,287	$19,197,006
150	2	Merritt Island	18.1	0.0	18.1	0	$0	$0
2021	2	Mildred Island	0.0	7.3	7.3	0	$0	$0
	2	Montezuma Flats			0.0	0	$0	$0
	2	Montezuma Island			0.0	0	$0	$0
2107	2	Mossdale 2	4.2	0.0	4.2	0	$0	$0
17	2	Mossdale Tract	14.0	0.0	14.0	0	$0	$0
1007	1	Naglee Burke Tract	0.0	8.3	8.3	83,000	$1,813,377	$4,762,587
348		New Hope Tract	0.0	18.6	18.6	291,322	$4,928,678	$13,860,672

Table 1

Sacramento-San Joaquin Delta, California

Levee Rehabilitation Study

District Number		Reclamation District	Levee Miles Project	Levee Miles Non-Project	Levee Miles Total	Total Fill Volume (yd³)	Estimated PL-99 Improvement Cost Low	Estimated PL-99 Improvement Cost High
	2	Oakley			0.0	0	$0	$0
2024		Orwood Tract	0.0	10.9	10.9	12,633	$729,834	$1,640,042
2036		Palm Tract	0.0	7.5	7.5	199,301	$3,298,313	$9,338,080
2095	2	Paradise	4.0	0.0	4.0	0	$0	$0
2058	1	Pescadero Tract	6.7	2.2	8.9	43,340	$1,325,842	$3,248,954
2104	2	Peters	7.4	0.0	7.4	0	$0	$0
551	2	Pierson District	8.4	7.0	15.4	0	$0	$0
1667	2	Prospect Island	2.9	7.1	10.0	0	$0	$0
2090		Quimby Island	0.0	7.0	7.0	426,462	$6,244,751	$18,343,567
755	2	Randall	1.9	0.0	1.9	0	$0	$0
2037		Rindge Tract	0.0	15.7	15.7	520,276	$8,310,102	$23,847,863
2114	2	Rio Blanco Tract	0.0	4.0	4.0	0	$0	$0
2064	2	River Junction	11.6	0.0	11.6	0	$0	$0
524	1	Robert Island, Middle	6.1	3.7	9.8	63,447	$1,932,828	$4,741,046
684		Roberts Island, Lower	0.0	16.0	16.0	43,689	$1,824,462	$4,259,136
544	1	Roberts Island, Upper	10.6	4.4	15.0	88,068	$2,678,112	$6,574,274
	2	Rough and Ready Island	0.0	6.7	6.7	0	$0	$0
501	2	Ryer Island	20.6	0.0	20.6	0	$0	$0
	2	Sacramento Deepwater			0.0	0	$0	$0
2074	2	Sargent Barnhart Tract	1.5	2.8	4.3	0	$0	$0
341		Sherman Island	9.7	9.8	19.5	321,559	$5,778,494	$15,639,373
	2	Sherman Island, West			0.0	0	$0	$0
2115		Shima Tract	0.0	6.6	6.6	41,563	$1,142,313	$2,853,331
	1	Shin Kee Tract	0.0	3.9	3.9	360,000	$5,079,744	$15,099,311
	2	SJCFCD Five Mile Slough			0.0	0	$0	$0
	2	SJCFCD Fourteen Mile Slough			0.0	0	$0	$0
	2	SJCFCD Mosher Slough			0.0	0	$0	$0
1614	2	Smith Tract	6.0	2.8	8.8	0	$0	$0
	2	Spinner Island			0.0	0	$0	$0
2089	2	Stark	2.9	0.7	3.6	0	$0	$0
38		Staten Island	0.0	25.4	25.4	921,949	$14,349,298	$41,373,293
2062	2	Stewart Tract	12.3	0.0	12.3	0	$0	$0
349	2	Sutter Island	12.5	0.0	12.5	0	$0	$0
548	1	Terminous Tract	0.0	16.1	16.1	1,262,330	$18,495,932	$54,337,453
2108	2	Tinsley			0.0	0	$0	$0
1601		Twitchell Island	2.5	9.3	11.8	1,291,084	$18,588,176	$54,670,526
563		Tyler Island	12.2	10.7	22.9	2,863,563	$41,800,546	$121,994,769
1		Union Island, East	1.0	13.0	14.0	0	$0	$0
2	1	Union Island, West	0.0	16.2	16.2	80,492	$2,611,017	$6,240,156
1607	1	Van Sickle Island	0.0	3.8	3.8	380,000	$5,357,353	$15,925,323
2065		Veale Tract	0.0	5.7	5.7	21,243	$718,854	$1,721,402
2023	1	Venice Island	0.0	12.3	12.3	123,977	$2,668,367	$7,001,564
2040	1	Victoria Island	0.0	15.1	15.1	150,775	$3,316,281	$8,735,545
554	2	Walnut Grove	1.0	1.2	2.2	0	$0	$0
2094	2	Walthall	3.3	0.0	3.3	0	$0	$0
2026		Webb Tract	0.0	12.8	12.8	606,166	$9,042,328	$26,322,968
828	2	Weber	0.0	1.2	1.2	0	$0	$0
	2	West Island			0.0	0	$0	$0
900	2	West Sacramento	12.0	1.3	13.3	0	$0	$0
2096	2	Wetherbee	0.2	0.0	0.2	0	$0	$0
2122	1	Winter Island	0.0	4.8	4.8	480,000	$6,765,248	$20,115,682
2072		Woodward Island	0.0	8.8	8.8	323,327	$5,042,183	$14,524,929
2119		Wright-Elmwood Tract	0.0	6.8	6.8	82,516	$1,957,902	$4,914,584
2068	2	Yolano	8.7	0.0	8.7	0	$0	$0
	2	Yolo Bypass Unit 4	3.6	0.0	3.6	0	$0	$0
			430.6	635.2	1065.8	22,864,165	$356,970,324	$1,023,686,285

1 Extrapolated Values

2 Project Levee, Meets or Exceeds PL84-99 or Non-Levee

	Districts	Levee Miles Project	Levee Miles Non-Project
Detailed Quantity Estimates	32	44.7	352.0
Extrapolated Values	23	35.6	169.2
Project Levee, Meets or Exceeds PL84-99 or Non-Levee	69	350.3	114.0
	124	430.6	635.2

Sacramento - San Joaquin Delta, California

Levee Rehabilitation Study

Seepage Control

Reclamation District No.	Name of Island/Tract	Mobilization/Demo (cost est.)	Berm Drain Rock (cost est.)	Berm Material (cost est.)	Geotextile (cost est.)	Total (cost est.)
317, 407 & 2067	Brannan-Andrus Island	$150,000	$21,318,528	$2,173,248	$3,622,080	$27,263,856
3	Grand Island	$150,000	$21,028,480	$2,143,680	$3,572,800	$26,894,960
2025	Holland Tract	$150,000	$7,903,808	$805,728	$1,342,880	$10,202,416
2075	McMullin Ranch	$150,000	$5,365,888	$547,008	$911,680	$6,974,576
2107	Mossdale 2	$150,000	$3,045,504	$310,464	$517,440	$4,023,408
17	Mossdale Tract	$150,000	$10,151,680	$1,034,880	$1,724,800	$13,061,360
2095	Paradise	$150,000	$2,900,480	$295,680	$492,800	$3,838,960
2058	Pescadero Tract	$150,000	$6,453,568	$657,888	$1,096,480	$8,357,936
2064	River Junction	$150,000	$8,411,392	$857,472	$1,429,120	$10,847,984
684	Roberts Island, Lower	$150,000	$11,601,920	$1,182,720	$1,971,200	$14,905,840
524	Roberts Island, Middle	$150,000	$7,106,176	$724,416	$1,207,360	$9,187,952
544	Roberts Island, Upper	$150,000	$10,876,800	$1,108,800	$1,848,000	$13,983,600
2062	Stewart Tract	$150,000	$8,918,976	$909,216	$1,515,360	$11,493,552
2094	Walthall	$150,000	$2,392,896	$243,936	$406,560	$3,193,392
					SEEPAGE CONTROL GRAND TOTAL:	**$164,229,790**

Table 2

Sacramento - San Joaquin Delta, California

Lands, Easements, Right of Ways, Relocations & Disposals
(LERRDS)

Reclamation District No.		Name of Island/Tract	Negotiation (cost est.)	Land (cost est.)	Toe Drain (cost est.)	Siphons (cost est.)	Power Poles (cost est.)	Land (seepage) (cost est.)	Total LERRDS (cost est.)
556	1	Andrus Island, Upper	$15,000	$8,000	$5,000	$15,000	$100,000	$0	$143,000
2126	1	Atlas Tract	$90,000	$32,000	$20,000	$60,000	$100,000	$0	$302,000
2028		Bacon Island	$405,000	$396,000	$151,000	$975,000	$100,000	$0	$2,027,000
		Bethel Island MID	$10,230,000	$10,259,000	$122,000	$345,000	$100,000	$0	$21,056,000
756		Bouldin Island	$105,000	$435,000	$190,000	$795,000	$125,000	$0	$1,650,000
2033		Brack Tract	$225,000	$224,000	$122,000	$300,000	$100,000	$0	$971,000
2059		Bradford Island	$915,000	$212,000	$78,000	$120,000	$100,000	$0	$1,425,000
317, 407 & 2067		Brannan-Andrus LMD	$3,330,000	$219,000	$136,000	$390,000	$100,000	$136,000	$4,175,000
2086		Canal Ranch	$105,000	$257,000	$102,000	$315,000	$100,000	$0	$879,000
2117		Coney Island	$30,000	$92,000	$57,000	$75,000	$100,000	$0	$354,000
2111	1	Dead Horse Island	$60,000	$51,000	$28,000	$105,000	$100,000	$0	$344,000
		Drexler Island	$90,000	$68,000	$42,000	$120,000	$100,000	$0	$420,000
2029		Empire Tract	$255,000	$275,000	$111,000	$705,000	$100,000	$0	$1,446,000
773	1	Fabian Tract	$435,000	$319,000	$199,000	$570,000	$130,000	$0	$1,653,000
2113	1	Fay Island	$45,000	$31,000	$17,000	$45,000	$100,000	$0	$238,000
1002	1	Glanville Tract	$255,000	$253,000	$137,000	$30,000	$100,000	$0	$775,000
3	1	Grand Island	$2,175,000	$0	$0	$870,000	$100,000	$1,406,000	$3,145,000
2025		Holland Tract	$435,000	$223,000	$116,000	$360,000	$100,000	$103,000	$1,234,000
799	1	Hotchkiss Tract	$375,000	$2,310,000	$94,000	$570,000	$100,000	$0	$3,449,000
830	1	Jersey Island	$315,000	$265,000	$165,000	$465,000	$105,000	$0	$1,315,000
2038		Jones Tract, Lower	$180,000	$162,000	$95,000	$330,000	$100,000	$0	$867,000
2039		Jones Tract, Upper	$120,000	$85,000	$53,000	$255,000	$100,000	$0	$613,000
2044		King Island	$180,000	$207,000	$96,000	$615,000	$100,000	$0	$1,198,000
369	1	Libby McNeil	$15,000	$19,000	$12,000	$30,000	$100,000	$0	$176,000
2118	1	Little Mandeville	$15,000	$76,000	$48,000	$90,000	$100,000	$0	$329,000
2027		Mandeville Island	$105,000	$275,000	$150,000	$300,000	$100,000	$0	$930,000
2110	1	McCormack-Williamson Tract	$660,000	$427,000	$93,000	$264,000	$100,000	$0	$1,544,000
2030		McDonald Island	$150,000	$247,000	$145,000	$450,000	$100,000	$0	$1,092,000
2075	1	McMullin Ranch	$555,000	$0	$0	$222,000	$100,000	$359,000	$877,000
2041		Medford Island	$60,000	$120,000	$62,000	$150,000	$100,000	$0	$492,000
2107	1	Mossdale 2	$315,000	$0	$0	$126,000	$100,000	$204,000	$541,000
17	1	Mossdale Tract	$1,050,000	$0	$0	$420,000	$100,000	$679,000	$1,570,000
1007	1	Naglee Burke	$180,000	$141,000	$88,000	$255,000	$100,000	$0	$764,000
348		New Hope Tract	$645,000	$316,000	$197,000	$555,000	$130,000	$0	$1,843,000
2024		Orwood Tract	$225,000	$108,000	$67,000	$195,000	$100,000	$0	$695,000
2036		Palm Tract	$30,000	$134,000	$83,000	$240,000	$100,000	$0	$587,000
2095	1	Paradise	$300,000	$0	$0	$120,000	$100,000	$194,000	$520,000
2058	1	Pescadero Tract	$180,000	$147,000	$92,000	$150,000	$100,000	$91,000	$669,000
2090		Quimby Island	$30,000	$135,000	$74,000	$90,000	$100,000	$0	$429,000
2037		Rindge Tract	$240,000	$329,000	$167,000	$1,005,000	$110,000	$0	$1,851,000
2064	1	River Junction	$870,000	$0	$0	$348,000	$100,000	$562,000	$1,318,000
684		Roberts Island, Lower	$780,000	$251,000	$156,000	$795,000	$100,000	$155,000	$2,082,000
524	1	Roberts Island, Middle	$255,000	$215,000	$134,000	$255,000	$100,000	$133,000	$959,000
544	1	Roberts Island, Upper	$360,000	$299,000	$186,000	$360,000	$120,000	$185,000	$1,325,000
341		Sherman Island	$1,440,000	$329,000	$205,000	$585,000	$135,000	$0	$2,694,000
2115		Shima Tract	$60,000	$111,000	$69,000	$120,000	$100,000	$0	$460,000
	1	Shin Kee Tract	$15,000	$61,000	$38,000	$105,000	$100,000	$0	$319,000
38		Staten Island	$15,000	$554,000	$268,000	$765,000	$180,000	$0	$1,782,000
2062	1	Stewart Tract	$930,000	$0	$0	$369,000	$100,000	$596,000	$1,399,000
548	1	Terminous Tract	$630,000	$343,000	$170,000	$615,000	$110,000	$0	$1,868,000
1601		Twitchell Island	$345,000	$254,000	$126,000	$345,000	$100,000	$0	$1,170,000
563		Tyler Island	$705,000	$542,000	$246,000	$915,000	$165,000	$0	$2,573,000
1		Union Island, East	$300,000	$255,000	$159,000	$300,000	$100,000	$0	$1,114,000

Table 3

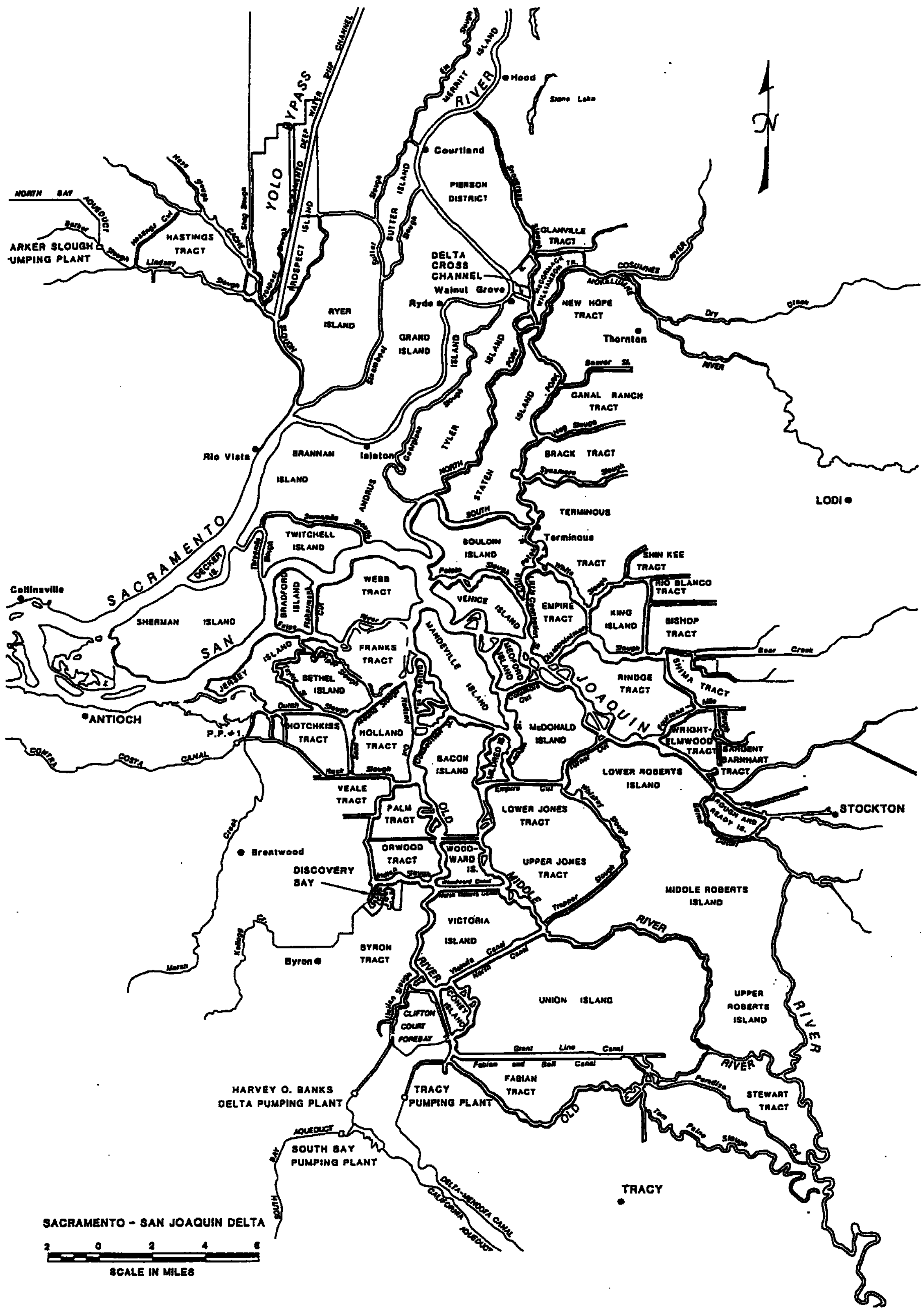
Sacramento - San Joaquin Delta, California

Lands, Easements, Right of Ways, Relocations & Disposals
(LERRDS)

Reclamation District No.		Name of Island/Tract	Negotiation (cost est.)	Land (cost est.)	Toe Drain (cost est.)	Siphons (cost est.)	Power Poles (cost est.)	Land (seepage) (cost est.)	Total LERRDS (cost est.)
2	1	Union Island, West	$375,000	$273,000	$170,000	$885,000	$110,000	$0	$1,813,000
1607		Van Sickle Island	$90,000	$64,000	$40,000	$120,000	$100,000	$0	$414,000
2065		Veale Tract	$45,000	$86,000	$53,000	$150,000	$100,000	$0	$434,000
2023	1	Venice Island	$90,000	$240,000	$131,000	$375,000	$100,000	$0	$936,000
2040	1	Victoria Island	$120,000	$292,000	$159,000	$495,000	$100,000	$0	$1,166,000
2094	1	Walthall	$255,000	$56,000	$35,000	$99,000	$100,000	$35,000	$545,000
2026		Webb Tract	$270,000	$269,000	$136,000	$330,000	$100,000	$0	$1,105,000
2122	1	Winter Island	$15,000	$81,000	$51,000	$150,000	$100,000	$0	$397,000
2072		Woodward Island	$90,000	$163,000	$94,000	$330,000	$100,000	$0	$777,000
2119		Wright-Elmwood Tract	$165,000	$120,000	$75,000	$330,000	$100,000	$0	$790,000
						LERRDS GRAND TOTAL:			**$92,028,000**

1 Extrapolated: When no specific data was available, the data was derived from adjoining islands/tracts with similar conditions.

CALFED Levee Rehabilitation Study

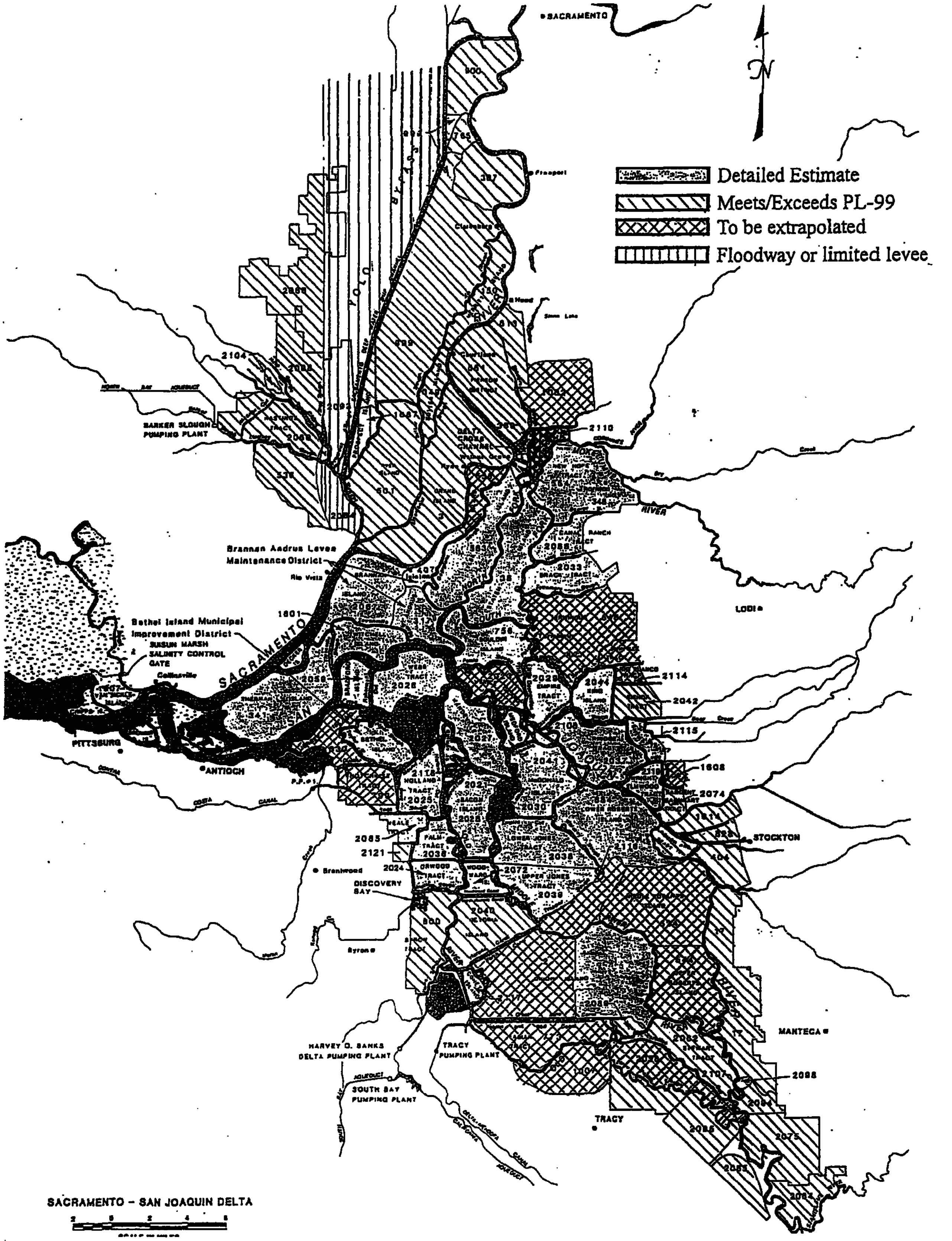


MURRAY BURNS AND KIENLEN - Consulting Civil Engineers
1616 29th Street Ste 300, Sacramento CA 95816 - (916) 456-4400

Local Flood Control Nonproject Levees

Figure 1

CALFED Levee Rehabilitation Study

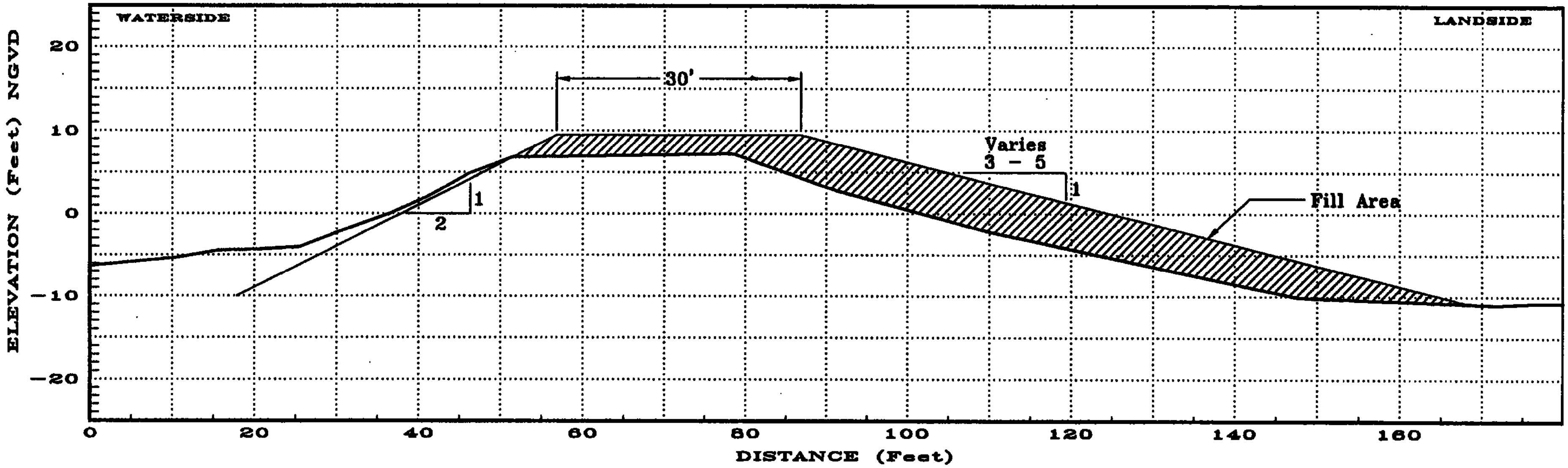


Murray Burns and Kienlen - Consulting Civil Engineers 1616 29th Street Ste 300, Sacramento CA 95816 - (916) 456-4400	Reclamation and Levee Maintenance Districts

Figure 2

TYPICAL LEVEE CROSS SECTION

Stations supporting a County Road



Stations not supporting a County Road

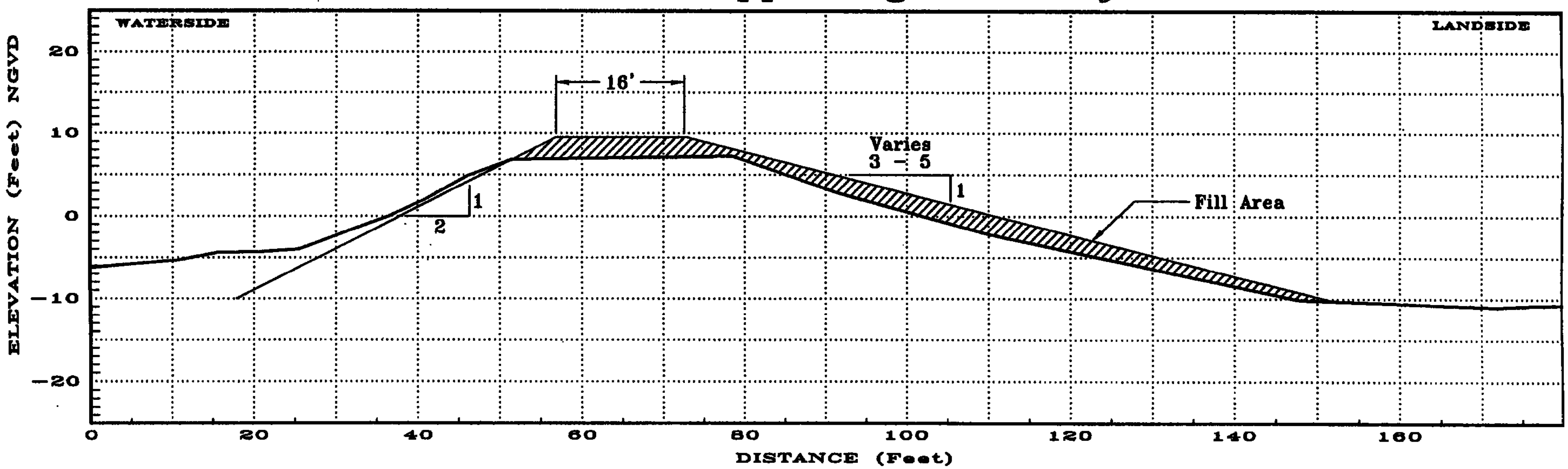
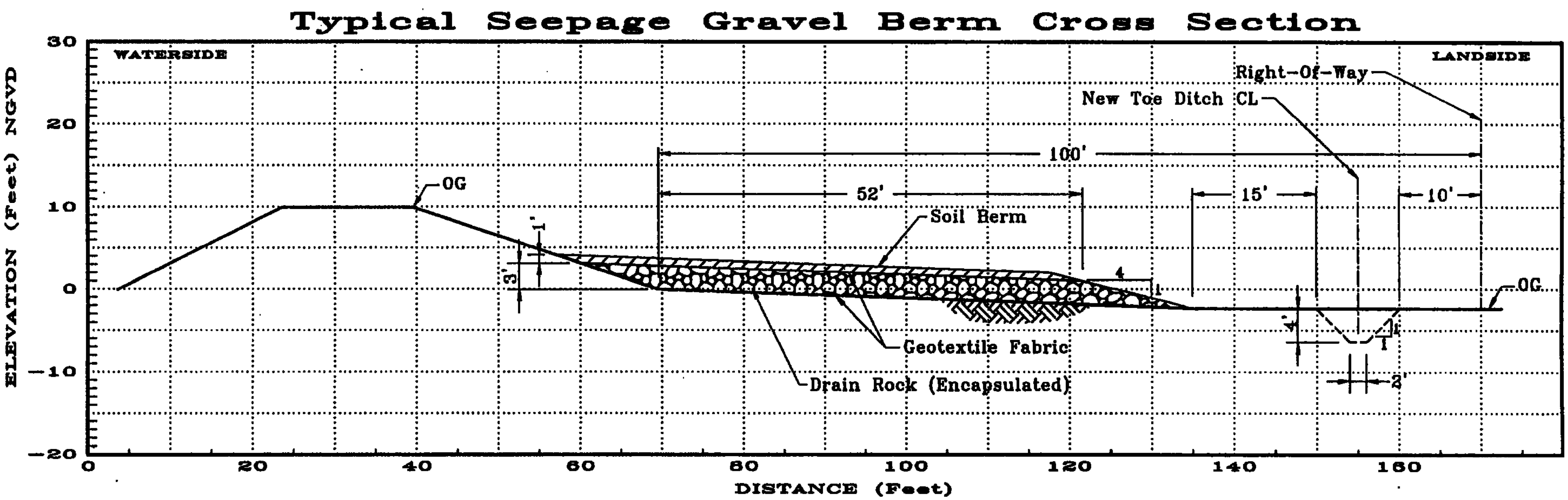


Figure 3



Typical Seepage Gravel Berm Cross Section
WATERSIDE
LANDSIDE
Right-Of-Way
New Toe Ditch CL
100'
52'
15'
10'
OG
Soil Berm
Geotextile Fabric
Drain Rock (Encapsulated)
3'
1'
4
1
4'
2'
ELEVATION (Feet) NGVD
DISTANCE (Feet)
30
20
10
0
-10
-20
0
20
40
60
80
100
120
140
160

Figure 4

Typical Right-Of-Way Cross Section

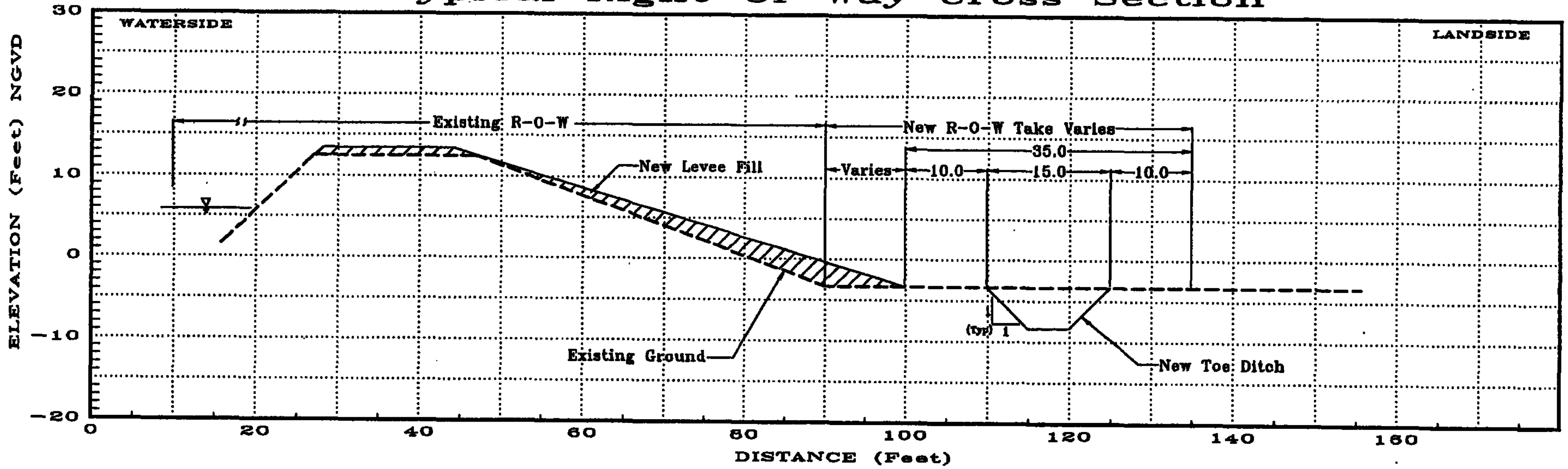
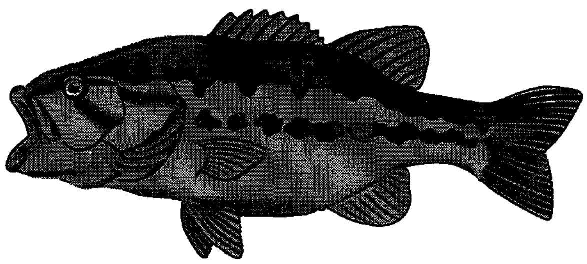


Figure 5

APPENDIX C

CALIFORNIA WATER CODE EXCERPTS



DIVISION 1. GENERAL STATE POWERS OVER WATER

Chapter 2. State Administration Genrally
Article 1. Department of Water Resources, Section 128

Article 1. Department of Water Resources, Section 128

128. (a) In times of extraordinary stress and of disaster, resulting from storms and floods, or where damage to watershed lands by forest fires has created an imminent threat of floods and damage by water, mud, or debris upon the occurrence of storms, the department may perform any work required or take any remedial measures necessary to avert, alleviate, repair, or restore damage or destruction to property having a general public and state interest and to protect the health, safety, convenience, and welfare of the general public of the state. In carrying out that work, the department may perform the work itself or through or in cooperation with any other state department or agency, the federal government, or any political subdivision, city, or district.

(b) This section is intended to supplement the emergency services of the state, and nothing in this section overrides or supersedes the authority of the Director of the Office of Emergency Services to coordinate and supervise state action, upon a declaration of a state of emergency, under the California Emergency Services Act (Chapter 7 (commencing with Section 8550) of Division 1 of Title 2 of the Government Code) or the Natural Disaster Assistance Act (Chapter 7.5 (commencing with Section 8680) of that division).

DIVISION 6. CONSERVATION, DEVELOPMENT, AND UTILIZATION OF STATE WATER RESOURCES

PART 4.5 SACRAMENTO-SAN JOAQUIN DELTA

Chapter 1. General Policy - Section 12200
Chapter 2. The Delta - Section 12220
Chapter 3. Sacramento-San Joaquin Delta Levees - Section 12225

Chapter 1. General Policy, Sections 12200-12205

12200. The Legislature hereby finds that the water problems of the Sacramento-San Joaquin Delta are unique within the State; the Sacramento and San Joaquin Rivers join at the Sacramento-San Joaquin Delta to discharge their fresh water flows into Suisun, San Pablo and San Francisco Bays and thence into the Pacific Ocean; the merging of fresh water with saline bay waters and drainage waters and the withdrawal of fresh water for beneficial uses creates an acute problem of salinity intrusion into the vast network of channels and sloughs of the Delta; the State Water Resources

Development System has as one of its objectives the transfer of waters from water-surplus areas in the Sacramento Valley and the north coastal area to water-deficient areas to the south and west of the Sacramento-San Joaquin Delta via the Delta; water surplus to the needs of the areas in which it originates is gathered in the Delta and thereby provides a common source of fresh water supply for water-deficient areas. It is, therefore, hereby declared that a general law cannot be made applicable to said Delta and that the enactment of this law is necessary for the protection, conservation, development, control and use of the waters in the Delta for the public good.

12201. The Legislature finds that the maintenance of an adequate water supply in the Delta sufficient to maintain and expand agriculture, industry, urban, and recreational development in the Delta area as set forth in Section 12220, Chapter 2, of this part, and to provide a common source of fresh water for export to areas of water deficiency is necessary to the peace, health, safety and welfare of the people of the State, except that delivery of such water shall be subject to the provisions of Section 10505 and Sections 11460 to 11463, inclusive, of this code.

12202. Among the functions to be provided by the State Water Resources Development System, in coordination with the activities of the United States in providing salinity control for the Delta through operation of the Federal Central Valley Project, shall be the provision of salinity control and an adequate water supply for the users of water in the Sacramento-San Joaquin Delta. If it is determined to be in the public interest to provide a substitute water supply to the users in said Delta in lieu of that which would be provided as a result of salinity control no added financial burden shall be placed upon said Delta water users solely by virtue of such substitution. Delivery of said substitute water supply shall be subject to the provisions of Section 10505 and Sections 11460 to 11463, inclusive, of this code.

12203. It is hereby declared to be the policy of the State that no person, corporation or public or private agency or the State or the United States should divert water from the channels of the Sacramento-San Joaquin Delta to which the users within said Delta are entitled.

12204. In determining the availability of water for export from the Sacramento-San Joaquin Delta no water shall be exported which is necessary to meet the requirements of Sections 12202 and 12203 of this chapter.

12205. It is the policy of the State that the operation and management of releases from storage into the Sacramento-San Joaquin Delta of water for use outside the area in which such water originates shall be integrated to the maximum extent possible in order to permit the fulfillment of the objectives of this part.

Chapter 2. The Delta, Section 12220

12220. The Sacramento-San Joaquin Delta shall include all the lands within the area bounded as follows, and as shown on the attached map prepared by the Department of Water Resources titled "Sacramento-San Joaquin Delta," dated May 26, 1959:

Beginning at the Sacramento River at the I Street bridge proceeding westerly along the Southern Pacific Railroad to its intersection with the west levee of the Yolo By-Pass; southerly along the west levee to an intersection with Putah Creek, then westerly along the left bank of Putah Creek to an intersection with the north-south section line dividing sections 29 and 28, T8N, R6E; south along this section line to the northeast corner of section 5, T7N, R3E; west to the northwest corner of said section; south along west boundary of said section to intersection of Reclamation District No. 2068 boundary at northeast corner of SE 1/4 of section 7, T7N, R3E; southwesterly along Reclamation District No. 2068 boundary to southeast corner of SW 1/4 of section 8, T6N, R2E; west to intersection of Maine Prairie Water Association boundary at southeast corner of SW 1/4 of section 7, T6N, R2E; along the Maine Prairie Water Association boundary around the northern and western sides to an intersection with the southeast corner of section 6, T5N, R2E; west to the southwest corner of the SE 1/4 of said section; south to the southwest corner of the NE 1/4 of section 7, T5N, R2E; east to the southeast corner of the NE 1/4 of said section; south to the southeast corner of said section; west to the northeast corner of section 13, T5N, R1E; south to the southeast corner of said section; west to the northwest corner of the NE 1/4 of section 23, T5N, R1E; south to the southwest corner of the NE 1/4 of said section; west to the northwest corner of the SW 1/4 of said section; south to the southwest corner of the NW 1/4 of section 26, T5N, R1E; east to the northeast corner of the SE 1/4 of section 25, T5N, R1E; south to the southeast corner of said section; east to the northeast corner of section 31, T5N, R2E; south to the southeast corner of the NE 1/4 of said section; east to the northeast corner of the SE 1/4 of section 32, T5N, R2E; south to the northwest corner of section 4, T4N, R2E; east to the northeast corner of said section; south to the southwest corner of the NW 1/4 of section 3, T4N, R2E; east to the northeast corner of the SE1/4 of said section; south to the southwest corner of the NW 1/4 of the NW 1/4 of section 11, T4N, R2E; east to the southeast corner of the NE 1/4 of the NE 1/4 of said section; south along the east line of section 11, T4N, R2E to a road intersection approximately 1000 feet south of the southeast corner of said section; southeasterly along an unnamed road to its intersection with the right bank of the Sacramento River about 0.7 mile upstream from the Rio Vista bridge; southwesterly along the right bank of the Sacramento River to the northern boundary of section 28, T3N, R2E; westerly along the northern boundary of sections 28, 29, and 30, T3N, R2E and sections 25 and extended 26, T3N, R1E to the northwest corner of extended section 26, T3N, R1E; northerly along the west boundary of section 23, T3N, R1E to the northwest corner of said section; westerly along the northern boundary of sections 22 and 21, T3N, R1E to the Sacramento Northern Railroad; southerly along the Sacramento

Northern Railroad; southerly along the Sacramento Northern Railroad to the ferry slip on Chipps Island; across the Sacramento River to the Mallard Slough pumping plant intake channel of the California Water Service Company; southward along the west bank of the intake channel and along an unnamed creek flowing from Lawler Ravine to the southern boundary of the Contra Costa County Water District; easterly along the southern boundary of the Contra Costa County Water District to the East Contra Costa Irrigation District boundary; southeasterly along the southwestern boundaries of the East Contra Costa Irrigation District, Byron-Bethany Irrigation District, West Side Irrigation District and Banta-Carbona Irrigation District to the northeast corner of the NW 1/4 of section 9, T3S, R6E; east along Linne Road to Kasson Road; southeasterly along Kasson Road to Durham Ferry Road; easterly along Durham Ferry Road to its intersection with the right bank of the San Joaquin River at Reclamation District No. 2064; southeasterly along Reclamation District No. 2064 boundary, around its eastern side to Reclamation District No. 2075 and along the eastern and northern sides of Reclamation District No. 2075 to its intersection with the Durham Ferry Road; north along the Durham Ferry Road to its intersection with Reclamation District No. 17; along the eastern side of Reclamation District No. 17 to French Camp Slough; northerly along French Camp Turnpike to Center Street; north along Center Street to Weber Avenue; east along Weber Avenue to El Dorado Street; north along El Dorado Street to Harding Way; west along Harding Way to Pacific Avenue; north along Pacific Avenue to the Calaveras River; easterly along the left bank of the Calaveras River to a point approximately 1,600 feet west of the intersection of the Western Pacific Railroad and the left bank of said river; across the Calaveras River and then north 18* 26' 36 west a distance of approximately 2,870 feet; south 72* 50' west a distance of approximately 4,500 feet to Pacific Avenue (Thornton Road); north along Pacific Avenue continuing onto Thornton Road to its intersection with the boundary line dividing Woodbridge Irrigation District and Reclamation District No. 348; east along this boundary line to its intersection with the Mokelumne River; continuing easterly along the right bank of the Mokelumne River to an intersection with the range line dividing R5E and R6E; north along this range line to the Sacramento-San Joaquin County line; west along the county line to an intersection with Reclamation District No. 1609; northerly along the eastern boundary of Reclamation District No. 1609 to the Cosumnes River, upstream along the right bank of the Cosumnes River to an intersection with the eastern boundary of extended section 23, T5N, R5E; north along the eastern boundary of said extended section to the southeast corner of the NE 1/4 of the NE 1/4 of said extended section; west to the southeast corner of the NE 1/4 of the NW 1/4 of extended section 14, T5N, R5E; west to an intersection with Desmond Road; north along Desmond Road to Wilder-Ferguson Road; west along Wilder-Ferguson Road to the Western Pacific Railroad; north along the Western Pacific Railroad to the boundary of the Elk Grove Irrigation District on the southerly boundary of the N ½ of section 4, T5N, R5E; northerly along the western boundary of the Elk Grove Irrigation District to Florin Road; west on Florin Road to the eastern boundary of Reclamation District No. 673; northerly around Reclamation District No. 673 to an intersection with the Sacramento River and then north along the left bank of the Sacramento River to I Street bridge. Section, range, and township locations are referenced to the Mount Diablo Base Line and Meridian. Road names and locations are as shown on the following United States Geological Survey Quadrangles, 7.5 minute series: Rio Vista, 1953; Clayton, 1953; Vernalis, 1952; Ripon, 1952; Bruceville, 1953; Florin, 1953; and Stockton West, 1952.

Chapter 3. Sacramento-San Joaquin Delta Levees, Sections 12225-12228

12225. The plan for improvement of the Sacramento-San Joaquin Delta levees, as set forth in Bulletin No. 192 of the Department of Water Resources, dated May 1975, is approved as a conceptual plan to guide the formulation of projects to preserve the integrity of the delta levee system.

12226. The department may prepare detailed plans and specifications for the improvement of the levees or levee segments specified in Section 12225.

12226.1. The department shall report on its recommendations to the Legislature concerning the improvement of the levees specified in Section 12225, including, but not limited to, recommendations concerning construction, cost sharing, land use, zoning, flood control, recreation, fish and wildlife habitat, and aesthetic values. The department shall submit interim reports to the Legislature concerning the status of the delta levees program on or before January 15 of each year beginning in 1978, with the final report on its recommendations to be made on or before January 15, 1980.

12226.2. The department may proceed immediately with the improvement of a pilot levee project which the department determines, after a public hearing, is in critical need of improvement and which is highly susceptible to failure in the absence of such immediate improvement. Prior to commencing such improvement, the department shall enter into an agreement with a local agency whereby the local agency will bear at least 20 percent of the cost of the improvement.

12227. This chapter shall be known and may be cited as the "Nejedly-Mobley Delta Levees Act".

12228. (a) The department shall submit to the Legislature, on or before January 1, 1994, a report on land use patterns within the boundaries of the Sacramento-San Joaquin Delta and the lands immediately adjacent to that delta.

(b) Subdivision (a) shall be implemented only to the extent money is appropriated in the annual Budget Act to carry out this section.

PART 4.6 SAN JOAQUIN RIVER

Sections 12230-12233

12230. The Legislature hereby finds and declares that a serious problem of water quality exists in the San Joaquin River between the junction of the San Joaquin River and the Merced River and the junction of the San Joaquin River with Middle River; that by virtue of the nature and causes of the problem and its effect upon water supplies in the Sacramento-San Joaquin Delta, it is a matter of statewide interest and is the responsibility of the State to determine an equitable and feasible solution to this problem.

12231. It is hereby declared to be the policy of the State that no person, corporation or public or private agency or the State or the United States should divert water from the San Joaquin River and its tributaries to which the users along the portion of the San Joaquin River described in Section 12230 are entitled.

12232. The State Water Resources Control Board, the State Department of Water Resources, the California Water Commission, and any other agency of the state having jurisdiction, shall do nothing, in connection with their responsibilities, to cause further significant degradation of the quality of water in that portion of the San Joaquin River between the points specified in Section 12230.

12233. Nothing in this part shall be construed as affecting the quality of water diverted into the Sacramento-San Joaquin Delta from the Sacramento River, nor as affecting any vested right to the use of water, regardless of origin, or any water project for which an application to appropriate water was filed with the State Water Resources Control Board prior to June 17, 1961.

PART 4.8 DELTA FLOOD PROTECTION

Chapter 1. Delta Flood Protection Fund, Sections 12300-12303

12300. (a) The Delta Flood Protection Fund is hereby created in the State Treasury. There shall be deposited in the fund all moneys appropriated to the fund and all income derived from the investment of moneys that are in the fund.

(b) It is the intent of the Legislature to appropriate, in accordance with Section 12938, twelve million dollars ($12,000,000) each year through fiscal year 1998-99 to the Delta Flood Protection Fund from moneys deposited in the California Water Fund pursuant to subdivision (b) of Section 6217 of the Public Resources Code. It is further the intent of the Legislature to appropriate annually moneys in the Delta Flood Protection Fund to the department for expenditure and allocation, without regard to fiscal years, in the following amounts and for the following purposes:

(1) Six million dollars ($6,000,000) annually for local assistance under the delta levee maintenance subventions program pursuant to Part 9 (commencing with Section 12980), and for the administration thereof.

(2) Six million dollars ($6,000,000) annually for special delta flood protection projects under Chapter 2 (commencing with Section 12310) and subsidence studies and monitoring, and the administration thereof. These funds shall only be allocated for projects on Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb Islands, and at other locations in the delta and for the Towns of Thornton and Walnut Grove and for approximately 12 miles of levees on islands bordering the Northern Suisun Bay from Van Sickle Island westerly to Montezuma Slough.

(c) Any moneys unexpended at the end of a fiscal year shall revert to the Delta Flood Protection Fund and shall be available for appropriation by the Legislature for the purposes specified in subdivision (b).

(d) It is the intent of the Legislature that, to the extent consistent with Sections 12314, 12987, and 78543, projects funded under subdivision (b) shall be consistent with the delta ecosystem restoration strategy of the CALFED Bay-Delta Program.

12301. The Delta Flood Protection Fund is hereby abolished on July 1, 2006, and all unencumbered moneys in the fund are transferred to the General Fund.

12303. (a) It is the intent of the Legislature that, subject to subdivision (b) of Section 12929.12, if twelve million dollars ($12,000,000) or any lesser amount is transferred pursuant to paragraph (3) of subdivision (b) of Section 12937 to the California Water Fund from the California Water Resources Development Bond Fund in each of the fiscal years 1990-91 to 1997-98, inclusive, and if six million dollars ($6,000,000) or any lesser amount is so transferred in the 1998-99 fiscal year, that amount shall be appropriated to the Delta Flood Protection Fund for the purposes specified in subdivision (b) of Section 12300, in lieu of the funds deposited in the California Water Fund pursuant to subdivision (b) of Section 6217 of the Public Resources Code. However, that the director, in consultation with the Department of Finance, may accelerate payments to the California

Water Fund for reappropriation to the Delta Flood Protection Fund if the director deems it appropriate to do so.

(b) The obligation of the State Water Resources Development System to reimburse the California Water Fund, pursuant to paragraph (3) of subdivision (b) of Section 12937, shall decrease by amounts equal to the amounts which are transferred from the California Water Resources Development Bond Fund to the California Water Fund and appropriated to the Delta Flood Protection Fund pursuant to subdivision (a).

(c) For any fiscal year, the Director of Finance, in consultation with the Director of Water Resources, may recommend in the Budget Act a source of funding for the Delta Flood Protection Fund which is different from that set forth in subdivision (a). If the Legislature approves the alternative source of funding, the portion of the State Water Resources Development System obligation specified in subdivision (b) which remains outstanding because of the selection of the alternative funding source shall be discharged pursuant to subdivision (b) of Section 11913.

(d) It is the intent of the Legislature, upon the creation of the Delta Levee Rehabilitation Subaccount pursuant to Section 78540, as proposed to be added by S.B. 900 of the 1995-96 Regular Session, that subdivisions (a), (b), and (c) shall not apply to the Delta Levee Rehabilitation Subaccount and that the funds of the subaccount shall be available to fund equally both of the following:

(1) The delta levee maintenance subventions program pursuant to Part 9 (commencing with Section 12980), associated mitigation and habitat improvement programs, and the administration thereof.

(2) The special delta flood protection projects pursuant to Chapter 2 (commencing with Section 12310), associated mitigation and habitat improvement programs, and the administration thereof.

Chapter 1.5. Environmental Mitigation and Protection Requirements, Sections 12306-12308

12306. This chapter applies to special flood control projects subject to Chapter 2 (commencing with Section 12310) and to the payment of delta levee subventions under Part 9 (commencing with Section 12980).

12306.5. The Resources Agency shall supervise the implementation of the programs subject to this chapter.

12307. (a) The Resources Agency, the department, the Reclamation Board, and the Department of Fish and Game shall enter into a memorandum of understanding to coordinate the implementation of the programs subject to this chapter.

(b) The memorandum of understanding shall provide that the Department of Fish and Game shall enforce any mitigation requirements involving programs subject to this chapter.

12308. The Resources Agency shall report to the Legislature not later than January 15 of each year all of the following information for each plan approved pursuant to this part:

(a) The name of each local agency submitting a plan, the island or tract involved, and a map of the island or tract indicating the work and the mitigation sites.

(b) The amount of money allocated to the plan, and the amount of money spent on project construction and on project mitigation.

(c) The number of acres of riparian, wildlife, and fisheries habitat and the number of lineal feet of shaded aquatic areas disturbed by projects funded under this part.

(d) The number and quality of acres of replacement habitat provided as mitigation.

(e) An annual assessment as to whether the cumulative impact of projects funded pursuant to this part has resulted in no net long-term loss of riparian, wildlife, or fisheries habitat. If the Resources Agency determines that a net long-term loss has occurred, it shall include in its assessment the necessary steps to correct those deficiencies.

Chapter 2. Special Flood Control Projects, Sections 12310-12318

12310. As used in this chapter, the following terms have the following meanings:

(a) "Local public agency" means a reclamation district or levee district or other public agency responsible for the maintenance of a nonproject levee as defined in subdivision (d) of Section 12980 or a project levee as defined in subdivision (e) of Section 12980.

(b) "Project" means the flood control improvement and any mitigation and habitat improvement constructed, or interests in land acquired, for those purposes pursuant to this part.

(c) "Department" means the Department of Water Resources.

(d) "Delta" means the Sacramento-San Joaquin Delta as described in Section 12220.

(e) "Net long-term habitat improvement" means enhancement of riparian, fisheries, and wildlife habitat.

(f) "CALFED Bay Delta Program" or "CALFED program" means the program established in May 1995 as a joint effort among state and federal agencies with management and regulatory responsibilities in the San Francisco Bay and Sacramento-San Joaquin River Delta to develop long-term solutions to resource management problems involving the bay-delta.

12311. (a) The department shall develop and implement a program of flood control projects on Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb Islands, and at other locations in the delta and for the Towns of Thornton and Walnut Grove, and for approximately 12 miles of levees on islands bordering Northern Suisun Bay from Van Sickle Island westerly to

Montezuma Slough. This program shall have, as its primary purpose, the protection of discrete and identifiable public benefits, including the protection of public highways and roads, utility lines and conduits, and other public facilities, and the protection of urbanized areas, water quality, recreation, navigation, and fish and wildlife habitats, and other public benefits. The program shall also include net long-term habitat improvement.

(b) Notwithstanding subdivision (a), the department shall develop and recommend a plan of action, including alternatives, for flood control for the Towns of Thornton and Walnut Grove and shall submit the plan to the Legislature by January 1, 1989. The department shall not allocate any funds for implementation of the plan of action for flood control for the Towns of Thornton and Walnut Grove until a plan is approved by the Legislature.

12312. The department may expend any moneys available to it pursuant to paragraph (2) of subdivision (b) of Section 12300 or any moneys available from other sources of funding appropriated by the Legislature for the purposes of this part. In addition, the department shall seek a sharing of costs with the beneficiaries or owners or operators of the public facilities benefitted by the flood protection projects. The department shall also seek cost sharing with, or financial assistance from, federal agencies which have programs applicable to, or which have an interest in, the flood protection projects.

12313. (a) The department shall develop a list of areas where flood control work is needed to protect public facilities or provide public benefits. In developing the list, the department shall consult with all appropriate federal, state, and local agencies. The list shall establish a priority for the areas based upon both of the following:

(1) The importance or degree of public benefit needing protection.

(2) The need for flood protective work.

(b) The list shall be submitted to the California Water Commission for approval, and shall be updated by the department, with the approval of the California Water Commission, as the department may deem appropriate.

12314. (a) Guided by the approved priority list developed pursuant to Section 12313, the department shall develop project plans to accomplish the needed flood protection work in cooperation with the local public agency, the public beneficiary, and the Department of Fish and Game.

(b) The plans shall be subject to the approval of the appropriate local public agency or agencies and subject to any cost-sharing agreement the department may have entered into under Section 12312. Project plans may include, or be a combination of, the improvement, rehabilitation, or modification of existing levees, and the conveyance of interests in land to limit or to modify land management practices which have a negative impact on flood control facilities.

(c) Project plans shall include provision for the protection of fish and wildlife habitat determined to be necessary by the Department of Fish and Game and not injurious to the integrity of flood control works. The Department of Fish and Game shall consider the value of the riparian and fisheries habitat and the need to provide greater flood protection in preparing its requirements, and shall not approve any plan which calls for the use of channel islands or berms with significant riparian communities as borrow sites for levee repair materials, unless fully mitigated, or any plans that will result in a net long-term loss of riparian, fisheries, or wildlife habitat.

(d) After the memorandum of understanding required pursuant to Section 12307 is amended as required by Section 78543, the Department of Fish and Game shall also make a written determination as part of its review and approval of a plan or project pursuant to this section and Section 12987 that the proposed expenditures are consistent with a net long-term habitat improvement program and have a net benefit for aquatic species in the delta. The memorandum of understanding in effect prior to the amendments required by Section 78543 shall remain in effect with regard to levee projects and plans until the memorandum of understanding is amended.

12315. Projects shall be undertaken and completed in accordance with the approved project plans. Project works may be undertaken by the department or, at the department's option, by the local public agency pursuant to an agreement with the department.

12316. In addition to any obligations assumed under an agreement with the department and to the extent consistent with that agreement, the local public agency shall do all of the following:

(a) Provide construction access to lands or rights-of-way which it owns or maintains for flood control purposes or for purposes with which the project's required uses are compatible and necessary to complete the project.

(b) Maintain the completed project pursuant to maintenance criteria developed and adopted in accordance with Section 12984.

(c) Apply for federal disaster assistance, whenever eligible,
under Public Law 93-288.

(d) Hold and save the department, any other agency or department of the state, and their employees free from any and all liability for damages, except that caused by gross negligence, that may arise out of the construction, operation, or maintenance of the project.

(e) Acquire easements from the crown along levees for the control and reversal of subsidence in areas where the department determines that such an easement is desirable to maintain structural stability of the levee. The easement shall (1) restrict the use of the land to open-space uses, nontillable crops, the propagation of wildlife habitat, and other compatible uses, (2) provide full access to the local agency for levee maintenance and improvement purposes, and (3) allow the owner to retain reasonable rights of ingress and egress as well as reasonable rights of access to the waterways for water supply and drainage. The local public agency costs of acquisition of the easements shall be reimbursable by the department from moneys appropriated pursuant to paragraph (2) of subdivision (b) of Section 12300 or any sources of funding appropriated by the Legislature for purposes of this part.

(f) Comply with all habitat mitigation and improvement requirements pursuant to this part.

(g) Use subsidence control alternatives, where appropriate, to reduce long-term maintenance and improvement costs.

12318. (a) The Resources Agency may establish a team of federal, state, and local agencies, and other persons or entities with a stake in finding a solution to the problems of the delta levees, to develop recommendations for the beneficial reuse of dredged material, consistent with actions identified by the CALFED Bay-Delta Program as core actions, which are those actions included in all bay-delta solutions. The recommendations shall address all of the following needs:

(1) Long-term availability of cost-effective, environmentally safe, and appropriate dredged material for delta levee maintenance and improvements.

(2) Beneficial reuse of dredged or suitable alternative materials.

(3) Coordination of dredging projects to augment on-island stockpiles.

(4) Development of a comprehensive monitoring program of the effects of the reuse of dredged material.

(5) A study of the applicability and appropriateness of constructing channel sediment traps and dredged material rehandling facilities adjacent to frequently dredged channel sections.

PART 9. DELTA LEVEE MAINTENANCE

Sections 12980-12995

12980. As used in this part:

(a) "Board" means the Reclamation Board.

(b) "Delta" means the Sacramento-San Joaquin Delta as described in Section 12220.

(c) "Local agency" means any city, county, district, or other political subdivision of the state which is authorized to maintain levees.

(d) "Net long-term habitat improvement" means enhancement of riparian, fisheries, and wildlife habitat.

(e) "Nonproject levee" means a local flood control levee in the delta that is not a project facility under the State Water Resources Law of 1945, as shown on page 38 of the Department of Water Resources "Sacramento-San Joaquin Delta Atlas," dated 1993.

(f) "Project levee" means a federal flood control levee, as shown on page 40 of the Department of Water Resources "Sacramento-San Joaquin Delta Atlas," dated 1993, that is a project facility under the State Water Resources Law of 1945 (Chapter 1 (commencing with Section 12570) and Chapter 2 (commencing with Section 12639) of Part 6), if not less than a majority of the acreage within the jurisdiction of the local agency that maintains the levee is within the primary zone of the delta, as defined in Section 29728 of the Public Resources Code.

12981. (a) The Legislature finds and declares that the delta is endowed with many invaluable and unique resources and that these resources are of major statewide significance.

(b) The Legislature further finds and declares that the delta's uniqueness is particularly characterized by its hundreds of miles of meandering waterways and the many islands adjacent thereto; that, in order to preserve the delta's invaluable resources, which include highly productive agriculture, recreational assets, fisheries, and wildlife environment, the physical characteristics of the delta should be preserved essentially in their present form; and that the key to preserving the delta's physical characteristics is the system of levees defining the waterways and producing the adjacent islands. However, the Legislature recognizes that it may not be economically justifiable to maintain all delta islands.

(c) The Legislature further finds and declares that funds necessary to maintain and improve the delta's levees to protect the delta's physical characteristics should be used to fund levee work that would promote agricultural and habitat uses in the delta consistent with the purpose of preserving the delta's invaluable resources.

12982. The Legislature further finds and declares that while most of the delta's levees are privately owned and maintained they are being subjected to varied multiple uses and serve to benefit many varied segments and interests of the public at large, and that as a result of the varied multiple uses of such levees, added maintenance costs are being borne by adjacent landowners.

12983. The Legislature further finds and declares that there is an urgent need for a higher degree of levee maintenance and rehabilitation generally throughout the delta and that the state has an interest in providing technical and financial assistance for delta levee maintenance and rehabilitation. The Legislature also finds and declares that, because of the instability of delta soils, the effect of winds, tides, and flood flows, and the unique problems of erosion, seepage, and subsidence, the same security against levee failure and flooding cannot be achieved by protective works in the delta as in areas less vulnerable to these problems. Although the rehabilitation and maintenance of delta levees is an important undertaking, a significant risk of levee failure will still persist. The purpose of the state's approval of plans and inspection of works, which duties are set forth in this part, is to ensure that subvention funds are properly expended and that delta levees are effectively rehabilitated and maintained, and the state does not thereby assume any responsibility for the safety of any delta levee against failure.

12984. The department shall develop and submit to the board, for adoption by the board, criteria for the maintenance and improvement of nonproject levees. The criteria shall vary as required to meet specific conditions and shall be multipurpose in nature, and include environmental considerations, when feasible. The criteria shall embody and implement both of the following:

(a) The short-term mitigation plan set forth in the "Flood Hazard Mitigation Plan for the Sacramento-San Joaquin Delta," prepared by the department for the Office of Emergency Services, dated September 15, 1983, or as amended.

(b) The "Vegetation Management Guidelines for Local Nonproject Delta Levees" dated April 1994, or any successor guidelines.

12985. Prior to adoption of any such criteria, the board shall hold public hearings and may revise the criteria as it determines necessary.

12986. (a) It is the intention of the Legislature to reimburse an eligible local agency pursuant to this part for costs incurred in any year for the maintenance or improvement of project or nonproject levees as follows:

(1) No costs incurred shall be reimbursed if the entire cost incurred per mile of project or nonproject levee is one thousand dollars ($1,000) or less.

(2) Not more than 75 percent of any costs incurred in excess of one thousand dollars ($1,000) per mile of project or nonproject levee shall be reimbursed.

(3) (A) As part of the project plans approved by the board, the department shall require the local agency or an independent financial consultant to provide information regarding the agency's ability to pay for the cost of levee maintenance or improvement. Based on that information, the department may require the local agency or an independent financial consultant to prepare a comprehensive study on the agency's ability to pay.

(B) The information or comprehensive study of the agency's ability to pay shall be the basis for determining the maximum allowable reimbursement eligible under this part. Nothing in this paragraph shall be interpreted to increase the maximum reimbursement allowed under paragraph (2).

(4) Reimbursements made to the local agency in excess of the maximum allowable reimbursement shall be returned to the department. (5) The department may recover, retroactively, excess reimbursements paid to the local agency from any time after January 1, 1997, based on an updated study of the agency's ability to pay.

(6) All final costs allocated or reimbursed under a plan shall be approved by the reclamation board for project and nonproject levee work.

(7) Costs incurred pursuant to this part that are eligible for reimbursement include construction costs and associated engineering services, financial or economic analyses, environmental costs, mitigation costs, and habitat improvement costs.

(b) This section shall become inoperative on July 1, 2006, and, as of January 1, 2007, is repealed, unless a later enacted statute, that becomes operative on or before January 1, 2007, deletes or extends the dates on which it becomes inoperative and is repealed.

12986. (a) It is the intention of the Legislature to reimburse from the General Fund an eligible local agency pursuant to this part for costs incurred in any year for the maintenance or improvement of project or nonproject levees as follows:

(1) No costs incurred shall be reimbursed if the entire cost incurred per mile of levee is one thousand dollars ($1,000) or less.

(2) Fifty percent of any costs incurred in excess of one thousand dollars ($1,000) per mile of levee shall be reimbursed.

(3) The maximum total reimbursement from the General Fund shall not exceed two million dollars ($2,000,000) annually.

(b) This section shall become operative on July 1, 2006.

12987. (a) Local agencies maintaining project or nonproject levees shall be eligible for reimbursement pursuant to this part upon submission to and approval by the board of plans for the maintenance and improvement of the project or nonproject levees, including plans for the annual routine maintenance of the levees, in accordance with the criteria adopted by the board.

(b) The nonproject plans shall also be compatible with the plan for improvement of the delta levees as set forth in Bulletin No. 192-82 of the department, dated December 1982, and as approved in Section 12225. Both project and nonproject plans shall include provisions to acquire easements along levees that allow for the control and reversal of subsidence in areas where the department determines that such an easement is desirable to maintain structural stability of the levee. The easement shall (1) restrict the use of the land to open-space uses, nontillable crops, the propagation of wildlife habitat, and other compatible uses, (2) provide full access to the local agency for levee maintenance and improvement purposes, and (3) allow the owner to retain reasonable rights of ingress and egress as well as reasonable rights of access to the waterways for water supply and drainage. The local agency cost of acquisition of the easements shall be reimbursable by the department from moneys appropriated pursuant to paragraph (1) of subdivision (b) of Section 12300, or any other sources appropriated by the Legislature for purposes of this part.

(c) The plans shall also include provision for protection of the fish and wildlife habitat determined to be necessary by the Department of Fish and Game and not injurious to the integrity of the levee. The Department of Fish and Game shall consider the value of the riparian and fisheries habitat and the need to provide safe levees in preparing its requirements. The Department of Fish and Game shall not approve any plan which calls for the use of channel islands or berms with significant riparian communities as borrow sites for levee repair material, unless fully mitigated, or any plans which will result in a net long-term loss of riparian, fisheries, or wildlife habitat.

(d) After the memorandum of understanding required pursuant to Section 12307 is amended as required by Section 78543, the Department of Fish and Game shall also make a written determination as part of its review and approval of a plan or project pursuant to Section 12314 and this section that the proposed expenditures are consistent with a net long-term habitat improvement program and have a net benefit for aquatic species in the delta. The memorandum of understanding in effect prior to the amendments required by Section 78543 shall remain in effect with regard to levee projects and plans until the memorandum of understanding is amended.

(e) The plans shall also take into account the most recently updated Delta Master Recreation Plan prepared by the Resources Agency.

(f) Upon approval of the plans by the board, the local agencies shall enter into an agreement with the board to perform the maintenance and improvement work, including the annual routine maintenance work, specified in the plans. If applications for state funding in any year exceed the state funds available, the board shall apportion the funds among those levees or levee segments that are identified by the department as most critical and beneficial, considering the needs of flood control, water quality, recreation, navigation, habitat improvements, and fish and wildlife.

12987.5. (a) In an agreement entered into under Section 12987, the board may provide for an advance to the applicant in an amount not to exceed 75 percent of the estimated state share. The agreement shall provide that no advance shall be made until the applicant has incurred costs averaging one thousand dollars ($1,000) per mile of levee.

(b) Advances made under subdivision (a) shall be subtracted from amounts to be reimbursed after the work has been performed. If the department finds that work has not been satisfactorily performed or where advances made actually exceed reimbursable costs, the local agency shall promptly remit to the state all amounts advanced in excess of reimbursable costs. If advances are sought, the board may require a bond to be posted to ensure the faithful performance of the work set forth in the agreement.

(c) This section shall become inoperative on July 1, 2006, and, as of January 1, 2007, is repealed, unless a later enacted statute, that becomes operative on or before January 1, 2007, deletes or extends the dates on which it becomes inoperative and is repealed.

12988. Upon the completion in any year of the maintenance or improvement work, including annual routine maintenance work, as specified in the plans approved by the board, the local agency shall notify the department, and the department shall inspect the completed work. The department, upon completion of such inspection, shall submit to the board a report as to its findings. Upon a finding that the work has been satisfactorily completed in accordance with the approved plans, the board shall certify for reimbursement 75 percent of any costs incurred per mile of levee if the entire cost incurred per mile of levee is greater than one thousand dollars ($1,000).

12989. (a) The department shall conduct at least one annual inspection of every levee for which maintenance or improvement costs have been reimbursed pursuant to this part. In addition, the department shall inspect nonproject levees of local agencies for the purpose of monitoring and ascertaining the degree of compliance with, or progress toward meeting, standards such as those set forth in Section 12984.

(b) The local agency shall cooperate with the department in the conduct of these inspections, including the provision of reasonable access over local agency lands and easements.

12990. Whenever the department finds that the annual routine maintenance work specified in the plans approved by the board is not being performed in accordance with the agreement entered into between the local agency and the board, the department may establish a maintenance area in accordance with the provisions of Chapter 4.5 (commencing with Section 12878) of Part 6 of this division, as nearly as the same may be applicable, except that the work to be performed shall be the routine annual maintenance work for the nonproject levee as specified in the plans approved by the board. Upon the formation of a maintenance area, the department shall thereafter annually maintain the nonproject levee in accordance with such plans and subject to the provisions of Chapter 4.5 (commencing with Section 12878) of Part 6 of this division, as nearly as the same may be applicable.

12991. The board is authorized to make, from time to time, such rules and regulations as may be necessary to carry out, and as are consistent with, this part.

12992. Before any plan is approved, agreement entered into, or moneys advanced or reimbursed under this part, the local agency shall first enter into an agreement with the board indemnifying and holding and saving the State of California, the board, the department, any other agency or department of the state, and their employees free from any and all liability for damages, except that caused by gross negligence, that may arise out of the approvals, agreements, inspections, or work performed under this part. Any funds appropriated for any of the purposes of this part may be used to satisfy any judgment against the state covered by this section, pending indemnification by the local agency.

12993. Applicants shall apply for federal disaster assistance, whenever eligible, under Public Law 93-288. If, and to the extent that, it is determined that the work performed does not qualify for federal disaster assistance, the applicant may apply for reimbursement under Section 12986, and the costs shall be deemed incurred by the applicant in the year in which the latter application is filed.

12994. (a) The Legislature finds and declares all of the following:

(1) The CALFED Bay-Delta Program has identified as a core action the need for emergency levee management planning for delta levees to improve system reliability.

(2) Even with active levee maintenance, the threat of delta levee failures from earthquake, flood, or poor levee foundation, will continue to exist.

(3) Because of this threat of failure, and the potential need to mobilize people and equipment in an emergency to protect delta levees and public benefits, the department needs authority that will enable it to act quickly.

(b) The department may do all of the following:

(1) In an emergency, as defined by Section 21060.3 of the Public Resources Code, that requires immediate levee work to protect public benefits in the delta, the department may use funds pursuant to this part without prior approval of a plan by the board or the Department of Fish and Game, in which case the requirements of Sections 12987 and 12314, and the memorandum of understanding pursuant to Section 12307, shall be carried out as soon as possible.

(A) The amount of funds that may be expended each year on emergency levee work under this section shall not be greater than two hundred thousand dollars ($200,000) and the amount that may be expended per emergency levee site shall not be greater than fifty thousand dollars ($50,000). The local agency shall fund 25 percent of the total costs of the emergency repair at a site or shall fund an appropriate share of the costs as approved by the board and based upon information of the local agency's ability to pay for the repairs.

(B) Department contracts executed for emergency levee work under this section shall be exempted from Department of General Services approval required under the Public Contract Code.

(C) As soon a feasible after the emergency repair, the department shall submit a report to the board describing the levee work, costs incurred, and plans for future work at the site, including any necessary mitigation.

(D) This section is intended to supplement emergency services provided by the state or the United States. Nothing in this section overrides or supersedes the authority of the Director of the Office of Emergency Services under the California Emergency Services Act (Chapter 7 (commencing with Section 8550) of Division 1 of Title 2 of the Government Code) or the Natural Disaster Assistance Act (Chapter 7.5 (commencing with Section 8680) of Division 1 of Title 2 of the Government Code).

(2) Prepare and submit to the board for adoption a delta emergency response plan for levee failures. The plan is exempt from Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code. The plan may include recommendations of the multiagency response team established pursuant to paragraph (3) and may include, but not be limited to, the following:

(A) Standardized contracts for emergency levee work to be executed by the department, local agencies, or other appropriate entities.

(B) Criteria for eligible emergency levee work.

(C) Definition of an emergency levee site.

(D) Documentation requirements.

(E) Proposals for complying with the federal Endangered Species Act of 1973 (16 U.S.C. Sec. 1531 et seq.) and the California Endangered Species Act (Chapter 1.5 (commencing with Section 2050) of Division 3 of the Fish and Game Code) in an emergency.

(F) Stages of emergency response that may occur in various situations.

(3) Establish a multiagency emergency response team, consisting of representatives from the department, the board, the Department of Fish and Game, the California Conservation Corps, the

Office of Emergency Services, the Federal Emergency Management Agency, the United States Army Corps of Engineers, and the United States Fish and Wildlife Service to advise on methods to ensure that levee emergencies will be resolved as quickly and safely as possible.

12995. (a) The Legislature hereby finds and declares both of the following:

(1) There is an urgent need for rehabilitation and improvement of delta levees, and that the United States Army Corps of Engineers has a crucial and continuing role in that work.

(2) The department and the board have been cooperating with the United States Army Corps of Engineers in a feasibility study for rehabilitation and improvement of the levees in the delta. That feasibility study identified a federal interest in levee rehabilitation and improvements due to benefits to navigation, commerce, the environment, and flood damage reduction.

(b) The department and the board may cooperate with the United States Army Corps of Engineers to develop and implement delta levee rehabilitation, improvement, and realignment, and to enhance the environment.

DIVISION 24. SAFE, CLEAN, RELIABLE WATER SUPPLY ACT

Article 1. The Delta Improvement Account, Sections 78525-78526

78525. Unless the context otherwise requires, as used in this chapter, "account" means the Delta Improvement Account created by Section 78526.

78526. The Delta Improvement Account is hereby created in the fund. The sum of one hundred ninety-three million dollars ($193,000,000) is hereby transferred from the fund to the account.

Article 2. Central Valley Project Improvement Program, Sections 78530-78531

78530. (a) There is hereby created in the account the Central Valley Project Improvement Subaccount.

(b) For the purposes of this article, "subaccount" means the Central Valley Project Improvement Subaccount created by subdivision (a).

78530.5. The sum of ninety-three million dollars ($93,000,000) is hereby transferred from the account to the subaccount for the purpose of implementing this article.

78531. (a) Notwithstanding Section 13340 of the Government Code, the money in the subaccount is hereby continuously appropriated, without regard to fiscal years, to the Controller, to be allocated to pay the state's share of the costs for fish and wildlife restoration measures required by Section 3406 of the Central Valley Project Improvement Act (P.L. 102-575), in accordance with subdivisions (b) and (c).

(b) Funds appropriated pursuant to subdivision (a) shall be allocated to the Department of Fish and Game or the department for expenditure pursuant to the terms of the cost-sharing agreement between the United States and the State of California as required by subsection (h) of Section 3406 of the Central Valley Project Improvement Act, or any agreements supplemental thereto, for the payment of costs allocated to the state for the protection and restoration of fish and wildlife resources and habitat pursuant to Section 3406 of that federal act.

(c) The money in the subaccount may be used for both of the following purposes:

(1) To pay for the state's cost-sharing allocations or for actions directly undertaken by the department or the Department of Fish and Game relating to fish and wildlife restoration actions required by Section 3406 of the Central Valley Project Improvement Act (P.L. 102-575). For purposes of this paragraph, and consistent with Attachment C of the "Principles for Agreement on Bay-Delta standards between the State of California and the Federal Government," dated December 15, 1994, preference for the screening of diversions shall be given to projects, and projects within programs, identified in the Central Valley Project Improvement Act (P.L. 102-575) for which deadlines have been established by state or federal agencies, or by a state or federal court. Any preference established under this paragraph shall be revised if the deadlines are extended or eliminated.

(2) To pay for administrative costs incurred in connection with the implementation of this section by the department and the Department of Fish and Game related to fish and wildlife restoration measures undertaken pursuant to Section 3406 of the Central Valley Project Improvement Act (P.L. 102-575), as follows:

(A) Not more than 3 percent of the total amount deposited in the subaccount for the use of the department may be used to pay the costs incurred in connection with the administration of this article by the department.

(B) Not more than 3 percent of the total amount deposited in the subaccount for the use of the Department of Fish and Game may be used to pay the costs incurred in connection with the administration of this article by the Department of Fish and Game.

Article 3. Bay-Delta Agreement Program, Sections 78535-78538

78535. (a) There is hereby created in the account the Bay-Delta Agreement Subaccount.
(b) For the purposes of this article, "subaccount" means the Bay-Delta Agreement Subaccount created by subdivision (a).

78535.5. The sum of sixty million dollars ($60,000,000) is hereby transferred from the account to the subaccount for the purpose of implementing this article.

78536. Notwithstanding Section 13340 of the Government Code, the money in the subaccount is hereby continuously appropriated, without regard to fiscal years, to the Resources Agency, to pay for the administration of this article and for non-flow-related projects called for in the Water Quality Control Plan for the Bay-Delta, adopted by the board in Resolution No. 95-24, and as it may be amended. Those projects are known as "Category III" activities called for in the "Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government," dated December 15, 1994.

