CALFED

TECHNICAL REPORT
AFFECTED ENVIRONMENT

FLOOD CONTROL

Including Flood Control Economics and Upper Watershed Flood Control

DRAFT

March 1998

CALFED
BAY-DELTA
PROGRAM

CALFED/1360

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LIST OF ACRONYMS

BDOC	Bay-Delta Oversight Council
CAC	county agricultural commissioner
CALFED	CALFED Bay-Delta Program
CDF	California Department of Forestry and Fire Protection
Center	State-Federal Flood Operations Center
Corps	U.S. Army Corps of Engineers
CFR	Code of Federal Regulations
CVP	Central Valley Project
DCC	Delta Cross Channel
DWR	California Department of Water Resources
EIR/EIS	environmental impact report/environmental impact statement
FEMA	Federal Emergency Management Act
HMP	Hazard Mitigation Plan
msl	mean sea level
Reclamation	U.S. Bureau of Reclamation
SRFCP	Sacramento River Flood Control Project
SWP	State Water Project

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FLOOD CONTROL

INTRODUCTION

This technical report describes the affected environment for flood control resources that could be affected by implementation of the CALFED Bay-Delta Program (CALFED). The level of detail included is highest for the Delta Region.

The following components of flood control are discussed:

- Flood control systems, including levees, reservoirs, weirs and bypasses;
- Flood control system operation;
- Flood control economics; and
- Upper watershed flood control.

Discussions of flood control economics focus on agriculture and levee repair in the Delta Region. Upper watershed flood control is described for the Sacramento River and San Joaquin River regions. Timber harvesting practices, grazing practices, and fire suppression activities in upper watersheds affect erosion in these areas. Accelerated erosion in upper watersheds increases the rate of reservoir sedimentation, reducing reservoir capacities available for flood control downstream.

Frequently used technical terms in this report are defined in a glossary in the Supplement.

SOURCES OF INFORMATION

Flood control information for the Delta and the basins that are tributary to the Delta was collected from reports prepared by DWR, the Bay-Delta Oversight Council (BDOC), the U.S. Army Corps of Engineers (Corps), and other public agencies and private firms. Information on the existing Delta flood control system was obtained primarily from BDOC's *Draft Briefing Paper on Delta Levee and Channel Management Issues* (1993) and DWR's 1993 *Sacramento-San Joaquin Delta Atlas.* Data on the risk of levee failure in the Delta were taken from the Corps 1982 Sacramento/San Joaquin Delta Draft Feasibility Report and Environmental Impact Report/Environmental Impact Statement (EIR/EIS) and from the 1993 Sacramento River Flood Control System Evaluation.

Other related studies that include information on the Delta flood control system were consulted, including the *Draft EIR/EIS for the North Delta Program* (DWR 1990a), *Draft EIR/EIS for the Interim South Delta Program* (DWR 1996a), Delta Levees Investigation (DWR 1982), and the *Draft EIR/EIS for the Delta Wetlands Project* (Jones & Stokes Associates 1995). A list of references used in preparing this report is included in the Reference section.

In addition to the sources above, discussions of flood control economics draw from other technical reports prepared for CALFED, including the Agricultural Resources and Urban Resources technical reports. The primary data sources for discussions of agricultural economics in the Agricultural Resources Technical Report were identified as County Agricultural Commissioner (CAC) reports, DWR Bulletin 160 reports, and the U.S. Burea of Commerce Census of Agriculture.

Additional information about flood control policy and economics was obtained from several sources, including the Final Report of the Governor's Flood Emergency Action Team, the California State Land Commission's *Delta Estuary California's Inland Coast*, and DWR's *California Flood Management: An Evaluation of Flood Damage Prevention Programs*. The Corps provided recent information through

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documents prepared for the Sacramento River Flood Control System Evaluation.

ENVIRONMENTAL SETTING

Regulatory Context

The flood control systems described in this report are governed by federal, state, and local agencies. Levee systems are referred to as federal project levees or local non-project levees. The San Joaquin River and Sacramento River Flood Control Projects, built by the Corps and turned over to the state for maintenance, provide flood control for the lower reaches of these rivers and into the Delta.

Project levees are associated primarily with conveying flood flows and maintaining the Sacramento Deep Water Ship Channel. The project levees work in conjunction with upstream reservoirs and bypass systems to protect adjacent lands against flooding, and to maintain flow velocities adequate to carry out sediments that might impede navigation. Project levees within the Delta are maintained to federal standards by the state or by local landowners under state supervision.

Non-project levees are levees constructed and maintained by local reclamation districts. Non-project levees constitute about 65% of levees in the Delta flood control system (DWR 1996c) Federal and state agencies have no jurisdiction over non-project levees and cannot require that they be maintained. However, future disaster claims could be denied if local reclamation districts do not follow federal and state requests or recommendations to upgrade or maintain levees. Maintaining non-project levees is largely financed by landowners, and the costs are shared with the state. Non-project levees often are maintained to widely ranging and less stringent standards than those applied to project levees.

If local reclamation districts are interested in maintenance cost sharing and disaster reimbursement, non-project levees are maintained, repaired, and upgraded according to the State's Flood Hazard Mitigation Plan (HMP) for the Delta. Upgrades and repairs are inspected by DWR, and the State Reclamation Board certifies those levees meeting HMP criteria. Certification qualifies these reclamation districts for maintenance cost reimbursement under the Delta Flood Protection Act of 1988 (California Water Code §§12310-12316; 12980-12993).

Since 1947, DWR has inspected and reported on the status and maintenance of flood control levees, channels, and other works operated under cooperative arrangements between federal, state, and local public entities. This work is part of the process of assurances given by the state to the federal government. These assurances state that certain flood control facilities constructed by the Corps for local flood protection will be continuously maintained and operated as necessary to obtain the maximum benefits, as stated in 33 Code of Federal Regulations (CFR) Part 208. DWR (under the authority of Water Code §§ 8360, 8370, and 8371) inspects the maintenance of the Sacramento River Flood Control Project (SRFCP) levees, as performed by the responsible agencies, and regularly reports to the Corps the status of levee maintenance accomplished under the provisions of 33 CFR 208.10. In addition to state inspections, the Corps also performs its own "spot" inspections each year as part of the continuing federal interest (DWR 1996b). These inspections at the state and federal levels indicate the ongoing government interest in the importance of levee system maintenance.

