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SACRAMENTO RIVER FLOOD CONTROL PROJECT, CALIFORNIA
MID-VALLEY AREA, PHASE III

DESIGN MEMORANDUM
VOLUME I OF II

US Army Corps of Engineers

Sacramento District
South Pacific Division

August 1995

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1. Little Dell Lake, Salt Lake City Streams, Utah, Embankment Criteria and Performance Report, August 1994
2. Caliente Creek Stream Group Investigation California, Draft Feasibility Report, June 1987
3. Fanchier Creek Dam Fresno, California, Embankment Criteria and Performance Report, July 1994
4. Sacramento Metropolitan Area California: Final Feasibility Report and Final Environmental Impact Statement/Final Environmental Impact Report, February 1992
5. Geologic and Seismologic Investigation, Hidden and Buchanan Dams, Hensley Lake and Eastman Lake, Fresno and Chowchilla Rivers, California, December 1988
6. Sacramento River Flood Control Project, California, Mid-Valley Area, Phase III, Design Memorandum, Volumes 1 and 2, August 1995
7. Reconnaissance Report Yolo Bypass, California, March 1992
8. Provo and Vicinity, Utah, General Investigation Reconnaissance Report, April 1997
9. Sacramento-San Joaquin Delta, California, Draft Feasibility Report and Draft Environmental Impact Statement, October 1982

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SYLLABUS

The Sacramento District, Corps of Engineers, has been authorized to conduct a comprehensive analysis of the long-term integrity of the levee system for the Sacramento River Flood Control Project. The project was authorized by the Flood Control Act of March 1917 and modified by various Flood Control and/or River and Harbor Acts in May 1928, August 1937, and August 1941. Additional modifications on Sacramento River and tributaries were authorized by the Flood Control Acts of December 1944 and May 1950 and incorporated under Sacramento River and Major and Minor Tributaries. Although construction of the project was initiated in 1918, many of the levees were originally constructed by local interests prior to that time and subsequently modified and adopted as part of the project. The Reclamation Board has participated as the local sponsor of the project and is responsible for the operation and maintenance of project facilities.

This report is the third phase of the comprehensive analysis and evaluates about 240 miles of project levees along the Sacramento and Feather Rivers and their tributaries. The study area, north and west of the Sacramento Urban Area (first phase), covers portions of five counties: Placer, Solano, Sutter, Yolo, and Yuba.

Studies indicate that sections of the project levees are susceptible to seepage and stability problems and do not provide the design levels of flood protection. Potential problems are primarily the result of sandy soils within the levee embankment and foundation. About 20 miles of reconstruction work is required to meet project design requirements at an estimated cost of $43.9 million. Between 2,000 and 3,000 people reside landward of the levees that need repair. Damageable property in those areas is estimated at $170 million.

Only a portion of the total reconstruction work required is economically justified (benefit-to-cost ratio greater than one) based on current guidance regarding incremental analysis. The justified work includes reconstruction of the levees around R.D. 1500 and the Knights Landing, Verona, and Elkhorn areas and costs about $36.2 million.

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VOLUME II

CHAPTER 1 - INTRODUCTION

1.01. Purpose

The purpose of this Design Memorandum (DM) is to present the results of engineering studies and investigations prior to preparing plans and specifications for construction. This DM provides the basis for local interest and cost-sharing agreements; preparation of plans and specifications; acquisition of lands, easements, and rights-of-way; accomplishment of relocations; and operation and maintenance. The basis of design for the project is outlined, cost and benefit data are presented, and requirements of local cooperation are explained. This DM pertains exclusively to the Mid-Valley Area Levee Reconstruction, Phase III, of the Sacramento River Flood Control Project.

1.02. Authorization

The Energy and Water Development Appropriation Act, 1987 (Public Law 99-591) included funds under Operation and Maintenance, General Appropriation, Inspection of Completed Works, for evaluation of the flood control system for the Sacramento River and its tributaries. Both the House of Representatives and Senate versions of the Conference Report contain similar language.

The House of Representatives Report, 99-670, is quoted as follows:

> *Inspection of Completed Works*: Sacramento River Flood Control Project, California. - The Committee has included $600,000 for a comprehensive analysis of the long-term integrity of the flood control system for the Sacramento River and its tributaries in collaboration with the State of California. The Committee is aware that even before the recent flooding, regional flood control officials felt the need for a thorough survey of the system. While it did serve well in the floods and prevented billions of dollars

in damages, under stress it validated concerns that in many places remedial work is necessary as soon as possible, as may be enhanced levels of protection. The Corps is directed to report back to the Committee on protection enhancement requirements which it encounters in the review of the project.

The Senate's Report, 99-441, states:

Inspection of Completed Works, Sacramento River FloodControl Project, California. - The Committee is aware of the need for a comprehensive analysis of the integrity of the flood control system for the Sacramento River and its tributaries. Given the importance of this flood protection system, the Committee believes that such an analysis is warranted.

By letter dated 9 September 1986, Robert K. Dawson, the Assistant Secretary of the Army, Civil Works, informed the Director of the California Department of Water Resources that the Corps of Engineers had commenced a five-phase evaluation of the levee system for the Sacramento River Flood Control Project (System Evaluation).

The first two phases of the evaluation included the most heavily populated project areas, the Sacramento Urban Area and the Marysville/Yuba City Area. Construction of the first phase for the Sacramento Urban Area was completed in September 1993. The second phase, for the Marysville/Yuba City Area, is presently under construction.

The third phase, the subject of this Design Memorandum, concentrated on the Mid-Valley Area and included portions of the Yolo and Sutter Bypasses and levees on the Sacramento, Feather, and Bear Rivers not considered in the second-phase report, as well as project levees on Yankee Slough and Dry Creek (see Plates 1 and 2).

The fourth phase of the five-phase evaluation is for the Lower Sacramento, or Delta, Area. It includes project levees on the Sacramento River south of the Sacramento Urban Area (including West Sacramento). Levees west and north of Sacramento along Cache Creek, Willow Slough Bypass, and Putah Creek were transferred from the third phase into the fourth phase at the request of The Reclamation Board. The fifth phase will focus on the Upper Valley area from Knights Landing on the Sacramento River north, including tributaries such as Elder and Butte Creeks.

1.03. Project Scope

There are about 1,000 miles of levees in the Sacramento River Flood Control Project (SRFCP). The Sacramento River Flood Control System Evaluation is a five-phase study examining the integrity of the levees within the SRFCP. Each phase is being studied separately. This DM presents information for the Mid-Valley Area, the third phase. About 240 miles of project levees along the Sacramento, Feather, and Bear Rivers and their tributaries were studied.

The engineering studies and investigations for this DM were conducted to evaluate the integrity of and level of flood protection provided by the existing Sacramento River Flood Control Project levees, to determine whether the levees currently function as designed, and to determine the type and extent of reconstruction work required. The existing levee embankments of the Sacramento River Flood Control Project were constructed based on (1) a design discharge or channel capacity, (2) a design water surface profile, and (3) a minimum freeboard requirement above the design water-surface profile (as authorized by the Flood Control Act of 1917). The objective of the System Evaluation was to develop reconstruction plans such that the project levees could safely pass the design flow (according to existing Corps criteria and guidance) at the design water surface. For this reason, geotechnical considerations were a major component of this evaluation. Borings of the levees were made and material samples taken and tested for physical properties, including gradation, Atterberg limits, moisture content, unconfined compression, and consolidated-undrained shear strength. Engineering analyses of the material properties and levee geometry were conducted. The results of those analyses indicated that about 20 miles of the 240 miles of levees evaluated are structurally deficient and cannot be depended upon as flood control structures. (Levee height restoration is not included in the total.) Reconstruction of the levees or other methods for stabilizing the levees in these areas is necessary to ensure that the channels can safely carry their design flows.

1.04. History of the Sacramento River Flood Control Project

A short history of the Sacramento River Flood Control Project is contained in the Initial Appraisal Report, Sacramento Urban Area, dated May 1988. Additional pertinent information is contained in the report by Frank Kochis, 1969. The project is described, in general, in the following section.

1.05. Study Area Description

a. Study Location. - The study area, located in Placer, Solano, Sutter, Yolo, and Yuba Counties, includes about 238 miles of Sacramento River Flood Control Project levees along the Sacramento and Feather Rivers and their tributaries. Locations of project levees are shown on Plate 2. Specific levees considered include the following:

(1) Western Pacific Intercept Canal. - About 4.2 miles of the east levee from the confluence with the Bear River to the upstream project limit, which includes about 2.0 miles of levee along Best Slough. Levee heights range from 5 to 15 feet above the landside ground surface; crown widths are about 12 feet.

(2) Dry Creek. - About 1.0 mile of the north levee from the confluence with Bear River to the upstream project limit and about 9.7 miles of the south levee from the confluence with Bear River to the upstream project limit. Levee heights range from 5 to 15 feet above the landside ground surface; crown widths range from 15 to 20 feet.