78536.5. The Secretary of the Resources Agency shall carry out this article in accordance with procedures established by CALFED for the purposes of undertaking Category III activities and other ecosystem restoration programs until the Legislature, by statute, authorizes another entity that is recommended by CALFED, to carry out this article.

78537. The state shall, to the greatest extent possible, secure federal and nonfederal matching funds to implement this article.

78538. Not more than 3 percent of the total amount deposited in the subaccount may be used to pay the costs incurred in connection with the administration of this article.

Article 4. Delta Levee Rehabilitation Program, Sections 78540-78545

78540. (a) There is hereby created in the account the Delta Levee Rehabilitation Subaccount.

(b) For the purposes of this article, "subaccount" means the Delta Levee Rehabilitation Subaccount created by subdivision (a).

78540.5. The sum of twenty-five million dollars ($25,000,000) is hereby transferred from the account to the subaccount for the purpose of implementing this article.

78541. Notwithstanding Section 13340 of the Government Code, the money in the subaccount is hereby continuously appropriated, without regard to fiscal years, to the department, as follows:

(a) Twelve million five hundred thousand dollars ($12,500,000) for local assistance under the delta levee maintenance subventions program under Part 9 (commencing with Section 12980) of Division 6, and for the administration of that assistance.

(b) Twelve million five hundred thousand dollars ($12,500,000) for special flood protection projects under Chapter 2 (commencing with Section 12310) of Part 4.8 of Division 6, subsidence studies and monitoring, and for the administration of this subdivision. Allocation of these funds shall be for flood protection projects on Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb Islands, and at other locations in the delta.

78542. The expenditure of funds under this article is subject to Chapter 1.5 (commencing with Section 12306) of Part 4.8 of Division 6.

78543. (a) No expenditure of funds may be made under this article unless the Department of Fish and Game makes a written determination as part of its review and approval of a plan or project pursuant to Section 12314 or 12987 that the proposed expenditures are consistent with a net long-term habitat improvement program, and have a net benefit for aquatic species in the delta. The Department of Fish and Game shall make its determination in a reasonable and timely manner following the submission of the project or plan to that department. For the purposes of this article, an expenditure may include more than one levee project or plan.

(b) The memorandum of understanding entered into pursuant to Section 12307 shall be amended to require, in accordance with this section, that projects or plans be consistent with a net long-term habitat improvement program in the delta. The memorandum of understanding shall define the term "net long-term habitat improvement program in the delta" for purposes of this section. The memorandum of understanding in effect prior to the amendment required by this section shall continue to apply to levee projects and plans until the memorandum of understanding is amended.

78544. For the purposes of this article, a levee project includes levee improvements and related habitat improvements which may be undertaken in the delta at a location other than the location of that levee improvement.

78545. The expenditure of funds under this article shall result in levee rehabilitation improvement projects that, to the greatest extent possible, are consistent with the CALFED program.

Article 5. South Delta Barriers Program, Sections 78550-78552

78550. (a) There is hereby created in the account the South Delta Barriers Subaccount.
(b) For the purposes of this article, "subaccount" means the South Delta Barriers Subaccount created by subdivision (a).

78550.5. The sum of ten million dollars ($10,000,000) is hereby transferred from the account to the subaccount for the purpose of implementing this article.

78551. (a) Notwithstanding Section 13340 of the Government Code, the money in the subaccount is hereby continuously appropriated, without regard to fiscal years, to the department, to pay the costs incurred by the department that are not attributable to the State Water Project's or the Central Valley Project's share of costs for the South Delta Barriers Program, and for the administration of this article.
(b) The costs identified in subdivision (a) include costs incurred for the purpose of mitigating non-State Water Project or non-Central Valley Project impacts and for the purpose of environmental enhancement in the delta.
(c) No funds shall be expended under this article unless the Department of Fish and Game determines, in writing, that a net habitat benefit will result.

78552. Not more than 3 percent of the total amount deposited in the subaccount may be used to pay the costs incurred in connection with the administration of this article.

Article 6. Delta Recreation Program, Sections 78560-78568

78560. (a) There is hereby created in the account the Delta Recreation Subaccount.
(b) For the purposes of this article, "subaccount" means the Delta Recreation Subaccount created by subdivision (a).

78560.5. The sum of two million dollars ($2,000,000) is hereby transferred from the account to the subaccount for the purposes of implementing this article.

78562. Notwithstanding Section 13340 of the Government Code, the money in the subaccount is hereby continuously appropriated, without regard to fiscal years, to the Department of Parks and Recreation to provide for, and improve, public access to, and to maximize public recreational opportunities on, the lands and waters of the delta in a way that is consistent with existing uses of the islands, sound resource conservation principles, and appropriate protection for the rights of private property owners, and for the administration of this article.

78564. The Department of Parks and Recreation may use funds in the subaccount for grants to local public agencies and nonprofit organizations for the purposes of acquiring fee title, development rights, easements, or other interests in land located in the delta to provide for, or improve, public access in the delta. The amount of any grant and the degree of local participation shall be determined by the fiscal resources of the grant applicant, the degree of public benefit provided by the proposed project, and other factors prescribed by the Department of Parks and Recreation.

78565. Any acquisition pursuant to this article shall be from willing sellers.

78566. The Department of Parks and Recreation may adopt regulations to carry out this article.

78568. Not more than 3 percent of the total amount deposited in the subaccount may be used to pay the costs incurred in connection with the administration of this article.

Article 7. CALFED Bay-Delta Program, Sections 78570-78572

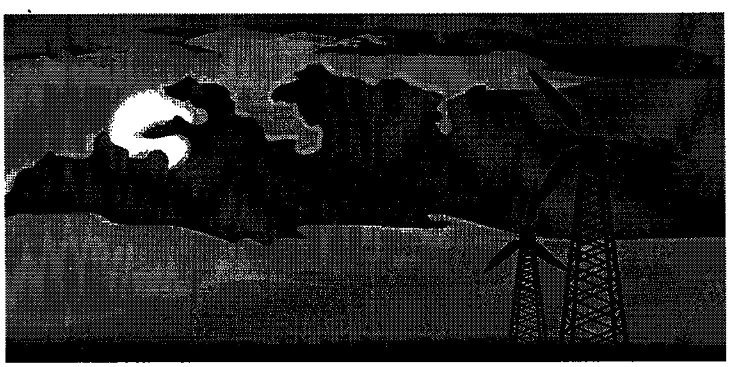
78570. (a) There is hereby created in the account the CALFED Subaccount.
(b) For the purposes of this article, "subaccount" means the CALFED Subaccount created by subdivision (a).

78571. The sum of three million dollars ($3,000,000) is hereby transferred from the account to the subaccount for the purposes of Section 78572.

78572. Notwithstanding Section 13340 of the Government Code, the money in the subaccount is continuously appropriated, without regard to fiscal years, to the department, for the purpose of paying for the state's share of costs incurred in connection with the CALFED Bay-Delta Program.

Appendix D

Special Projects Information Matrix



INTRODUCTION

The information matrix presents attribute data for the reclamation districts within the lowlands of the legal Delta (as defined by Section 12220 of the Water Code). The information matrix, an Excel spreadsheet, is organized by subject or objective. For each subject area, an introductory table lists the sources of information for the attribute data and includes comments on the data set or additional information pertinent to the subject area.

NOTES ON THE ISLANDS AND RECLAMATION DISTRICTS

The information matrix displays island names and reclamation districts with the lowlands of the legal Delta. Because Brannan/Andrus Island, Jones Tract, Roberts Island, and Tyler Island/Walnut Grove include more than one reclamation district, information is presented for each reclamation district wherever possible. Where information is available for the entire island only, the cumulative information for the island is presented under the complete island name (e.g., Jones Tract), and a "-" is included in the column for the individual reclamation districts (e.g., Lower Jones RD 2038).

Three islands do not have a reclamation district number. The Bethel Island reclamation district is the Bethel Island Municipal Improvement District. Shim Kee Tract and Rough & Ready Island levees are managed and maintained privately by the independent landowner.

Information for Winters Island is not complete for many attributes. A member of the Levee and Channel Technical Team recommended that Winter Island - RD2122, located south of Collinsville and immediately east of Browns Island, be included in the study area. The island has been included in the information spreadsheet but little attribute data has been compiled to complete the matrix information on this small west Delta island.

Instances where no data was available for an island or reclamation district are indicated by "N/D".

ISLAND ACREAGE AND LEVEE MILEAGE

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
Island size	California Department of Water Resources. 1994. Land use mapping program. Sacramento, CA. (DWR Land use mapping data)
Length of project levees	California Department of Water Resources. 1993. Sacramento-San Joaquin Delta atlas. Sacramento, CA. (DWR Delta atlas)
Length of nonproject levees	DWR Delta atlas The data for levee lengths is taken from both the Delta Atlas and GIS coverage produced by Jones & Stokes Associates.

		Island Acres & Levee Miles		
ISLAND	Reclamation District	Island Size (Acres)	Flood-Control Levees, federal (Miles)	Flood-Control Levees, local (Miles)
Bacon Island	2028	5589	0	14.3
Bethel Island	-	3532	0	11.5
Bishop Tract	2042	2975	0	5.8
Boggs (Moss Tract)	404	3211	4	1.2
Bouldin Island	756	6020	0	18.0
Brack Tract	2033	4621	0	10.8
Bradford Island	2059	2183	0	7.4
Brannan/Andrus Island	-	15383	30.5	10.6
Andrus	317	3606		
Andrus, Isleton	407	1648		
Andrus, Upper	556	2351		
Brannan	2067	7778		
Byron Tract	800	6249	0	9.7
Canal Ranch	2086	3213	0	7.5
Coney Island	2117	998	0	5.4
Dead Horse Island	2111	225	0	2.6
Empire Tract	2029	3688	0	10.5
Fabian Tract	773	6725	0	18.8
Fay	2113	99	0	1.6
Glanville Tract	1002	6994	0	13.0
Grand Island	3	16892	29.0	0.0
Hastings Tract	2060	4519	16.0	0.0
Holland Tract	2025	4254	0	10.9
Holt Station	2116	197	0	0.4
Hotchkiss Tract	799	3621	0	6.3
Jersey Island	830	3571	0	15.6
Jones Tract	-			
Jones, Lower	2038	5743	0	8.8
Jones, Upper	2039	6501	0	9.3
King Island	2044	3256	0	9.0
Little Mandeville	2118	360	0	4.5
Mandeville Island	2027	5266	0	14.3
McCormack Williamson Tract	2110	2139	0	8.8
McDonald Island	2030	6058	0	13.7
Medford Island	2041	1205	0	5.9
Merritt Island	150	4901	18.1	0.0
Mildred Island	2021	1001	0	7.3
Naglee Burke	1007	5917	0	8.3
New Hope Tract	348	9798	0	18.6
Orwood Island	2024	2431	0	10.9
Palm Tract	2036	2505	0	7.5
Pescadero	2058	9004	6.7	2.2
Pierson District	551	9427	8.4	7.0
Prospect Island	1667	2275	2.9	7.1
Quimby Island	2090	809	0	7.0
Rindge Tract	2037	6840	0	15.7
Rio Blanco Tract	2114	959	0	4.0
Roberts Island	-	36189		
Roberts, Lower	684	10819	0.0	16.0
Roberts, Middle	524	12839	6.1	3.7
Roberts, Upper	544	8248	10.6	4.4
Rough and Ready Island	-	1461	0	6.7
Ryer Island	501	11955	20.6	0.0
Sargent Barnhart Tract	2074	1051	1.5	2.8
Sherman Island	341	11321	9.7	9.8
Shima Tract	2115	1848	0	6.6
Shin Kee Tract	-	960	0	3.9
Smith	1614	2163	6	2.8
Stark	2089	742	2.8	0.7
Staten Island	38	9229	0	25.4
Stewart Tract	2062	5364	12.3	0.0
Sutter Island	349	2619	12.5	0.0
Terminous	548	12187	0	16.1
Twitchell	1601	3648	2.5	9.3
Tyler Island	563	9453	12.2	10.7
Walnut Grove	554	459	1	1.2
Union Island	-	25016	1.0	29.2
Van Sickle Island	1607	2193	0	3.8
Veale Tract	2065	1499	0	5.7
Venice Island	2023	3159	0	12.3
Victoria Island	2040	7266	0	15.1
Webb Tract	2026	5507	0	12.8
Weber	828	1149	0	1.2
Winter Island	2122	482	0	4.8
Woodward Island	2072	1859	0	8.8
Wright-Elmwood Tract	2119	2134	0	6.8
-	307	6016.9	7.8	5.2
-	369	532.3	1	0.7
-	536	6389.7	14	0
-	765	1348.8	1.7	4
-	813	2537.5	2	6
-	900	10832.3	12	1.3
-	999	25775.7	27	5.8
-	1608	906.1	0	4
-	2084	3170.4	0	7
-	2093	5031.3	0	20.5
-	2095	5552.1	4	0
-	2098	6033.7	18.5	0
-	2121	527.9	0	2.3

LIFE AND PERSONAL PROPERTY

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
Permanent population (1990)	DWR Delta atlas
Towns	DWR Delta atlas
Housing units	DWR Delta atlas
Residential lands	DWR Land use mapping data Residential lands include farmsteads (see Agricultural data). In some cases, residential lands = 0 yet housing units are shown (see for example, Victoria Island). This is probably because some housing units are located on lands that are not considered 'residential". Specifically, agricultural farmworker housing is often located on lands categorized as "incidental agricultural lands" or a specific crop rather than farmsteads or residential lands.

		Life and Property			
ISLAND	Reclamation District	Permanent Population (1990)	Towns	Housing Units	Residential Lands (Acres)
Bacon Island	2028	260		39	35.7
Bethel Island	-	2115		1257	133.8
Bishop Tract	2042	52		23	16.6
Boggs (Moss Tract)	404	N/D		N/D	3.7
Bouldin Island	756	74		19	17.5
Brack Tract	2033	80		22	18.5
Bradford Island	2059	0		0	43.4
Brannan/Andrus Island	-	2093	-	1014	-
Andrus	317	-		-	167.6
Andrus, Isleton	407	-	Isleton	-	57.4
Andrus, Upper	556	-		-	36.0
Brannan	2067	-		-	38.9
Byron Tract	800	6336	Byron, Disco Bay	2964	12.2
Canal Ranch	2086	103		30	10.7
Coney Island	2117	0		0	2.8
Dead Horse Island	2111	39		23	0.0
Empire Tract	2029	5		3	10.8
Fabian Tract	773	130		28	45.9
Fay	2113	N/D		N/D	0.0
Glanville Tract	1002	N/D		N/D	24.6
Grand Island	3	1021	Ryde	411	193.8
Hastings Tract	2060	94	Hastings	22	17.6
Holland Tract	2025	35		28	14.1
Holt Station	2116	N/D		N/D	8.0
Hotchkiss Tract	799	847		373	122.8
Jersey Island	830	13		3	8.7
Jones Tract	-	-	-	-	-
Jones, Lower	2038	112		14	30.2
Jones, Upper	2039	46		8	57.0
King Island	2044	195		94	4.2
Little Mandeville	2118	N/D		N/D	0.0
Mandeville Island	2027	118		5	29.9
McCormack Williamson Tr	2110	0		0	2.5
McDonald Island	2030	95		0	73.2
Medford Island	2041	14		9	0.0
Merritt Island	150	238		97	68.7
Mildred Island	2021	0		0	0.0
Naglee Burke	1007	24		5	0.0
New Hope Tract	348	1376	Thornton	501	124.3
Orwood Island	2024	98		22	31.3
Palm Tract	2036	16		5	3.2
Pescadero	2058	54		19	164.2
Pierson District	551	355	Courtland	140	146.1
Prospect Island	1667	N/D		N/D	3.1
Quimby Island	2090	N/D		N/D	0.0
Rindge Tract	2037	33		29	31.6
Rio Blanco Tract	2114	10		5	7.4
Roberts Island	-	-	-	-	-
Roberts, Lower	684	221		88	113.6
Roberts, Middle	524	435		95	114.4
Roberts, Upper	544	231		75	91.2
Rough and Ready Island	-	174		43	0.0
Ryer Island	501	246		98	83.6
Sargent Barnhart Tract	2074	1902		806	0.0
Sherman Island	341	233		105	46.7
Shima Tract	2115	101		N/D	6.2
Shin Kee Tract	-	8		3	0.0
Smith	1614	N/D		N/D	0.0
Stark	2089	N/D		N/D	3.2
Staten Island	38	35		13	16.6
Stewart Tract	2062	213		104	29.5
Sutter Island	349	173		48	31.9
Terminous	548	602	Terminous	279	52.5
Twitchell	1601	87		41	15.4
Tyler Island	563	644		286	40.0
Walnut Grove	554	-	Walnut Grove	-	-
Union Island	1,2	779		144	151.6
Van Sickle Island	1607	0		0	0.0
Veale Tract	2065	4		2	0.0
Venice Island	2023	0		0	4.1
Victoria Island	2040	155		6	10.8
Webb Tract	2026	0		0	24.1
Weber	828	N/D		N/D	0.0
Winter Island	2122	0		N/D	0.0
Woodward Island	2072	6		1	4.6
Wright-Elmwood Tract	2119	31		0	20.3
-	307	N/D		N/D	33.9
-	369	N/D	Locke	N/D	4.1
-	536	N/D		N/D	53.9
-	765	N/D		N/D	5.5
-	813	N/D		N/D	15.4
-	900	N/D		N/D	130.7
-	999	303	Clarksburg	11652	375.6
-	1608	N/D		N/D	0.0
-	2084	N/D		N/D	0.0
-	2093	N/D		N/D	220.6
-	2095	N/D		N/D	43.5
-	2098	N/D		N/D	38.8
-	2121	N/D		N/D	2.9

AGRICULTURAL PRODUCTION

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
Total agricultural lands	DWR Land use mapping data Includes grain and hay crops, field crops, truck and berry crops, pasture, rice, idle agricultural area, deciduous fruits and nuts, vineyards, and semiagricultural and incidental to agricultural area. Farmstead lands, shown here, are included in the "residential" land category.
Value of damageable crops	DWR Land use mapping data and California Department of Food and Agriculture. 1996. County Agriculture Commissioner's Reports for 1995. Sacramento, CA. Value is determined by crop acreages multiplied by the average values for each major agricultural classification. Crop values are based on 1995 production value information for Sacramento, San Joaquin, Contra Costa, Yolo, and Solano counties. In some instances, value of crops is $0 although agricultural acres are shown. This is the result of those lands being categorized as idle, semiagricultural and incidental to agricultural, or farmsteads which are not included in the value of damageable crops analysis.

Agricultural Production

Crop Acreages and Values

ISLAND	Reclamation District	Grain & Hay Crops (Acres)	Field Crops (Acres)	Truck & Berry Crops (Acres)	Pasture (Acres)	Rice (Acres)	Subtropical Fruits (Acres)	Deciduous Fruits & Nuts (Acres)	Vineyards (Acres)	Idle (Acres)	Semiagricultural & Incidental to Agriculture w/farms(Acres)	Farmsteads (Acres)	Semiagricultural & Incidental to Agriculture (Acres)	Total Agricultural (Acres)	Total Value ($1,000)
Bacon Island	2028	0.0	2148.9	2905.8	0.0	0.0	0.0	0.0	56.7	29.0	35.7	35.7	0.0	5140.4	$10,968
Bethel Island	-	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.0	2484.8	136.5	14.8	121.7	2614.2	$4
Bishop Tract	2042	523.6	293.9	191.8	1730.8	0.0	0.0	0.0	0.0	0.0	50.1	16.6	33.5	2773.6	$1,815
Boggs (Moss Tract)	404	0.0	0.0	0.0	78.1	0.0	0.0	0.0	0.0	0.0	152.3	3.7	148.6	226.7	$37
Bouldin Island	756	1982.9	3393.1	0.0	0.0	0.0	0.0	0.0	0.0	4.1	17.5	17.5	0.0	5380.1	$2,826
Brack Tract	2033	607.2	2182.4	404.8	567.3	0.0	0.0	2.7	472.3	145.5	18.5	18.5	0.0	4382.2	$4,429
Bradford Island	2059	0.0	0.0	0.0	636.7	0.0	0.0	0.0	0.0	1286.2	8.6	8.5	0.1	1923.0	$306
Brannan/Andrus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Andrus	317	440.3	2741.1	0.0	0.0	0.0	0.0	0.0	0.0	34.1	1.6	1.6	0.0	3215.5	$1,900
Andrus, Isleton	407	406.9	713.7	0.0	0.0	0.0	0.0	122.7	20.6	3.4	8.8	8.8	0.0	1267.3	$964
Andrus, Upper	556	534.7	704.3	233.7	217.5	0.0	0.0	426.6	0.0	0.0	28.4	28.4	0.0	2116.8	$2,600
Brannan	2067	1528.4	5104.4	25.3	62.9	0.0	0.0	164.5	102.5	43.4	36.3	0.0	36.3	7067.7	$4,580
Byron Tract	800	802.9	731.0	1204.2	1103.9	0.0	0.0	0.0	0.0	119.9	12.2	12.2	0.0	3961.9	$5,176
Canal Ranch	2086	476.6	1891.8	419.8	167.1	0.0	0.0	0.0	34.7	0.0	10.7	10.7	0.0	2990.0	$2,904
Coney Island	2117	347.9	526.1	30.9	0.0	0.0	0.0	0.0	0.0	0.0	2.8	2.8	0.0	904.9	$552
Dead Horse Island	2111	0.0	0.0	190.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	190.1	$618
Empire Tract	2029	1343.9	1979.7	122.6	0.0	0.0	0.0	0.0	0.0	0.0	10.8	10.8	0.0	3446.2	$2,109
Fabian Tract	773	260.8	743.0	2972.9	2240.0	0.0	0.0	52.7	0.0	36.8	34.5	34.5	0.0	6306.2	$11,438
Fay	2113	0.0	63.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.9	$41
Glanville Tract	1002	931.1	2346.5	534.9	2108.9	0.0	0.0	131.4	309.8	0.0	63.8	24.6	39.2	6401.8	$5,713
Grand Island	3	4576.2	6465.5	1820.4	1047.9	0.0	0.0	1903.1	0.0	0.0	177.7	174.1	3.6	15816.7	$17,015
Hastings Tract	2060	291.8	1584.3	517.1	1970.8	0.0	0.0	0.0	28.5	1388.6	21.4	17.6	3.8	5784.9	$3,811
Holland Tract	2025	2923.7	62.7	0.0	303.9	0.0	0.0	0.0	0.0	481.2	14.1	14.1	0.0	3771.5	$1,151
Holt Station	2116	96.5	17.1	0.0	18.7	0.0	0.0	0.0	0.0	37.3	8.0	8.0	0.0	169.6	$52
Hotchkiss Tract	799	179.9	8.6	1.0	1709.4	0.0	0.0	54.7	0.0	476.4	60.5	32.9	27.6	2457.6	$1,031
Jersey Island	830	0.0	0.0	0.0	2803.0	0.0	0.0	0.0	0.0	16.2	8.7	8.7	0.0	2819.2	$1,345
Jones Tract	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jones, Lower	2038	1752.9	929.2	2568.7	0.0	0.0	0.0	0.0	0.0	266.2	30.2	30.2	0.0	5517.0	$9,521
Jones, Upper	2039	1103.5	3140.5	3688.4	1810.1	0.0	0.0	0.0	0.0	18.0	57.0	57.0	0.0	9760.6	$15,230
King Island	2044	1888.7	689.7	511.4	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2	0.0	3089.8	$2,727
Little Mandeville	2118	0.0	269.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	269.2	$172
Mandeville Island	2027	400.3	2634.9	1015.2	5.8	0.0	31.8	1.1	464.0	46.8	28.6	28.5	0.1	4600.0	$6,422
McCormack Williamson Tr	2110	180.7	1271.5	275.9	0.0	0.0	0.0	0.0	0.0	65.9	2.5	2.5	0.0	1794.0	$1,770
McDonald Island	2030	911.8	1000.9	2369.8	559.4	0.0	0.0	0.0	0.0	533.8	73.2	73.2	0.0	5395.7	$8,977
Medford Island	2041	134.2	942.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1077.0	$648
Merritt Island	150	839.2	845.1	776.9	547.3	0.0	0.0	380.1	1092.2	24.7	68.7	68.6	0.1	4505.6	$7,455
Mildred Island	2021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
Naglee Burke	1007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
New Hope Tract	348	1646.1	3333.5	2050.2	390.2	0.0	0.0	279.9	1174.2	0.8	124.1	108.8	15.3	8890.2	$13,331
Orwood Island	2024	172.2	438.1	1146.8	381.2	0.0	0.0	0.0	0.0	31.6	31.3	31.3	0.0	2169.9	$4,247
Palm Tract	2036	1308.6	573.8	15.1	292.2	0.0	0.0	0.0	0.0	81.3	3.2	3.2	0.0	2271.0	$988
Pescadero	2058	118.4	1868.1	1778.7	3511.6	0.0	0.0	247.8	0.0	99.9	216.1	117.3	98.8	7723.3	$9,345
Pierson District	551	871.2	2535.6	0.0	332.1	0.0	0.0	1840.4	1002.2	312.1	146.1	146.1	0.0	6893.6	$9,480
Prospect Island	1667	388.9	489.2	226.9	0.0	0.0	0.0	0.0	0.0	7.4	3.1	3.1	0.0	1112.4	$1,179
Quimby Island	2090	303.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	295.4	0.0	0.0	0.0	598.6	$100
Rindge Tract	2037	710.9	4532.4	1024.6	19.3	0.0	0.0	0.0	0.0	132.4	31.6	31.6	0.0	6419.6	$6,475
Rio Blanco Tract	2114	351.1	126.1	0.0	326.4	0.0	0.0	0.0	0.0	0.0	7.4	7.4	0.0	803.6	$353
Roberts Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Roberts, Lower	684	2829.2	2791.8	3134.8	1268.3	0.0	0.0	14.1	0.0	202.8	113.6	113.6	0.0	10241.0	$13,554
Roberts, Middle	524	1083.7	3675.9	2958.5	3902.6	0.0	0.0	31.9	0.0	33.2	142.5	114.4	28.1	11713.9	$14,282
Roberts, Upper	544	1712.9	2012.2	957.8	2882.8	0.0	0.0	228.0	121.8	20.2	91.2	91.2	0.0	7935.7	$7,282
Rough and Ready Island	-	357.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	357.9	$118
Ryer Island	501	3252.4	3868.4	2122.4	1163.6	0.0	19.8	418.7	536.6	22.4	79.3	79.3	0.0	11404.3	$13,551
Sargent Barnhart Tract	2074	129.5	25.6	0.0	147.2	0.0	0.0	0.0	0.0	79.8	0.0	0.0	0.0	382.1	$130
Sherman Island	341	1731.2	6581.4	462.5	379.6	0.0	0.0	0.0	0.0	645.6	46.7	46.7	0.0	9800.3	$6,469
Shima Tract	2115	263.9	178.0	266.2	783.9	0.0	0.0	208.8	0.0	8.1	6.2	6.2	0.0	1708.9	$1,985
Shin Kee Tract	-	283.6	321.6	147.9	180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	933.1	$666
Smith	1614	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	130.4	0.0	130.4	130.4	$0
Stark	2089	129.8	209.7	0.9	308.1	0.0	0.0	0.0	0.0	0.0	3.2	3.2	0.0	648.5	$328
Staten Island	38	3201.3	5196.6	336.8	0.0	18.2	0.0	0.0	0.0	0.0	16.6	16.6	0.0	8752.9	$5,494
Stewart Tract	2062	760.5	355.4	1288.3	2223.4	0.0	0.0	153.3	0.0	0.0	22.9	22.9	0.0	4780.9	$6,131
Sutter Island	349	180.4	453.8	284.3	166.9	0.0	12.6	1078.8	152.9	0.9	31.9	31.9	0.0	2330.6	$4,592
Terminous	548	3532.2	5618.9	331.4	1345.1	0.0	0.0	0.0	190.6	205.7	90.7	52.5	38.2	11262.1	$6,984
Twitchell	1601	188.9	2567.1	242.2	319.9	0.0	0.0	0.0	0.0	24.7	15.4	15.4	0.0	3342.8	$2,646
Tyler Island	563	2671.7	4916.8	198.8	350.9	0.0	0.0	274.5	0.0	4.9	39.9	39.9	0.0	8419.6	$5,558
Walnut Grove	554	137.8	0.1	0.0	179.2	0.0	0.0	0.0	0.0	3.8	4.4	0.1	4.3	325.2	$132
Union Island	-	1099.2	9100.7	5025.9	8372.9	0.0	0.0	512.9	0.0	45.8	151.6	151.6	0.0	24157.4	$27,874
Van Sickle Island	1607	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
Veale Tract	2065	926.2	0.0	0.0	73.7	0.0	0.0	0.0	0.0	311.5	0.0	0.0	0.0	1311.4	$341
Venice Island	2023	1145.4	1568.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	4.1	0.0	2713.7	$1,382
Victoria Island	2040	1316.9	933.9	3235.9	1400.9	0.0	0.0	0.0	0.0	0.0	10.8	10.8	0.0	6887.6	$12,221
Webb Tract	2026	1332.8	3461.6	0.0	0.0	0.0	0.0	0.0	0.0	45.9	24.1	24.1	0.0	4840.3	$2,655
Weber	828	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
Winter Island	2122	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
Woodward Island	2072	898.1	0.0	748.6	0.0	0.0	0.0	0.0	0.0	40.1	4.6	4.6	0.0	1686.8	$2,729
Wright-Elmwood Tract	2119	1238.1	601.3	143.7	0.0	0.0	0.0	0.0	0.0	0.0	20.3	20.3	0.0	1983.1	$1,260
-	307	882.7	2315.3	1091.9	1049.0	0.0	18.8	21.0	201.9	23.1	33.9	33.9	0.0	5603.7	$6,458
-	369	0.0	0.0	0.0	59.3	0.0	0.0	89.2	0.0	0.6	4.2	4.1	0.1	149.2	$260
-	536	476.6	1640.4	0.0	1159.7	0.0	0.0	0.0	0.0	1489.6	42.0	42.0	0.0	4766.3	$1,764
-	765	227.7	201.0	365.6	390.1	0.0	0.0	0.0	0.0	0.0	5.5	5.5	0.0	1184.4	$1,579
-	813	113.8	714.8	336.3	204.9	0.0	0.0	166.7	787.6	25.1	15.4	15.4	0.0	2349.2	$4,183
-	900	1183.8	2802.9	256.7	603.1	0.0	0.0	93.7	50.3	426.0	193.7	130.7	63.0	5479.5	$3,684
-	999	5976.1	8191.2	4199.2	4442.3	0.0	0.0	74.4	711.9	387.6	375.6	375.6	0.0	23982.7	$25,053
-	1608	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.1	0.0	30.1	30.1	$0
-	2084	3.5	1766.6	283.3	559.7	0.0	0.0	0.0	0.0	289.2	0.0	0.0	0.0	2902.3	$2,321
-	2093	2533.1	1230.1	264.5	0.0	0.0	0.0	0.0	0.0	24.9	220.6	220.6	0.0	4052.6	$2,483
-	2095	280.9	1413.5	1236.6	1832.5	0.0	0.0	36.7	0.0	39.3	62.5	31.4	31.1	4870.3	$5,991
-	2098	985.2	498.8	581.7	1801.8	0.0	0.0	0.0	0.0	666.9	53.0	38.8	14.2	4548.6	$3,400
-	2121	261.9	0.0	1.7	0.0	0.0	0.0	0.0	0.0	233.9	2.9	2.9	0.0	497.5	$92
CROP VALUES	($/ACRE)	$330	$640	$3,250	$480	$930	$2,600	$2,600	$2,620	$0		-	$0		

Agricultural Production

Crop Acreages and Values

ISLAND	Reclamation District	Grain & Hay Crops (Acres)	Field Crops (Acres)	Truck & Berry Crops (Acres)	Pasture (Acres)	Rice (Acres)	Subtropical Fruits (Acres)	Deciduous Fruits & Nuts (Acres)	Vineyards (Acres)	Idle (Acres)	Semiagricultural & Incidental to Agriculture w/farms(Acres)	Farmsteads (Acres)	Semiagricultural & Incidental to Agriculture (Acres)	Total Agricultural (Acres)	Total Value ($1,000)
Bacon Island	2028	0.0	2148.9	2905.8	0.0	0.0	0.0	0.0	56.7	29.0	35.7	35.7	0.0	5140.4	$10.968
Bethel Island	-	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.0	2484.8	136.5	14.8	121.7	2614.2	$4
Bishop Tract	2042	523.6	293.9	191.8	1730.8	0.0	0.0	0.0	0.0	0.0	50.1	16.6	33.5	2773.6	$1,815
Boggs (Moss Tract)	404	0.0	0.0	0.0	78.1	0.0	0.0	0.0	0.0	0.0	152.3	3.7	148.6	226.7	$37
Bouldin Island	756	1982.9	3393.1	0.0	0.0	0.0	0.0	0.0	0.0	4.1	17.5	17.5	0.0	5380.1	$2,826
Brack Tract	2033	607.2	2182.4	404.8	567.3	0.0	0.0	2.7	472.3	145.5	18.5	18.5	0.0	4382.2	$4,429
Bradford Island	2059	0.0	0.0	0.0	636.7	0.0	0.0	0.0	0.0	1286.2	8.6	8.5	0.1	1923.0	$306
Brannan/Andrus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Andrus	317	440.3	2741.1	0.0	0.0	0.0	0.0	0.0	0.0	34.1	1.6	1.6	0.0	3215.5	$1,900
Andrus, Isleton	407	406.9	713.7	0.0	0.0	0.0	0.0	122.7	20.6	3.4	8.8	8.8	0.0	1267.3	$964
Andrus, Upper	556	534.7	704.3	233.7	217.5	0.0	0.0	426.6	0.0	0.0	28.4	28.4	0.0	2116.8	$2,600
Brannan	2067	1528.4	5104.4	25.3	62.9	0.0	0.0	164.5	102.5	43.4	36.3	0.0	36.3	7067.7	$4,580
Byron Tract	800	802.9	731.0	1204.2	1103.9	0.0	0.0	0.0	0.0	119.9	12.2	12.2	0.0	3961.9	$5,176
Canal Ranch	2086	476.6	1891.8	419.8	167.1	0.0	0.0	0.0	34.7	0.0	10.7	10.7	0.0	2990.0	$2,904
Coney Island	2117	347.9	526.1	30.9	0.0	0.0	0.0	0.0	0.0	0.0	2.8	2.8	0.0	904.9	$552
Dead Horse Island	2111	0.0	0.0	190.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	190.1	$618
Empire Tract	2029	1343.9	1979.7	122.6	0.0	0.0	0.0	0.0	0.0	0.0	10.8	10.8	0.0	3446.2	$2,109
Fabian Tract	773	260.8	743.0	2972.9	2240.0	0.0	0.0	52.7	0.0	36.8	34.5	34.5	0.0	6306.2	$11,436
Fay	2113	0.0	63.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.9	$41
Glanville Tract	1002	931.1	2346.5	534.9	2108.9	0.0	0.0	131.4	309.8	0.0	63.8	24.6	39.2	6401.8	$5,713
Grand Island	3	4576.2	6465.5	1820.4	1047.9	0.0	0.0	1903.1	0.0	0.0	177.7	174.1	3.6	15816.7	$17,015
Hastings Tract	2060	291.8	1584.3	517.1	1970.8	0.0	0.0	0.0	28.5	1388.6	21.4	17.6	3.8	5784.9	$3,811
Holland Tract	2025	2923.7	62.7	0.0	303.9	0.0	0.0	0.0	0.0	481.2	14.1	14.1	0.0	3771.5	$1,151
Holt Station	2116	96.5	17.1	0.0	18.7	0.0	0.0	0.0	0.0	37.3	8.0	8.0	0.0	169.6	$52
Hotchkiss Tract	799	179.9	8.6	1.0	1709.4	0.0	0.0	54.7	0.0	476.4	60.5	32.9	27.6	2457.6	$1,031
Jersey Island	830	0.0	0.0	0.0	2803.0	0.0	0.0	0.0	0.0	16.2	8.7	8.7	0.0	2819.2	$1,345
Jones Tract	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jones, Lower	2038	1752.9	929.2	2568.7	0.0	0.0	0.0	0.0	0.0	266.2	30.2	30.2	0.0	5517.0	$9,521
Jones, Upper	2039	1103.5	3140.5	3688.4	1810.1	0.0	0.0	0.0	0.0	18.0	57.0	57.0	0.0	9760.6	$15,230
King Island	2044	1888.7	689.7	511.4	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2	0.0	3089.8	$2,727
Little Mandeville	2118	0.0	269.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	269.2	$172
Mandeville Island	2027	400.3	2634.9	1015.2	5.8	0.0	31.8	1.1	464.0	46.8	28.6	28.5	0.1	4600.0	$6,422
McCormack Williamson Tr	2110	180.7	1271.5	275.9	0.0	0.0	0.0	0.0	0.0	65.9	2.5	2.5	0.0	1794.0	$1,770
McDonald Island	2030	911.8	1000.9	2389.8	559.4	0.0	0.0	0.0	0.0	533.8	73.2	73.2	0.0	5395.7	$8,977
Medford Island	2041	134.2	942.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1077.0	$648
Merritt Island	150	839.2	845.1	776.9	547.3	0.0	0.0	380.1	1092.2	24.7	68.7	68.6	0.1	4505.6	$7,455
Mildred Island	2021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
Naglee Burke	1007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
New Hope Tract	348	1646.1	3333.5	2050.2	390.2	0.0	0.0	279.9	1174.2	0.8	124.1	108.8	15.3	8890.2	$13,331
Orwood Island	2024	172.2	438.1	1146.8	381.2	0.0	0.0	0.0	0.0	31.6	31.3	31.3	0.0	2169.9	$4,247
Palm Tract	2036	1308.6	573.8	15.1	292.2	0.0	0.0	0.0	0.0	81.3	3.2	3.2	0.0	2271.0	$988
Pescadero	2058	118.4	1868.1	1778.7	3511.6	0.0	0.0	247.8	0.0	89.9	216.1	117.3	98.8	7723.3	$9,345
Pierson District	551	871.2	2535.6	0.0	332.1	0.0	0.0	1840.4	1002.2	312.1	146.1	146.1	0.0	6893.6	$9,480
Prospect Island	1667	388.9	489.2	226.9	0.0	0.0	0.0	0.0	0.0	7.4	3.1	3.1	0.0	1112.4	$1,179
Quimby Island	2090	303.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	295.4	0.0	0.0	0.0	598.6	$100
Rindge Tract	2037	710.9	4532.4	1024.6	19.3	0.0	0.0	0.0	0.0	132.4	31.6	31.6	0.0	6419.6	$6,475
Rio Blanco Tract	2114	351.1	126.1	0.0	326.4	0.0	0.0	0.0	0.0	0.0	7.4	7.4	0.0	803.6	$353
Roberts Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Roberts, Lower	684	2829.2	2791.8	3134.8	1268.3	0.0	0.0	14.1	0.0	202.8	113.6	113.6	0.0	10241.0	$13,554
Roberts, Middle	524	1083.7	3675.9	2958.5	3902.6	0.0	0.0	31.9	0.0	33.2	142.5	114.4	28.1	11713.9	$14,282
Roberts, Upper	544	1712.9	2012.2	957.8	2882.8	0.0	0.0	228.0	121.8	20.2	91.2	91.2	0.0	7935.7	$7,262
Rough and Ready Island	-	357.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	357.9	$118
Ryer Island	501	3252.4	3868.4	2122.4	1163.6	0.0	19.8	418.7	536.6	22.4	79.3	79.3	0.0	11404.3	$13,551
Sargent Barnhart Tract	2074	129.5	25.6	0.0	147.2	0.0	0.0	0.0	0.0	79.8	0.0	U.0	0.0	382.1	$130
Sherman Island	341	1731.2	6581.4	462.5	379.6	0.0	0.0	0.0	0.0	645.6	46.7	46.7	0.0	9800.3	$6,469
Shima Tract	2115	263.9	178.0	266.2	783.9	0.0	0.0	208.8	0.0	8.1	6.2	6.2	0.0	1708.9	$1,985
Shin Kee Tract	-	283.6	321.6	147.9	180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	933.1	$866
Smith	1614	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	130.4	0.0	130.4	130.4	$0
Stark	2089	129.8	209.7	0.9	308.1	0.0	0.0	0.0	0.0	0.0	3.2	3.2	0.0	648.5	$328
Staten Island	38	3201.3	5196.6	336.8	0.0	18.2	0.0	0.0	0.0	0.0	16.6	16.6	0.0	8752.9	$5,494
Stewart Tract	2062	760.5	355.4	1288.3	2223.4	0.0	0.0	153.3	0.0	0.0	22.9	22.9	0.0	4780.9	$8,131
Sutter Island	349	180.4	453.8	284.3	166.9	0.0	12.6	1078.8	152.9	0.9	31.9	31.9	0.0	2330.6	$4,592
Terminous	548	3532.2	5618.9	331.4	1345.1	0.0	0.0	0.0	190.6	205.7	90.7	52.5	38.2	11262.1	$6,984
Twitchell	1601	188.9	2567.1	242.2	319.9	0.0	0.0	0.0	0.0	24.7	15.4	15.4	0.0	3342.8	$2,646
Tyler Island	563	2671.7	4918.8	198.8	350.9	0.0	0.0	274.5	0.0	4.9	39.9	39.9	0.0	8419.6	$5,558
Walnut Grove	554	137.8	0.1	0.0	179.2	0.0	0.0	0.0	0.0	3.8	4.4	0.1	4.3	325.2	$132
Union Island	-	1099.2	9100.7	5025.9	8372.9	0.0	0.0	512.9	0.0	45.8	151.6	151.6	0.0	24157.4	$27,874
Van Sickle Island	1607	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
Veale Tract	2065	926.2	0.0	0.0	73.7	0.0	0.0	0.0	0.0	311.5	0.0	0.0	0.0	1311.4	$341
Venice Island	2023	1145.4	1568.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	4.1	0.0	2713.7	$1,382
Victoria Island	2040	1316.9	933.9	3235.9	1400.9	0.0	0.0	0.0	0.0	0.0	10.8	10.8	0.0	6887.6	$12,221
Webb Tract	2026	1332.8	3461.6	0.0	0.0	0.0	0.0	0.0	0.0	45.9	24.1	24.1	0.0	4840.3	$2,655
Weber	828	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
Winter Island	2122	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
Woodward Island	2072	898.1	0.0	748.6	0.0	0.0	0.0	0.0	0.0	40.1	4.6	4.6	0.0	1686.8	$2,729
Wright-Elmwood Tract	2119	1238.1	601.3	143.7	0.0	0.0	0.0	0.0	0.0	0.0	20.3	20.3	0.0	1983.1	$1,260
-	307	882.7	2315.3	1091.9	1049.0	0.0	18.8	21.0	201.9	23.1	33.9	33.9	0.0	5603.7	$6,458
-	369	0.0	0.0	0.0	59.3	0.0	0.0	89.2	0.0	0.6	4.2	4.1	0.1	149.2	$260
-	536	476.6	1640.4	0.0	1159.7	0.0	0.0	0.0	0.0	1489.6	42.0	42.0	0.0	4766.3	$1,764
-	765	227.7	201.0	365.6	390.1	0.0	0.0	0.0	0.0	0.0	5.5	5.5	0.0	1184.4	$1,579
-	813	113.8	714.8	336.3	204.9	0.0	0.0	166.7	787.6	25.1	15.4	15.4	0.0	2349.2	$4,183
-	900	1183.8	2802.9	256.7	603.1	0.0	0.0	93.7	50.3	426.0	193.7	130.7	63.0	5479.5	$3,684
-	999	5976.1	8191.2	4199.2	4442.3	0.0	0.0	74.4	711.9	387.6	375.6	375.6	0.0	23982.7	$25,053
-	1608	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.1	0.0	30.1	30.1	$0
-	2084	3.5	1766.6	283.3	559.7	0.0	0.0	0.0	0.0	289.2	0.0	0.0	0.0	2902.3	$2,321
-	2093	2533.1	1230.1	264.5	0.0	0.0	0.0	0.0	0.0	24.9	220.6	220.6	0.0	4052.6	$2,483
-	2095	280.6	1413.5	1236.6	1832.5	0.0	0.0	36.7	0.0	39.3	62.5	31.4	31.1	4870.3	$5,991
-	2098	985.2	498.8	581.7	1801.8	0.0	0.0	0.0	0.0	666.9	53.0	38.8	14.2	4548.6	$3,400
-	2121	261.9	0.0	1.7	0.0	0.0	0.0	0.0	0.0	233.9	2.9	2.9	u.u	497.5	$92
CROP VALUES	($/ACRE)	$330	$640	$3,250	$480	$930	$2,600	$2,600	$2,620	$0		--	$0		

WATER QUALITY

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
Long-term salinity intrusion induced	Enright, Chris. n.d. Western Delta Island Flood Assumptions - DWRDSM Modeling Analysis. California Department of Water Resources, Delta Modeling Section. Sacramento, CA. Represents the long-term average change in salinity at Clifton Court Forebay based on DWR's Delta Simulation Model (DWRDSM) analysis.
Critical to water quality (SB-34)	California Water Code Section 12311(a) The Delta Flood Protection Act (SB-34) identified eight islands as critical to water quality.
Island volume	DWR Delta atlas and DWR Land use mapping data The island volume is used as an indicator of short-term water quality effects during specific hydrologic conditions in the Delta. An island breach would have a short-term, immediate effect on salinity intrusion only if the rate of filling of an island is greater than the outflow of water through the Delta. These elements are a function of the inflow of water into the Delta, the rate of water being exported out of the Delta, and the location and size of the breached island. Because most levee breaches occur during high inflows when outflow would exceed the rate of island filling, short-term effects on water quality (i.e., salinity) would seldom occur. However, the team felt it important to capture the possible of water quality effects of a levee breach during low inflow periods. Island volume estimates are derived from information on the "Land Surface Below Sea Level" and "Lowest surface Elevation" maps in the DWR Delta atlas. Weighted average surface elevations are multiplied by the island acreage (from DWR land use mapping data) to produce the estimated island volume.

		Water Quality		
ISLAND	Reclamation District	Salinity Intrusion Induced (% salinity increase @ Clifton Court)	Critical to Water Quality SB 34	Island Volume (short-term water quality effects) (Acre Feet; estimate)
Bacon Island	2028		No	77700
Bethel Island	-		Yes	29600
Bishop Tract	2042		No	10400
Boggs (Moss Tract)	404		No	0
Bouldin Island	756	2%	No	83700
Brack Tract	2033		No	32900
Bradford Island	2059		Yes	25100
Brannan/Andrus Island	-	-5%	-	-
Andrus	317		No	52400
Andrus, Isleton	407		No	10700
Andrus, Upper	556		No	11800
Brannan	2067		No	117200
Byron Tract	800		No	37500
Canal Ranch	2086		No	19700
Coney Island	2117		No	5000
Dead Horse Island	2111		No	1100
Empire Tract	2029		No	50500
Fabian Tract	773		No	16800
Fay	2113		No	500
Glanville Tract	1002		No	0
Grand Island	3		No	110000
Hastings Tract	2060		No	5600
Holland Tract	2025	12%	Yes	38800
Holt Station	2116		No	1000
Hotchkiss Tract	799		Yes	10000
Jersey Island	830	40%	Yes	33500
Jones Tract	-		-	-
Jones, Lower	2038		No	45900
Jones, Upper	2039		No	71500
King Island	2044		No	30900
Little Mandeville	2118		No	1800
Mandeville Island	2027		No	76400
McCormack Williamson Tr	2110		No	2100
McDonald Island	2030	2%	No	83000
Medford Island	2041		No	15100
Merritt Island	150		No	0
Mildred Island	2021		No	0
Naglee Burke	1007		No	0
New Hope Tract	348		No	17100
Orwood Island	2024		No	21300
Palm Tract	2036		No	23800
Pescadero	2058		No	0
Pierson District	551		No	35400
Prospect Island	1667		No	8500
Quimby Island	2090		No	7100
Rindge Tract	2037		No	71800
Rio Blanco Tract	2114		No	2900
Roberts Island	-		-	-
Roberts, Lower	684		No	97400
Roberts, Middle	524		No	32100
Roberts, Upper	544		No	0
Rough and Ready Island	-		No	3700
Ryer Island	501		No	68700
Sargent Barnhart Tract	2074		No	3200
Sherman Island	341	41%	Yes	133600
Shima Tract	2115		No	9200
Shin Kee Tract	-		No	3800
Smith	1614		No	0
Stark	2089		No	3000
Staten Island	38	-4%	No	108400
Stewart Tract	2062		No	0
Sutter Island	349		No	10500
Terminous	548		No	102100
Twitchell	1601	19%	Yes	47900
Tyler Island	563		No	85600
Walnut Grove	554		No	2300
Union Island	1,2		No	103200
Van Sickle Island	1607		No	0
Veale Tract	2065		No	7500
Venice Island	2023		No	44700
Victoria Island	2040		No	74500
Webb Tract	2026	24%	Yes	80400
Weber	828		No	0
Winter Island	2122		No	0
Woodward Island	2072		No	21600
Wright-Elmwood Tract	2119		No	10700
-	307		No	0
-	369		No	2100
-	536		No	9600
-	765		No	0
-	813		No	0
-	900		No	0
-	999		No	6400
-	1608		No	3600
-	2084		No	15100
-	2093		No	8800
-	2095		No	0
-	2098		No	1500
-	2121		No	800
		0.41		133600

RECREATION

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
State or regional parks, wildlife areas, and easements	Parisi, Monica. Geographic information System specialist. California Department of Fish and Game, Sacramento, CA. January 2 and 3, 1997 - telephone conversations. These figures do not include parks and boating facilities external to the levee system.
Recreation lands	DWR Land use mapping data. 1993. Recreational lands include commercial lands related to recreational activities. There are many areas of the Delta that are used for private recreation (e.g., waterfowl hunting) but are not categorized as 'recreational' lands. We were unable to get island-specific data on private recreation lands and hunting clubs. Therefore, these figures most likely underestimate all the recreational resources in the area.
Recreation resorts	DWR Delta atlas and Schnell, Hal. n.d. San Joaquin River - Sacramento River California Delta boating map. Stockton, CA. Most of these 'resorts' are marinas and boating facilities external to the levee system.

		Recreation		
ISLAND	Reclamation District	State or Regional Parks (Acres)	Recreation Lands (Acres)	Recreation Resorts
Bacon Island	2028	0	0.0	0
Bethel Island	-	0	6.4	19
Bishop Tract	2042	0	17.7	1
Boggs (Moss Tract)	404	0	0.0	2
Bouldin Island	756	0	0.0	0
Brack Tract	2033	359	0.0	0
Bradford Island	2059	0	0.0	0
Brannan/Andrus Island	-		0.0	24
Andrus	317	0	7.2	-
Andrus, Isleton	407	0	0.0	-
Andrus, Upper	556	0	5.2	-
Brannan	2067	0	93.4	-
Byron Tract	800	0	0.0	1
Canal Ranch	2086	0	0.0	0
Coney Island	2117	0	0.0	0
Dead Horse Island	2111	0	0.0	0
Empire Tract	2029	0	7.0	1
Fabian Tract	773	0	0.0	2
Fay	2113	0	0.0	0
Glanville Tract	1002	0	0.0	1
Grand Island	3	0	4.9	9
Hastings Tract	2060	0	0.0	0
Holland Tract	2025	0	0.0	2
Holt Station	2116	0	0.0	0
Hotchkiss Tract	799	0	0.0	18
Jersey Island	830	0	0.0	0
Jones Tract	-		0.0	-
Jones, Lower	2038	0	0.0	1
Jones, Upper	2039	0	0.0	1
King Island	2044	0	0.0	3
Little Mandeville	2118	0	0.0	0
Mandeville Island	2027	0	0.0	0
McCormack Williamson Tr	2110	0	0.0	0
McDonald Island	2030	0	0.0	0
Medford Island	2041	0	0.0	0
Merritt Island	150	0	0.0	1
Mildred Island	2021	0	0.0	0
Naglee Burke	1007	0	0.0	0
New Hope Tract	348	915	0.0	3
Orwood Island	2024	0	0.0	1
Palm Tract	2036	0	0.0	0
Pescadero	2058	0	9.3	0
Pierson District	551	0	0.0	3
Prospect Island	1667	0	0.0	1
Quimby Island	2090	0	0.0	0
Rindge Tract	2037	0	0.0	0
Rio Blanco Tract	2114	0	0.0	1
Roberts Island	-		-	-
Roberts, Lower	684	0	47.6	4
Roberts, Middle	524	0	0.0	0
Roberts, Upper	544	0	0.0	0
Rough and Ready Island	-	0	0.0	0
Ryer Island	501	0	17.0	2
Sargent Barnhart Tract	2074	0	32.5	3
Sherman Island	341	3100	66.7	7
Shima Tract	2115	0	0.0	0
Shin Kee Tract	-	0	0.0	2
Smith	1614	0	0.0	1
Stark	2089	0	0.0	0
Staten Island	38	0	0.0	0
Stewart Tract	2062	0	0.0	2
Sutter Island	349	0	0.0	1
Terminous	548	0	0.0	5
Twitchell	1601	0	0.0	1
Tyler Island	563	0	0.0	2
Walnut Grove	554	0	4.5	3
Union Island	1,2	0	0.0	0
Van Sickle Island	1607	0	0.0	0
Veale Tract	2065	0	0.0	0
Venice Island	2023	0	0.0	0
Victoria Island	2040	0	0.0	0
Webb Tract	2026	285	0.0	0
Weber	828	0	0.0	3
Winter Island	2122	0	0.0	0
Woodward Island	2072	0	0.0	0
Wright-Elmwood Tract	2119	0	0.0	1
-	307	0	0.0	1
-	369	0	0.0	0
-	536	0	0.0	0
-	765	0	0.0	N/D
-	813	0	0.0	0
-	900	0	0.0	2
-	999	0	0.0	1
-	1608	0	15.4	2
-	2084	0	0.0	1
-	2093	0	0.0	0
-	2095	0	0.0	0
-	2098	0	0.0	0
-	2121	0	0.0	0
			93.4	24
			0 0	

CULTURAL RESOURCES

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
Known prehistoric sites	U.S Bureau of Reclamation. 1996. Cultural resources of the Sacramento-San Joaquin Delta, CALFED Bay-Delta Program. Draft. Sacramento, CA. The information on prehistoric and historic resources in the Delta depends on whether an area has been surveyed and results have been reported. Therefore, the lack of an occurrence on an island does not preclude the presence of prehistoric and historic resources.
Potential historic sites	U.S Bureau of Reclamation. 1996. Cultural resources of the Sacramento-San Joaquin Delta, CALFED Bay-Delta Program. Draft. Sacramento, CA. See above note.

		Cultural Resources	
ISLAND	Reclamation District	Known Prehistoric Sites	Potential Historic Sites
Bacon Island	2028		13
Bethel Island	-	4	
Bishop Tract	2042	1	
Boggs (Moss Tract)	404	1	
Bouldin Island	756		6
Brack Tract	2033		
Bradford Island	2059		
Brannan/Andrus Island	-		
Andrus	317		
Andrus, Isleton	407		
Andrus, Upper	556	1	
Brannan	2067		
Byron Tract	800	5	1
Canal Ranch	2086		
Coney Island	2117		
Dead Horse Island	2111		
Empire Tract	2029		
Fabian Tract	773	3	2
Fay	2113		
Glanville Tract	1002	2	
Grand Island	3		
Hastings Tract	2060		
Holland Tract	2025	4	2
Holt Station	2116		
Hotchkiss Tract	799	8	
Jersey Island	830	1	
Jones Tract	-		
Jones, Lower	2038		
Jones, Upper	2039		
King Island	2044		
Little Mandeville	2118		
Mandeville Island	2027		
McCormack Williamson Tr	2110		
McDonald Island	2030	1	
Medford Island	2041		
Merritt Island	150	2	
Mildred Island	2021		
Naglee Burke	1007		
New Hope Tract	348	24	2
Orwood Island	2024		
Palm Tract	2036	1	
Pescadero	2058	2	1
Pierson District	551	3	
Prospect Island	1667		
Quimby Island	2090		
Rindge Tract	2037		
Rio Blanco Tract	2114		
Roberts Island	-	-	
Roberts, Lower	684		
Roberts, Middle	524	1	
Roberts, Upper	544		
Rough and Ready Island	-		
Ryer Island	501		
Sargent Barnhart Tract	2074	1	1
Sherman Island	341		
Shima Tract	2115		
Shin Kee Tract	-		
Smith	1614		
Stark	2089		
Staten Island	38		1
Stewart Tract	2062		
Sutter Island	349		
Terminous	548	1	
Twitchell	1601		
Tyler Island	563	4	
Walnut Grove	554	-	
Union Island	1,2	1	
Van Sickle Island	1607		
Veale Tract	2065	2	
Venice Island	2023		
Victoria Island	2040		
Webb Tract	2026		2
Weber	828	1	
Winter Island	2122		
Woodward Island	2072		1
Wright-Elmwood Tract	2119		
-	307	5	1
-	369	4	
-	536		
-	765		
-	813	4	
-	900		
-	999	5	
-	1608		
-	2084		
-	2093		
-	2095	1	
-	2098		
-	2121		

INFRASTRUCTURE OF LOCAL CONCERN

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
County roads	DWR Delta atlas. The team selected "present/absent" as the appropriate unit to report over "miles of roadway" because if any portion of a road is damaged or inundated during a levee breach or flood event, circulation patterns would need to be re-routed.
Commercial lands	DWR Land use mapping data.
Industrial lands	DWR Land use mapping data.
Acreage protected per levee mile	DWR Delta atlas and DWR Land use mapping data. Acreage protected per levee mile was computed by dividing each island's acreage by the corresponding number of levee miles.

		Infrastructure of Local Concern			
ISLAND	Reclamation District	County Roads	Commercial Lands (Acres)	Industrial Lands (Acres)	Acreage Protected per Levee Mile (Acres/Mile)
Bacon Island	2028	present	0.0	13.8	393
Bethel Island	-	present	0.0	0.0	304
Bishop Tract	2042	present	0.0	0.0	374
Boggs (Moss Tract)	404	absent	31.5	42.0	617
Bouldin Island	756	absent	0.0	45.3	334
Brack Tract	2033	present	0.0	0.0	451
Bradford Island	2059	absent	0.0	0.0	277
Brannan/Andrus Islan	-	-	-	-	376
Andrus	317	present	0.0	5.3	-
Andrus, Isleton	407	present	3.8	46.7	-
Andrus, Upper	556	present	0.0	1.8	-
Brannan	2067	present	2.4	9.8	-
Byron Tract	800	present	0.0	0.0	715
Canal Ranch	2086	absent	0.0	0.0	399
Coney Island	2117	absent	0.0	0.0	173
Dead Horse Island	2111	absent	0.0	0.0	81
Empire Tract	2029	present	0.0	0.0	327
Fabian Tract	773	present	0.0	0.0	347
Fay	2113	absent	0.0	0.0	63
Glanville Tract	1002	present	0.0	0.0	538
Grand Island	3	present	5.8	5.3	587
Hastings Tract	2060	absent	0.0	0.0	447
Holland Tract	2025	present	0.0	0.0	372
Holt Station	2116	present	0.0	0.0	490
Hotchkiss Tract	799	present	17.3	9.9	492
Jersey Island	830	present	0.0	0.0	223
Jones Tract	-	-	-	-	-
Jones, Lower	2038	present	0.0	0.0	670
Jones, Upper	2039	present	0.0	0.0	673
King Island	2044	present	0.0	0.0	362
Little Mandeville	2118	absent	0.0	0.0	80
Mandeville Island	2027	absent	0.0	0.0	371
McCormack Williamso	2110	absent	0.0	3.0	188
McDonald Island	2030	absent	0.0	84.0	449
Medford Island	2041	absent	0.0	0.0	207
Merritt Island	150	present	0.0	3.3	262
Mildred Island	2021	absent	0.0	0.0	137
Naglee Burke	1007	present	0.0	0.0	734
New Hope Tract	348	present	18.8	26.0	500
Orwood Island	2024	present	0.0	0.0	380
Palm Tract	2036	absent	0.0	0.0	325
Pescadero	2058	present	3.1	138.4	955
Pierson District	551	present	0.0	16.4	612
Prospect Island	1667	absent	0.0	0.0	123
Quimby Island	2090	absent	0.0	0.0	110
Rindge Tract	2037	absent	0.0	0.0	435
Rio Blanco Tract	2114	absent	0.0	0.0	176
Roberts Island	-	-	-	-	-
Roberts, Lower	684	present	5.5	53.5	676
Roberts, Middle	524	present	0.0	672.2	1310
Roberts, Upper	544	present	0.0	0.0	550
Rough and Ready Isla	-	absent	0.0	835.7	218
Ryer Island	501	present	0.0	0.0	577
Sargent Barnhart Trac	2074	present	0.0	0.0	282
Sherman Island	341	present	7.1	0.0	510
Shima Tract	2115	absent	0.0	0.0	363
Shin Kee Tract	-	absent	0.0	0.0	246
Smith	1614	present	0.0	0.0	246
Stark	2089	absent	0.0	0.0	210
Staten Island	38	present	0.0	9.4	361
Stewart Tract	2062	present	0.0	0.0	318
Sutter Island	349	present	0.0	0.0	210
Terminous	548	present	0.0	0.0	650
Twitchell	1601	present	0.0	10.1	298
Tyler Island	563	present	0.0	3.0	375
Walnut Grove	554	present	0.0	25.3	208
Union Island	1,2	present	10.1	0.0	735
Van Sickle Island	1607	absent	0.0	0.0	278
Veale Tract	2065	present	0.0	4.0	228
Venice Island	2023	absent	0.0	0.0	262
Victoria Island	2040	absent	0.0	0.0	480
Webb Tract	2026	absent	0.0	0.0	429
Weber	828	absent	0.0	0.0	958
Winter Island	2122	absent	0.0	0.0	100
Woodward Island	2072	absent	0.0	0.0	207
Wright-Elmwood Tract	2119	present	0.0	0.0	312
-	307	present	0.0	1.7	463
-	369	present	0.0	0.0	313
-	536	present	0.0	0.0	456
-	765	present	0.0	0.0	237
-	813	present	0.0	0.0	317
-	900	present	0.0	0.0	814
-	999	present	0.0	105.2	786
-	1608	absent	0.0	39.8	302
-	2084	present	0.0	51.1	453
-	2093	absent	0.0	0.0	245
-	2095	present	147.8	55.6	1388
-	2098	absent	0.0	0.0	326
-	2121	present	0.0	0.0	229

INFRASTRUCTURE OF STATEWIDE CONCERN

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
Federal and state highways	DWR Delta atlas. See note for "County Roads" above.
Water supply conveyance	DWR Delta atlas.
Railroad mainlines	DWR Delta atlas.
Natural gas pipelines	Warner, Chris. Supervisor of mapping. Pacific Gas and Electric, Central Area, Walnut Creek, CA. November 25 and December 7, 1996; January 2,3 and 17, 1997 - telephone conversations and facsimile. (PG&E natural gas facilities data) Gas distribution line mileages are approximate.
Natural gas fields and storage	DWR Delta atlas and PG&E natural gas facilities data.
Power transmission lines	DWR Delta atlas.

		Statewide Infrastructure					
ISLAND	Reclamation District	Federal and State Highways	Water Supply Conveyance (Miles)	Railroad Mainlines (Miles)	Natural Gas Fields and Storage	Natural Gas Pipelines (Miles)	Power Transmission Lines (Miles)
Bacon Island	2028	absent	0	0	Absent	4.32	0
Bethel Island	-	absent	0	0	Production	1.29	0
Bishop Tract	2042	present	0	0	Absent	0	2
Boggs (Moss Tract)	404	present	0	3	Production	na	1
Bouldin Island	756	present	0	0	Absent	0	0
Brack Tract	2033	absent	0	0	Absent	10.03	0
Bradford Island	2059	absent	0	0	Production	5.43	0
Brannan/Andrus Island	-		-	-	-	-	-
Andrus	317	present	0	0	Production	15.34	0
Andrus, Isleton	407	present	0	0	Production	na	0
Andrus, Upper	556	absent	0	0	Production	na	0
Brannan	2067	present	0	0	Production	49.26	6
Byron Tract	800	present	0	1	Absent	1.85	2
Canal Ranch	2086	absent	0	0	Absent	0.89	0
Coney Island	2117	absent	0	0	Absent	0	0
Dead Horse Island	2111	absent	0	0	Absent	0	0
Empire Tract	2029	absent	0	0	Absent	0	0
Fabian Tract	773	absent	0	0	Absent	0	0
Fay	2113	absent	0	0	Absent	0	0
Glanville Tract	1002	present	0	0	Absent	0	0
Grand Island	3	present	0	0	Production	6.06	9
Hastings Tract	2060	absent	3.4	0	Production	3.91	2
Holland Tract	2025	absent	0	0	Absent	0	0
Holt Station	2116	present	0.2	0	Absent	na	0
Hotchkiss Tract	799	absent	1.7	0	Production	9.2	3
Jersey Island	830	absent	0	0	Production	4.89	3
Jones Tract	-	-	-	-	-	-	-
Jones, Lower	2038	absent	5.5	5	Absent	0	0
Jones, Upper	2039	present	5.5	0	Absent	0	4
King Island	2044	absent	0	0	Production	0.61	0
Little Mandeville	2118	absent	0	0	Absent	na	0
Mandeville Island	2027	absent	0	0	Absent	0	0
McCormack Williamson Tr	2110	absent	0	0	Present	na	0
McDonald Island	2030	absent	0	0	STORAGE	9.27	0
Medford Island	2041	absent	0	0	Absent	0	0
Merritt Island	150	absent	0	0	Production	0	0
Mildred Island	2021	absent	0	0	Absent	2.53	0
Naglee Burke	1007	absent	0	0	Absent	na	3
New Hope Tract	348	present	0	2	Production	16.46	0
Orwood Island	2024	absent	2.6	0	Absent	1.15	0
Palm Tract	2036	absent	0	2	Absent	5.24	0
Pescadero	2058	present	0	4	Absent	0	0
Pierson District	551	present	0.8	0	Production	0.05	4
Prospect Island	1667	absent	0	0	Absent	0	0
Quimby Island	2090	absent	0	0	Absent	0	0
Rindge Tract	2037	absent	0	0	Absent	0	0
Rio Blanco Tract	2114	absent	0	0	Production	0	1
Roberts Island	-	-	-	-	-	15.34	-
Roberts, Lower	684	absent	3	5	Production	-	3
Roberts, Middle	524	present	0	0	Production	-	1
Roberts, Upper	544	absent	0	0	Production	-	4
Rough and Ready Island	-	absent	0	0	Absent	0	0
Ryer Island	501	present	0	0	Absent	0	0
Sargent Barnhart Tract	2074	absent	1.5	0	Absent	0	0
Sherman Island	341	present	0	0	Production	40.72	13
Shima Tract	2115	absent	0	0	Absent	0	1
Shin Kee Tract	-	present	0	0	Absent	0.97	1
Smith	1614	present	0	0	Absent	na	0
Stark	2089	absent	0	0	Absent	0	1
Staten Island	38	absent	0	0	Production	4.15	0
Stewart Tract	2062	present	0	3	Absent	0	1
Sutter Island	349	absent	0	0	Absent	0	0
Terminous	548	present	0	0	Production	7.56	3
Twitchell	1601	absent	0	0	Production	8.89	0
Tyler Island	563	absent	0.8	0	Production	19.09	0
Walnut Grove	554	absent	0.7	0	Production	-	-
Union Island	1,2	absent	0	0	Production	12.53	6
Van Sickle Island	1607	absent	0	0	Absent	0	0
Veale Tract	2065	absent	0	0	Absent	1.02	1
Venice Island	2023	absent	0	0	Absent	0	0
Victoria Island	2040	present	0	0	Absent	0	0
Webb Tract	2026	absent	0	0	Production	0.02	0
Weber	828	present	0	0	Production	N/D	0
Winter Island	2122	absent	0	0	Absent	N/D	0
Woodward Island	2072	absent	1.5	0	Absent	0	0
Wright-Elmwood Tract	2119	absent	0	0	Absent	0	2
-	307	absent	0	0	N/D	N/D	3
-	369	absent	0	0	Production	N/D	0
-	536	absent	0	0	Production	N/D	2
-	765	present	0	0	N/D	N/D	0
-	813	present	0	0	Absent	N/D	2
-	900	present	0	0	N/D	N/D	0
-	999	present	0	0	Absent	N/D	1
-	1608	present	0	0	Absent	N/D	0
-	2084	absent	0	0	Production	N/D	0
-	2093	absent	0	0	Production	N/D	0
-	2095	present	0	2.7	Absent	N/D	3
-	2098	absent	0	0	Production	N/D	3
-	2121	absent	0	1	Absent	N/D	0
			5.5	5 3		49.26	12 9

ADJACENT ISLAND RESOURCES

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
Adjacent levees at risk	**
Adjacent acreage at risk	**
Seepage risk	**

Adjacent island resources are an important element to the Delta levee system integrity program. This objective has been included in the Special Projects prioritization process to recognize the relationships between a breached island and adjacent islands. The main factors that the team wants to capture in the information matrix include wind and wave erosion and seepage. Waterside levee slopes are subject to varying erosional effects of channel flows, tidal action, wind-generated waves, and boat wakes. A levee breach can result in increased wave action over time because the wind fetch across open water results in bigger waves which can affect erosion of an adjacent island's exterior levee slopes. Seepage of water from waterways or adjacent islands is a major concern of Delta land users. Seepage from these sources can affect levee erosion problems or instability and create drainage problems for landowners. The amount of seepage that occurs is controlled by the permeability of soils, length of the seepage path, and height of the hydraulic head (i.e., the pressure created by water within a given volume). A flooded island would result in potential increases in seepage to adjacent islands.

In discussing how to capture these issues, the team recommended using the attributes listed above. However, detailed assumptions needed to characterize these attributes have not yet been worked out. For example, what is an appropriate distance between levees to define "adjacent"? How can the seepage risk attribute capture differences in soil and current seepage conditions throughout the Delta? and How should the seepage risk attribute be characterized (e.g., a qualitative or quantitative scale). Additional investigation and discussion is needed to fully develop the "Adjacent Island Resources" attributes. Therefore, data will be presented in a future version of the information matrix.

		Adjacent Islands		
ISLAND	Reclamation District	Adjacent Levees At Risk (Miles)	Adjacent Acreage At Risk (Acres)	Seepage Risk
Bacon Island	2028		19512	
Bethel Island	-		10631	
Bishop Tract	2042		13193	
Boggs (Moss Tract)	404			
Bouldin Island	756		50326	
Brack Tract	2033		22639	
Bradford Island	2059		22414	
Brannan/Andrus Island	-		50542	
Andrus	317		-	
Andrus, Isleton	407		-	
Andrus, Upper	556		-	
Brannan	2067		-	
Byron Tract	800		13210	
Canal Ranch	2086		23346	
Coney Island	2117		29452	
Dead Horse Island	2111		28710	
Empire Tract	2029		29790	
Fabian Tract	773		36972	
Fay	2113		8061	
Glanville Tract	1002		10634	
Grand Island	3		38930	
Hastings Tract	2060		0	
Holland Tract	2025		16728	
Holt Station	2116			
Hotchkiss Tract	799		12329	
Jersey Island	830		18588	
Jones Tract	-		-	
Jones, Lower	2038		52398	
Jones, Upper	2039		41619	
King Island	2044		24624	
Little Mandeville	2118			
Mandeville Island	2027		22468	
McCormack Williamson Tr	2110		34684	
McDonald Island	2030		51794	
Medford Island	2041		18095	
Merritt Island	150		11600	
Mildred Island	2021			
Naglee Burke	1007		15210	
New Hope Tract	348		13823	
Orwood Island	2024		11191	
Palm Tract	2036		15121	
Pescadero	2058		12590	
Pierson District	551		31370	
Prospect Island	1667		11880	
Quimby Island	2090		9360	
Rindge Tract	2037		52066	
Rio Blanco Tract	2114		6445	
Roberts Island	-		56009	
Roberts, Lower	684		-	
Roberts, Middle	524		-	
Roberts, Upper	544		-	
Rough and Ready Island	-		33761	
Ryer Island	501		20858	
Sargent Barnhart Tract	2074		36098	
Sherman Island	341		25118	
Shima Tract	2115		11124	
Shin Kee Tract	-		14435	
Smith	1614			
Stark	2089		34792	
Staten Island	38		42439	
Stewart Tract	2062		64163	
Sutter Island	349		42610	
Terminous	548		27758	
Twitchell	1601		32928	
Tyler Island	563		58484	
Walnut Grove	554		-	
Union Island	1,2		51906	
Van Sickle Island	1607			
Veale Tract	2065		9596	
Venice Island	2023		21445	
Victoria Island	2040		38151	
Webb Tract	2026		35543	
Weber	828			
Winter Island	2122			
Woodward Island	2072		36099	
Wright-Elmwood Tract	2119		42989	
-	307			
-	369			
-	536			
-	765			
-	813			
-	900			
-	999			
-	1608			
-	2084			
-	2093			
-	2095			
-	2098			
-	2121			

ECOSYSTEM

ISLAND ATTRIBUTE	DATA SOURCE and NOTES
Native vegetation	DWR Land use mapping data. 1993.
Wetlands	U.S. Fish and Wildlife Service. 1995. National Wetland Inventory based on 1985 aerial photographs mapped at 1:124,000 scale. (NWI mapping data)
Riparian habitats	NWI mapping data
Agricultural waterfowl habitats	DWR Land use mapping data. 1993. Agricultural land classifications considered potential waterfowl habitat are grain and hay crops (barley, wheat, oats, miscellaneous and mixed hay and grain); field crops (safflower, flax, hops, sugar beets, corn [field or sweet], grain sorghum); and rice.
Known special-status plant occurrences	Natural Diversity Database. 1996. Records search for the Bay-Delta study area. California Department of Fish and Game. Sacramento, CA. (NDDB) California Department of Fish and Game. 1995. SB 34 Delta Levees Master Environmental Assessment. Sacramento, CA. (SB 34 MEA) Data for the "Habitat and Special-Status Species Interior to Levee Systems" category was compiled from the Natural Diversity Database and California Department of Fish and Game's SB 34 Delta Levees Master Environmental Assessment. Species locations were reconciled (cross-referenced) in order to eliminate duplicative data. The information on special-status plant and wildlife occurrences in the Delta depends on whether an area has been surveyed and results have been reported. Therefore, the lack of an occurrence on an island does not preclude the presence of special-status plants and wildlife.
Known special-status wildlife occurrences	NDDB and SB 34 MEA See above notes.

Ecosystem attribute data (acreages and species occurrences) have been presented in three ways: totals for each island, resources interior to the levee system, and resources on the exterior (water side) of the island levees. The attribute data are divided this way to distinguish those resources that are protected by the existing levee system (interior to the levee system) and those resources exterior to the system. This distinction was used in ranking the islands for the Special Projects prioritization exercise.