Additional detail on federal and state statutes, orders, and regulations affecting flood control is provided in Table S-1 in the Supplement to this technical report.

Flood management operations are coordinated by an integrated team of representatives from federal, state, and local agencies. For all phases of a flood event, the Flood Operations Center

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assumes responsibility for coordinating the repair and reinforcement of existing levees, constructing emergency levees, coordinating with media and law enforcement for public notification and evacuation as necessary, and identifying flood stages and areas forecasted to be flooded.

In general, reservoir water level management is governed by an approved flood control diagram. This diagram essentially defines the amount of space that should be available to store flood waters at various times of the year. Each reservoir has a unique flood control diagram that is based on the following criteria:

- Flood response characteristics of the basin,
- Agreements for the level of flood protection to be provided by the reservoir,
- Obligations for water conservation, and
- Requirements necessary to maintain environmental conditions in the downstream water courses.

Flood control projects in the upper watershed are typically small-scale projects under the jurisdiction of local agencies, often county flood control and water conservation districts or public works departments. County or flood district ordinances govern land use restrictions in flood-prone areas.

The federal Watershed Protection and Flood Prevention Act (Public Law 83-566) provides for federal coordination with, and assistance to, state and local agencies, in order to prevent erosion, flooding, and sediment damage in small watersheds of the rivers and streams of the U.S. Projects must fall within certain size limitations and provide benefits to rural and agricultural communities. The corresponding state regulations are contained in Chapter 4 of Division 5 of the State Water Code.

Reservoir owners are responsible for operating reservoirs safely, in compliance with state dam safety regulations in Division 3 of the State Water Code, administered by DWR's Division of Safety of Dams.

Timber harvesting practices are regulated on national forest lands by the U.S. Forest Service and are required on private forest lands by the California Forest Practice Rules.

The California Department of Forestry and Fire Protection (CDF) is responsible for fire protection in many parts of the upper watershed. Fire suppression is managed in keeping with the California Board of Forestry's California Fire Plan.

DELTA REGION

The Delta lies at the confluence of the Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras rivers. Together, these rivers channel more than 47% of the state's total annual runoff into the Delta (DWR 1993). This runoff can become high volumes of flood waters during storms.

Upper watershed areas basically encompass the entire drainage basin of the Sacramento and San Joaquin watersheds. Therefore, for the purposes of this report, the upper watershed areas for the Delta Region will be covered under the Sacramento River and San Joaquin River geographic regions, as described below.

HISTORICAL PERSPECTIVE

Until the 1850s, the Delta region was mostly a tidal marsh, part of an interconnected estuary system that included the Suisun Marsh and San Francisco Bay. During the flood season, the Delta became a great inland lake, and when the floodwaters receded, the network of sloughs and channels reappeared throughout the marsh. Early settlers avoided the Delta for two reasons. First, the attempts at levee construction were hampered by high costs and lack of mechanical equipment. Second, there were inadequate laws giving landowners clear title to wetlands and seasonally flooded lands. The discovery of gold at Sutter's Mill in the foothills of the Sierra Nevada resulted in a large inflow of people. The growing population increased the demand

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for food. Congress passed the "Arkansas Act" in 1850, which warranted title of wetlands and flooded lands to private ownership. The higher demand for food and clear ownership laws accelerated land reclamation in the Delta.

Land surveys were the first step in developing the Delta. The Delta channels were surveyed in 1841 and again in 1849 by the U.S. Navy. These surveys facilitated transportation and helped open the Delta and upstream communities to increased trade with the San Francisco Bay area. Already experiencing a population boom because of the Gold Rush, Delta and northern California communities expanded even more as travel to the area became easier and less expensive. (DWR 1994b.)

Table 1 shows a chronology by decade of the area reclaimed in the Delta. The total acreage reclaimed from 1860 to 1890 was 216,000 acres. This amount almost doubled over the next four decades. Reclamation of Delta lands was nearly completed by 1930; there was little or no additional land reclaimed between 1930 and 1960.

Historical records indicate agriculture and irrigation development in the study area began in the mid-1800s. Prior to the extensive levee system and water development facilities in the Delta, agriculture in the region consisted primarily of dryland farming or irrigated agriculture from artesian wells, groundwater pumping, and some creek canals. Reports indicate that the number of irrigated acres in the Sacramento Valley and San Joaquin River Basin regions were gradually increasing from the 1880s through the 1920s.

Development of the Delta began in late 1850 when the Federal Swamp Land Act conveyed ownership of all swamp and overflow land, including Delta marshes, from the federal government to the State of California. Proceeds from the state's sale of swampland were to go toward reclaiming them, primarily for conversion to agricultural land.

In 1861, the State Legislature created the Board of Swamp and Overflowed Land Commissioners to manage reclamation projects. In 1866, the board's authority was transferred to county boards of supervisors. The first reclamation projects began in 1869, when developers constructed 4-foot-high by 12-foot-wide levees on Sherman and Twitchell Islands using the peat soils of the Delta. Since then, levee construction has improved and expanded to 1,100 miles throughout the Delta to protect agricultural and urban lands against flooding (Figures 1a, 1b).

Shortly after the completion of the levees in 1913, the construction of a complicated series of human-made waterways and water development facilities began in the Delta. The purpose of constructed waterways was to provide navigation, improve water circulation, or to obtain material for levee construction. Water development facilities were constructed to ship water from the Delta to other parts of the State for agricultural, urban, and other uses.

Accounts of urban land development (urban acreage calculations) in California were not recorded and, therefore, are not readily available prior to 1920. In general, the San Francisco Bay and southern California geographic regions were developing into urban centers. Urban development in the Central Valley also began during this period, following construction of the railroads.