(3) Yankee Slough. - About 7.8 miles of levee along both banks from the confluence with the Bear River to the upstream project limits. Levee heights range from 5 to 15 feet above the landside ground surface; crown widths range from 15 to 25 feet.

(4) Bear River. - About 9.9 miles of the north levee, which includes about 1.0 mile of levee between the Western Pacific Intercept Canal and the confluence with Dry Creek and about 8.9 miles of levee from the confluence with the south levee of Dry Creek to the upstream project limit, and about 12.6 miles of the south levee from the confluence with

the Feather River to the upstream project limit. Levee heights range from 5 to 30 feet above the landside ground surface. Crown widths are from 12 to 20 feet.

(5) Tisdale Bypass. - About 4.5 miles of the south levee from the confluence with the Sacramento River downstream to the confluence with Sutter Bypass. Levee heights range from 15 to 25 feet above the landside ground surface. Most of the levee crest is greater than 20 feet wide because, in recent years, sediment removed from the bypass has been placed on the landside levee slope for disposal. An irrigation ditch about 25 feet wide is located near the landside levee embankment toe.

(6) Sutter Bypass. - About 20.8 miles of the west levee from the confluence with Tisdale Bypass downstream to the confluence with the Sacramento River. Levee heights range from 20 to 35 feet above the landside ground surface. Crown widths are from 15 to 20 feet. Ditches are located along both the waterside and landside levee embankment toes.

(7) Feather River. - About 12.3 miles of the east levee from the confluence with the Bear River downstream to the confluence of the Feather and Sacramento Rivers. Levee heights range from 15 to 25 feet above the landside ground surface. Crown widths are from 25 to 35 feet.

(8) Natomas Cross Canal. - About 5.4 miles of the north levee from the confluence with the Coon Creek Group Interceptor Canal downstream to the confluence with the Sacramento River. Levee heights range from 20 to 30 feet above the landside ground surface; crown widths are 20 feet and greater.

(9) Coon Creek Group Interceptor. - About 4.8 miles of levee from the confluence with the Natomas Cross Canal to the upstream project limit. Levee heights range from 10 to 20 feet above the landside ground surface. Crown widths are from 15 to 20 feet.

(10) Sacramento River. - About 34.7 miles of the east levee from the confluence with Tisdale Bypass downstream to the confluence with the Natomas Cross Canal and about 24.1 miles of the west levee from the confluence with Knights Landing Ridge Cut

(Colusa Basin Drainage Canal) downstream to the confluence with the Sacramento Bypass. Levee heights range from 12 to 20 feet above the landside ground surface. Crown widths are from 15 to 45 feet.

(11) Knights Landing Ridge Cut. - About 13 miles of levee along both banks from the confluence with Yolo Bypass to the upstream project limits. Levee heights range from 10 to 20 feet above the landside ground surface; crown widths range from 15 to 45 feet. (These levees and channel are being studied in greater detail under the Colusa Basin separable element of the Sacramento River Flood Control Project.)

(12) Sacramento Bypass. - About 1.8 miles of the north levee from the confluence with the Sacramento River downstream to the confluence with Yolo Bypass. The levee is generally 20 feet above the landside ground surface; crown widths are greater than 20 feet.

(13) Yolo Bypass. - About 12.3 miles of the east levee from the confluence with the Sacramento River downstream to the confluence with the Sacramento Bypass and about 15.4 miles of the west levee from the confluence with the Sacramento River downstream to the confluence with Putah Creek (excluding that segment of levee bordering the Cache Creek settling basin). Levee heights range from 15 to 25 feet above the landside ground surface. Crown widths are from 15 to 35 feet.

b. Area Description. - The study area is located in the Central Valley of California, along the Sacramento and Feather Rivers. The area includes portions of the Sutter and Yolo Bypasses and portions of Bear River; Yankee Slough; Dry, Cache, and Putah Creeks; Knights Landing Ridge Cut; and the Natomas Cross Canal.

Climate in this area of the California Central Valley is semi-arid, with warm, dry summers and moderate winters. Rainfall averages about 18 inches annually, generally between November and March.

The study area is within the Sacramento Valley Air Basin. The topographic boundaries of the basin contribute to accumulation of air pollutants, particularly oxidants from motor vehicles and suspended particulates from the agriculture and lumber industries.

Overall, water quality of the Sacramento River is good; however, water quality at specific sites may vary due to the effects of variations in streamflow and the quantity of local waste discharges and irrigation return flows.

Agriculture dominates land use in the Mid-Valley Area. Orchard, row crops, and grain are cultivated landward of the project levees. Portions of both the Yolo and Sutter Bypasses are within the Mid-Valley Area. The bypasses convey overflow from the Sacramento River during the flood season and are farmed during the non-flood season. A portion of the Sutter Bypass is also designated as a National Wildlife Refuge.

The Sacramento and Feather Rivers provide important habitat for both anadromous and resident fish species. Anadromous fish such as striped bass, steelhead trout, American Shad, and four races of chinook salmon use the rivers for both spawning or rearing habitat. In addition, white sturgeon are present in the Feather River. In the Sacramento River, the fall-run chinook salmon, the most abundant of the four runs, accounts for about 80 percent of the stock. The winter-run chinook salmon has declined dramatically since 1969 and is currently listed as a threatened species at the Federal level and an endangered species at the State level.

Resident fish in the Sacramento River include catfish, black bass, largemouth bass, black crappie, warmouth, Sacramento squawfish and Sacramento Sucker. Resident species in the Feather River include smallmouth bass, largemouth bass, white and channel catfish, and greensunfish.

The same fish present in the Sacramento and Feather Rivers are also found in the Yolo and Sutter Bypasses when the rivers overflow into the bypasses.

Generally, wildlife depends upon the type of habitat available for food, cover, and nesting. Riparian vegetation is generally found waterward of project levees and supports species such as the red-shouldered hawk and wood duck. Annual grasses and forbs found on levee slopes typically support the California ground squirrel, mourning dove, and gopher snake. Agricultural fields found landward of the project levees provide foraging habitat for raptor species.

The bald eagle and the American peregrine falcon, two species on the Federal endangered species list, may be in the study area, according to the U.S. Fish and Wildlife Service. Federal listed threatened species include the winter-run chinook salmon and the valley elderberry longhorn beetle. The ferruginous hawk, Sacramento splittail, California tiger salamander, California red-legged frog, giant garter snake, Sacramento Valley tiger beetle, and Sacramento anthicid beetle are on the Federal list of candidate species and may be found in the study area.

The State of California lists the Swainson's hawk, western yellow-billed cuckoo, bank swallow, and giant garter snake as threatened and Mason's lilaeopsis as rare; these may also be in the study area.

The Federal list of endangered plant species includes the palmate-bracted bird's beak, which may be present in the study area. Plants that are candidates for Federal listing are the Suisun aster, heart-scale, California hibiscus, delta tule-pea, Mason's lilaeopsis, little mousetail, and Colusa grass.

No sites in the study area are listed in the National Register of Historic Places. Records of California State University, Chico, and Sonoma State University show that five cultural resources surveys have been conducted in the area and that one archeological site has been identified in an area of potential reconstruction. As part of the current study, an intensive archeological field survey was conducted, but no historic or additional prehistoric sites were identified. The known site will be tested for National Register eligibility in future phases of the investigation.

1.06. Local Participation

For this investigation, the State of California, in cooperation with the Corps of Engineers, provided February 1986 high water mark information, surveyed levee crown profiles, surveyed levee embankment cross sections, and completed a report identifying past problem areas (due to high flood stages) of the levees.

1.07. Local Cooperation

By letter dated April 5, 1990 (Attachment A), The Reclamation Board, State of California, has indicated intent to be the local sponsor for the project works of the Mid-Valley Area, Phase III of the Sacramento River Flood Control System Evaluation. The Board will be responsible for fulfilling the non-Federal obligations required by the project works and will coordinate all activities, including cost sharing, with the responsible local entities (see letter dated April 10, 1990, Attachment A). The Board also stated that the extent of the project works will be at least partially determined by the ability of local interests to fund their share of the work. The local cooperation requirements for this project will include the following provisions:

a. Pay 5 percent cash of the cost of the project assigned to flood control during construction of the project. Such costs will include, but not be limited to, all engineering and design costs; engineering and design during construction; actual construction costs; supervision and administration costs; costs to settle and award contract disputes; and the value of lands, easements, rights-of-way, and suitable borrow and disposal areas provided for the project by The Reclamation Board. Any costs for betterments, operation, maintenance, repair, replacement, or rehabilitation will not be included.

b. Provide all lands, easements, rights-of-way, relocations, and excavated material disposal areas (LERRD) required for flood control and fish and wildlife mitigation. The necessary lands, easements, and rights-of-way may be provided incrementally, but all lands, easements, and rights-of-way determined by the Corps to be necessary for work to be performed under a construction contract must be furnished prior to the advertisement of the construction contract. The Reclamation Board will comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17); and the Uniform Regulations contained in 49 CFR Part 24 in acquiring lands, easements, and rights-of-way for construction and subsequent operation and maintenance of the project. The Board will also inform all affected persons of applicable benefits, policies, and procedures in connection with said Act.

c. Perform operations, maintenance, replacement, rehabilitation, and repair (OMRR&R) for the flood control facilities after completion in accordance with regulations or directions prescribed by the Secretary of the Army. The Corps will provide revisions to the existing operation and maintenance manual(s) to The Reclamation Board.

d. Hold and save the United States free from damages due to the construction and OMRR&R of the flood control features of the project, not including damages due to the fault or negligence of the United States or its contractors.

e. Publicize flood plain information in the area concerned and provide this information to zoning and other regulatory agencies for their guidance and leadership in preventing unwise future development in the flood plain. Adopt regulations as may be necessary to ensure compatibility between future development and protection levels provided by the project.

f. At least annually inform affected interests regarding the limitations of the protection afforded by the project.