		Island Total							
						Known Special-Status Plant Occurrences (by 1995)		Known Special-Status Wildlife Occurrences (by 1995)	
ISLAND	Reclamation District	Native Vegetation (Acres)	Wetlands (Acres)	Riparian Habitats (Acres)	Agricultural Waterfowl Habitats (Acres)	# species	# occurences	# species	# occurences
Bacon Island	2028	360.3	0.0	7.2	1112.7	4	48	3	9
Bethel Island	-	344.7	2.4	90.9	0	4	19	1	1
Bishop Tract	2042	103.1	7.6	1.7	817.5	1	1	1	1
Boggs (Moss Tract)	404	193.5	3.4	62.5	0.0				
Bouldin Island	756	217.4	0.3	5.3	5348.9	5	46	4	5
Brack Tract	2033	196.0	8.3	0.0	1263.7	2	7	3	15
Bradford Island	2059	171.1	0.0	14.8	0.0	2	5		
Brannan/Andrus Island	-	-	-	-	-	6	46	3	7
Andrus	317	136.0	7.7	5.6	2723.4	-	-	-	-
Andrus, Isleton	407	138.6	24.1	0.0	947.7	-	-	-	-
Andrus, Upper	556	157.1	0.0	1.7	873.3	-	-	-	-
Brannan	2067	475.5	26.5	15.6	4691.5	-	-	-	-
Byron Tract	800	874.3	54.9	0.6	1280.8	7	17	2	5
Canal Ranch	2086	179.4	18.5	0.0	2255.8	4	9	2	8
Coney Island	2117	84.4	2.5	1.6	658.1	2	8	1	3
Dead Horse Island	2111	28.8	0.0	0.0	0.0	1	5	1	1
Empire Tract	2029	176.6	18.2	14.7	2159.9	4	15	2	2
Fabian Tract	773	339.8	13.0	38.6	1003.8	2	9	3	10
Fay	2113	31.4	0.0	2.7	63.9	2	5	1	1
Glanville Tract	1002	298.5	100.9	39.6	1212.1	4	9	3	3
Grand Island	3	666.6	37.3	28.8	7901.0			1	2
Hastings Tract	2060	385.0	82.2	0.0	503.3	2	3		
Holland Tract	2025	384.0	15.8	31.0	2923.7	4	39	2	2
Holt Station	2116	2.9	0.9	0.0	113.6				
Hotchkiss Tract	799	746.5	4.7	44.5	185.4	2	11	2	2
Jersey Island	830	697.5	16.8	58.3	0.0				
Jones Tract	-	-	-	-	-	-	-	-	-
Jones, Lower	2038	167.6	0.0	1.1	2458.4	4	14	2	3
Jones, Upper	2039	406.1	5.5	0.0	2447.7	4	15	3	4
King Island	2044	115.0	0.0	0.0	2819.3				
Little Mandeville	2118	50.3	0.0	7.6	269.2				
Mandeville Island	2027	336.1	85.7	41.9	501.6	3	20	1	1
McCormack Williamson Tr	2110	66.7	0.0	8.5	180.7	4	18	1	5
McDonald Island	2030	395.2	76.8	14.2	1537.6	4	16	2	2
Medford Island	2041	84.7	3.2	17.4	328.8	2	4	3	3
Merritt Island	150	238.5	0.0	1.0	1007.5			1	2
Mildred Island	2021	151.9	0.0	0.0	-	1	1		
Naglee Burke	1007	0.0	0.0	0.0	-			1	1
New Hope Tract	348	303.0	54.5	4.7	3905.7	1	12	4	17
Orwood Island	2024	212.3	0.0	4.7	596.2	2	4		
Palm Tract	2036	205.6	0.6	0.0	1882.4	3	17	2	5
Pescadero	2058	304.9	10.5	24.2	873.4			2	6
Pierson District	551	277.7	64.4	24.7	2012.2	2	6	3	5
Prospect Island	1667	418.4	3.3	3.4	389.0	2	3		
Quimby Island	2090	139.4	0.0	14.2	303.2	4	7		
Rindge Tract	2037	347.3	0.0	0.6	3075.4	3	26	1	1
Rio Blanco Tract	2114	94.5	17.1	14.4	422.4			1	1
Roberts Island	-	-	-	-	-	3	9	4	23
Roberts, Lower	684	303.8	26.7	10.0	4947.3	-	-	-	-
Roberts, Middle	524	177.3	8.8	24.8	4569.8	-	-	-	-
Roberts, Upper	544	207.1	9.9	7.4	3141.5	-	-	-	-
Rough and Ready Island	-	233.9	84.6	118.7	358.0	1	2		
Ryer Island	501	317.8	6.0	12.3	6178.8				
Sargent Barnhart Tract	2074	41.6	4.3	9.3	155.1	1	1		
Sherman Island	341	381.9	40.6	2.4	1772.4	5	65	5	6
Shima Tract	2115	103.1	0.0	0.0	442.0	2	3	1	2
Shin Kee Tract	-	26.7	0.2	0.0	605.2	1	1	2	2
Smith	1614	24.3	0.0	38.3	0.0				
Stark	2089	85.9	9.4	6.8	339.5	1	2	2	4
Staten Island	38	250.1	0.0	2.4	8397.9	7	26	3	11
Stewart Tract	2062	233.9	42.9	17.2	1115.9				
Sutter Island	349	223.5	0.0	0.0	494.1				
Terminous	548	648.0	181.5	4.4	7859.6	5	19	4	8
Twitchell	1601	236.7	0.0	4.6	632.1	4	5		
Tyler Island	563	403.8	10.2	1.4	5599.8	3	4	3	5
Walnut Grove	554	23.8	0.0	0.0	137.8	-	-	-	-
Union Island	1,2	645.0	8.9	46.7	8391.0	4	29	4	11
Van Sickle Island	1607	0.0	0.0	0.0	0.0	4	14	1	1
Veale Tract	2065	161.1	5.2	0.0	926.2				
Venice Island	2023	265.0	3.2	66.9	1211.9	3	7	1	1
Victoria Island	2040	265.6	1.7	0.0	2097.6	4	34	1	3
Webb Tract	2026	400.6	78.7	92.9	1332.8	5	33		
Weber	828	0.0	0.0	3.9	898.1				
Winter Island	2122	N/D	N/D	N/D	0.0				
Woodward Island	2072	143.0	0.1	0.0	0.0	2	22	3	4
Wright-Elmwood Tract	2119	122.9	0.1	7.7	0.0	1	1		
-	307	199.7	10.9	6.0	1264.7				
-	369	73.9	156.8	139.5	0.0				
-	536	1179.4	78.9	0.3	807.6				
-	765	96.2	4.8	11.2	428.8				
-	813	90.9	9.3	1.7	405.9				
-	900	687.7	70.7	21.8	1740.2				
-	999	852.5	33.6	23.3	8779.4				
-	1608	0.0	0.1	0.0	0.0				
-	2084	205.4	1.1	5.7	1005.6				
-	2093	240.8	39.6	12.5	3087.3				
-	2095	228.9	69.7	74.9	1111.8				
-	2098	1265.8	857.0	5.8	1350.4				
-	2121	10.3	45.6	0.4	261.9				

		Interior to Levee						
					Known Special-Status Plant Occurrences (by 1995)		Known Special-Status Wildlife Occurrences (by 1995)	
ISLAND	Reclamation District	Native Vegetation (Acres)	Wetlands (Acres)	Riparian Habitats (Acres)	# species	# occurences	# species	# occurences
Bacon Island	2028	260.5	0.0	6.8	1	1	1	1
Bethel Island	-	326.7	2.4	90.7			1	1
Bishop Tract	2042	70.2	6.7	1.1			1	1
Boggs (Moss Tract)	404	158.2	3.4	61.9				
Bouldin Island	756	144.2	0.0	5.3				
Brack Tract	2033	106.3	8.3	0.0	1	2	2	8
Bradford Island	2059	121.9	0.0	14.8				
Brannan/Andrus Island	-	-	-	-	3	6	2	2
Andrus	317	67.5	6.2	2.2	-	-	-	-
Andrus, Isleton	407	44.2	23.9	0.0	-	-	-	-
Andrus, Upper	556	8.6	0.0	0.0	-	-	-	-
Brannan	2067	124.9	21.6	5.7	-	-	-	-
Byron Tract	800	836.5	54.7	0.3	6	7	1	3
Canal Ranch	2086	132.1	18.5	0.0			2	6
Coney Island	2117	35.4	1.8	1.4				
Dead Horse Island	2111	10.1	0.0	0.0				
Empire Tract	2029	106.2	18.2	14.6				
Fabian Tract	773	124.4	10.9	10.0				
Fay	2113	18.4	0.0	2.7				
Glanville Tract	1002	239.0	55.7	11.3				
Grand Island	3	256.7	37.3	13.2	2	3	1	1
Hastings Tract	2060	266.8	80.3	0.0				
Holland Tract	2025	310.9	15.7	31.0			1	1
Holt Station	2116	2.2	0.8	0.0				
Hotchkiss Tract	799	723.5	4.3	44.5				
Jersey Island	830	574.6	16.3	51.6				
Jones Tract	-	-	-	-	-	-	-	-
Jones, Lower	2038	95.6	0.0	1.1			1	1
Jones, Upper	2039	312.7	2.4	0.0				
King Island	2044	51.2	0.0	0.0				
Little Mandeville	2118	33.4	0.0	5.8				
Mandeville Island	2027	291.3	85.6	13.7				
McCormack Williamson Tr	2110	34.1	0.0	6.6				
McDonald Island	2030	223.1	76.8	10.9				
Medford Island	2041	67.9	2.3	16.2			1	1
Merritt Island	150	117.1	0.0	0.0				
Mildred Island	2021	100.2	0.0	0.0				
Naglee Burke	1007	0.0	0.0	0.0				
New Hope Tract	348	236.1	52.9	4.2			1	1
Orwood Island	2024	158.7	0.0	3.3				
Palm Tract	2036	148.9	0.0	0.0				
Pescadero	2058	164.6	8.7	6.4			2	4
Pierson District	551	124.6	25.8	3.6				
Prospect Island	1667	368.4	2.6	0.2	1	1		
Quimby Island	2090	120.6	0.0	13.6				
Rindge Tract	2037	232.8	0.0	0.5				
Rio Blanco Tract	2114	76.7	16.6	4.7				
Roberts Island	-	-	-	-			2	6
Roberts, Lower	684	173.5	21.4	4.7	-	-	-	-
Roberts, Middle	524	99.6	8.8	1.3	-	-	-	-
Roberts, Upper	544	47.8	0.7	4.2	-	-	-	-
Rough and Ready Island	-	201.2	80.7	113.0				
Ryer Island	501	66.7	4.5	0.4				
Sargent Barnhart Tract	2074	19.4	1.2	8.3				
Sherman Island	341	167.4	0.0	2.0			2	2
Shima Tract	2115	64.7	0.0	0.0				
Shin Kee Tract	-	3.7	0.1	0.0	1	1		
Smith	1614	12.1	0.0	1.9				
Stark	2089	47.7	8.3	0.4				
Staten Island	38	138.5	0.0	0.9	2	2	1	6
Stewart Tract	2062	105.9	2.6	3.6	2	2	2	2
Sutter Island	349	104.7	0.0	0.0				
Terminous	548	517.3	174.9	4.4			1	1
Twitchell	1601	141.6	0.0	4.5				
Tyler Island	563	50.7	9.9	0.5			1	1
Walnut Grove	554	11.9	0.0	0.0	-	-	-	-
Union Island	1,2	398.2	7.0	42.8	2	2	3	5
Van Sickle Island	1607	0.0	0.0	0.0				
Veale Tract	2065	125.6	4.4	0.0				
Venice Island	2023	216.0	3.2	66.5				
Victoria Island	2040	140.6	0.0	0.0				
Webb Tract	2026	337.9	78.7	84.3				
Weber	828	0.0	0.0	3.9				
Winter Island	2122	n/d	n/d	n/d				
Woodward Island	2072	79.8	0.0	0.0				
Wright-Elmwood Tract	2119	67.4	0.0	7.5				
-	307	153.5	10.9	1.2				
-	369	63.6	15.6	18.3				
-	536	1154.5	78.9	0.0				
-	765	85.4	4.8	0.0				
-	813	57.3	9.1	0.0				
-	900	531.2	66.5	17.6				
-	999	420.2	28.4	18.6				
-	1608	0.0	0.0	0.0				
-	2084	161.6	1.1	5.7				
-	2093	140.3	21.9	2.8				
-	2095	191.5	60.3	63.2				
-	2098	1229.0	844.8	0.0				
-	2121	10.2	43.7	0.0				

		Exterior to Levee						
					Known Special-Status Plant Occurrences (by 1995)		Known Special-Status Wildlife Occurrences (by 1995)	
ISLAND	Reclamation District	Native Vegetation (Acres)	Wetlands (Acres)	Riparian Habitats (Acres)	# species	# occurences	# species	# occurences
Bacon Island	2028	99.7	0.0	0.4	4	47	2	8
Bethel Island	-	18.0	0.0	0.2	4	19		
Bishop Tract	2042	32.9	0.9	0.5	1	1		
Boggs (Moss Tract)	404	35.3	0.0	0.7				
Bouldin Island	756	73.2	0.3	0.0	5	46	4	5
Brack Tract	2033	89.6	0.0	0.0	2	5	2	7
Bradford Island	2059	49.2	0.0	0.0	2	5		
Brannan/Andrus Island	-	-	-	-	6	40	3	5
Andrus	317	68.5	1.5	3.3	-	-	-	-
Andrus, Isleton	407	94.5	0.2	0.0	-	-	-	-
Andrus, Upper	556	148.5	0.0	1.7	-	-	-	-
Brannan	2067	350.6	10.0	2067	-	-	-	-
Byron Tract	800	37.8	0.2	0.3	3	10	1	2
Canal Ranch	2086	47.3	0.0	0.0	4	9	1	2
Coney Island	2117	49.0	0.7	0.2	2	8	1	3
Dead Horse Island	2111	18.7	0.0	0.0	1	5	1	1
Empire Tract	2029	70.4	0.0	0.1	4	15	2	2
Fabian Tract	773	215.1	2.1	28.6	2	9	3	10
Fay	2113	13.1	0.0	0.0	2	5	1	1
Glanville Tract	1002	59.5	45.3	28.3	4	9	3	3
Grand Island	3	410.0	0.0	15.6			1	1
Hastings Tract	2060	118.2	1.9	0.0	2	3		
Holland Tract	2025	73.1	0.1	0.0	4	39	1	1
Holt Station	2116	0.7	0.2	0.0				
Hotchkiss Tract	799	23.1	0.4	0.0	2	11	2	2
Jersey Island	830	122.9	0.5	8.6				
Jones Tract	-	-	-	-	-	-	-	-
Jones, Lower	2038	72.0	0.0	0.0	4	14	1	2
Jones, Upper	2039	93.3	31.4	0.0	4	15	3	4
King Island	2044	63.8	0.0	0.0				
Little Mandeville	2118	17.0	0.0	1.8				
Mandeville Island	2027	44.8	0.1	28.2	3	20	1	1
McCormack Williamson Tr	2110	32.6	0.0	1.9	4	18	1	5
McDonald Island	2030	172.1	0.0	3.3	4	16	2	2
Medford Island	2041	16.8	0.9	1.1	2	4	2	2
Merritt Island	150	121.4	0.0	1.0			1	2
Mildred Island	2021	51.7	0.0	0.0	1	1		
Naglee Burke	1007	0.0	0.0	0.0			1	1
New Hope Tract	348	66.9	1.6	0.5	1	12	4	16
Orwood Island	2024	53.6	0.0	1.3	2	4		
Palm Tract	2036	56.7	0.6	0.0	3	17	2	5
Pescadero	2058	140.3	1.8	17.8			1	2
Pierson District	551	153.0	38.6	21.1	2	6	3	5
Prospect Island	1667	50.0	0.7	3.2	2	2		
Quimby Island	2090	18.8	0.0	0.6	4	7		
Rindge Tract	2037	114.6	0.0	0.1	3	26	1	1
Rio Blanco Tract	2114	17.8	0.5	9.7			1	1
Roberts Island	-	-	-	-	3	9	4	17
Roberts, Lower	684	130.2	5.3	5.2	-	-	-	-
Roberts, Middle	524	77.7	0.1	23.5	-	-	-	-
Roberts, Upper	544	159.3	9.2	3.2	-	-	-	-
Rough and Ready Island	-	32.7	3.9	5.7	1	2		
Ryer Island	501	251.1	1.5	11.9				
Sargent Barnhart Tract	2074	22.2	3.1	0.9	1	1		
Sherman Island	341	214.5	40.6	0.4	5	65	3	4
Shima Tract	2115	38.4	0.0	0.0	2	3	1	2
Shin Kee Tract	-	23.0	0.1	0.0			2	2
Smith	1614	12.2	0.0	36.3				
Stark	2089	38.2	1.1	6.4	1	2	2	4
Staten Island	38	111.7	0.0	1.5	7	24	3	5
Stewart Tract	2062	127.9	40.4	13.6				
Sutter Island	349	118.8	0.0	0.0				
Terminous	548	130.7	6.6	0.0	5	19	4	7
Twitchell	1601	95.1	0.0	0.0	4	5		
Tyler Island	563	353.0	0.3	0.9	3	4	2	4
Walnut Grove	554	11.9	0.0	0.0	-	-	-	-
Union Island	1,2	246.8	1.9	3.9	4	27	2	6
Van Sickle Island	1607	0.0	0.0	0.0	4	14	1	1
Veale Tract	2065	35.5	0.8	0.0				
Venice Island	2023	49.0	0.0	0.3	3	7	1	1
Victoria Island	2040	125.0	1.7	0.0	4	34	1	3
Webb Tract	2026	62.7	0.0	8.6	5	33		
Weber	828	0.0	0.0	0.0				
Winter Island	2122	n/d	n/d	n/d				
Woodward Island	2072	63.2	0.1	0.0	2	22	3	4
Wright-Elmwood Tract	2119	55.6	0.1	0.1	1	1		
-	307	46.2	0.0	4.8				
-	369	10.3	141.2	121.2				
-	536	24.9	0.0	0.3				
-	765	10.8	0.0	11.2				
-	813	33.6	0.2	1.7				
-	900	156.5	4.2	4.2				
-	999	432.3	5.1	4.7				
-	1608	0.0	0.1	0.0				
-	2084	43.8	0.0	0.1				
-	2093	100.5	17.7	9.7				
-	2095	37.4	9.4	11.7				
-	2098	38.8	12.2	5.8				
-	2121	0.1	1.8	0.4				
		432.2915	141.1941	121.199				

ISLAND		Swainson's Hawk	Giant Garter Snake	Western Pond Turtle	Burrowing Owl	San Joaquin Pocket Mouse	California Black Rail	Greater Sandhill Crane	Valley Elderberry Longhorn Beetle	San Joaquin Kit Fox	Lange's Metalmark Butterfly	Tri-colored Blackbird	Great Blue Heron	Salt Marsh Harvest Mouse	Sacramento Anthicid Beetle	California Least Tern	Antioch Dunes Anthicid Beetle	White-tailed Kite	Double Crested Cormorant
		Known Special-Status Wildlife Occurrences Interior to Levee Systems (by 1995)																	
Bacon Island					1														
Bethel Island					1														
Bishop Tract		1																	
Bouldin Island																			
Brack Tract					1			7											
Bradford Island																			
Brannan Island		1													1				
Byron Tract					3														
Canal Ranch		1						5											
Coney Island																			
Dead Horse Island																			
Decker Island																			
Empire Tract																			
Fabian Tract																			
Fay																			
Glanville Tract																			
Grand Island		1																	
Hastings Tract																			
Holland Tract												1							
Hotchkiss Tract																			
Jersey Island																			
Jones, Lower					1														
Jones, Upper																			
King Island																			
Mandeville Island																			
McCormack Williamson Tract																			
McDonald Island																			
Medford Island		1																	
Merritt Island																			
Mildred Island																			
Naglee Burke																			
New Hope Tract		1																	
Orwood Island																			
Palm Tract																			
Pescadero		3										1							
Pierson District																			
Prospect Island																			
Quimby Island																			
Rindge Tract																			
Rio Blanco Tract																			
Roberts Island	f	5			1														
Rough and Ready Island																			
Ryer Island																			
Sargent Barnhart Tract																			
Sherman Island								1											1
Shima Tract																			
Shin Kee Tract																			
Stark																			
Staten Island								6											
Stewart Tract		1										1							
Sutter Island																			
Terminous			1																
Twitchell																			
Tyler Island								1											
Union Island	g	3				1			1										
Van Sickle Island																			
Veale Tract																			
Venice Island																			
Victoria Island																			
Webb Tract																			
Woodward Island																			
Wright-Elmwood Tract																			

	Known Special-Status Plant Occurrences Interior to Levee Systems (by 1995)																
ISLAND	Mason's Lilaeopsis	Delta Tule Pea	California Hibiscus	Elderberry Bush	Suisun Marsh Aster	Delta Button Celery	Caper Fruited Tropidocarpum	Recurved Larkspur	Delta Mudwort	Sanford's Arrowhead	Antioch Dunes Evening Primrose	Carquinez Goldenbush	Brittlescale	San Joaquin Saltbush	Soft Bird's Beak	Slough Thistle	Marsh Skullcap
Bacon Island			1														
Bethel Island																	
Bishop Tract																	
Bouldin Island																	
Brack Tract			2														
Bradford Island																	
Brannan Island	2				2						2						
Byron Tract			1				2	1				1	1	1			
Canal Ranch																	
Coney Island																	
Dead Horse Island																	
Decker Island																	
Empire Tract																	
Fabian Tract																	
Fay																	
Glanville Tract																	
Grand Island	2	1															
Hastings Tract																	
Holland Tract																	
Hotchkiss Tract																	
Jersey Island																	
Jones, Lower																	
Jones, Upper																	
King Island																	
Mandeville Island																	
McCormack Williamson Tract																	
McDonald Island																	
Medford Island																	
Merritt Island																	
Mildred Island																	
Naglee Burke																	
New Hope Tract																	
Orwood Island																	
Palm Tract																	
Pescadero																	
Pierson District																	
Prospect Island		1															
Quimby Island																	
Rindge Tract																	
Rio Blanco Tract																	
Roberts Island																	
Rough and Ready Island																	
Ryer Island																	
Sargent Barnhart Tract																	
Sherman Island																	
Shima Tract																	
Shin Kee Tract			1														
Stark																	
Staten Island		1	1														
Stewart Tract						1										1	
Sutter Island																	
Terminous																	
Twitchell																	
Tyler Island																	
Union Island			1	1													
Van Sickle Island																	
Veale Tract																	
Venice Island																	
Victoria Island																	
Webb Tract																	
Woodward Island																	
Wright-Elmwood Tract																	

ISLAND		Mason's Lilaeopsis	Delta Tule Pea	California Hibiscus	Elderberry Bush	Suisun Marsh Aster	Delta Button Celery	Caper Fruited Tropidocarpum	Recurved Larkspur	Delta Mudwort	Sanford's Arrowhead	Antioch Dunes Evening Primrose	Carquinez Goldenbush	Brittlescale	San Joaquin Saltbush	Soft Bird's Beak	Marsh Skullcap
		Known Special-Status Plant Occurrences (by 1995)															
Bacon Island		22		16		8				2							
Bethel Island		7		2		4				6							
Bishop Tract				1													
Bouldin Island		10	9	6		18				3							
Brack Tract		4		3													
Bradford Island		3				2											
Brannan Island		10	11		6	12				2		5					
Byron Tract		4		5				4	1				1	1	1		
Canal Ranch		3	2	3						1							
Coney Island		5		3													
Dead Horse Island					5												
Decker Island																	
Empire Tract		3		5		6				1							
Fabian Tract		8			1												
Fay		4		1													
Glanville Tract		1	3	4	1												
Grand Island		2	1														
Hastings Tract		2				1											
Holland Tract		16		12		10											1
Hotchkiss Tract		8								3							
Jersey Island																	
Jones, Lower		6	1	6						1							
Jones, Upper		6	4	4													1
King Island																	
Mandeville Island		11		2		7											
McCormack Williamson Tract		1	5	1	11												
McDonald Island		2		6	2	6											
Medford Island		3				1											
Merritt Island																	
Mildred Island							1										
Naglee Burke																	
New Hope Tract					12												
Orwood Island		2		2													
Palm Tract		10		4		3											
Pescadero																	
Pierson District			2	4													
Prospect Island		1	2														
Quimby Island		3		2		1											1
Rindge Tract		7		8		11											
Rio Blanco Tract																	
Roberts Island	f		1	7		1											
Rough and Ready Island			2														
Ryer Island										1							
Sargent Barnhart Tract				1													
Sherman Island		35	2			25				2						1	
Shima Tract		2		1													
Shin Kee Tract				1													
Stark					2												
Staten Island		9	4	3	3	1				5							1
Stewart Tract							1										
Sutter Island																	
Terminous		3	2	3		9				2							
Twitchell		1	1			1						2					
Tyler Island		2	1								1						
Union Island	g	4		12	10		3										
Van Sickle Island		2	6			5				1							
Veale Tract																	
Venice Island		2		1		4											
Victoria Island		8	5	20													1
Webb Tract		9	2	5		13				4							
Woodward Island		10		12													
Wright-Elmwood Tract				1													

ISLAND		Mason's Lilaeopsis	Delta Tule Pea	California Hibiscus	Elderberry Bush	Suisun Marsh Aster	Delta Button Celery	Caper Fruited Tropidocarpum	Recurved Larkspur	Delta Mudwort	Sanford's Arrowhead	Antioch Dunes Evening Primrose	Carquinez Goldenbush	Brittlescale	San Joaquin Saltbush	Soft Bird's Beak	Slough Thistle	Marsh Skullcap
		Known Special-Status Plant Occurrences Exterior to Levee Systems (by 1995)																
Bacon Island		22		15		8				2								
Bethel Island		7		2		4				6								
Bishop Tract				1														
Bouldin Island		10	9	6		18				3								
Brack Tract		4		1														
Bradford Island		3				2												
Brannan Island		8	11		6	10				2		3						
Byron Tract		4		4				2										
Canal Ranch		3	2	3						1								
Coney Island		5		3														
Dead Horse Island					5													
Decker Island																		
Empire Tract		3		5		6				1								
Fabian Tract		8			1													
Fay		4		1														
Glanville Tract		1	3	4	1													
Grand Island																		
Hastings Tract		2				1												
Holland Tract		16		12		10												1
Hotchkiss Tract		8								3								
Jersey Island																		
Jones, Lower		6	1	6						1								
Jones, Upper		6	4	4														1
King Island																		
Mandeville Island		11		2		7												
McCormack Williamson Tract		1	5	1	11													
McDonald Island		2		6	2	6												
Medford Island		3				1												
Merritt Island																		
Mildred Island							1											
Naglee Burke																		
New Hope Tract					12													
Orwood Island		2		2														
Palm Tract		10		4		3												
Pescadero																		
Pierson District			2	4														
Prospect Island		1	1															
Quimby Island		3		2		1												1
Rindge Tract		7		8		11												
Rio Blanco Tract																		
Roberts Island	f		1	7		1												
Rough and Ready Island			2															
Ryer Island										1								
Sargent Barnhart Tract				1														
Sherman Island		35	2			25				2						1		
Shima Tract		2		1														
Shin Kee Tract																		
Stark					2													
Staten Island		9	3	2	3	1				5								1
Stewart Tract																		
Sutter Island																		
Terminous		3	2	3		9				2								
Twitchell		1	1			1						2						
Tyler Island		2	1								1							
Union Island	g	4		11	9		3											
Van Sickle Island		2	6			5				1								
Veale Tract																		
Venice Island		2		1		4												
Victoria Island		8	5	20														1
Webb Tract		9	2	5		13				4								
Woodward Island		10		12														
Wright-Elmwood Tract				1														

ISLAND		Swainson's Hawk	Giant Garter Snake	Western Pond Turtle	Burrowing Owl	San Joaquin Pocket Mouse	California Black Rail	Greater Sandhill Crane	Valley Elderberry Longhorn Beetle	San Joaquin Kit Fox	Lange's Metalmark Butterfly	Tri-colored Blackbird	Great Blue Heron	Salt Marsh Harvest Mouse	Sacramento Anthicid Beetle	California Least Tern	Antioch Dunes Anthicid Beetle	White-tailed Kite	Double Crested Cormorant
		Known Special-Status Wildlife Occurrences Exterior to the Levee Systems (by 1995)																	
Bacon Island				2			6												
Bethel Island																			
Bishop Tract																			
Bouldin Island				1	1		2	1											
Brack Tract		1						6											
Bradford Island																			
Brannan Island		2													2		1		
Byron Tract				2															
Canal Ranch								2											
Coney Island		3																	
Dead Horse Island									1										
Decker Island																			
Empire Tract					1		1												
Fabian Tract		8	1	1															
Fay							1												
Glanville Tract		1			1				1										
Grand Island		1																	
Hastings Tract																			
Holland Tract							1												
Hotchkiss Tract					1					1									
Jersey Island																			
Jones, Lower							2												
Jones, Upper				1			2								1				
King Island																			
Mandeville Island							1												
McCormack Williamson Tract									5										
McDonald Island							1		1										
Medford Island							1		1										
Merritt Island		2																	
Mildred Island																			
Naglee Burke					1														
New Hope Tract		9	1				1		5										
Orwood Island																			
Palm Tract				1			4												
Pescadero		2																	
Pierson District		3	1															1	
Prospect Island																			
Quimby Island																			
Rindge Tract									1										
Rio Blanco Tract					1														
Roberts Island	f	8			1				5			3							
Rough and Ready Island																			
Ryer Island																			
Sargent Barnhart Tract																			
Sherman Island			1								2				1				
Shima Tract		2																	
Shin Kee Tract			1				1												
Stark		2		2															
Staten Island				2				2	1										
Stewart Tract																			
Sutter Island																			
Terminous			2		1		3	1											
Twitchell																			
Tyler Island		2							2										
Union Island	g	4	2																
Van Sickle Island				1															
Veale Tract																			
Venice Island													1						
Victoria Island				3															
Webb Tract																			
Woodward Island				1			2								1				
Wright-Elmwood Tract																			

ISLAND		Known Special-Status Wildlife Occurrences (by 1995)																
		Swainson's Hawk	Giant Garter Snake	Western Pond Turtle	Burrowing Owl	San Joaquin Pocket Mouse	California Black Rail	Greater Sandhill Crane	Valley Elderberry Longhorn Beetle	San Joaquin Kit Fox	Lance's Metalwork Butterfly	Tri-colored Blackbird	Great Blue Heron	Sacramento Anthicid Beetle	California Least Tern	Antioch Dunes Anthicid Beetle	White-tailed Kite	Double Crested Cormorant
Bacon Island				2	1		6											
Bethel Island					1													
Bishop Tract		1																
Bouldin Island				1	1		2	1										
Brack Tract		1			1			13										
Bradford Island																		
Brannan Island		3												3		1		
Byron Tract				2	3													
Canal Ranch		1						7										
Coney Island		3																
Dead Horse Island									1									
Decker Island																		
Empire Tract					1		1											
Fabian Tract		8	1	1														
Fay							1											
Glanville Tract		1			1				1									
Grand Island		2																
Hastings Tract																		
Holland Tract							1					1						
Hotchkiss Tract					1					1								
Jersey Island																		
Jones, Lower					1		2											
Jones, Upper				1			2							1				
King Island																		
Mandeville Island							1											
McCormack Williamson Tract									5									
McDonald Island							1		1									
Medford Island		1					1		1									
Merritt Island		2																
Mildred Island																		
Naglee Burke					1													
New Hope Tract		10	1				1		5									
Orwood Island																		
Palm Tract				1			4											
Pescadero		5										1						
Pierson District		3	1														1	
Prospect Island																		
Quimby Island																		
Rindge Tract									1									
Rio Blanco Tract					1													
Roberts Island	f	13			2				5			3						
Rough and Ready Island																		
Ryer Island																		
Sargent Barnhart Tract																		
Sherman Island			1					1			2			1				1
Shima Tract		2																
Shin Kee Tract			1				1											
Stark		2		2														
Staten Island				2				8	1									
Stewart Tract		1										1						
Sutter Island																		
Terminous			3		1		3	1										
Twitchell																		
Tyler Island		2						1	2									
Union Island	g	7	2			1			1									
Van Sickle Island				1														
Veale Tract																		
Venice Island													1					
Victoria Island				3														
Webb Tract																		
Woodward Island				1			2							1				
Wright-Elmwood Tract																		

USGS 1

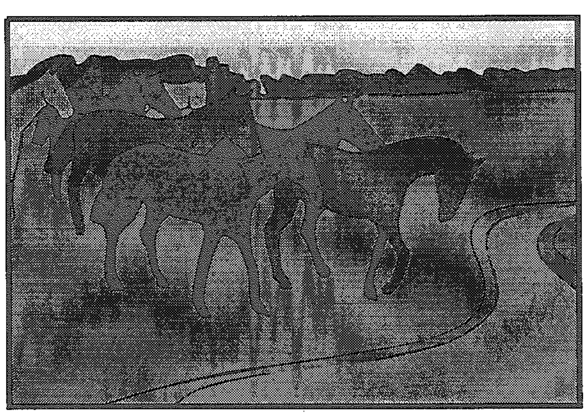
	Reclamation	
ISLAND	District	USGS Quad
Bacon Island	2028	Bouldin Island, Woodward Island
Bethel Island	-	Bouldin Island, Jersey Island
Bishop Tract	2042	Terminous
Boggs (Moss Tract)	404	Stockton West
Bouldin Island	756	Bouldin Island, Isleton, Terminous
Brack Tract	2033	Thornton
Bradford Island	2059	Jersey Island
Brannan/Andrus Island	-	
Andrus	317	Bouldin Island, Isleton
Andrus, Isleton	407	Isleton
Andrus, Upper	556	Isleton
Brannan	2067	Rio Vista, Jersey Island
Byron Tract	800	Clifton Court Forebay, Woodward Island
Canal Ranch	2086	Thornton
Coney Island	2117	Clifton Court Forebay
Dead Horse Island	2111	Thornton
Empire Tract	2029	Terminous
Fabian Tract	773	Clifton Court Forebay, Union Island
Fay	2113	Woodward Island
Glanville Tract	1002	Bruceville
Grand Island	3	Rio Vista, Courtland, Isleton
Hastings Tract	2060	Dozier, Liberty Island
Holland Tract	2025	Bouldin Island, Woodward Island
Holt Station	2116	Holt
Hotchkiss Tract	799	Jersey Island
Jersey Island	830	Jersey Island
Jones Tract	-	
Jones, Lower	2038	Woodward Island, Holt
Jones, Upper	2039	Woodward Island, Holt
King Island	2044	Terminous
Little Mandeville	2118	Bouldin Island
Mandeville Island	2027	Bouldin Island
McCormack Williamson Tr	2110	Bruceville
McDonald Island	2030	Bouldin Island, Woodward Island, Holt, Terminous
Medford Island	2041	Bouldin Island
Merritt Island	150	Clarksburg, Courtland
Mildred Island	2021	Woodward Island
Naglee Burke	1007	Union Island
New Hope Tract	348	Bruceville, Thornton
Orwood Island	2024	Woodward Island
Palm Tract	2036	Woodward Island
Pescadero	2058	Lathrop, Union Island
Pierson District	551	Courtland
Prospect Island	1667	Rio Vista, Liberty Island
Quimby Island	2090	Bouldin Island
Rindge Tract	2037	Holt, Terminous

USGS 2

ISLAND	Reclamation District	USGS Quad
Rio Blanco Tract	2114	Terminous
Roberts Island	-	
Roberts, Lower	684	Holt
Roberts, Middle	524	Stockton West, Holt
Roberts, Upper	544	Lathrop, Union Island, Holt
Rough and Ready Island	-	Stockton West
Ryer Island	501	Rio Vista, Liberty Island, Courtland, Isleton
Sargent Barnhart Tract	2074	Stockton West
Sherman Island	341	Antioch North, Jersey Island
Shima Tract	2115	Lodi South, Terminous
Shin Kee Tract	-	Terminous
Smith	1614	Stockton West
Stark	2089	Union Island
Staten Island	38	Bouldin Island, Isleton, Thornton
Stewart Tract	2062	Stewart, Union Island
Sutter Island	349	Courtland
Terminous	548	Thornton, Terminous
Twitchell	1601	Jersey Island
Tyler Island	563	Isleton
Union Island	1, 2	Clifton Court Forebay, Woodward Island, Union Island, Holt
Van Sickle Island	1607	Honker Bay
Veale Tract	2065	Woodward Island
Venice Island	2023	Bouldin Island
Victoria Island	2040	Clifton Court Forebay, Woodward Island, Holt
Walnut Grove	554	Thornton, Isleton
Webb Tract	2026	Bouldin Island, Jersey Island
Weber	828	Stockton West
Winter Island	2122	Antioch North
Woodward Island	2072	Woodward Island
Wright-Elmwood Tract	2119	Stockton West, Lodi South, Holt, Terminous
-	307	Clarksburg
-	369	Thornton, Courtland
-	536	Rio Vista
-	765	Clarksburg
-	813	Courtland
-	900	Sacramento West
-	999	Clarksburg, Liberty Island, Courtland
-	1608	Lodi South, Stockton West
-	2084	Rio Vista
-	2093	Liberty Island
-	2095	Vernalis, Lathrop
-	2098	Liberty Island
-	2121	Woodward Island

APPENDIX E

SUBSIDENCE REPORTS



SUBSIDENCE AND LEVEE INTEGRITY IN THE SACRAMENTO-SAN JOAQUIN DELTA

By
The Subsidence Sub-Team
of the Levees and Channels Technical Team

DRAFT

December 16, 1998

Summary

Island subsidence has played a key role in bringing the Delta islands to where they are today; relatively tall levees (8 to 25 feet above sea level) protecting interiors (up to 22 feet) below sea-level. Island subsidence is an important issue in the Delta. The Subsidence Subteam, however, was tasked with addressing the relation of island subsidence to levee system integrity.

The risk to levee integrity from island subsidence has diminished because of improved levee maintenance practices and land management practices. Island subsidence rates have decreased, and levee construction techniques have improved. In addition, a zone of influence extending from the levee crest to some distance inland has been identified, beyond which interior island subsidence will not affect levee integrity. The levees lose ground elevation on their own due to the addition of levee material, but this is a very different process than island subsidence. This report addresses subsidence as it affects levee integrity within the zone of influence adjacent to levees.

Goal

The goals of the Subsidence element of the Levee Program are to reduce or eliminate the risk to levee integrity from subsidence, and assist in the coordination of subsidence-related linkages with the other CALFED programs.

Scope

The Long Term Levee Protection Plan focuses on subsidence that affects the levee system. This report describes Delta conditions, causes of subsidence, subsidence as it affects levee integrity, mitigation options related to levee integrity, and target areas for subsidence control based on the best available information. Subsidence issues, concerns, and solutions will also be addressed in the Ecosystem Restoration and Water Quality Programs.

Conditions In The Delta

<u>Surface and subsurface materials.</u> (References 5 through 12)

The present-day Delta deposits began to form during the end of the last glacial period, 7,000 to 11,000 years ago as sea level began to rise (Ref 4). As the Delta evolved, tributaries formed a series of channels, natural levees, berms, islands and sloughs. The major rivers and channels periodically incised, then were backfilled as the climate changed. Tules, reeds, and other fibrous aquatic plants growing at water level were preserved as peat beds when post glacial sea levels rose slowly and inundated the

Delta. Under natural conditions, the islands received fine- and coarse-grained sediments during river floods. As a result, the subsurface sedimentary profile generally contains inter-bedded layers of sand, silt, clay and peat of varying thickness. The complexity of subsurface conditions is reflected in the wide variety of surface soil types found throughout the delta. The surficial materials encountered in the Delta include mineral soils, mineral organic complexes, organic soils, and peat.

Ground surface elevations. (Reference 11, Delta Atlas)

Ground surface elevation varies throughout the Delta from the high ground along the levee crests to the low ground in the island interiors. Levee crest elevations generally range from about 8 to 25 feet above sea level. A significant portion of Delta land surface is below sea level. Lowest surface elevations are on the order of 22 feet below sea level. Refer to Figure 1 (based upon a 1974 survey) for an indication of the extent of land surface elevation below sea level. Updated ground surface elevation data is needed.

Island Subsidence and Levee Subsidence

Definition

Subsidence is a downward movement of the ground surface over time. For the purposes of this report, "Island subsidence" refers to the loss of interior Delta island ground surface elevation. The downward movement of the levee itself, generally due to an application of a load, is referred to as "levee subsidence." The causes and impacts of levee subsidence are much different than the causes and impacts of island subsidence, but the primary causes of both will be discussed here together because there is an overlap of contributing causes.

Causes of Island Subsidence and Levee Subsidence (References 1 through 12)

Island subsidence and levee subsidence in the Delta are mainly caused by near-surface processes including consolidation/settlement, shrinkage, and aerobic decomposition. Other near-surface causes of island and levee subsidence include anaerobic decomposition, wind erosion, and burning. Deep seated causes of subsidence include the withdrawal of oil, natural gas, and water, and tectonic activity. These causes were assumed to contribute little to present-day subsidence.

a) Consolidation/settlement: Consolidation/settlement occurs in response to an increase in load, such as when ground water is removed or when materials are deposited in an area by humans or nature. Consolidation due to levee building (increasing loads on foundation materials) is the primary cause of levee subsidence. Consolidation also occurs due to increased effective stress on underlying peat and decreased buoyant forces supporting peat as a result of incremental dewatering (Ref. 1).

b) Shrinkage: Shallow de-watering is considered a cause of island and levee subsidence because it leads directly to shrinkage and drying of soils above the water table, consolidation of soils just above the water table, and leads to aerobic decomposition of organic soils above the water table. The relative effect of each of these factors depends on the amount of organic matter in the soil, the depth of de-watering, and climate. With each incremental lowering of the water table, the contribution to island subsidence from shrinkage, consolidation, and oxidation are all high. With time, long-term island subsidence is sustained by oxidation. Shrinkage is governed by the initial moisture content and the organic matter content. Fine grained organic soils and peat can shrink 50% or more in volume.

c) Aerobic decomposition (microbial oxidation): Long-term island subsidence is sustained primarily by the microbial oxidation of soil organic carbon. The peat soils contain a complex mass of carbon. Microorganisms such as bacteria and fungi use it as an energy source resulting in peat decomposition and the release of carbon dioxide (CO_2) under drained, oxygen-rich conditions. Studies by the Department of Water Resources and the US Geological Survey (Deverel and Rojstaczer, 1996) demonstrate that the amount of oxidation is proportional to the soil temperature and moisture content.

Oxidation rates increase with temperature, higher pH, and higher organic matter content of the soil. There is an optimum moisture content for oxidation; oxidation decreases at very high and very low moisture contents. Drainage and tillage promote aerobic decomposition, but island subsidence is not substantially affected by crop type. Island subsidence due to oxidation will decrease with time as the organic matter content in the upper soil decreases and the relative percentage of mineral constituents increases. There does not appear to be a correlation between peat thickness and subsidence rates. There is a direct correlation between depth to the water table and the amount of subsidence due to microbial oxidation. The higher the water table, the less the island subsidence.

Levee Subsidence (Reference 4,12,13)

Most levee subsidence is caused by the weight of the levee fills compressing the foundation materials. The foundation materials underlying the levees vary throughout the Delta from various thicknesses of peat soils to mineral soils. Rate of levee building and foundation conditions govern levee subsidence rates and the total amount of subsidence. Geotechnical engineering fundamentals must be applied to safely and economically build new levees and rehabilitate existing levees founded on weak, compressible materials.

Regardless of load application to the levees, the levees settle with time. In the 1960's, a set of curves was developed for estimating crest settlement with respect to variables of peat thickness, height of levee, and age of levee. These curves were updated to incorporate recent data, and are included as Figures 8 and 9. These curves of predicted movement were compared with actual crest elevation measurements on selected islands, and results indicated that measured settlements were generally comparable to calculated values and ranged from 2 to 7 inches per year (Ref 5).

There is a great deal of information on the causes and effects of interior island subsidence, but interior island subsidence has never been directly linked in publications to levee subsidence. A recent Corps of Engineers geotechnical report stated that, "Independent of the island subsidence, the levees settle with time. This settlement is caused primarily as a result of consolidation and plastic flows of the underlying organic soils. Since island subsidence is independent of levee settlement, numerous levee geometries are produced (Ref. 5)." Although "independent," the Corps document recognizes that island subsidence may influence levee integrity. This document also presents the concept of a "zone of influence(ZOI)," beyond which interior island subsidence does not affect levee integrity.

The Corps developed curves for estimating settlement of fills placed on organic material (figures 6 and 7). Considerable judgement should be exercised in using these curves. As examples, settlements were calculated using these curves for a 4.5-foot-thick stabilizing berm and a 2-foot-thick subsidence control cap. Assuming a 45-foot-thick unconsolidated peat layer, the 4.5-foot thick fill causes approximately 13.8 feet of total settlement at an initial time-averaged rate of about 6 inches per year, and the 2.5-foot-thick soil cap causes approximately 6.0 feet of total settlement at an initial time-averaged rate of about 2 inches per year. Based on experience, the calculated settlements are too high and the initial settlement rates are too low. It is common in the Delta for new fill to settle rapidly and total settlement to be roughly equal to the applied fill layer thickness. When compared to interior island subsidence, levee subsidence (settlement) can be significantly greater than island subsidence and is probably the primary reason for performing a high level of levee maintenance.

Near-levee subsidence will effect levee stability. This subsidence is the result of de-watering and the associated consolidation, shrinkage and decomposition of high organic content materials near the levee. Engineering analysis indicates there is a discrete distance away from a levee, a zone of influence, beyond which subsidence no longer adversely affects levee integrity.

Zone of Influence

The zone of influence is an area from the crest of the levee to some distance inland where island subsidence may impact levee integrity. Beyond this zone of influence, island subsidence will not affect levee integrity. Although the ZOI for a reach of levee can only be determined using site-specific data, geotechnical engineering analysis and judgement can be applied to characterize its extent. The Subteam estimated the ZOI for planning purposes. Based upon available information and engineering judgement, the ZOI is estimated to range from 0 to 500 feet from the levee crest, depending on site-specific conditions. Since the ZOI is a site-specific characteristic, it could change with time as site conditions change. The following engineering analyses could contribute to the determination of the ZOI on a site-specific basis.

a) Static stability: geotechnical engineers use stability analysis to determine factors of safety and critical failure modes for earthen structures (Refer to Figure 2). Numerous Delta levee stability analyses indicate that there is a definable distance from the levee beyond which soil properties and changes do not affect levee stability. The limiting distance often turns out to be approximately 3- to 4-times the thickness of the peat layer beneath the levee. For example, the thickness of the deepest peat layer in the Delta is approximately 60 feet (Refer to Figure 3). Therefore, any island subsidence beyond 180-to 240 feet from the levee would probably not affect static levee stability. If the peat layer was less thick, which it is for most of the Delta, then the distance would be smaller for static stability.

b) Seepage: Subsidence of the land side ground surface adjacent to a levee may cause through-levee and foundation seepage changes. Changes in hydraulic gradients, seepage volume, water levels, and exit gradients may all result from subsidence. Site specific analysis will determine whether these changes impact levee integrity, however, we can use generalized flow net analysis to make some observations.

Flow net analyses indicate that critical exit gradients are most likely to be exceeded at or in close proximity to the levees. Critical gradients are less likely to be exceeded as the distance from the levee increases. In addition, flow net analyses indicate that drainage ditches located near the levees can have a detrimental effect on levee seepage (Refer to Figure 4). Interior island subsidence adjacent to levees could affect seepage by decreasing the seepage path. A shorter seepage path leads to increased seepage. Increased seepage may lead to piping and levee integrity problems.

Seepage analyses also indicate that there is a definable distance from a levee beyond which soil properties and changes in ground surface elevations do not affect seepage and levee integrity. Similar to the stability analyses, determining a precise zone of influence with respect to seepage is difficult, because seepage is dependent upon complex local subsurface conditions and levee and foundation geometry. What the seepage modeling and "flow nets" show, however, is that there are limits beyond which changes and affects are negligible. Thus we can deduce that there are boundaries beyond which changes will not affect seepage and levee integrity. This boundary can be determined through site-specific analysis, but from a practical standpoint, wherever an open seepage collection trench can be constructed without jeopardizing levee integrity, then interior island subsidence beyond that point is unlikely to be a levee concern.

c) Deformation: Deformation is the spreading movement of soft soils in a reaction to load. Deformation can also be the result of loss of support at the levee toe, i.e, subsidence, and excavation of a drainage ditch. The Sherman Island deformation analysis report (ref 13) provided analysis for an island that might be considered worst-case due to the thickness of the peat layer beneath the levee and the size (load) of the levee. Although the Sherman Island analysis did not consider the impact of future island subsidence on deformation, the information indicates that there is a distance beyond which deformations do not occur. For the computer deformation modeling, a boundary condition was set at approximately 300 feet from the crest of the levee, a distance beyond which deformation did not occur. Extreme future island subsidence may impact a levee, however, it is important to note that island subsidence occurs slowly, and that levees usually adjust to island subsidence as it occurs without detrimental effects on stability.

Clearly, the zone of influence will vary with site specific levee and foundation conditions and levee geometry. For example, the greater the height of the levee embankment above the island floor and the greater the thickness of weak and compressible layers, such as peat, the wider is the zone of influence. Monitoring and research will later define this zone.

Hydrostatic Pressure.

It has been commonly reported that subsidence of island interiors leads to increased hydrostatic pressure and levee instability. The implication that levees are now required to withstand a greater hydrostatic head of water than they were originally constructed is inaccurate in that the exterior water elevations remain the same. However, a decrease in the land mass resisting such hydraulic pressures may occur. Also, seepage forces and quantity will change due to increased hydraulic gradient. The decrease of island surface elevations is a contributing cause to the need for ongoing work to maintain the height and desired safety factor of the levees. Periodic levee improvements replace some of the land mass that was lost to subsidence.

Island Subsidence

Island Subsidence will be generally discussed here, because the focus of this report is subsidence as it impacts levee integrity. Island subsidence impacts levee integrity only when it occurs in proximity to a levee. Subsidence within the ZOI may decrease stability, increase seepage, increase the potential for piping, or increase the potential for levee deformation. At many locations, however, island subsidence is occurring too slowly or too far from the levee to be a threat to levee integrity. As long as the ZOI is protected from subsidence, levee integrity with respect to island subsidence should be assured. Although island subsidence outside of the ZOI does not impact levee integrity, it does impact the interior of Delta islands and their associated land uses.

Historically, time-averaged Delta-wide island subsidence rates have ranged from about 0.5 to 5.0 in/yr. Recent research indicates that island subsidence varied from about 0.2 in/yr to 1.2 in/yr for soils with organic contents varying between 20% and 50% (Reference 4, Rojstaczer and Deverel (1995).

Subsidence rates are slowing . Present day subsidence rates were measured continuously from 1990 to 1992 by Deverel and Rojstaczer (1996) on Sherman and Jersey Islands and Orwood Tract. These authors reported rates of 0.2, 0.24, and 0.32 inch per year on Sherman, Jersey, and Orwood, respectively.

Island subsidence rates are site specific. No single island subsidence rate, such as the commonly used 2.5 to 3 inches per year, is valid for an entire island. Total island subsidence rates vary greatly and average island subsidence rates at specific sites appear to be diminishing with time. Rates may be greater in areas subjected to new or deeper de-watering.

Remedial Action and Prevention

The approach to control of levee subsidence will be fundamentally different than the means and methods employed to control island subsidence because of the differences in the primary causes of subsidence.

<u>Levees</u> (References 4 through 13)

Potential levee subsidence mitigation actions that should be considered are:

1)Thorough application of geotechnical engineering principles and practices in conjunction with proven construction methods. Levee subsidence will continue as long as levee building and repair continue to add loads onto weak compressible foundations.

2)Seepage control, de-watering efforts, excavations, and land management activities in proximity to levees must be modified to minimize adverse impacts to levee integrity.

3)Stability and drainage berms can be strategically located and sequentially constructed to minimize or prevent levee deformation.

4)Land leveling and other ground surface modifications (e.g. ditching) should be restricted within the zone of influence. High ground water levels and vegetative growth could be tolerated in some areas to accommodate measures aimed at reducing island subsidence due to oxidation.

<u>Island Interiors, Including the ZOI</u> (References 1 through 10)

Currently the best approaches to managing island subsidence, include a) minimizing or preventing the lowering of the groundwater level, b) capping or covering susceptible surface deposits with mineral soil, and c) permanent shallow flooding. and d)reverse wetland flooding.

Delineation of Target Areas for Subsidence

Subsidence control and monitoring will be most important for the western and central Delta islands, where the depth of organic soils are the greatest and the organic content of the deposits are commonly high. Previous attempts at prioritizing areas and islands, based on depth of peat and organic matter content, provide a good starting point for the development of a subsidence control and prevention program. It appears from this initial prioritization effort that only some islands and in some cases only parts of islands are affected. Refer to Figures 5-1 through 5-8, Subsidence Target Areas, for examples of islands and levee reaches most likely to be affected by subsidence (Deverel 1997, References 1&2). The number of levee miles potentially affected by subsidence was calculated using Figure 5. About 60% of the levees in the central and western Delta, but less than 30% of all the levees in the legal Delta, are targeted for subsidence control.

The objective of the maps in Figures 5-1 through 5-8 is to target areas for subsidence monitoring and control in the Delta. The general approach was to enter recent available data for the Delta for island subsidence rates, depth of peat soils and soil characteristics into a geographic information system (GIS). The estimates for rates of island subsidence and peat thickness are an improvement relative to the previous efforts by the Department of Water Resources because 1) the error in the estimated island subsidence rate is lower, quantifiable and the result of uniform elevation change measurements, and 2) the estimates for peat thickness are based on more recent and comprehensive data.. Also, the data was entered into a GIS which facilitated the evaluation of the data for delineation of target areas in greater areal detail than entire islands such as is presented in Department of Water Resources (1980).

The areal distribution of island subsidence rates and peat thickness is used to delineate target areas for additional data gathering and monitoring. The maps in Figures 5-1 through 5-8 used the estimated ZOI boundary of 500 feet around the islands. Within this boundary, the target areas are those where the island subsidence rates are high and there is substantial peat remaining. The target areas have time-averaged island subsidence rates greater than 1.5 inches per year (island subsidence rates ranged from about 0.4 inches per year to 5 inches per year) and peat thickness greater than 10 feet within the 500 foot boundary.

The term "peat" has been defined in many different ways. For the maps in Figure 5, "peat" will refer to peat or peaty mud of tidal wetlands comprised of the organic deposits derived from decayed vegetation that formed as the result of sea level rise during the last 7,000 to 11,000 years. The peat thickness shown on the maps was calculated as the difference between the basal elevation of peat or peaty mud deposits of tidal wetlands as mapped by Atwater (1982) and the land-surface elevation from the USGS topographic maps(1976-1978). Atwater's delineation of peat and peaty mud include the organic soils mapped by Cosby (1941) and more recent soils surveys. The maps reflect borehole data collected as of 1980.

Monitoring

Subsidence monitoring should be tied to constructed base level projects because these areas provide the most economical opportunities for gathering more data in conjunction with construction explorations and monitoring. Subsidence monitoring should start with an evaluation of existing soils and their distribution and a determination of land surface elevation within Target Areas in the Delta. Efforts should be directed to areas on and adjacent to the levees, within the ZOI. From a new, continually updated database, a target list of levees and islands being impacted by subsidence can be maintained. Monitoring will allow subsidence control to be adaptively managed as levee rehabilitation goes forward. This monitoring efforts will be coordinated through CALFED's Comprehensive Monitoring, Assessment, and Research Program (CMARP).

Conclusions

Although subsidence has caused problems in the past, and will continue to be a problem for island interiors, the potential impact of island subsidence on levee integrity has diminished. Land management and levee maintenance practices have improved and island subsidence rates have decreased. As long as island subsidence is adequately managed within the ZOI, levee integrity should be unaffected. Although the ZOI for a reach of levee can only be determined using site-specific data, the Subteam has estimated the ZOI for planning purposes. Based upon available information and engineering judgement, the ZOI is estimated to range from 0 to 500 feet from the levee crest depending on site-specific conditions. The ZOI could change with time as site-specific conditions change.

Subsidence control and monitoring will be most important for the western and central Delta islands, where the depth of organic soils are the greatest and the organic content of the deposits are commonly high. Previous attempts at prioritizing areas and islands, based on depth of peat and organic matter content, provide a good starting point for the development of a subsidence monitoring, control, and prevention program.

The levees identified as being target areas for subsidence remedial action and prevention will require screening and integration with other issues affecting levees such as seismic stability requirements, ecosystem restoration, and Delta water operations. This integration will allow a better prioritization of future subsidence remediation of the Delta levees.

References: Subsidence in the Sacramento-San Joaquin Delta

1. Deverel, Steven J., et al.,(1998); Subsidence Mitigation in the Sacramento-San Joaquin Delta.

2. Deverel, Steven J., (1997) ; Priority Areas For Subsidence Mitigation In The Sacramento-San Joaquin Delta. Draft.

3. Deverel, Steven J. and Stuart Rojstaczer, (1996); Subsidence of Agricultural Lands in the Sacramento-San Joaquin Delta, California: Role of Aqueous and Gaseous Carbon Fluxes; Water Resources Research, Vol.32, No.8, August 1996.

4. Rojstaczer, Stuart and Steven J. Deverel , (1995); Land Subsidence in Drained Histosols and Highly Organic Mineral Soils of California; Soil Science Society of America Journal Volume 59, No. 4 July-August 1995.

5. U.S. Department of Defense, Corps of Engineers, Sacramento District, South Pacific Division and State of California, Department of Water Resources and The Reclamation Board, 1993; Sacramento-San Joaquin Delta, California Special Study, Documentation Report.

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7. U.S. Department of Agriculture-Soil Conservation Service (1989); Land Subsidence in the Sacrament-San Joaquin Delta Literature Review.

8. California, State of (1986); Delta Subsidence Investigation, Progress Report; The Resources Agency, Department of Water Resources, Central District.

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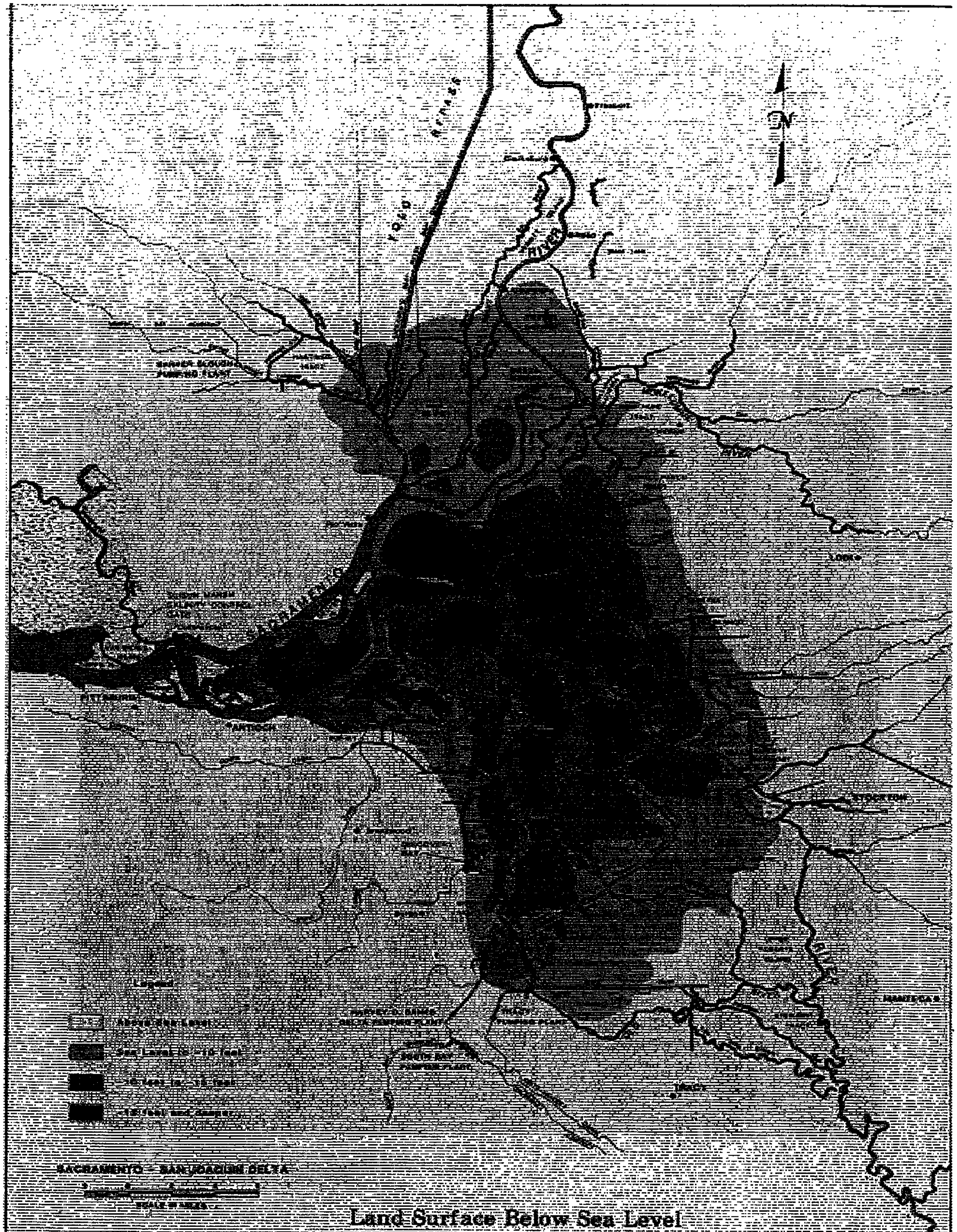
11. Weir, Walter W. (1949) ; Subsidence of Peat Lands of the Sacramento-San Joaquin Delta; Summary by Agricultural Extension Service, San Joaquin County.

12. California, State of (1995); Sacramento San Joaquin Delta Atlas, California Department of Water Resources Reprinted 7/95.

13. U.S. Department of Defense, Corps of Engineers, Sacramento District, Geotechnical Branch, Soil Design Section (1998) ; Office Report titled "Sherman Island Levee Test Section, Geotechnical Basis

of Design.."

14. Foott, Sisson, and Bell (1992) ; Threatened Levees on Sherman Island. A reprint from Stability and Performance of Slopes and Embankments II Proceedings, GT Div/ASCE, Berkeley, CA, June 29-July 1, 1992.



Sacramento–San Joaquin Delta Atlas *Department of Water Resources*

FIGURE 1

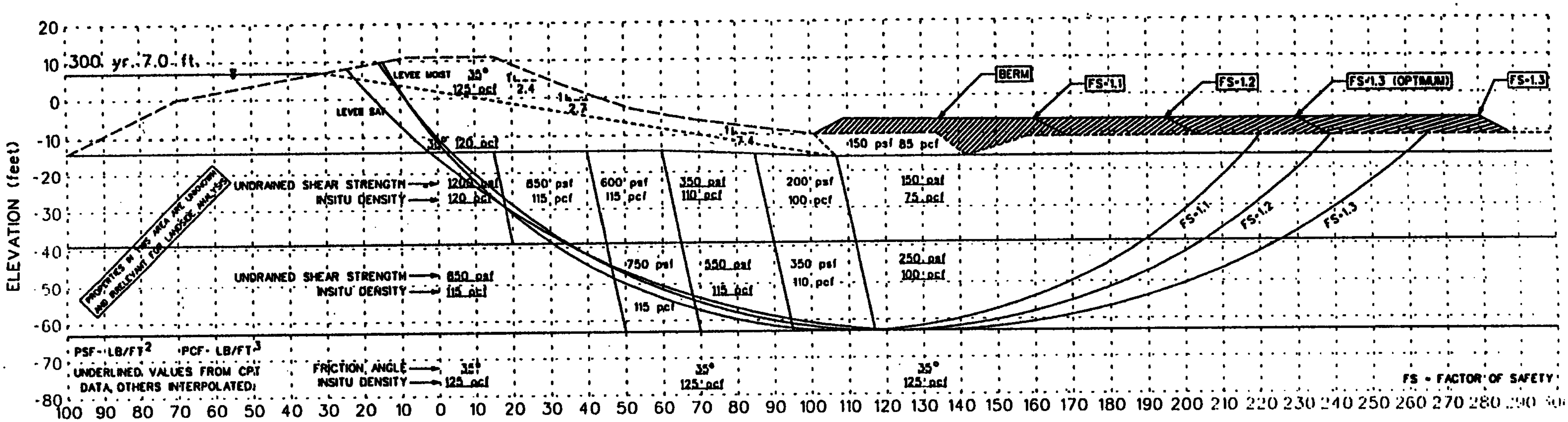


FIGURE 2 SLOPE STABILITY - OPTIMUM BERM SECTION (BERM FILL ONLY).

FIGURE 2

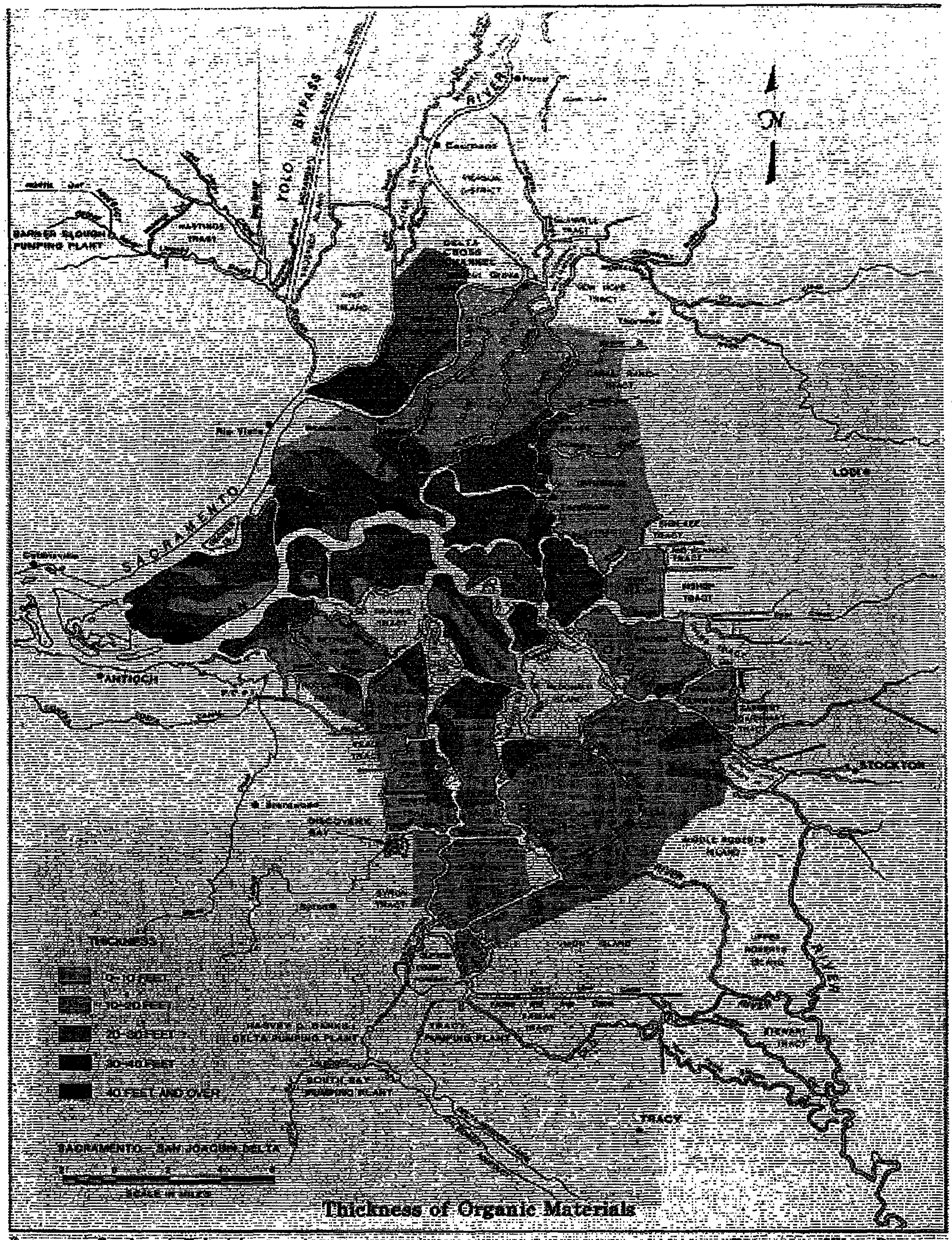
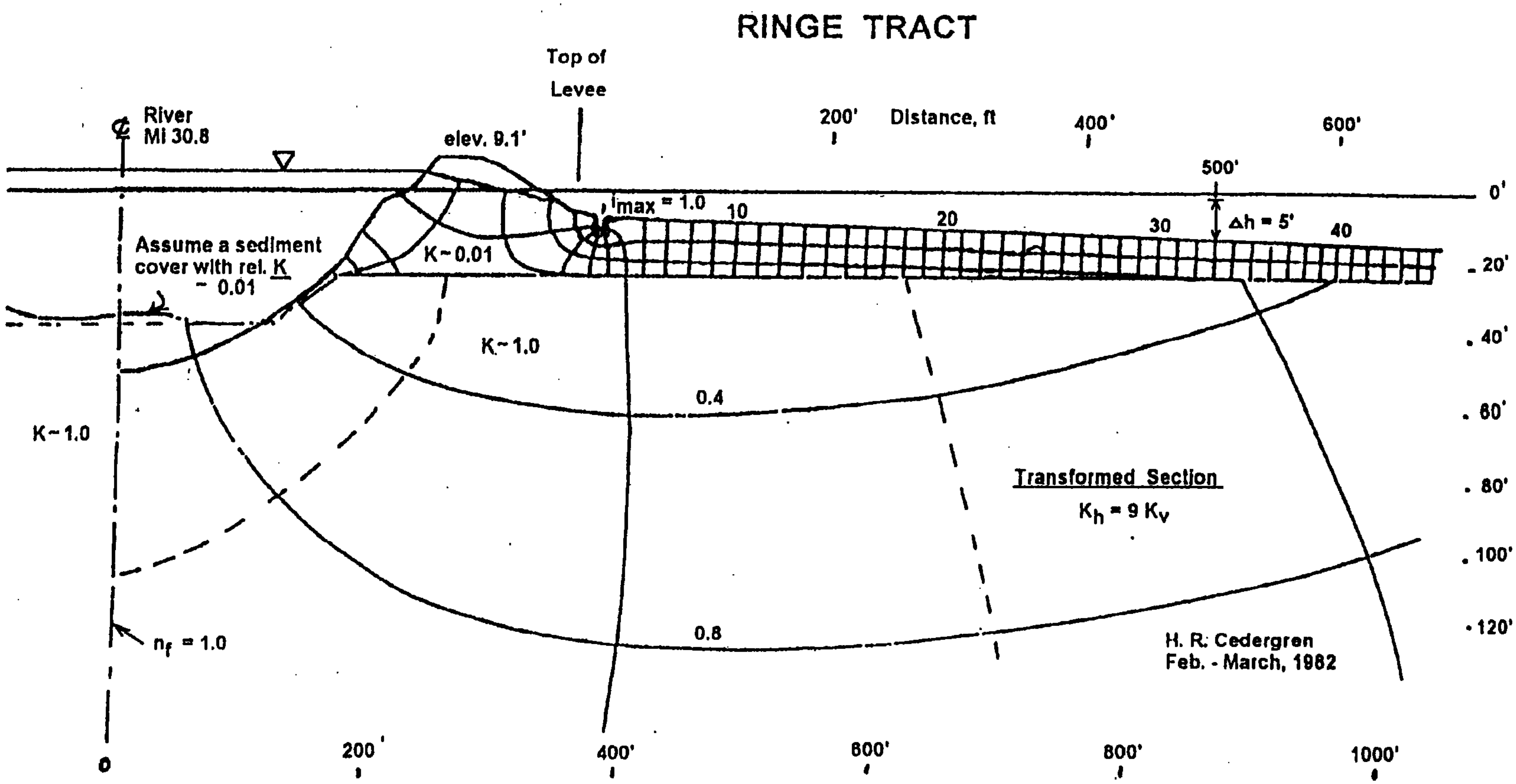

Thickness of Organic Materials
SACRAMENTO
YOLO BYPASS
RIVER
ANTIOCH
STOCKTON
LODI
TRACY
THICKNESS
0-10 FEET
10-20 FEET
20-30 FEET
30-40 FEET
40 FEET AND OVER
SACRAMENTO - SAN JOAQUIN DELTA
SCALE IN MILES
BARKER SLOUGH PUMPING PLANT
HARVEY O. BANKS DELTA PUMPING PLANT
TRACY PUMPING PLANT
SOUTH BAY PUMPING PLANT
DISCOVERY BAY
DELTA CROSS CHANNEL
N