The history of the Delta was changed by the authorization of the CVP in 1933 and the SWP in 1960. These projects consisted of a series of additions and improvements to the water storage/water transfer/flood control systems in the Delta and its tributaries. Prior to the 1940s, flooding of reclaimed Delta lands was a frequent result of levee erosion and overtopping during high flow events. Since construction of the CVP and SWP, the frequency of levee failure due to

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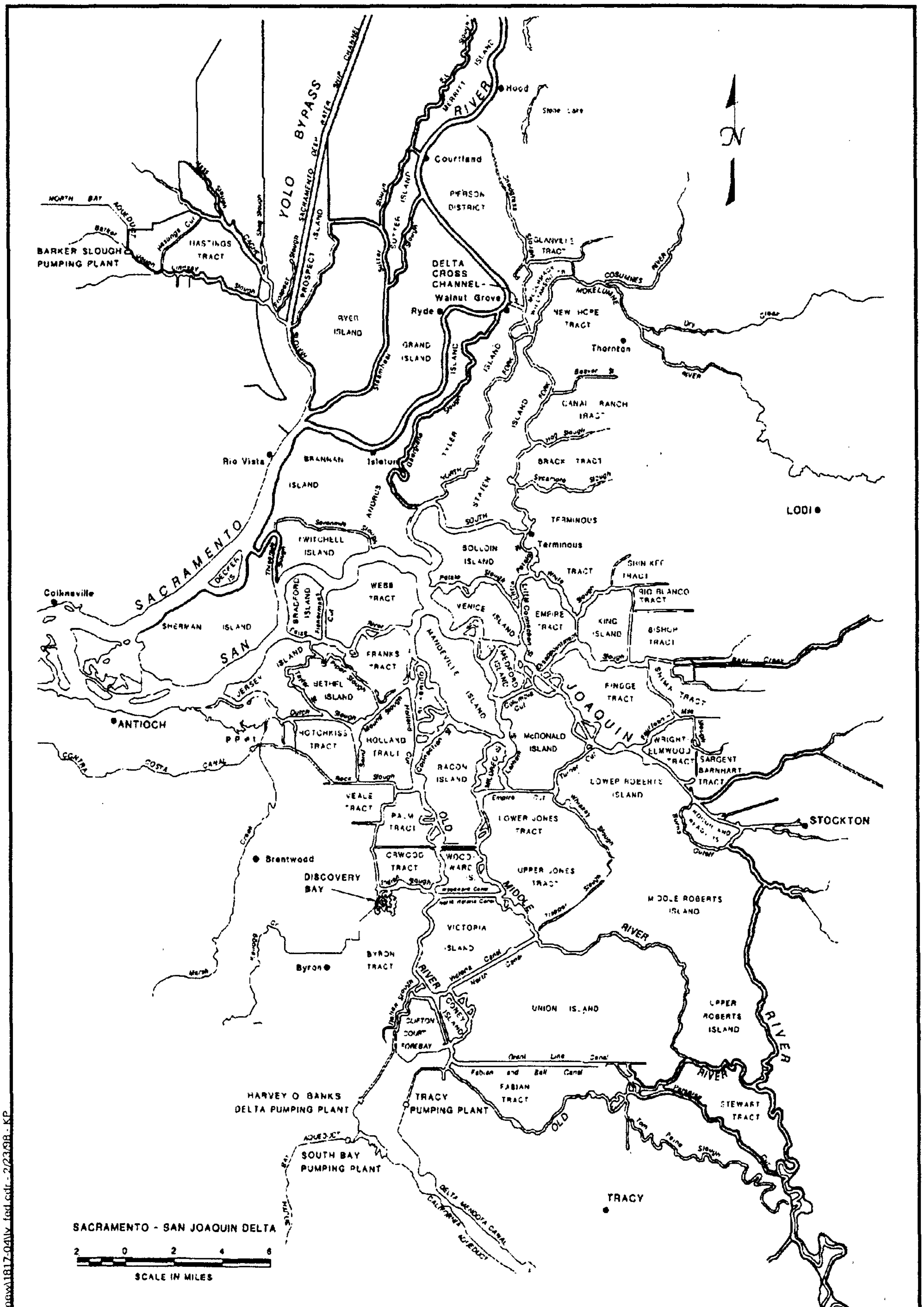

Figure 1a. Federal Flood Control Project Levees

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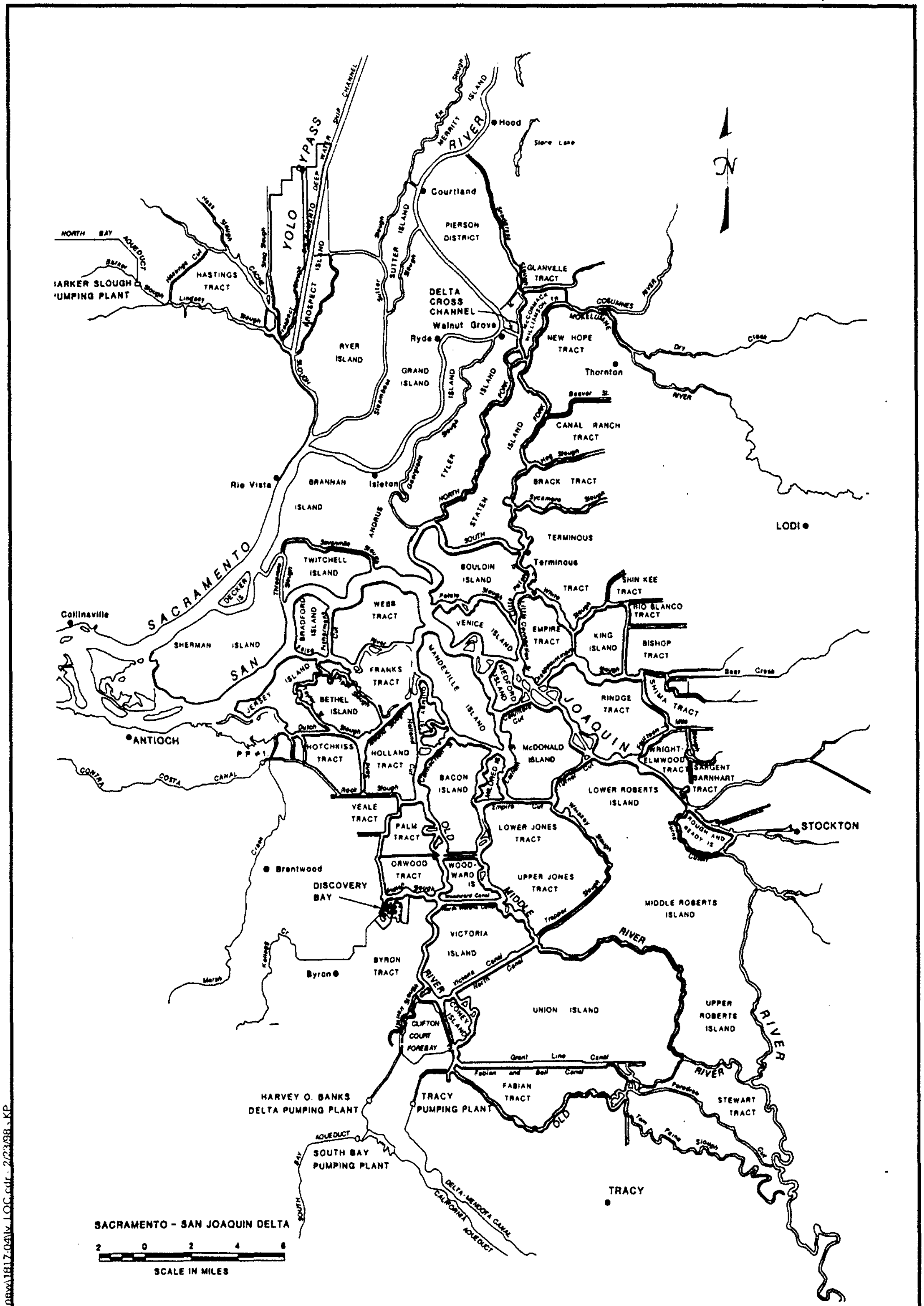