1.08. Project Cooperation Agreement

Construction will not be undertaken until satisfactory assurances, in the form of a formal Project Cooperation Agreement (PCA), are in hand covering all required cooperation, including cost sharing by the local sponsor for the project. All lands, easements, or rights-of-way owned by the local sponsor as of the date of the first construction contract will be credited at the fair market value. The PCA must be a binding, enforceable contract as required pursuant to Section 221 of the River and Harbor Act of 1970 and Section 103(j) of WRDA 1986. A PCA must be executed between the local sponsor and the Office of the Assistant Secretary of the Army (Civil Works) prior to real estate acquisition.

1.09. Coordination

The plan presented in this DM has been coordinated with the following agencies: U.S. Fish and Wildlife Service, National Marine Fisheries Service, California Reclamation Board, California Department of Water Resources, California Department of Fish and Game, Yuba County, Sutter County, and Butte County. Coordination with local, State, and Federal agencies will continue throughout the design and construction phases of the project.

1.10. Hazardous and Toxic Waste Sites

Potential borrow sites needed to provide the necessary material for levee reconstruction have been identified in Sutter and Yolo Counties. Sites in Sutter County are located (1) in Reclamation District (R.D.) 1500 south of the community of Robbins, (2) within the Sutter Bypass just upstream from the confluence with the Sacramento River, and (3) in the vicinity of the East Side Canal. Sites in Yolo County are located (1) in the Yolo Bypass just upstream from Fremont Weir and (2) within the Cache Creek Settling Basin.

By letter dated June 21, 1990 (see Appendix A), the California Regional Water Quality Control Board—Central Valley Region advised the Sacramento District, Corps of Engineers, that no known hazardous or toxic waste sites are present in the vicinity of the borrow areas. Furthermore, no facilities are currently permitted by the Board to discharge waste near the areas of concern.

Engineers, that no known hazardous or toxic waste sites are present in the vicinity of the borrow areas. Furthermore, no facilities are currently permitted by the Board to discharge waste near the areas of concern.

CHAPTER 2 - FLOOD PROBLEMS

2.01 Flood Problems

The study area, north and west of the Sacramento Urban Area, covers portions of five counties: Placer (population 147,200), Solano (312,800), Sutter (62,600), Yolo (133,000), and Yuba (57,300); population statistics are estimates from the Rand McNally 1990 Commercial Atlas and Marketing Guide. Davis and Woodland, two of the largest cities within the study area, have populations of 52,237 and 36,500, respectively. Smaller communities include East Nicolaus (225), Nicolaus (100), and Robbins (400) in Sutter County, as well as rural communities such as Karnak, Kirkville, and Verona, for which no population statistics are available. In Yolo County, Knights Landing has a population of 846 and Yolo 650. Wheatland, in Yuba County, has a population of 1,474. (Population statistics for the cities are from the California Department of Finance, Population of California Cities, January 1989.)

2.02 Historic Flooding

The study area has experienced frequent floods during the past, many occurring before streamflow data were recorded. Prior to completion of Oroville Dam, large floods caused levee failures and resulted in severe damages to lands in the flood plain. In addition, devastating floods in 1950, 1955, and 1964 caused loss of life and property damage in the study area.

The flood of 1955 was the most widespread and destructive of any in the recorded history of northern California since the legendary floods of the 1800's.

On December 23, 1955, the east levee of Feather River about 1 mile downstream from Nicolaus failed, and about 24,600 acres were flooded in R.D. 1001. The towns of Nicolaus and East Nicolaus were partially flooded. Two people reportedly lost their lives as a direct result of the flooding, and about 1,000 people had to be evacuated from the area. In addition, the west levee of the Western Pacific Intercept Canal was breached in three places. Two breaches in the north levee of Yankee Slough resulted in flooding to several hundred acres of highly developed orchard land, also in R.D. 1001. In all, 37,000 acres of highly productive farm and ranch lands were inundated, and large numbers of livestock drowned. Roads, railroads, and bridges, and public, commercial, and industrial properties were also flooded and damaged. Flood damage in the area downstream from Marysville was estimated at more than $34 million.

In 1958, high flows on the Sacramento River caused flooding in the Sutter and Yolo Bypasses. For more than 2 months, about 57,000 acres were flooded to depths estimated at 6 to 12 feet. The main agricultural damages were loss of crops, costs of releveling land, repair of farm roads, costs of repair and replacement of fences, repair of pumps and other irrigation facilities, repair of private levees, and the costs of removing debris.

The storm of December 1964 had the greatest flood-producing potential of any storm on record at that time. Widespread damages were primarily in areas not protected by project works. Sutter and Yolo Bypasses were flooded. Downstream levees on Feather River and tributary levees on Bear and Yuba Rivers confined the floodflows and limited damages to the cost of repairing the levees and the loss of various improvements within the levees. On the Bear River system, flood damage occurred along Yankee Slough and on the streams tributary to the Western Pacific Intercept Canal.

2.03. Floods of 1982-83

The winter of 1982-83 has been described as California's wettest winter in more than a century and resulted in a disastrous year of flooding. Of California's 58 counties, 45 were declared national disaster areas, including the five in the Mid-Valley study area (Placer, Solano, Sutter, Yolo, and Yuba).

In Yolo County, a major storm during the latter part of January 1983 brought flood stages to Cache Creek. Early on the morning of January 24, the south levee of Cache Creek, a Sacramento River Flood Control Project levee, failed about 2 miles east of

Woodland, north of Highway 5. Following the break, twelve flood fighters were stranded for a few hours between the break site and the stub end of the levee system before rescue by a California Highway Patrol helicopter. About 600 acres of farmland was flooded as a result of the levee break, and another 30 acres were inundated when a hole was punched into the north levee to relieve pressure on gradually deteriorating levees. Upstream from the break, local emergency officials, volunteers, and DWR crews formed a protective sandbag barrier around portions of the town of Yolo.

The town of Knights Landing was threatened when water backed up in the Knights Landing Ridge Cut (a bypass channel parallel to the Sacramento River from Knights Landing to the Yolo Bypass). Volunteers constructed sandbag barriers which were successful in keeping water out of the town. Nevertheless, overflowing local sloughs caused several homes in the Knights Landing area to be flooded.