FIGURE 3



STOCKTON DEEP WATER CHANNEL
SEEPAGE STUDY
FLOW NET NO. 6 - NA

SACRAMENTO - SAN JOAQUIN DELTA
APPENDIX B
SPECIAL STUDY
JANUARY 1993

FIGURE 4

Figure 5-1

Brannan & Andrus Islands

Target Areas

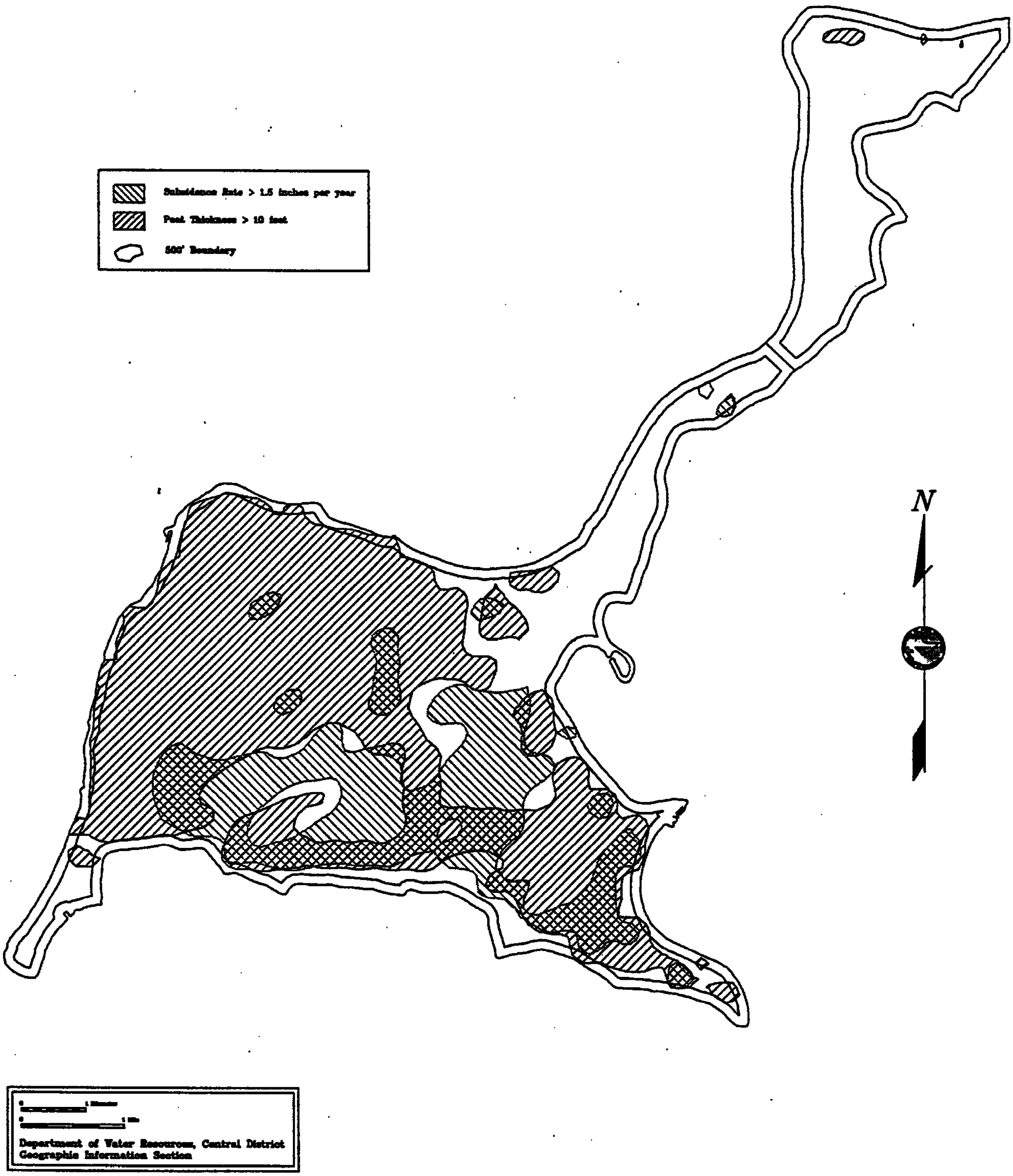


Figure 5–2

Staten & Tyler Islands

Target Areas

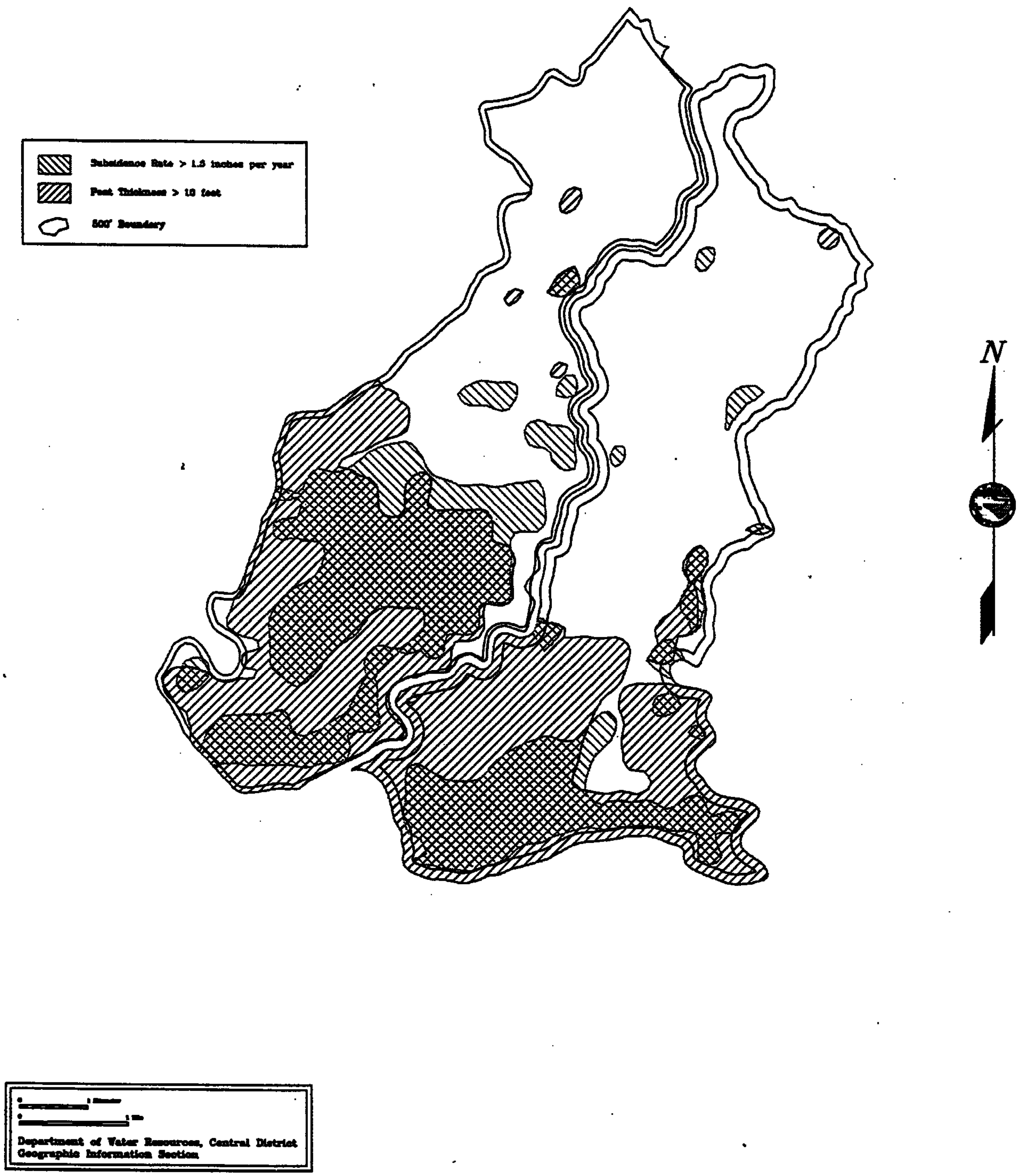


Figure 5-3

Bethel, Bradford, Jersey, Twichell & Webb

Target Areas

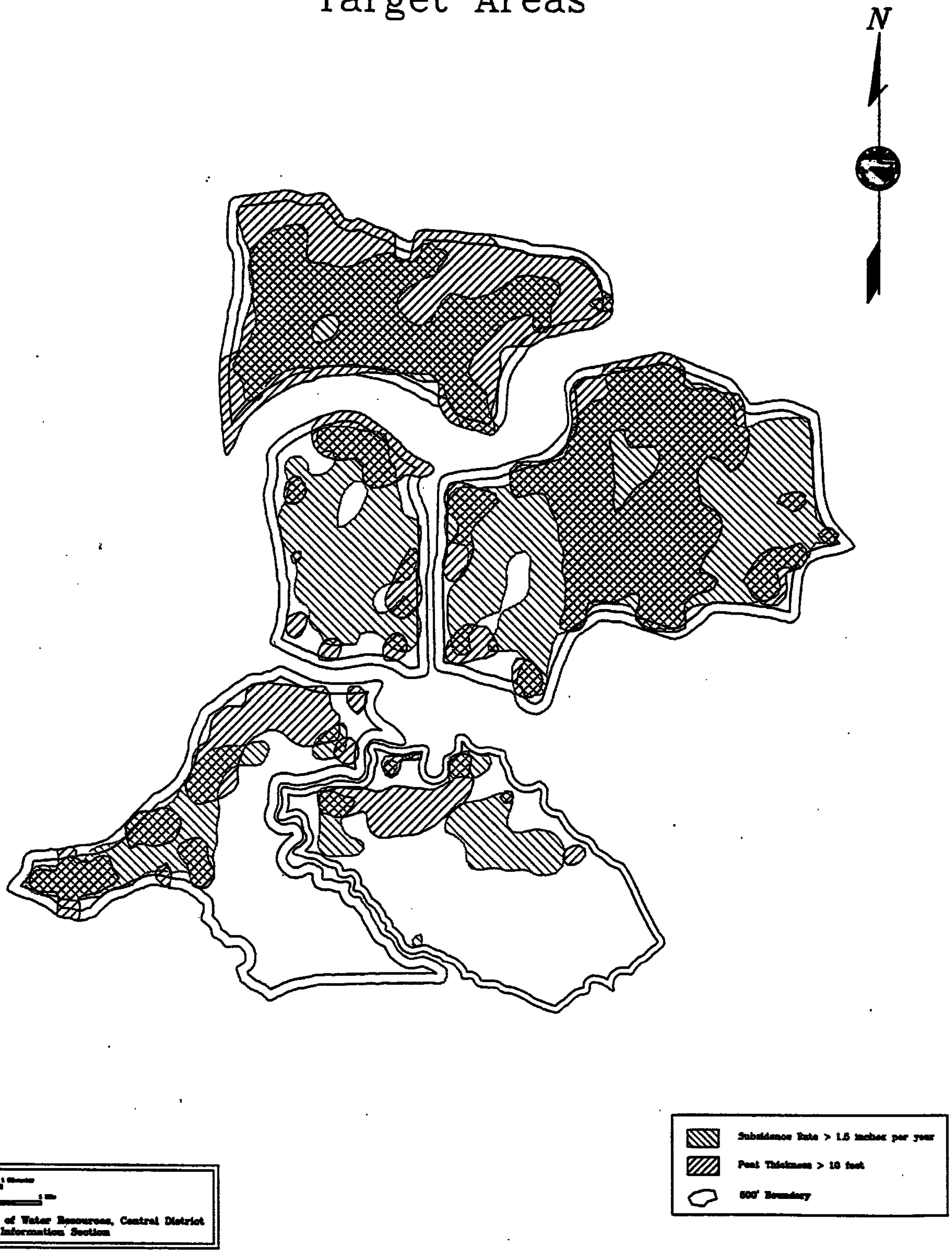


Figure 5-4

Sherman Island

Target Areas

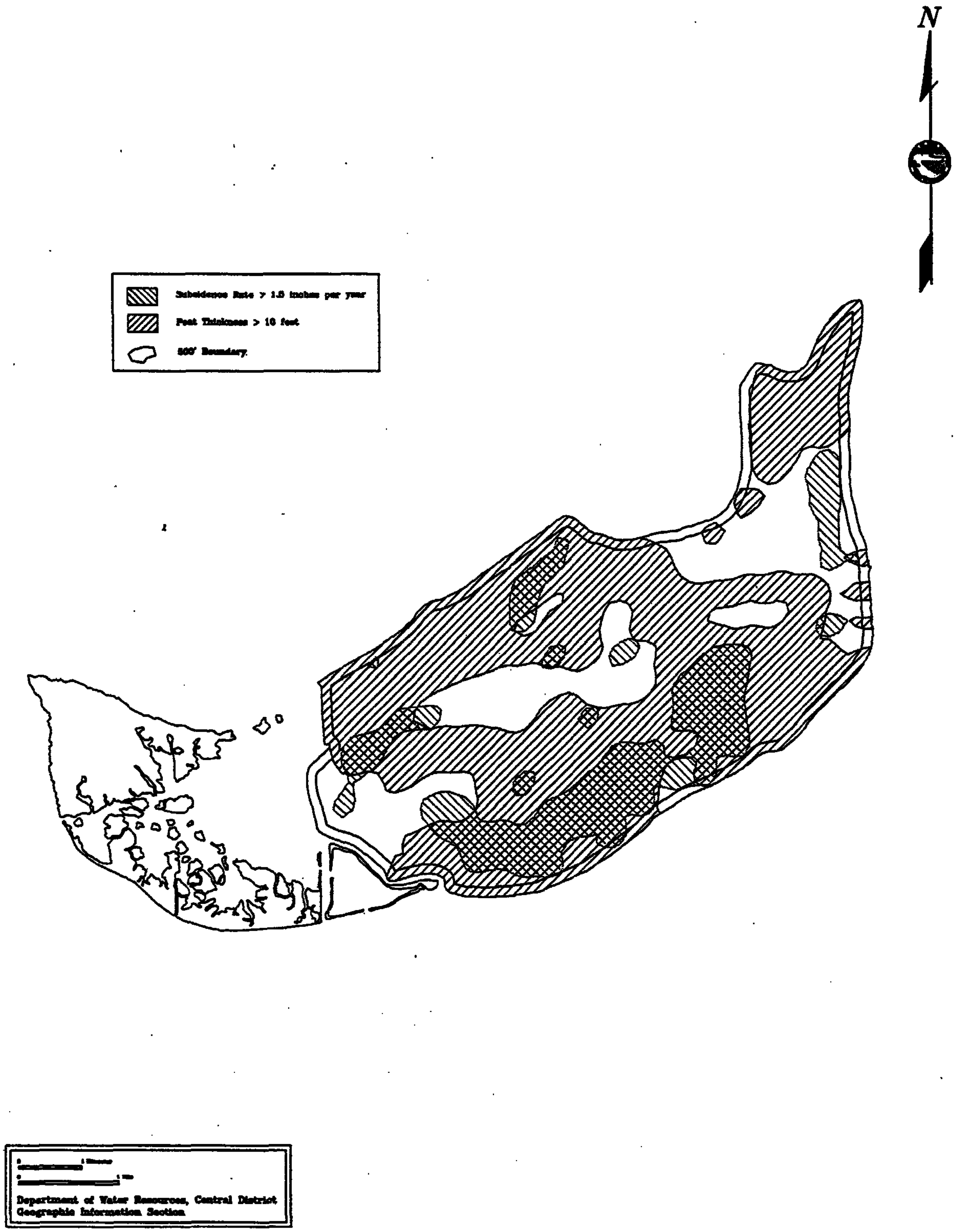


Figure 5-5

Bouldin, Empire, McDonald, Medford & Venice

Target Areas

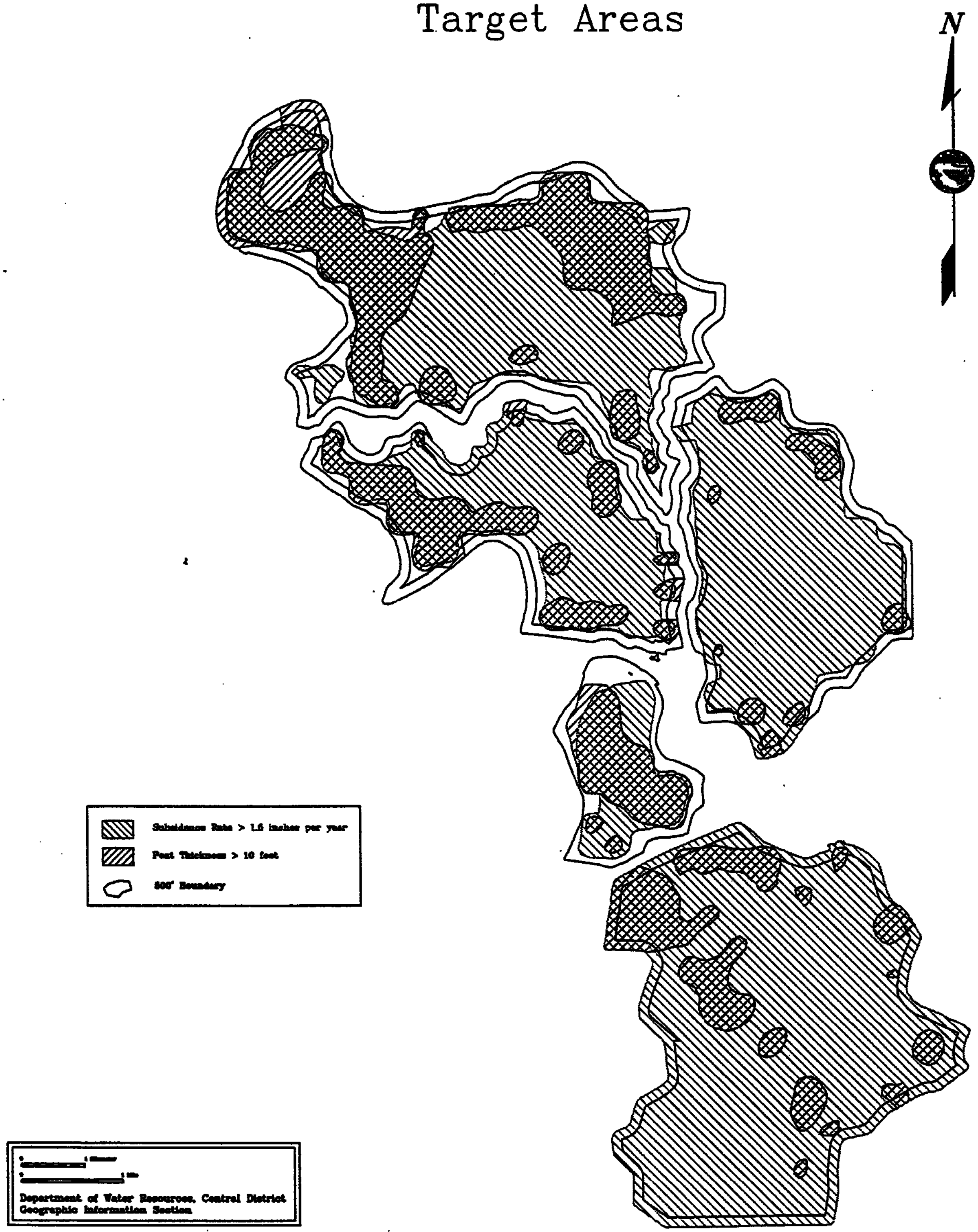


Figure 5-6

King & Ringe

Target Areas

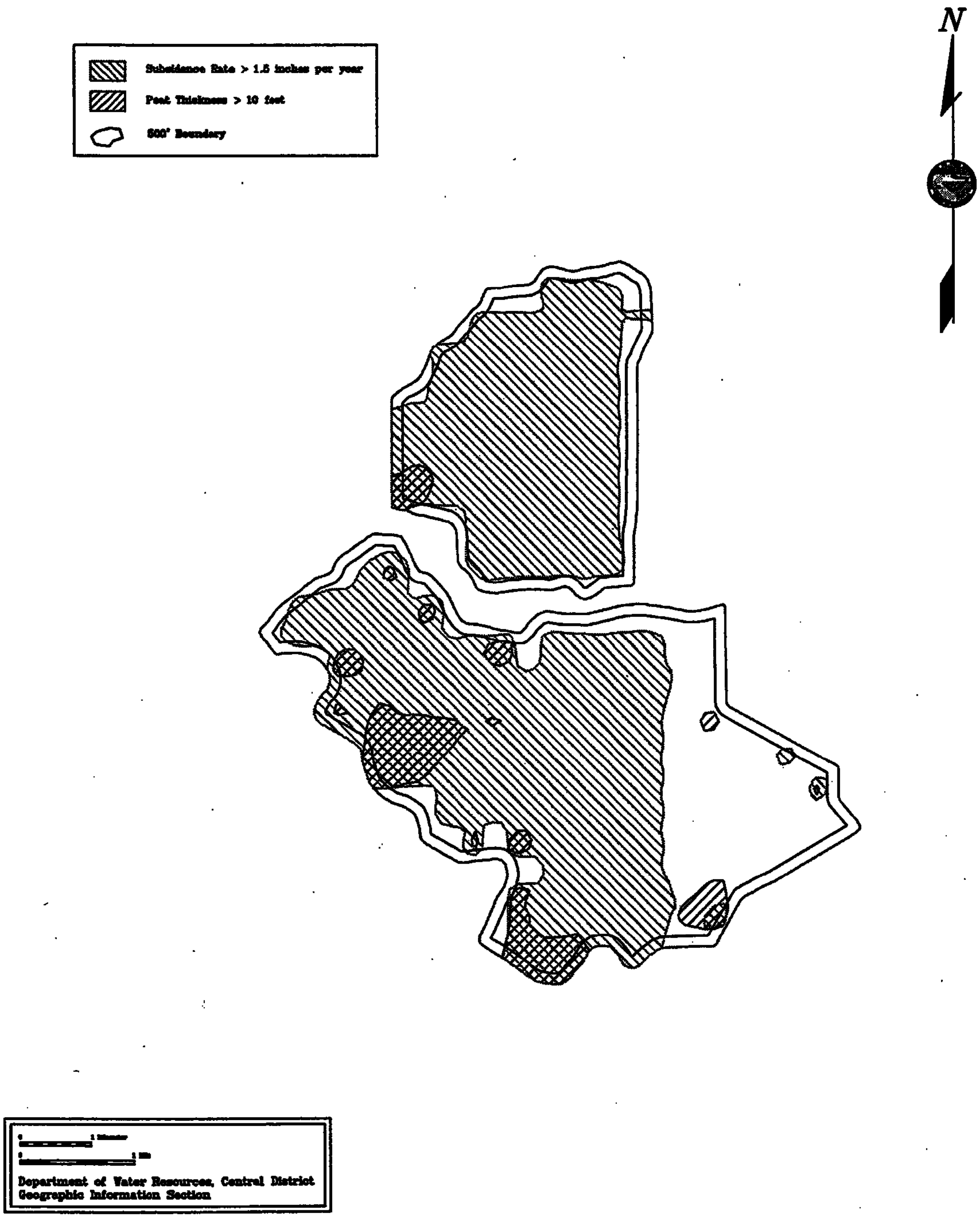


Figure 5–7

Bacon, Holland, Hotchkiss Palm, Quimby & Veale

Target Areas

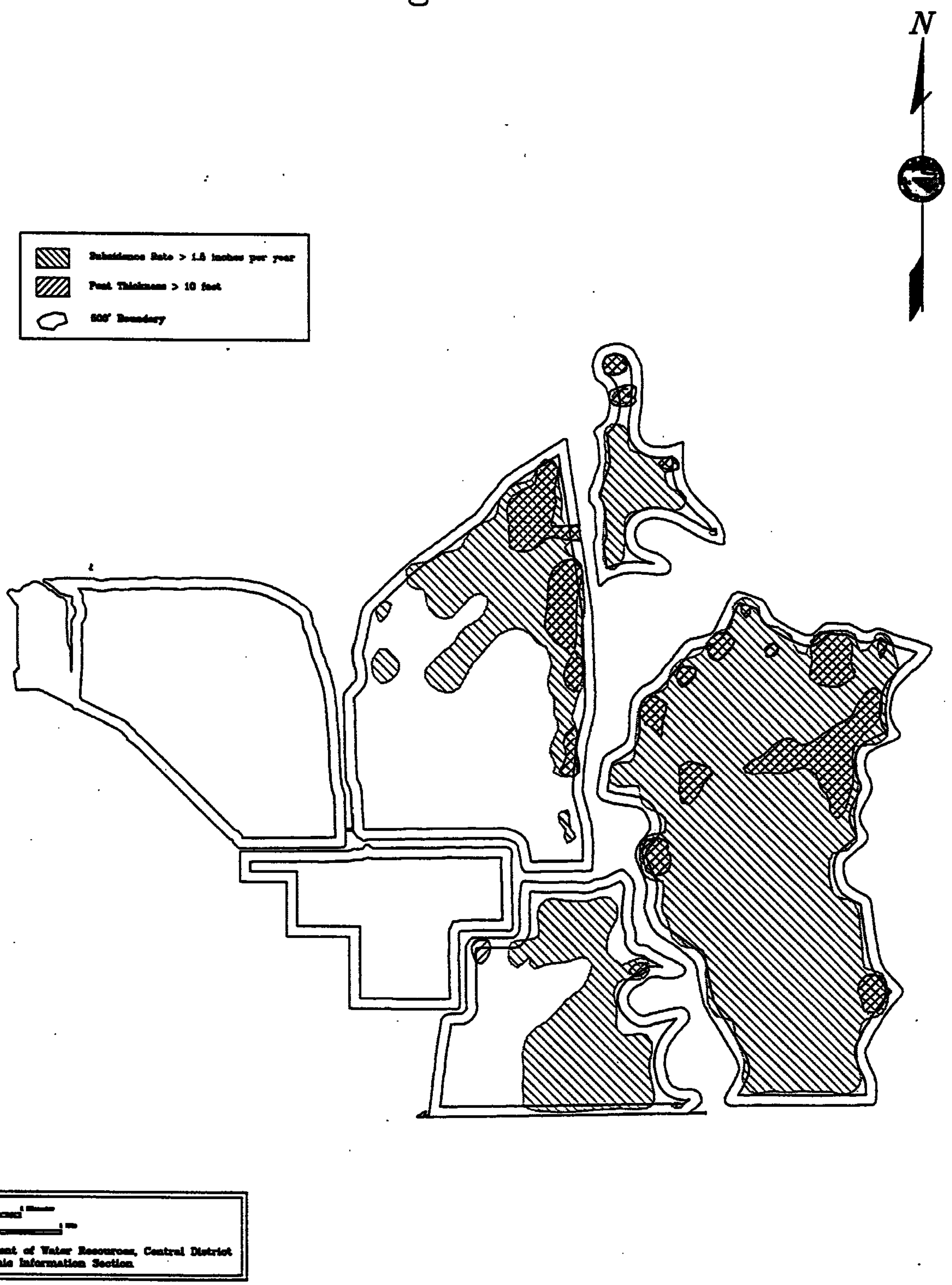
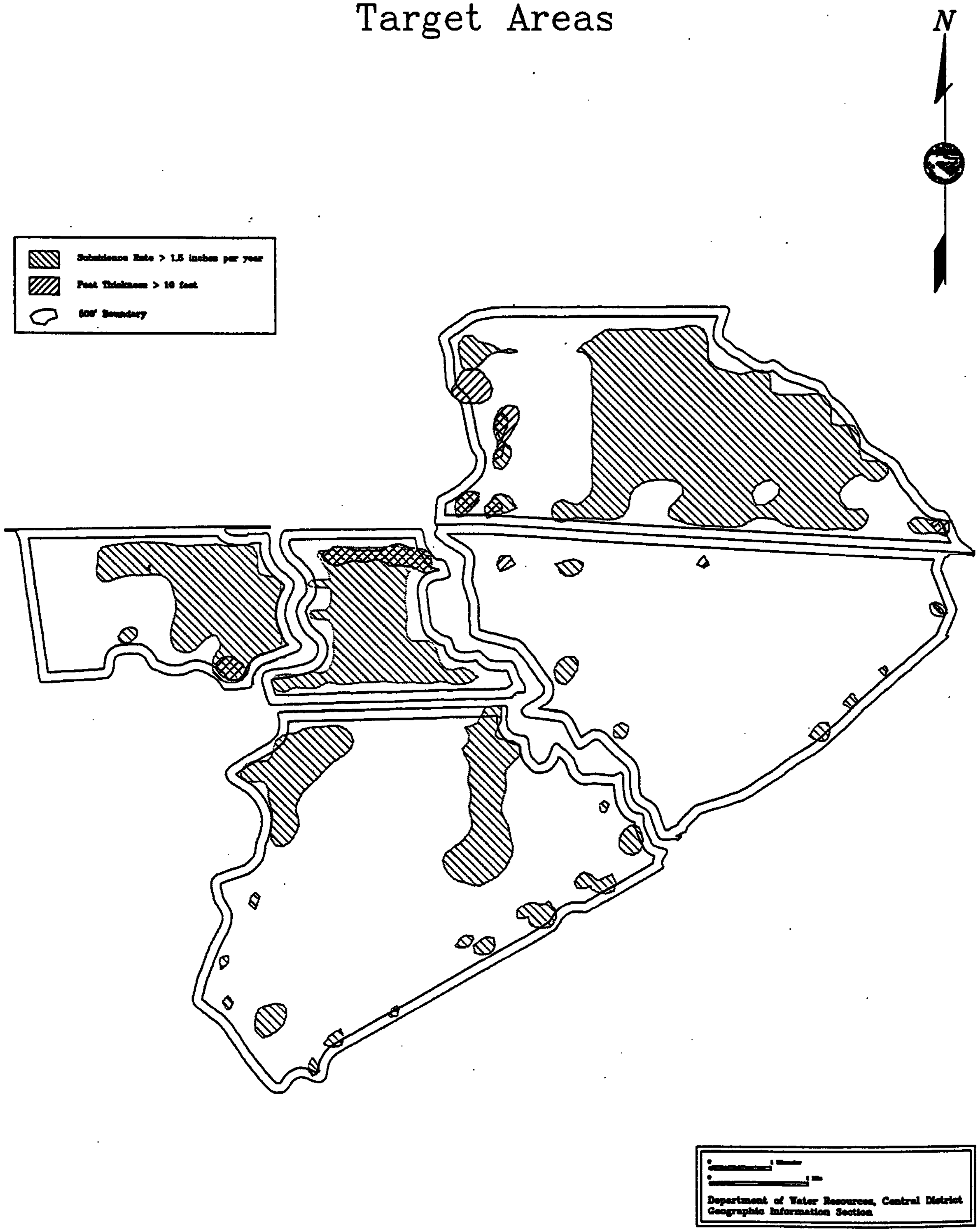
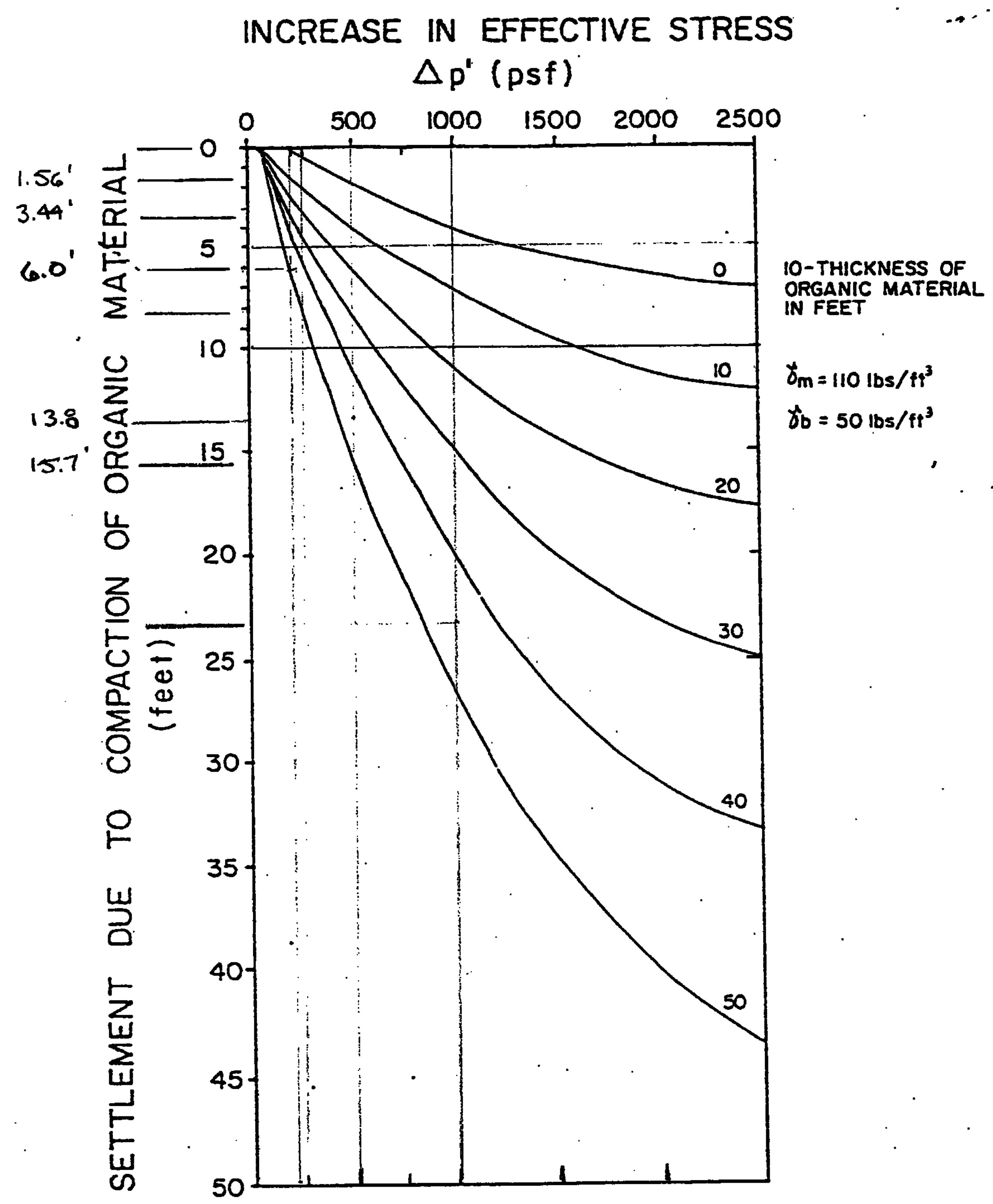


Figure 5-8

Upper & Lower Jones, Orwood Woodward & Victoria

Target Areas





SETTLEMENT OF FILLS PLACED ON ORGANIC MATERIAL

SACRAMENTO-SAN JOAQUIN DELTA

SPECIAL STUDY

APPENDIX B

JANUARY 1993

Figure 4-

FIGURE 6

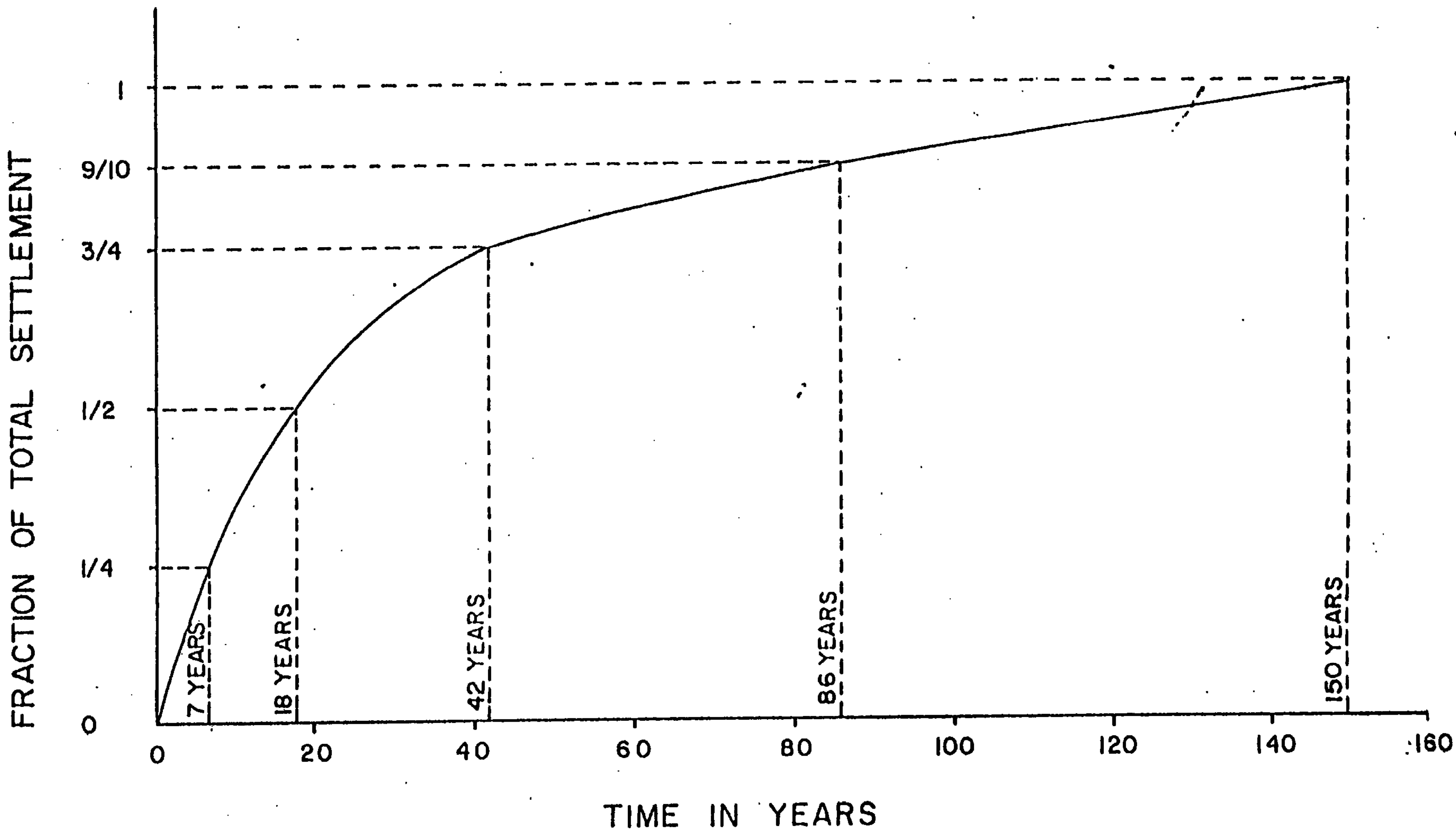


FIGURE 7

FRACTIONAL RATE OF SETTLEMENT

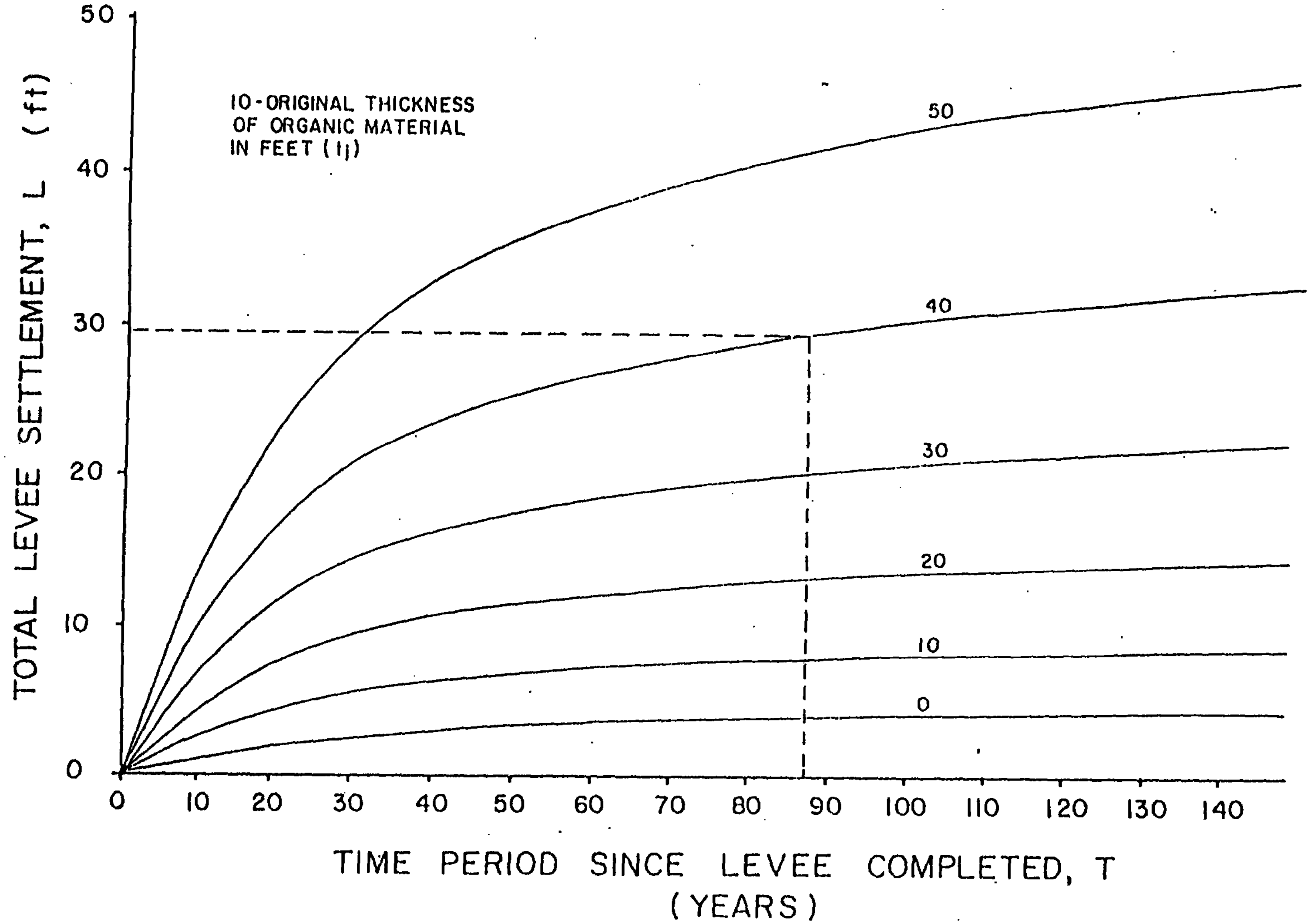
SACRAMENTO-SAN JOAQUIN DEL

SPECIAL STUDY

APPENDIX B 4-13

JANUARY 1993 Figure

FIGURE 8



EXAMPLE: FIND TOTAL LEVEE SETTLEMENT ON BOULDIN ISLAND FROM RECLAMATIOI TO 1987.

FROM FIGURE 4-5, l_1 = 40 ft.

FROM TABLE 4-1, RECLAMATION 1910.
IN 1987 TIME PERIOD, T=1987-1910=77yrs.

FROM BELOW
ENTER T=77yrs
EXTEND LINE VERTICALLY TO l = 40 ft,
EXTEND LINE HORIZON TALLY TO READ
L_s = 29 ft

SACRAMENTO-SAN JOAQUIN DELTA

SPECIAL STUDY

APPENDIX B

JANUARY 1993 Figure 4-9

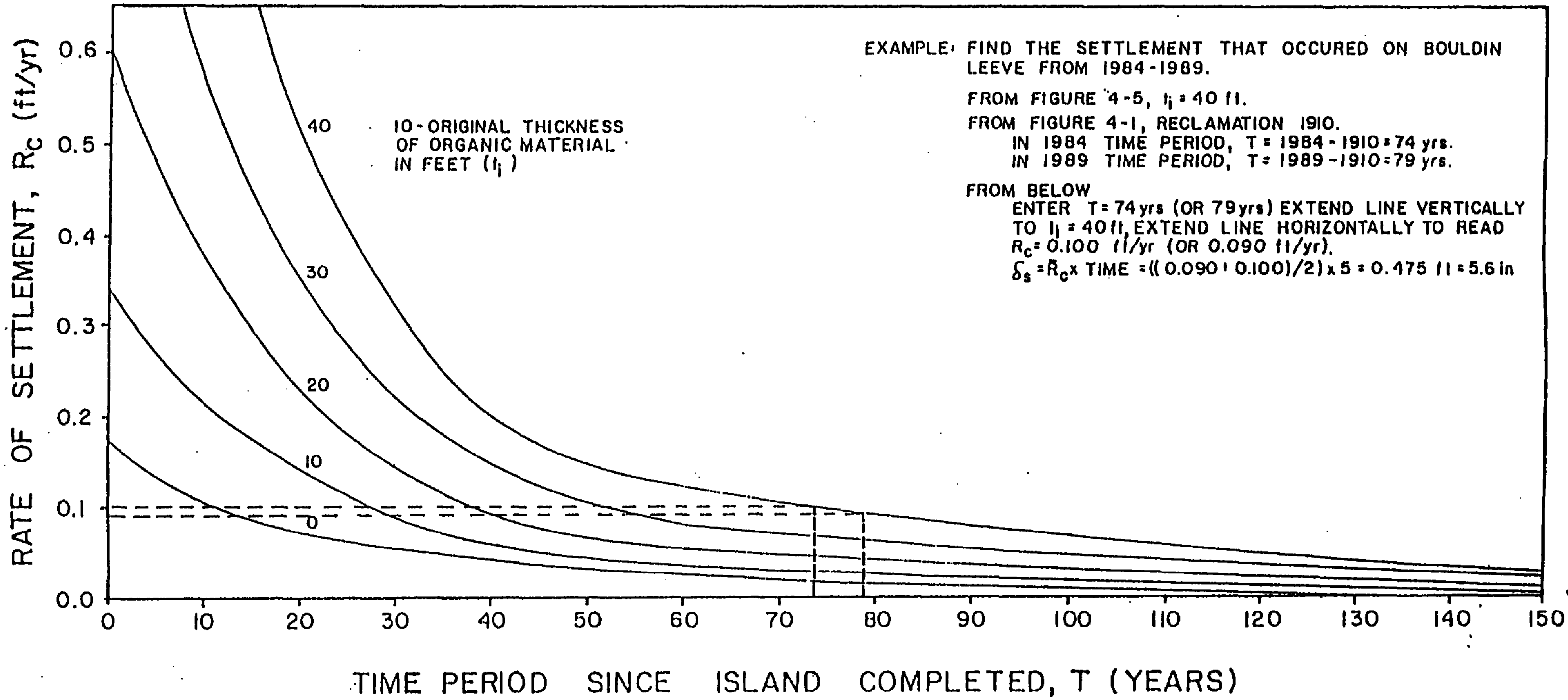


FIGURE 9

SACRAMENTO - SAN JOAQUIN DELTA

SPECIAL STUDY

APPENDIX B

JANUARY 1993

Figure 4-10

SUBSIDENCE MITIGATION IN THE SACRAMENTO-SAN JOAQUIN DELTA

Prepared for the CALFED Bay-Delta Program

by

Steven Deverel
Hydrofocus, Inc.
December 1, 1998

TABLE OF CONTENTS

APPENDIX B.

FIGURES

TABLES

SUBSIDENCE MITIGATION IN THE SACRAMENTO-SAN JOAQUIN DELTA

Executive Summary

Subsidence on Delta islands crosses the boundaries of three of the CALFED common programs, Water Quality, Ecosystem Restoration and Levee System Integrity. Consistent with the CALFED values of integration, synergy and developing equitable solutions, subsidence mitigation needs to be addressed comprehensively. Island subsidence merits attention, future study and mitigation because of its relation to ecosystem restoration, Delta water quality, levee stability and seepage onto islands from Delta channels.

Subsidence of peat soils on Delta islands has caused the land-surface elevations to decrease since the islands were initially drained for agriculture in the late 1800's and early 1900's. The land-surface elevations of islands where peat was once present or where peat is present today range from 5 to over 20 feet below sea level. The peat soils have historically subsided at rates ranging from 0.5 to 4.5 inches per year but subsidence rates have decreased in recent years. The decreasing land-surface elevations have resulted in a decrease in the landmass resisting the hydraulic pressures on the levees and levees have been enlarged and strengthened over time. As the result of subsidence and other factors, levee failure and flooding of islands have occurred frequently since the early 1900's. A long-term approach to subsidence mitigation needs to consider a combination of non-structural and structural alternatives for managing and reversing the effects of subsidence and integrating these efforts with ecosystem restoration.

Management and reversal of the effects of subsidence in the Delta is necessary to achieve CALFED's ecosystem restoration objectives. Ecological connectivity is important for migratory fish species in the Delta, but the current lack of connectivity between Suisun Marsh west of the Delta and riparian riverine habitat east of the Delta may limit the restoration of these species. Steve Johnson of The Nature Conservancy in 1997 said: "From an ecological perspective, there needs to be tidal freshwater wetlands covering the full range of ecosystem gradients in the Delta, not just a few points here and there with the rest of the tidal wetlands hugging the shores of the eastern Delta. To achieve this range, elevations need to be restored on western Delta islands so that they can be brought back into tidal circulation." Long-term reversal of the effects of subsidence in the Delta combined with habitat restoration will be necessary to restore connectivity across the entire Delta.

Mitigation and reversal of the effects of interior-island subsidence is necessary to minimize the consequences of levee failure over the long term. Probabilistic analysis developed by the CALFED seismic hazard team suggest that levee failure is inevitable over the long-term regardless of plans to upgrade levees to PL-99 standards. The consequences and costs of levee failure and island flooding will be proportional to the depth of interior-island subsidence.

Water quality degradation in the Delta channel waters can result from levee failure in the western Delta during periods of low flow, as in the example of the flooding of Brannan and Andrus islands in 1972. This flooding required substantial operational changes in the State and Federal water projects to reestablish the hydraulic balance and compensate for salt-water intrusion. Continued subsidence on western Delta islands where there remains 10 to 60 feet of peat, will increase the volume of water that is drawn onto flooded islands thus increasing salt water intrusion and the need for dilution releases from the State and Federal water projects. For example, an average additional foot of subsidence on Sherman Island (at the rate of 0.5 inch per year this will occur in 24 years) would create about 9,900 acre feet of additional volume below sea level. This additional volume of water could be drawn from the west during flooding and could increase reclamation costs. Repairs and upgrades of Delta levees can cost from several tens of thousands of dollars to over 1 million dollars per mile.

Seepage onto Delta islands will increase as the difference in the water level in the channel and the groundwater level on the islands increases due to continued subsidence and deepening of drainage ditches. Increased seepage may require increased volumes of drainage to be pumped from Delta islands and increased pumping capacity and pumping costs. Increased drainage volumes may lead to increased loading of dissolved organic carbon to Delta channels. Increased seepage may also detrimentally affect levee stability.

The objectives of this report are to summarize the current knowledge of the causes, rates and effects of subsidence, to present the information about non-structural alternatives for stopping and reversing the effects of subsidence and to recommend directions for future research and data collection. The approach was to 1) review and summarize the available literature, 2) determine the relative magnitude of the different causes of subsidence using the available data, 3) use the areal distribution of historic subsidence rates and peat thickness to delineate priority areas for subsidence mitigation and future study and 4) determine and describe possible mitigation measures and future data collection efforts.

Consistent with the May, 1997 Governor's Flood Emergency Action Team Report that recommended that "proactive nonstructural floodplain management strategies...be implemented to reduce future flood loss and curtail the spiraling cost of State and Federal disaster assistance", this report describes non-structural options for subsidence mitigation. This report is a first step towards implementation of subsidence mitigation measures on Delta islands. The focus is the subsidence of peat soils on Delta islands. Levee subsidence that occurs primarily as the result of consolidation of organic materials underlying levees is described in another report that focuses on levee integrity.

The results of the analyses presented here indicate that present-day subsidence in the Sacramento-San Joaquin Delta is primarily the result of microbial oxidation of the peat soils. The peat soils contain a complex mass of carbon that microbes such as bacteria and fungi use as an energy source thus oxidizing the carbon to carbon dioxide gas. The available data indicate that historically, microbial oxidation caused 29 to 55 percent, consolidation and shrinkage caused 22 to 29 percent, wind erosion caused 3 to 34 percent and burning caused 9 to 24 percent of the total subsidence that occurred from the late

1800's through the 1970's. Consolidation continues to occur as the elevations of drainage ditches are lowered in response to subsidence due to microbial oxidation. Burning and wind erosion no longer appear to be significant causes of subsidence.

This report summarizes the data for changing land- and water-management practices for stopping and reversing the effects of subsidence of the peat soils. The results of research conducted by the USGS in cooperation with DWR on Twitchell Island indicate that seasonal wetlands in which the land is flooded during the fall and winter and drained in the spring and summer will not stop subsidence or reverse its effects. The primary cause of subsidence is carbon loss due to microbial oxidation of the peat. This oxidation is highest during the spring and summer. In general, land- and water management practices that result in drained and oxidized conditions during the spring and summer will result in a net carbon loss and continued subsidence. In contrast, permanent shallow flooding to a depth of about one foot resulted in a net accumulation of carbon which lead to the accumulation of biomass. The results of coring in the experimental flooded pond showed that about 3 to 6 inches of firm biomass accreted from 1993 to 1997 during 2 years of growth under full vegetative cover and 2 years of growth under partial vegetative cover. Capping of the peat with mineral material in the laboratory reduced carbon loss from the peat.

A Geographic Information System developed and housed at the Department of Water Resources Central District and available data for subsidence rates and peat thickness were used to delineate priority areas for subsidence mitigation. Figure 2 shows the location of the priority areas. There are about 23,000 acres in first priority area that includes lands where time-averaged subsidence rates from the early 1900's to the mid-1970's were 1.5 inch per year or greater and the peat is greater than 10 feet thick. There are about 36,000 acres in the priority 2 area that includes lands where time-averaged subsidence rates were greater than 1.5 inch per year and the peat is equal to or less than 10 feet thick. Lands in the priority 1 area are generally located in the central and central-western Delta where there is relatively deep peat and time-averaged subsidence rates have been generally high. Large tracts of land in the western Delta are also included in the priority 1 area. Most of the lands in the priority 2 area are in the central and central-eastern Delta where there have historically been high rates of subsidence but the peat thickness is generally less than 10 feet.

The error in the determination of areas in each priority varies depending on the magnitude of the time-averaged subsidence rate and the error in the peat thickness data. Where time-averaged subsidence rates were generally greater than 1.5 to 2 inches per year, the possible error in the delineation of the priority areas appears to be low. Where time-averaged subsidence rates are less than or equal to 1.5 inch per year, the error can be large. The peat thickness estimates can be in error due to lack of data for specific areas and because the data are based on land surface elevation data that are over 20 years old. The possible error in the delineation of priority areas for subsidence mitigation and slowing of subsidence rates in recent years points to the need for data collection to determine the present-day magnitude and areal distribution of subsidence rates.

The delineation of priority areas for subsidence mitigation is a first step towards implementation, designed to identify areas where future research and data collection efforts are needed. There is still much to be learned about subsidence, subsidence mitigation and the effects of subsidence. A comprehensive CALFED program is needed to effectively conduct and integrate future subsidence mitigation efforts. Additional data collection and research are required to:

- quantify and predict present-day and future subsidence rates,
- determine the present-day areal distribution of peat thickness,
- refine the delineation of priority areas for subsidence mitigation,
- temporally and spatially define the effects of subsidence on levee stability,
- determine the influence of future subsidence on levee foundation deformation and seepage through levees,
- determine the effects of continuing subsidence on future land use,
- determine the effects of future land subsidence on drainage water quality in Delta channels and seepage onto islands,
- develop land- and water-management practices for stopping and reversing the effects of subsidence and
- integrate subsidence mitigation into ecosystem restoration efforts.

This report resulted from a cooperative effort among the Department of Water Resources Central District (DWR), U.S. Geological Survey (USGS), the CALFED Bay-Delta Program and HydroFocus, Inc. DWR funded the majority of the data analysis and data collection described in this report related to the causes of subsidence, delineation of priority areas for subsidence mitigation and development of options for stopping and reversing the effects of subsidence. USGS provided partial funding for data collection and analysis related to the development of options for stopping and reversing the effects of subsidence and provided comments on this report. CALFED provided the majority of the funds for the writing of this report. Hydrofocus, Inc. donated time and materials for the writing of this report. The Natural Heritage Institute also provided comments on the report.

SUBSIDENCE MITIGATION IN THE SACRAMENTO-SAN JOAQUIN DELTA

1.0 Introduction and Background

Prior to 1850, the Sacramento-San Joaquin Delta was a tidal wetland. The Delta was drained for agriculture in the late 1800's and early 1900's (Thompson, 1957). The organic or peat deposits of the Delta formed during the past 7,000 to 11,000 years from decaying plants at the confluence of the Sacramento and San Joaquin Rivers (Atwater, 1982 and Schlemon and Begg, 1975). The drained peat soils on over 60 islands and tracts are highly valued for their agricultural productivity and have undergone continuous subsidence since they were initially drained[1]. A network of levees protects the island surfaces that range from 5 to over 20 feet below sea level, from inundation.

Drainage of the Delta islands was essentially complete by the 1930's when the Delta assumed its present configuration of the islands and tracts surrounded by 1,100 miles of man-made levees and 675 miles of channels and sloughs. When most of the original levees were constructed on foundations of sand, peat and organic sediments, the difference between the water level in the channels and island surfaces was less than 5 feet. Because of the decreasing island-surface elevations due to subsidence, there has been a decrease in the landmass resisting the hydraulic pressures on the levees and the levees have been enlarged and strengthened over time.

As the result of subsidence and other factors, levee failure and flooding of islands has occurred since the early 1900's. Prokopovitch (1985) reviewed the history, causes and costs of flooding of Delta islands since the early 1900's and the information in this and the following paragraph was excerpted from pages 409-410 of his journal article. Island flooding in the early 1900's resulted mainly from overtopping of levees during high tides or spring and winter flooding. With the flood control provided by the construction of the Central Valley Project in the 1940's, overtopping became less of a factor and levee foundation instability increasingly became an important factor in island flooding. Over 50 islands or tracts have flooded since 1930.

The data for cost of levee failures and flood damage are incomplete. However, as an example, the cost associated with 11 of the 28 islands that flooded from 1969 to 1983 was about $177 million. Levee failure and island flooding can result in loss of agricultural, commercial, industrial and residential property, recreational use, communication lines and storage and transport of electricity and natural gas. The cost for levee maintenance, upgrades and repair generally ranges from several tens of thousands to over 1 million dollars per mile. Subsidence contributes to the need for levee upgrades

[1] Subsidence is defined here as the decrease of land surface elevation. Subsidence in this report refers to the decrease in land surface elevation on the areas of the islands and tracts on the land side of the levees and is different from the lowering of the levee surface as the result of compaction of foundation materials.

and maintenance. Subsidence mitigation needs to be an integral part of any plan to prevent future flooding of Delta islands.

The cited causes of land subsidence in the Delta include aerobic microbial oxidation of soil organic carbon or microbial oxidation, anaerobic decomposition, consolidation, shrinkage, wind erosion, gas, water and oil withdrawal and dissolution of soil organic matter (Prokopovitch, 1985, Department of Water Resources, 1980; Weir, 1950). Stephens and others (1984) identified 6 causes of subsidence in drained organic soils worldwide; shrinkage due to desiccation, consolidation, compaction as the result of tillage, wind and water erosion, burning and microbial oxidation. Stephens and others (1984) reported that 53 percent of historical subsidence in organic soils in the Florida Everglades was due to microbial oxidation. Schothorst (1977) computed the percentage of the different causes of subsidence in organic soils in the Netherlands to be compaction, 28 percent; shrinkage, 20 percent; and microbial oxidation, 52 percent. The relative percentage of the different causes of subsidence in Delta have heretofore have not been quantified.

1.1 Purpose, Scope and Approach

To effectively mitigate the effects of subsidence in the Delta, the effects, rates and causes of subsidence and methods for stopping or reversing the effects of subsidence need to be identified and quantified. This report 1) summarizes information about the effects, causes and rates of subsidence, and 2) presents information about and recommendations for subsidence mitigation and future data collection.

The approach was to 1) review, synthesize and summarize the available literature and available research results, 2) estimate the relative magnitude of the different causes of subsidence using the available data, 3) use the areal distribution of historic subsidence rates and peat thickness to delineate priority areas for subsidence mitigation and future study and 4) determine and describe mitigation measures and future data collection efforts.

The overall approach for estimating the relative magnitude of the causes of subsidence was to use a computer model to synthesize and integrate the available data for subsidence rates and causes. The model estimated the amount of yearly subsidence due to different causes based on available data. The model results were compared with measured elevation change for five islands; Jersey, Sherman, Bacon and Mildred Islands and Lower Jones Tract.

The approach for the delineation of priority areas for subsidence mitigation was to use a geographic information system (GIS) developed by the Department of Water Resources Central District to analyze available data for the Delta for subsidence rates, depth of peat soils and soil characteristics. The Department of Water Resources (1980) mapped the islands of greatest subsidence and listed the peat thickness for each island. The representation of the areal distribution of subsidence rates and peat thickness presented here is an improvement relative to the previous effort (Department of Water Resources,

1980) because 1) the error in the estimated subsidence rate is generally lower, quantifiable and the result of temporally uniform elevation change determinations, and 2) the estimates for peat thickness are based on more recent and comprehensive data. Also, the data was entered into a GIS which facilitated the evaluation of the data for delineation of priority areas in greater areal detail than entire islands such as generally presented in Department of Water Resources (1980).

2.0 Methodology

2.1 Methodology for Estimating the Relative Magnitudes of the Causes of Subsidence

A computer model was developed to estimate yearly subsidence. The simulated causes of subsidence were aerobic microbial oxidation of organic carbon, consolidation and shrinkage, wind erosion, burning and withdrawal of natural gas and groundwater. Subsidence due to aqueous carbon loss was not simulated because data presented by Deverel and Rojstaczer (1996) indicated that it accounts for less than 1 percent of the measured subsidence. Data presented in Deverel and others (1998) indicated that anaerobic decomposition of Delta organic soils is small relative to other causes of subsidence and was also not included in the model. The data and methodology for simulating the causes of subsidence are summarized here and are described in detail in Appendix A.

2.1.1 Microbial Oxidation

The carbon flux data for Jersey Island collected from 1990 to 1992 (Deverel and Rojstaczer, 1996) was used to approximate the relation of microbial oxidation of organic carbon to soil organic carbon content. This relation was then used to simulate subsidence due to microbial oxidation for Jersey Island at the study location of Deverel and Rojstaczer (1996). The mass of carbon lost by microbial oxidation was assumed to follow Michaelis-Menton kinetics (Conn and Stumpf, 1976). In the Michaelis-Menton equation, the amount of carbon loss due to microbial oxidation is proportional to the amount of organic carbon in the soil.

2.1.2 Consolidation and Shrinkage

When the organic soils of the Delta were initially drained, there was substantial consolidation and shrinkage due to water loss. There is also annual consolidation that is a result of an effective stress on the peat material near the water table. As the soil subsides and oxidizes, the elevation of the bottom of drainage ditches is decreased to lower the water table thus decreasing the buoyant force of water supporting the peat. There is also an increase in loading due to the increasing density of the oxidizing soil. Shrinkage may also cause a loss in volume as the peat soils are dried but this has not been well quantified in the Delta. This annual subsidence due to consolidation was simulated in the model as equal to the volume of water lost when the water table is lowered. The amount of initial shrinkage and consolidation during reclamation was estimated from an empirical equation presented in Eggelsmann and others (1990).

2.1.3 Wind Erosion

Wind erosion of peat soils caused dust storms that affected Stockton, Lodi and Tracy prior to the early 1960's (Alan Carlton, former University of California Extension Specialist for the Delta, personal communication, 1997). The prevailing westerly winds of oceanic air masses moving to the Central Valley caused dust storms primarily during May and June (Schultz and Carlton, 1959; Schultz and others, 1963). There are few reported values of annual amounts of peat soil eroded by wind that range from 0.1 to 0.57 inch per year (Department of Water Resources, 1980; Carlton, 1965).

Crop histories in Thompson (1958) and the Weir transect notes (see Rojstaczer and others, 1991) were used to determined the spatial distribution of crops grown on the islands where land surface elevation changes were simulated. Wind erosion was calculated at varying rates of 0.1 to 0.57 inch per year where asparagus was grown or where the land was fallow. There was generally a shift from the planting of asparagus and other vegetable crops to corn in the Delta in the 1950's and 1960's and the model calculated minimal wind erosion after 1965.

2.1.4 Burning

Weir (1950) and Cosby (1941) estimated that the peat soils were burned once every 5 to 10 years. Data analysis in Rojstaczer and Deverel (1995) and Rojstaczer and others (1991) indicated that burning occurred more frequently during World War II when potatoes were grown extensively. Burning was used to control weeds and diseases and to create ash for potatoes. Weir (1950) stated that 3 to 5 inches of peat were typically lost during a single burning. Burning was simulated differently for the islands depending on the distribution of crops following the information presented in Cosby (1941) and Weir (1950).

2.1.5 Withdrawal of Natural Gas

Since the discovery of the Rio Vista Gas field in the 1930's, several natural gas fields have been developed in the Delta. Compaction of the sediments could occur if the gas reservoirs were substantially depressurized which could result in subsidence of Delta islands. To determine the subsidence due to natural gas withdrawal, sediment cores collected from channel islands were dated by determining the levels of cesium-137 at 1-inch depth intervals (Rojstaczer and others, 1991). Records from the California Department of Conservation, Division of Oil and Gas, indicate that gas production began to increase substantially in the mid-1950's and gas withdrawal was simulated as a contributor to subsidence in the model after 1955.

2.1.6 Simulation of Total Subsidence

The total annual depth of subsidence was estimated by summing the depths of subsidence due to the different causes for each yearly time step. The model accreted the land surface as it progressed backward in time based on the mathematical representation of the causes of subsidence. The soil organic carbon content and bulk density were estimated for the most recent elevation data and were recalculated for each subsequent time step. Subsidence and the microbial oxidation of organic carbon were simulated as a two-layer process based on data presented by Carlton (1966). The soil organic matter content was recalculated for each layer at each time step based on the simulated change in the total mass of carbon for each layer.

2.2 Methodology for Delineation of Priority Areas for Subsidence Mitigation

The delineation of priority areas for subsidence mitigation in the Delta is based on the areal distribution of historical, time-averaged subsidence rates calculated from the early 1900's to the mid-1970's and peat thickness. The first priority area was chosen to include those lands where the time-averaged subsidence rates were high (greater than 1.5 inch per year) and where there is still substantial peat (greater than 10 feet) remaining. The second priority area was chosen to include those areas where the time-averaged subsidence rates were high (greater than 1.5 inch per year) but there was 10 feet or less of peat remaining. It was assumed that the distribution of time-averaged subsidence rates generally reflects the relative distribution of present-day subsidence rates. Areas where time-averaged subsidence rates were lower than 1.5 inch per year were not considered to be high priority areas for immediate subsidence mitigation. A Geographic Information System for the Delta developed by, and housed at the Department of Water Resources Central District was used for the delineation of priority areas. The methodology used is summarized here and described in detail in Appendix B.

Two sets of US Geological Survey topographic maps were used to estimate the time-averaged rates of subsidence throughout the Delta from the early 1900's to 1974 through 1978. The difference in elevation between the two time periods was estimated to be the total depth of subsidence. The time-averaged rate of subsidence was calculated as the total amount of subsidence divided by the time interval that ranged from 60 to 72 years. The error in the subsidence rate estimate results from the error in the elevation estimate from the topographic maps and the change in mean sea level datum from the early 1900's to 1976 to 1978. The methodology for estimating the error associated with the time-averaged subsidence rate is described in Appendix B.

The peat thickness was calculated as the difference between the basal elevation of peat and peaty mud deposits of tidal wetlands as mapped by Atwater (1982) and the land-surface elevation from the USGS topographic maps. Atwater's (1982) peat and peaty mud of tidal wetlands include the organic deposits derived from decayed vegetation that formed during the sea level rise during the last 7,000 years. Atwater's (1982) delineation of peat and peaty mud include the organic soils mapped by Cosby (1941) and more recent soil surveys.

The peat thickness data was compared with the delineation of organic soils or highly organic mineral soils in the soil surveys for Contra Costa (Soil Conservation Service, 1978), San Joaquin (Soil Conservation Service, 1992) and Sacramento counties (Soil Conservation Service, 1993). Where there were discrepancies between the two sources of information for the extent of peat soils, the soil survey data was assumed to be correct.

The delineation of soil series as mapped in the soil surveys for Contra Costa (Soil Conservation Service, 1978), San Joaquin (Soil Conservation Service, 1992) and Sacramento counties (Soil Conservation Service, 1993) were entered in digital form into the GIS developed by the Department of Water Resources Central District. The soil organic matter content was the primary soil characteristic of interest. The soil organic matter content was estimated for the 11 soil series which were either organic soils or highly organic mineral soils based on the data provided in the soil surveys.

3.0 Effects of Subsidence

Levee stability is directly affected by continued subsidence within a zone of influence adjacent to levees. The spatial and temporal definitions of the zone of influence have not been quantified for the Delta and are site specific. The temporal and spatial definitions of the zone of influence should be based on analysis of the effects of future subsidence primarily on seepage and deformation of levee foundations. Deformation analysis (e.g. Foote and Sisson, 1992) of Delta levees heretofore have not considered the effects of future subsidence.

Seepage onto Delta islands will increase due to future subsidence. As the water level on the island is lowered as the result in increased drainage depth, the hydraulic gradient from the water surface in the channel to the groundwater in the interior of the island will increase. This will in turn increase the rate of seepage onto the island and may affect seepage through the levee and the erosion of foundation materials. Future data collection and analysis are needed to determine these effects.

Seepage onto Delta islands is removed, along with agricultural return flows, through a network of drainage ditches and one or more drainage pumps that pump drainage water from the islands into the channels. Templin and Cherry (1997) quantified the volume of drainage water pumped from Delta islands in 1995. Their data indicate that volumes of drainage water ranged from 2 to 4 acre-feet per acre in the central and western Delta. As a point of reference, average reference evapotranspiration for the Delta (Orang and others, 1995) is about 4.5 feet. Actual consumptive use of water by crops is less than reference evapotranspiration. About 260 agricultural drains discharge and contribute to high dissolved organic carbon (DOC) loading into the Delta channels as the result of leaching of the organic soils (Department of Water Resources Municipal Water Quality Investigations Program, 1997). High DOC concentrations can result in unacceptably high concentrations of disinfection byproducts when the water is treated for drinking. Because of increasing seepage volumes, drainage loads for DOC and disinfection byproducts may increase with increasing subsidence.

Unintentional flooding of Delta islands as the result of levee failures can cause additional water quality degradation due to salinity intrusion. Past subsidence has resulted in reduced landmass to support levees and continued subsidence can exacerbate the water quality effects of flooding by increasing the volume of water that will move onto the island during flooding. Cook and Coleman (1973) described the effects of flooding of Andrus and Brannan islands in June 1972. The Brannan-Andrus flooding is the only documented example of water quality degradation as the result of island flooding. The water balance in the Delta was upset as the result of the levee failure as 150,000 acre-feet of water moved onto the islands that in turn resulted in the movement of salt water from the west into the Delta. State and Federal exports of water from the Delta were temporarily reduced and releases from Central Valley Project reservoirs were increased to reduce the salinity intrusion. The total cost of the flooding was $22.5 million. Three hundred thousand acre-feet of additional water were released from storage from State and Federal water projects.

Short-term water quality problems probably would not occur if breaks occur during winter periods of high flow. Nor do water quality problems occur with all flooding during periods of low flow. The extent of water quality degradation is dependent on the location of the flooding and the flow conditions. Island flooding in the western Delta during low flow periods is the primary concern. Several of the western Delta islands have depths of 10 to 60 feet of peat remaining and continued subsidence will increase the volume of water that will move onto the island during flooding. For example, on Sherman Island an additional foot of subsidence over the entire island during the next 24 years (0.5 inch per year) will result in an additional volume of 9,900 acre-feet below sea level that can move onto the island during flooding. Probabilistic analysis developed by the CALFED seismic hazard team suggest that levee failure is inevitable over the long-term regardless of plans to upgrade levees to PL-99 standards. The consequences and costs of levee failure and island flooding will be proportional to the depth of interior-island subsidence.

4.0 Rates and Causes of Subsidence

4.1 Rates of Subsidence

Cited historic and time-averaged rates of subsidence in the Delta range from about 0.5 to 4.6 inches per year (Rojstazcer and others, 1991; Prokopovich, 1985, Department of Water Resources, 1980). Department of Water Resources (1980, p. 1) stated that estimates of subsidence for the years 1911 to 1952 were 3.0 inches per year on 17 Delta Islands or tracts. Department of Water Resources (1980) also listed the total amount of subsidence for 21 islands as ranging from 10 to 21 feet and time-averaged rates ranging from 1 to 4.6 inches per year. Prokopovitch (1985, p. 405) reported the same range for time-averaged subsidence rates. Rojstaczer and others (1991) evaluated subsidence from changes in land-surface elevations against power pole foundations installed in 1910 and 1952 in 1987 on Sherman and Jersey Islands. The time-averaged subsidence rate from 1910 to 1987 ranged from 0.5 to 1.2 inch per year. The time-averaged subsidence rate from 1952 to 1987 ranged from less than 0.3 to 0.7 inch per year. This and information presented by Rojstaczer and Deverel (1993) indicate that subsidence rates have slowed in recent years.

Rojstaczer and Deverel (1993) determined that a logarithmic expression for the decrease in the land-surface elevation over time statistically fit the data best for Bacon and Midlred islands and Lower Jones Tract where the time averaged historic subsidence rates were 2 and 3 inches per year from 1924 to 1981. The estimates for subsidence rates in 1980 for these three islands ranged from 1.2 to 1.6 inch per year (Rojstaczer and Deverel, 1993). Subsidence rates are slowing for two reasons. First, the rate of microbial oxidation is proportional to the amount of organic carbon in the soil which is decreasing with time. Second, other factors such as wind erosion and burning contributed to subsidence in the past but do not appear to contribute significantly to present-day subsidence. Deverel and Rojstaczer (1996) continuously measured present-day subsidence rates from 1990 to 1992 by on Sherman and Jersey Islands and Orwood Tract. These authors reported rates of 0.2, 0.24 and 0.32 inch per year on Sherman, Jersey and Orwood, respectively.

4.2 Causes of Subsidence

4.2.1 Simulation Results

Table 1 shows the range of simulated elevation changes and percentages of the total subsidence due to the different causes. The results in Table 1 for the different simulations reflect variations in the amount of wind erosion for all the islands and the parameters in the Michaelis-Menton equation for microbial oxidation.

Table 1. Simulated changes in elevation and causes of subsidence for Jersey, Sherman, Mildred and Bacon islands and Lower Jones Tract.

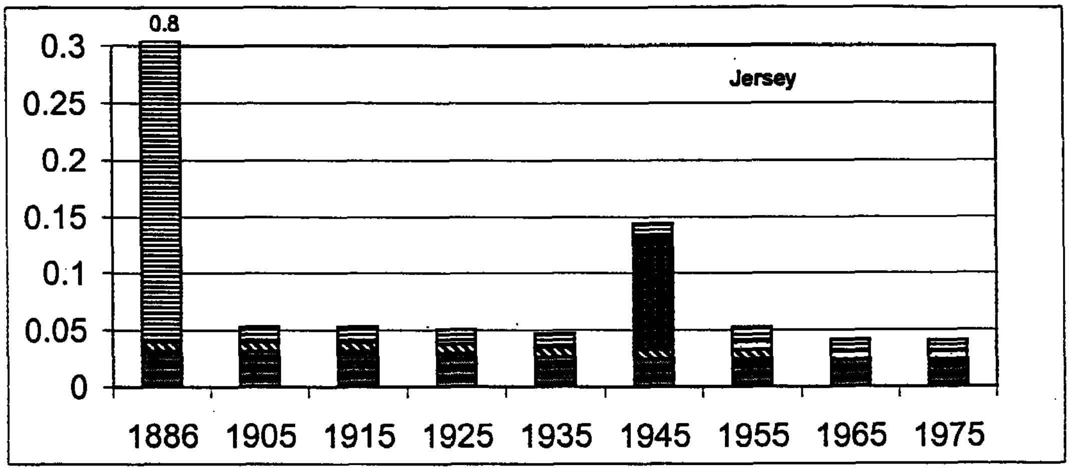
			Simulated range in percent of total subsidence due to:				
Island (years of simulation)	**Simulated changes in elevation (in feet)**	**Measured change in elevation (in feet)**	**Microbial oxidation**	**Consolidation and shrinkage**	**Wind erosion**	**Burning**	**Gas with-drawal**
Jersey (1886 –1975)	5.3 – 8.1	6.7 +/- 2.5	31 – 48	22 – 25	11 –26	9 – 13	2 – 3
Sherman (1910 – 1987)	4.7 – 6.05	6.0 +/- 1.0	29– 47	24 – 25	9 – 34	10 – 14	
Mildred (1924 – 1981)	10.8 – 11.4	11.6 +/- 2.0	37 – 50	29 – 30	3 – 17	18 –19	
Bacon (1924 – 1978)	10.5 – 11.0	10.5 +/- 1.0	36 – 49	24 – 25	3 – 17	23 – 24	
Lower Jones (1924 – 1981)	10.0 – 10.4	9.45 +/- 1.5	41 - 55	24 – 25	3 – 18	18 - 19	
Total range	-	-	29 – 55	22 – 29	3 – 34	10 - 24	2 - 3

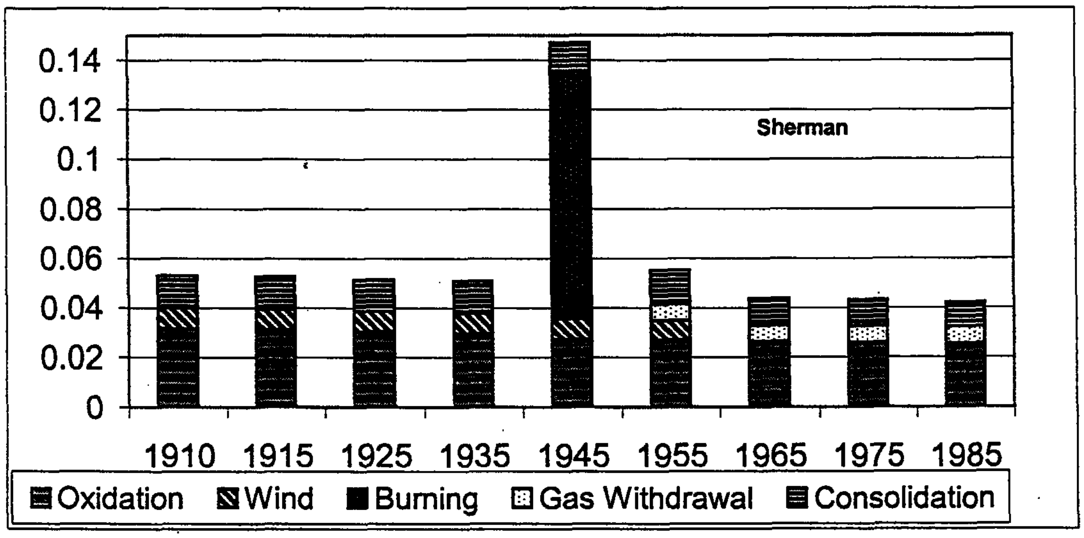
The most recent elevation data for Jersey Island in Table 1 is from the 1978 topographic map that shows topography from photogrammetric methods using aerial photos conducted in 1974 and plane table elevation data collected in 1976. Thompson (1957) indicated that Jersey Island was initially drained in 1886. The measured elevations for Sherman Island in Table 1 were from elevations determined in 1988 against power pole foundations installed in 1910 (Rojstaczer and others, 1991; Rojstaczer and Deverel, 1995). The estimated error for the Sherman data was about 1 foot (Rojstaczer and others, 1991). The estimated error in the Jersey elevation change is about 2.5 feet. The measured changes for Mildred, Bacon and Lower Jones were from the leveling data collected along the Weir transect (Weir, 1950) by University of California personnel (see Rojsatczer and others, 1991).

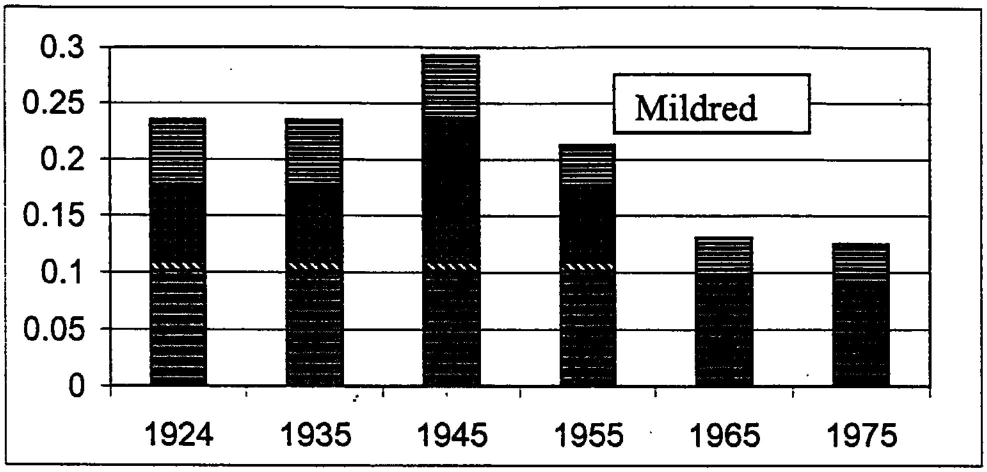
Table 1 shows that the primary causes of historical subsidence simulated on the five islands are microbial oxidation of organic carbon (29 to 55 %) and consolidation and shrinkage (22 to 29 %). Much of the consolidation for Jersey and Mildred islands occurred when these islands were initially drained. This accounts for the relatively large percentage of total simulated subsidence due to consolidation for these islands. The Jersey Island simulation extends from the approximate year of initial drainage to 1975 when the most recent elevation data was collected. The Mildred Island simulation extended from 1924 (the year of initial drainage) through 1981 to coincide with the leveling data reported in Rojstaczer and others (1991).

The amounts of the different causes of subsidence varied with time. Figure 1 shows the amount of subsidence contributed by the different processes for the five islands from 1886 to 1985 in 10-year intervals. Consolidation is the predominant process during the first year after initial drainage. Burning was the predominant cause in 1945. Wind erosion and gas withdrawal are minor causes that account for less than 10 percent of the total yearly subsidence. Simulation results for 1975 on Jersey, Mildred, Bacon and Lower Jones and 1985 on Sherman indicate that present-day subsidence is caused primarily by microbial oxidation and consolidation (75 percent and 25 percent, respectively). Deverel and Rojstaczer (1996) also studied present-day subsidence from 1990 to 1992 on Jersey and Sherman Islands and Orwood Tract. Their results indicated that 60 to 76 % of the measured subsidence was due to microbial oxidation. Comparison of model results and measured elevations shown in Apendix A indicate good agreement between simulated and measured results for Mildred, Bacon and Lower Jones.

Figure 1. Subsidence rates in feet per year from 1886 to 1985 due to different causes for Jersey, Sherman, Bacon and Mildred Islands and Lower Jones Tract.






0.3
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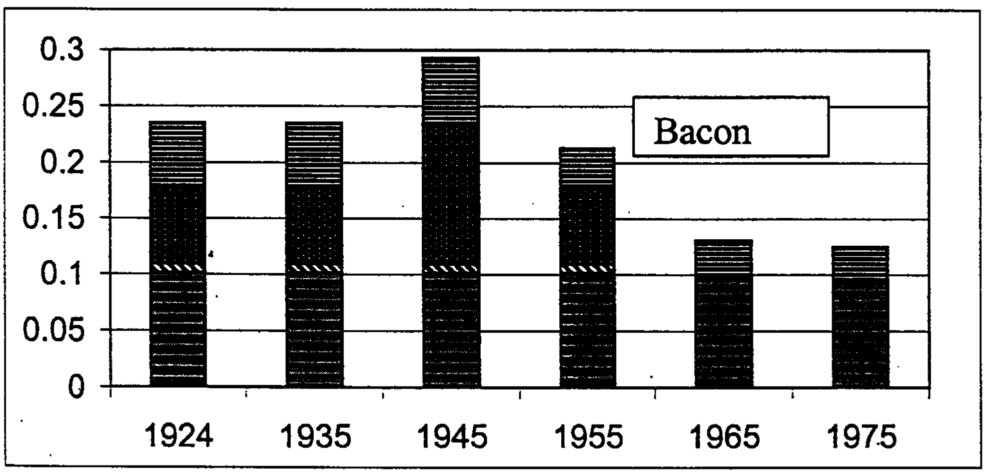
0.1
0.05
0
Mildred
1924
1935
1945
1955
1965
1975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Bacon
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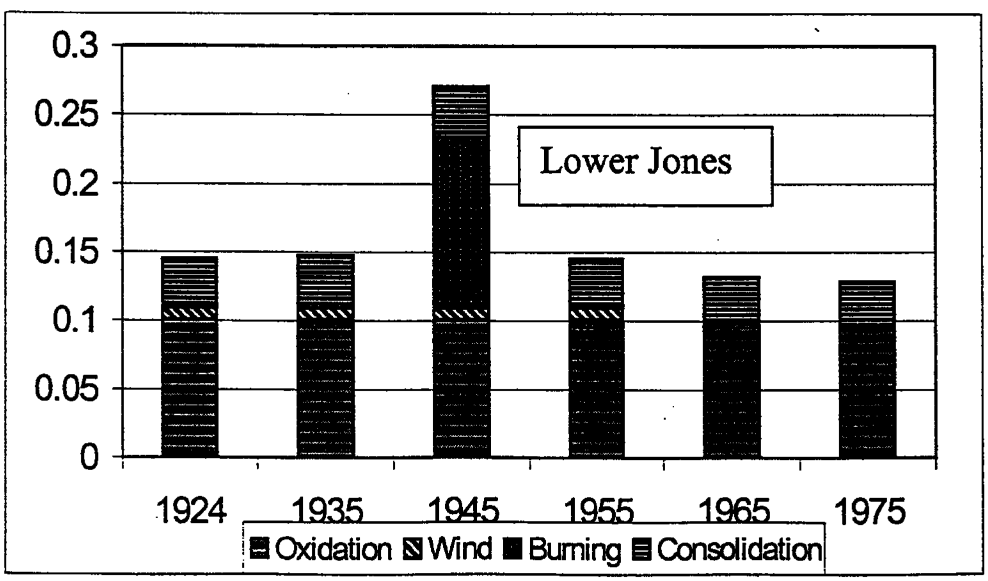

0.3
0.25
0.2
0.15
0.1
0.05
0
Lower Jones
1924
1935
1945
1955
1965
1975
Oxidation
Wind
Burning
Consolidation

4.2.2 Limitations in the Determination of the Causes of Subsidence

Although estimates of the magnitude of the causes of subsidence are consistent with what is known about the processes affecting subsidence in the Delta, the primary limitation of the analysis is the lack of explicit and deterministic simulation of the causes of subsidence. The equation for microbial oxidation is based on limited data and does not explicitly simulate the microbial decomposition of the different components of the soil organic carbon. Consolidation during initial drainage is empirically based. Also, ongoing consolidation of the organic soil after initial drainage is simulated to be the result of water loss only. There is probably a rearrangement of the soil fabric as subsidence and decomposition proceeds that is not currently quantifiable and is not included in the model. Burning of organic soils in the Delta was not well documented and simulation of burning is based on limited data discussed in Cosby (1941) and Weir (1950). The mechanics of wind erosion are also not explicitly modeled due to lack of data. These limitations, especially as related to the simulation of microbial oxidation and consolidation, point to the need for additional data collection and research for improved understanding and prediction of subsidence rates.