Figure 1b. Local Non-Project Levees in Delta

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Year	Acreage Reclaimed	Permanent Inundation	Accumulated Acreage
1860-1870	15		15
1870-1880	73		88
1880-1890	70		158
1890-1990	58		216
1900-1910	93		309
1910-1920	94		403
1920-1930	20	4[a]	419
1930-1940	0	3[b]	416
1940-1950	0		416
1950-1960	0		416

NOTES:
[a] Lower Sherman (1925) and Big Break (1927)
[b] Franks Tract (1938).

SOURCE:
Association of State Water Project Agencies 1976.

Table 1. Trends in Early Land Development in the Delta Region (1,000 acres)

overtopping has decreased. Delta levees still fail, but the most frequent cause is either high hydrostatic pressure, resulting in piping and stability failures, or overtopping due to high tides and high winds

Since reclamation, each of the 70 islands or tracts has flooded at least once (DWR 1993; Figure 2). Prior to the federal CVP in the 1940s, Delta flooding was characterized by the frequent inundation of vast tracts of land (Table 2). About 100 failures have occurred since the early 1900s (Corps 1982). Except for Big Break, Little Franks, Franks, and Little Holland tracts and Little Mandeville, Lower Sherman, and Mildred islands, flooded islands historically have been restored even when the cost of repairs exceeded the appraised value of the land. In contrast, Little Mandeville Island, which was flooded in summer 1995, may not be restored.

With the advent of the large state and federal water projects that allow more control over flood flows, flooding generally has been restricted to inundation of individual islands or tracts resulting from levee instability or overtopping. Since 1950, the construction of upstream dams has allowed dam and reservoir managers to detain flows. This management ability and control of flood waters has further reduced the threat of overtopping. Between 1950 and 1986, 60% of levee failures have been due to mass instability, such as subsidence and hydrostatic pressure, and 40% has been due to overtopping (DWR 1982). Table S-2 in the Supplement to this technical report lists historical inundations of Delta islands from 1900 through 1997.

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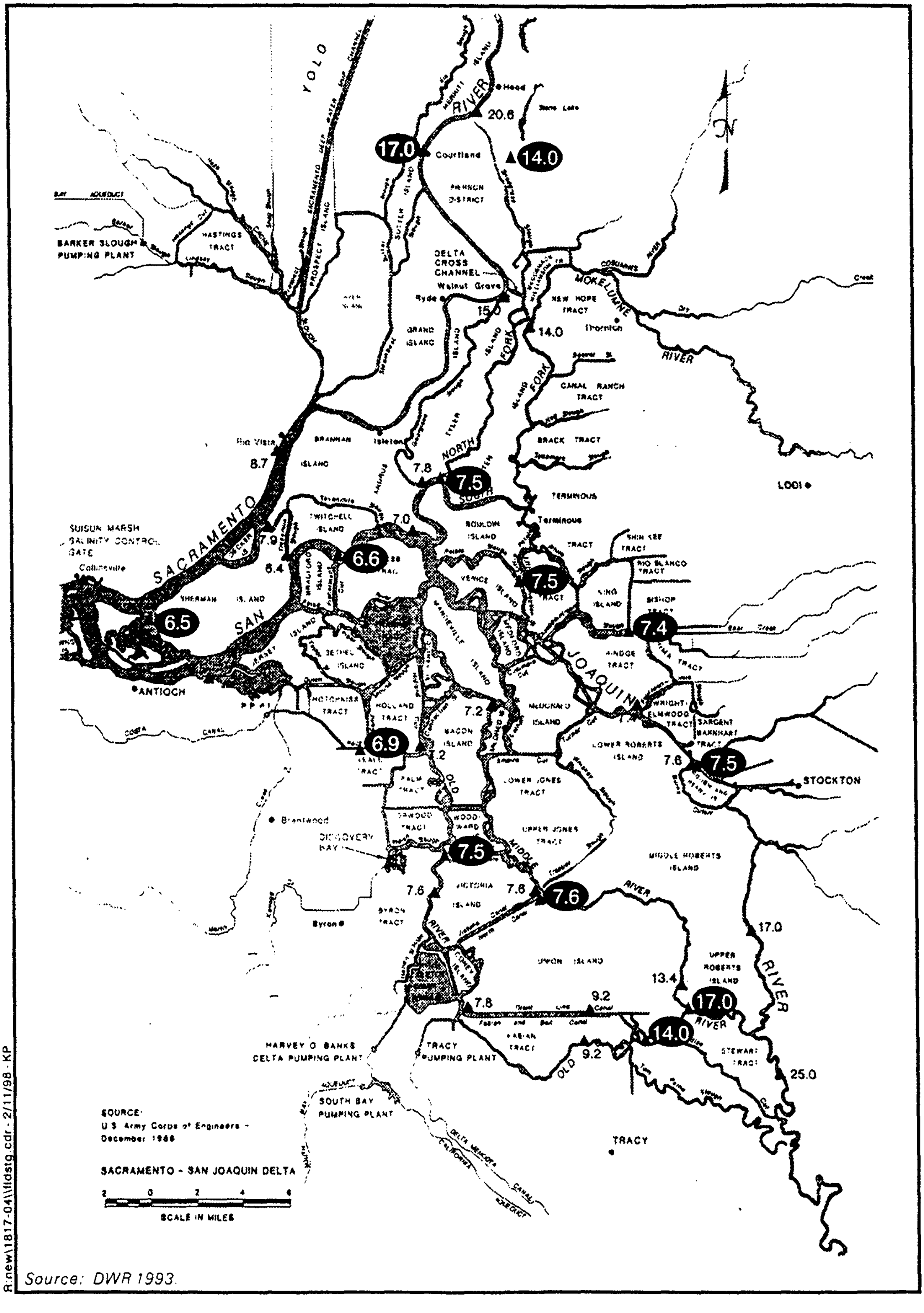