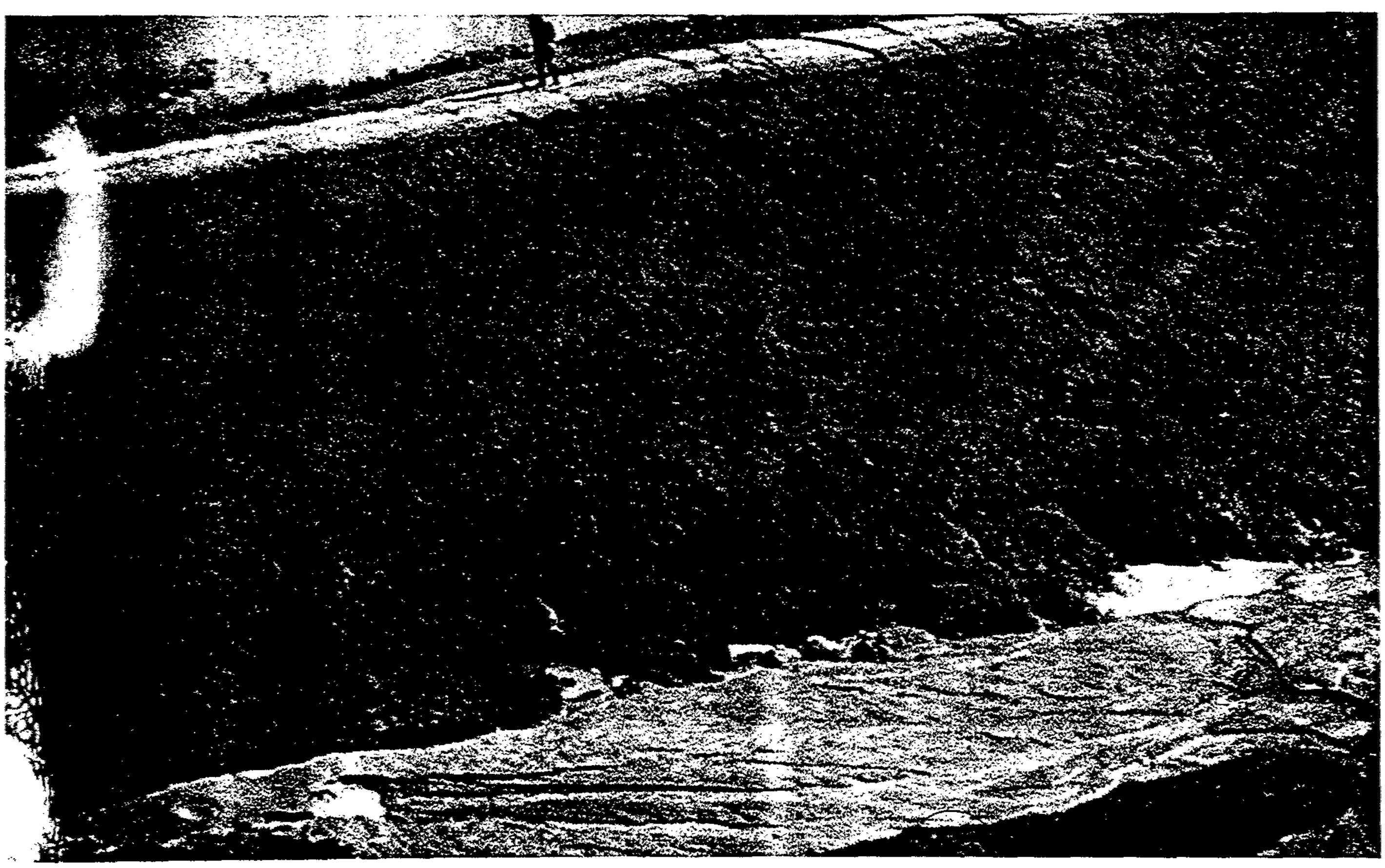
With the continuing high runoff, several portions of the Yolo Bypass levees began to slip, including a 500-foot section on the east levee upstream from Highway 80. The Corps constructed a landside berm along the damaged section to prevent further slippage.

In Sutter County, thousands of acres of fruit trees were inundated during the 16 days of March rain. Near Robbins, a landside section of levee slipped vertically 2 feet, and prompt action by Reclamation District officials and State flood fighters prevented its loss. The slippage site and other vulnerable sites were monitored for several weeks.

2.04. Floods of February 1986

Major storms in February 1986 resulted in floods of record for many parts of northern and central California. Record flow releases from reservoirs impacted downstream levee systems, eroded levee embankments, and exceeded flood control project design levels.

At 8:00 a.m. on February 22, levee patrols of Sutter County's R.D. 1500 discovered a 500-foot-long slump, up to 4 feet deep, on the west levee of the Sutter Bypass near Robbins (see Figure 1). High flows in the bypass had caused boils and



LEVEE EMBANKMENT SLUMP ON WEST LEVEE SUTTER BYPASS
DURING FEBRUARY 1986 FLOOD.

FIGURE 1

extensive piping damage. The Robbins fire chief ordered the community of nearly 400 residents evacuated at 8:15 a.m., and evacuation was completed within an hour. Emergency flood fight efforts by the Corps of Engineers (see Figure 2) reinforced the sagging levee and probably prevented a levee break. To stabilize the levee and prevent total failure, sand and gravel were dumped on the waterside slope, creating a waterside berm about 50 feet wide and 300 feet long. Cost of the flood fight was about $290,000. Complete levee failure was averted, but extensive damages resulted, including slumping of the levee crown, landside slope cracking, and large holes at the landside levee toe.

In May 1986, Wahler Associates prepared a report indicating that the levee was constructed mainly of clayey soils with occasional layers of clean or silty sand and that damage to the levee was the result of piping due to the sustained high water and the presence of nearly continuous layers of highly pervious and erodible sands and silts within the levee embankment and foundation.

Subsequently, a construction contract was awarded in September 1986 to repair the levee, at a cost of $460,000, including erosion repairs to three other smaller sites. The repairs included excavation, blending the clean sand with less pervious silt and clay materials, and recompacting a 600-foot-long section of levee. In the most extensively damaged portion of the levee, excavation extended 20 feet below the original ground surface. In addition to the onsite materials, embankment fill was obtained from a borrow site about 2 miles west of the repair site. Stone protection was also used, and stabilized aggregate base material was used for the levee crown surface. Work was completed in December 1986.

2.05. Historic Levee Embankment Problem Areas

To determine past problem areas, Department of Water Resources (DWR) personnel interviewed individuals responsible for maintaining the levees within the study area. DWR personnel also accompanied knowledgeable individuals from the maintaining agencies on levee inspections to locate and identify areas of concern. Particular emphasis was given to

EMERGENCY FLOOD FIGHT EFFORTS ON WEST LEVEE SUTTER BYPASS DURING FEBRUARY 1986 FLOOD.

FIGURE 2

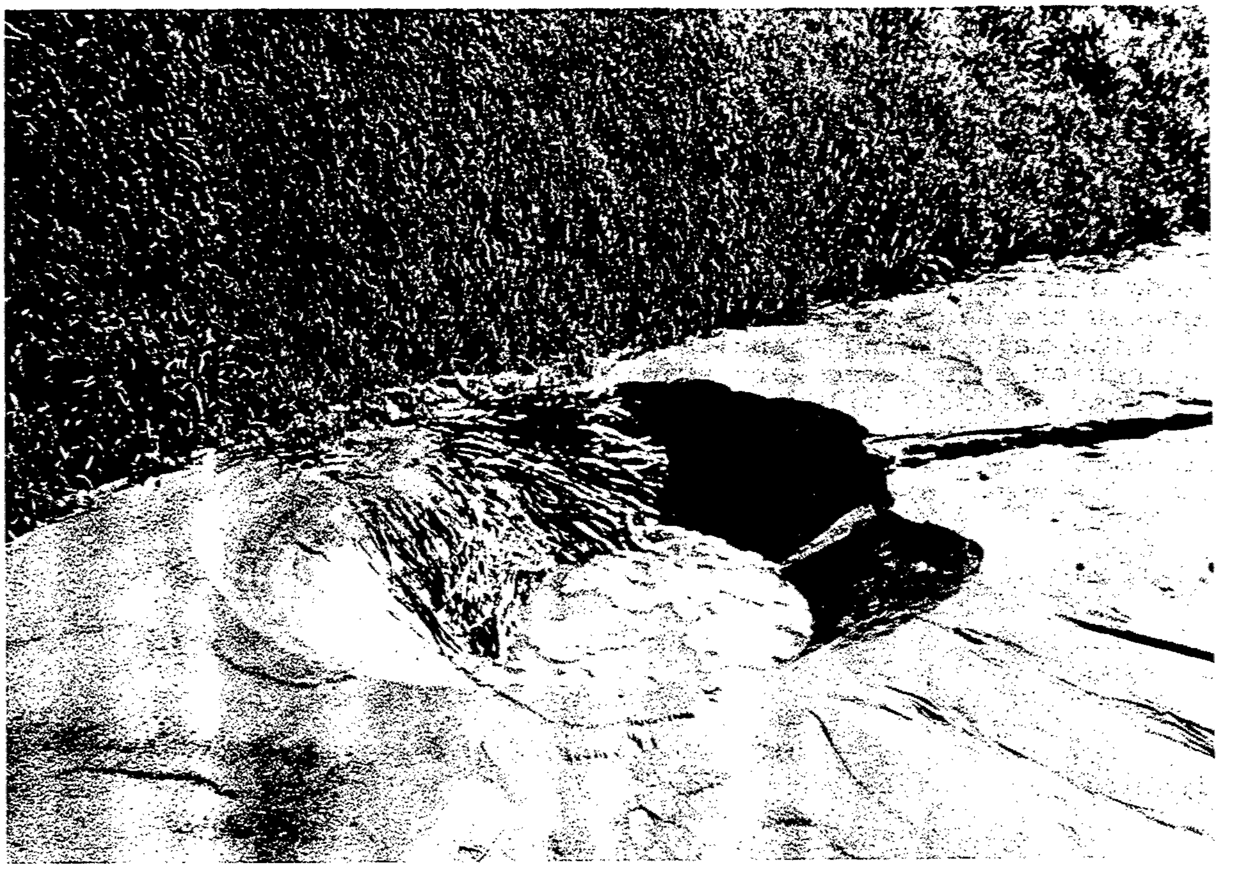
identifying the levee embankment problem areas that resulted from the February 1986 flood, including high water, bank erosion, seepage, and boils.

Prior to commencing the field drilling explorations for the geotechnical programs, personnel from the geotechnical consulting firm (Roger Foott Associates, Inc., under contract to the Corps) performed a reconnaissance of the subject levees. The reconnaissance was completed in May 1989 and consisted of field inspections of potential and existing levee embankment problem areas. During their field investigations, the existing condition of the levees was observed, surface soil samples were collected, and future exploration locations were selected.