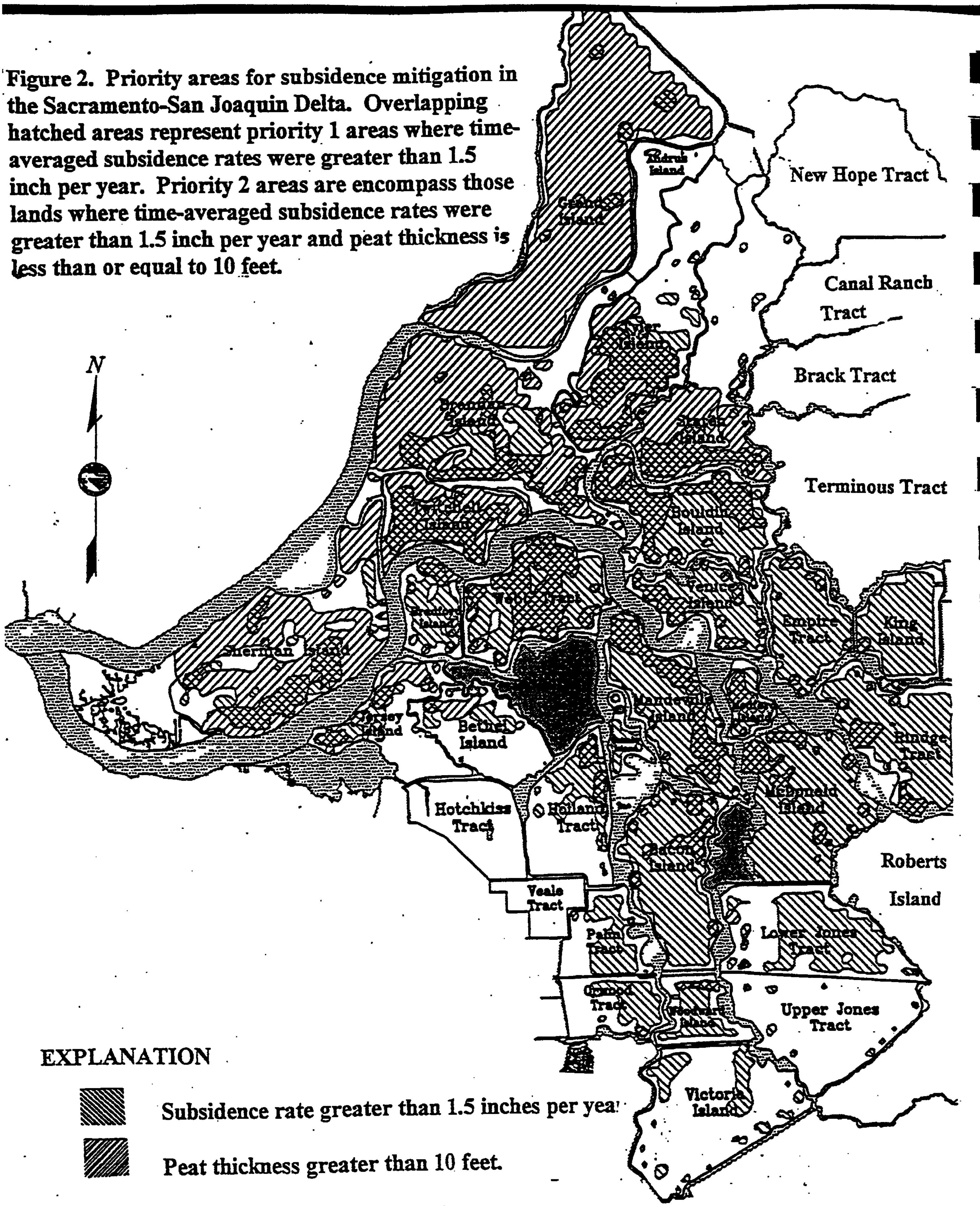
5.0 Distribution of Priority Areas for Subsidence Mitigation

Figure 2 shows the distribution of the two priority areas for subsidence mitigation. The priority 1 area is comprised of lands where the peat thickness is greater than 10 feet and the time-averaged subsidence rate was greater than 1.5 inch per year. The priority 2 area is comprised of lands where the time-averaged subsidence rate was greater than 1.5 inch per year and the peat thickness is 10 feet or less. Peat thickness is generally greatest in the western and northern parts of the Delta; the largest areas of peat thickness greater than 10 feet are on Sherman, Twitchell, Brannan-Andrus, Grand, Staten and Tyler islands and Webb Tract. The amount of area in priority 1 varies among these and other islands according to the distribution of time-averaged subsidence rates. The acres for the two priority areas for the different islands are presented in Appendix B.

The largest acreage for priority 1 is on Webb Tract in the west-central Delta. Venice, Bouldin and Mandeville islands in the central Delta also have large acreage assigned to the priority 1 area. Twitchell, Brannan-Andrus and Sherman islands and Webb Tract in the western and west-central Delta and Tyler Island in the northern Delta also have large areas in this priority. Although Grand Island has a large acreage of peat thicker than 10 feet, the time averaged subsidence rates are almost all less than 1.5 inch per year. The total area for priority 1 is about 22,900 acres.

The islands with the largest acreage in the priority 2 area are in the central Delta where subsidence rates have been historically high and there are large areas of peat that are less than 10 feet thick. MacDonald, Bacon and Mandeville islands and Empire Tract in the Central Delta and Rindge Tract in east-central Delta and Webb Tract in the west-central Delta have large areas in priority 2. Other central Delta islands (Lower Jones Tract, Bouldin Island and Venice Island) have substantial areas in priority 2. The islands and tracts of the western and northern Delta generally have low acreage in the priority 2 area

Figure 2. Priority areas for subsidence mitigation in the Sacramento-San Joaquin Delta. Overlapping hatched areas represent priority 1 areas where time-averaged subsidence rates were greater than 1.5 inch per year. Priority 2 areas are encompass those lands where time-averaged subsidence rates were greater than 1.5 inch per year and peat thickness is less than or equal to 10 feet.



because of the relatively low time-averaged subsidence rates. The total area for priority 2 is about 35,700 acres. The total area for priorities 1 and 2 is about 58,600 acres.

Deverel and others (1998) reported that time-averaged subsidence rates were highly correlated with percent soil organic matter on Sherman Island. The distribution of soil organic matter content in the Delta generally reflects the distribution of subsidence rates shown in Figure 2. For example, the highest organic matter contents (greater than 30 percent) are in the central, east-central and the west-central Delta (Twitchell Island, Bradford Island, Webb Tract, Bouldin Island, Venice Island, Empire Tract, Rindge Tract, King Island, Bacon Island, Lower Jones Tract). The time-averaged subsidence rate for the majority of these islands is greater than 1.5 inch per year (Figure 2). Islands where organic matter contents are generally lower than 15 and 30 percent such as Sherman Island, Brannan-Andrus Island, Staten Island and Victoria Island are generally at the periphery of the Delta. The subsidence rates on these islands are generally less than 1.5 inch per year.

5.1 Uncertainty in the Delineation of Priority Areas

The primary uncertainties in the spatial analysis are the result of uncertainties in the thickness of the peat soil and the error in the estimation of the subsidence rate. The subsidence rate error is the result of errors associated with the use of topographic elevations as described above and the use of different datums for the 2 surveys for the topographic maps published in 1906 to 1911 and 1976 to 1978. In general, large errors in the subsidence rates correspond to areas of the lowest time-averaged subsidence rates. The error in the subsidence rate estimate due to the mapping error is 50 percent or less for much of the Delta where there are peat deposits. The error in the subsidence rate generally increases approaching the periphery of the Delta. The error in the western, eastern, southern and northern edges of the Delta generally approaches or exceeds 100 percent.

The key questions related to the error for the purpose of determining the priority areas based on time-averaged subsidence rates are: 1) Is the distribution of subsidence rates consistent with what is known about the distribution of present-day subsidence rates? and 2) What is the error associated with assignment of areas to one of the two categories (less than and greater than 1.5 inch per year) for subsidence rates?

The first question can be answered qualitatively based on recently collected data for subsidence for selected areas of the Delta. Specifically, data from Rojstaczer and Deverel (1995), Rojstaczer and others (1991) and Deverel and Rojstaczer (1996) are consistent with the spatial distribution of subsidence rates presented here. Time-averaged subsidence rates reported for the central Delta (Lower Jones Track, Bacon and Mildred islands) are greater than in the western Delta (Sherman and Jersey islands) (Rojstaczer and others, 1991). However, subsidence has not been measured extensively throughout the Delta so that it is impossible to compare rates for all the islands. The subsidence rates in Figure 2 are generally consistent with what is known about subsidence and organic soils in the Delta (Prokopovitch, 1985). The highest soil organic matter contents and subsidence rates are in the central Delta. The soils are lower in organic matter content and subsidence rates are lower approaching the margins of the Delta

The second question can be answered based on the distribution of error for subsidence rates. The error analysis is discussed in Appendix B. Data for Sherman Island and Webb Tract were used to evaluate the effect of errors on the acreage within each priority area. The data for these islands represent the variability in the data set and the error analysis illustrates the possible range in calculated acreage in the two priority areas.

The range of acreage on Webb Tract for priority 1 shows that the acreage in priority 1 could be overestimated by 54 % and underestimated by less than 1 %. For priority 2, the range in acreage on Webb Tract shows that the acreage in priority 2 could be overestimated by 24 % and underestimated by 10%. In contrast, the ranges of acreage in each priority for Sherman Island are large, ranging up to 1,000 percent. The time-averaged subsidence rates for Sherman were lower than Webb and therefore the error associated with the subsidence-rate estimate is higher and the range of acreage classified in each priority area is large. The results of this analysis point to a need for additional data collection for subsidence rates, especially in the western Delta.

The areal distribution of the estimation error for the peat thickness was not determined. The density of borehole data and the error in the land-surface elevation primarily determines the error. The land-surface elevation error is due to leveling error in the determination of land-surface elevation that is about plus or minus 2.5 feet and the subsidence that has occurred since 1974 (about 1 to 4 feet). The total land-surface elevation error ranges from about –1.5 to 6.5 feet.

Appendix B shows and discusses the number and average density of data points for borehole logs used to estimate the peat thickness. In general, data densities greater than 200 acres per data point result in moderate to high uncertainty in the estimation of the basal peat elevation for large areas of the islands. Of those islands where the density of peat thickness data is greater than 200 acres per data point, only 7 have acreage in the 2 priorities (Orwood Tract, Victoria Island, Brannan and Andrus islands, King Tract, Tyler Island and Grand Island). Brannan-Andrus Island, King Tract and Tyler Island have significant acreage in the 2 priorities. Grand Island is mapped as having a large area of thick peat but has little acreage in priority area 1 because of the low time-averaged subsidence rates. The percent organic matter in the soils on Grand Island is relatively low. Although there is uncertainty in the delineation of the priority areas for subsidence mitigation, the delineation is based on the available data and provides a starting point for further data collection efforts to better define areas and management practices for subsidence mitigation.

6.0 Land- and Water Management Practices for Subsidence Mitigation

The primary factor contributing to present-day subsidence in the Delta is microbial oxidation of soil organic carbon. The oxidation of soil organic carbon is directly proportional to soil temperature and decreases with increasing soil moisture (Deverel and Rojstaczer, 1996). The results of studies conducted by the US Geological Survey and

Department of Water Resources (Deverel and others, 1998) demonstrated that permanent shallow flooding reversed the effects of subsidence on Twitchell Island. Permanent shallow (about 1 foot) flooding resulted in a net carbon accumulation and accretion of biomass. The plots were first flooded in February 1993. Cattails were the primary species that colonized the plots. During 1993, the cattails covered about 25 percent of the plot. In 1994, 30 to 55 percent of the plot was covered and full vegetative cover was achieved in 1995. Cores were collected in the flooded plot while it was temporarily drained in July 1997. The results of the coring showed that about 3 to 6 inches of firm biomass accreted from 1993 to 1997 during 2 years of growth under full vegetative cover and 2 years of growth under partial cover. Other water-management strategies that were evaluated; seasonal flooding during the late fall and winter with and without irrigation during the spring and summer, resulted in a net carbon loss and are not viable mitigation strategies for stopping subsidence. This is due to large microbial oxidation rates that occur during the spring and summer.

Consistent with the potential of permanent shallow flooding to reverse the effects of subsidence, two projects are funded and one is underway to evaluate the large scale effects of this management practice. First, data collection began in October of 1997 on Twitchell Island on a 15-acres demonstration project for increasing land-surface elevation through biomass accumulation under permanently flooded conditions. The overall approach is to verify the reversal of subsidence in organic soils under permanently flooded conditions at a larger scale than used in previous research (Deverel and others, 1998). The demonstration project will provide information about: 1) the large scale effects of permanent flooding on the carbon balance and land-surface elevation changes; 2) the effects of different water-management practices and vegetation on biomass accumulation and land-surface-elevation changes; 3) the effects of varying soil organic matter content on the carbon balance under permanently flooded conditions and 4) future potential increases in land-surface elevation.

Second, a $3.5 million project has been funded through the CALFED Category 3 process to develop quantitative answers to the key unanswered questions about the reversal of the effects of subsidence and the development of tidal wetland habitat in the Sacramento-San Joaquin Delta. The focus of the project is the development of cost-effective techniques for the reversal of the effects of subsidence. This will be accomplished through research and a demonstration project for tidal wetland habitat restoration on Twitchell Island that will be transferable to other Delta islands. Quantitative answers to questions about the feasibility of depositing sediment on Delta islands and potential water quality impacts of accreting the land surface through biomass accumulation will be addressed during the conduct of this project. This project is scheduled to begin in early 1999.

Other water- and land-management strategies are being evaluated that may stop, or reverse the effects of, subsidence include capping the organic soil with mineral material and reverse wetland flooding. Preliminary results by the USGS (Lauren Hastings, USGS, personal communication, 1998) indicate that capping the unsaturated peat soil with 2 feet of dredge sand reduces the emission of carbon dioxide by about 35%. Capping of partially saturated soil reduced emission of carbon dioxide by 23%. Capping saturated peat soil with dredge material could provide upland habitat in shallow flooded wetlands. Capping of the peat reduces the transport of oxygen and carbon dioxide in and out of the soil causing the rate of carbon dioxide emission to decrease.

Reverse wetland flooding involves shallow flooding during the spring and summer and drainage during the fall and winter. This may reduce oxidation when it is usually the greatest and result in organic matter accumulation. The USGS is currently evaluating this as a subsidence mitigation strategy.

Subsidence mitigation efforts should be coordinated with efforts to restore the ecological health of the Delta. From an ecological perspective, there needs to be freshwater wetlands covering the full range of ecosystem gradients in the Delta. To achieve this range, elevations on western Delta islands must be restored to bring some of the islands back into tidal circulation (Steve Johnson, The Nature Conservancy, 1997).

7.0 Summary and Recommendations

7.1 Summary

- A computer model was used to integrate and synthesize the available data for the historic causes of subsidence in Delta organic soils. The model that simulated the relative magnitude of the causes of subsidence was validated using measured data for carbon fluxes and subsidence rates on Sherman, Jersey, Bacon, and Mildred Islands and Lower Jones Tract.
- The model simulations indicate that 29 to 55 percent of the total amount of historical subsidence on the Delta organic soils that occurred from the late 1800's through the 1970's was due to microbial oxidation of organic carbon.
- The model simulations indicate that consolidation and shrinkage, whether initially or over time because of drainage, accounted for about 22 to 29 percent of the total historical subsidence. Burning has accounted for 9 to 24 percent of the total historical subsidence. Wind erosion has historically accounted for 3 to 34 percent. Gas withdrawal has historically accounted for less than 3 percent.
- Present-day subsidence is caused primarily by the microbial oxidation of organic carbon.
- Time-averaged subsidence rates and peat-thickness were used to determine priority areas for subsidence mitigation in the Sacramento-San Joaquin Delta.
- Two priority areas for subsidence mitigation were determined as follows. The priority 1 area encompasses lands where time-averaged subsidence rates were greater than 1.5 inch per year and peat thickness was greater than 10 feet. The priority 2 area encompasses lands where the subsidence rates were greater than 1.5 inch per year and the peat is less than or equal to 10 feet thick.
- The largest priority-1 areas are in the western, west central and central Delta. The total area for priority 1 is about 22,900 acres.
- The largest priority 2 areas in are in the central Delta and central-eastern Delta where subsidence rates have been historically high. The islands and tracts of the western and northern Delta generally have low acreage in priority 2 because of the low

historical subsidence rates in these areas. The total priority-2 area is about 35,700 acres.

- The total area for both priorities is about 58,600 acres.
- The uncertainty in the estimation of priorities depends on the magnitude of the time-averaged subsidence rate and the uncertainty in the estimation of the peat thickness. The error in the subsidence rate estimate is generally less than 50 percent where subsidence rates are greater than 1.5 inch per year. This primarily corresponds to areas in the central Delta. The error in the subsidence rate increases approaching the margins of the Delta.
- The error in the subsidence rate has relatively less effect in the assignment of priorities on islands where the time-averaged subsidence rates were high such as Webb Tract. However, it has a large effect on the assignment of priorities for islands such as Sherman where historical subsidence rates have been lower.
- Permanent and shallow flooding of organic soils and capping, reduce or stop subsidence rates and shallow flooding can stop or reverse of the effects of subsidence.
- The effects of continued subsidence include levee instability, increased seepage onto islands and water quality effects related to seepage and flooding.

7.2 Recommendations for Research and Additional Data Collection

Eight western Delta islands (Sherman, Jersey, Twitchell, Bradford, Holland, Hotchkiss, Bethel and Webb) encompass a key area for subsidence mitigation because of the potential for water quality deterioration as the result of a levee break on these islands during low flow. Figure 2 shows that large areas of Twitchell, Webb and Bradford are included in the first priority area. Relatively small areas of Sherman, Jersey, Bethel, Hotchkiss and Holland are included in the two priorities. However, the error analysis discussed above indicates that the uncertainty in the assignment of priority areas on Sherman Island is as large as 1,000 percent. The uncertainty on Webb Tract is small. Examination of the subsidence rates and the error in the subsidence rates for Jersey, Holland, Hotckiss and Bethel indicate that the error in the assignment of priorities for these islands is generally similar to the error for Sherman Island.

The uncertainty in the assignment of priorities points to the need for additional data for subsidence rates throughout the Delta prior to implementation of subsidence mitigation measures. Since subsidence mitigation is critical in the western Delta yet the uncertainty in the time-averaged subsidence rates can be high, additional data about the distribution of subsidence rates is recommended in the western Delta for a higher level of certainty for the implementation of subsidence control measures. Also, analysis by Rojstaczer and others (1991) and Deverel and Rojstaczer (1996) demonstrate that subsidence rates are decreasing with time. Therefore, the present-day subsidence rates are lower than those reported here and additional information is required to refine the delineation of priority areas based on present-day subsidence rates.

Uncertainty in the basal peat elevations and current elevations in the Delta also point to the need for additional data. Because the most recent topographic leveling in the Delta was completed in the 1970's, the peat thickness data presented here are about 20 years old. These peat thickness data could be in error by as much as 6.5 feet because of subsidence that has occurred over the past 20 years. The peat thickness values are also uncertain for several islands as discussed above where data is sparse or lacking.

The effects of future subsidence on Delta levee stability have not been studied. Seepage and deformation are key processes that may be affected as the result of future subsidence. The area adjacent to the levee where levee stability is affected by subsidence and the time frame associated with this zone of influence needs to be determined through general and site specific analysis. Analysis should be conducted to determine the effects of future subsidence on levee deformation for different environments where the thickness of the peat and subsidence rates vary. Similarly, seepage analysis should be used to estimate volumes of seepage and the effects on levees for different subsurface materials, varying subsidence rates and different drain configurations.

Specific recommendations for future data collection efforts are as follows.

- Refine the delineation of priority areas by reducing the errors in subsidence rate estimates and peat thickness and determining present-day subsidence rates.
- Collect data for present-day subsidence rates and predict future subsidence rates. Present-day subsidence rates can be determined by measuring land-surface elevations in areas where there is historical data such as Mildred, Lower Jones and Bacon and determining land-surface elevations throughout the Delta at regular intervals. In the short-term, determination of soil organic carbon throughout the Delta in combination with measurement of land-surface elevations on selected islands will improve the delineation of priority areas.
- Future subsidence rates can be predicted by collecting data that will give more precision to the calculation of microbial oxidation described in this report. The evaluation and estimation of consolidation also require more data and analysis.
- Collect data for peat thickness. This can be done using geophysical methods or by determining land surface elevations and calculating the peat thickness using well-log data.
- Determine the effects of future subsidence on levee deformation and seepage.
- Continue to support development and pilot- and large-scale implementation of land- and water-management practices for subsidence mitigation.
- Integrate subsidence mitigation efforts with ecosystem restoration efforts.

APPENDIX A. DESCRIPTION OF COMPUTER MODEL FOR ESTIMATING THE RELATIVE MAGNITUDE OF THE CAUSES OF SUBSIDENCE AND MODEL RESULTS

A.1 Microbial Oxidation

The carbon flux data for Jersey Island collected from 1990 to 1992 (Deverel and Rojstaczer, 1996) was used to approximate the relation of microbial oxidation of organic carbon to soil organic carbon content. This relation was used to simulate subsidence due to microbial oxidation for Jersey Island at the study location of Deverel and Rojstaczer (1996). The mass of carbon lost by microbial oxidation was assumed to follow Michaelis-Menton kinetics (Conn and Stumpf, 1976):

$$CFLUX = (CFLUXMAX \times foc)/(Km - foc) \quad \text{(A.1)}$$

where
CFLUX = CO_2 loss from the soil in grams carbon cm^{-2} yr^{-1} due to microbial oxidation of organic carbon in the peat soil.
CFLUXMAX= maximum CO_2 loss from the soil in grams carbon cm^{-2} yr^{-1}
Km = Michealis-Menton constant, and
foc = the fraction of organic carbon in the soil in grams carbon per g soil

The values of CFLUXMAX and Km were determined from annual averages of monthly carbon flux measurements for two sites on Jersey Island where soil organic matter content values of 0.28 and 0.22 were measured (Deverel and Rojstaczer, 1996). The foc values were estimated to be one-half of the soil organic matter content for the sites on Jersey and other sites in the Delta as per Broadbent (1960). The average annual soil temperature and depth of the groundwater at these two sites were nearly identical during the period of measurement (1990 - 1992). These two data points were used to develop a linear plot of the reciprocal of CFLUX versus the reciprocal of the foc. The slope of this plot is equal to Km/CFLUXMAX and the intercept is equal to 1/CFLUXMAX. For each year of model simulation, CFLUX was recalculated based on the change in foc as the result of the change in soil carbon during the previous time step. The change in land surface elevation due to oxidation was estimated by dividing the annual carbon flux by the soil bulk density and the foc.

The parameters for equation A.1 developed from the Jersey Island data were used to simulate microbial oxidation on Sherman Island. For the central Delta Islands, Mildred and Bacon islands and Lower Jones Tract, the elevation data for Mildred Island in Rojstaczer and others (1991) was used to determine the parameters for equation 2.1. The parameters were determined by model calibration against elevation measurements determined from 1924 through 1981 (Weir, 1950; Rojstaczer and others, 1991). The values for CFLUXMAX and Km determined for the Mildred Island calibration were then used to simulate land surface elevation changes for Lower Jones Tract and Bacon Island. Additional information about subsidence due to consolidation, wind erosion, burning, and withdrawal of natural gas and groundwater was also incorporated into the model.

A.2 Consolidation and Shrinkage

The amount of initial shrinkage and consolidation during reclamation was estimated from an empirical equation presented in Eggelsmann and others (1990) in which the consolidation is expressed as a function of the initial drainage depth in meters:

$$Consolidation = a \times (0.08 \times T - 0.066) \qquad (A.2)$$

where a is and empirical constant that is dependent on the degree of decomposition and texture of the peat, and T is the depth of initial drainage (assumed to be 6 feet).

Equation A.2 was used to estimate the total amount of consolidation due to initial drainage and was applied only once during simulation of subsidence for Jersey and Mildred islands. The empirical constant was assumed to have a value of 1.9 based on information presented in Eggelsmann and others (1990). For comparison, the amount of consolidation during initial drainage was also calculated using the drainage curves reported by Hanson and Carlton (1980). The results using the drainage curves were about 13 percent greater than those in which the Eggelsmann and others' (1990) equation was used.

A.3 Wind Erosion

Wind erosion of peat soils caused dust storms that affected Stockton, Lodi and Tracy prior to the early 1960's (Alan Carlton, former University of California Extenstion Specialist, personal communication, 1997). The prevailing westerly winds of oceanic air masses moving to the Central Valley caused dust storms primarily during May and June when wind speeds exceeded 15 miles per hour at a height of about 6 feet (Schultz and Carlton, 1959; Schultz and others, 1963). Carlton and Schultz (1956 – 1966) conducted experiments to determine the frequency and duration of dust storms caused by wind erosion of peat soils and methods for reducing wind erosion. Asparagus fields were a primary source of wind-eroded soil as the soil surface was mostly bare during May and June.

The Department of Water Resources (1980) reported values ranging from 0.1 inch per year based on personal communication from Alan Carlton to 0.25 to 0.5 inch per year from Weir (1950). Weir (1950) made no measurements of wind erosion and stated that "it may be as much as 0.25 to 0.5 inch per year." Carlton (1965) estimated wind erosion on Terminous Tract to be 0.57 inch per year from 1927 to 1957. This estimate was based on the elevation difference between a plot of land owned by Southern Pacific Railroad which was not farmed or cultivated but was surrounded by cultivated cropland. It is unclear whether the Southern Pacific Railroad land had been burned.

Crop histories in Thompson (1957) and the Weir transect notes (see Rojstaczer and others, 1991) were examined to determine the spatial distribution of crops grown on the islands where land surface elevation changes were simulated. Wind erosion was calculated at varying rates of 0.1 to 0.57 inch per year where asparagus was grown or where the land was fallow. There was generally a shift from the planting of asparagus and other vegetable crops to corn in the Delta in the 1950's and 1960's and the model calculated minimal wind erosion after 1965.

A.4 Burning

Weir (1950) and Cosby (1941) estimated that the peat soils were burned once every 5 to 10 years. Burning probably occurred more frequently during World War II when potatoes were grown extensively (Rojstaczer and others, 1991). Burning was used to control weeds and diseases and to create ash for potatoes. Weir (1950) stated that 3 to 5 inches of peat was lost during burning. Burning was simulated differently for the islands depending on the distribution of crops.

It was assumed that most of the Delta organic soils were planted to potatoes from 1938 to 1945. Elevation loss on all five islands due to burning was simulated to be 4 inches per burning during 2.5 burnings during this time period. Individual cropping patterns were used to simulate burning during other time periods for Mildred and Bacon islands. Potatoes were grown on Mildred Island from 1930-1938 and 6 inches of soil loss during 1.5 burning was simulated during this time period. Potatoes were also a predominant crop on Bacon from 1930 to 1938 and 1945 to 1955 and 6 inches of soil loss during 1.5 burning was simulated during each of these time periods. Alan Carlton (former University of California Extension Specialist, personal communication, 1997) stated that there was no burning in the Delta after 1955.

A.5 Withdrawal of Natural Gas and Groundwater

To determine the subsidence due to natural gas withdrawal, sediment cores collected from channel islands were dated by determining the levels of cesium-137 at 1-inch depth intervals (Rojstaczer and others, 1991). The surface elevation of channel islands has remained at sea level since the 1850's even though sea level rose about 0.08 inches per year indicating that sediment has been deposited on these islands. The peak fallout of ceisum-137 occurred in 1963 and was identified 3 to 7 inches below the sediment surface in cores collected on channel islands adjacent to Twitchell, Bradford and Bethel islands and Webb Tract, indicating that the channel islands subsided since 1963.

From 1963 to 1988 when the cores were collected, sea level rose about 2 inches. Therefore, the amount of subsidence due to gas withdrawal was between 0.04 and 0.2 inches per year ((3 – 2 inches) divided by (1988-1963)) = 0.04 inch/year, ((7- 2 inches) divided by (1988-1963) = 0.2 inches/year)). For modeling of subsidence, 0.08 inch per year of subsidence as the result of gas withdrawal was estimated for Jersey Island based on the results of ceisum-137 results reported in Rojstaczer and others (1991) for the channel island adjacent to Bradford Island. Subsidence due to gas withdrawal was not simulated for the Sherman, Mildred and Bacon islands or Lower Jones Tract because elevation changes along the Weir transect were compared to a benchmark and structures that was also affected by these withdrawals. Records from the California Department of

Conservation, Division of Oil and Gas, indicate that gas production began to increase substantially in the mid-1950's and gas withdrawal was simulated as a contributor to subsidence in the model after 1955.

A.6 Simulation of Total Subsidence

The total annual depth of subsidence was estimated by summing the depths of subsidence due to the different causes. The model accreted the land surface as it progressed backward in time based on the mathematical representation of the processes described above. The foc and bulk density were estimated for the most recent elevation data and time step and were recalculated for each subsequent time step. For Sherman and Jersey Islands, the initial foc and bulk density were from Deverel and Rojstaczer (1996). For Mildred and Bacon islands and Lower Jones Tract the foc was estimated from the soil survey for San Joaquin County (Soil Conversation Service, 1992) to be 0.25. The bulk density for the surface (0 to 2 feet) soils for Mildred, Bacon and Lower Jones was estimated at 0.74 g/cm^3 from the relation for data for organic matter content and bulk density collected on Rindge and Empire tracts and Bouldin Island reported in Hanson and Carlton (1980). A regression equation ($r^2 = 0.50$) was fit to the all the data of the form.

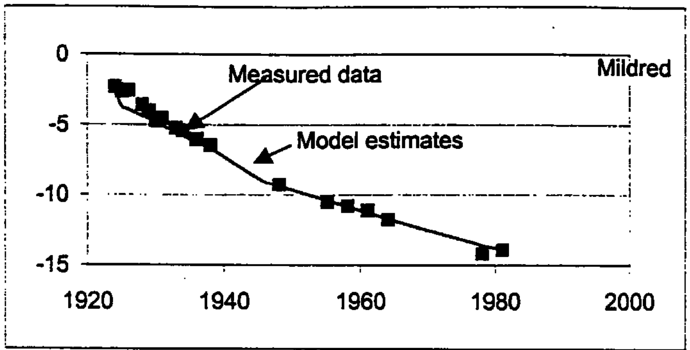
$$\log \text{bulk density} = 0.058 - 0.76 \times foc. \qquad \text{(A.3)}$$

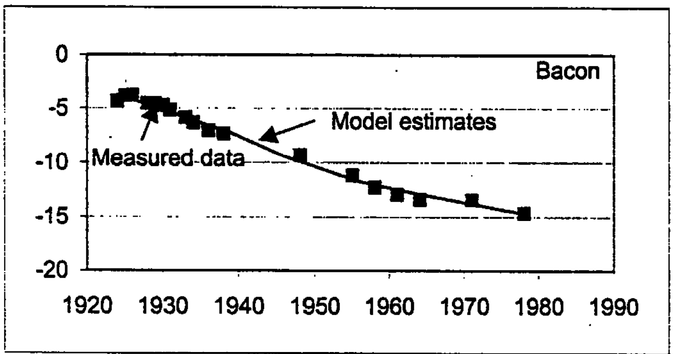
This equation was also used to estimate the bulk density at the beginning of each time step.

Subsidence and the microbial oxidation of organic carbon were simulated as a two-layer process based on data collected by Carlton (1966). The depth of soil affected by subsidence was assumed to be 5 feet. Carlton (1966) measured the depth of subsidence occurring in different layers on Venice Island from 1962 to 1966. Eighty-one percent of the total subsidence occurred in the upper 2 feet of the soil profile. Therefore, eighty-one percent of the organic carbon oxidation was simulated to occur in the upper 2 feet of the soil profile. The remainder was simulated to occur in the lower 3 feet. The foc was recalculated for each layer at each time step based on the change in the total mass of carbon for each layer. The final foc for the most recent and initial time step for the model for the lower layer was estimated at 0.375 based on information in Deverel (1983). The new oxidation rate was calculated for subsequent time steps using equation 2.1. The foc was not allowed to exceed 0.40 for either layer.

A.7 Model Results

Figure A.1 shows that there is good agreement between measured and modeled values for land-surface elevation changes for Bacon, Mildred and Lower Jones.





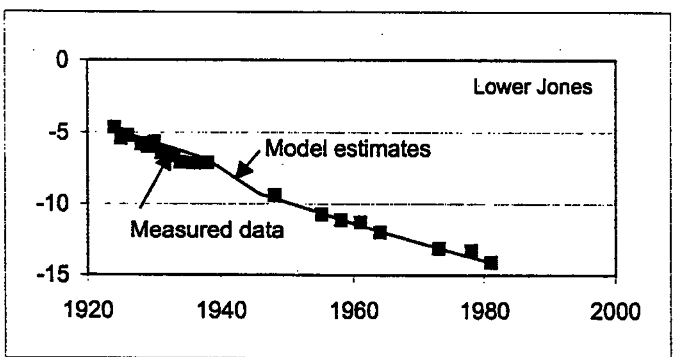


Figure A.1 Measured and model estimates for elevation changes for Mildred, Bacon and Lower Jones from 1924 to 1981. Squares represent measured data and solid lines represent model estimates. Elevation changes on the vertical axis are in feet above sea level.

APPENDIX B. METHODOLOGY, RESULTS, AND UNCERTAINTY ANALYSIS FOR THE DELINEATION OF PRIORITY AREAS FOR SUBSIDENCE MITIGATION.

A Geographic Information System developed by and housed at the Department of Water Resources Central District was used to delineate priority areas for subsidence mitigation based on time-averaged subsidence rates and peat thickness. The following describes the methodology, data, results and error analysis.

B.1 Determination of Areal Variability of Time-averaged Subsidence Rates

Two sets of US Geological Survey topographic maps were used to estimate the time-averaged rates of subsidence throughout the Delta from the early 1900's to 1976 through 1978. Specifically, topographic maps for the 1906-1911 mapping of the Delta at 1:31,680 scale were used to estimate land surface elevation on a 500-meter grid. The 1976 to 1978, 1:24,000 scale topographic maps were used to estimate land surface elevation for the same 500-meter grid. The difference in elevation between the two time periods was estimated to be the total depth of subsidence. The time-averaged rate of subsidence was calculated as the total amount of subsidence divided by the time interval that ranged from 60 to 72 years..

The error in the subsidence rate estimate results from the error in the elevation estimate from the topographic maps and the change in mean sea level datum from the early 1900's to 1976 to 1978. Early leveling in California used the average of tide level gauges in California for the mean sea level datum (Birdseye, 1925). The sea level datum for the 1976 to 1978 maps is the National Geodetic Vertical Datum of 1929 (NGVD-29) that was an average of mean sea level data for 21 tide stations in the United States (Ziloski and others, 1992). The error resulting from the comparison of the two datums for mean sea level was estimated by comparing the elevations for 10 benchmarks on both sets of maps. The elevations for the benchmarks for the maps published in the early 1900's were obtained from Birdseye (1925). The elevations for the same benchmarks using NGVD-29 were obtained from Joe Vukovitch, USGS, Denver.

The benchmark elevations for the maps published in the early 1900's were generally larger than the elevations using NGVD-29. The difference between the benchmark elevations for the maps published in the early 1900's and the elevations using NGVD-29 ranged from 0.008 to 0.704 feet. The average absolute difference was 0.275 feet. This difference was not accounted for in the determination of the time-averaged subsidence rates.

The error due to estimating the elevations from the contours is about one-half of the contour interval (5 feet) for the topographic maps or 2.5 feet (Joe Vukovitch, USGS, Denver, personal communication, 1996). The percent error for each subsidence rate was calculated as follows. The subsidence rate was calculated at each grid point as the difference between the elevations on the two maps plus or minus the error, divided by the time interval between the two mappings:

subsidence rate = (Elev1978 - Elev1906 +/- e)/T (B.1)

where Elev1978 is the elevation from the 1976 to 1978 USGS topographic maps,
Elev1906 is the elevation from the 1906 to 1911 USGS topographic maps,
e is the error associated with the elevation contours (1/2 the contour interval) and,
T is the time interval between the two elevation measurements.

The error was calculated as

e = E1978 + E1906 = +/- 5 feet (B.2)

where E1978 and E1906 are the errors associated with the two sets of topographic maps (E1978 = E1906 = +/- 2.5 feet).

The percent error was calculated as the absolute value of 5 feet divided by the total subsidence multiplied times 100. The percentage error in the subsidence rate is dependent on the amount of subsidence that occurred during the approximately 70 years that elapsed between the surveying for the topographic maps.

B.2 Determination of the Areal Distribution of Peat Thickness

The peat thickness was calculated on the 500-meter grid as the difference between the basal elevation of peat or peaty mud deposits of tidal wetlands as mapped by Atwater (1982) and the land-surface elevation from the USGS topographic maps. Peat or peaty mud of tidal wetlands includes the organic deposits derived from decayed vegetation that formed as the result of sea level rise during the last 7,000 years. Atwater's (1982) delineation of peat and peaty mud include the organic soils mapped by Cosby (1941) and more recent soil surveys. The areal distribution of the basal elevations of the peat deposits was delineated from about 1,200 borehole logs collected through 1980.

The majority of the locations of the borehole logs were on or near the levees. The peat thickness data was compared with the delineation of organic soils or highly organic mineral soils in the soil surveys for Contra Costa (Soil Conservation Service, 1978), San Joaquin (Soil Conservation Service, 1992) and Sacramento counties (Soil Conservation Service, 1993). Where there were discrepancies between the two sources of information for the extent of peat soils, the soil survey data was assumed to be correct.

B.3 Areal Variability of Soil Characteristics

The delineation of soil series as mapped in the soil surveys for Contra Costa (Soil Conservation Service, 1978), San Joaquin (Soil Conservation Service, 1992) and Sacramento counties (Soil Conservation Service, 1993) were entered into the GIS developed by the Department of Water Resources Central District in digital form. The soil organic matter content was the primary soil characteristic of interest. The soil organic matter content was estimated for the 11 soil series which were either organic soils or highly organic mineral soils based on the data provided in the soil surveys. Specifically, the soil surveys for San Joaquin and Sacramento counties provided a range of values for percent soil organic matter. The midpoint of this range was assigned to that series in the GIS database. The percent organic matter for the soil series mapped in Contra Costa County was estimated from the data provided in the soil surveys for San Joaquin and Sacramento Counties.

B.4 Geographic and Hydrographic Data

Geographic and hydrographic data was obtained as USGS Digitial Line Graphs at 1:100,000 scale from the Teale Data Center.

B.5 Delineation of Priority Areas for Subsidence

The areal distribution of time-averaged subsidence rates and peat thickness was used to delineate priority areas for subsidence mitigation. The first priority area includes those lands where the time-averaged subsidence rates were greater than 1.5 inch per year and the peat thickness was greater than 10 feet. The second priority area includes lands where the time-averaged subsidence rates were greater than 1.5 inch per year and the peat thickness was less than or equal to 10 feet.

B.6 Results of Delineation of Priority Areas

Table B.1. Acreages by island for the 2 priorities for subsidence mitigation. Priority 1 includes areas where the time-averaged subsidence rate was greater than 1.5 inch per year and the peat thickness was greater than 10 feet. Priority 2 includes areas where the subsidence rate was greater than 1.5 inch per year and the peat thickness was less than or equal to 10 feet.

Priority 1		Priority 2	
Quimby	35	Quimby	35
Grand	250	Staten	144
King	70	King	1,478
Bethel	70	Brannan	1,440
Woodward	130	Bethel	350
Holland Tract	410	Tyler	610
Medford	570	Sherman	390
Rindge	600	Bradford	860
Sherman	1,480	Holland Tract	930
Empire	600	Lower Jones	2,340
McDonald	910	Bouldin	2,940
Bacon	790	Orwood	840
Jersey	670	Victoria	1,000
Bradford	710	Venice	1,270
Twitchell	1,720	Palm	1,020
Tyler	2,180	Empire	2,570
Brannan	1,700	Mandeville	2,350
Staten	1,400	Rindge	3,680
Venice	950	Webb Tract	2,400
Bouldin	1,860	Bacon	3,830
Mandeville	1,940	McDonald	4,940
Webb Tract	3,920	Woodward	310
Total	22,900	Total	35,700

B.7 Uncertainty in the Spatial Analysis

Uncertainty in the spatial analysis is the result of uncertainty in the thickness of the peat soil and the error in the estimation of the subsidence rate. The subsidence rate error is the result of errors associated with the use of topographic elevations as described above and the use of different datums for the 2 surveys for the topographic maps published in 1906 to 1911 and 1976 to 1978. In general, large errors in the subsidence rate correspond to areas of the lowest time-averaged subsidence rates. The error in the subsidence rate estimate due to the mapping error is 50 percent or less for much of the Delta. The error in the estimation of the subsidence rate generally increases approaching the periphery of the Delta. The error in the western, eastern, southern and northern edges of the Delta generally approaches or exceeds 100 percent.

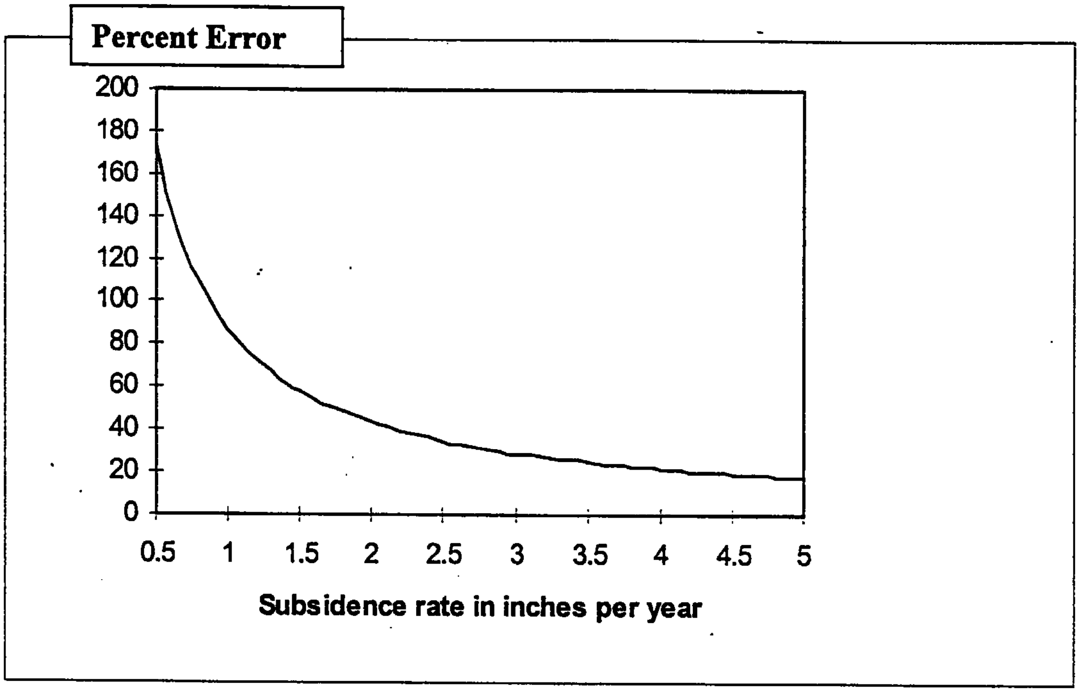
Specifically, the error in the subsidence rate on the central Delta islands, Bouldin, Island, Venice Island, Empire Tract, Mandeville Island, Bacon Island, Lower Jones Tract, McDonald Island and Empire Tract is generally less than 50 percent. Also, the error in the subsidence rates for the west-central and east-central islands, Webb Tract, Twitchell Island, Bradford Island, Rindge Tract and King Island is also generally lower than 50 percent.

Figure B.1 shows the exponential decrease in the percent error in the subsidence rate as the result of mapping errors with increasing time-averaged subsidence rates. The error was calculated for the average time between elevation measurements of 69 years for the topographic maps used in determining the total elevation change. The key questions related to the error for the purpose of determining the priority areas based on time-averaged subsidence rates are: 1) Is the distribution of subsidence rates consistent with the what is known about the distribution of present-day subsidence rates? and 2) What is the error associated with assignment of areas to one of the two categories (less than and greater than 1.5 inch per year) for subsidence rates?

The first question can be answered qualitatively based on recently collected data for subsidence for selected areas of the Delta. Specifically, data from Rojstaczer and Deverel (1995), Rojstaczer and others (1991) and Deverel and Rojstaczer (1996) are consistent with the spatial distribution of subsidence rates presented here. Subsidence rates in the central Delta (Lower Jones Track, Bacon and Mildred islands) are greater than in the western Delta (Sherman and Jersey islands). However, subsidence has not been measured extensively throughout the Delta so that it is impossible to compare rates for all the islands. The subsidence rates in Figure 2 are generally consistent with what is known about subsidence and organic soils in the Delta (Prokopovitch, 1985). The highest soil organic matter contents and subsidence rates are in the central Delta. The soils are lower in organic matter content and subsidence rates are lower approaching the margins of the Delta

The second question can be answered based on the distribution of error for subsidence rates. Further error analysis using the data shown Figure B.1 and the distribution of error in the subsidence rate was used to determine the effect of the distribution of error on the assignment of priorities.

Figure B.1. Relation of error in the estimation of the time-averaged subsidence rate to the subsidence rate.



Using the data shown in Figure B.1 and the distribution of error in the subsidence rate, the lowest time-averaged rate of subsidence that could be erroneously classed as a rate of over 1.5 inch per year is 0.7 inch per year (the error associated with the rate of 0.7 inch per year is 122 percent). The highest time-averaged subsidence rate that could be classed under 1.5 inch per year is 2.3 inches per year (the error associated with the rate of 2.3 inches per year is 36 percent). Data for Sherman Island and Webb Tract was used to evaluate the effect of errors on the acreage within each priority area.

The data for these two islands represent the variability in the data set and the error analysis illustrates the possible range in calculated acreage in the two priority areas. About 80 percent of Sherman Island in the western Delta have peat greater than 10 feet thick but most of the time-averaged subsidence rates were below 1.5 inch per year. In contrast, Webb Tract has experienced time-averaged subsidence rates generally greater than 2.5 inches per year and about 50 percent of the island have peat soils greater than 10 feet thick. Webb Tract has the largest acreage in priority 1. The acreage in priority 1 on Sherman Island is about equal to the median. Sherman has one of the smallest acreage in priority 2.

The results of the error analysis are shown in Table B.2. The range of acreage on Webb Tract for priority 1 shows that the acreage in priority 1 could be overestimated by 54 % and underestimated by less than 1 %. For priority 2, the range in acreage on Webb Tract shows that the acreage in priority 2 could be overestimated by 24 % and underestimated by 10%. In contrast, the ranges of acreage in each priority for Sherman Island are large, ranging up to 1,000 percent. The subsidence rates for Sherman are lower than Webb and the error associated with the subsidence-rate estimate is higher and the range of acreage classified in each priority is large. The results of this analysis point to the need for additional data collection for subsidence rates in the western Delta and other areas where time-averaged subsidence rates are mapped as1.5 inch per year or less.

Table B.2. Range in acreage for each priority for Sherman Island and Webb Tract.

Island	Estimated acreage in priority 1	Range	Estimated acreage in priority 2	Range
Sherman	1,480	0 - 5,410	390	41 – 2,200
Webb	3,920	1,770 - 3,940	2,400	1,860 – 2,650

The areal distribution of the estimation error for the peat thickness was not determined. The density of borehole data and the error in the land-surface elevation primarily determines the error. The land-surface elevation error is due to leveling error in the determination of land-surface elevation that is about plus or minus 2.5 feet and the subsidence that has occurred since 1974 (about 1 to 4 feet). The total land-surface elevation error ranges from about –1.5 to 6.5 feet.

Table B.3 shows the number and average density of data points from borehole logs used to estimate the peat thickness. The data in Table B.3 does not present the entire story relative to the density of data points for peat thickness. Some data points were used for islands besides those for which they are assigned in Table B.3 since the data for peat thickness was extrapolated across channels. Also, most of the data points are on the levees so that the range of area without borehole data for each island varies substantially. In general, data densities greater than 200 acres per point result in moderate to high uncertainty in the estimation of the basal peat elevation for large areas of the islands.

Of those islands where the density of peat thickness data is greater than 200 acres per point, only 6 have acreage in the 2 priorities (Orwood Tract, Victoria Island, Brannan-Andrus Island, King Tract, Tyler Island and Grand Island). Brannan-Andrus Island, King Tract and Tyler Island have significant acreage in the 2 priority areas. Grand Island is mapped as having a large area of deep peat but has little acreage in the two priority areas because of the low time-averaged subsidence rates. Although there is uncertainty in the delineation of the priority areas for subsidence mitigation, the delineation is based on the available data and provides a starting point for further data collection efforts to better define areas for subsidence mitigation.

Table B.3. Number of data points, acreage and data density for each island used to delineate the distribution of peat thickness.

Island	Number of points	Acreage	Data density (acres/point)
Medford	31	1,219	39
Jersey	60	3,471	58
Bradford	28	2,051	73
Palm	32	2,436	76
Mandeville	68	5,300	78
Woodward	23	1,822	79
Bethel	43	3,500	81
Bacon	66	5,625	85
Sherman	105	9,937	95
Webb Tract	58	5,490	95
Twitchell	36	3,516	98
Venice	31	3,220	104
Empire	28	3,430	123
Canal Ranch	23	2,996	130
Holand	31	4,060	131
Coney	7	935	134
Bouldin	44	6,006	137
Staten	61	9,173	150
McDonald	39	6,145	158
Lower Jones	33	5,894	179
Hotchkiss	17	3,100	182
Byron	36	6,933	193
Rindge Tract	35	6,834	195
Terminous	50	10,470	209
Lower Roberts	48	10,600	221
Upper Jones	27	6,259	232
Orwood	13	4,138	318
Brack	14	4,873	348
Victoria	19	7,250	382
Brannan-Andrus	31	13,000	419
Bishop	3	2,169	723
King	4	3,260	815
New Hope	8	9,300	1,163
Tyler	7	8,583	1,226
Grand	3	17,010	5,670
Veale	0	1,298	
Shin Kee	0	1,016	
Rio Blanco	0	705	
Union	0	22,202	
Shima	0	2,394	
Ryer	0	11,880	

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APPENDIX F

EMERGENCY MANAGEMENT AND RESPONSE

DELTA LEVEE EMERGENCY MANAGEMENT AND RESPONSE PLAN

May 17, 2000

INTRODUCTION

Important local, statewide and national resources depend upon maintenance of an effective levee system in the Sacramento-San Joaquin Delta (Delta). A strong, on-going preventive levee repair, reconstruction, and maintenance program will reduce levee vulnerability, reduce (or in some cases, prevent) future emergencies and ensure the availability of the heavy marine construction equipment needed for effective emergency response. Notwithstanding increased efforts to upgrade and maintain Delta levees, the threats to levee system integrity cannot be totally eliminated. Thus an emergency management and response plan is required to protect Delta resources.

SCOPE

This report is intended to outline a major component of the CALFED Levee Program's Long-Term Levee Protection Plan and thereby supplement and suggest needed improvements in state and federal emergency response plans, while remaining consistent with their basic mandates and overall structure. It is focused on levee integrity. There are other types of emergency conditions, such as hazardous material spills, which could occur in Delta waterways and which, while not threatening levee integrity, could endanger water quality to the detriment of public water supplies and biological programs in which CALFED will have made substantial public investments. While such potential emergencies are recognized, they are presently excluded from the scope of this document. Similarly, the more widely recognized emergency response activities such as rescue, emergency medical services and evacuation are not addressed here.

BACKGROUND

The Delta is an area of farmland, waterways and communities. It includes approximately 740,000 acres and is roughly located between the cities of Sacramento, Stockton, Tracy and Antioch. There are about 700 miles of interlaced channels, rivers and sloughs that convey flood waters from the entire Central Valley to the ocean. Over 60 islands and tracts are protected by a network of approximately 1,100 miles of Local Flood Control Non-project Levees and Federal Flood Control Project Levees as shown in the California Department of Water Resources (DWR) Delta Atlas on pages 38 and 40. The Delta provides habitat for fish and wildlife, accommodates shipping, protects population centers and infrastructure including railroads, highways, and pipelines, provides for agriculture and a vast array of recreational activities, and conveys water to over 20 million Californians.

Most of the land in the central and western Delta is below sea level and rapid response to levee threats is unusually critical. A levee failure can endanger public safety, inundate thousands of acres of farmland and habitat, degrade in-Delta and export water quality, and disrupt the operations of the major State and Federal water delivery systems. Of course, multiple levee failures would substantially increase the scale of the emergency and the challenge of prompt response.

Delta levee integrity can be threatened several ways. Levee failure can occur from instability, overtopping and seepage. High water stages in the Delta can occur due to floods, unusually high tides, and atmospheric conditions involving high wind and low pressure. Levee performance during a seismic event is also a concern. Since original reclamation, each of the Delta islands or tracts has flooded at least once. With improved funding for preventive actions since 1986, disaster assistance spending has been reduced substantially.

FUTURE CONDITIONS

Implementation of CALFED's Levee System Integrity Program will not eliminate all threats to the levee system. Threatening circumstances, emergencies, and flooding should be anticipated. Embankments can be more vulnerable to failure during, or immediately after, construction. Thus, levee upgrades involving major earthwork may temporarily reduce levee stability. Commonly, combinations of high tributary flows, strong winds, high tides and low barometric pressure generate flood stage conditions in the Delta. Continued development and construction of upstream flood control features may increase floodwater stages in the Delta. Rise in sea level, channel dredging, and subsidence near the levees may increase seepage through levees and their foundations and reduce levee integrity. Conversion of land near levees to habitat and other land use practices may increase problems related to burrowing animals, may reduce the probability that levee inspection will detect levee defects before the problem becomes a threat, and may hinder emergency flood fight efforts. Lastly, the seismic threat to Delta levees remains a major concern.

GOALS

The goal of the Delta Levee Emergency Management and Response Plan is to enhance existing emergency response programs and capabilities in order to protect the Public or restore critical Delta resources in the event of a levee emergency. A levee emergency is a condition of extreme peril to the safety of persons or property as a result of a threat of levee failure and island inundation. There are three critical components to emergency response.

1. Preparation The ability to respond effectively to a threat, emergency or actual levee failure depends heavily on advanced preparation. All agencies and people involved need to understand their respective roles and responsibilities. There must be emergency planning at all levels of responsibility, clear understanding, scripted procedures for the recognition and declaration of emergency conditions, and an established and rehearsed command and control system. Local, county, State, and federal responses must be better coordinated to enhance decision-making, communication and action protocols. Regulatory and environmental compliance must be incorporated into all response planning. Critical response resources must be immediately available at all levels. Resources include funding, equipment, materiel stockpiles, and appropriately trained personnel.

2. Quick and Effective Emergency Response Time is of the essence in response to any incident or threatening circumstance. An imminent threat of levee failure or a failure requires immediate action that can only be the result of a thoroughly prepared and rehearsed emergency response plan with an identified funding base that ensures immediate, simultaneous, and integrated response by all levels of government. If failure can be prevented or addressed quickly, total losses and expenditures can be dramatically reduced and lives saved.

3. Completion of Post-Emergency Repairs In the event of an emergency, including breach closures, a smooth and quick transition to post emergency recovery work is needed to complete repairs and prepare for continued or new threats. Oftentimes one incident quickly follows another. It is important to facilitate resumption of normal economic activities, restore environmental resources damaged by the incident, prepare for subsequent emergency response, and expedite post-emergency repair efforts.

ANALYSIS OF THE CURRENT EMERGENCY RESPONSE PROGRAM

Significant improvements have been made to the existing emergency response system over the past several years. However, continuous improvements in the system must be made to reduce the risk to resources protected by Delta levees. Improving our emergency response capability is a very cost-effective method of reducing risk and preventing the huge losses, economic disruption, and human suffering resulting from levee failures.

Fluctuations in funding and the environmental regulations applicable to ongoing levee reconstruction, maintenance and repair work have impacted the capability of local, state and federal agencies to respond to imminent threats of levee failure in several ways.

At the current time, there are impediments to year-round in-water construction activities in the Delta. "Work windows," established under biological opinions on endangered species (Chinook Salmon and Delta Smelt), significantly limit the period of time when in-water work can occur in most of the Delta. In addition, environmental permitting practices require constraint in performing work essential to proper levee reconstruction, repair, and maintenance.

Without sufficient work opportunities, the specialized levee building equipment (especially side draft dredges, barge cranes and rock barges) and personnel experienced in operating conditions in the Delta have almost disappeared. These types of equipment and experienced operators are necessary during levee emergencies in those locations and under conditions where work often cannot be performed from the land.

Levee funding resources have been severely impacted by inconsistent and inadequate program funding. Local financial resources have been impacted by bank audit procedures which have reduced the availability of credit to local reclamation districts and by lengthy delays in reimbursement from state and federal disaster assistance programs because of often-unclear inspection, documentation, and audit procedures.

Some levee maintaining agencies do not generate the revenues needed to provide adequate maintenance and emergency response. The role of counties and cities in directly supporting floodfight operations by levee maintaining agencies has not been clearly defined in the past although these organizations can obviously provide rapid and important logistical support to these types of activities.

In some instances, direct State and federal emergency floodfight assistance has been delayed by the required showing that local resources have been exhausted and the lack of an operational plan providing the basis for an immediate, integrated, simultaneous response by all levels of government.

Although historically there has been confusion over the procedures for declaration of a state of emergency and the respective roles of the various local, State and federal interests, these areas have shown considerable improvement as a result of experience gained in the 1997 and 1998 flood emergencies. Three documents were completed in compliance with the Flood Emergency Action Team (FEAT) recommendations and have enhanced emergency operations: 1) Guidelines for Coordinating Flood Emergency Operations, 2) Flood Preparedness Guide for Levee Maintaining Agencies, and 3) Protocol for Closure of Delta Waterways. These guidelines have clarified the responsibilities of local agencies that maintain levees and flood control structures.

By law, State agencies must use the Standardized Emergency Management System (SEMS) when responding to emergencies involving multiple jurisdictions or multiple agencies. The basic framework of SEMS and the Incident Command System (ICS) incorporates multi-agency or inter-agency coordination, the State's master mutual aid agreement and mutual aid program, the operational area concept, and the Operational Area Satellite Information System (OASIS). SEMS has also enhanced the emergency response capability of local and State agencies.

The California Department of Water Resources approved Water Resources Engineering Memorandum No. 63 on January 29, 1999, which establishes the Department's policy and procedures for responding to emergency levee-endangering incidents in the Sacramento-San Joaquin Delta. Similar advance work is necessary relative to potential earthquake emergencies and in the regulatory arena to pre-define environmental regulations applicable to levee emergencies and recovery activities.

Although California Water Code Section 128 gives authority to the Department of Water Resources to flood fight during emergencies, it does not provide funds to support flood fighting. Consequently, the DWR response has generally been limited to technical assistance and coordination of work with the California Conservation Corps, and California Department of Forestry and Fire Protection for crews for placement of sandbags, plastic and other hand-labor-related work. On the other hand, the AB360 Program (Section 12994 of the California Water Code) has been a vehicle for providing funds for emergency response within the context of an emergency plan. These limited funds have historically been primarily used to reimburse local agency expenditures, to establish stockpiles of resources for use by levee maintaining agencies and to provide technical advice.

PROPOSED PROGRAM

CALFED's contribution to an effective Delta levee emergency response program should be concentrated in eight areas:

1. Funding for Ongoing Repair, Reconstruction and Maintenance The vulnerability of the levee system can be reduced by implementing an integrated and comprehensive reconstruction, repair and maintenance program for Delta levees and channels, as described and recommended under the Levee System Integrity Program. This can only be accomplished by supplementing local funding capability through State and federal cost-sharing at adequate and consistent levels, and by establishing workable environmental permitting so that a viable Delta levee building and repair industry can be reestablished and sustained. From a levee emergency response viewpoint, the significant (even crucial) incidental benefit of a well-funded, on-going Delta levee program is to establish a continuous local presence of specialized equipment. Marine-based equipment required to perform levee rehabilitation on some central and western Delta islands will likely be more accessible during emergencies if there is sufficient ongoing work to maintain local operations.

2. Improved Environmental Regulations and Permitting. CALFED will explore conditions under which expanded "work windows," or even year-round work activities, can be implemented and assess other alternatives so a workforce is developed that is sufficient to handle emergency levee situations. Improvements in the permitting process and regulations will also be pursued. CALFED will use a collaborative process that involves ecologists, biologists, engineers and contractors, in addition to the relevant regulatory agencies. During the process, improved construction techniques, protection, and mitigation measures, and more precise definitions of species' needs and related construction impacts will be identified.

3. Emergency Response (and Associated Funding) by State and Federal Agencies In accordance with the "Guidelines for Coordinating Flood Emergency Operations," if a flood fight exceeds the capability of the local levee-maintaining agency or if communities are threatened, the responsible city or county will assist with the flood fight with support from all other SEMS levels. Under SEMS, requests for flood fight assistance from the local LMA's are made to the county Operational Area's Emergency Operations Center, and, if necessary, are escalated to State OES' Regional Emergency Operations Center in Sacramento. The REOC will coordinate information and resources among OA' s and provide a liaison to federal agencies.

Lack of specific funding sources and obstacles within federal public assistance reimbursement rules have hindered direct involvement in flood fight activities by counties, cities, and State agencies. Creation of funding to support a delta levee emergency response plan would eliminate past hesitation and inefficiencies.

a. Federal Assistance The U. S. Army Corps of Engineers has primary federal authority for assisting states with flood fight efforts that meet the criteria established by

Public Law 84-99. Under a Memorandum of Understanding with the Corps, DWR serves as the facilitator for all PL 84-99 flood-fighting efforts. DWR coordinates with the local agency, initiates the PL 84-99 request process, and assists the Corps in determining the applicability of PL 84-99.

Prior to making requests to the Corps, DWR reviews requests and information from the OA on the capability of the local agency. DWR ensures that local and State resources require supplementation and that an emergency situation exists. Once these determinations are made, DWR requests Corps assistance. DWR can also provide technical advice and assistance to local agencies concerning flood fighting and emergency flood control measures.

Every effort is made to expedite the Corps-DWR coordination on PL 84-99 requests consistent with the urgency of the situation. There have been some instances where the response was delayed, with a strong perception by local LMA's that the PL 84-99 decision process is hindered by a need to demonstrate that local and State resources "have been exhausted."

When the Corps does respond under the PL 84-99 emergency flood fight provisions, its efforts are 100 percent federally funded. Under the rehabilitation phase of PL 84-99, the Corps of Engineers repairs the flood-related damage to "federal project levees" and eligible non-project levees. The only non-federal costs are for lands, easements and rights-of-way, and local obligations to hold the government harmless and to operate and maintain the project, and to provide borrow material for repairs.

The role of the Corps should be clarified and confirmed through their participation in the preparation of and commitments to a delta levee emergency response plan so as to eliminate delay in response and avoid any dispute as to whether or not the local and State response is sufficient. This emergency response plan needs to address levee emergencies other than normal rain floods (e. g., earthquakes), and the Corps' role in any such emergencies. Special circumstances, such as multiple breaches within a short time frame, should be identified with criteria established for expedited response.

b. State Assistance For flood control projects sponsored by the Reclamation Board, DWR technical assistance may be requested directly. Existing State funding limits DWR's response to only providing technical assistance. The DWR financial capability to respond to flood emergencies in the Delta should be expanded to include all aspects of a flood fight where levees or other flood control structures are in danger of failure, regardless of whether or not the danger is due to storms, floods, earthquakes, rodents, vessel impacts or any other cause. The funding for support of DWR's efforts, either through expansion of existing programs or through creation of a new program should be ample and clearly committed for comprehensive emergency response[1].

Bond authorization might be particularly helpful to ensure the availability of State funds when needed. For example, authorization of $60 million in bonds to create and replenish a $10 million revolving fund specifically for financing implementation of a delta emergency response plan, as defined in California Water Code Section 12994(b)(2), would provide the assurance that pre-identified response commitments by DWR and other agencies would be funded, should help ensure that the local share requirement of federal disaster assistance programs will be available, and would provide the basis for seeking elimination of obstacles within federal reimbursement policies that hinder multi-jurisdictional flood fight responses.

4. Ensuring Availability of Levee Emergency Resources

a. Specialized equipment and operators: A revitalized levee rehabilitation industry under the Levee System Integrity Program will establish a fleet of specialized equipment essential to a rapid emergency response[2], but will not ensure its availability during emergencies which often extend to other areas. The Emergency Response Plan established under Assembly Bill 360 should establish pre-emergency contracting for specialized equipment to secure the availability of the equipment and experienced operators, and establish pricing for emergency services.

b. Materiel stockpiles: The State Department of Water Resources has established stockpiles for flood fight materiel (sandbags, plastic, stakes, light equipment, pumps, etc.) at locations in the northern, southern, and western Delta. This program needs to be expanded to include rock and sand stockpiles, and to key locations in the central and south Delta regions. Additionally, assurance of supply and/or stockpiling of drain rock and riprap should be included. Coordination between the stockpiling activities of other agencies would be desirable. Transportation of the materials to where they are most needed also needs to be addressed.

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[1] The $200,000 currently provided to DWR under the Delta Levee Subventions Program (Water Code § 12994) is not only inadequate, but will expire under the terms of its authorizing legislation.

[2] Ideally, the resident population of specialized equipment needs to be sufficient to operate in several locations at once, whether because of high flood stages threatening many sites, or because of a strong earthquake damaging several sites. A Delta-based dredging company estimates that it takes at least a $5 million annual levee program expenditure level to generate enough dredger work to justify operating one dredge, with a work window of 3 to 4 months. One barge crane/rock barge unit would be justified in a program of that size with a ten-month work window. By extrapolation, we might expect a $30 million annual program to support approximately 5 dredgers and 5 barge crane/rock barge units in the Delta given appropriate work windows.

c. Labor: The Emergency Response Plan established under AB 360 should consider formal arrangements with the California Department of Forestry and Fire Protection as well as with the California Conservation Corps and with the State prison system for emergency assistance.

5. Integrated Response A detailed response plan should be developed for the Delta that would allow an immediate, simultaneous response to a serious incident (such as a major flood or an earthquake) by all levels of government within a single integrated organizational structure. The plan would identify common needs and functions of all agencies, e.g., housing, feeding, transportation, supplies (including rock and sand), equipment and contracted services and assign the most capable agency/jurisdiction to perform each on behalf of all agencies. The detailed floodfight/earthquake response plans for specific LMAs or areas of the Delta would provide the basis for pre-identifying and assigning specific responsibilities for each agency as well as the level of resources which the individual LMA would be expected to provide in response to the emergency. With detailed assignment of responsibilities, an organizational structure for the "area command" could be delineated so as to assure coordination with the "incident commands." The detailed response plan would serve as the basis for requesting modification to disaster assistance programs, including any needed legislation. The FEAT-produced documents, discussed earlier, may partially serve this purpose.

6. Clarifying Regulatory Procedures Although both State and federal laws suspend environmental regulation during emergencies, some clarifications are desirable.

a. The definitions of emergency for response and regulatory activities need to be consistent. It is especially important that the defined duration of the emergency be consistent for both purposes.

b. Mitigation measures which will be expected during post-emergency recovery work should be defined by a series of examples in order that emergency work will not unnecessarily exacerbate mitigation responsibilities, so that post-emergency recovery work will not be unnecessarily delayed, and so appropriate mitigation can be rapidly defined and implemented.

7. Clarifying Program Eligibility, Inspection, Documentation, Auditing, and Reimbursement Procedures In virtually all of the declared levee emergencies in the last twenty-five years there have been lengthy reimbursement delays, or outright denials which have adversely affected the financial condition and trade-credit and bank-credit opportunities of the local flood control agencies. The requirements of these programs need to be standardized to be consistent with one another, be well and timely communicated to the local agencies, and not be changed or re-interpreted during the completion of the reimbursement process. In addition, legal jurisdiction as a criterion for cost reimbursement needs to be clarified to eliminate obstacles to integrated, multi-jurisdictional emergency response.

8. Dispute Resolution Because events move swiftly during emergency response, there should be a timely dispute resolution process. Currently, the "exhaustion of administrative remedies" followed by court system recourse is truly exhausting both in terms of energy and money. Reimbursement disputes have consumed more than fifteen years in many cases, with local resources being used, which should be going into levee work. A binding arbitration procedure conducted by knowledgeable but impartial arbiters should be established encompassing both the State and federal programs.

APPENDIX G

SEISMIC REPORT

CALFED
BAY-DELTA
PROGRAM

Levees and Channels Technical Team
Seismic Vulnerability Sub-Team

Seismic Vulnerability of the Sacramento - San Joaquin Delta Levees

April 2000

Seismic Vulnerability of the Sacramento - San Joaquin Delta Levees

Levees and Channels Technical Team
Seismic Vulnerability Sub-Team
Members

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Fred N. Brovold
Gilbert Cosio
Michael W. Driller
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Dr. N. Dean Marachi
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CALFED BAY-DELTA PROGRAM
SEISMIC VULNERABILITY
OF THE
SACRAMENTO/SAN JOAQUIN DELTA LEVEES

FORWORD

The CALFED Bay-Delta program is an unprecedented collaboration among state and federal agencies and the state's leading urban, agricultural and environmental interests to address and resolve the environmental and water management problems associated with the Bay-Delta system. The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta system. The objective of CALFED's Levee System Integrity Program is to reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic damage associated with breaching of Delta levees.

Delta levees are the most visible man-made feature of the Bay-Delta system. They are an integral part of the Delta landscape and are key to preserving the Delta's physical characteristics and processes, including definition of the Delta waterways and islands. There is concern that California's Bay-Delta system levees are vulnerable to failure, especially during earthquakes. Levee failures in the Delta could flood farmland and wildlife habitat, and also interrupt water supply deliveries to urban and agricultural users and disrupt highway and rail use. Although there has never been a documented levee failure from a seismic event, the Delta has not experienced a significant seismic event since the levees have been at their current size. One goal of CALFED's Levee Program is to identify the risk of failure of Delta levees due to seismic events and develop recommendations to reduce levee vulnerability and improve levee seismic stability.

A Seismic Vulnerability Sub-Team of CALFED's Levees and Channels Technical Team was formed to assess the seismic risk. This sub-team, composed of seismic experts and geotechnical engineers with experience in the Delta, evaluated levee fragility and assessed the seismic vulnerability of the current levee system. This report presents the findings and conclusions of the Seismic Sub-Team. CALFED's Levee Program will conduct further studies to apply this information to overall risk assessment.

CALFED thanks DWR's Division of Engineering for sponsoring this exceptional study and also recognizes the superior efforts of the experts on the sub-team who contributed their unique technical knowledge, diverse views, and willingness to work long hours.

CALFED BAY-DELTA PROGRAM SEISMIC VULNERABILITY OF THE SACRAMENTO/SAN JOAQUIN DELTA LEVEES EXECUTIVE SUMMARY

The objective of CALFED's Levee System Integrity Program is to reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic damage associated with breaching of California's Bay-Delta system levees. Delta levees are at risk from many sources of failure, including stability, seepage, overtopping, erosion, unseen defects, and seismic. This report only addresses the seismic risk.

Although there has never been a documented levee failure from a seismic event, the Delta has not experienced a significant seismic event since the levees have been at their current size. A team composed of seismic experts and geotechnical engineers with experience in the Delta assessed the seismic risk.

This report provides an assessment of the Delta levees' current vulnerability to potential damage caused by an earthquake. These seismic risk analyses and assessments are based on the most current available information. It is not likely that additional information in the near future would significantly change the present characterization. This assessment also provides an estimate of the probability or likelihood that a damaging earthquake will occur.

This study subdivided the Delta into four Damage Potential Zones. Seismic vulnerability is highest in Zone I, Sherman Island, due to poor levee embankment and foundation soils, and higher exposure to seismic shaking at the western edge of the Delta. Zone II, the central area of the Delta, has the next highest overall level of seismic levee fragility and exposure to seismic shaking. Zones III and IV, with levees of lower heights more distant from earthquake shaking, have generally lower levels of seismic vulnerability.

The final, overall estimate of potential levee failures during a single seismic event is shown in Figure 5-2 on page 23. This figure shows, for example, that an earthquake with a 100-year return period is predicted to cause 3 to 10 levee failures in the Delta, on one or more islands.

While this report quantifies the magnitude of the current seismic vulnerability of Delta levees, CALFED continues to investigate the overall risk. Two teams have been formed. One team of geotechnical engineers is developing recommendations for seismic upgrades and other measures to reduce levee failures. Another team will perform an overall risk assessment of multiple factors that contribute to levee failure, evaluate the consequences of failure, and develop risk management options. Once these two studies are completed, the level of seismic risk in relation to the total risk to Delta levees will be better understood.

CALFED staff will work with stakeholders, the public, and state and federal agencies to develop and implement a Delta levee risk assessment and risk management strategy. CALFED will incorporate the findings from the Geotechnical and Risk Assessment Subteams into an overall risk assessment. Once the risk to Delta levees is quantified and the consequences evaluated, CALFED will develop and implement an appropriate risk management strategy.

CALFED BAY-DELTA PROGRAM
SEISMIC VULNERABILITY
OF THE
SACRAMENTO/SAN JOAQUIN DELTA LEVEES

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CALFED BAY-DELTA PROGRAM
SEISMIC VULNERABILITY
OF THE
SACRAMENTO/SAN JOAQUIN DELTA LEVEES

1 INTRODUCTION

1.1 BACKGROUND

The CALFED process has produced a draft programmatic environmental impact report that describes three alternatives for improving the Delta's levees, environment, water quality, and water supply reliability. The seismic risk assessment described in this report provides an assessment of the Delta's levees current vulnerability to potential damage caused by an earthquake. This assessment also provides an estimate of the probability or likelihood that a damaging earthquake will occur. This information will be used to evaluate the CALFED alternatives with respect to the seismic impact to the Delta.

1.2 ORGANIZATION

This seismic risk assessment was performed by a sub-team of the Levees and Channels Technical Team of CALFED. The sub-team is comprised of geotechnical engineers and a seismologist. The members represent Federal and State government, local interests, and independent consultants. The members of the sub-team are:

Dr. Norman A. Abrahamson	Consulting Seismologist
Fred N. Brovold	GEI Consultants
Gilbert Cosio	Murray, Burns, and Kienlen, Consulting Engineers
Michael W. Driller	Department of Water Resources
Dr. Leslie F. Harder, Jr.	Department of Water Resources
Dr. N. Dean Marachi	The Mark Group, Consulting Engineers
Christopher H. Neudeck	Kjeldsen, Sinnock, Neudeck, Consulting Engineers
Lynn Moquette O'Leary	CALFED/U.S. Army Corps of Engineers
Michael Ramsbotham	CALFED/U.S. Army Corps of Engineers
Dr. Raymond B. Seed	Seismic Geotechnical Consultant
Raphael A. Torres - Chair	Department of Water Resources

1.3 BASIS FOR THE ASSESSMENTS

The seismic risk analyses and assessments presented in this report are based on the most current available information. Information on the seismic response of peat/organic soils is still being developed. Even though hundreds of borings describing the subsurface conditions of Delta levees were reviewed, these borings can only provide a limited characterization of the hundreds of miles of levees. Yet, it is not likely that a finite number of additional borings would significantly change the present characterization.

Additional investigations cannot be completed within the CALFED time frame. Consequently, a combination of sensitivity analyses and assumptions were used to fill this information void. The sub-team determined that even though there was little information available on some issues, a reasonable assessment of the Delta as a whole could still be achieved. This is described in more detail in the report.

Members of the Seismic Vulnerability Sub-Team:
Top Row, Left to Right: Michael W. Driller, Dr. Raymond B. Seed, Frederick N. Brovold, Dr. Leslie F. Harder, Jr., Dr. Norman A. Abrahamson, Michael Ramsbotham
Bottom Row, Left to Right: Christopher H. Neudeck, Gilbert Cosio, Dr. N. Dean Marachi, Lynn Moquette O'Leary, Raphael A. Torres

2 GEOLOGIC SETTING

2.1 GEOLOGY

The Sacramento-San Joaquin Delta, located at the confluence of the Sacramento and San Joaquin Rivers, is a unique feature of the California landscape (see Figure 2-1). The Delta is part of the Central Valley geomorphic province, a northwest-trending structural basin separating the primarily granitic rock of the Sierra Nevada from the primarily Franciscan Formation rock of the California Coastal Ranges (Converse et al., 1981). The Delta occurs in an area that contains 3 to 6 mile thick/deep sedimentary deposits, most of which accumulated in a marine environment from about 175 million years ago to 25 million years ago.

Since late Quaternary time, the Delta area has undergone several cycles of deposition, non-deposition, and erosion, resulting in the accumulation of a few hundred feet of poorly consolidated to unconsolidated sediments. Delta peats and organic soils began to form about 11,000 years ago during a rise in sea levels (Shlemon and Begg, 1975). This rise in sea level created tule marshes that covered most of the Delta. Peat formed from repeated burial of the tules and other vegetation growing in the marshes.

During the cycles of erosion and deposition, rivers were entering from the north, northeast, and southeast. These included the Sacramento, Mokelumne, and San Joaquin Rivers. As the rivers merged, they formed a complex pattern of islands and interconnecting sloughs. River and slough channels were repeatedly incised and backfilled with sediments with each major fluctuation. These processes were complicated by concurrent subsidence and tectonic changes in the land surface.

Debris produced by hydraulic mining during the gold rush of the mid-1800's disrupted the natural depositional history of the Delta. Hundreds of thousands of tons of silt, sand, and gravel were washed from the Sierra Nevada into the Delta. This sediment filled stream channels, caused flooding, and raised the natural levees along Delta streams and sloughs.

2.2 LEVEE BUILDING HISTORY

In the late 1800's, Delta inhabitants began fortifying existing natural levees and draining inundated islands in the Delta for agricultural use.

Most of the early levees in the Delta were constructed by Chinese laborers (Thompson, 1982) using hand shovels and wheelbarrows, and some were built using scrapers pulled by horses. Later, when the farmers realized that levees of sufficient height could not be efficiently built by hand, the barge-mounted, sidedraft-clamshell dredge was used. The levees were generally built of non-select, uncompacted materials without engineering design and without good construction methods.

Figure 2-1: Sacramento - San Joaquin Delta

The original levees were usually less than five feet high, but continuous settlement of the levees and subsidence of near levee soils has required the periodic addition of new fill to maintain protection against overtopping by waters of the Delta. The interiors of many islands are now commonly 10 to 15 feet below sea level. Presently, some levee crowns are 25 feet higher than the interior of their respective islands. Figure 2-2 illustrates the evolution of Delta levees over time.

In general, the upper portion of Delta levee embankments are comprised of mixtures of dredged organic and inorganic sandy, silty, or clayey soils that have been placed on either natural peat or natural sand and silt levees. The variability in foundation materials for Delta levees can be great, even between sites that are in close proximity to one another. Such heterogeneity is due to a history of continuous stream meandering and channel migration within the Delta.