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Figure 2. 100-Year Flood Stage Elevations in the Sacramento - San Joaquin Delta

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Flood Control Economics

In the study area, the extensive levee system, constructed waterways (the Contra Costa Canal and Stockton Deep Water Channel), water development facilities, groundwater development, and railroads enabled irrigated agriculture and urban communities to extend deeper into the Delta. Between 1920 and 1950, irrigated agriculture development increased rapidly from 2.7 million acres to over 4.7 million acres for the entire Central Valley. During the same period, urban land use also expanded. Private water development projects by cities and utility districts assisted in the expansion of urban development throughout California.

The types of crops grown and their value have changed over time. Prior to the 1950s, early crops were grains, fruits, and vegetables that were marketed to nearby cities. Specialty crops, such as wheat, barley, beans, and potatoes, also were grown in the Delta Region. A greater variety of crops were planted in the Delta as they grew in popularity (for example, asparagus, sugar beets, tomatoes, and celery) (Delta Protection Commission 1995). Currently, the Delta region raises over 70 different types of grains, fruits, nuts, and vegetables (DWR 1993b).

Table 3 shows Delta crop-harvested acreage and gross production value in 1973. Among the three groups of crops, field crops had the largest share of total harvested acres (48%), followed by other crops (33%), and vegetables (19%). Of the field crops, corn represented the largest share, about 24%.

The total gross crop value was estimated at $240 million in 1973. Field crops and vegetables each produced about 35% of the total value; the remaining 30% was from other crops. Vegetables accounted for 20% of total harvested acres but produced 35% of the total crop value.

Year	Acres Inundated (1,000)
1900	12.9
1901	20.8
1902	14.7
1904	75.9
1906	63.1
1907	114.7
1908	12.4
1909	43.5
1911	9.2
1925	11.8
1926	3.4
1927	2.2
1928	8.9
1932	3.0
1936	5.1
1937	3.0
1938	19.0
1950	20.9
1955	11.5
1958	11.2
1969	10.9
1972	13.0
1980	15.7
1982	9.4

SOURCES:
Data for 1900 to 1958, Association of State Water Project Agencies 1976.

Data for 1969 to 1982, DWR 1984.

Table 2. Historical Floods in the Sacramento-San Joaquin Delta, 1900 to 1960

CURRENT RESOURCE CONDITIONS

The flood control facilities that protect the Delta Region include the following elements:

- Levees
- Delta Cross Channel Control (DCC) Gates
- Suisin Marsh Salinity Control Gates

An additional resource at work in the Delta

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	Harvested Acreage		Gross Crop Value	
	(1,000 Acres)	Percent	($1,000)	Percent
Field Crops				
Rice	2.0	0.4	1.2	0.5
Sugar Beets	34.0	6.2	17.0	7.1
Safflower	32.0	5.8	6.2	2.6
Corn	134.0	24.3	43.3	18.0
Milo	30.0	5.4	7.5	3.1
Other [a]	30.0	5.4	7.5	3.1
Total	**262.0**	**47.5**	**82.8**	**34.4**
Vegetables				
Asparagus	38.0	6.9	26.6	11.1
Tomatoes	53.0	9.6	42.9	17.9
Other [b]	17.0	3.1	14.5	6.0
Total	**108.0**	**19.6**	**84.0**	**34.9**
Other Crops				
Alfalfa	63.0	11.4	23.0	9.6
Irrigated Pasture	62.0	11.3	4.7	1.9
Grain	23.0	4.2	4.7	2.0
Orchard	33.0	6.0	41.3	17.2
Total	**181.0**	**32.8**	**73.6**	**30.6**
Total (all crops)	**551.0**	**100.0**	**240.4**	**100.0**

NOTES:

[a] Other field crops includes corn, milo, beans, seed crops, and sunflowers.
[b] Other vegetables include potatoes, and onions.

Source:
Association of State Water Project Agencies 1976.

Table 3. 1973 Harvested Acreage and Gross Production Value in the Sacramento-San Joaquin Delta

Region is the system of gates that protect the Suisun Marsh from salinity intrusion during low- flow periods. They also provide minimal incidental flood protection. Each of these elements is described in the following sections.

Levees

The Delta levee system initially served to control island flooding during periods of high flow. Because of island subsidence due to peat oxidation, however, it is now necessary for the levee system to prevent inundation during normal runoff and tidal cycles. About 1,111 miles of levees in the Delta provide flood

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protection to the 76 islands and tracts located there.

Recent flooding in the Delta occurred in 1986 on Dead Horse Island, McCormack-Williamson Tract, New Hope Tract, Prospect Island, and Tyler Island (1997 floods are not mentioned here because the study period is from 1910 to 1995). The major factors influencing Delta water stage included high flows, high tide, and wind. Historically, the highest water stages usually have occurred from December through February, when high runoff combines with high tides and wind-generated waves (BDOC 1993). Flood flow-carrying capacity of rivers and channels surrounding the Delta islands is influenced by sedimentation and channel characteristics. Delta 100-year flood stage elevations (DWR 1993a) generally range from 6.5 to 7.5 feet above mean sea level (msl) in the western and central Delta where the most tidal influence is present. However, the 100-year flood stage ranges from 14.0 to 17.0 feet above msl in the north Delta (near New Hope Tract and Courtland, respectively); and in the south Delta (near Stewart Tract on the Old and Middle River channels), where the streamflows become dominant during large floods. These flood stage ranges (6.5 to 17.0 feet above msl) emphasize the importance of maintaining levees to varying heights and strengths throughout the Delta to protect against flooding where channel geometry and flow conditions can cause rapid stage increases during storms.