Historic levee embankment problem areas, including type of problem and general location, are noted on Plate 3, particularly problems that resulted from the February 1986 flood. In addition, some of the problems are described below:

Yankee Slough. - A levee break occurred on the north side of Yankee Slough about 1 mile east of the confluence with the Bear River on February 17, 1986. At the time of failure, flood stages were about 7 to 8 feet below the levee crown. The failure was a sudden blowout which eventually widened to about 200 feet. The levee embankment was reconstructed in the summer of 1986 at a cost of $160,000.

Sutter Bypass. - The west levee of Sutter Bypass just east of Robbins was the site of significant seepage and settlement in February 1986 (see front cover and Figures 1, 2, and 3). The problem began suddenly as a blowout of levee embankment toe material. Erosion of the landside levee toe continued until the levee embankment subsided at the site. Seepage water then appeared immediately downstream, eroding levee material until this too was stopped by settlement of the levee. The process continued downstream for about 200 feet. Emergency flood fight efforts (see Figure 2) were initiated by the Corps of Engineers to stabilize the levee embankment. A temporary waterside berm about 50 feet wide and 300 feet long was constructed of sand and gravel at a cost of about $290,000. Upstream from this site (in the vicinity of Highway 113), numerous clear water boils have occurred along about 1 mile of levee during past high flows. Two of these boils, identified as boil numbers 12 and 16, have occurred regularly enough to have acquired numbers



LEVEE EMBANKMENT PROBLEM AREAS ON WEST LEVEE SUTTER BYPASS
DURING FEBRUARY 1986 FLOOD.

FIGURE 3

(numbered staffs at each boil). One of these boils has a permanently installed corrugated metal standpipe to control flow. On the east side of Sutter Bypass, seepage waters appear landward of the levee during high flood stages from the Natomas Cross Canal upstream along about 8 miles of levee. Significant seepage and small boils have occurred along this levee just upstream from the cross canal. The levee embankment also failed in this same area (see Plate 3 for location) in the past.

Knights Landing Ridge Cut. - The east levee of Knights Landing Ridge Cut at levee mile 2.4 had a 230-foot slipout within 342 feet of surface cracks along the levee crown. The site was repaired under Public Law 99-44 authority in the fall of 1986.

Feather River. - The south levee of Feather River, about 1 mile downstream from Nicolaus, failed during the 1955 flood event. The 1955 peak flood stage for this levee reach was at or near the design water surface. In spring 1995, a pond was created from extensive seepage along the landside toe of the east levee of the Feather River at levee mile 11.5 (river mile 0.93).

Sacramento River. - Seepage areas (as noted on Plate 3) have occurred landward of the east levee of Sacramento River during high flows. The site at river or channel mile 105 (river miles noted on Plate 2) is about 1 mile long, and seepage regularly occurs when Sacramento River flows are above adjacent ground levels. Years ago the adjacent landowner attempted to grow rice up to the landside toe of this levee, but lost significant amounts of irrigation water because of seepage under the levee embankment to the river. The sites on Sacramento River just downstream from Tisdale Bypass and just upstream from Sutter Bypass experienced significant seepage during the February 1986 flood event. In addition, landside slippage occurred at the latter site. Seepage and boils have also been observed landward of the west levee of Sacramento River. During the February 1986 flood, several boils were sandbagged by Yolo County personnel along the levee reach between Fremont Weir and Knights Landing. In addition, after the 1986 flood, the Corps repaired the seepage area just downstream from Fremont Weir by installing a landside berm with drain at a cost of about $300,000.

IN 1995, POND CREATED FROM EXTENSIVE SEEPAGE ALONG LEVEE TOE AT SITE 18, FEATHER RIVER/YOLO BYPASS. LAST TIME WATER PONDED HERE WAS IN 1986.

SITE 17 WATERSIDE VIEW MARCH 16, 1995 OPPOSITE OLD LEVEE BREAK POND.

FIGURE 4

Yolo Bypass. - Levee embankment subsidence has occurred along different sections of the east levee of Yolo Bypass between the Sacramento Bypass and Fremont Weir. Personnel from the maintaining agencies indicate that substantial reaches of this levee were originally constructed on tule marshes. About 3 miles south of Fremont Weir, 1,000 feet of this levee settled in 1983. In 1936, 500 feet of levee embankment settled just to the north of the 1983 settlement area (in some parts, as much as 8 feet of settlement was observed).

DWR personnel also provided cross-section surveys of the levee embankment at exploratory drill hole locations (54 surveyed cross sections referenced to mean sea level datum). The cross sections define the levee embankment above the adjacent land surface and include landside and waterside ditches that are close to the toe of the levee (within about 200 feet).

The cross sections were used primarily in potential designs for raising the levee in those reaches that do not have the minimum freeboard requirements specified for the Sacramento River Flood Control Project (see Table 2 and "Levee and Channel Profiles," Corps of Engineers, March 1957). In addition, the existing cross sections were compared to the Corps cross sections used in the original design and construction of the project levees. In general, the original designs specified a 20-foot crown width for the bypasses and major streams and a 12-foot crown width for minor streams. Bypass levee embankment slopes specified range from 2-1/2 to 4:1 (2-1/2 to 4 horizontal on 1 vertical) on the waterward side and 2-1/2:1 on the landward side. Flatter bypass levee slopes were required in some areas because of the potential for wave erosion. Major and minor streams were originally designed with 3:1 waterside slopes and 2:1 landside slopes. The comparison indicated that particular levee reaches have less than the design crown width and that levee embankment slopes are flatter than design specifications. In some cases, the differences are significant and suggest levee embankment subsidence and slumping or spreading at the base of the levee.

The contractor for the geotechnical work also provided graphical displays of the levee embankment cross section (101 cross sections to scale) at various study sites. The levee sections were used in the levee stability analysis and in the evaluation of the impacts of drainage ditches on levee stability and seepage.

TABLE 1

LEVEE EMBANKMENT DESIGN FREEBOARD

MID-VALLEY AREA

Location	Design Freeboard [1] feet
Western Pacific Intercept Canal	3
Dry Creek	3
Yankee Slough	3
Bear River	3
Tisdale Bypass	5
Sutter Bypass	5
Feather River	
upstream from confluence with Sutter Bypass	3
Natomas Cross Canal	3
Coon Creek Group Interceptor	3
Sacramento River	3
Knights Landing Ridge Cut	3
Cache Creek	3
Willow Slough Bypaass	3
Putah Creek	3
Sacramento Bypass	6
Yolo Bypass	6

[1] Minimum freeboard required in the specified reaches of the project levee system as authorized by the Flood Control Act of March 1917 and specified in House Document No. 81, 62d Congress, 1st Session.

CHAPTER 3 - HYDROLOGY

3.01. Discharge-Frequency Relationship

Discharge and stage-frequency relationships developed for the study area (see Figures 5 through 15) provide information on the recurrence interval associated with the February 1986 high water mark profiles. Figures 5 through 15 show the 1986 peak flow or stage (see Table 2 also) and design stages at the following locations:

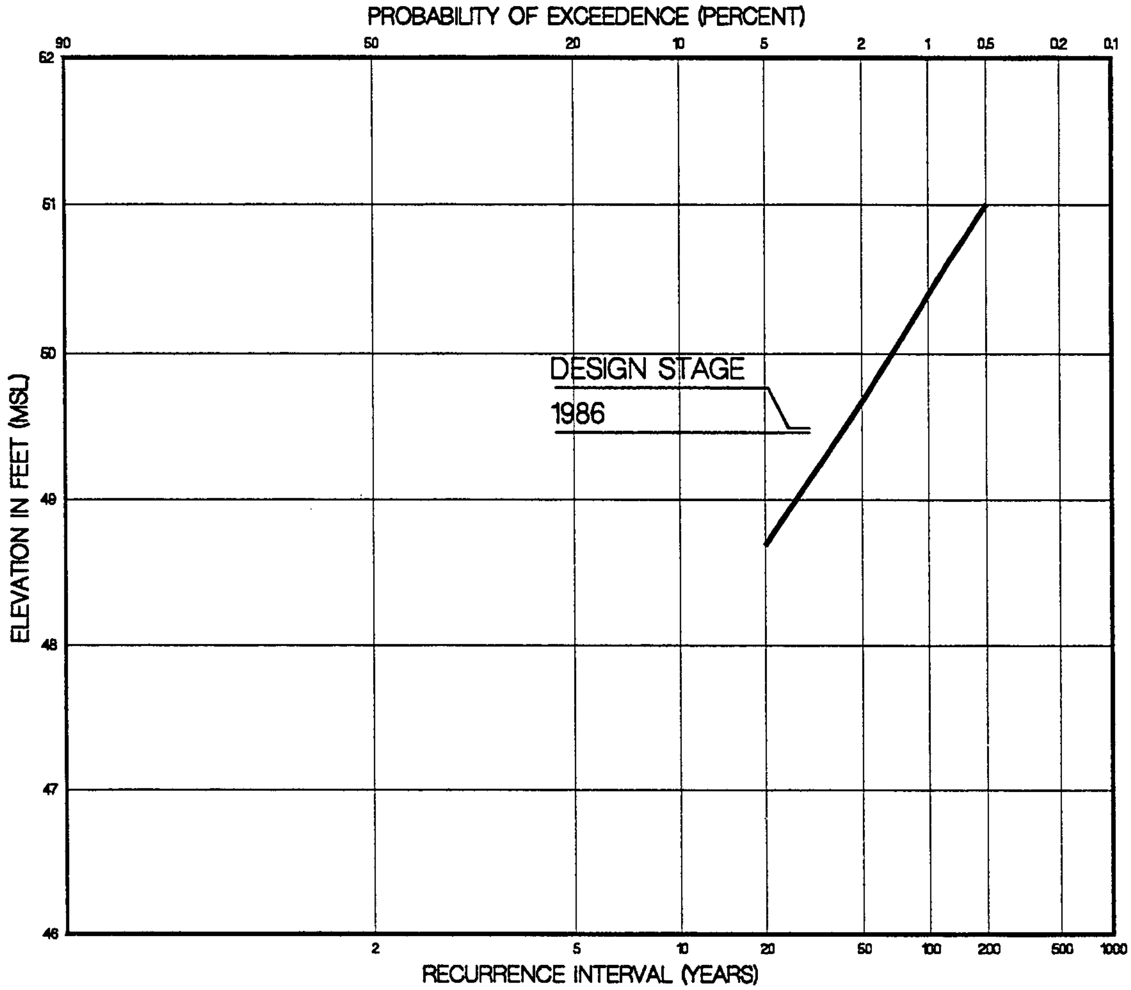
- Sacramento River below Wilkins Slough
- Sacramento River at Knights Landing
- Sacramento River Fremont Weir Spill
- Sacramento River at Verona
- Sacramento River Sacramento Weir Spill
- Sutter Bypass at Tisdale Bypass (at Obanion Pumping Plant)
- Sutter Bypass at RD 1500
- Feather River above Sutter Bypass
- Bear River near Wheatland
- Yolo Bypass near Woodland
- Yolo Bypass near Lisbon

TABLE 2

PEAK FLOWS AND STAGES

Location	Time (date/hours)	Elevation (msl)	Flow (cfs)
Bear River near Wheatland	Feb 17/2000	93.52	48,000
Feather River at Nicolaus	Feb 20/0230	45.76	285,000 [1]
Sutter Bypass at R.D. 1500	Feb 20/0415	39.61	
Sacramento River at Tisdale Weir	Feb 20/0945	49.66	
Sacramento River below Wilkins Slough	Feb 20/1350	49.50	32,700
Sacramento River at Knights Landing	Feb 20/0800	40.39	
Colusa Basin Drain at Knights Landing	Feb 21/0300	35.94	
Sacramento River at Verona	Feb 20/0215	39.11 [2]	92,900
Sacramento River Fremont Weir Spill	Feb 20/0300	38.54 [3]	341,000
Yolo Bypass near Woodland	Feb 20/0745	31.46	374,000
Sacramento River Sacramento Weir Spill	Feb 20/0115	30.56 [4]	127,680
Cache Creek at Yolo	Feb 17/2245	80.36	26,100
Putah Creek near Winters	Feb 20/1545		6,630
South Fork Putah Creek near Davis	Feb 20/1745	41.96	
Yolo Bypass near Lisbon	Feb 20/1330	24.88	495,000 to 509,000 (estimated)

1 Estimate by the Corps of Engineers based on flood routing studies.
2 Elevation recorded at mouth of Natomas Cross Creek.
3 Elevation recorded 550 feet upstream from west end of Fremont Weir on Sacramento River.
4 Elevation recorded 550 feet upstream from Sacramento Weir on Sacramento River.



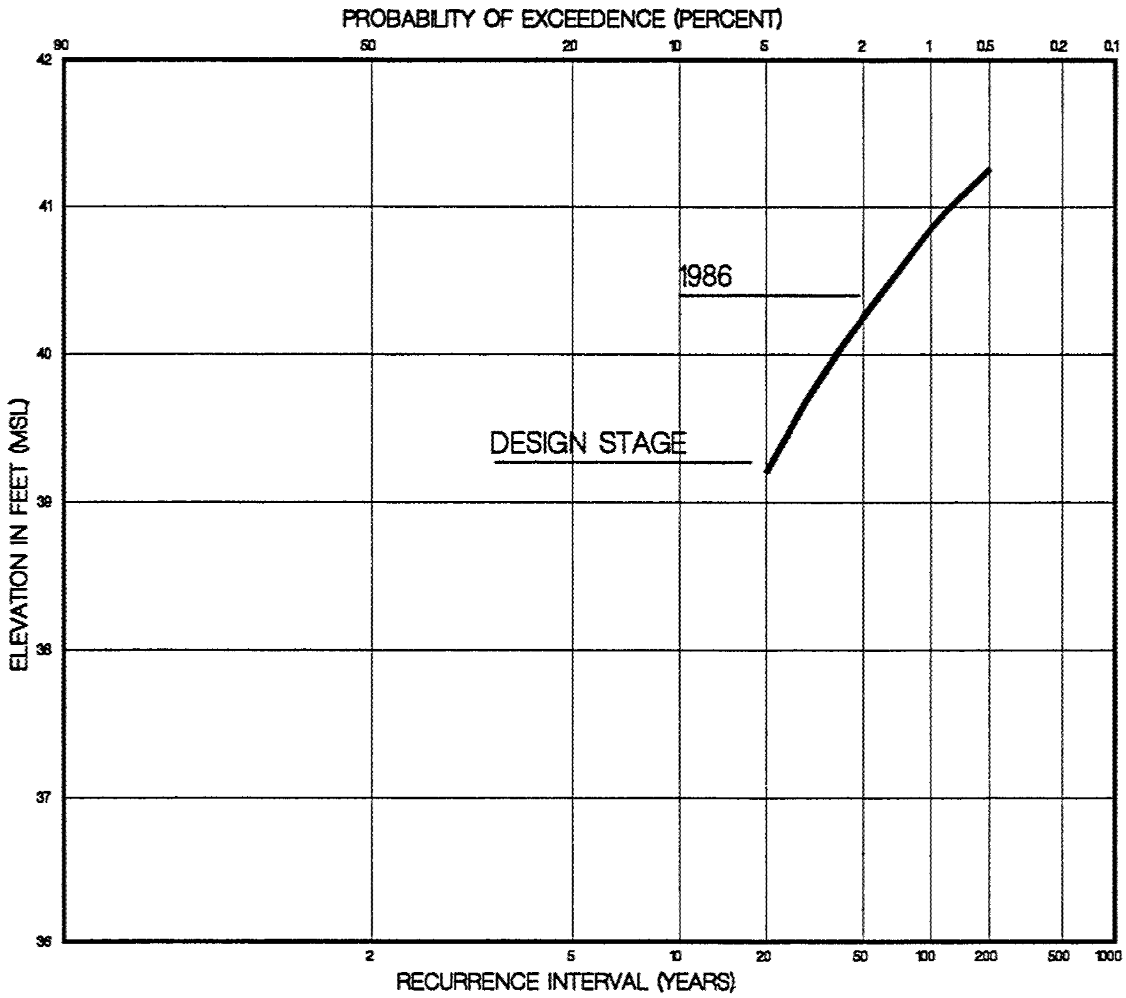
NOTE: Present condition (peak stage) stage-frequency relationship developed for this study, July 1990.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP
SACRAMENTO RIVER BELOW
WILKINS SLOUGH