2.3 LEVEE DAMAGE CAUSED BY PAST EARTHQUAKES

Historical information indicates that there has been little damage to Delta levees caused by earthquakes (CDWR, 1992). No reports could be found to indicate that an island or tract had been flooded due to an earthquake-induced levee failure. Further, no report could be found to indicate that significant damage had ever been induced by earthquake shaking. The minor damage that has been reported has not significantly jeopardized the stability of the Delta levee system.

This lack of severe earthquake-induced levee damage corresponds to the fact that no significant earthquake motion has apparently ever been sustained in the Delta area since the construction of the levee system approximately a century ago. The 1906 San Francisco earthquake occurred 50 miles to the west, on the San Andreas Fault, and produced only minor levels of shaking in the Delta; as the levees were not very tall yet in 1906, these shaking levels posed little threat. Continued settlement and subsidence over the past 90 years has, however, significantly changed this situation. Consequently, the lack of historic damage to date should not lead, necessarily, to a conclusion that the levee system is not vulnerable to moderate-to-strong earthquake shaking. The current levee system simply has never been significantly tested.

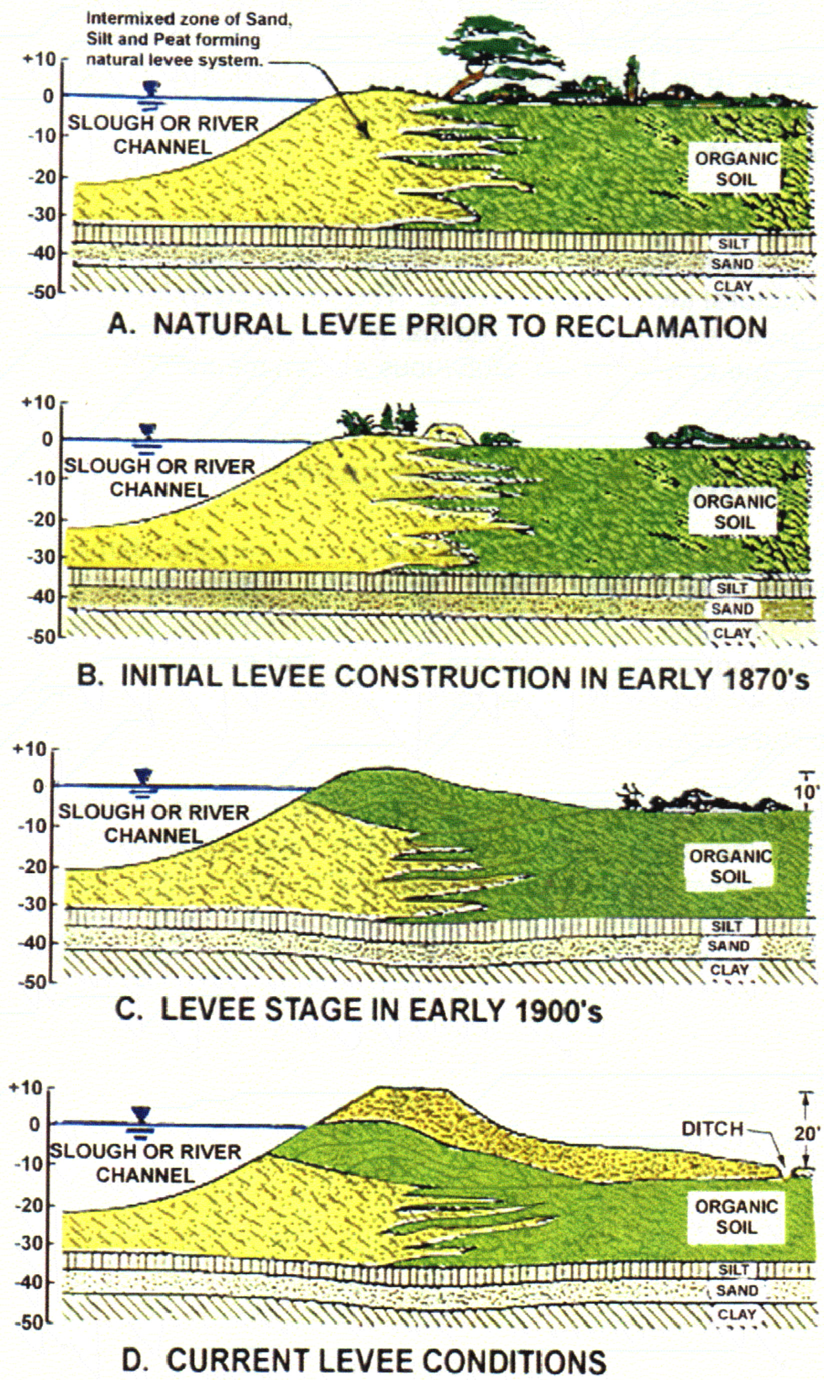

Figure 2-2: Evolution of Delta Levees Over Time

3.0 SEISMICITY OF THE DELTA REGION

3.1 REGIONAL FAULTING AND MODELS

The Delta Levees are located in a region of relatively low seismic activity as compared to the San Francisco Bay area. The major strike-slip faults in the Bay Area (San Andreas, Hayward, Calaveras faults) are located over 16 miles from the Delta region (see Figure 3-1). The less active Green Valley and Marsh Creek-Clayton faults are over 9 miles from the Delta region. There are also small but significant local faults in the Delta region, and there is a possibility that there are blind thrust faults along the western Delta (see Figures 3-1 and 3-2).

3.2 LOCAL FAULTING AND MODELS

In recent seismic studies of the Delta region, a series of blind thrust faults along the western edge of the Central Valley and extending through the Delta has typically been used in the seismic source characterization. However, there is large uncertainty in the location, activity, and even existence of these blind thrust faults in the Delta region. Although various names have been used for this theoretical system of blind thrust faults, in this study we have used the term Coast-Range Central Valley (CRCV) boundary thrust fault system. While there is clear evidence that the CRCV fault system exists and is potentially active to the south and north of the Delta, there is not clear evidence of potentially active blind thrust faults in the Delta region. The possibility that the CRCV fault system exists in the Delta region has a significant effect on the seismic risk to the Delta levees. Due to the large uncertainty in this important aspect of the source characterization, two alternative models of the local faulting have been used in this study: One that includes the CRCV feature in the Delta region, and an alternate one that includes smaller thrust faults west of the Delta region.

The first model is based on the seismic source characterization currently used by the California Division of Mines and Geology (1996) which are part of the state seismic hazard map. In this model, the CRCV is assumed to extend into the Delta region (see Figure 3-1). This model is called the "CRCV" model in this study.

The second model is based on a recent evaluation of the faulting in the Delta region by (Lettis and Associates 1998). This study has concluded that the blind thrust faults do not exist in the Delta region. Instead, thrust faults located further west of the Delta region are postulated as accounting for the crustal shortening across the region (see Figure 3-2). This model is called the "without-CRCV," or "Lettis," model in this study.

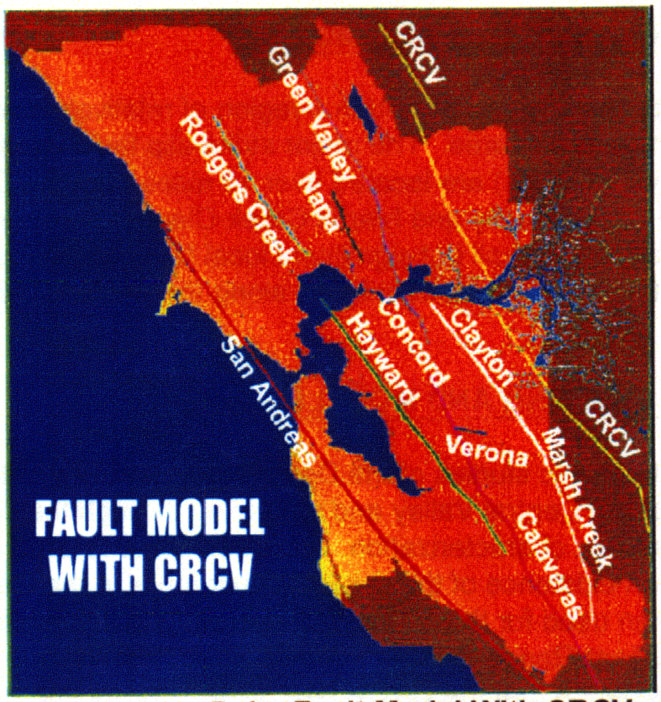

Figure 3-1: Delta Fault Model With CRCV

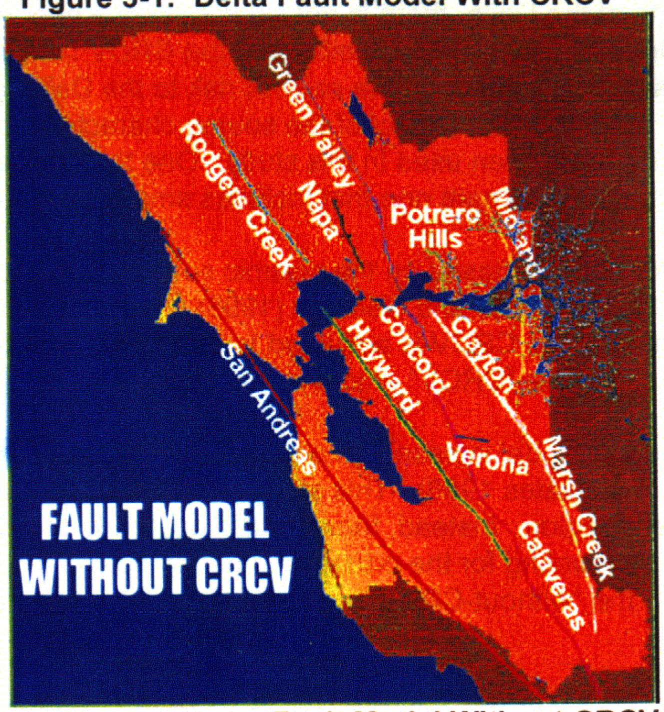

Figure 3-2: Delta Fault Model Without CRCV

3.3 SEISMIC HAZARD RESULTS

Although the two local faulting models are quite different, they produce similar levels of peak ground acceleration (PGA) at individual sites in the Delta region using a probabilistic analysis. For an outcrop of stiff soil or rock, the 100-year PGA ranges from 0.2g in the western Delta to 0.1g along the northeastern Delta (see Figure 3-3). Figure 3-4 presents the estimated PGA at Sherman Island for a range of return periods. Once again, both the "with CRCV" and "without CRCV" models produce similar predictions of PGA. However, while the individual site PGA is similar for the two models, the magnitudes associated with them are different and this leads to very different predictions of performance of the Delta as a system which is discussed later.

For the western Delta, the dominant earthquake contributing to the 100-year PGA is a magnitude 5.8 to 6.2 earthquake at a distance of about 13 miles from local sources. For the eastern Delta, earthquakes with magnitudes of 7 or higher on the more distant San Andreas and Hayward Faults also contribute significantly to the hazard. However, the main magnitude contributing to the 100-year return period hazard for the eastern Delta is also about magnitude 6.

Since the overall seismic hazard is dominated by moderate local events, it is unlikely that the entire Delta region will be subjected to large motions in any single earthquake. For example, a magnitude 6 event near the northern Delta may cause significant ground motions in the northern Delta, but not in the southern Delta, as peak accelerations produced by events of only moderate magnitude attenuate fairly rapidly with distance from the source (fault rupture).

Appendix A presents additional information regarding the seismic source models of the Delta region and the results of the probabilistic hazard analysis.

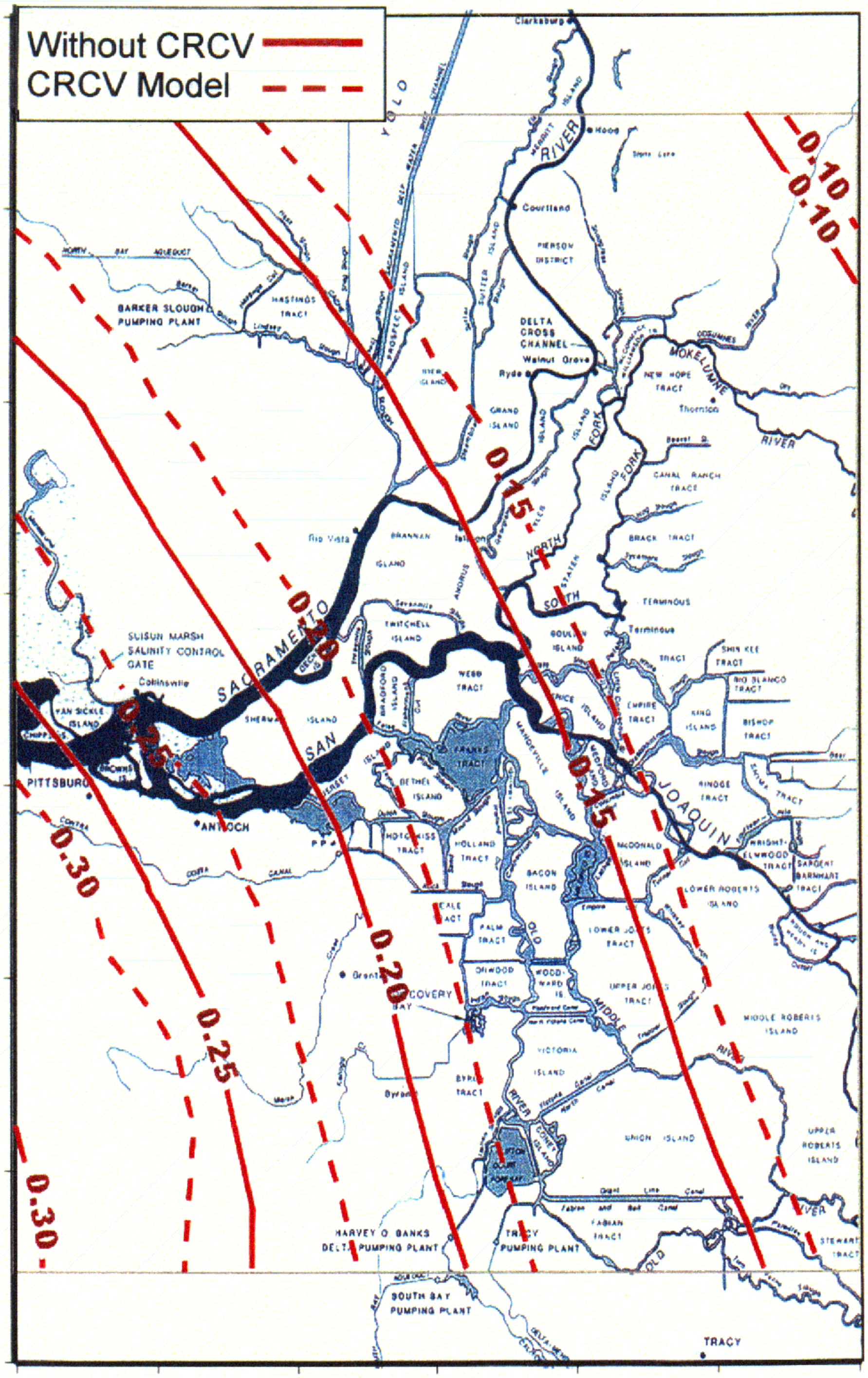

Figure 3-3: Peak Ground Acceleration (g) Contours for 100-year Return Interval – both Models

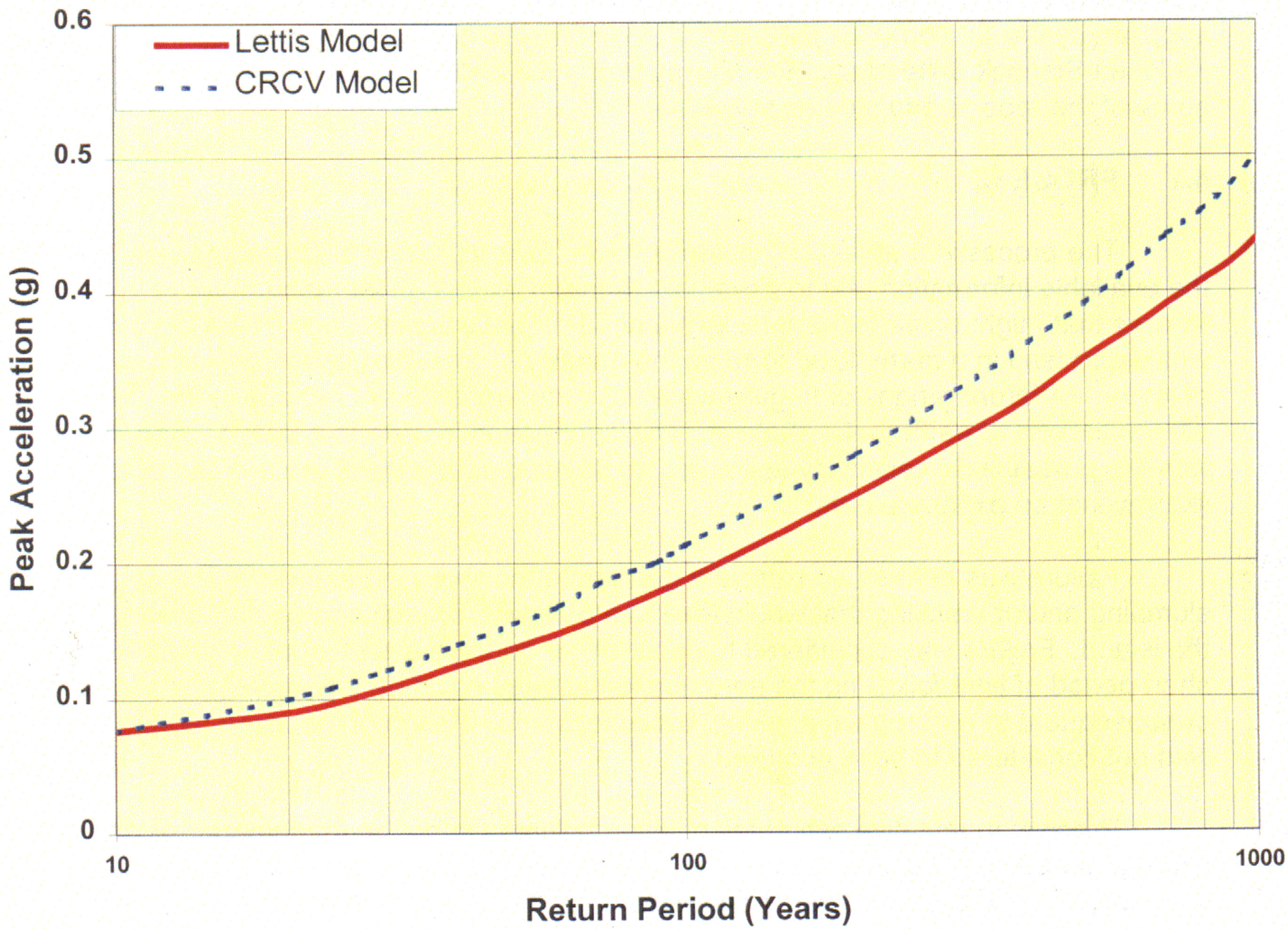

Figure 3-4: Peak Ground Acceleration vs. Return Period for the CRCV and Lettis Models at Sherman Island

4 ESTIMATES OF LEVEE FRAGILITY DUE TO EARTHQUAKE SHAKING

4.1 INTRODUCTION

Levee fragility is defined as a measure of the susceptibility of a levee to fail due to seismic loading. Available geotechnical information and previous seismic stability studies associated with levees in the Delta were used to assess the relative vulnerability of the levees and their foundations to earthquake shaking. Geotechnical reports and data were supplied by the California Department of Water Resources, U. S. Army Corps of Engineers, Kjeldsen Sinnock & Neudeck, and Murray Burns & Kienlen. Appendix E presents a list of some of the reports and studies reviewed.

4.2 PROCESS

The process for assessing potential levee failures during earthquakes was to review the available information and to develop a range of estimates for the number of levee failures that might occur for various levels of earthquake acceleration. This levee fragility was expressed in a normalized form as the number of expected levee failures per 100 miles of levee. Different ranges of fragility were estimated for different regions in the Delta, and for different levels of earthquake shaking. This information is used in a later section, together with the probabilistic seismicity estimates, to develop estimates of the number of failures likely within an exposure period.

Failure was defined as sufficient distress to the levee in the form of lateral spreading, slumping and/or cracking that would lead to a complete breach and uncontrolled flooding of the island. Failure was considered to occur either during the earthquake, or within a very short period of time following the earthquake. Levees could be extensively damaged during or subsequent to earthquake shaking, but unless a full breach of the levee resulted, failure was not considered to have occurred.

Precise quantitative estimates of levee failures cannot be made because geotechnical information for over 600 miles of levees remains limited, particularly for the levees themselves. The sub-team members relied upon the available information and their individual knowledge and experience to develop individual assessments of the frequencies of levee failure for different levels of earthquake shaking. These individual assessments were then discussed by the sub-team and refined into a single consensus range of values.

4.3 EARTHQUAKE MOTIONS CONSIDERED

The likely range of bedrock/stiff soil accelerations that might be experienced on an outcrop of such materials within the Delta within the next 30 to 300 years is between 0.05

and 0.30g (see Section 3). Such motions are expected to be generally associated with a Magnitude 6 event. However, the Delta has thick and deep deposits of soft organic and mineral soils overlying the top of stiff soils. Layers of soft soils overlying stiffer deposits are generally expected to amplify earthquake motions developed in the deeper, stiffer deposits. Based on the studies by CDWR (1992) and Boulanger, et al. (1997), the most likely acceleration amplification factors from deep and stiff base layers to the levee crowns range between 1 and 2. For the purposes of the current assessments, an average amplification factor of 1.6 was used. This crown amplification accounted for both soft soil amplification as well as topographic amplification. Accordingly, the earthquake parameters considered in these fragility assessments can be summarized as follows:

Earthquake Magnitude: 6.
Peak Bedrock/Stiff Soil Outcrop Accelerations: 0.05 to 0.30g.
Base Layer to Levee Crown Amplification Factor: 1.6.

Magnitude scaling factors to adjust acceleration levels for earthquakes having magnitudes other than Magnitude 6 were incorporated in the probabilistic seismicity analyses (see Appendix B). These scaling factors account for the fact that larger magnitude events typically cause longer durations of stronger shaking, and these duration differences affect the severity of the loading.

4.4 DAMAGE POTENTIAL ZONES

Qualitative assessments of high, medium, and low failure potential during earthquake shaking were made for different regions within the Delta. The principal geotechnical parameters affecting this assessment included the following:

- The presence of loose, cohesionless sandy and silty layers in the levee embankment generally lead to a high or medium-high failure potential rating. Such soils are liquefiable when saturated. Since levees are manmade and not formed by intermittent natural processes, loose soils are expected to have greater lateral continuity within a levee than in a natural deposit. The presence of such soil beneath the phreatic line within the manmade levee embankment, as detected by penetration testing, indicates a relatively high potential for a liquefaction-induced levee failure. Levees with substantial amounts of liquefied material are likely to exhibit flow slides and lateral spreading as very loose, cohesionless soils have low post-liquefaction shear strengths.

- The presence of loose, cohesionless sandy and silty layers in the levee foundation was also considered detrimental because of the potential for liquefaction. However, it was not considered as serious as having such materials within the levee. This is because such layers within the natural foundation are more likely to be discontinuous. Foundation liquefaction beneath a levee is also generally less critical than liquefaction within the levee embankment as the post-liquefaction shear resistance necessary to prevent flow and lateral spreading is lower due to geometry and net driving force considerations. In addition, somewhat higher penetration resistance is commonly reported for such foundation layers and this suggests somewhat higher liquefaction resistance and post-liquefaction shear strength.

- High levees on thick, soft foundations were considered more fragile because of their potential to have marginal static stability. Levee sections with only marginal static stability were considered to be likely to slide and experience significant displacements during earthquake shaking even without liquefaction.

- Levees with narrow cross sections, limited freeboard, or histories of previous distress were also considered to have a higher probability of failure.

Two principal modes of potential earthquake-induced levee failure were considered while developing the different damage potential zones: 1) Flow slides and lateral spreading associated with strength loss (liquefaction) of levee embankment or foundation soils, and 2) Inertially-induced seismic deformations of levees experiencing no liquefaction. Potential failure mechanisms included overtopping, seepage erosion due to cracking, and exacerbation of existing seepage problems due to deformations and cracking. Seasonal variations in river and slough water elevations, and their interactions with tides, were also considered. This evaluation resulted in dividing the Delta area into four Damage Potential Zones as described in Table 4-1 and shown in Figure 4-1.

TABLE 4-1: DAMAGE POTENTIAL ZONES WITHIN THE DELTA

Damage Potential Zone	Levee Length in Zone (miles)	Description
I	20	**High susceptibility** to earthquake-induced levee failure. This zone encompasses only Sherman Island and was considered to have high potential for failure due to the presence of substantial liquefiable soils within the non-project levees, especially those along the San Joaquin River. These levee reaches have an unusually high amount of cohesionless sandy and silty soils within the levee section, are relatively narrow, are founded on thick deposits of soft soil, and have a history of distress.
II	301	**Medium to medium-high susceptibility** to earthquake-induced levee failure. This zone is within the central Delta and generally includes levees with high sections founded on thick deposits of soft soil. Most of the levees which have had histories of distress or that have failed during flood events are located within this zone. Vulnerability varies significantly within this region, even along adjacent levee reaches, principally as a function of the presence or absence of liquefiable soils at the base of the levee embankment sections.
III	116	**Low to medium susceptibility** to earthquake-induced levee failure. This zone is located on the southern and western periphery of the Delta and generally involves levees of smaller heights founded on thinner layers of soft soil.
IV	223	**Low susceptibility** to earthquake-induced levee failure. This zone is located on the northern and eastern periphery of the Delta and generally involves levees of smaller heights founded on thinner layers of soft soil.
TOTAL LENGTH	660 miles	

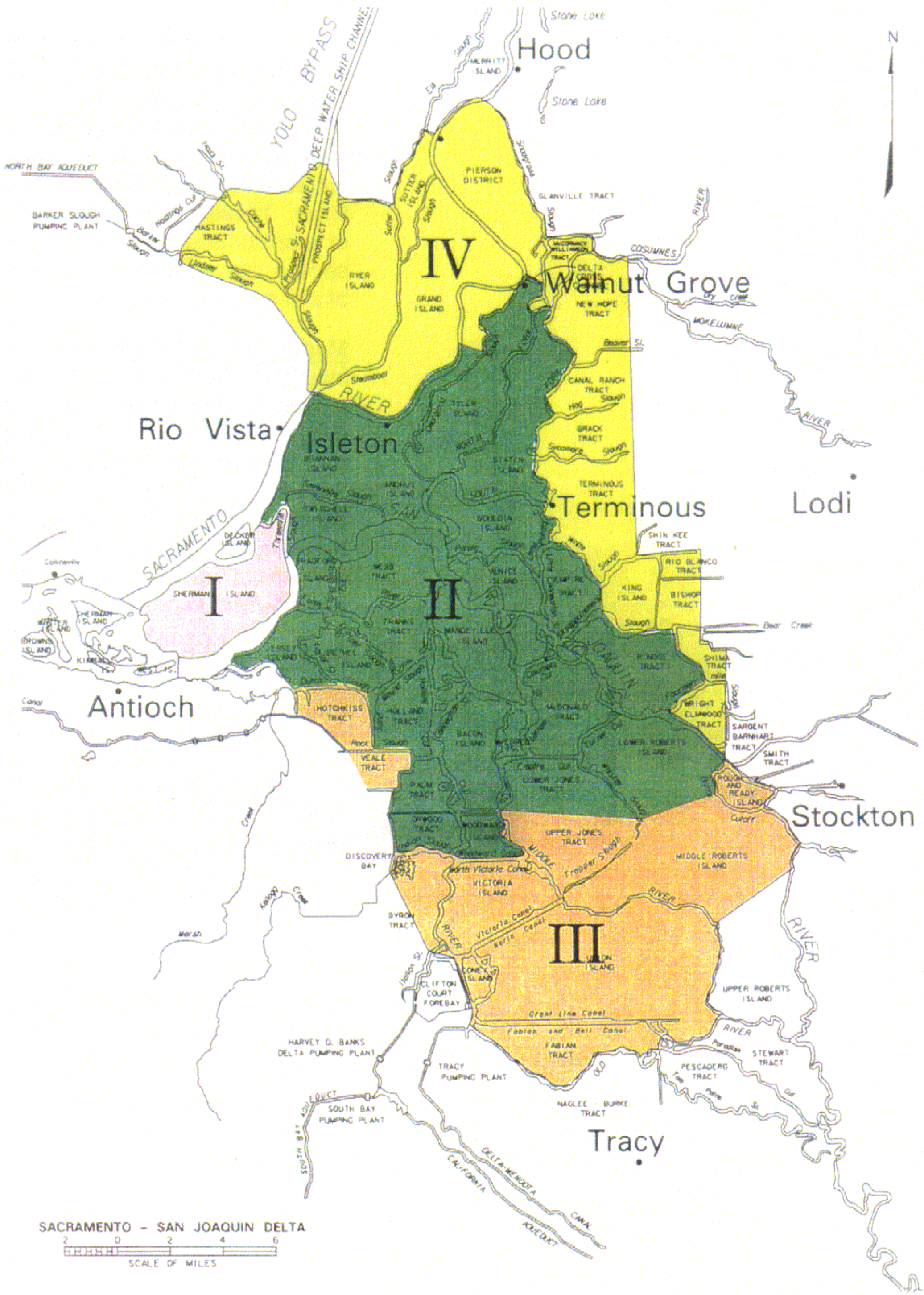

Figure 4-1: Damage Potential Zones within the Delta

4.5 ESTIMATES OF LIQUEFACTION-INDUCED LEVEE FAILURES

Liquefaction fragility estimates (failures per 100 miles of levee) were developed for different earthquake loadings based on the sub-team's experience with the performance of similar earth structures. The three principal steps in developing these estimates were as follows:

1. Levee geometries and geotechnical data from over 34 sites within the Delta were reviewed and evaluated. Each site was a levee reach (or length), and these varied from about 200 feet to 2,000 feet in length. The information reviewed included results from boring logs, Standard Penetration Tests (SPT), Cone Penetration Tests (CPT), soil classification testing, and shear strength testing.

2. The liquefaction potential of sandy and silty soils within both the levee and foundation soil strata was evaluated using the penetration test data and the well-established correlation developed by Seed, et al. (1984), with suitable corrections for magnitude and duration effects. Post-liquefaction shear strengths were evaluated based on the correlation developed by Seed and Harder (1990), and the performance of similar earth structures during recent earthquakes.

   Post-liquefaction shear strength estimates were used to evaluate the associated displacement and deformation potential of levees following liquefaction. The displacement or deformation evaluation was used to obtain an estimate of the potential for levee sections at each site to fail following an earthquake.

3. The resulting estimated levees failures due to liquefaction were then used to statistically characterize the likelihood of liquefaction-induced levee failures, for various levels of shaking, within each of the four Damage Potential Zones shown in Figure 4-1.

The evaluations outlined in these three steps were performed in both qualitative assessments as well as with quantitative approaches. Individual evaluations developed by sub-team members were resolved into a consensus ranges of fragility estimates. These estimates also incorporate differences in risk associated with daily (tidal) and seasonal variations in water levels in the rivers and sloughs.

The resulting liquefaction-related fragility estimates for each of the four Delta Damage Potential Zones are presented in Table 4-2. For peak accelerations less than 0.1g, the estimated fragility values are relatively low. This is in good agreement with the documented performance of Delta levees. Peak base accelerations have been estimated to be less than about 0.08g since reclamation of the Delta began in 1868 (see CDWR, 1992). As base accelerations (seismic loading) increase, the estimated levee fragility also increases for all four damage potential zones.

One of the important findings derived from the liquefaction fragility estimates is that the hazard associated with this mode of failure is much greater for Zone I (Sherman Island) than for the other three zones. This is because extensive layers of liquefiable sandy soils are known to exist within the levees protecting Sherman Island. No other levee is known to have such a large extent of liquefiable soil. In addition, Sherman Island is the western-most island, and is closest to the principal seismic source zones. Thus the island is most likely to experience strong shaking levels.

Another important finding is that for all four Damage Potential Zones, the fragility associated with potential soil liquefaction is much higher than that associated with potential non-liquefaction failure modes. This has important ramifications with regard to potential options for reducing seismic fragility along levee sections. Refer to Section 6 "Mitigation of Seismic Vulnerability".

TABLE 4-2: ESTIMATED FAILURE RATE (FRAGILITY) FOR BOTH LIQUEFIED AND NON-LIQUEFIED REACHES - FAILURES PER 100 MILES

Magnitude 6.0 Rock/Stiff Soil Peak Acc. (g)	Damage Potential Zone	Levee Length (miles)	Estimated Fragility - Number of Levee Failures per 100 miles	
			Liquefied Reaches	Non-Liq. Reaches
	I	20	0.005 - 0.50	0.030 - 0.075
	II	301	0.001 - 0.083	0.015 - 0.036
0.05	III	116	0.001 - 0.033	0.003 - 0.010
	IV	223	0.001 - 0.033	0.003 - 0.010
	I	20	0.20 - 2.5	0.050 - 0.12
	II	301	0.080 - 0.33	0.023 - 0.052
0.10	III	116	0.050 - 0.15	0.004 - 0.017
	IV	223	0.050 - 0.15	0.004 - 0.016
	I	20	2.5 - 10.	0.16 - 0.35
	II	301	0.66 - 1.7	0.070 - 0.15
0.15	III	116	0.29 - 1.2	0.010 - 0.057
	IV	223	0.29 - 1.2	0.011 - 0.049
	I	20	5. - 20.	0.36 - 0.77
	II	301	1.7 - 5.0	0.16 - 0.33
0.20	III	116	0.88 - 2.3	0.022 - 0.13
	IV	223	0.88 - 2.3	0.025 - 0.11
	I	20	15. - 30.	1.5 - 3.2
	II	301	5.0 - 10.	0.66 - 1.4
0.30	III	116	2.4 - 5.9	0.092 - 0.53
	IV	223	2.4 - 5.9	0.11 - 0.46

4.6 ESTIMATES OF LEVEE FAILURES FOR NON-LIQUEFACTION EARTHQUAKE-INDUCED DISPLACEMENTS

Some marginally-stable levees will deform significantly during an earthquake due to cyclic inertial loading. Such deformations could lead to levee failure even if the levee and foundation soils did not experience liquefaction. Estimates of levee fragility for the non-liquefaction deformation mode of failure used the following approach:

- First, an estimate was made of the number of marginally stable levee sites in each Damage Potential Zone. Three levels of marginal stability were considered and the number of marginal sites for each level was estimated for each zone.

- The levee deformation that would be induced by earthquake shaking was estimated for each level of marginal stability using one-dimensional dynamic response analyses coupled with Newmark-type double-integration deformation calculations. The response analyses were used to develop estimates of deformation potential specifically appropriate to the usual foundation soil conditions prevalent throughout the Delta. Levee deformation estimates were generated for a range of base accelerations.

- The estimated levee deformations were then converted into probabilities of failure by considering daily and seasonal variations of channel water levels, varying freeboard, cracking, and seepage erosion and piping potential. The failure probabilities were then summed for each level of marginal stability within a zone, and then expressed as a levee fragility in terms of expected failures per 100 miles of levee within each zone for a range of base accelerations. These results are presented in the last two columns of Table 4-2.

4.7 ESTIMATES OF LEVEE FRAGILITY DURING SEISMIC EVENTS

Table 4-2 presents levee fragility values estimated for both liquefaction and non-liquefaction deformation modes of failure. In comparison with the liquefaction mode of failure, the non-liquefaction deformation levee fragility values are much lower, only approximately 10 percent of the liquefaction values. In addition, while there is a significant difference in the liquefaction fragilities estimated for Zones I and II, there is not as large a difference in the non-liquefaction deformation fragilities. This is principally because the number of marginally stable sites per levee mile are believed to be within the same order of magnitude within both Zones I and II in the central Delta.

4.8 MAGNITUDE CORRECTION FACTORS

The estimates for levee failures and fragility presented in Table 4-2 are for earthquake shaking associated with a magnitude 6.0 event. For the same level of shaking, larger magnitude earthquakes will induce more damage and more levee failures than smaller magnitude events because larger magnitude earthquakes have longer durations of strong shaking. To adjust the fragilities for earthquake magnitudes other than Magnitude 6.0, the following scaling factors were used:

A. Liquefaction Mode of Failure:

A magnitude correction factor for the liquefaction mode of failure was developed using the Idriss (1997) magnitude scaling factors for triggering of liquefaction. These corrections are slightly larger than those previously used by Seed, et al. (1984), and are slightly lower than those recommended by the NCEER Liquefaction Working Group (NCEER, 1997).

B. Non-Liquefaction Deformation Mode of Failure:

A magnitude correction factor for the non-liquefaction deformation mode of failure was developed using the Earthquake Severity Index described by Bureau et al. (1988). This correction is much larger than the one for liquefaction, but is comparable with the cyclic inertial deformation results obtained by Makdisi and Seed (1977).

Appendix B presents additional information regarding the estimates of the levee fragilities and the associated evaluations and calculations used to develop them.

5 PROBABILISTIC EVALUATION OF LEVEE FAILURES

5.1 METHODOLOGY

The seismic hazard analysis (or Probabilistic Seismicity Evaluation, as described in Section 3) was combined with the levee fragility evaluation to develop a probabilistic evaluation of the number of levee failures. The number of levee failures expected to occur in a single earthquake is a function of return period or annual likelihood of occurrence of different levels of earthquake intensity.

The levee failure probability analysis is an extension of standard probabilistic seismic hazard analysis. The difference is that instead of calculating the probability of the ground motion exceeding a specified value at a location, the probability of a specified number of levee failures being exceeded in a single earthquake was computed. In this way, the performance of the entire levee system was considered simultaneously. This avoids the problems of using individual site hazard curves, which may represent different earthquakes at different parts of the Delta.

These analyses consider the performance of the Delta levees for specific earthquake scenarios. For each earthquake scenario, the probability of one or more levee failures occurring within the Delta was computed. This process is repeated for two or more failures, three or more failures, and so on. Following the probabilistic seismic hazard analysis, rather than considering just one or two scenarios, all possible earthquake scenarios were considered and their probabilities of occurring were determined.

The probability of a given number of levee failures for an earthquake scenario is multiplied by the probability of the scenario earthquake actually occurring. This rate of failure is then summed over all of the scenarios to give the total rate of various numbers of levees failing in a single earthquake. A Poisson assumption for the earthquake occurrence is used to convert the rate of failures into a probability of failures. The result is a hazard curve for the "expected" number of levee failures in a single earthquake. The details of the mathematical formulation used in the probability calculation is described in Appendix C.

The resulting median hazard curves for levee failures are shown in Figure 5-1. Two curves are presented; one for the CRCV model and one for the without-CRCV model (see Section 3). The large difference for the two models reflects the impact of an assumed large CRCV blind thrust fault under the west end of the Delta. At low numbers of failures, the two source models lead to similar levee failure hazard because the hazard is controlled by large distant earthquakes on the Hayward and San Andreas fault and small local earthquakes. At larger numbers of failures, the differences between the two fault models become more pronounced.

The final, overall estimate of seismic levee fragility shown in Figure 5-2 was tempered by considering the uncertainties in the two fault models and the uncertainties inherent in the various elements of the overall seismic fragility and hazard evaluation. Thus, the fragility estimates include allowances for current sources of uncertainty with regard to both seismicity (loading) and seismic levee fragility (resistance).

The same Levee Fragility estimates are alternately shown with respect to return periods of 50, 100, and 200 years (see Figure 5-3). These graphs show the probability of exceeding a particular number of levee breaks in a single event during a given exposure time period.

5.2 ILLUSTRATIVE SCENARIO EVENTS

Three illustrative scenario earthquake events were developed to illustrate the potential for levee failures following a single earthquake:

1. Magnitude 7.1 earthquake on the Hayward Fault
2. Magnitude 6.25 earthquake on the Concord Fault
3. Magnitude 6.0 earthquake on the CRCV Fault, immediately northwest of Sherman Island

Figures 5-4 to 5-6 show the estimated number of levee breaks per zone and the peak acceleration contours for stiff soil or rock for each of these three scenario events.

As shown in Figure 5-4, a Magnitude 7.1 event on the relatively distant Hayward Fault produces low to moderate levels of acceleration of fair duration, and results in a low predicted number of levee failures (on the order of 0 to 4 failures throughout the Delta).

As shown in Figure 5-5, a Magnitude 6.25 Concord Fault event produces similar levels of peak acceleration at the western end of the Delta (on the order of 0.1g), but these rapidly decrease to the east. This, coupled with a relatively short duration, results in a lower level of predicted levee failures than for the Hayward fault event shown in Figure 5-4.

Figure 5-6 illustrates the third scenario event, a Magnitude 6.0 on the CRCV Fault at the northwestern edge of the Delta. The proximity of the fault rupture produces much higher levels of acceleration, and results in much higher predicted numbers of levee failures, especially in Zones I and II. The numbers of predicted failures for this scenario event are fairly high (on the order of 13 to 32 through the entire Delta), but the annual likelihood of occurrence of this even is much lower than for the events illustrated in Figures 5-4 and 5-5.

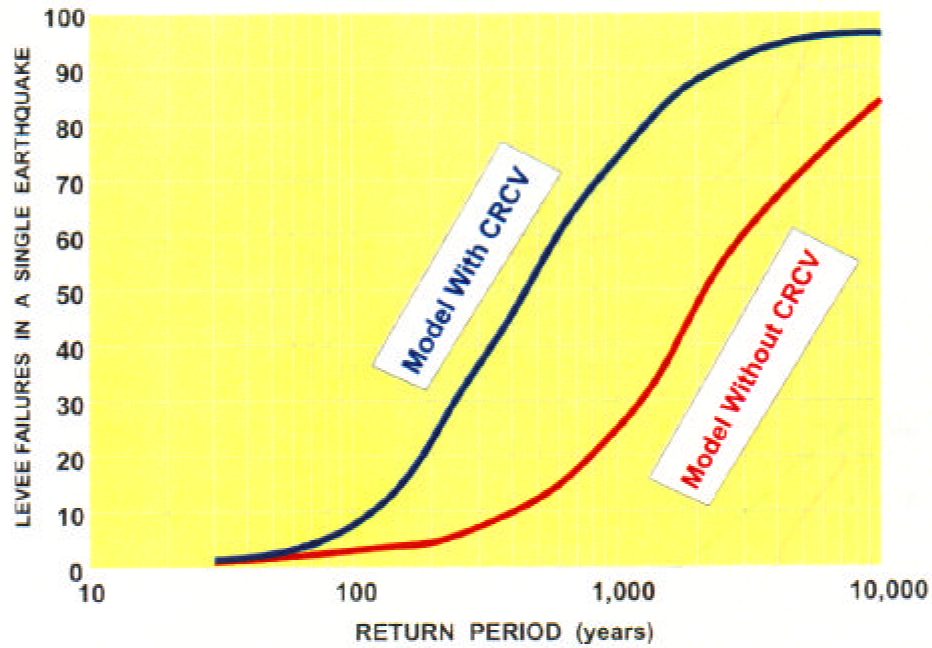

Figure 5-1: Number of Levee Failures in a Single Earthquake–both Fault Models Show

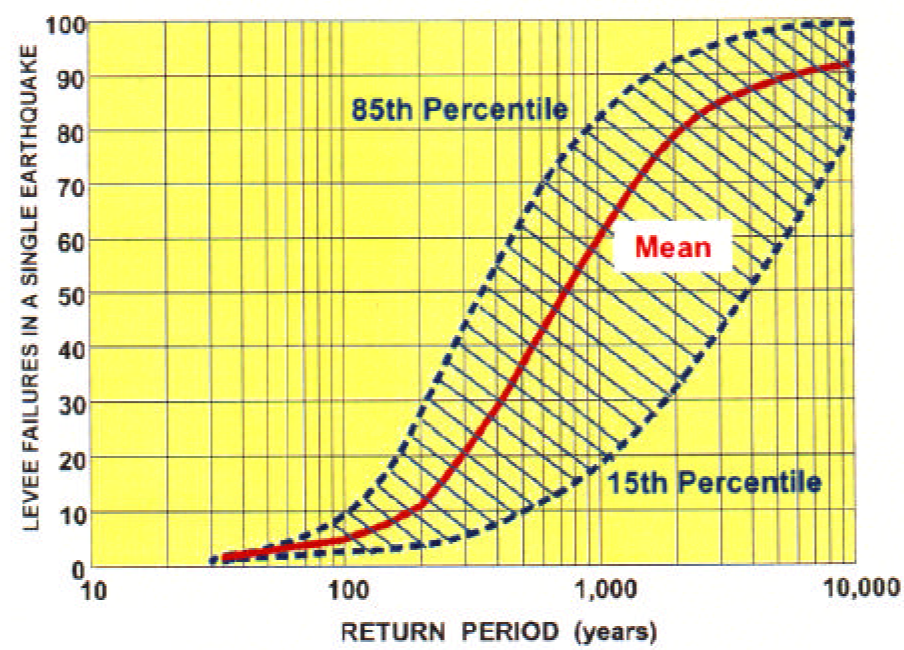

Figure 5-2: Number of Levee Failures in a Single Earthquake-Fault Models Combined
Note: Number of Levee Failures does not equate to Number of Islands Flooded

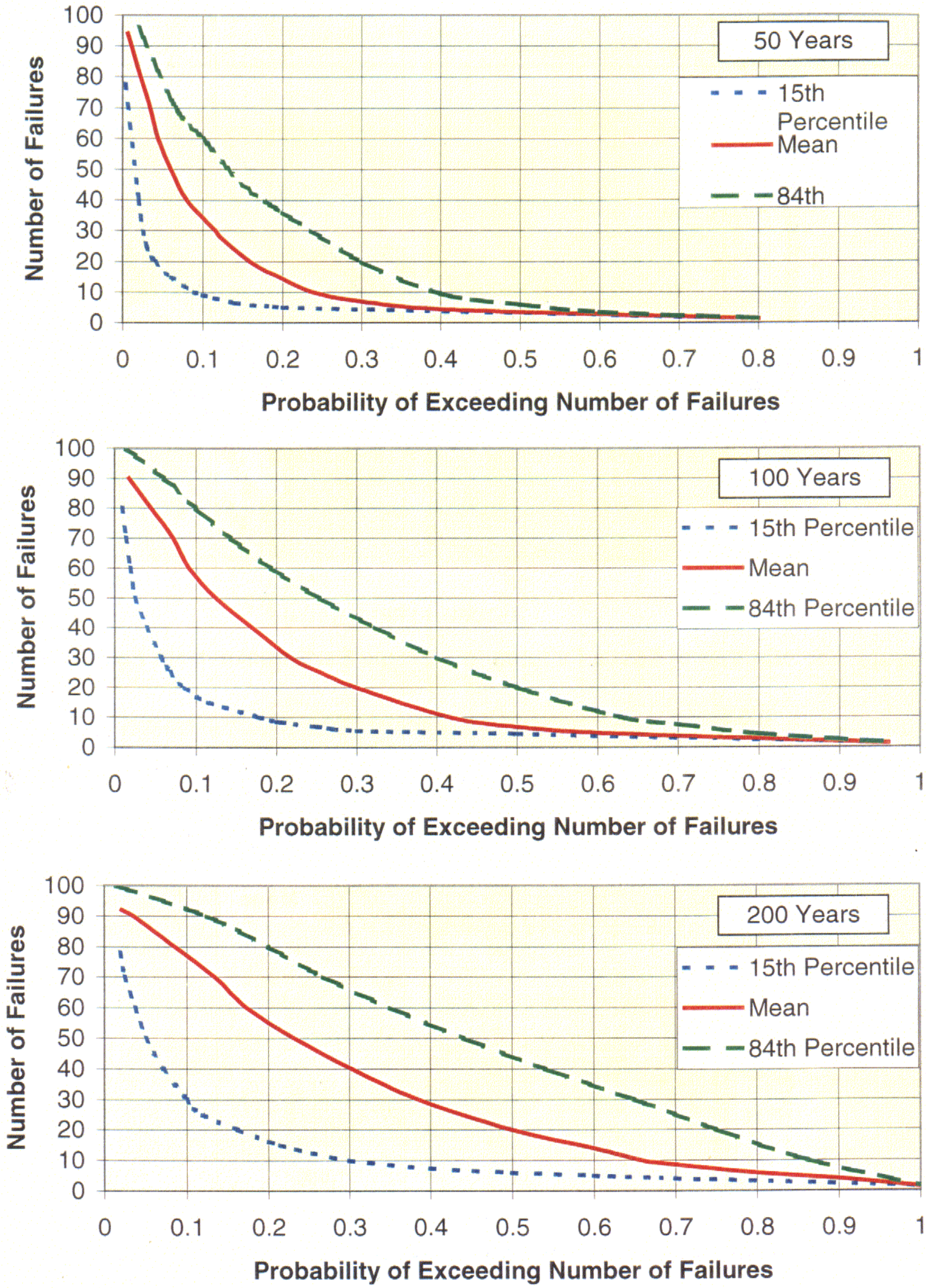

Figure 5-3: Probability of Exceedance vs. Number of Levee Failures for 50, 100 and 200 Year Return Periods

Note: Number of failures does not equate to numbers of islands flooded

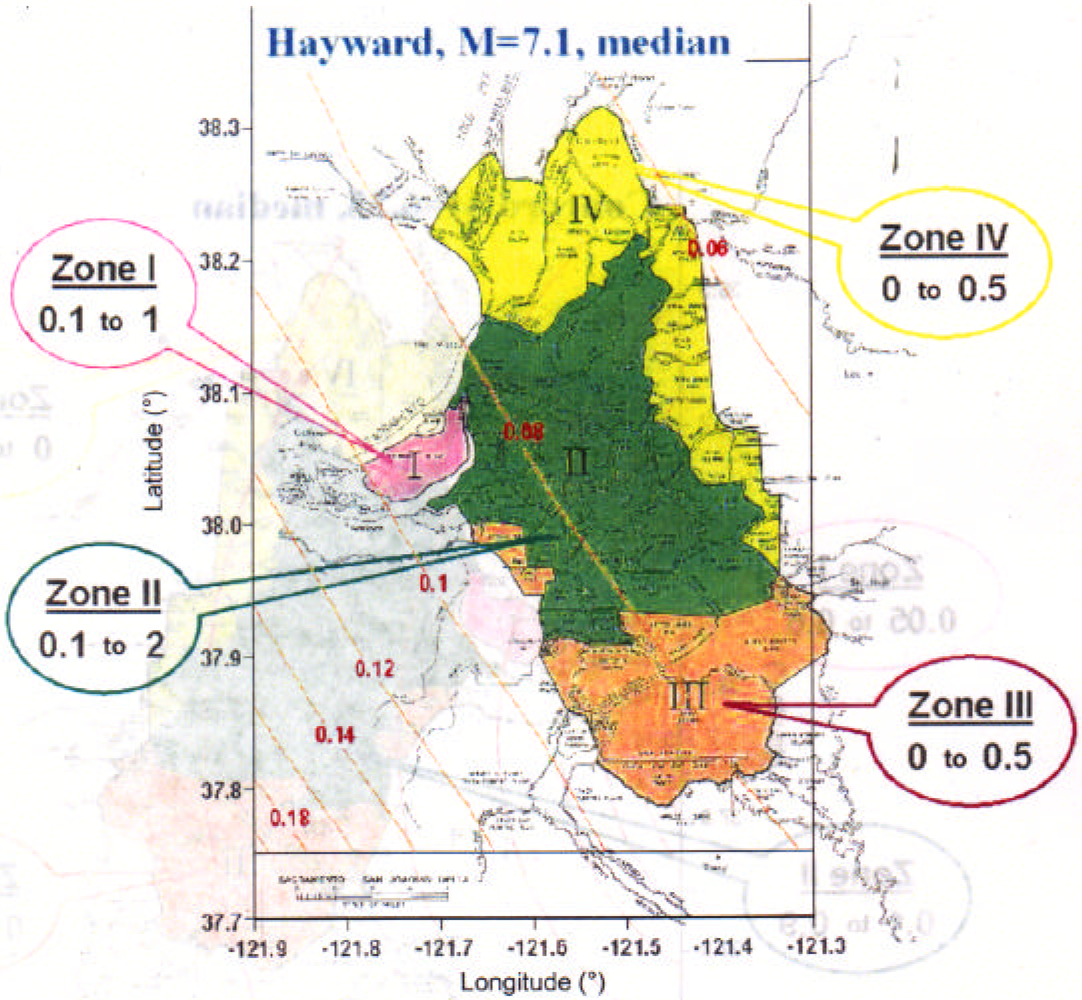

Figure 5-4: Expected Number of Levee Failures for a Magnitude 7.1 Earthquake on the Hayward Fault

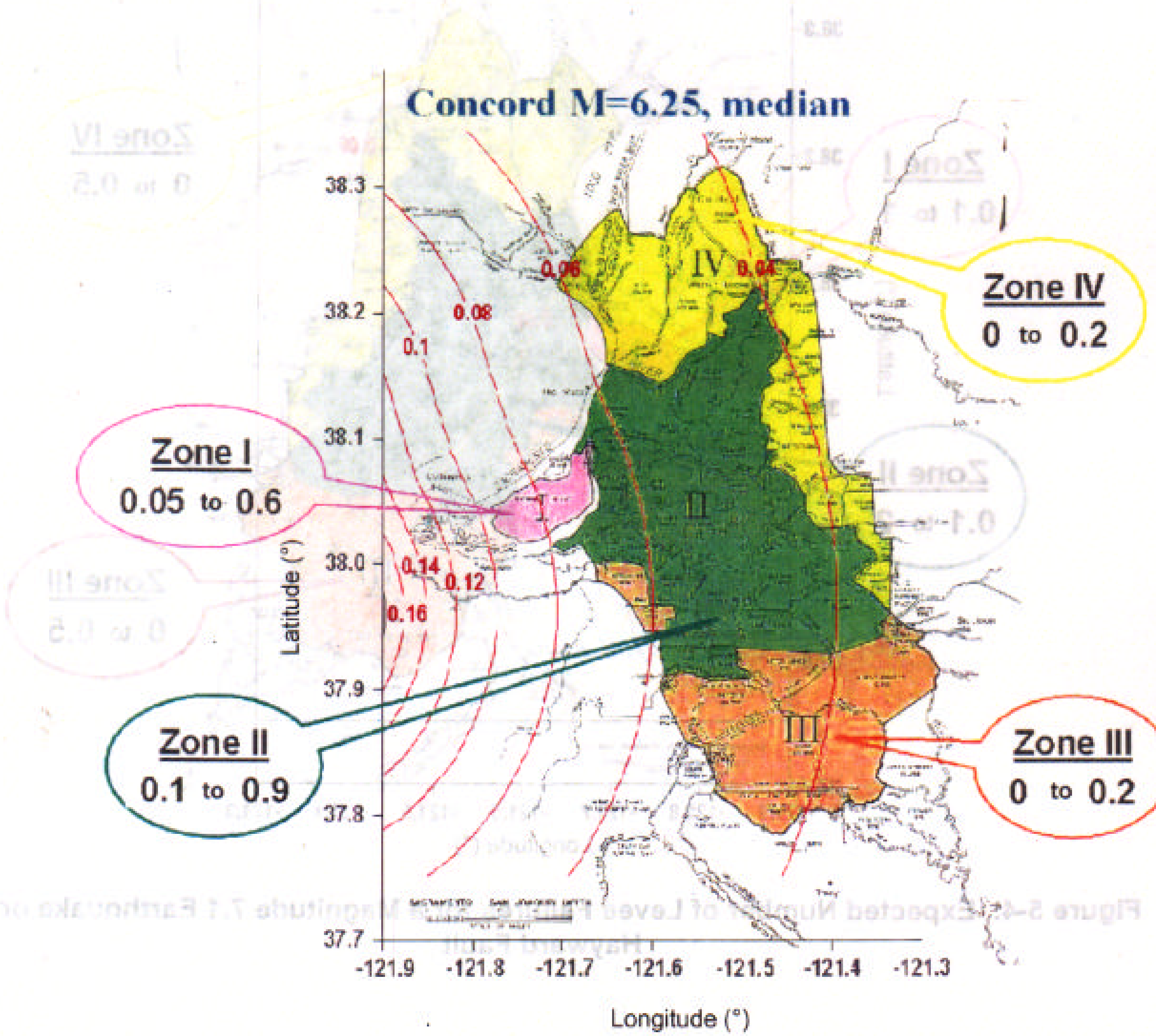

Figure 5-5: Expected Number of Levee Failures for a Magnitude 6.25 Earthquake on the Concord Fault

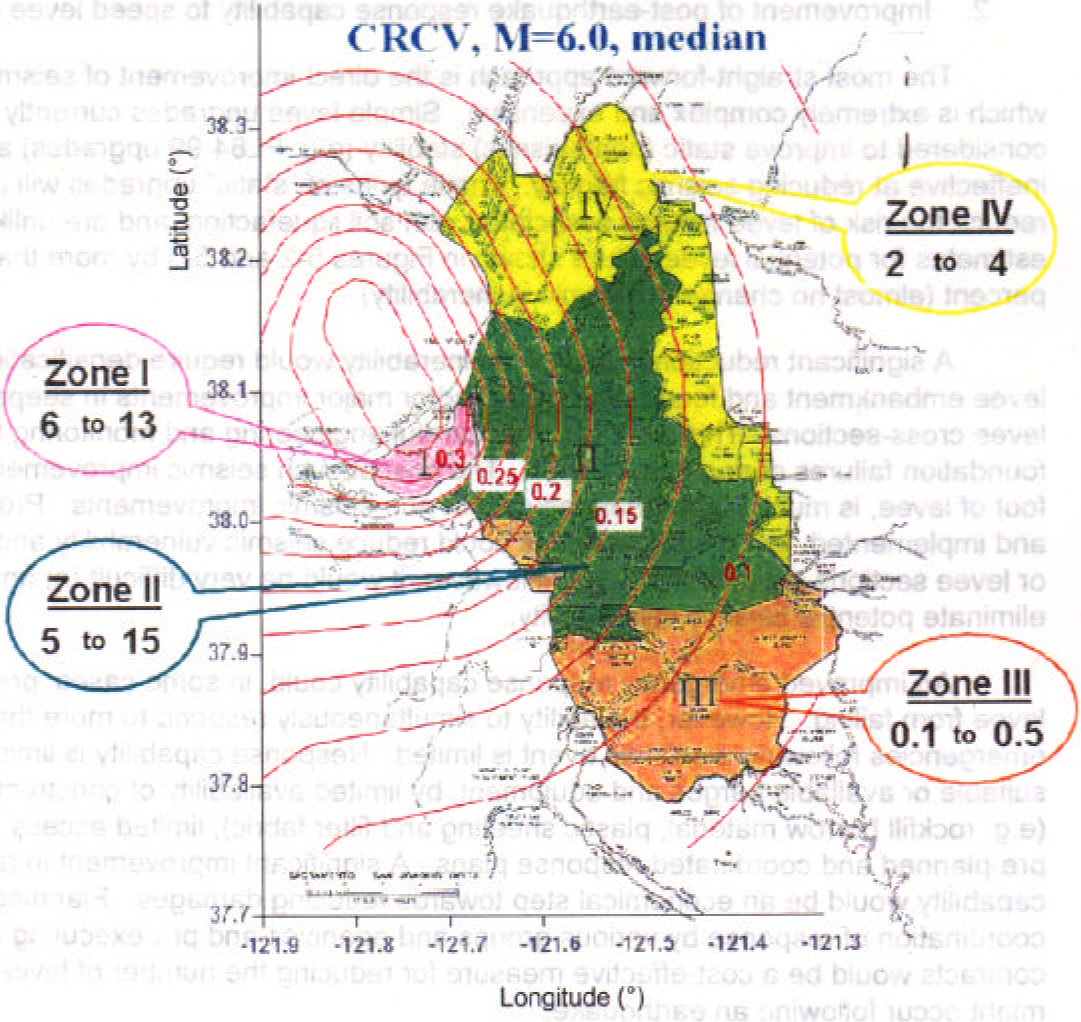

Figure 5-6: Expected Number of Levee Failures for a Magnitude 6.0 Earthquake on th
CRCV Fault

6 MITIGATION OF SEISMIC LEVEE VULNERABILITY

There are several approaches which might be considered to reduce seismic levee vulnerability and its potential impacts. Two approaches are:

1. Improvement of seismic levee stability in order to directly reduce seismic vulnerability.

2. Improvement of post-earthquake response capability to speed levee repairs.

The most straight-forward approach is the direct improvement of seismic levee stability, which is extremely complex and expensive. Simple levee upgrades currently being considered to improve static (non-seismic) stability (e.g. PL84-99 upgrades) are largely ineffective at reducing seismic fragility. These types of "static" upgrades will do very little to reduce the risk of levee failures associated with soil liquefaction, and are unlikely to reduce the estimates for potential levee failure shown in Figures 5-2 and 5-3 by more than about 10 percent (almost no change in seismic vulnerability).

A significant reduction in seismic vulnerability would require densification of the loose levee embankment and foundation soils, and/or major improvements in seepage control and levee cross-sections. This work requires careful engineering and monitoring to avoid levee or foundation failures during construction. The cost of such seismic improvements, per linear foot of levee, is much higher than the cost of non-seismic improvements. Properly engineered and implemented, levee improvements could reduce seismic vulnerability and selected islands or levee sections could be targeted. However, it would be very difficult (at any cost) to fully eliminate potential seismic vulnerability.

An improved emergency response capability could, in some cases, prevent a damaged levee from failing. However, the ability to simultaneously respond to more than a few levee emergencies following a seismic event is limited. Response capability is limited by lack of suitable or available barges and equipment, by limited availability of construction materials (e.g. rockfill borrow material, plastic sheeting and filter fabric), limited access, and by a lack of pre-planned and coordinated response plans. A significant improvement in response capability would be an economical step towards reducing damages. Planning and coordination of response by various groups and agencies and pre-executing construction contracts would be a cost-effective measure for reducing the number of levee failures that might occur following an earthquake.

The development of seismically-protected water conveyance routes, either through the Delta or around the Delta, has been considered by others. Evaluating such alternatives was beyond the scope of the sub-team.

Similarly, it was beyond our scope to comment on expanding storage capacity south of the Delta.

7 SUMMARY OF FINDINGS

The studies presented in the previous sections were completed to provide an evaluation of the current seismic vulnerability of levees in the Sacramento-San Joaquin Delta. The major findings of this study are summarized as follows:

- Figures 3-1 and 3-2 show the principal faults considered in the development of a probabilistic assessment of seismicity. Two models were considered in this analysis: one includes a potentially significant blind thrust fault system along the western edge of the Delta, and the other one does not. Although both fault models predict about the same general levels of peak accelerations for a given return period (see Figures 3-3 and 3-4), the earthquake magnitudes associated with the motions are different, with somewhat higher magnitudes resulting from the CRCV fault model with the blind thrust fault.

- This study characterized the levee fragility of the Delta by subdividing the Delta into four Damage Potential Zones (see Figure 4-1). Seismic fragility is highest in Zone I, Sherman Island, due to poor levee embankment and foundation soils. Zone II, the central area of the Delta, has the next highest overall level of seismic levee fragility. Zones III and IV, with levees of lower heights and less saturated soil conditions, founded on generally firmer soils, have generally lower levels of levee fragility.

- Levee fragility within each of the four damage potential zones was estimated for a range of potential earthquake shaking. The two potential modes of levee failure used in this assessment were:

  (1) Soil liquefaction (loss of strength of saturated sandy and silty soils).

  (2) Inertially-driven deformations of "weak," marginally-stable levee sections.

  Levee fragility values for both of these potential modes of failure are presented in Table 4-2.

- Finally, seismic vulnerability was evaluated by combining the probabilistic assessment for various earthquake motions (loading) with the estimated seismic fragility (resistance) of different levee reaches. The fault model without the blind thrust fault gave lower predicted numbers of levee failures (see Figure 5-2: 3 vs. 7 levee failures in a single earthquake for a return period of 100-years). As it is not presently possible to conclusively select between the two faulting models studied, this study ended up averaging the results from the two fault models, with the final levee vulnerability results shown in Figures 5-2 and 5-3.

- A brief discussion of options for reducing the current Delta levee seismic vulnerability was presented in Section 6. It was concluded that attempting to significantly reduce seismic levee fragility will be both difficult and expensive, and that simply making relatively minor geometric modifications (e.g. along the lines of PL84-99 criteria) will not significantly reduce seismic vulnerability. Developing improved emergency response plans and measures (including stockpiling of critical materials and equipment) is thought to have considerable merit, especially in the short-term.

- The next phase of this committees' studies should include further examination of various proposed long-term mitigation alternatives and emergency response measures.

APPENDIX A:

SEISMICITY OF THE DELTA REGION

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SEISMICITY OF THE DELTA REGION

A1. INTRODUCTION

The Delta is located in a region of relatively low seismic activity. However, if a large earthquake (M≈6.5-7) occurs on a local fault in the Delta region, then there will be large ground motions (with peak horizontal accelerations exceeding 0.2g) at the western edge of the Delta. Although a large local event cannot be ruled out, it has a low probability of occurring. Probabilistic seismic hazard analysis is a method that explicitly considers how often earthquakes of various sizes are likely to occur, and what is the likely ground motion that will result if an earthquake occurs. In this manner, it allows for an evaluation of the seismic risk of the levees.

The probabilistic approach used in this study follows the standard approach first developed by Cornell (1968), with some modifications to more fully address all sources of variability.

There are three main components of variability that are considered in a seismic hazard analysis: what are the likely magnitudes of the earthquakes, where are the earthquakes likely to be located, and what is the likely ground motion given that an earthquake of a specified magnitude has occurred at a specified location.

The source characterization describes the expected rate of earthquakes as well as the distribution of magnitudes and locations. The attenuation relationships describe how strong the resulting ground shaking will be for an event of a given magnitude and location. These components of the hazard analysis are briefly described below. The resulting horizontal peak acceleration hazard is then discussed.

A2. DESCRIPTION OF SEISMIC SOURCES

The faults considered in the hazard analysis are shown in Figure A-1 and A-2, for the two alternative models of the Delta region thrust faults considered in this study. The mean slip-rate, fault width, and maximum magnitude of the faults are listed in Table A-1. The main strike-slip faults in the Bay area (San Andreas, Hayward, Calaveras) contribute to the hazard in the Delta for short return periods, but the smaller (and more local) faults contribute more significantly to the overall hazard at longer return intervals.

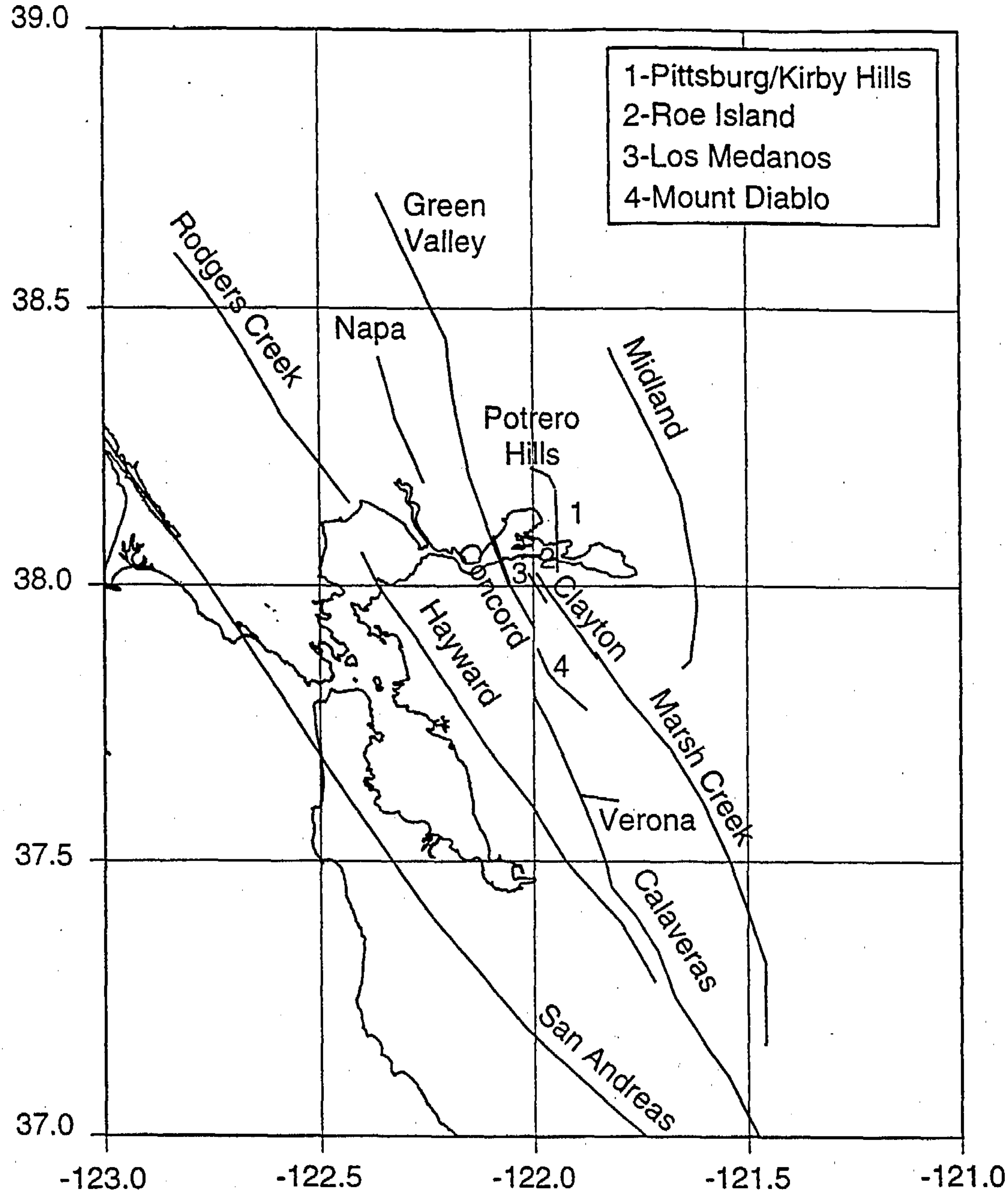


Figure A-1: Map showing the significant faults in the Delta region used in the seismic hazard computations based on the Lettis Delta fault model.

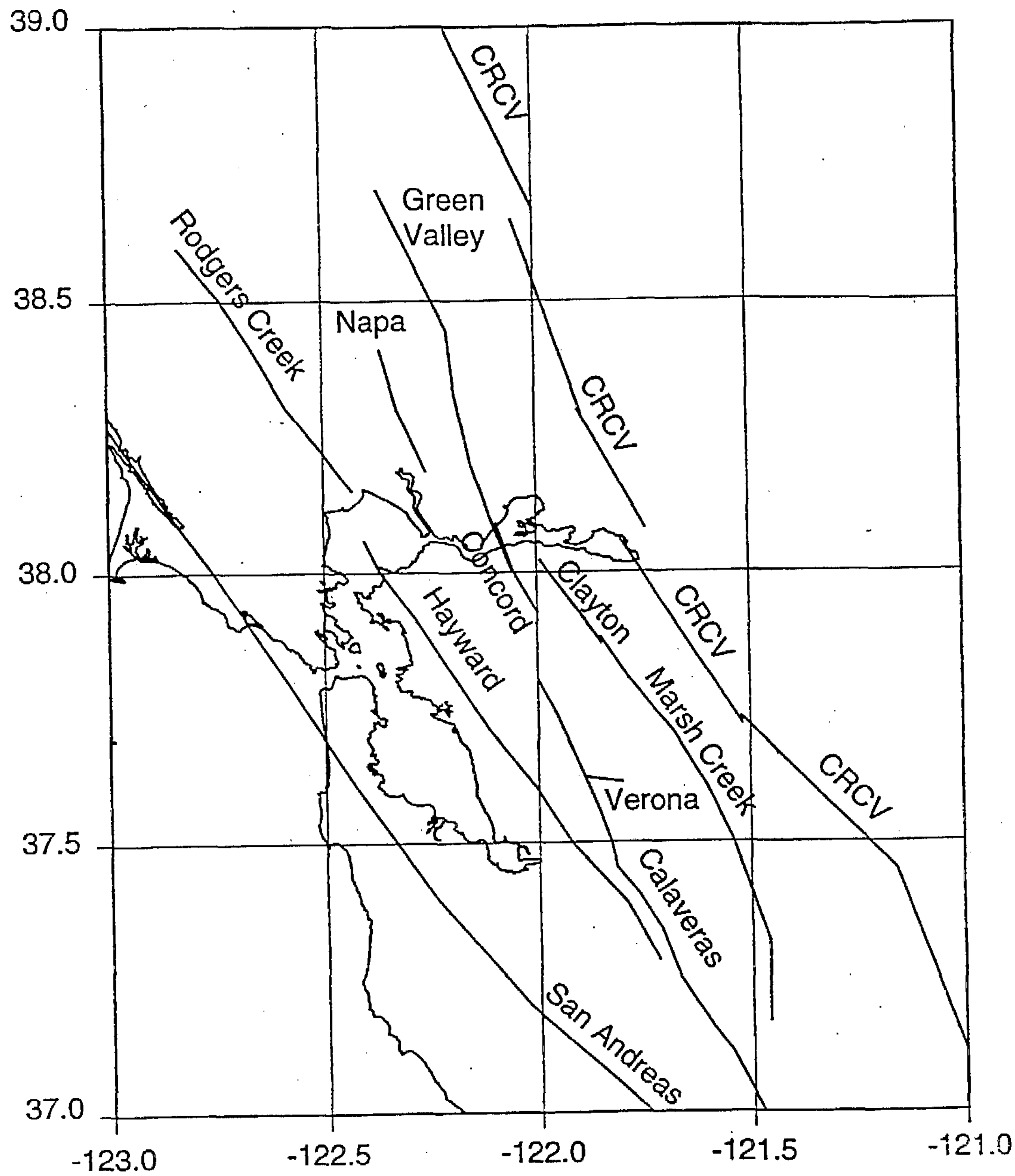


Figure A-2: Map showing the significant faults in the Delta region used in the seismic hazard computations based on the CRCV Delta fault model.

Table A-1. Seismic Source Parameters

Fault	Slip Rate (Weight)	Fault Width (Weights)	Max Magnitude (Weights)
Concord	3.0, 4.0, 6.0 (0.25, 0.5, 0.25)	12.0 (1.0)	6.4, 6.6, 6.8 (0.2, 0.6, 0.2)
Calaveras (North)	2.0, 6.0, 8.0 (0.25, 0.5, 0.25)	12.0 (1.0)	6.7 (1.0)
Calaveras (South)	13.0, 15.0, 17.0 (0.25, 0.5, 0.25)	12.0 (1.0)	6.8 (1.0)
Hayward	7.0, 9.0, 11.0 (0.25, 0.5, 0.25)	12.0 (1.0)	7.1 (1.0)
Marsh Creek/Greenville	0.5, 2.0, 3.0 (0.25, 0.5, 0.25)	12.0 (1.0)	6.7 (1.0)
Clayton	0.2, 0.5, 1.0 (0.25, 0.5, 0.25)	12.0 (1.0)	6.7 (1.0)
Green Valley	1.5, 4.0, 5.0 (0.2, 0.6, 0.2)	12.0 (1.0)	6.6 (1.0)
Napa	0.1, 0.3, 0.5 (0.3, 0.5, 0.2)	12.0 (1.0)	6.5 (1.0)
Rogers Creek	6.0, 8.0, 11.0 (0.25, 0.5, 0.25)	12.0 (1.0)	7.0 (1.0)
San Andreas	19.0, 24.0, 29.0 (0.2, 0.6, 0.2)	15.0 (1.0)	7.8, 8.0 (0.8, 0.2)
Verona	0.1 (1.0)	10.0 (1.0)	6.1 (1.0)
Antioch	0.3 (1.0)	15.0 (1.0)	6.5 (1.0)
Mt. Diablo Thrust[1]	1.3, 1.7, 5.0 (0.3, 0.6, 0.1)	11.0 (1.0)	6.25, 6.75 (0.30, 0.70)
Los Medanos Thrust[1]	0.3, 0.7 (0.8, 0.2)	13.0 (1.0)	6.00, 6.25 (0.8, 0.2)
Roe Island Thrust[1]	0.1, 0.3, 0.7 (0.1, 0.7, 0.2)	14.0 (1.0)	5.75, 6.00 (0.5, 0.5)
Potrero Hills Thrust[1]	0.1, 0.3, 0.6 (0.3, 0.6, 0.1)	14.25 (1.0)	6.00, 6.25 (0.8, 0.2)
Pittsburg/Kirby Hills Thrust[1]	0.2, 0.3, 0.7 (0.5, 0.4, 0.1)	15.0 (1.0)	6.00, 6.50 (0.4, 0.6)
Midland Thrust[1]	0.1, 0.2 (0.6, 0.4)	13.0 (1.0)	6.00, 6.25 (0.7, 0.3)
CRCV[2]	0.5, 1.5, 2.5 (0.25, 0.5, 0.25)	10.0 (1.0)	6.8 (1.0)

1 Lettis source model for the Delta region.
2 CRCV source model for the Delta region.

In addition to the known faults, a background source zone is also included to capture the earthquakes expected to occur on other fault sources. The background zone is based on the smoothed historical regional background seismicity ($M \geq 4.0$) developed by USGS (1996) and used by the CDMG in its state hazard maps. This background seismicity is smoothed over a distance of 50 km, resulting in very smooth background seismicity. The rate of magnitude 5 or greater earthquakes per 100 years per 100 square km is shown in Figure A-3. To avoid double counting seismicity, the background zone is used for magnitudes 5-6 and the individual known faults are used for magnitudes greater than 6.0.

The two alternative models for the thrust faults are discussed in more detail below.

Delta Region Thrust Faults

Geodetic data indicates that there is crustal shortening of about 3 mm/yr in the direction normal to the San Andreas fault between the Pacific Plate and the North American Plate. The primarily strike-slip earthquakes in the Bay Area region accommodate some of this shortening, but some additional thrust faults are needed to explain the remainder of the shortening between the Pacific and North American plates in this region. These thrust faults generally do not reach the surface and are considered "blind thrust" faults.

In most recent studies, most of the additional shortening has been assumed to be accommodated along the western edge of the central valley along a feature called the Coast Range/Central Valley Thrust (CRCV) fault zone (also called the Coast Range Sierran Block Boundary Zone).