The stability of a levee depends on the strength of its foundation materials and its internal strength. If used in the proper proportions and engineered correctly, sands, silts, and clays can be used to build stable levees. High percentages of sand or peat within or beneath a levee, however, can weaken its stability. East Delta levees generally are supported by foundation materials composed of clay, silt, and sand; while some central and western Delta levees primarily are resting on peat with some alluvial clay, bay mud, sand, and silt layers. While inorganic materials (sands, silts, and clays) provide adequate foundations, uncompressed peat is highly deformable and unstable (BDOC 1993).Levees can fail by three often interrelated mechanisms: overtopping, seepage and piping, and instability. Several other factors can damage levees and eventually lead to levee failure. These include erosion associated with deformation of soft soils (peat or highly organic) and settlement, seismic movements, rodent burrows, wind and wave action, dead or decaying roots from levee vegetation (living vegetation also can provide some protection against levee erosion by reducing wave and wind action), and subsidence. Subsidence of leveed Delta Islands has been measured at rates of up to 1 to 3 inches per year (SCS 1989), and some areas in the central and western Delta are more than 15 feet below sea level (DWR 1993a). Additional information on levee system integrity is found in the Supplement to this report. Levee design standards are defined in five general classifications based on levee dimensions, proof of structural stability, and a level of protection from 100-year or greater flood events. Levee design standards are discussed in greater detail in the Supplement to this report.

Delta Cross Channel Control Gates

Delta Cross Channel Control Gates are closed during high flows and floods on the Sacramento River. During floods, when stages on the Sacramento River exceed those on Mokelumne River channels, the gates prevent water from spilling out of the Sacramento River into the Mokelumne River and flooding leveed and non-leveed lands. If storms hit central California while the river stages are lower on the Sacramento River, the DCC gates can be opened to spill high flows out of the Mokelumne System and to reduce stages on the north and south forks of the Mokelumne. This transfers flood water from the non-project levees of the Mokelumne River to the Sacramento River, which is protected with project levees.

Suisun Marsh Salinity Control Gates

The Suisun Marsh Salinity Control Gates project was implemented in 1988. The gate system works primarily to protect the marsh from the saline waters of the Bay during periods of low Delta outflows. The Suisun Marsh Salinity Control Gates do not play a specific role in flood control but are part of the affected environment that should be considered during CALFED solution evaluation.

Yolo Bypass

The Yolo Bypass carries five-sixths of the volume of the Sacramento River at peak flood flows. The lower end of the bypass is in the Delta and provides significant spawning habitat for Delta smelt.

Flood Control System Operation

Unlike the system of reservoirs and weirs that control the magnitude of flooding on the rivers upstream of the Delta, the flood control system in the Delta (aside from the DCC Control Gates) operates passively. However, the levee system does require maintenance, monitoring, and improvement, particularly during floods, to maximize the level of protection provided by the levee system.

Flood Control Economics

Costs of maintaining and repairing the levee system in the Delta are substantial (DWR 1982, 1993_). In some instances, the expenditures exceeded the appraised value of the island or tract being protected. The average annual cost of levee maintenance on non-project levees in the Delta ranged from $3,000 to $165,000 per levee mile, averaging $11,800 per levee mile between 1981 and 1991. From 1981 to 1991, $63 million was spent to repair levees, $26 million of which was contributed by the state's levee subventions program.(DWR 1993a). Beginning in 1988, state cost-sharing authorization was increased to 75% of costs exceeding $1,000 per mile under the Delta Flood Protection Act of 1988. The Act provided $60 million over 10 years to control subsidence and rehabilitate levees on eight western Delta islands and an additional $60 million for Delta-wide levee maintenance and upgrades (DWR 1988).

Emergency expenditures by federal and state governments under the Federal Emergency Management Act (FEMA) and the Natural Disaster Assistance Act, respectively, from 1980 to 1986 was $137.3 million ($65 million FEMA, $26.5 million Natural Disaster Assistance Act, and $45.8 million by local sponsors). The cost per acre of island of these repairs ranged from less than $410 to $4,000. (DWR 1988). Additionally, the Corps has spent $120 million in 1997 under their PL 84-99 flood fight and rehabilitation authority.

Table 4 lists western Delta islands that flooded or had flood-related problems between 1900 and 1983. For example, the Andrus Island levee broke on June 21, 1972, resulting in the flooding of both Andrus and Brannan Islands. The direct cost to agriculture and property was estimated at $24 million. Although flooded islands can be drained by pumping the floodwater from the island after the levee is closed and reinforced, the cost can be substantial. According to DWR (1994) estimates, the total emergency cost resulting from levee failures was $97 million between 1980 and 1986. In addition, Delta levee maintenance program expenditures were estimated at $64 million between 1981 and 1991 (DWR 1993).

Land Subsidence and Flooding. Of the Delta lowlands, approximately 380,000 acres primarily consist of peat soil. During cultivation, the peat oxidizes into fine, light particles, easily eroded by wind and water, and resulting in land subsidence. Land subsidence is a serious problem for agricultural production in the delta because it jeopardizes the stability of

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Island	Years Flooded
Bethel	1907, 1908, 1909, 1911
Bradford	1950, 1983
Holland	1986
Jersey	1900, 1904, 1907, 1909
Sherman	1904, 1906, 1909, 1937, 1969
Twitchell	1906, 1907, 1909
Webb	1950, 1980

SOURCE:
DWR 1997.

Table 4. Flood Incidence on Western Islands in the Sacramento-San Joaquin Delta, 1900 to 1983

the levees, which, in turn, causes flooding. From 1950 to 1986, there were 15 stability-failure floods and eight overtopping floods in the region.

Developed Uses. Approximately 71,000 acres of the delta are developed for urban uses, with most of the development located on the periphery of the delta in Sacramento, San Joaquin, and Contra Costa counties. The majority of urban development is located in the legal Delta, with less than 1,800 acres of developed land in the Suisun Marsh and Bay area. Urban development includes residential, commercial, industrial, and other urban uses.

Much of the urban development in the study area is located in the incorporated cities (Antioch, Brentwood, Isleton, Pittsburg, Rio Vista, and Tracy are located entirely within the Delta and Sacramento, Stockton, and West Sacramento are located partially within the legal Delta), and the 14 unincorporated communities within the legal Delta (Discovery Bay, Oakley, Bethel, Courtland, Freeport, Hood, Ryde, Walnut Grove, Byron, Terminous, Thornton, Hastings Tract, and Clarksburg).