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 5



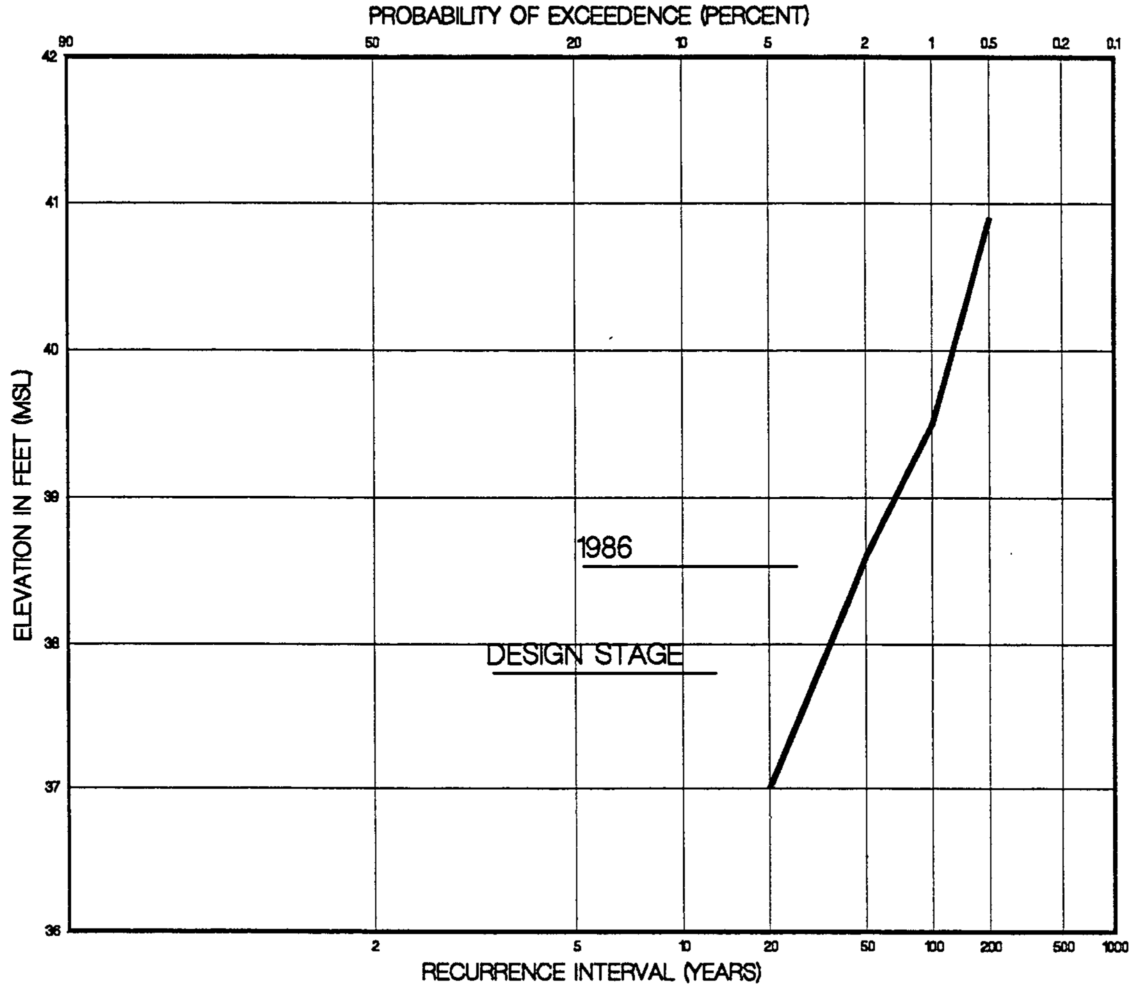
NOTE: Present condition (peak stage) stage-frequency relationship developed for this study, July 1990.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP
SACRAMENTO RIVER AT
KNIGHTS LANDING

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 6



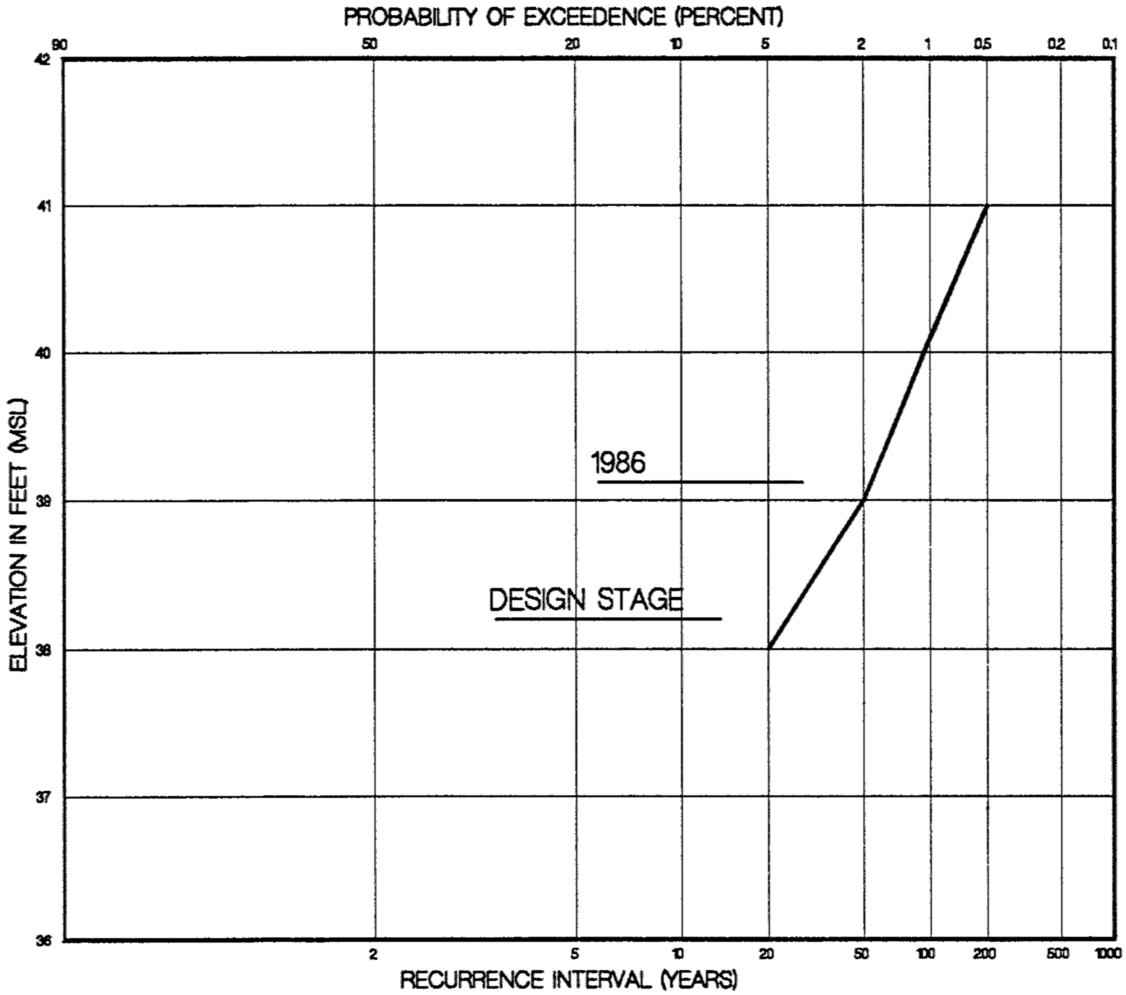
NOTE: Present condition (peak stage) stage-frequency relationship prepared during American River Investigation.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP
SACRAMENTO RIVER UPSTREAM
OF FREMONT WEIR

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 7



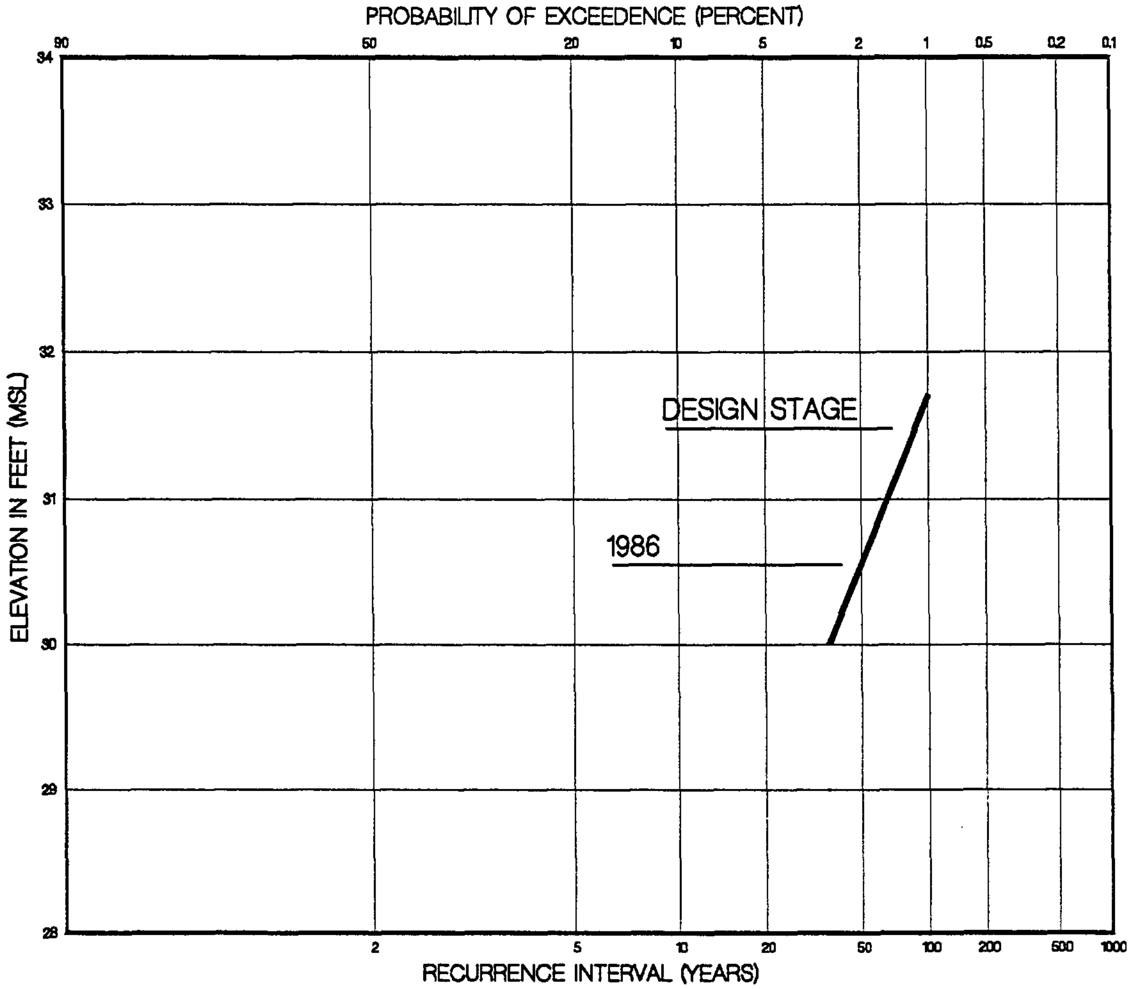
NOTE: Present condition (peak stage) stage-frequency relationship prepared during American River Investigation.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP
SACRAMENTO RIVER
AT VERONA