There have been several earthquakes over magnitude 6 that have occurred along the CRCV fault zone to the north and to the south of the Delta region, but there are no known CRCV events of $M \geq 6$ in the vicinity of the Delta. The 1983 Coalinga earthquake (M=6.4) and the 1985 Kettleman Hills earthquake (M=6.1) occurred on the CRCV. The 1892 Winters-Vaccaville earthquake (M=6.4) may also have occurred on the CRCV, but its location is not well constrained (Toppozada, Real, and Parke, 1981). The CRCV is clearly an active fault in some regions, but it may not exist in the Delta region, or it may not be active in the Delta region.

In this evaluation, we consider two alternative models of the thrust faults in the Delta region: the CRCV model and the without CRCV model developed by Lettis and Associates model. These two alternative models are discussed in the following sections.

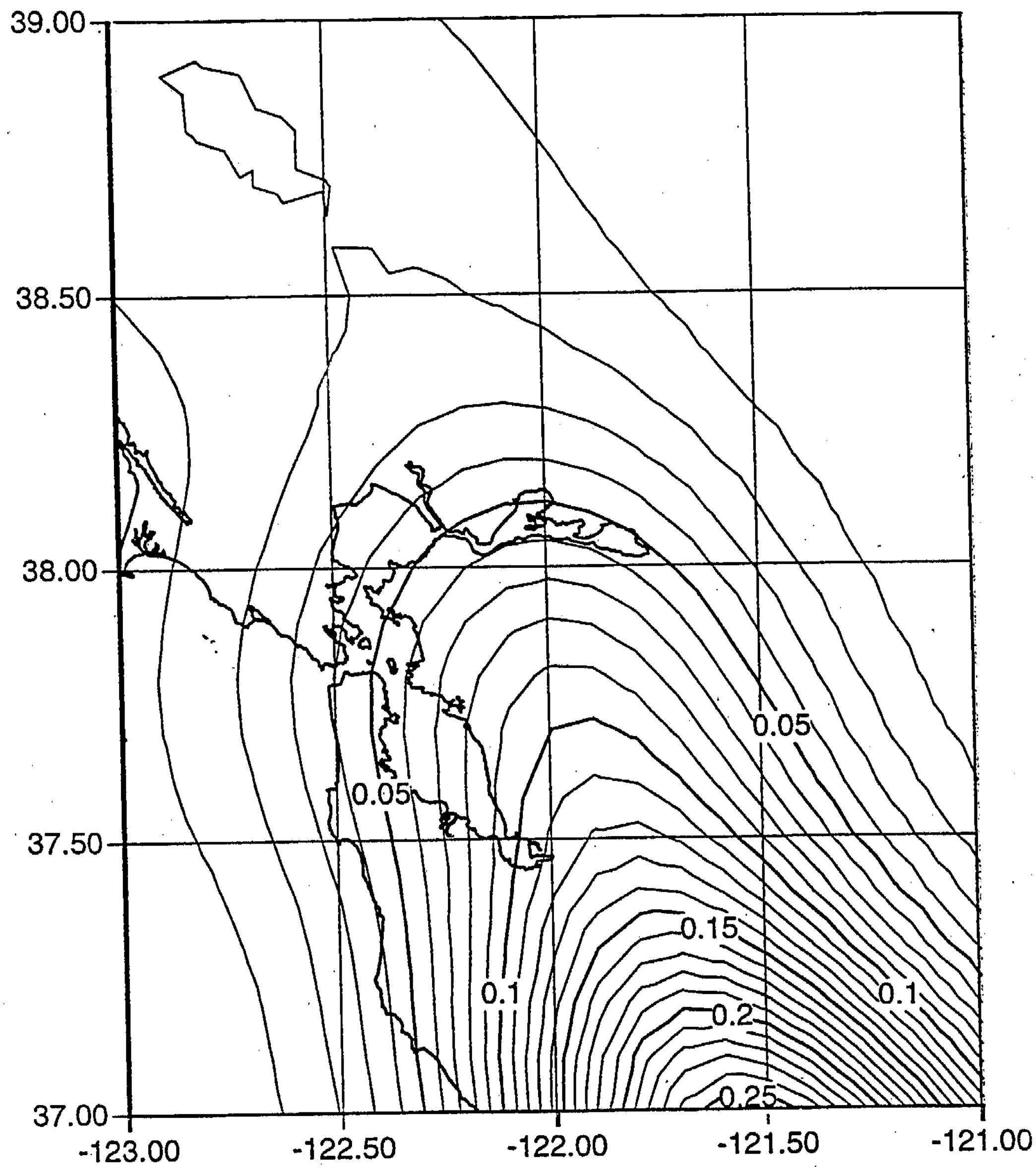


Figure A-3. Map showing the contour of smoothed background seismicity for magnitude 5.0 and greater per 100 years per 100 square kilometers. Based on the USGS gridded seismicity maps (1996).

CRCV Thrust Fault Model

The CRCV extends about 600 km along the western edge of the Central Valley in central and Northern California (Wong et al., 1988), but the faulting is discontinuous. Most of the segment lengths are 5 to 20 km with a maximum segment length of about 50 km. In the CRCV model, this set of thrust faults extends through the Delta region and runs near Sherman Island (see Figure A-2).

The CRCV model has been used in the state hazard maps developed by the California Division of Mines and Geology (CDMG). The slip-rate of the CRCV in the Delta region is uncertain. The sub-team used a range of slip-rates from 0.5 to 2.5 mm/yr. The CDMG (1996) used a slip-rate of 1.5 mm/yr and that is the mean value that is used in this study.

The exact location of the CRCV fault in the Delta region is uncertain. In this study, the top of the fault is located at a depth of 8 km with a dip of 15 degrees. For a down-dip fault width of 15 km and a segment length of 40 km, the Wells and Coppersmith (1994) magnitude vs. fault area relation gives a mean maximum magnitude of $M_w \approx 6.8$.

Without CRCV Model Developed by Lettis and Associates

A recent study by Unruh (Lettis and Associates written comm., 1998) suggests that the CRCV is not present in the Delta region. According to this model, the CRCV begins to decrease in activity north of the San Luis Reservoir and south of Lake Berryessa. In the Delta region, the CRCV ceases to exist, or ceases to be active. As an alternative to the CRCV, the Lettis and Associates model postulates a different set of thrust faults slightly further to the west to accommodate the crustal shortening (see Figure A-1).

These faults, the Pittsburg/Kirby Hills, Roe Island, Los Medanos, and Mount Diablo faults are all short faults with lengths of less than 20 km located 10-20 km west of the western edge of the Delta. The mean slip-rates of these faults range from 0.3 to 2 mm/yr. The maximum magnitudes of the small thrust faults range from $M_w \approx 6.0$ to 6.6.

This model also includes the Midland fault located beneath the Delta, but with a small mean slip-rate of 0.15 mm/yr. Although the Midland fault has a length of about 60 km, the maximum magnitude of the Midland fault in this model is only $M_w \approx 6.2$.

A3. ATTENUATION RELATIONS

There are many attenuation relations that can be used for the deep soil site conditions (below the peat) in the Delta. In this study, we have selected four of the most recent attenuation models: Abrahamson and Silva (1997), Boore, et al. (1997), Campbell

(1997), and Sadigh, et al. (1997) as being appropriate. These models are given equal weight in the hazard analysis.

A4. PROBABILISTIC HAZARD RESULTS

The probabilistic hazard is shown separately for the Lettis and the CRCV models of the Delta thrust faults. The results for the Lettis model are shown first, and the results for the CRCV model are shown second. Sherman Island and Terminous Island are used as example locations representative of the western and eastern edges of the Delta, respectively. All acceleration levels shown are peak horizontal accelerations at surface outcrops of deep, stiff soils (soils underlying the softer and organic superficial Delta deposits.)

Figures A-4 and A-5 show the peak acceleration hazard for Sherman Island and Terminous Island, respectively, based on the Lettis thrust fault model. At a return period of 100 years (annual probability of 0.01), the hazard at Sherman Island is dominated by the local thrust faults, with significant contribution from the background zone and "other" faults. For Terminous Island, the background zone and thrust faults contribute about equally to the overall 100 year return-interval level of hazard.

The magnitudes and distances of the earthquakes dominating the hazard can be estimated by deaggregating the hazard. The distributions of contribution to the hazard are shown in Figures A-6 and A-7. For Sherman Island, the hazard is primarily from moderate magnitude events ($M \approx 5.5$-6.5) at distances of 10 to 30 km. For Terminous Island, the more distant sources also contribute significantly to the hazard, and there is a wide range of magnitudes and distances ($M \approx 5$-6 at distances of 10-30 km to $M \approx 7$-7.5 at 100 km) contributing to the hazard. Figures A-8 and A-9 show the mean magnitude and mean distance of the earthquakes contributing to the hazard as a function of the return period.

A similar set of plots for the CRCV model is shown in Figure A-10 and A-11. The main difference is that for the CRCV model, the local CRCV thrust faults are the principal controlling source for both Sherman Island and Terminous Island.

The hazard for the Lettis and CRCV models is compared in Figure A-12. This figure shows that the hazard from these two models is very similar for both the Sherman Island and Terminous Island sites when expressed in terms of expected peak horizontal acceleration. The models differ, however, in terms of the principal magnitudes that contribute to these acceleration hazard levels. These differences in contributing magnitudes, in turn, imply differences in the duration of shaking, and this has a potentially significant impact on both the liquefaction and cyclic inertial deformation hazard evaluations for Delta levees.

The two models are given equal weight in the final hazard analysis. Contours of the peak acceleration in the Delta region for return period of 43 years, 100 years, 200 years, and 475 years (building code level) are shown in Figures A-13 through A-16. The hazard systematically decreases from the southwest to the northeast.

For the top of stiff soils, the 100 year return-interval horizontal peak acceleration ranges from 0.2 g in the western Delta to 0.1 g in the northeastern Delta. Since the hazard is dominated by moderate magnitude local events, it is unlikely that the entire Delta will be subject to the 100-year ground motion in a single 100-year earthquake.

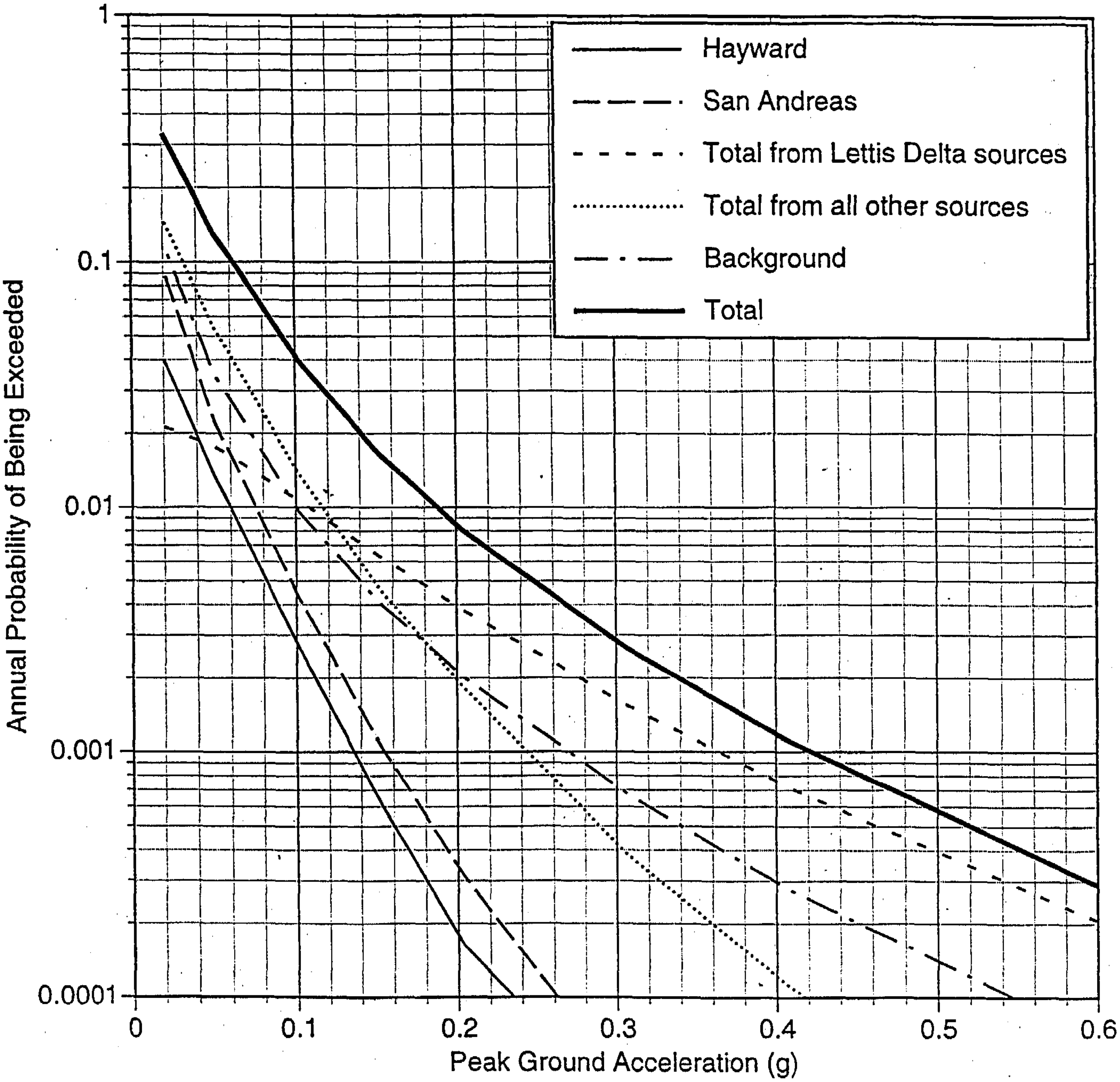


Figure A-4. Seismic hazard curves for the Sherman Island site. The hazard curves are based on the Lettis seismic model for the Delta region. The contribution to the total hazard is shown for the significant faults.

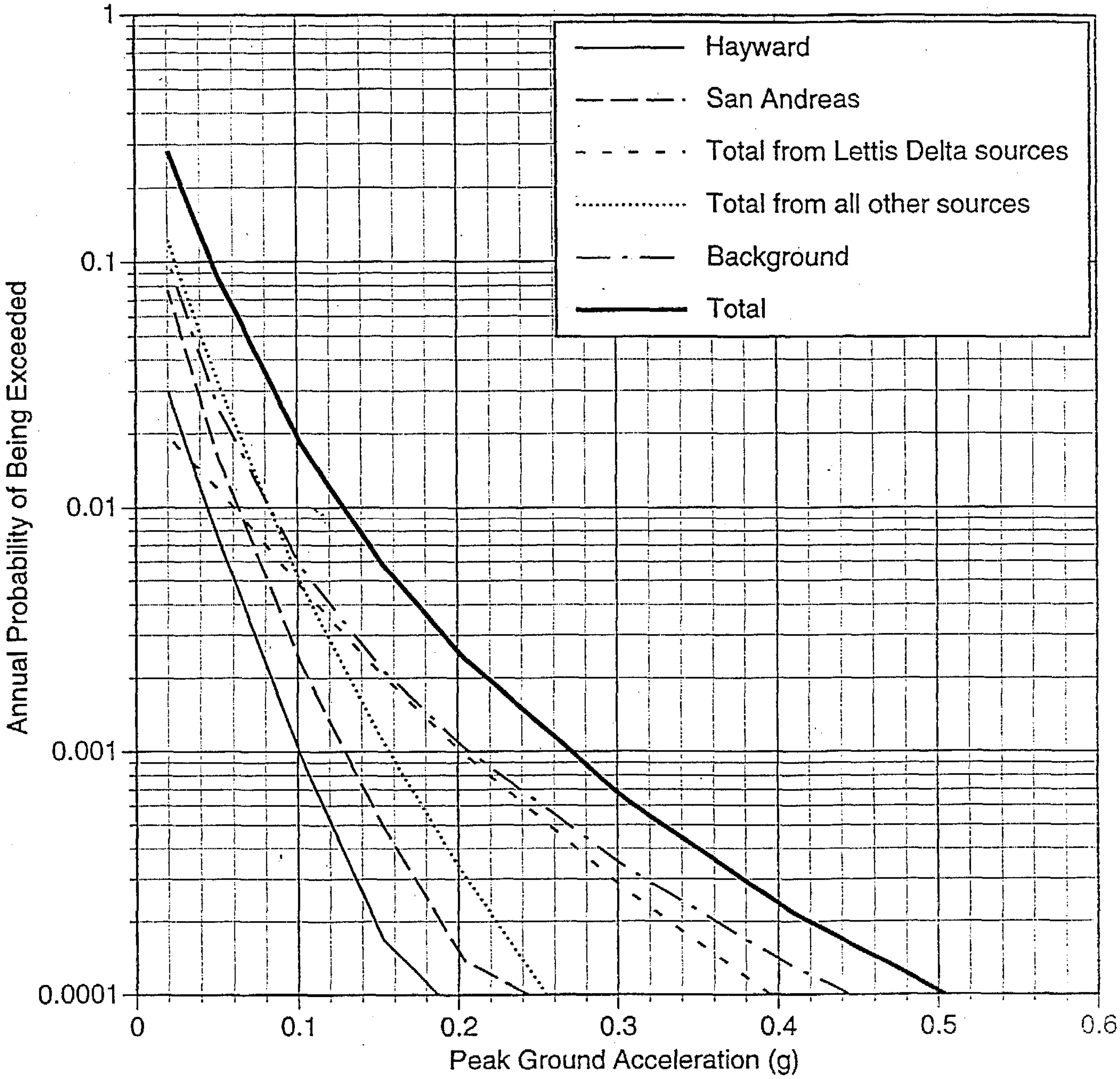


Figure A-5. Seismic hazard curves for the Terminous site. The hazard curves are based on the Lettis seismic source model for the Delta region. The contribution to the total hazard is shown for the significant faults.

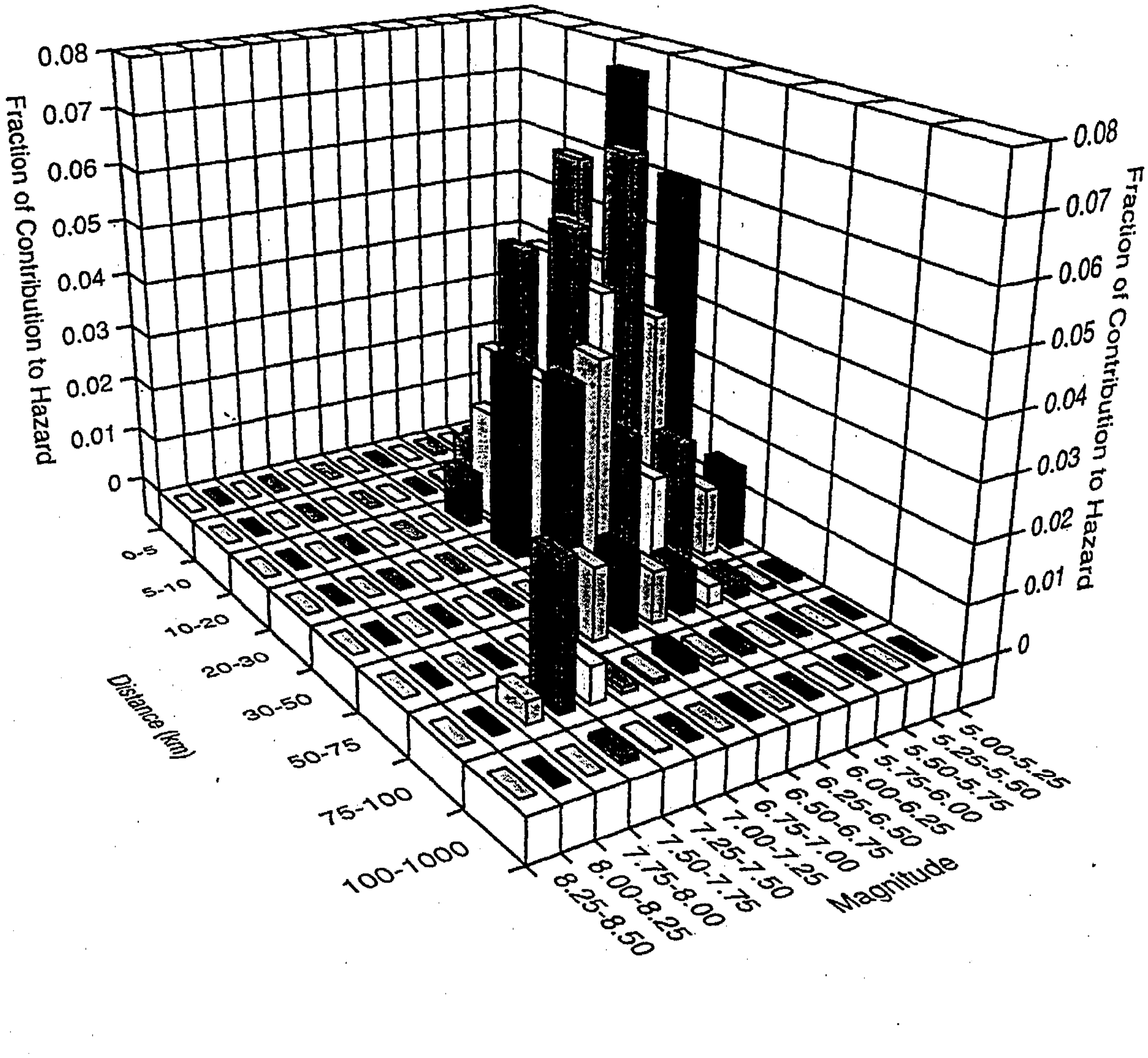


Figure A-6. Deaggregation of the seismic hazard (100 year return period) for the Sherman Island site based on the Lettis seismic source model for the Delta region.

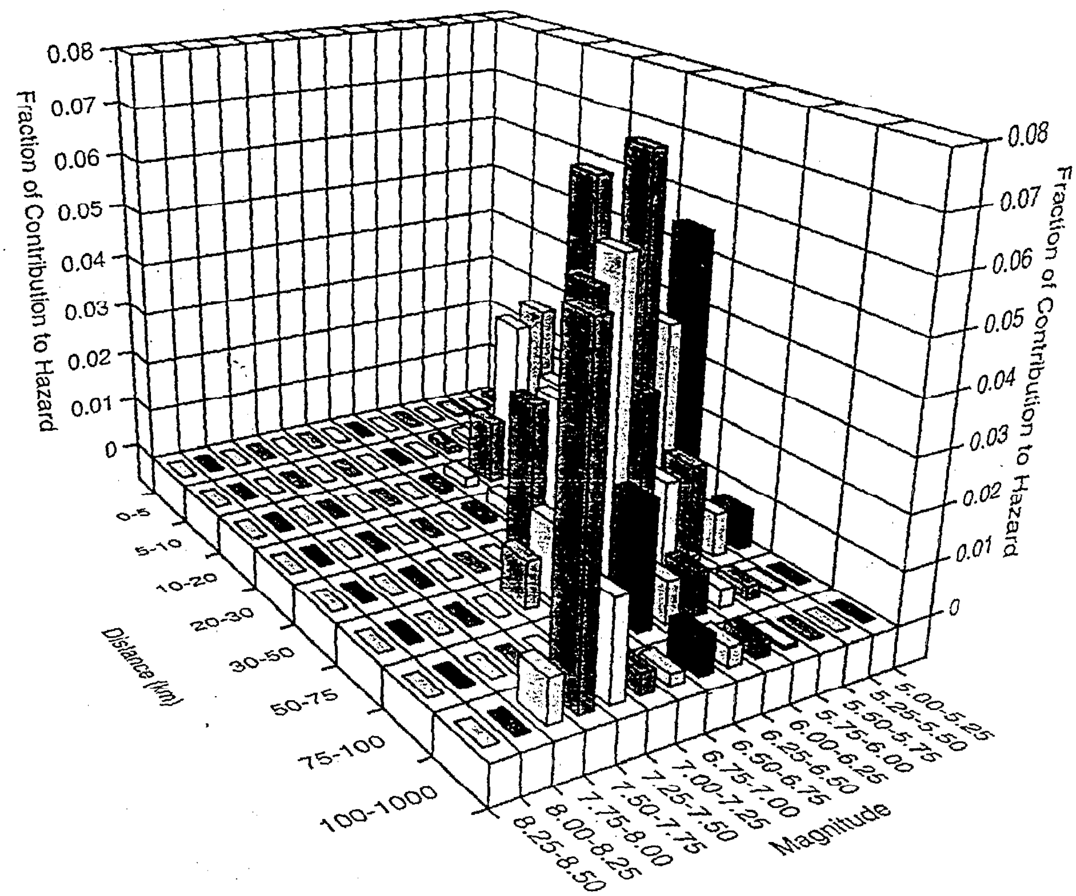


Figure A-7. Deaggregation of the seismic hazard (100 year return period) for the Terminous site based on the Lettis seismic source model for the Delta region.

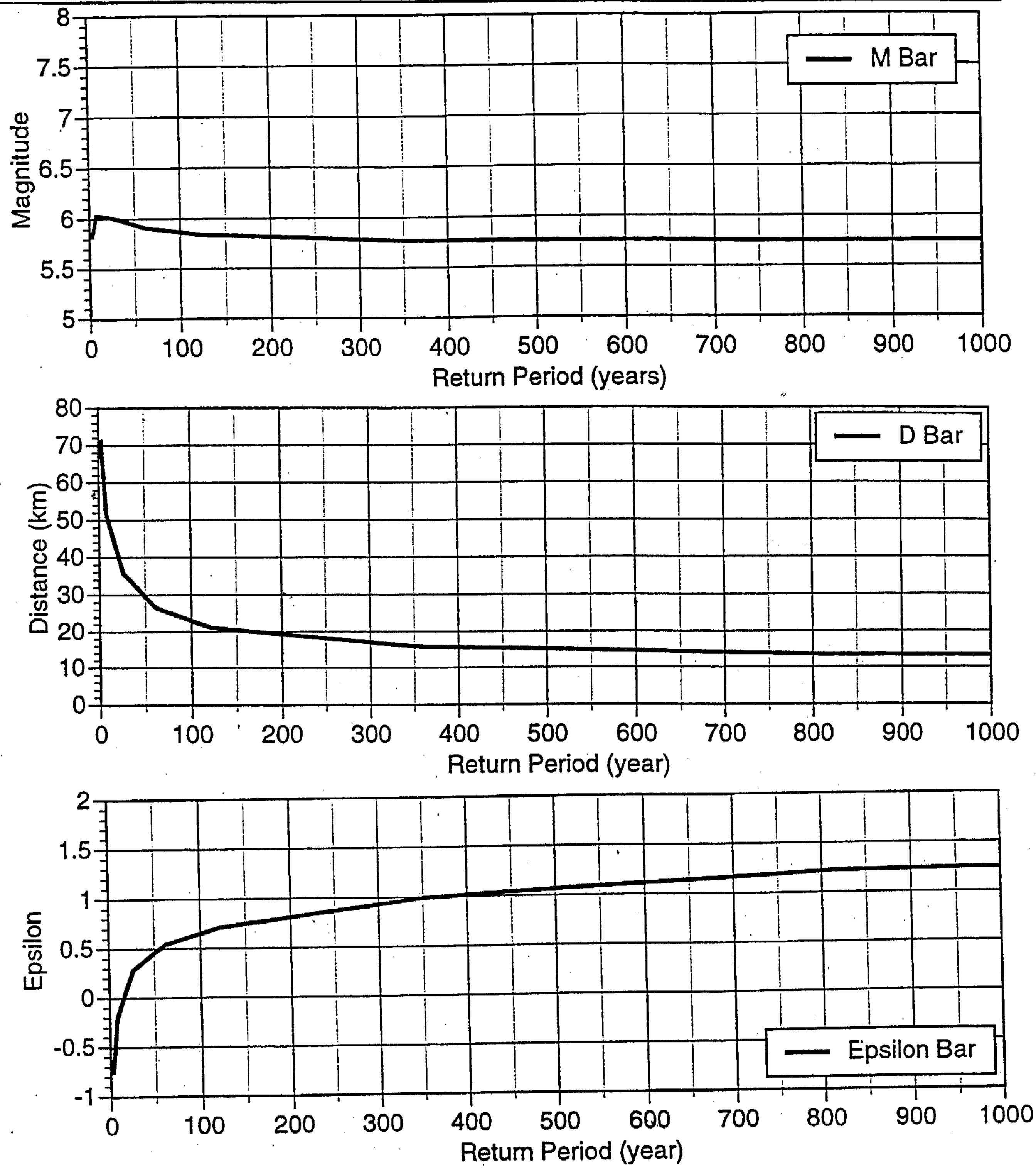


Figure A-8. Magnitude, distance and epsilon bar for the Sherman Island site based on the Lettis seismic source model for the Delta region.

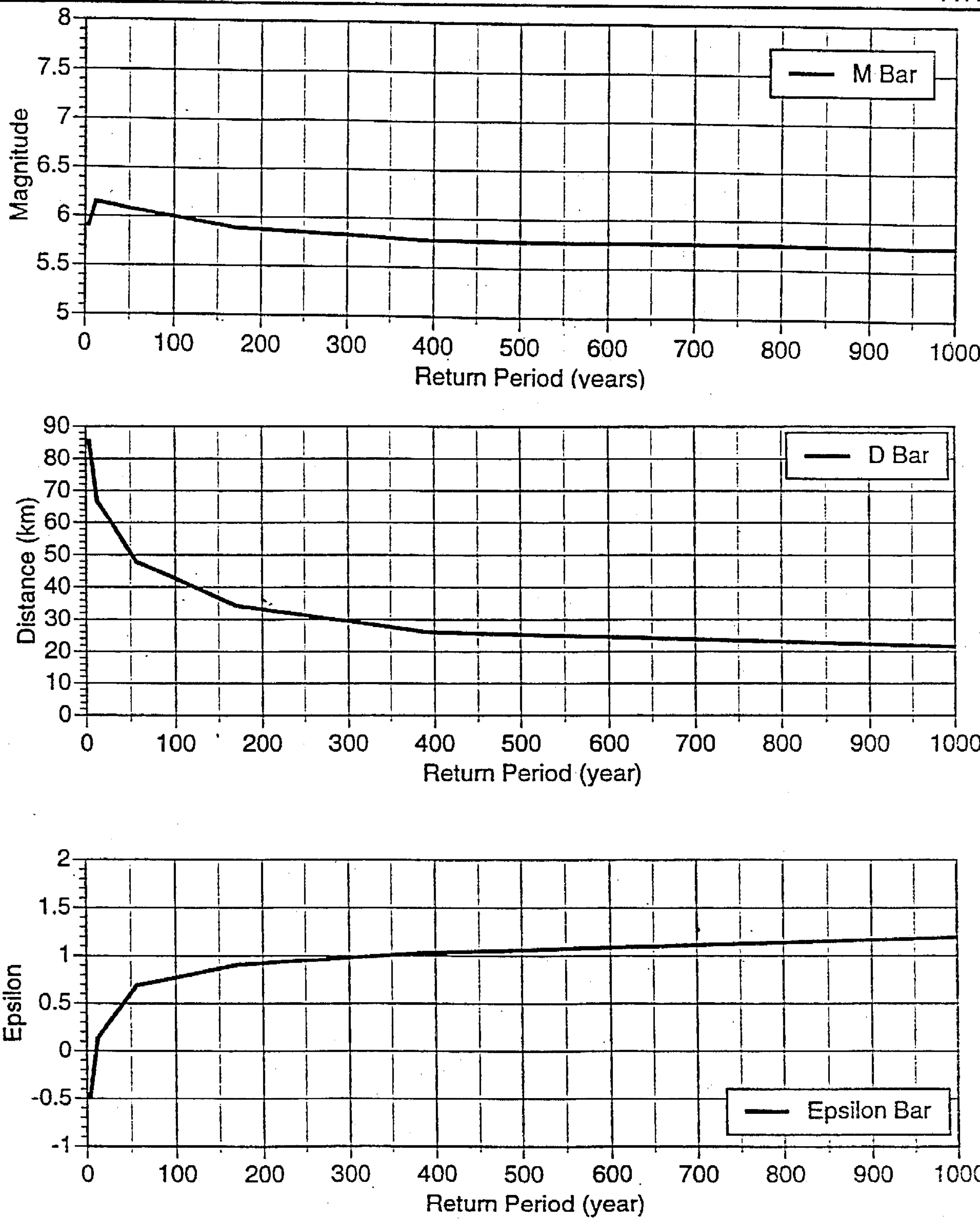
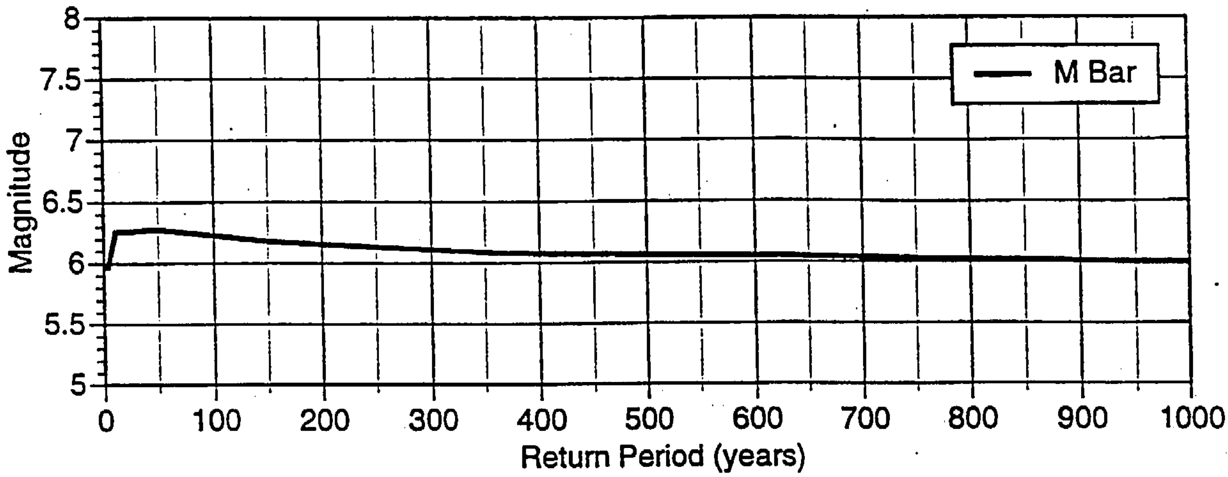
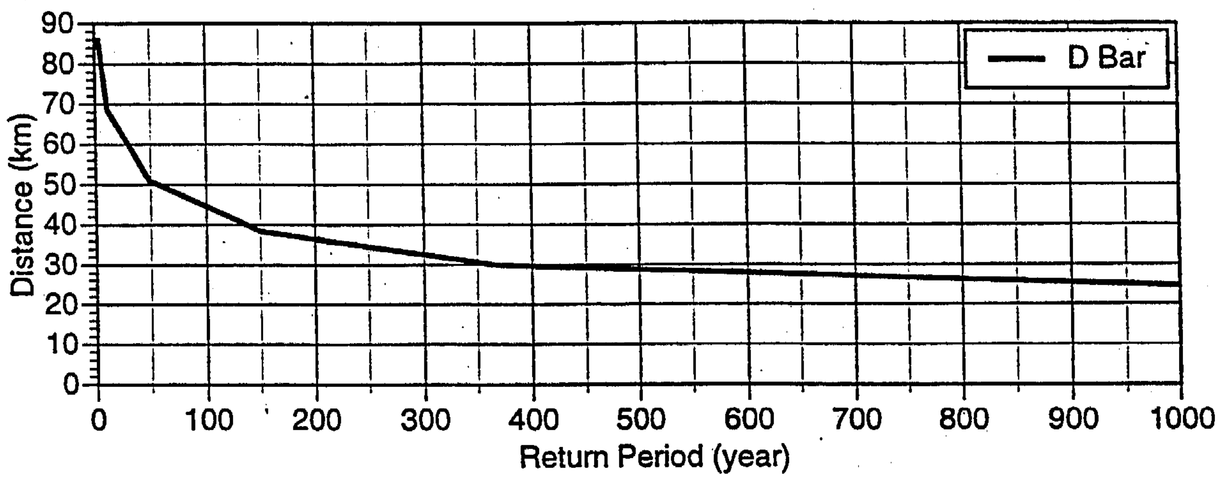


Figure A-9. Magnitude, distance and epsilon bar for the Terminous site based on the Lettis seismic source model for the Delta region.





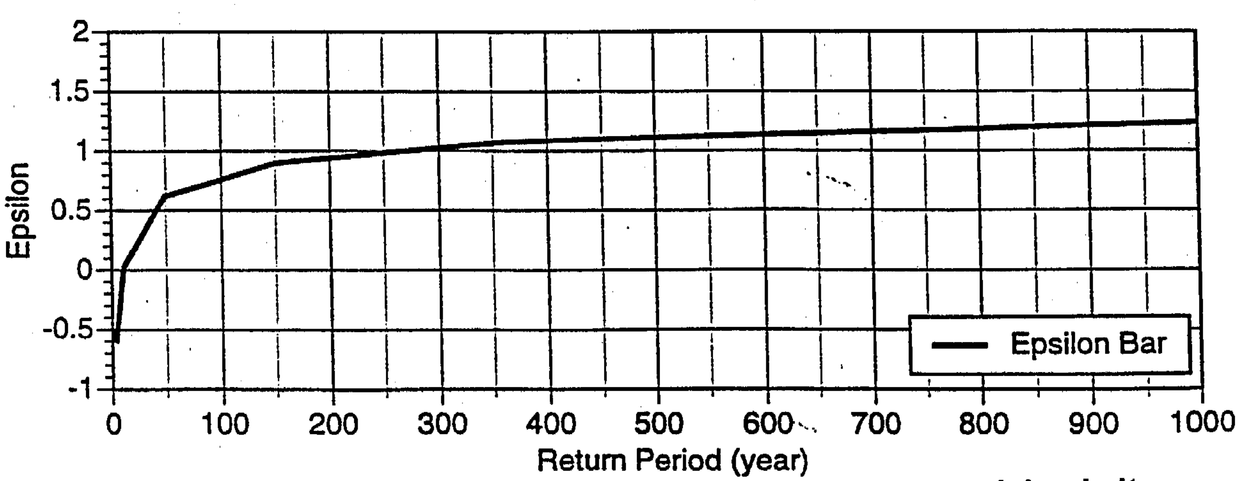


Figure A-10. Magnitude, distance and epsilon bar for the Sherman Island site based on the CRCV seismic source model for the Delta region.

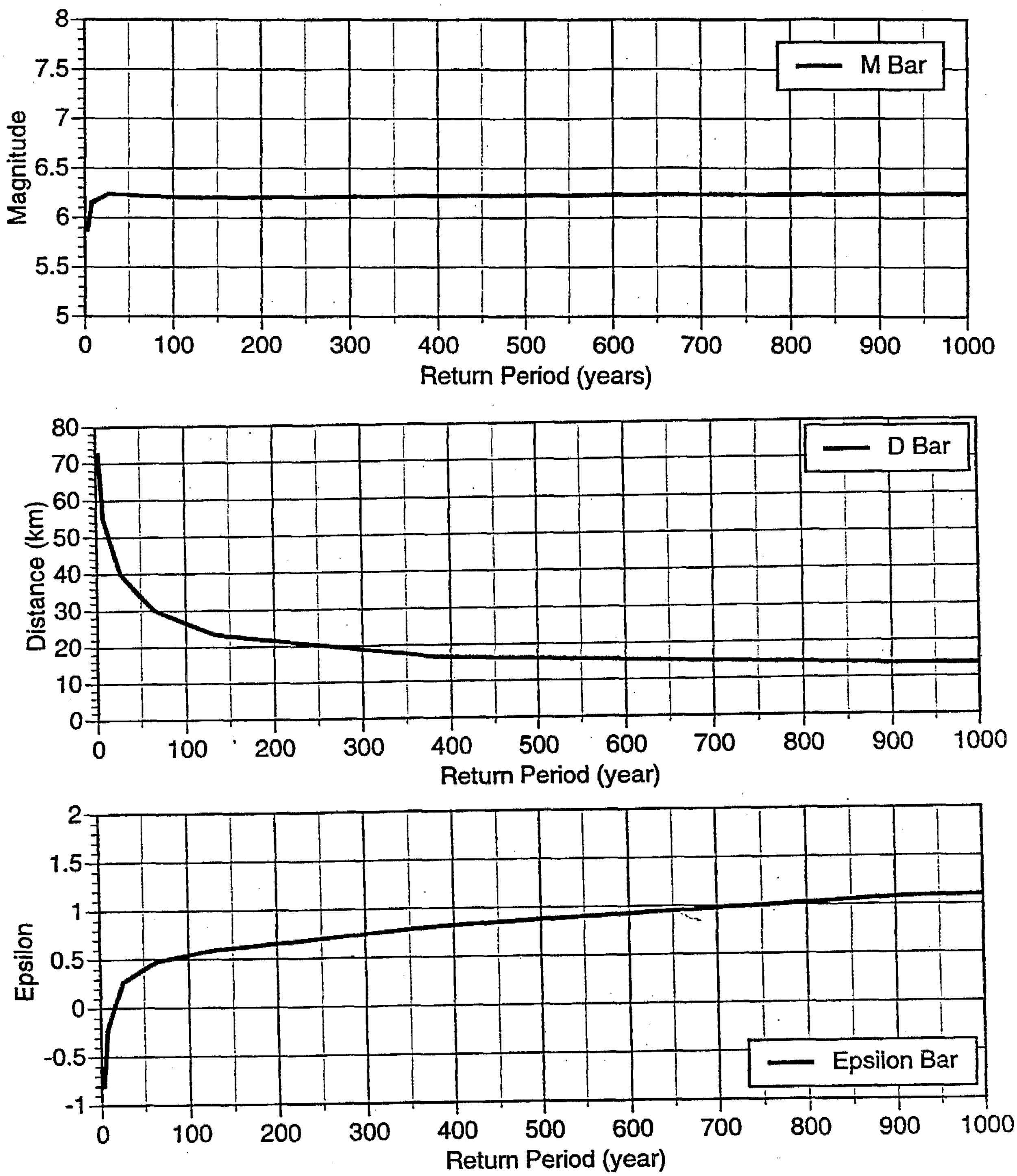


Figure A-11. Magnitude, distance and epsilon bar for the Terminous site based on the CRCV seismic source model for the Delta region.

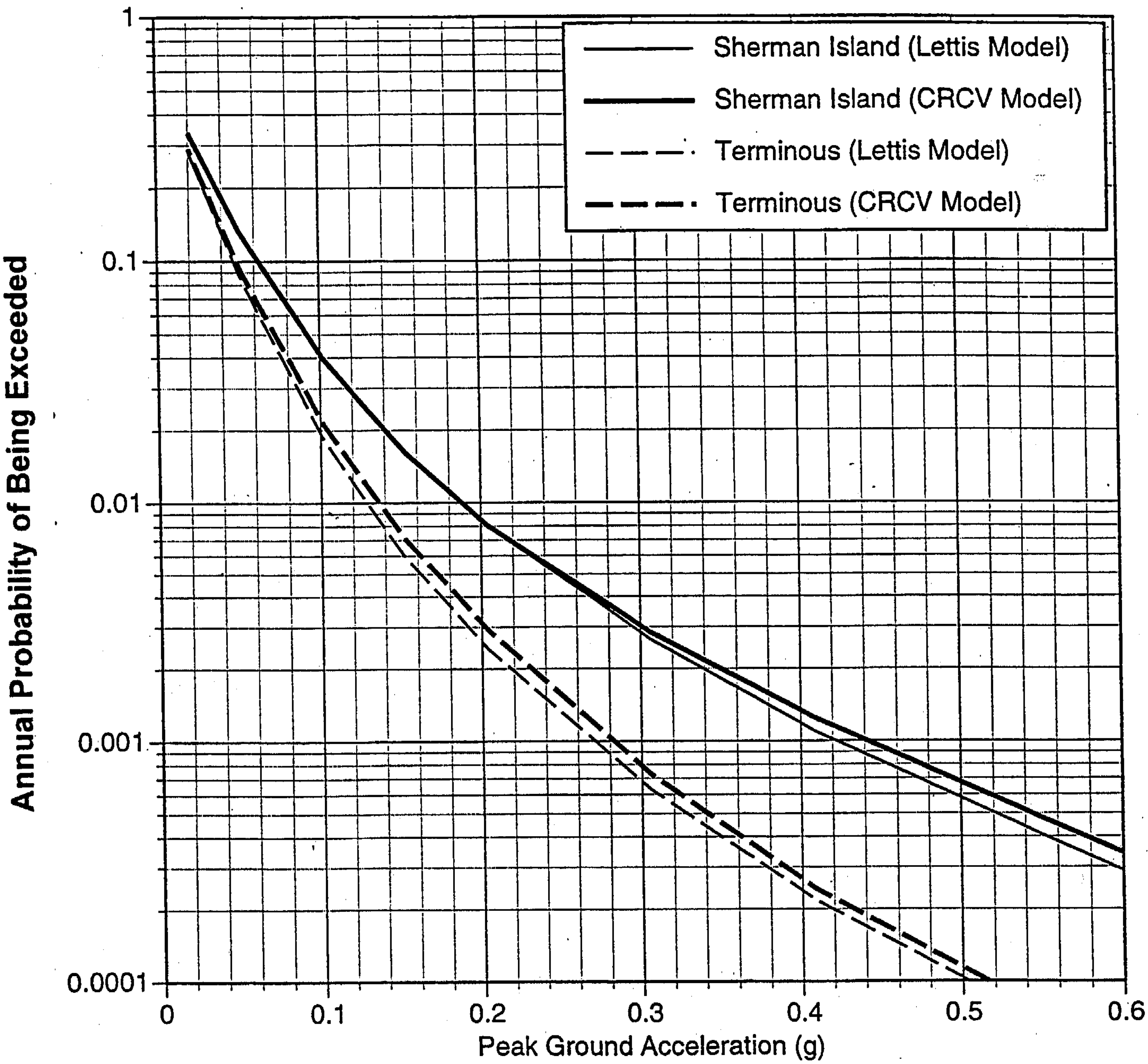


Figure A-12. Comparison of the seismic hazard for the Sherman Island and Terminous sited based on both the Lettis and CRCV seismic source model for the Delta region.

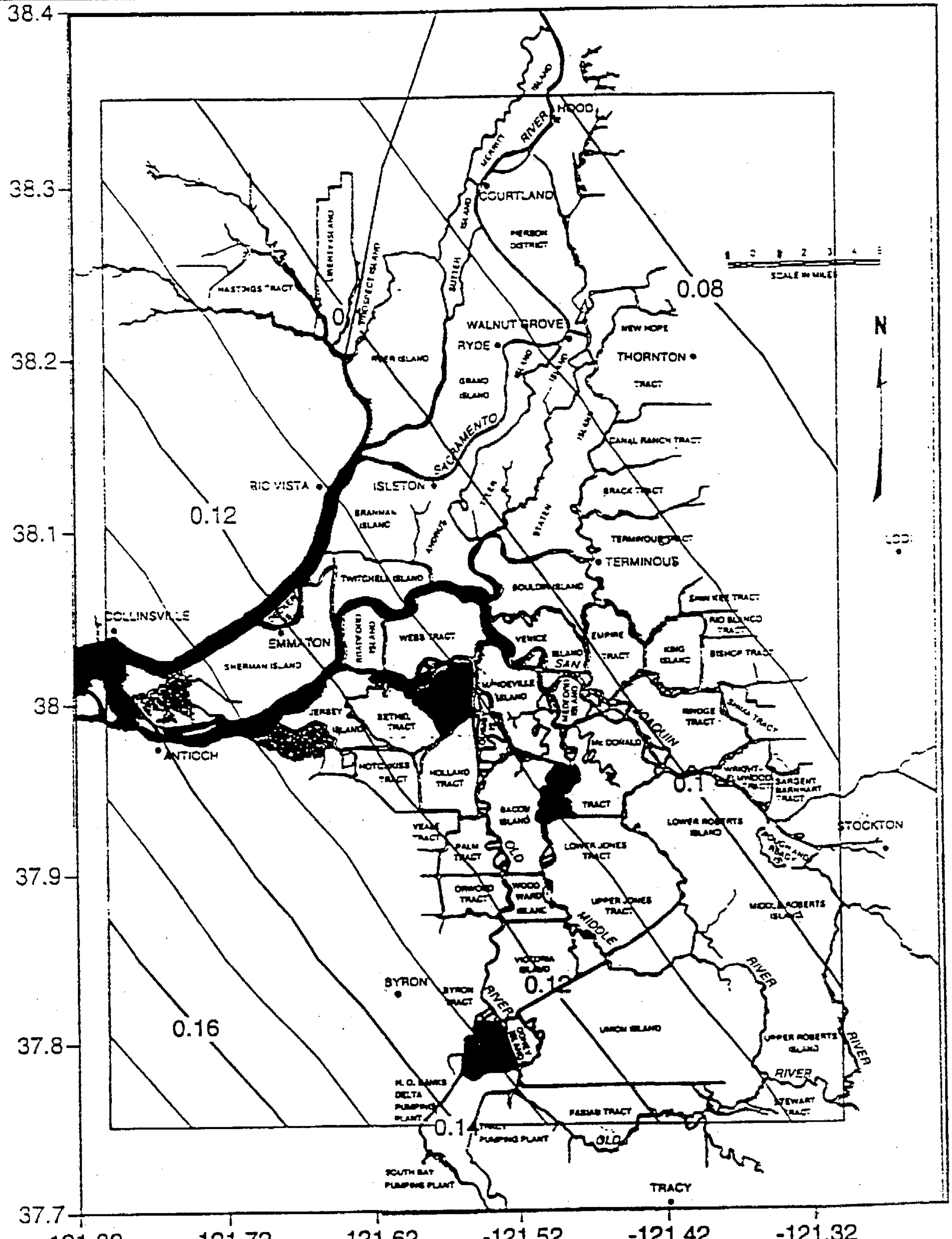


Figure A-13. Contour map of seismic hazard (PGA) for soil site conditions for a return period of 43 years.

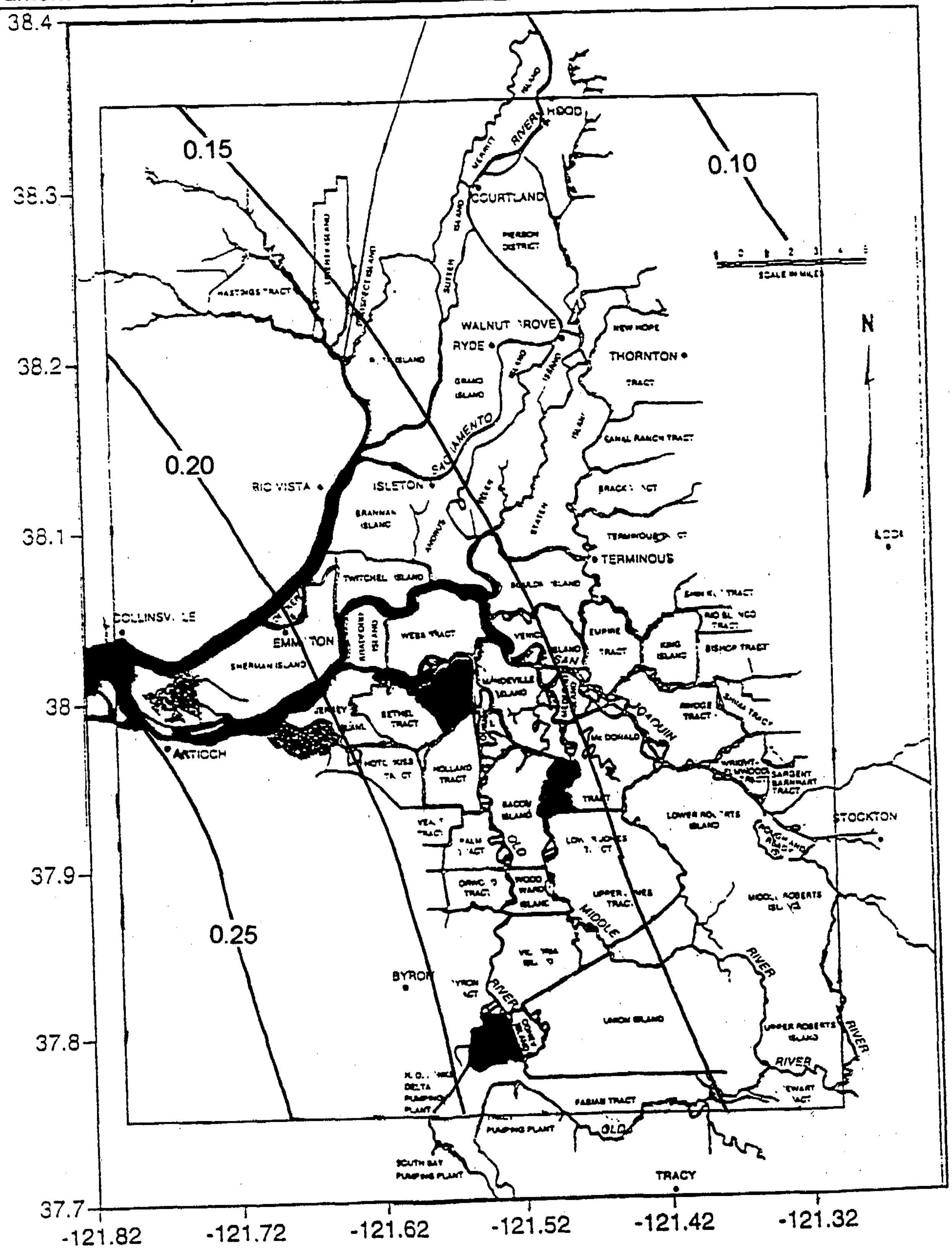


Figure A-14. Contour map of seismic hazard (PGA) for soil site conditions for a return period of 100 years.

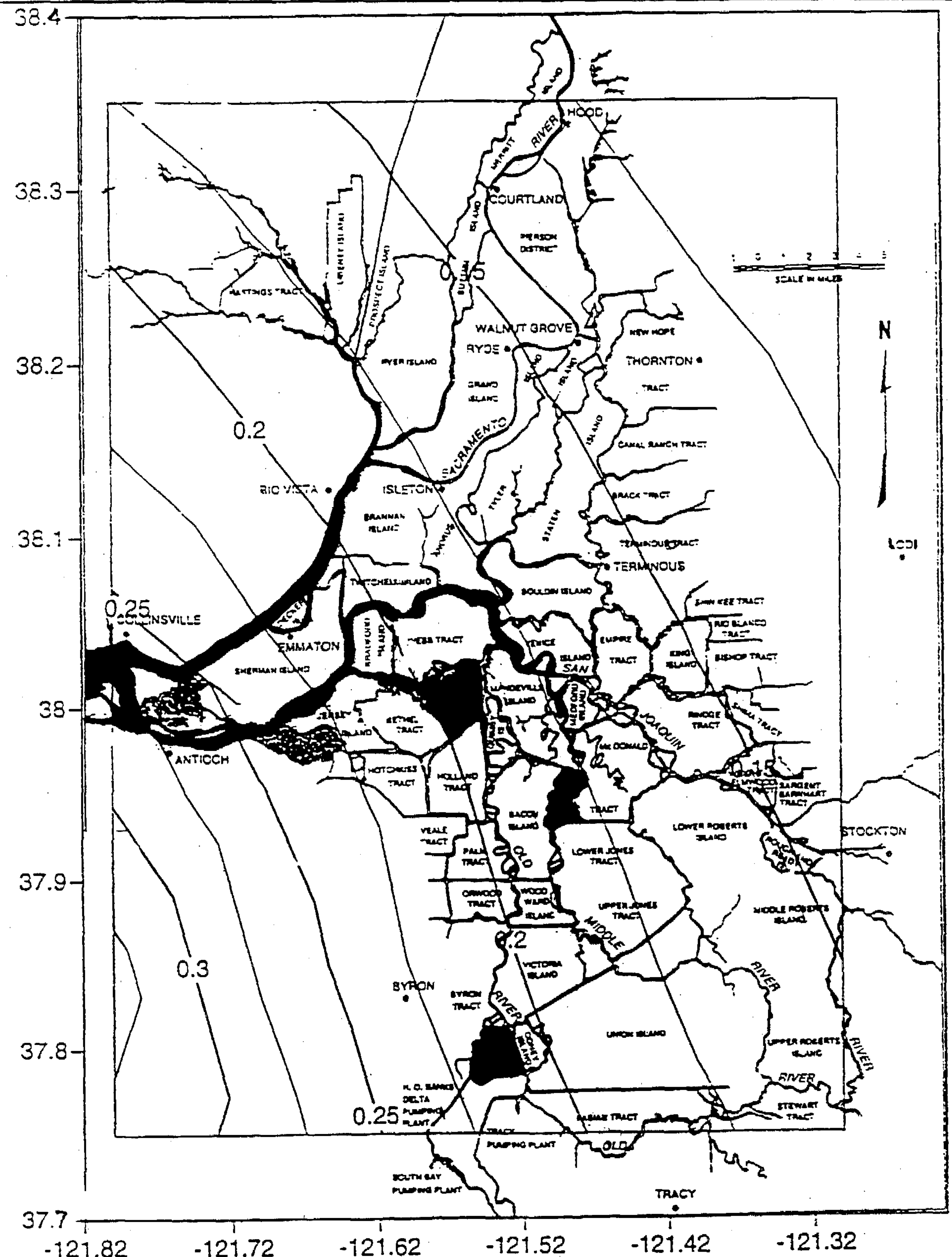


Figure A-15. Contour map of seismic hazard (PGA) for soil site conditions for a return period of 200 years

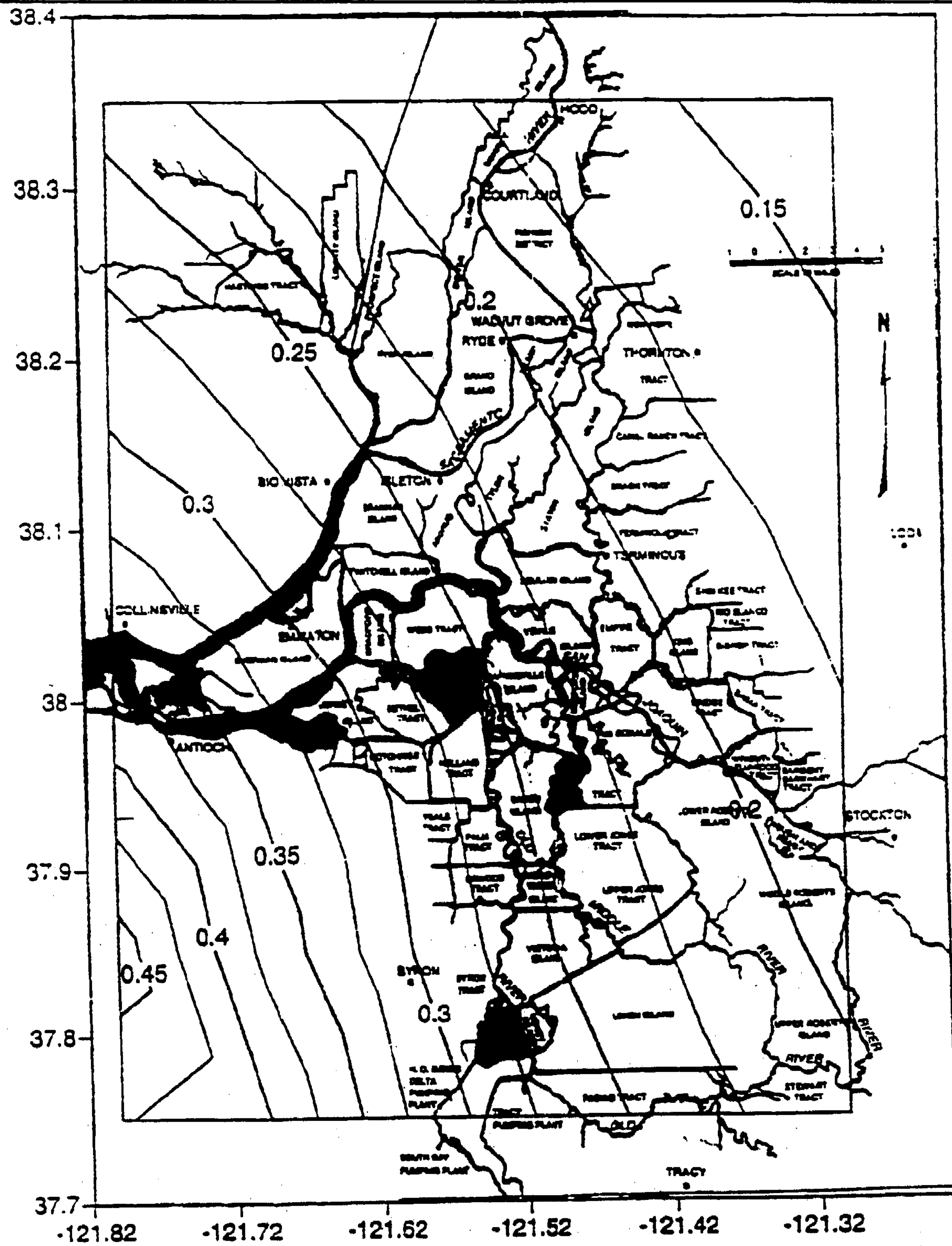


Figure A-16. Contour map of seismic hazard (PGA) for soil site conditions for a return period of 475 years.

APPENDIX B:

EVALUATION OF LEVEE FRAGILITY

- **Liquefaction Mode of Failure**
- **Non-Liquefaction Deformation Mode of Failure**

APPENDIX B: EVALUATION OF LEVEE FRAGILITY

B1. GENERAL

This appendix presents more detailed information regarding the development of levee fragility estimates for potential levee failures due to future seismic events. The fragility estimates were previously described in general terms in Chapter 4. Many of the estimates were based on consensus judgements made by the sub-team members. Sub-team members applied their knowledge of the performance of similar earth structures to the conditions which currently exist in the Delta, and to the potential seismic loadings which might develop in the future. In addition, a number of geotechnical earthquake engineering analyses were also performed to provide information for these judgements, and to extend the estimates for a range of loadings.

The seismic risk analyses and assessments presented in this report are based on the most current available information. Information on the seismic response of peat/organic soils is still being developed. Also, even though hundreds of borings describing the subsurface conditions of Delta levees were reviewed, these borings can only provide a limited characterization of the hundreds of miles of levees in the Delta. It does not appear likely that additional borings will significantly change the present characterization in the near future.

B2. DAMAGE POTENTIAL ZONES

As previously described in Chapter 4, the central portion of the Delta was divided into four Damage Potential Zones in order to allow for different levels of levee fragility in different areas of the Delta (see Figure 4-1). The criteria used for establishing the zoning was discussed previously in Chapter 4. The four zones encompass essentially all of the Delta land which lies below sea level and includes approximately 660 levee miles. Another 440 miles of levee exist at higher elevations within the legal limits of the Delta, but were not included because these levees retain significant depths of water only during flood season. Table B-1 summarizes the Delta islands and tracts included in the four zones along with the lengths of levees to be found in each zone.

B3. ESTIMATES OF LIQUEFACTION-INDUCED LEVEE FAILURES

The sub-team gathered data from borings and CPT soundings to establish "typical" conditions at a number of representative levee reaches throughout the Delta. Data from prior seismic fragility studies, DWR data, and data supplied by individual sub-team members were all reviewed. Liquefaction potential (i.e. resistance to "triggering" or

TABLE B-1: DELTA ISLANDS AND LEVEE LENGTHS CONSIDERED IN EVALUATING POTENTIAL EARTHQUAKE-INDUCED LEVEE FAILURE

Damage Potential Zone	Delta Island/ Reclamation District	Project Levee[1] (miles)	Non-Project[1] Levee (miles)	Total Levee Length[1] (miles)
I	Sherman	9.7	9.8	19.5 [19.5]
	Bacon		14.3	14.3
	Bethel		11.5	11.5
	Bouldin		18.0	18.0
	Bradford		7.4	7.4
	Brannan	9.3	10.1	19.4
	Empire		10.5	10.5
	Holland		10.9	10.9
	Jersey		15.6	15.6
	Lower Jones		8.8	8.8
	Lower Roberts		16.0	16.0
II	Mandeville		14.3	14.3
	McDonald		13.7	13.7
	Medford		5.9	5.9
	Orwood		10.9	10.9
	Palm		7.5	7.5
	Quimby		7.0	7.0
	Rindge		15.7	15.7
	Staten		25.4	25.4
	Twitchell	2.5	9.3	11.8
	Tyler	12.2	10.7	22.9
	Venice		12.3	12.3
	Webb		12.8	12.8
	Woodward		8.8	8.8 [301.4]
	Byron		9.7	9.7
	Coney		5.4	5.4
	Fabian		18.8	18.8
	Hotchkiss		6.3	6.3
III	Middle Roberts	6.1	3.7	9.8
	Rough and Ready		5.5	5.5
	Union	1.0	29.2	30.2
	Upper Jones		9.3	9.3
	Veale		5.7	5.7
	Victoria		15.1	15.1 [115.8]
	Andrus	10.0		10.0
	Bishop		5.8	5.8
	Brack		10.8	10.8
	Canal Ranch		7.5	7.5
	Dead Horse		2.6	2.6
	Grand	29.0		29.0
	Hastings	4.0	1.0	5.0
	King		9.0	9.0
	Liberty Island	9.0	9.0	18.0
	McCormack-Williamson		8.8	8.8
IV	New Hope		18.6	18.6
	Pierson	10.0		10.0
	Prospect	7.0	5.0	12.0
	Rio Blanco		4.0	4.0
	Ryer	20.6		20.6
	Sacramento Co.	2.0	5.0	7.0
	Shima		6.6	6.6
	Sutter	12.5		12.5
	Terminous		16.1	16.1
	Walnut Grove	1.0	1.2	2.2
	Wright Elmwood		6.8	6.8 [222.9]
				[659.6]Miles

[1] Levee lengths listed in Sacramento-San Joaquin Delta Atlas, DWR (1993)

initiation of liquefaction) for sandy and silty soils of low plasticity was evaluated using the SPT-based methodology described by Seed and Harder (1990), as updated by the NCEER Liquefaction Workshop expert panel (NCEER, 1997). Of particular concern to the sub-team was the presence of cohesionless sandy and/or silty soils within the manmade levee embankment. When present, such soils often had SPT $(N_1)_{60}$ blowcounts of less than 10, and commonly less than 5. Post-liquefaction residual strengths were estimated using the correlation proposed by Seed and Harder (1990), and these indicated very low values, commonly only about 50 to 200 psf. With such low residual shear strengths, major levee displacements and/or failure would be expected if major portions of the levee embankment were triggered to liquefy.

Of somewhat lesser concern, but still potentially serious, was the occurrence of potentially liquefiable sandy and silty soils in the foundation zone (beneath the levee embankments). These soils tended to have variable SPT blowcounts, but generally somewhat higher than those in the loose embankment soils. The liquefiable foundation soils were also less hazardous due to levee and foundation geometries, as well as due to the irregular and discontinuous nature of some of these natural foundation deposits. Potential liquefaction of foundation soils was not a benign condition, however, and liquefaction of foundation soils was eventually judged to contribute approximately 25% to 30% of the overall liquefaction-related hazard (with liquefaction of levee embankment fills contributing the remainder.)

The sub-team worked together to assemble and review the available geotechnical data. Each of the individuals then prepared independent assessments of expected levee failure frequencies for various levels of shaking within each of the four Damage Potential Zones. These individual assessments, and their basis, were then shared and discussed to develop a single set of overall consensus estimates. These consensus estimates of potential number of levee failures were presented as a range for each level of shaking and for each of the four Damage Potential Zones. Each range was considered to represent about an 80-percent confidence level for the range of "expected" number of liquefaction-induced levee failures for a particular level of shaking.

B4. ESTIMATES OF LEVEE FAILURES FOR NON-LIQUEFACTION EARTHQUAKE-INDUCED DISPLACEMENTS

Based on Newmark-type cyclic inertial deformation analyses for a range of levels of static (non-seismic) stability, the sub-team concluded that any levee reaches which might fail without major strength losses such as liquefaction would have to be only marginally stable during static conditions. The effect of seismic shaking would be to either trigger or induce deformations as a result of inertial effects. To estimate the number of failures associated with a non-liquefaction deformation mode of failure, the sub-team proceeded in the following steps:

1. The number of marginally stable levee sites in each Damage Potential Zone was first estimated based on the experience of the sub-team members in dealing with problem sites. Three levels of marginal stability were considered. The estimated numbers of potentially marginal sites in each zone are listed in Table B-2. Also presented in Table B-2 are the estimated ranges of yield acceleration, k_y, for each level of marginal stability (k_y is the level of acceleration at which yielding and onset of permanent deformations will occur).

2. Estimates of earthquake-induced deformations were calculated using the Newmark double-integration method for a selected number of accelerograms. Seven accelerograms were selected to provide a reasonable range of duration and frequency content characteristics representative of the levels of seismic excitation being considered (M~5 to 7). These records from "stiff soil" or "rock" sites were then modified by means of site response analyses, using computer program SHAKE91 (Idriss et al., 1991), to develop motions representative of typical Delta levee embankment and foundation soil conditions. The base accelerograms were input as outcrop motions at a stiff soil base layer and then propagated through a deep Delta soil profile up to the surface of the levee. Near-surface motions (at the bases of potential deformation zones) were then scaled to different peak accelerations, and these were then double-integrated to obtain displacements for a range of yield accelerations. An allowance was made to account for spatial and temporal incoherence across a potential slide mass or deformation zone. Figure B-1 and Table B-3 present the results of these calculations. For the purposes of relating probabilistic base accelerations developed in Chapter 3 to a deformation mode of failure, the following was assumed:

   - The base acceleration would be amplified through soft Delta deposits by a factor of 1.6. Thus, a "stiff soil" acceleration of 0.1g would lead to a peak acceleration of 0.16g at the crown of the levee.

   - The average peak acceleration of a potential sliding mass would be approximately 40 percent of the levee crown acceleration. This is based on the work by Makdisi and Seed (1977) and assuming that the marginal sites have relatively deep potential sliding surfaces.

   - Thus, the average acceleration of potential sliding surface, k_{max}, is approximately 65 percent of the base acceleration of a stiff soil outcrop motion [1.6x0.4 ≈ 0.65].

TABLE B-2: ESTIMATED NUMBER OF MARGINALLY STABLE LEVEE SITES IN NON-LIQUEFIED REACHES WITHIN DAMAGE ASSESSMENT ZONES

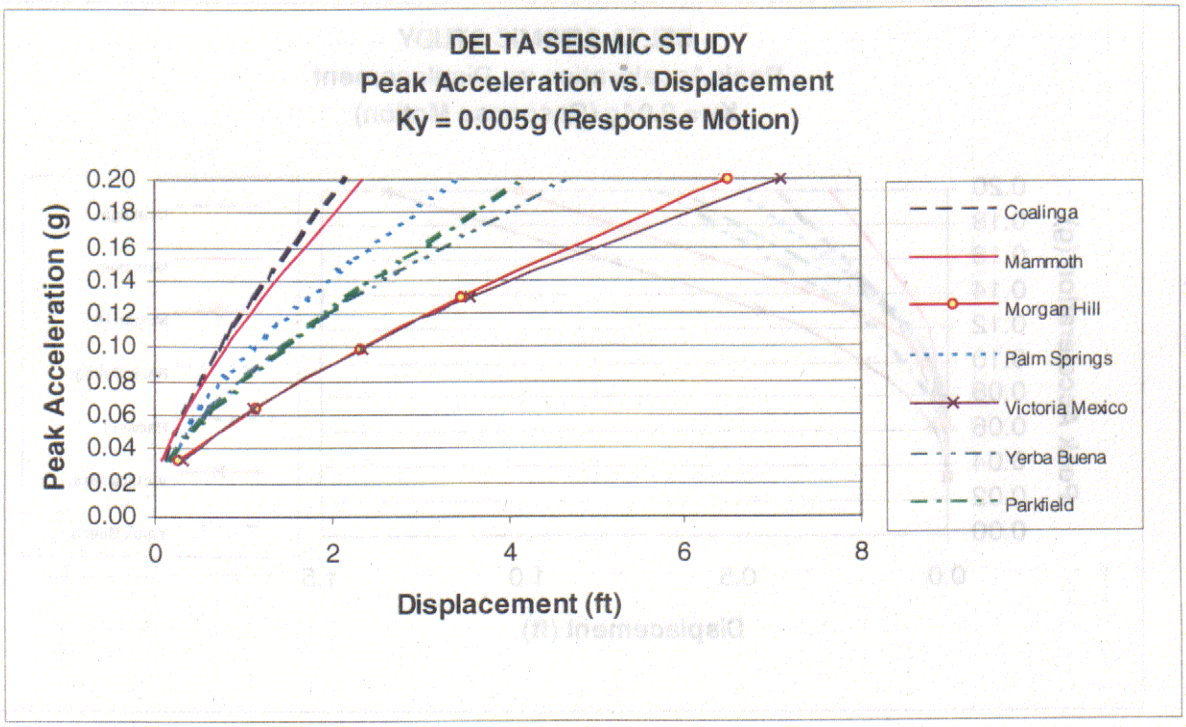
Stability Category	Approximate Yield Acceleration k_y(g)	Estimated Number of Sites in each Damage Potential Zone				
		Zone I (20 miles)	Zone II (301 miles)	Zone III (116 miles)	Zone IV (223 miles)	Total (660 miles)
A	0.00 - 0.01	1 - 2	6 - 12	0.3 - 2	0.7 - 3	8 - 19
B	0.01 - 0.03	1 - 3	12 - 24	0.7 - 3	1.3 - 7	15 - 37
C	0.03 - 0.05	3 - 8	20 - 60	1.7 - 5	3.3 - 10	28 - 83

TABLE B-3: ESTIMATED EARTHQUAKE-INDUCED DISPLACEMENTS IN NON-LIQUEFIED REACHES WITHIN DAMAGE ASSESSMENT ZONES

Magnitude 6.0 Bedrock/Stiff Soil Peak Acceleration (g)	Average Peak Acceleration[1] k_{max}(g)	Earthquake-Induced Displacement for Stability Categories[2]		
		A (k_y=0.005g)	B (k_y=0.02g)	C (k_y=0.04g)
0.05	0.033	0.1 - 0.3 ft [0.2 ft.]	0.0 - 0.0 ft. [0.1 ft.]	0.0 - 0.0 ft. [0.1 ft.]
0.10	0.065	0.3 - 1.1 ft [0.6 ft.]	0.1 - 0.2 ft. [0.1 ft]	0.0 - 0.0 ft. [0.1 ft.]
0.15	0.10	0.7 - 2.3 ft [1.4 ft]	0.1 -0.7 ft. [0.3 ft.]	0.0 - 0.2 ft. [0.1 ft.]
0.20	0.13	1.1 - 3.6 ft [2.2 ft]	0.3 - 1.2 ft. [0.6 ft.]	0.1 - 0.4 ft. [0.15 ft.]
0.30	0.20	2.2 - 7.1 [4.2 ft]	0.9 - 2.8 ft. [1.5 ft.]	0.3 - 1.4 ft. [0.6 ft.]

Notes: 1. Average Peak Acceleration assumed to be equal to 65 percent of the base bedrock/stiff soil motion.