BAY REGION

HISTORICAL PERSPECTIVE

The land in the Bay Region historically has suffered little from Sacramento-San Joaquin River system flooding; however, extensive flooding has occurred in the Bay Area due to local runoff during intense rainstorms. The broad, deep channels and large bays downstream from the Suisun Marsh have not demonstrated significant variability in water level beyond that which occurs as a result of natural tidal fluctuations (except for sea level rise). Historical records indicate that sea level has been rising (DWR 1992). If the trend continues, rising sea level has the long-term potential to intensify flooding, worsen water quality, and complicate water management in the Delta.

Bay water is usually saline to brackish, making reclamation of the surrounding marsh lands unattractive for agricultural purposes. Improvements to control flooding therefore have been minimal and now are directed mainly toward ecological habitat creation and preservation.

CURRENT RESOURCE CONDITIONS

No significant flood control resources are at work in the Bay Region to control floods emanating from the Delta.

SACRAMENTO RIVER REGION

The Sacramento River Region is bounded by the Sierra Nevada Mountains on the east, the Coast Ranges on the west, the Cascade Range and Trinity Mountains on the north, and the Delta Region on the south. The Sacramento River is the principal river in the basin. Its major tributaries are the Pit and McCloud rivers, which join the Sacramento River from the north, and the Feather and American rivers, which join it from the east. Numerous minor tributary

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creeks flow from the east and west. The average runoff from the basin is second only to the North Coastal Basins and is estimated at 21,300,000 acre-feet per year (Corps 1979). The melting snowpack in the Sierra Nevada generally maintains streamflows up to midsummer. Although spring snowmelt can cause flooding on the Sacramento River, extreme flood events almost always are triggered by excessive rainfall.

HISTORICAL PERSPECTIVE

The bottomlands of the Sacramento River Region consisted of tule marshlands prior to the Gold Rush of the mid-19th century. Before the beginning of agricultural development in the Sacramento Valley, large portions of the valley were subject to periodic inundation by flood flows from the Sacramento River and its tributaries. The floodplains varied in width from 2 to 30 miles (Jones & Stokes Associates 1987).

Individual landowners began flood control system development in the mid-1800s when the Gold Rush increased demands for food. By 1884, many miles of levees had been completed, and some areas had formed flood protection districts. These first levees were constructed by hand and were demonstratively inadequate, based on the damage that occurred during high-flow periods (WET 1991).

This damage was accentuated by hydraulic mining in the mountains. The mining activities resulted in large volumes of silt, sand, and gravel being deposited into the rivers in the Sacramento Basin. These sediments were deposited in the channels and increased the flood stages associated with high-flow events by reducing channel capacity. Hydraulic mining activities essentially stopped in 1893.

In the upper watersheds of the Sacramento River Region fire has historically been the principal mechanism by which nutrients in forest material were recycled. However, since the late 1800s, the frequency of fires has been reduced in the upper watershed, with the effect that less frequent fires burn larger areas with higher intensity and greater environmental damage. Catastrophic wildfires produce more intensive and extensive changes in watershed conditions that any other form of disturbance. As a consequence of fire suppression and logging practices during the last century, the character of forests has changed dramatically, and there has been a large increase in dead wood fuels near the forest floor. Severe fires accelerate runoff from the watershed by reducing organic matter in soil and forming impervious soil layers.

Improper location and construction of roads and culverts may be the most significant cause of accelerated erosion in western montane forests (Kattelmann 1996).

Past grazing policies reportedly may have affected more land in the Sierra Nevada than any other management activity. Loss of streamside vegetation from grazing has promoted soil compaction and erosion. Removal of riparian vegetation by livestock in headwater valleys of the North Fork Feather River, for example, has led to rapid channel widening and massive sediment loads (Kattelman 1996).

Federal flood control activities were initiated in 1917 when Congress authorized the SRFCP. This project consisted of a comprehensive system of levees, overflow weirs, outfall gates, pumping plants, leveed bypass floodways, overbank floodway areas, enlarged and improved channels, and dredging in the lower reach of the Sacramento River. The effectiveness of the SRFCP was increased by the completion of multipurpose reservoirs that provide flood control storage. The reduction of the flood hazard has encouraged extensive development in the protected areas and has prevented billions of dollars in flood damage since project completion (Corps 1979).

Multipurpose reservoirs and a system of weirs and bypasses contribute to the flood control system in the Sacramento Basin by storing or diverting water during periods of high runoff, thereby reducing the ultimate load placed on the levee system during floods. These elements have been established by a variety of state- and federally funded projects.

CURRENT RESOURCE CONDITIONS

The flood control resources at work in the Sacramento River Region include levees, reservoirs, weirs and bypasses.

Rapid runoff due to poor timber and grazing practices, combined with increased urban development has increased the local flood hazard and exposure in some upper watershed areas. Accelerated erosion increases the rate of reservoir sedimentation, reducing reservoir capacities available for flood control downstream.

Levees

Stability issues affecting the project levees in the Sacramento River Region include settlement, erosion, and seepage. These issues are the same as those discussed for the Delta Region; additional detail may be found in the Supplement to this technical report.

Although non-project levees are present in the Sacramento River Region, these levees are not significant to the overall level of flood control protection at work in the basin.

SRFCP levees are characterized by variations in levee embankment and foundation soil conditions that frequently occur over short vertical and lateral distances. Results from geotechnical studies conducted by the Corps in 1992 indicated that the primary concern along the Sacramento River related to levee embankment integrity in the Upper Sacramento River area is the susceptibility of levee embankment and foundation soils to seepage and piping. For example, along the Colusa Basin Drain and Knights Landing Ridge Cut, levee stability is related to the type of material in the levee (such as fat clays, lean clays, and organic layers) and cross-section geometry. Historically, levee cracking due to wet-dry cycles followed by a flood have resulted in numerous slope failures, both on the landside and waterside. These slope failures generally are shallow—4 feet or less. Vegetation along the waterside bank of the Colusa Basin Drain is noted as having a stabilizing effect(Corps 1995).

Reservoirs

The following major reservoirs provide flood protection to the Sacramento River Region:

- Black Butte Reservoir,
- Camp Far West Reservoir,
- Union Valley Reservoir,
- Clear Lake,
- East Park Reservoir,
- Englebright Reservoir,
- French Meadows Reservoir,
- Berryessa Reservoir
- Folsom Lake,
- Lake Almanor,
- Lake Oroville,
- New Bullards Bar Reservoir,
- Rollins Reservoir,
- Shasta Lake,
- Stony Gorge Reservoir, and
- Whiskeytown Reservoir.