2. Range and best estimate of earthquake-induced displacements calculated using the Newmark double-integration method.



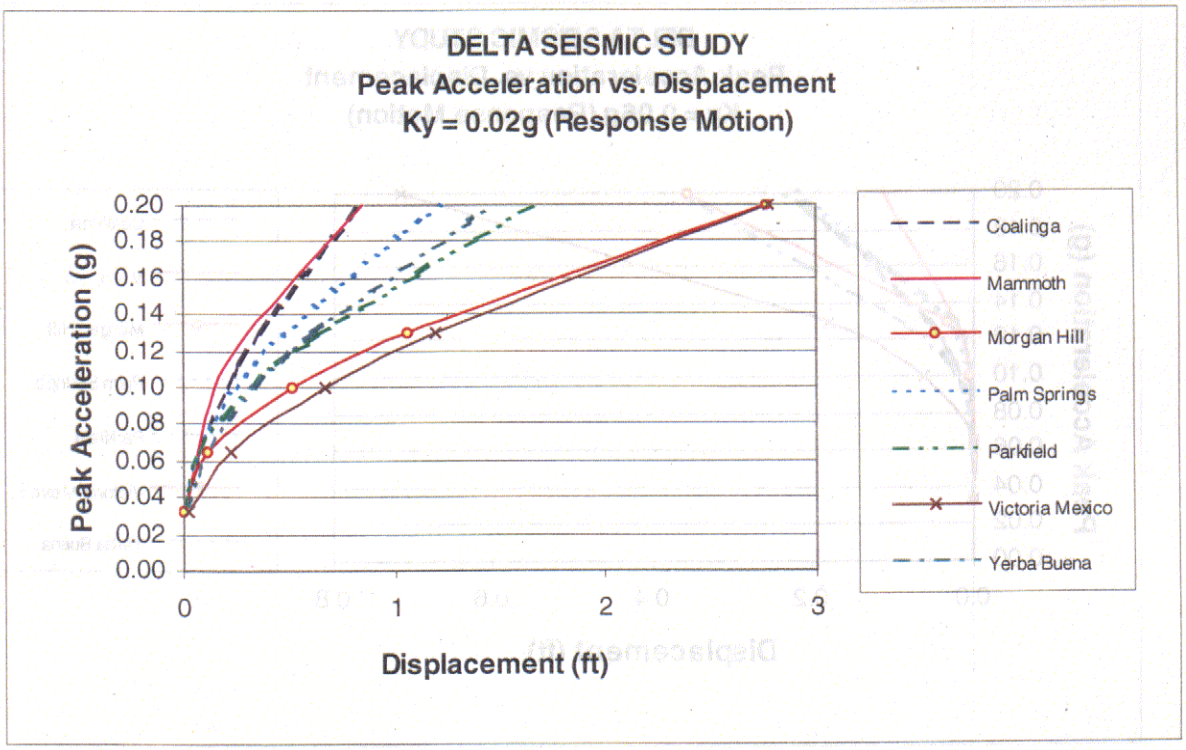
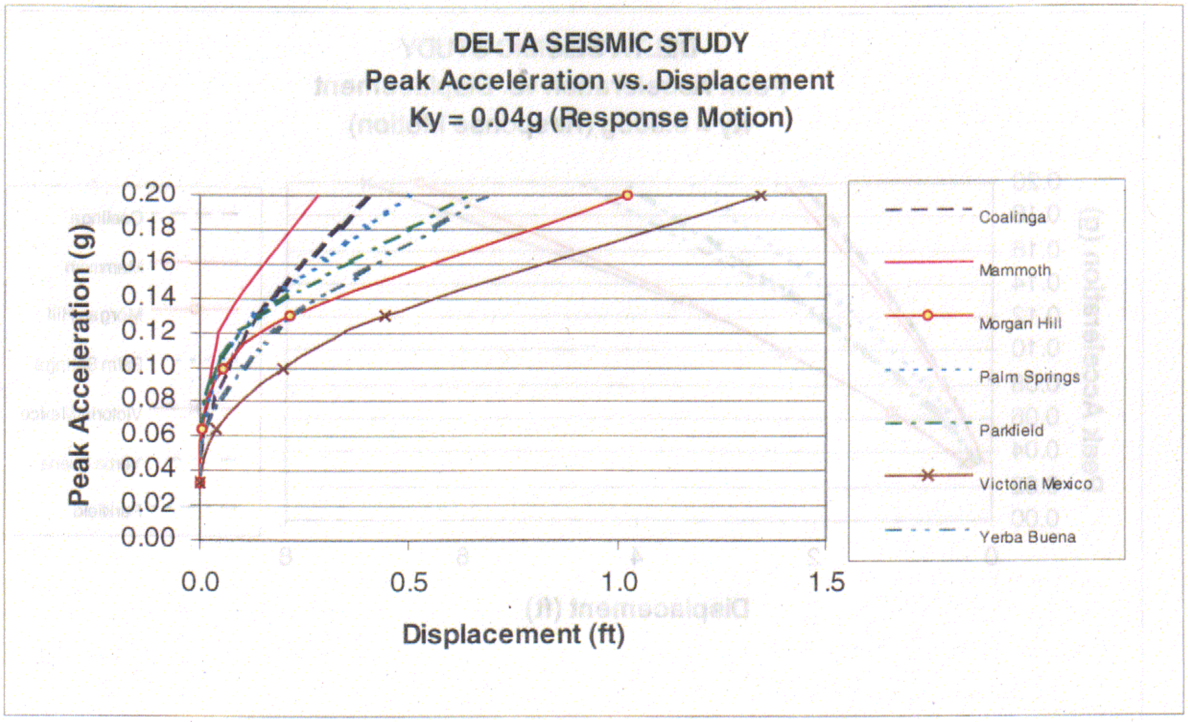


Figure B-1a: Range of Calculated Deformations for Selected Accelerograms



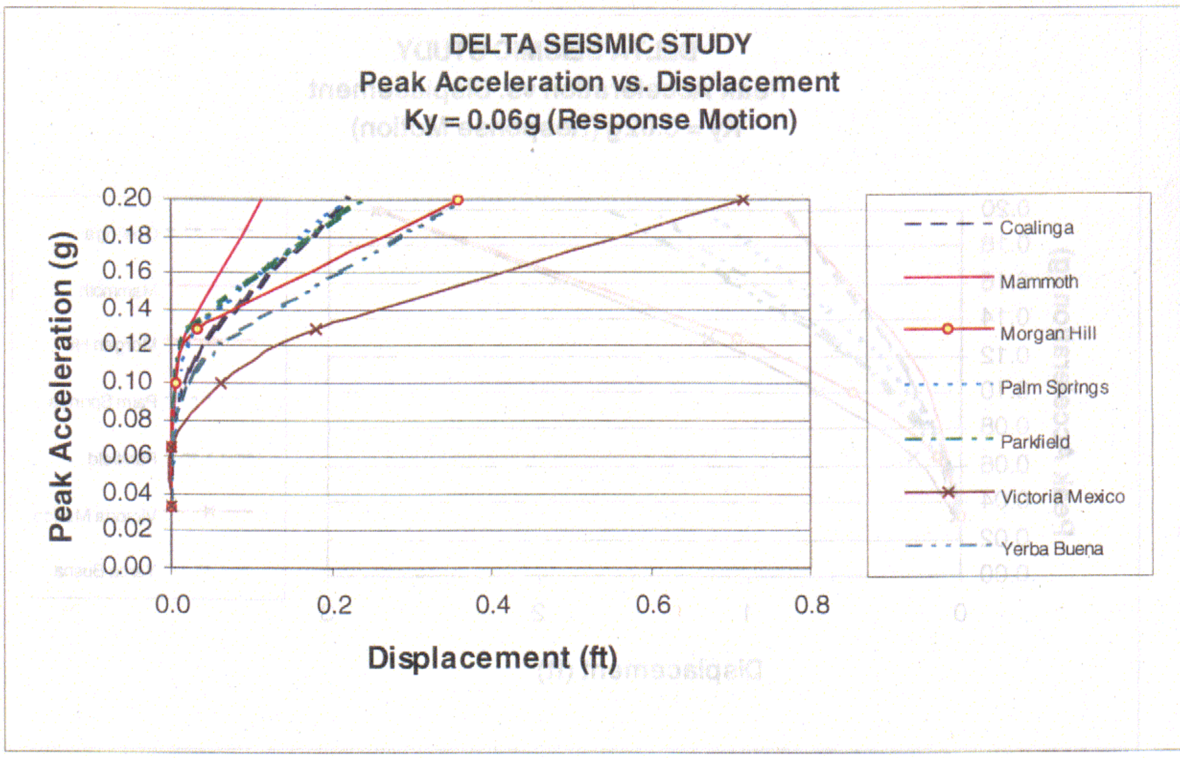


Figure B-1b: Range of Calculated Deformations for Selected Accelerograms

For the purposes of these evaluations, the median values of calculated displacement from the seven accelerograms were selected for use. This was judged to be representative of the cyclic inertial deformations expected to result from earthquakes of $M_w \approx 6$. For larger and smaller magnitudes, the induced deformations would be greater or smaller due to the longer or shorter durations of shaking (larger or smaller numbers of cycles of loading). Accordingly, these deformation estimates were later scaled for magnitude (duration) effects.

3. The estimated levee deformations were then converted into probabilities of failure using an approximate relationship developed by the sub-team based on their experience with static levee distress in the Delta (see Figure B-2 and Table B-4). As discussed previously, the hazard curve in Figure B-2 jointly accounts for the following issues and variables:

   a. cracking associated with various deformation levels,
   b. potential exacerbation of seepage problems due to cracking and slumping,
   c. potential overtopping,
   d. potential inboard toe and/or face erosion and piping, and
   e. varying outboard water levels in rivers and sloughs due to both daily tidal fluctuations, and seasonal flow variations.

4. The failure probabilities were then summed for the different levels of marginal stability within a Damage Potential Zone, and then totaled as the number of failures for the non-liquefaction deformation mode of failure (see Table B-5).

B5. ESTIMATED POTENTIAL NUMBER OF LEVEE FAILURES

The total number of potential levee failures for both liquefaction and non-liquefaction deformation modes of failure are presented in Table B-6 and Figure B-3. As may be noted in both places, the failure potential associated with liquefaction is far greater than that estimated for non-liquefaction failures. This is probably related to the relatively low magnitude and corresponding short duration of a typical Magnitude 6 earthquake. Accordingly, there are only a very small number of acceleration peaks which would exceed any particular yield acceleration.

B6. ESTIMATED POTENTIAL LEVEE FRAGILITY

It should also be noted that the estimated numbers of failures shown in Table B-6 and Figure B-3 assume that the entire Delta is shaken to the same level of earthquake motion (e.g. 0.2g). This is unrealistic as no one earthquake event will ever do this. A better way of representing the potential for failure is to normalize the estimated number of failures by levee length for each Damage Potential Zone. A normalized levee fragility can then be determined in the form of estimated number of failures per 100 miles of levee (these values were obtained by taking the values in Table B-6 and then dividing by the levee length in each zone and then multiplying by 100). The estimated levee fragility values for both liquefaction and non-liquefaction modes of failure, for causative events of $M_w \approx 6.0$, are shown in Table B-7.

SEISMIC STABILITY OF LEVEES IN THE SACRAMENTO - SAN JOAQUIN DELTA
PROBABILITY OF FAILURE ASSOCIATED WITH EARTHQUAKE-INDUCED DISPLACEMENTS

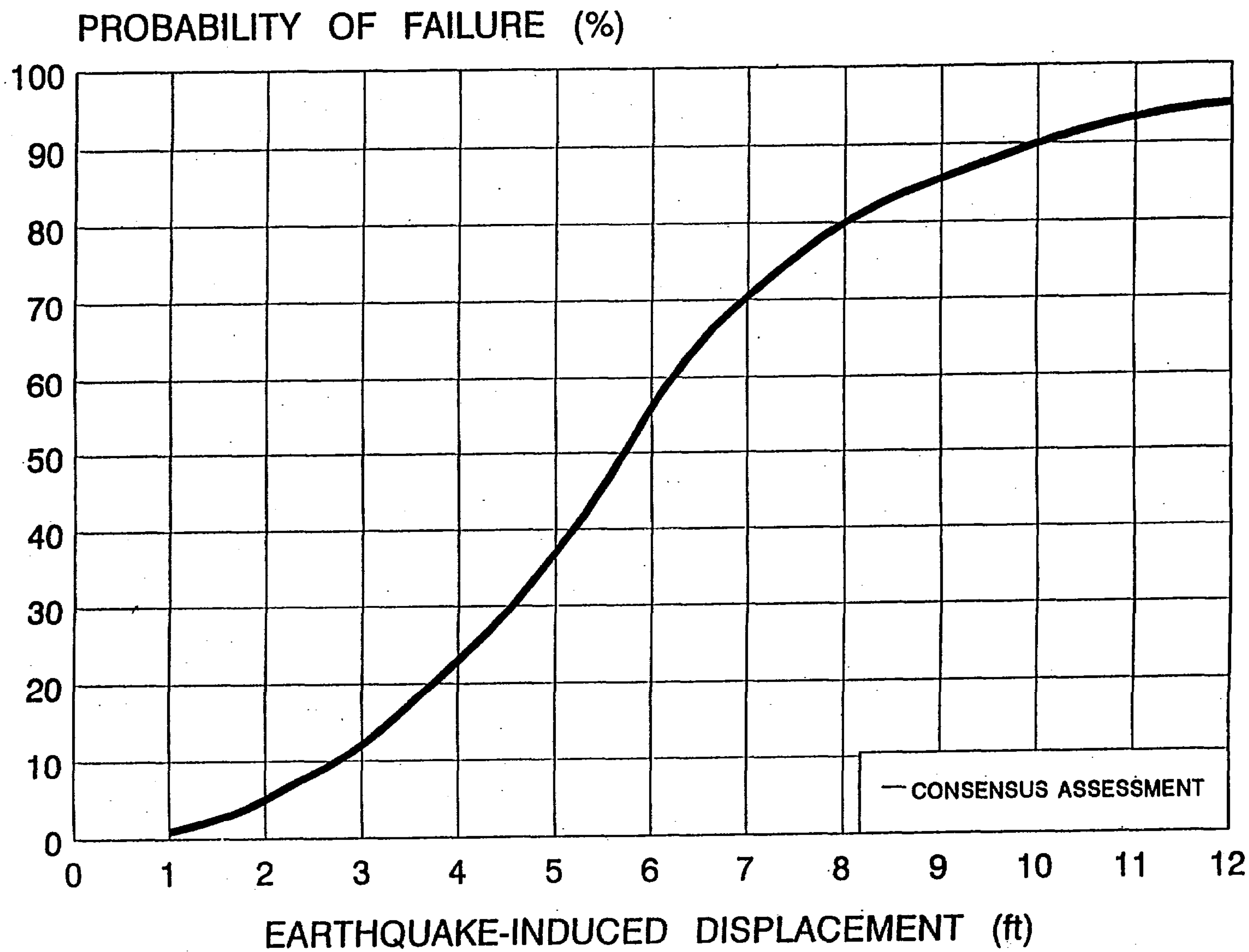


FIGURE B-2: PROBABILITY OF FAILURE ASSOCIATED WITH EARTHQUAKE-INDUCED DISPLACEMENTS

TABLE B-4: ESTIMATED PROBABILITIES OF LEVEE FAILURE ASSOCIATED WITH EARTHQUAKE-INDUCED DISPLACEMENTS IN NON-LIQUEFIED REACHES

Magnitude 6.0 Bedrock/Stiff Soil Peak Acceleration (g)	Average Peak Acceleration[1] k_{max}(g)	Estimated Probability of Levee Failure for Stability Categories[2]		
		A (k_y=0.005g)	B (k_y=0.02g)	C (k_y=0.04g)
0.05	0.033	**0.2%** [0.2 ft.]	**0.1%** [0.1 ft.]	**0.1%** [0.1 ft.]
0.10	0.065	**0.6%** [0.6 ft.]	**0.1%** [0.1 ft]	**0.1%** [0.1 ft.]
0.15	0.10	**2.6%** [1.4 ft]	**0.3%** [0.3 ft.]	**0.1%** [0.1 ft.]
0.20	0.13	**6.0%** [2.2 ft]	**0.6%** [0.6 ft.]	**0.2%** [0.15 ft.]
0.30	0.20	**25.0%** [4.2 ft]	**3.0%** [1.5 ft.]	**0.6%** [0.6 ft.]

Notes: 1. Average Peak Acceleration assumed to be equal to 65 percent of the base bedrock/stiff soil motion.
2. Estimated Probability of Levee Failure for non-liquefied levees based on estimated earthquake-induced deformations calculated using the Newmark method (see Table B-3).

TABLE B-5: ESTIMATED NUMBER OF LEVEE FAILURES ASSOCIATED WITH EARTHQUAKE-INDUCED DISPLACEMENTS IN NON-LIQUEFIED REACHES

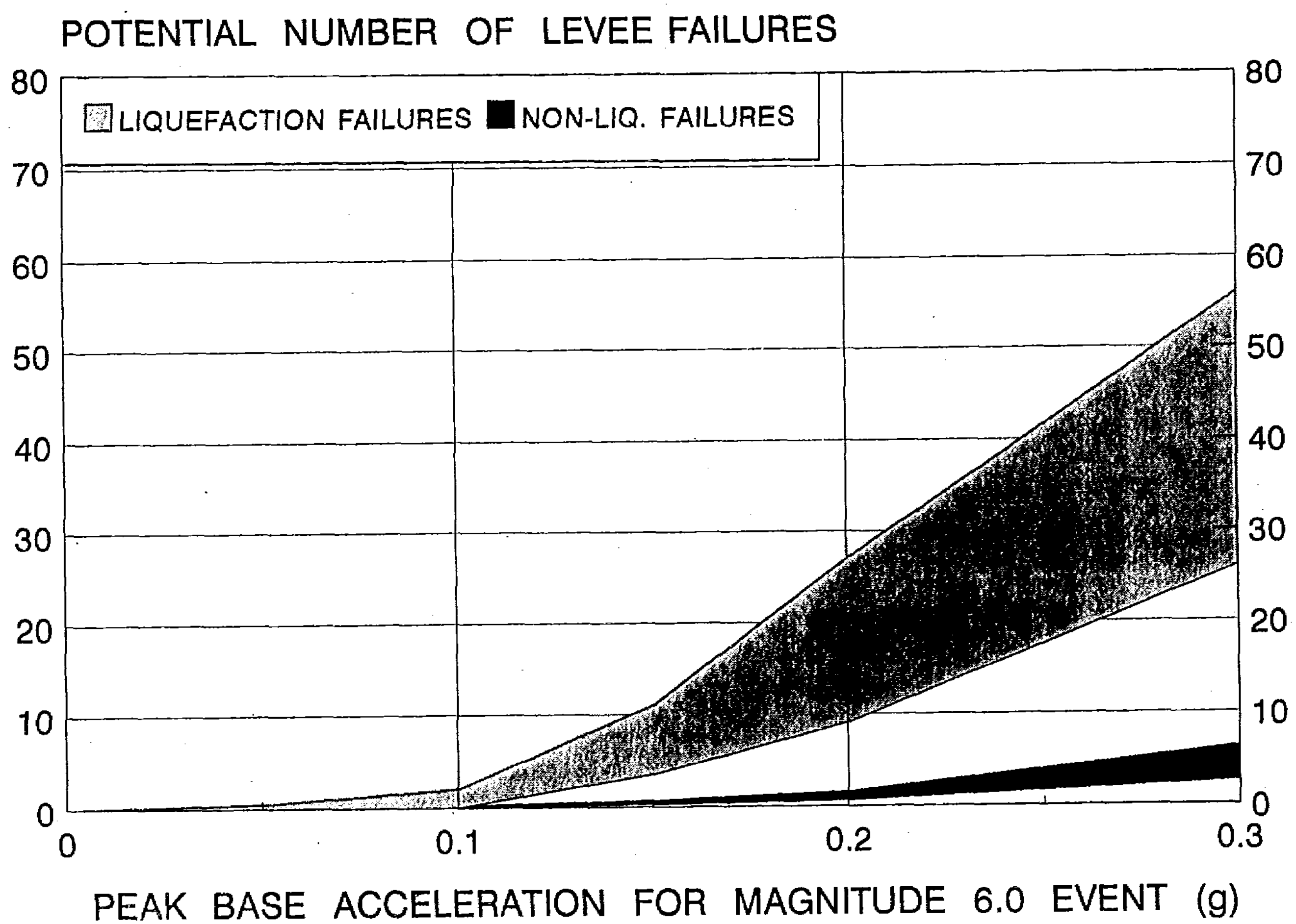
Magnitude 6.0 Rock/Stiff Soil Peak Acc. (g)	Damage Potential Zone	Levee Length (miles)	Estimated Number of Levee Failures in Non-Liquefied Reaches		Estimated Failure Rate (Fragility) Failures per 100 miles
0.05	I	20	[1x0.002+1x0.001+3x0.001]-[2x0.002+3x0.001+8x0.001]=	**0.006 - 0.015**	**0.030 - 0.075**
	II	301	[6x0.002+12x0.001+20x0.001]-[12x0.002+24x0.001+60x0.001]=	**0.044 - 0.108**	**0.015 - 0.036**
	III	116	[0.3x0.002-0.7x0.001+1.7x0.001]-[2x0.002+3x0.001+5x0.001]=	**0.003 - 0.012**	**0.003 - 0.010**
	IV	223	[0.7x0.002+1.3x0.001+3.3x0.001]-[3x0.002+7x0.001+10x0.001]=	**0.006 - 0.023**	**0.003 - 0.010**
0.10	I	20	[1x0.006+1x0.001+3x0.001]-[2x0.006+3x0.001+8x0.001]=	**0.010 - 0.023**	**0.050 - 0.12**
	II	301	[6x0.006+12x0.001+20x0.001]-[12x0.006+24x0.001+60x0.001]=	**0.068 - 0.156**	**0.023 - 0.052**
	III	116	[0.3x0.006+0.7x0.001+1.7x0.001]-[2x0.006+3x0.001+5x0.001]=	**0.004 - 0.020**	**0.004 - 0.017**
	IV	223	[0.7x0.006+1.3x0.001+3.3x0.001]-[3x0.006+7x0.001+10x0.001]=	**0.009 - 0.035**	**0.004 - 0.016**
0.15	I	20	[1x0.026+1x0.003+3x0.001]-[2x0.026+3x0.003+8x0.001]=	**0.032 - 0.069**	**0.16 - 0.35**
	II	301	[6x0.026+12x0.003+20x0.001]-[12x0.026+24x0.003+60x0.001]=	**0.212 - 0.444**	**0.070 - 0.15**
	III	116	[0.3x0.026+0.7x0.003+1.7x0.001]-[2x0.026+3x0.003+5x0.001]=	**0.012 - 0.066**	**0.010 - 0.057**
	IV	223	[0.7x0.026+1.3x0.003+3.3x0.001]-[3x0.026+7x0.003+10x0.001]=	**0.025 - 0.109**	**0.011 - 0.049**
0.20	I	20	[1x0.060+1x0.006+3x0.002]-[2x0.060+3x0.006+8x0.002]=	**0.072 - 0.154**	**0.36 - 0.77**
	II	301	[6x0.060+12x0.006+20x0.002]-[12x0.060+24x0.006+60x0.002]=	**0.472 - 0.984**	**0.16 - 0.33**
	III	116	[0.3x0.060+0.7x0.006+1.7x0.002]-[2x0.060+3x0.006+5x0.002]=	**0.026 - 0.148**	**0.022 - 0.13**
	IV	223	[0.7x0.060+1.3x0.006+3.3x0.002]-[3x0.060+7x0.006+10x0.002]=	**0.056 - 0.242**	**0.025 - 0.11**
0.30	I	20	[1x0.250+1x0.030+3x0.006]-[2x0.250+3x0.030+8x0.006]=	**0.298 - 0.638**	**1.5 - 3.2**
	II	301	[6x0.250+12x0.030+20x0.006]-[12x0.250+24x0.030+60x0.006]=	**1.980 - 4.080**	**0.66 - 1.4**
	III	116	[0.3x0.250+0.7x0.030+1.7x0.006]-[2x0.250+3x0.030+5x0.006]=	**0.106 - 0.620**	**0.092 - 0.53**
	IV	223	[0.7x0.250+1.3x0.030+3.3x0.006]-[3x0.250+7x0.030+10x0.006]=	**0.234 - 1.020**	**0.11 - 0.46**

TABLE B-6: ESTIMATED NUMBER OF FAILURES FOR BOTH LIQUEFIED AND NON-LIQUEFIED REACHES

Magnitude 6.0 Rock/Stiff Soil Peak Acc. (g)	Damaged Potential Zone	Levee Length (miles)	Estimated Number of Levee Failures		
			Liquefied Reaches	Non-Liq. Reaches	Total
0.05	I	20	0 - 0.13	0.01 - 0.02	**0.01 - 0.15**
	II	301	0 - 0.25	0.04 - 0.11	**0.04 - 0.36**
	III	116	0 - 0.03	0 - 0.01	**0 - 0.04**
	IV	223	0 - 0.07	0.01 - 0.02	**0.01 - 0.09**
	Total	**660**	**0 - 0.48**	**0.06 - 0.16**	**0.06 - 0.64**
0.10	I	20	0 - 0.5	0.01 - 0.02	**0.01 - 0.52**
	II	301	0 - 1.0	0.07 - 0.16	**0.07 - 1.16**
	III	116	0 - 0.2	0 - 0.02	**0 - 0.22**
	IV	223	0 - 0.3	0.01 - 0.04	**0.01 - 0.34**
	Total	**660**	**0 - 2**	**0.09 - 0.24**	**0.09 - 2.24**
0.15	I	20	0.5 - 2	0.03 - 0.07	**0.53 - 2.07**
	II	301	2 - 5	0.21 - 0.44	**2.21 - 5.44**
	III	116	0.3 - 1.4	0.01 - 0.07	**0.31 - 1.47**
	IV	223	0.7 - 2.6	0.03 - 0.11	**0.73 - 2.71**
	Total	**660**	**3.5 - 11**	**0.28 - 0.69**	**3.78 - 11.69**
0.20	I	20	1 - 4	0.07 - 0.15	**1.07 - 4.15**
	II	301	5 - 15	0.47 - 0.98	**5.47 - 15.98**
	III	116	1 - 3	0.03 - 0.15	**1.03 - 3.15**
	IV	223	2 - 5	0.06 - 0.24	**2.06 - 5.24**
	Total	**660**	**9 - 27**	**0.63 - 1.52**	**9.63 - 28.52**
0.30	I	20	3 - 6	0.30 - 0.64	**3.30 - 6.64**
	II	301	15 - 30	1.98 - 4.08	**16.98 - 34.08**
	III	116	3 - 7	0.11 - 0.62	**3.11 - 7.62**
	IV	223	5 - 13	0.23 - 1.02	**5.23 - 14.02**
	Total	**660**	**26 - 56**	**2.62 - 6.36**	**28.62 - 62.36**

SEISMIC STABILITY OF LEVEES IN THE SACRAMENTO - SAN JOAQUIN DELTA

ASSESSMENT OF POTENTIAL NUMBER OF LEVEE FAILURES



Note: Assessment assumes that the entire Delta area is shaken by the postulated earthquake shaking

FIGURE B-3: ESTIMATED NUMBER OF LEVEE FAILURES FOR DIFFERENT LEVELS OF EARTHQUAKE SHAKING

TABLE B-7: ESTIMATED FAILURE RATE (FRAGILITY) FOR BOTH LIQUEFIED AND NON-LIQUEFIED REACHES - FAILURES PER 100 MILES

Magnitude 6.0 Rock/Stiff Soil Peak Acc. (g)	Damaged Potential Zone	Levee Length (miles)	Estimated Fragility - Number of Levee Failures per 100 miles: Liquefied Reaches	Non-Liq. Reaches
0.05	I	20	0.005 - 0.50	0.030 - 0.075
	II	301	0.001 - 0.083	0.015 - 0.036
	III	116	0.001 - 0.033	0.003 - 0.010
	IV	223	0.001 - 0.033	0.003 - 0.010
0.10	I	20	0.20 - 2.5	0.050 - 0.12
	II	301	0.080 - 0.33	0.023 - 0.052
	III	116	0.050 - 0.15	0.004 - 0.017
	IV	223	0.050 - 0.15	0.004 - 0.016
0.15	I	20	2.5 - 10.	0.16 - 0.35
	II	301	0.66 - 1.7	0.070 - 0.15
	III	116	0.29 - 1.2	0.010 - 0.057
	IV	223	0.29 - 1.2	0.011 - 0.049
0.20	I	20	5. - 20.	0.36 - 0.77
	II	301	1.7 - 5.0	0.16 - 0.33
	III	116	0.88 - 2.3	0.022 - 0.13
	IV	223	0.88 - 2.3	0.025 - 0.11
0.30	I	20	15. - 30.	1.5 - 3.2
	II	301	5.0 - 10.	0.66 - 1.4
	III	116	2.4 - 5.9	0.092 - 0.53
	IV	223	2.4 - 5.9	0.11 - 0.46

B7. MAGNITUDE CORRECTION FACTORS

The estimates for levee failures and fragility presented in the previous tables are for earthquake shaking associated with a magnitude 6.0 event. For the same level of shaking, larger earthquake magnitudes will induce more damage and levee failures than smaller events because larger magnitude earthquakes have longer durations and larger numbers of strong cycles of shaking. To adjust the fragilities for earthquake magnitudes other than Magnitude 6.0, the following corrections were used:

A. Liquefaction Mode of Failure:

A magnitude correction factor for the liquefaction mode of failure was developed using the Idriss (1997) magnitude scaling factors for triggering liquefaction. These corrections are slightly larger than those previously used by Seed et al. (1984).

B. Non-Liquefaction Deformation Mode of Failure:

A magnitude correction factor for the non-liquefaction deformation mode of failure was developed using the Earthquake Severity Index described by Bureau et al. (1988). This correction is much larger than the one for liquefaction, but is comparable with the deformation results obtained by Makdisi and Seed (1977).

For both failure modes (liquefaction, and non-liquefaction cyclic inertial deformation), the principal fragility estimates (Table B-7) were developed for events of $M_w \approx 6.0$, as that was central to the range of magnitudes principally contributing to the overall risk for the Delta. Figure B-4 shows the magnitude correction factors used for both modes of failure.

SEISMIC STABILITY OF DELTA LEVEES
MAGNITUDE CORRECTION FACTORS TO LEVEE FRAGILITY

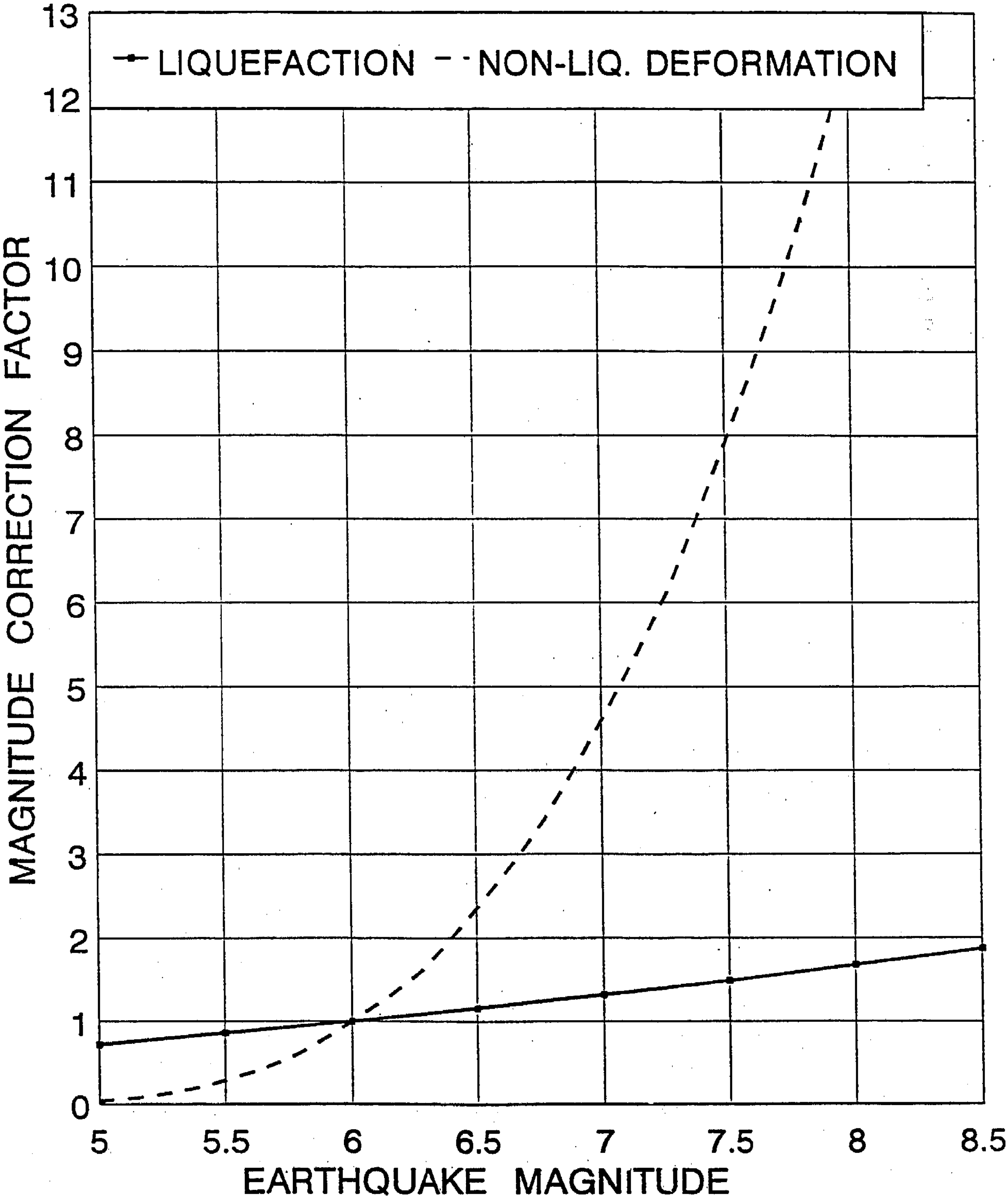


FIGURE B-4: MAGNITUDE CORRECTION FACTORS FOR LIQUEFACTION AND NON-LIQUEFACTION DEFORMATION MODES OF FAILURE

APPENDIX C

PROBABILISTIC LEVEE FAILURE METHODOLOGY

APPENDIX C
PROBABILISTIC LEVEE FAILURE METHODOLOGY

The mathematical models used in the calculation of the probability of levee failures are described in this Appendix. To apply the probabilistic approach, we need to first parameterize the point estimates of the fragilities.

C1. PARAMETRIC MODELS FOR LEVEE FRAGILITIES

The point estimates of the levee fragilities developed for this study were fit to simple equations to facilitate the probabilistic calculations. The simplified models for the median and coefficient of variation (cov) for both liquefaction and non-liquefaction induced failures are given below.

Fragility Curves for Liquefaction Induced Failures

The median fragility liquefaction for In liquefaction induced failures is modeled by

$$frag_{Li}(pga,M)=0.8\exp(p_1+p_2[\ln(pga)+c_1+c_2M+c_3M^2+c_4M^3]+c_{5i})$$

The coefficients p_1, p_2, c_1, c_2, c_3, c_4, and c_5 were estimated from the central value of the range given in the point estimates. The 0.8 factor represents the interpretation of the sub-team that the median fragility is not at the center of the range given in the point estimates, but rather it is approximately at 40% of the range.

The coefficient of variation for all zones is modeled by

$$cov_L=(b_1+b_2pga)/1.3$$

with a constraint that it not be less then 0.3/1.3. The factor of 1.3 represents the interpretation of the sub-team that the range on the fragility given in the point estimates represents the 80% confidence interval.

The distribution of the fragility is modeled as an asymmetric distribution based on the judgement of the sub-team. This asymmetry is modeled using two different normal distributions above and below the median. The standard deviation (cov*median) is scaled by 1.2 for values above the median and by 0.8 for values below the median. This results in a distribution that is skewed to the right (skewed to higher numbers of failures).

The levee fragility group estimates of the ranges of numbers of failures for each zone is based on the total number of failures for each zone. That is, the standard deviation does not apply to a single levee, but rather to the total number of levees in each zone. This impacts the use of the standard deviation in the probabilistic evaluation. Specifically, the distribution is applied to the median number of breaks in each zone (summation of the median number of breaks for each levee in a zone). This distribution is truncated at 1.5 standard deviations above and below the median.

The coefficients for these models are listed in Table C-1.

Fragility Curves for Non-Liquefaction Induced Failures

The median fragility for non-liquefaction induced failures is modeled by a bilinear model:

If

$$\ln(pga)+c_1+c_2M+c_3M^2+c_4M^3\leq-2.3,$$

then

$$frag_{Ni}(pga,M)=\exp\{p_1+p_2[\ln(pga)+c_1+c_2M+c_3M^2+c_4M^3]+c_{5i}\}$$

otherwise,

$$frag_{Ni}(pga,M)=\exp\{p_1+p_2[\ln(pga)+c_1+c_2M+c_3M^2+c_4M^3]+c_{5i}+p_3\ln(pga)\}$$

The coefficient of variation is modeled by

$$cov_{Ni}=b_{1i}/1.3$$

The factor of 1.3 represents the interpretation that the range on the fragility given in the point estimates represents the 80% confidence interval. A normal distribution is used for the number of failures. This distribution is truncated at 1.5 standard deviations above or below the median.

The coefficients for these models are listed in Table C-2. All of the coefficients are constant for all zones except for C_5 and b_1 which can vary by zone as shown in Table C-2.

C2. PROBABILISTIC METHODOLOGY

The levee failure probability is an extension of standard probabilistic seismic hazard analysis. The difference is that instead of calculating the probability of the ground motion exceeding a specified value at a location, we compute the probability of specified number of levee failures being exceeded in a single earthquake. That is, we consider the entire levee system simultaneously.

In the following probabilistic seismic hazard analysis, we consider all possible earthquake magnitudes, locations, and ground motion. For each possible earthquake, we then compute the probability of one or more levee failures occurring within the Delta. This process is repeated for two or more failures, three or more failures, and so on.

Let μ_{Lij} be the median number of failures due to liquefaction for the j^{th} levee in the i^{th} zone. Then

$$\mu_{Lij} = frag_{Li}(pga, M) * L_j$$

where $frag_{Li}$ is the median fragility, pga is the median peak acceleration at the center of the island, M is the magnitude of the earthquake, and L_j is the length of the j^{th} levee in miles. The median number of failures for the i^{th} zone is given by:

$$\mu_{Li} = \sum_{j=1}^{Ni} \mu_{Lij}$$

and the standard deviation of the number of failures due to the uncertainty in the ground motion is given by:

$$\sigma_{GLij} = \mu_{Lij} P2\sigma_{pga}(M)$$

based on propagation of errors. Assuming that the peak acceleration variability is uncorrectable between levees (which is reasonable for separation distance of greater than 500m), then the standard deviation of the total number of failures within the zone is given by:

$$\sigma_{GLi} = \sqrt{\sum_{j=1}^{Ni} \sigma_{GLij}^2}$$

Since the standard deviation due to uncertainty in the fragility is for the zone and not for individual levees, the fragility uncertainty is fully correlated for each levee within a zone. Therefore, the standard deviation of the total number of failures within a zone due to fragility variability is given by:

$$\sigma_{FLi} = \sum_{j=1}^{Ni} \mathrm{cov}_L \, \mu_{Lij}$$

Similar equations are developed for the non-liquefaction induced failures.

We then use a Monte Carlo approach to sample the distributions for the number of failures in each zone and sum the number of failures from liquefaction and non-liquefaction failures for each zone. Finally, we sum up the number of failures for all the zones to get the total number of failures in the levee system. The frequency of failures in the Monte Carlo sampling defines the conditional probability of the number of failures for a given earthquake magnitude and location.

Let (P(fail>N_F I M, A, W, Hx, Hy) be this conditional probability of the number of failures exceeding N for the given magnitude (M), rupture area (A), rupture width (W), energy center along strike (Hx), and energy center along dip (Hy).

Then the rate of failures is given by:

$$v(Fail > N) = \sum_{k=1}^{NF} N_k \int_M \int_A \int_W \int_x \int_y f_m(M) f_A(M) F_W(M) f_x(x) f_y(y) P(fail > N_F | M, A, W, x, y) dM dA dW dx dy$$

where f_m, f_A, f_W, f_x, f_y are the probability density functions for magnitude, rupture area, rupture width, and energy center. The N_k is the rate of earthquake above the minimum magnitude (here taken as 5.0) for the k^{th} source and NF is the number of faults.

In this equation, the conditional probability of failure is multiplied by the probability of the specified earthquake occurring (given that an earthquake has happened) and then multiplied by the rate of earthquake for the given seismic source. This rate of failure is then summed over all the seismic sources to give the total rate of various numbers of levees failing in a single earthquake. A Poisson assumption for the earthquake occurrence is used to convert the rate of failures into a probability of failures. The result is a hazard curve for the number of levee failures in a single earthquake.

Table C-1.
Fragility Model Coefficients for Liquefaction Induced Failures

Coefficient	All Zones	I	II	III	IV
p1	7.33				
p2	3.02				
c1	-3.47				
c2	0.97				
c3	-0.0838				
c4	0.0031				
c5		0.0	-1.55	-2.23	-2.23
b1	0.94				
b2	-2.05				

Table C-2.
Fragility Model Coefficients for Liquefaction Induced Failures

Coefficient	All Zones	I	II	III	IV
p1	-1.32				
p2	0.54				
p3	2.49				
c1	-75.7				
c2	28.6				
c3	-3.61				
c4	0.156				
c5		0.0	-0.115	-0.810	-2.08
b1		0.38	0.38	0.60	0.60

APPENDIX D

REVIEW COMMENTS BY DRS. BRUCE BOLT AND I. M. IDRISS

June 24, 1999

Mr. Raphael A. Torres
Chief
Civil Engineering Branch
Department of Water Resources

Seismic Vulnerability of the Sacramento-San Joaquin Delta Levees

Dear Mr. Torres:

As you requested, I have reviewed the final draft report (December 1998) and set out below some comments and conclusions related to it. I have previously, in 1982, prepared a short report in which I estimated likely earthquake ground motions in the Delta region (included in Report references). Of course, in the ensuing seventeen years more relevant information has become available, and the CALFED report is much more extensive and detailed.

More recently, I have served on your DWR Consulting Board, which considered Phase I and Phase II of "The Seismic Stability Evaluation of Sacramento-San Joaquin Delta Levees." Several questions addressed to this Consulting Board were responded to formally and various aspects of the work in progress were discussed on an individual basis. My comments on the CALFED report address mainly Chapters 2 and 3 and then the Summary of Findings (Chapter 7).

General Comments

The Report is a comprehensive, well-written, and sound review of the problem of seismic vulnerability of these levees. It is unfortunately the case that little relevant information is available specific to the seismic response of levees with the Sacramento

Delta evolutionary construction history. Almost every qualitative parameter involved in the assessment has considerable uncertainty. What is sure is that the levees will someday be subject to a repetition of the 1868 Hayward earthquake, or a similar one centered further north, or a 1906-type earthquake, or one or more derived from thrust faulting under the west margin of the Central Valley. In addition, we know little instrumentally about the propagation of large amplitude seismic waves through the thick sedimentary deposits underlying the Delta. Also, the estimation problem is much hampered by the paucity of data on the strong wave response of the surficial Delta peats and organic soils.

On the last point, it is encouraging that DWR has responded to the 1992 Consulting Board's recommendation to install surface and downhole strong motion instruments "at the earliest possible date." Although there have not been even moderate magnitude earthquakes in the region since that time, some small ground motions have already been measured at Delta sites (e.g., March 27, 1997 from Fairfield-Vacaville). Of course, there is the problem of valid extrapolation from weak to strong motions. Nonlinear effects have been claimed to have been substantial in some recent California earthquakes (see, e.g., E.H. Field et al., Sei*smological Research Letters*, **69**, pg. 230, 1998). It is not clear to me, however, that many of the reported spectral and duration effects are not the result of source asperities, and especially phase conversion scattering in sedimentary basin structures (see Dan O'Connell of the Bureau of Reclamation, *Science*, 1999).

The Report follows a more-or-less direct probabilistic hazard analysis, which is appropriate given the seismicity uncertainties summarized above. A deterministic approach may well lead to similar average ground motion results, but without the more robust temporal estimates (return periods) given here.

According to the present Report (Figure A-12), peak ground accelerations at Sherman Island of about 0.25g have an annual probability of being exceeded of one in two hundred. It is of passing historical interest that in a 1982 Report to the East Bay Municipal Utility District my quite independent estimate was, for accelerations exceeding 0.25g per year, "about 1 in 200 or so"!

Section 3: Seismicity

The seismicity catalogs and fault information appears complete and sound. I lean towards Model 1, but it seems advisable to consider also the mapping of capable blind thurst faults more to the west (Lettus's model). Both may be true. The hazard result (M6 in 100y RT) for the eastern Delta again agrees with earlier assessments of mine inferred on a more deterministic basis.

Section 4: Fragility

The discussion of levee fragility seems well based to me. It is particularly satisfactory to have probability estimates of the number of failures per exposure period (Appendix B). Given the various uncertainties, however (both intrinsic and from the assumptions), it might have been better to describe the failure functions as bands rather than lines.

Incidentally, it is not quite clear (pg. 13, Section 4.3) how the critical ground motion property of shaking duration was handled. The sentence here leaves open the question of adequate incorporation of the physical response of peaty soils to many cycles of moderate srrong motion.

The results of the study, based on present knowledge, are not very encouraging. According to Table 4.2, peak accelerations of about 0.2g lead to one or more levee failures per 100 miles. As I and others concluded years ago, Sherman Island is particularly vulnerable to flooding. I am still not entirely convinced, however, that an amplification factor of 1.6 (pg. 13) will occur. More relevant strong-motion measurements are vital.

Section 7: Summary of Findings

I judge all six paragraphs to be adequately supported by the studies discussed or referenced. There are really no surprises, so the last two recommendations are, until further earthquake measurements become available, particularly valuable and in need of follow up.

Signed,

Bruce A Bolt

Bruce A. Bolt

Professor of Seismology, Emeritus.

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7 July 1999

Mr. Ralph A. Torres, Chief
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Dear Mr. Torres:

As requested in your letter, I have reviewed the copy of the final draft report on "Seismic Vulnerability of the Sacramento-San Joaquin Delta Levees", which you enclosed with that letter. A committee chaired by you prepared this report for CALFED.

The report does provide an excellent framework for assessing the vulnerability and the potential risks associated with maintaining the Sacramento-San Joaquin Delta Levees. Your Committee is to be congratulated on completing a comprehensive study and documenting the results in a reasonably complete report. The appendices contain a wealth of information useful for this and other projects in this area.

One issue that deserves further consideration is the resolution regarding the blind thrust faults in the area (page 7 of the report).

The other issue that deserves further detailed evaluation is that related to assessing the seismic response of the levees. I believe that it would be very useful to complete a series of two-dimensional analyses to estimate the response of these levees during various size earthquakes and at various levels of shaking. These analyses can then be used to estimate the hazard (i.e., levels of shaking for given return periods) for the levees. These levels of shaking can be significantly different from those calculated for the rock outcrop. The use of a constant amplification factor (i.e., independent of height of levee, independent of earthquake magnitude, and independent of the level of shaking) may not be justifiable and deserves further study.

While the fragility discussion is presented in elegant equation format, the derivation and the utilization of specific parameters does need further explanations and documentation. This report will have long-term usefulness and it is essential that each part be fully documented and reasonably well supported.

Please accept my apologies for the delay in transmitting these comments to you. I read the report shortly after receiving it from you, but my travel schedule precluded transmitting the comments in a more timely manner. I trust, nevertheless, that you will find these comments useful in finalizing the report and in scheduling and implementing future tasks.

Please let me know if you wish any amplification or additional input regarding the above comments.

Sincerely,

I. M. Idriss

APPENDIX E

BIBLIOGRAPHY

APPENDIX E
BIBLIOGRAPHY

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APPENDIX H

PROPOSALS FOR ECOSYSTEM RESTORATION

STATE OF CALIFORNIA PETE WILSON, Governor

DELTA PROTECTION COMMISSION
14215 RIVER ROAD
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WALNUT GROVE, CA 95690
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July 10, 1998

To: Delta Protection Commission

From: Margit Aramburu, Executive Director

Subject: Alternative Proposal for CALFED Ecosystem Restoration Program in the Delta

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BACKGROUND:

In the Delta Protection Commission's comment letter on the CALFED Draft Ecosystem Restoration Program Plan (ERPP), the Commission made a number of suggestions for high priority projects to enhance and restore habitat. This memo outlines more specific ideas for implementation of those recommended priorities. The memo has been prepared in partnership with representatives of the North, Central, and South Delta Water agencies, and represents ideas acceptable to those entities. None of the Water Agencies have taken a formal position on the memo or the ideas in the memo. The purpose of the review by the Delta Protection Commission is to help refine this list of suggested "alternative" projects to forward to the CALFED Bay Delta Advisory Committee (BDAC), the public entity providing input to the CALFED process. The list is a draft list which should change after public and Commission review and input.

The Commission should review the attached memo, seek public comments and input on the suggestions in the memo, and direct staff to continue working on refinement of the memo with other Delta interests to present to BDAC at its September 1998 meeting to be held in Stockton.

CALFED ERPP HABITAT RESTORATION TARGETS FOR DELTA ECOLOGICAL ZONE (See Exhibit 1):

Tidal Perennial Aquatic	7,000 ac
Shoal	500 ac
Nontidal Perennial Aquatic (deep open water)	500 ac
Nontidal Perennial Aquatic (shallow open water)	2,100 ac
Midchannel Islands	200 to 800 ac

Fresh Emergent Wetland (tidal)		30,000 to 45,000 ac
Fresh Emergent Wetland (nontidal)		20,000 ac
Seasonal Wetland	Improve:	4,000 ac
	Restore:	30,000 ac
Inland Dune Scrub		50 to 100 ac
Perennial Grassland		4,000 to 6,000 ac
Wildlife Friendly Agricultural Land		40,000 to 75,000 ac

DELTA PROTECTION COMMISSION COMMENTS ON DRAFT ERPP:

The Delta Protection Commission comments regarding the ERPP recommended that the ERPP be modified to prioritize the following restoration programs:

Restoration and/or enhancement of lands currently in public and/or nonprofit ownership (or currently in the acquisition process) and designated for restoration, including Twitchell Island, Sherman Island and Prospect Island. Approximately 35,000 acres fall in this category.

Acquisition and/or enhancement of currently flooded lands to create and/or enhance emergent habitat, including Franks Tract, Big Break, Mildred Island, Little Mandeville, Island, etc. Approximately 7,000 acres fall in this category.

Development and implementation of management plans for upland areas already in public or nonprofit ownership, including Calhoun Cut Ecological Preserve (approximately 1,000 acres), Rhode Island, etc.

Development and implementation of individual management plans for private agricultural properties and development of funds to offset costs of voluntary implementation of such plans (plans could include flooding programs, enhanced levees and pumps to enhance flooding and drainage, recommended crop rotation cycles, size and location of permanent brood ponds, etc.)

Development and implementation of individual management plans for privately-owned lands managed for wildlife habitat, such as duck clubs and upland hunting clubs, and development of funds to offset costs of voluntary implementation of such plans.

Control of stressors should be revised to avoid duplication with existing regulatory programs, such as existing dredging "windows", and the programs that are developed should respect the needs of existing land uses, such as water-oriented recreation. Where funds are needed to carry out specific programs, those funds should be made available to private land owners to implement CALFED programs.

Protection, enhancement and restoration of in-channel islands and waterside berms.

LISTING OF SITES BY TYPE OF HABITAT TO BE CREATED/ENHANCED:

Managed Wetlands (within levees):

GOAL: Prepare specific enhancement and management plans and obtain funding for restoration and management on all lands already owned by public agencies or nonprofits before funding any additional retirement of privately-owned agricultural lands.

OPPORTUNITIES:

Yolo Bypass Wetlands:	3,600 ac /DFG
Sherman Island:	10,000 ac /DWR
Twitchell Island:	3,500 ac /DWR
Stone Lakes Wildlife Refuge:	1,090 ac /DPR
	1,000 ac /Sacramento County
[plus additional acquisition and management to complete the 9,000 ac refuge]	
Jepsen Prairie Preserve:	1,600 ac /Solano County Farmlands and Open Space Trust
Calhoun Cut:	970 ac /DFG
Tip of Grand Island:	250 ac /Corps of Engineers
Prospect Island:	1,200 ac /Bureau of Reclamation
North Delta Cross Channel:	100 ac /Bureau of Reclamation
Wright-Elmwood Mitgn.Bank:	80 ac /Private
Medford Island Mitign. Bank:	1,200 ac /Private

Enhancement of Existing Shallow Water Areas and Other Areas Outside Levees:

GOAL: Identify publicly-owned, water-covered sites and privately-owned, water-covered sites that could be enhanced and managed to provide improved shallow water habitat suitable for fish nursery areas. Identify other sites outside existing levees that could be enhanced for shallow water or other related habitats.

OPPORTUNITIES:

Big Break:	800 ac /EBRPD
Browns Island:	600 ac / EBRPD
Franks Tract:	3,500 ac /DPR
Little Franks Tract:	330 ac /DPR
Mildred Island:	1,000 ac /Private
Little Mandeville Island:	375 ac /Private
Venice Tip:	160 ac /Port of Stockton
Tip of Prospect:	300 ac /Port of Sacramento
Decker: North Tip:	40 ac /DFG
Decker: East Side:	140 ac /Port of Sacramento
Lower Sherman Island Wildlife Area:	3,100 ac /DFG

Delta Meadows:	134 ac /DPR
Little Holland Tract:	1,600 ac /Private
Kimball Island:	100 ac /Private
Rhode Island:	DFG
Fern Island:	80 ac/ Private
Little Hastings Tract:	125 ac/ Private
Port of Stockton Lands such as:	
Browns Island:	100 ac
Donlon Island:	225 ac
Mandeville Tip:	176 ac
Venice Cut	211 ac
North Headreach:	53 ac
Tule Island:	36 ac
North Spud:	28 ac
South Spud:	60 ac
Acker Island:	7 ac
Webb Tract Berms and Islands:	285 ac /DFG
Sycamore Island:	13 ac /DFG
Acker Island:	25 ac /DFG
Cabin Slough Islands:	15 ac /DFG
Miner Slough Islands:	34 ac /DFG
Lost Slough Islands:	38 ac /DFG

DESCRIPTION OF SITES SHOWN ON MAPS:

One map illustrates sites which are publicly owned, owned by a nonprofit entity, or which are subject to a conservation easement, which are currently managed for ecosystem values:

Yolo Bypass Wetlands Project, DFG and Yolo Basin Foundation
Various Duck Clubs in the Yolo Bypass with a Conservation Easement, Private
Jepsen Prairie Preserve, Solano County Farmlands and Open Space Foundation
Cosumnes Preserve, Nature Conservancy, Bureau of Reclamation and others
Stone Lakes Wildlife Refuge Lands Under Management, U.S. Fish and Wildlife Service
Lower Sherman Island Wildlife Management Area, DFG
Palm Tract/Portions Subject to Conservation Easement, Private
White Slough Wildlife Area, DFG/DWR
Medford Island/Portions included in Mitigation Bank, Private
Woodbridge Ecological Preserve, DFG/DWR
Kimball Island Mitigation Bank, Private
Wright Elmwood Mitigation Bank, Private

One map illustrates publicly owned lands **not** actively managed for ecosystem values:

- Calhoun Cut, DFG
- Port of Sacramento Lands
- Port of Stockton Lands
- Twitchell Island, DWR
- Sherman Island, DWR
- Tip of Grand Island, Corps
- Browns Island, EBRPD/SLC
- Big Break, EBRPD
- Franks Tract, DPR
- Little Franks Tract, DPR
- Lands in the East Delta, DWR

One map illustrates private lands with opportunity for enhancement and/or restoration:

- Lands in the Yolo Bypass already subject to flood easements
- Other lands subject to levee height restrictions
- Lands in the boundary of Stone Lakes Wildlife Refuge south of Lambert Road (management agreements)
- Water-covered Lands in the Meadows (east of Locke)
- Lands proposed by the owner for restoration/enhancement (Bouldin and portions of Holland)
- In-Channel Islands

ENHANCEMENT OF RIPARIAN CORRIDORS:

One of the key concepts of the ERPP is restoration and enhancement of Delta riparian corridors. This memo describes alternative concepts for enhancement of three key riparian corridors consistent with the need to maintain and enhance the flood control and water conveyance functions of the major tributaries to the Delta.

The CALFED program has identified the need for riparian habitat enhancement to improve migratory corridors for anadromous fish, such as salmon, and spawning habitat for those fish species that spawn in the Delta environment, such as Delta smelt. In addition, the riparian habitat corridors provide habitat for birds, mammals, insects, reptiles, amphibians, and indigenous plants.

Sacramento River Corridor Enhancement: Currently the Sacramento River corridor is bounded by large, project levees which are largely unvegetated.

The ERPP recommends enhancing riparian corridors along several smaller sloughs and waterways between the Sacramento River and the Deep Water Ship Channel to the west, including Steamboat, Miner, Oxford, and Elk Sloughs. Additional enhancement is proposed on the main channel of the Sacramento River from Sacramento to Rio Vista.

As an alternative, CALFED should consider possible enlargement and enhancement of a corridor west of the Deep Water Ship Channel, within the Yolo Bypass. Such a waterway could connect to the main stem of the Sacramento River at either or both the Sutter Weir or the Sacramento Weir. There is an existing channel, the Toe Drain, which lies west of the Ship Channel. The Toe Drain is largely unvegetated but lies within the Yolo Bypass, where the lands are already subject to a flood easement purchased by the federal government to provide additional flood protection to the City of Sacramento and the Delta area. While the Sacramento River can contain flows of about 150,000 cfs, the Yolo Bypass can contain about 450,000 cfs. Locating an enhanced riparian corridor within the Yolo Bypass would also address the identified issues of stranding of fish within the Yolo Bypass at the end of the flood season. Creation of an enlarged, excavated channel would enhance flood water carrying capacity of the Yolo Bypass, which would then allow introduction and maintenance of beneficial plant material into the floodway.

Mokelumne River Corridor Enhancement: Currently the Mokelumne River, downstream of the confluence with the Cosumnes River, is within non-project levees. Downstream of McCormack Williamson Tract, the Mokelumne River splits into the North Fork, which lies between Tyler and Staten Islands, and the South Fork, which lies between Staten Island and New Hope, Brack, Canal Ranch and Terminous. At the south end of Staten Island, the South Fork turns toward the west and rejoins the North Fork near the south end of Tyler Island, at the northwest end of Bouldin Island, and near the crossing of Highway 12. The South Fork has been the subject of several projects on Staten Island to recreate berms at the waterside toe of the levees. At the south end of Staten Island, several in-channel islands have been protected with riprap and bolstered with placement of earthen material. Along the North Fork on the shoreline of Tyler Island, a Category III funded project is being planned to protect existing riparian vegetation on the waterside berms and at the toe of the levees.

The CALFED program and the ERPP recommend use of the North Fork as a water conveyance channel, and the use of the South Fork as a riparian corridor, with enhancement of the adjacent waterways of Beaver, Hog, and Sycamore Sloughs, and with new setback levees and flooding of large tracts of existing farmed lands on New Hope, Brack, Canal Ranch and Terminous Tracts. The deeply subsided lands would be temporarily flooded during flood season and the upper elevation areas in New Hope, Brack, Canal Ranch and Terminous would be permanently flooded, thereby eliminating some of the most productive farmland in the Delta.

As an alternative, CALFED should consider enhancing the South Fork for water conveyance and flood control, in effect dividing the flow of the Mokelumne River between its North and South Forks. Both Forks should be examined for additional habitat opportunities as channel capabilities are increased by dredging and/or necessary levee setbacks. There are major constrictions in the upper reaches of the South Fork. Relieving those restrictions will present important opportunities for flood control and habitat enhancement.

The easternmost location of a water conveyance alignment will keep the maximum possible distance between the saline waters of the Bay (the principal source of bromides and other salts), and water to be exported for irrigation and for drinking water.

In order to optimize the quality of the water conveyed through the Mokelumne corridor, the conveyance alignment should continue south from Staten Island, passing to the east of Bouldin and Venice Islands.

The Mokelumne River corridor must serve multiple purposes: water conveyance through the Delta, flood control for Sacramento and San Joaquin Counties, and a riparian habitat corridor for aquatic and terrestrial species.

San Joaquin River Corridor: The San Joaquin River is channelized, with newly enhanced levees along urban development in the South Stockton area.

The ERPP recommends restoration of floodplain habitat along the lower San Joaquin River between Mossdale and Stockton with levee setbacks and an overflow basin, and improved riparian habitat along leveed sloughs. The ERPP includes installation of a barrier at the head of Old River to keep migratory fish in the mainstem of the San Joaquin River. The purposes of the enhancement of the San Joaquin River are joint benefits associated with flood water transport and enhancement of fisheries migration corridors.

Currently, south of Mossdale to the San Joaquin County boundary, the San Joaquin River provides multiple opportunities to enhance riparian vegetation. For most months of most years, flows in these reaches of the San Joaquin River do not exceed 3,000 cfs. The low-flow channel could be established generally near the west or left bank of the existing levee system which, once stabilized and bermed, could support nearly continuous areas of large riparian vegetation to shade the low flow channel. Oxbows and bends currently cut off from the river flows could be re-opened and maintained providing feeding and resting areas for aquatic species.
North of Mossdale to Stockton, the mainstem of the San Joaquin could continue to be enhanced for seasonal migratory fish passage through the release of pulse flows necessary to stimulate inland migration, and enhance seaward migration.

Enhancement of riparian vegetation corridors could proceed on two other waterways: Paradise Cut to Old River to Grant Line Canal to Old River, and Old River to Middle River to San Joaquin River. Paradise Cut is a flood control channel designed to carry 15,000 cfs, which has not been maintained. To improve Paradise Cut, the weir to Paradise Cut could be enlarged, the Cut could be enlarged by incorporating mitigation lands east of the Cut to be provided by the Gold Rush City project (900 acres) and by clearing and dredging the connection to Grant Line Canal. Grant Line Canal connects to Old River, a waterway with numerous in-channel islands suitable for management and enhancement. The result could be flood flow capacity enlarged to 20,000 cfs, and a riparian corridor suitable for avian and terrestrial species. Middle River leaves the main stem of the San Joaquin north of Stewart Tract, flows north between Union and Roberts Islands, and rejoins the San Joaquin River between Medford and Mandeville Islands. The portions of this waterway between Roberts and Union Islands should be cleared of brush to increase flood flow capacity and the levees should be improved to accommodate the planting of trees that will not adversely affect flood flows and will provide habitat for avian and terrestrial species.

WILDLIFE FRIENDLY FARMING PRACTICES PROGRAM:

In the 1993-94 period, a Crop Shift Demonstration Project was conducted on Rindge Tract. The Department of Fish and Game recommended certain measures to mitigate any impact to wildlife from the demonstration project. Most of those measures were implemented as a part of the demonstration project, and the results were monitored and positive results were reported.

Based on this positive demonstration project, many years of previous and subsequent experiences with post-harvest flooding of agricultural lands in the Delta, and intuition, a wildlife friendly agricultural practices program might be formulated and described as follows:

Objectives:

1. Extend availability of post-harvest flooded grain fields to cover full period of usage by migratory birds.

2. Enhance food value of post-harvest flooded grain fields by intentionally leaving more grain in the fields by either modifying harvest practices or intentionally not harvesting portions of the fields to be flooded.

3. Create fringe areas during important periods to enhance forage opportunities for certain species (e.g. Sandhill cranes, Swainsons hawks)

4. Extend availaibity of program across the Delta lands utilized by important migratory speicies to discourage over-concentration in one area.

5. Avoid interference with exisitng agricultural economy of the region.

Program:

1. Participation would be voluntary.

2. Include a combination of early-harvested and late-harvested small grain crops to increase time availability of post-harvest flooded habitat.

3. Participants would agree to leave small percentages (5 to 10%) of crop unharvested in small plots in participating fields distributed across area to be flooded.

4. Harvest specifications:

   A. Wheat/Barley stubble 12 inches or less in height and not disced prior to flooding.

   B. Corn stubble 24 inches or less in height (harvested portions can be single-disced prior to flooding.

5. Flooding specifications:

   A. Wheat/Barley flooded as soon as practicable after September 15th.

   B. Corn fields flooded as soon as practicable after harvest and left flooded until at least January 15th.

   C. Where practicable, some marginal area of flooded fields to be left dry or shallowly flooded for raptor, crane, and shorebird foraging during flood-up periods.

6. Compensation. Payment for additional costs incurred and revenues foregone would be based on a dual scale:

   A. A payment to the entity incurring the additional drainage cost would be made for additional drainage costs resulting from increased drainage caused by the program (estimated to be approximately $15.00 per flooded acre).

   B. An additional payment would be made to the farming entity for unharvested acreage based on the value of the unharvested crop less harvest, drying (if any), hauling, and other similar costs not otherwise incurred (estimated to be approximately $100/ton of crop not harvested, or $20 to $40 per acre for participating acreage, depending on percentage of crop not harvested).

Summary of ERPP Habitat Restoration Targets and Programmatic Actions for the Sacramento-San Joaquin Delta Ecological Zone.

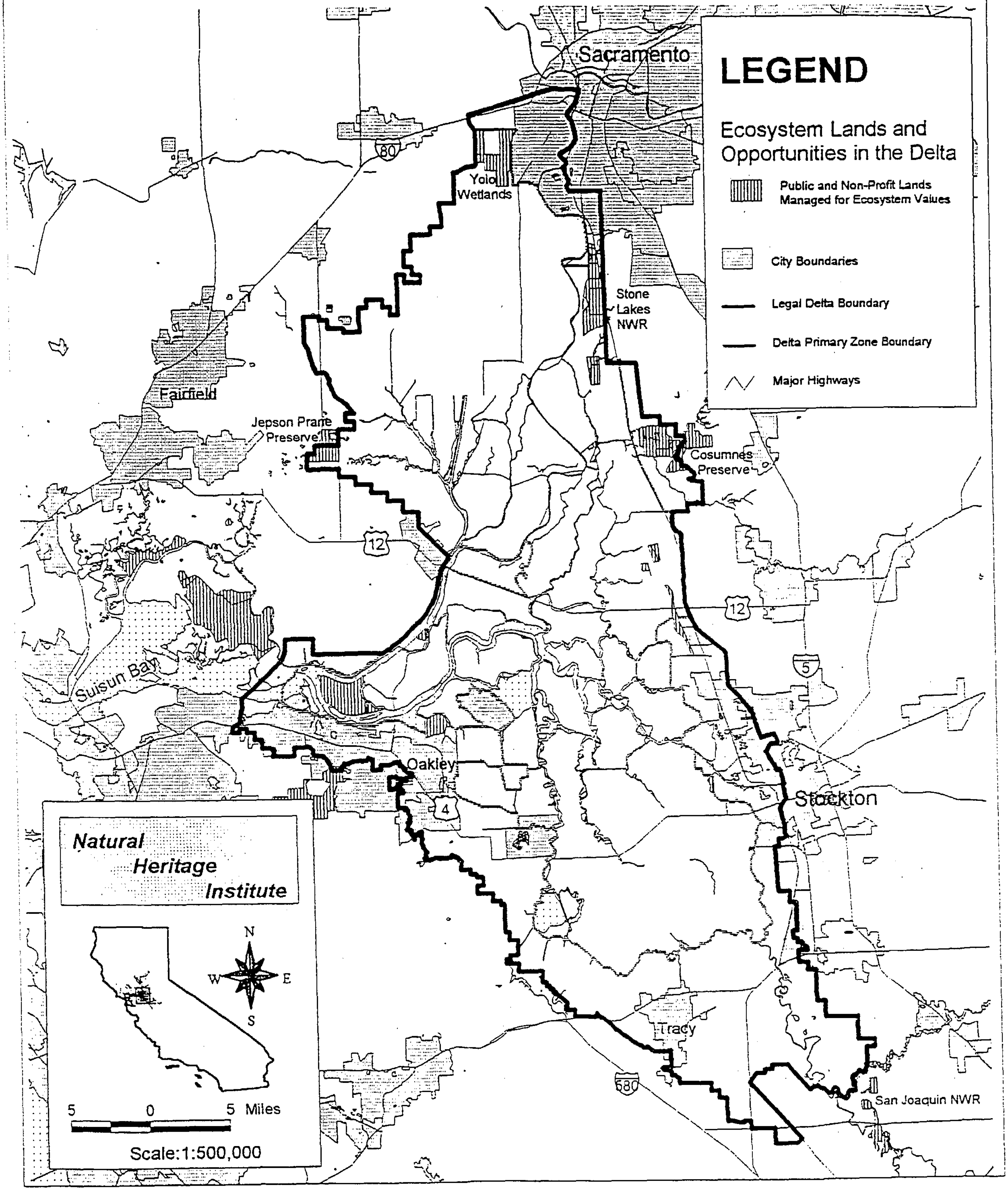
Habitat Type	North Delta Acreage	East Delta Acreage	South Delta Acreage	Central and West Delta Acreage	Total Acreage
Tidal Perennial Aquatic	1,500	1,000	2,000	2,500	7,000
Shoal	0	0	0	500	500*
Nontidal Perennial Aquatic (deep open water)	0	200	200	100	500
Nontidal Perennial Aquatic (shallow open water)	1,000	300	300	500	2,100
Midchannel Islands	50 to 200	50 to 200	50 to 200	50 to 200	200 to 800*
Fresh Emergent Wetland (tidal)	TBD [to be determined]	TBD	TBD	TBD	30,000 to 45,000
Fresh Emergent Wetland (nontidal)	3,000	3,000	4,000	10,000	20,000
Seasonal Wetland	Improve: 1,000 Restore: 4,000	1,000 6,000	500 12,000	1,500 8,000	4,000 30,000
Inland Dune Scrub	0	0	0	50 to 100	50 to 100*
Perennial Grassland	1,000	1,000	1,000 to 2,000	1,000 to 2,000	4,000 to 6,000
Wildlife Friendly Agricultural Land	TBD	TBD	TBD	TBD	40,000 to 75,000*
				Total acres	138,000 to 191,000

* Denotes acreages that have minimal impact to existing agricultural land uses and practices.

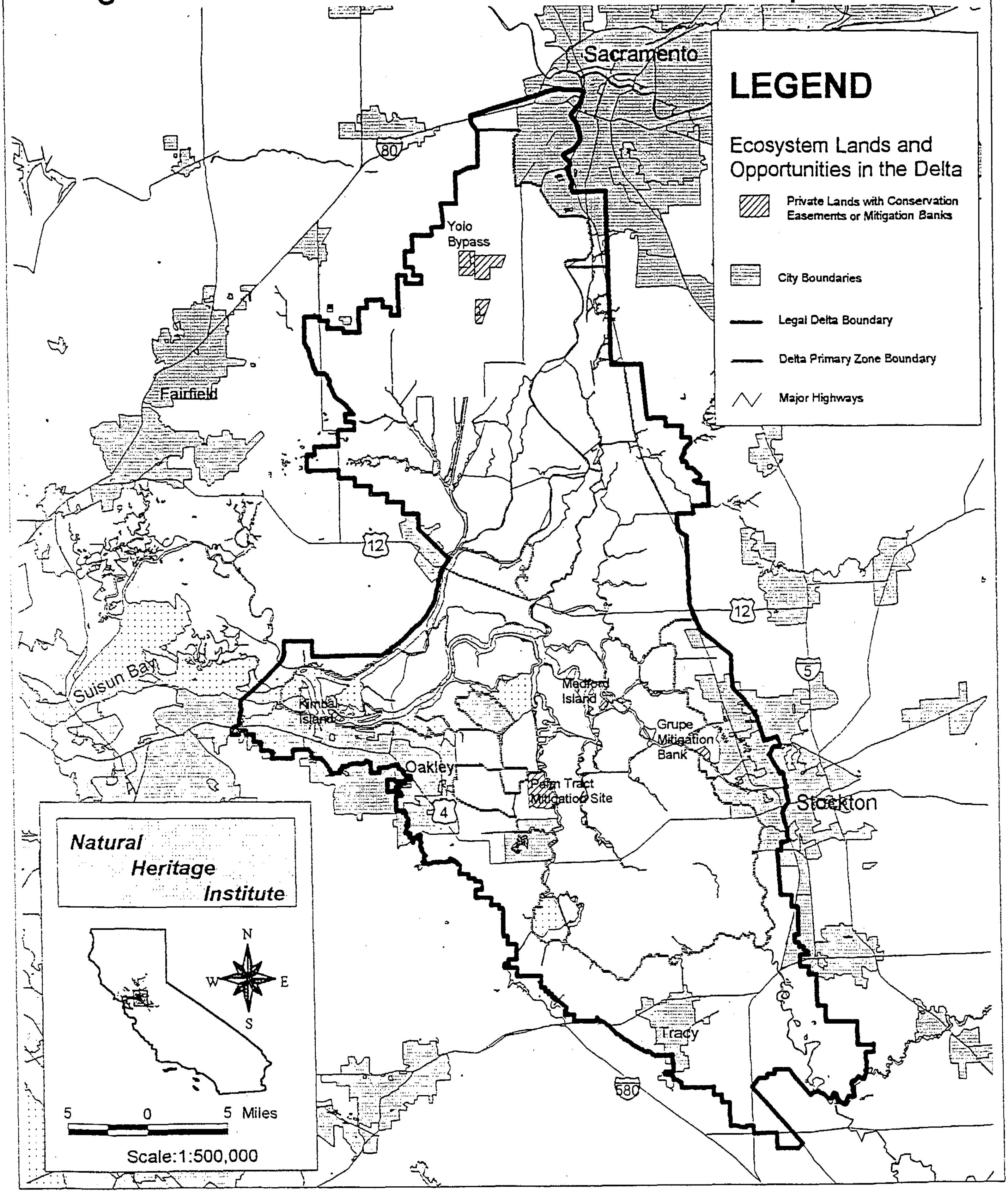
Note: Table does not include acreages for riparian and riverine aquatic habitat, Delta sloughs, levee reliability program, or conveyance facilities.

Exhibit 1

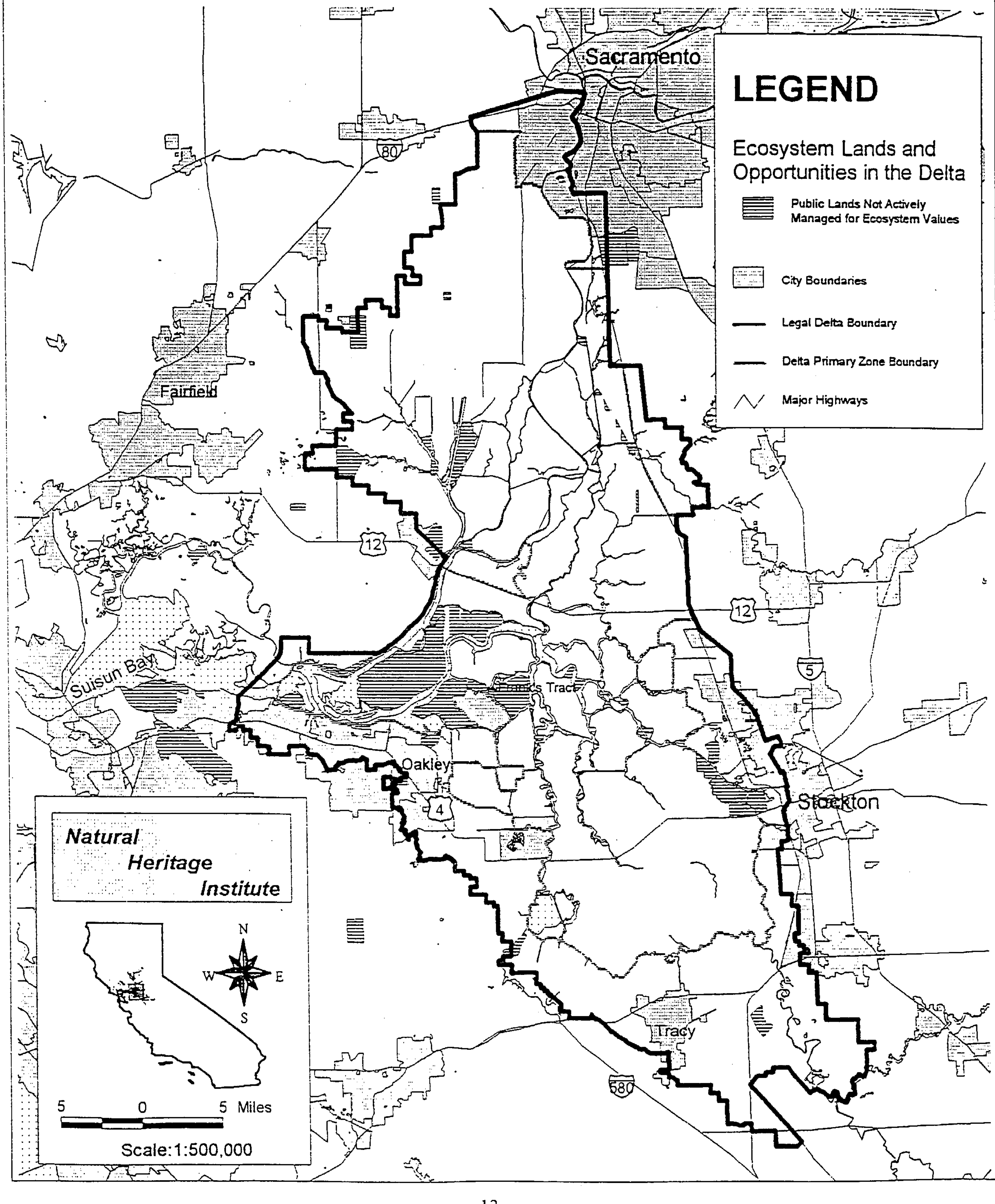
Public and Non-Profit Lands Managed for Ecosystem Values in the Sacramento-San Joaquin Delta



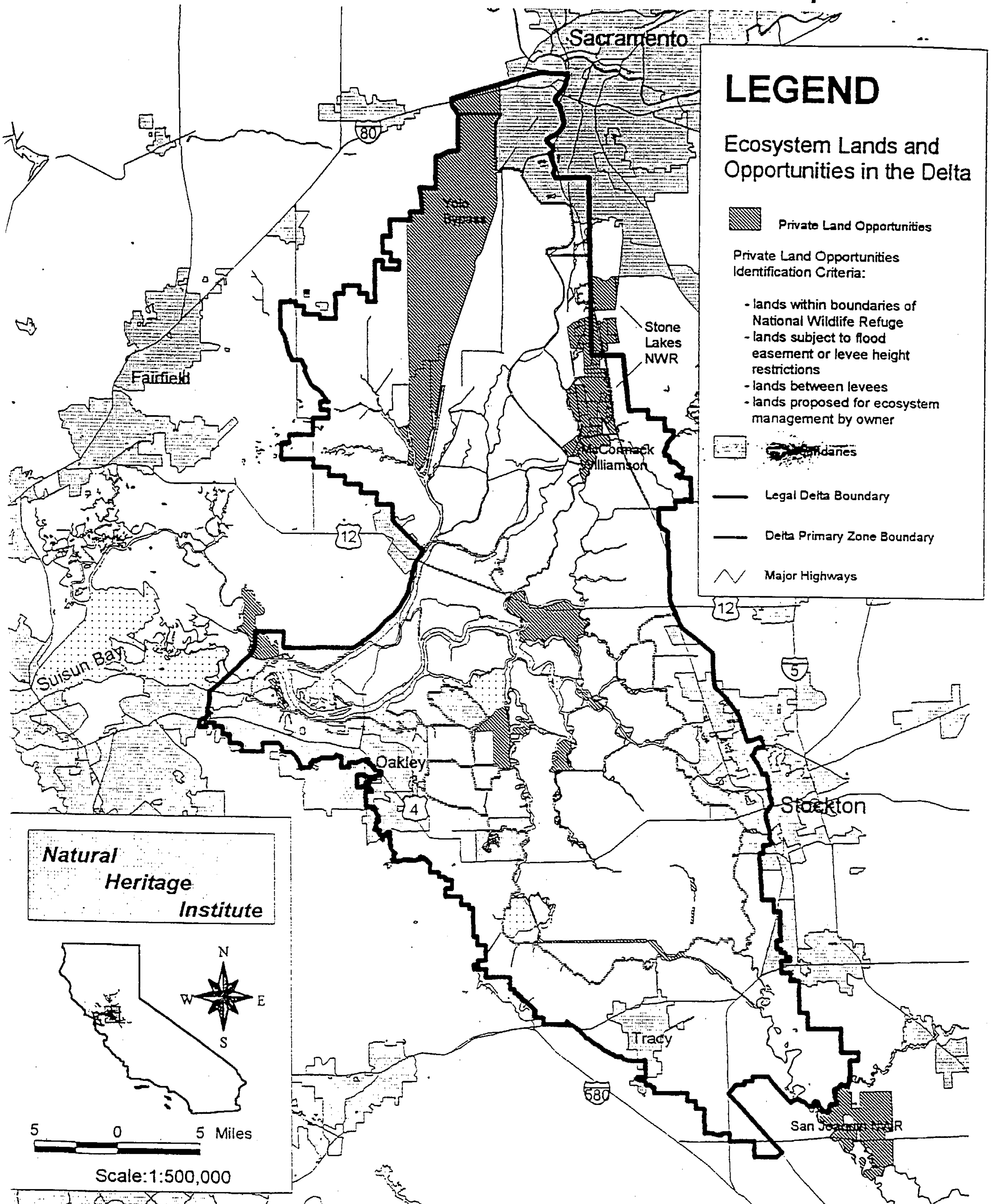
Private Lands with Conservation Easements or Mitigation Banks in the Sacramento-San Joaquin Delta



Public Lands Not Actively Managed for Ecosystem Values in the Sacramento-San Joaquin Delta



Opportunities for Ecosystem Protection and Restoration on Private Lands in the Sacramento-San Joaquin Delta



Ecosystem Management and Restoration Opportunities in the Sacramento-San Joaquin Delta