The reservoirs were constructed and are maintained by state, federal, and local agencies that cooperate in their funding, administration, operation, and maintenance.

Weirs and Bypasses

A system of weirs and bypasses was constructed by the Corps on the Sacramento River. The system includes three bypasses: the Butte Basin, Sutter Bypass, and Yolo Bypass. Moulton and Colusa weirs feed flood waters into Butte Basin Bypass, Tisdale Weir feeds into Sutter Bypass, and Fremont Weir feeds into Yolo Bypass.

The bypasses are large tracts of undeveloped or minimally developed land. Development within the bypasses typically is limited to agricultural

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activities that require minimal infrastructure. Water released to the Butte/Sutter/Yolo Bypass system flows south into the Delta, in effect creating a short-term storage system for the flood waters. Additionally, a significant volume of the water released to the bypass system infiltrates into the ground, recharging groundwater supplies—although this volume is small compared to the total volume of a flood.

Flood Control System Operation

When a flood occurs, reservoirs can restrain the high-volume flows and store water for later release back into the river. The system allows flood waters to be transported downstream in a controlled manner starting days before and continuing until weeks after a flood. By varying the amount of water kept in reservoirs during different times of the year, the system can be modified to maximize flood control capabilities during the early part of the flood season and to maximize water storage later as the flood risk abates. The water stored in the reservoirs can be used to maintain fisheries flows during dry periods and supply power to municipalities and industries.

When flooding occurs, the weir and bypass system diverts water to protect the levee system and frees flood storage capacity in the reservoirs. The weir system works by diverting flood waters in the leveed rivers into the bypasses.

By storing water in reservoirs and bypasses, the flood control system can minimize the peak flows that the river and levee system are required to handle. The levee system increases the magnitude of floods that the river system can handle without occupying the entire floodplain.

Upper Watershed Flood Control

Rapid runoff due to poor timber and grazing practices, combined with increased urban development has increased the local flood hazard and exposure in some areas of the upper watershed.

San Joaquin River Region

The major river system in the San Joaquin River Region is the San Joaquin River, and its major tributaries are the Stanislaus, Tuolumne, Kings, and Merced rivers. Despite extensive diversions, snowmelt from the Sierra Nevada and agricultural drain waters generally maintain some level of flow in the San Joaquin River and major tributaries throughout the summer—except near Gravelly Ford, where the river infiltrates the porous river bed. The Chowchilla and Fresno rivers are the largest of its minor tributaries, most of which are dry during summer. Average annual runoff from the San Joaquin River and its major tributaries is estimated at 6,000,000 acre-feet (Corps 1979). The Cosumnes River, Mokelumne River, Calaveras River, and Dry Creek also are part of the San Joaquin River Region. These rivers do not become tributaries to the San Joaquin River until they are within the Delta Region. In years of exceptionally heavy snowmelt, spill from the Tulare Lake Basin to the south flows northward into the San Joaquin River system.

Historical Perspective

Work on flood control projects in the San Joaquin River Region was begun early in the 20th century. Improvements have included the construction of levees and bypasses, maintenance or improvement of stream channels, and completion of a system of reservoirs. These projects have been completed primarily to provide flood control and to augment agricultural opportunities. Historical conditions for upper watershed flood control are similar to those discussed for the Sacramento River Region.

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CURRENT RESOURCE CONDITIONS

The flood control resources currently employed in the San Joaquin River Region include levees, reservoirs, weirs, and bypasses.

Levees

Stability issues affecting the project levees in the San Joaquin Basin include settlement, erosion, and seepage. These issues are discussed in greater detail in the Supplement to this technical report.

Although non-project levees are present in the San Joaquin River Region, they are not significant to the overall level of flood control at work in the basin.

Reconnaissance studies conducted by the Corps on levees on both banks of the San Joaquin River, from Friant Dam downstream to Old River, Mariposa Bypass, Eastside Bypass, and Chowchilla Bypass, indicated that materials used to construct levees on the San Joaquin River mainstem generally range from clay to silty sand (Corps 1993b). Evaluations of levee reaches ranged from "fair" to "acceptable and well-maintained" to "good" (Corps 1993b). Overall, the flood control project features were summarized as "adequate" (Corps 1993b). The primary problem is a lack of maintenance. Local bank protection is needed. Setback levees in some reaches may be needed in the future (Corps 1993a). Because the levees were inspected during relatively low summer water levels, seepage conditions could not be fully evaluated (Corps 1993b).

Reservoirs

Major reservoirs that protect the San Joaquin River Basin from floods include the following:

- Hensley Lake,
- Friant Reservoir,
- H. V. Eastman Lake,
- Terminus Reservoir,
- Millerton Lake,
- Success Reservoir,
- New Exchequer Reservoir,
- New Melones Lake,
- Pine Flat Lake, and
- Tuolumne River Reservoirs (Cherry Valley and New Don Pedro lakes).

These reservoirs were constructed and are maintained by a variety of state, federal, and local agencies that cooperate in their funding, administration, operation, and maintenance.

Weirs and Bypasses

A system of weirs and bypasses has been established on the San Joaquin River system. The system includes three bypasses (the Mariposa, Eastside, and Chowchilla bypasses) fed by weirs. The San Joaquin bypass system operates similarly to the Sacramento bypass system during flood events.

Flood Control System Operation

The levee and reservoir system in the San Joaquin River Basin is operated to control floods using the same methods as described for the Sacramento River Region. Historically, the San Joaquin Valley basin has been subject to floods occuring during late fall and winter months, primarily as a result of prolonged general rainstorms; and to floods occuring during spring and early summer months, primarily as a result of unseasonable and rapid melting of the winter snowpack in the Sierra Nevada (Corps 1993b).

Upper Watershed Flood Control

Rapid runoff from poor timber and grazing practices, combined with increased urban development, has increased the local flood hazard and exposure in some areas of the upper watershed in the San Joaquin River Region.

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SWP AND CVP SERVICE AREAS OUTSIDE THE CENTRAL VALLEY

No CALFED alternative would significantly affect flood control resources in SWP and CVP Service Areas Outside the Central Valley. If new storage or conveyance facilities are constructed, their operations would be integrated with current flood control operations criteria for existing facilities in these service areas. Nothing about these operations or integration suggest that they would affect levees outside the Central Valley.

The upper watersheds in the SWP and CVP Service Areas Outside the Central Valley are excluded from this report because no CALFED activities are proposed in these areas.

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