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 8



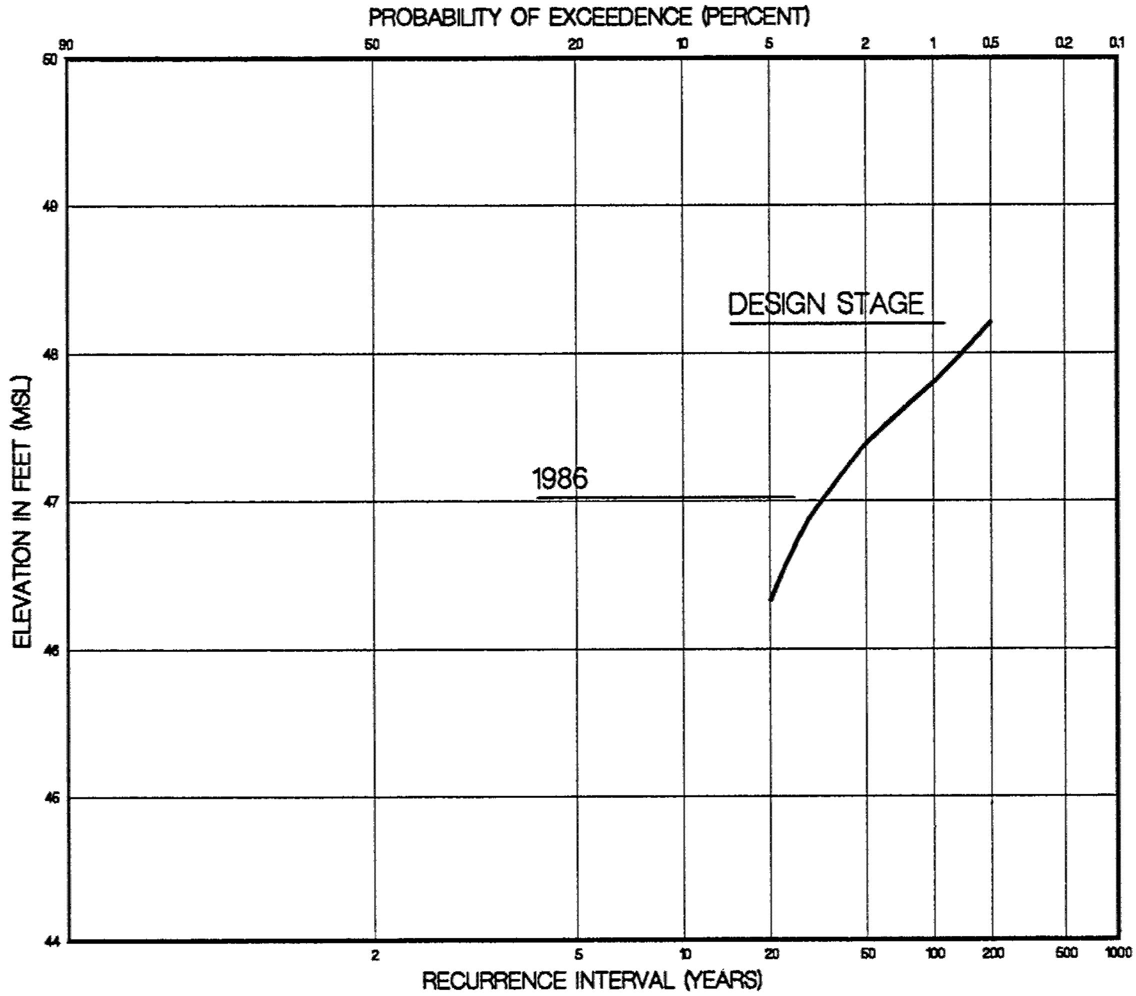
NOTE: Present condition (peak stage) for the 100-year recurrence interval taken from the Hydrology Office Report, American River and Sacramento Metro Investigations, California," Corps of Engineers, January 1990. The recurrence interval for the 1986 peak flood stage estimated based on correlations with stage-frequency curves developed in the area.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP SACRAMENTO RIVER AT SACRAMENTO WEIR

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 9



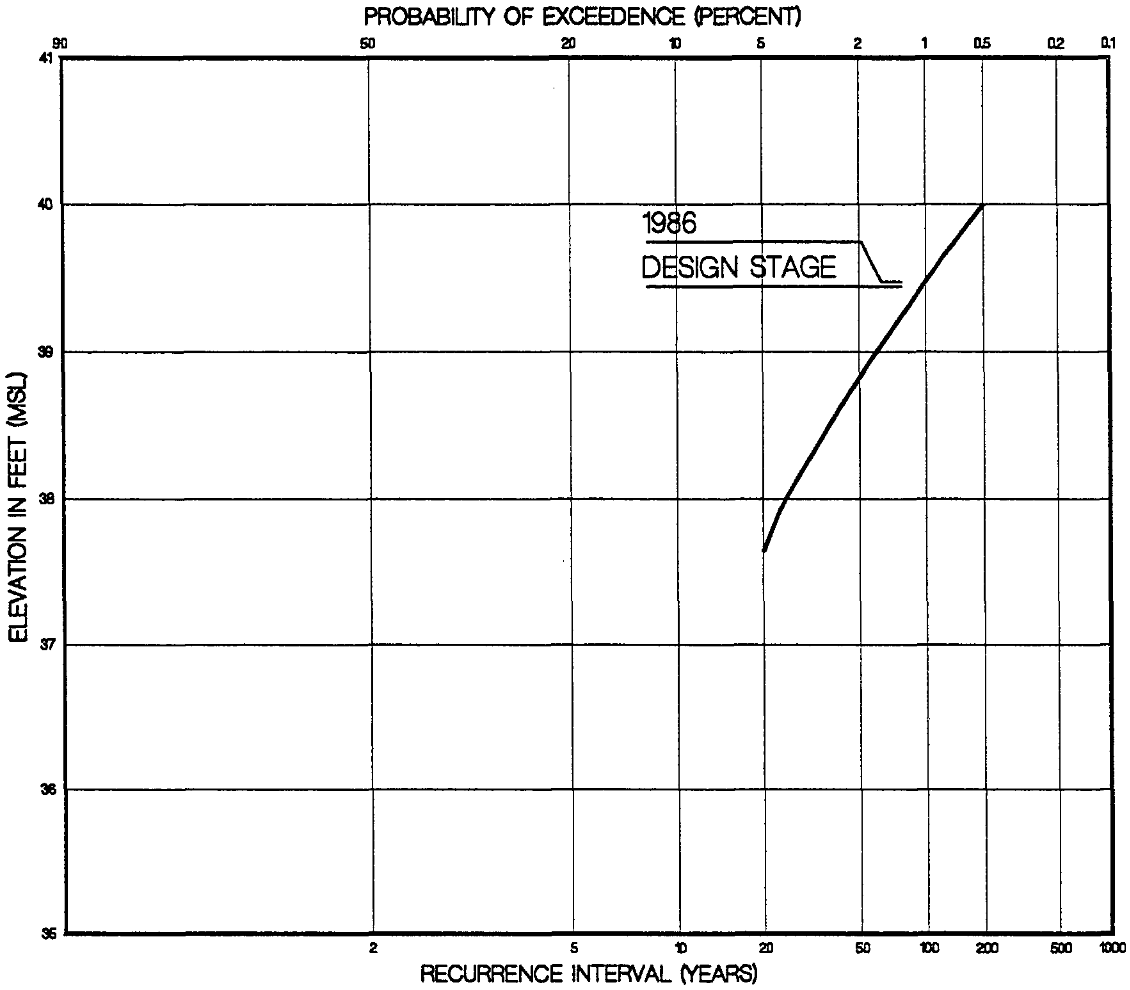
NOTE: Present condition (peak stage) stage-frequency relationship developed for this study, July 1990.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP
SUTTER BYPASS AT TISDALE BYPASS
(AT OBANION PUMPING PLANT)

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 10



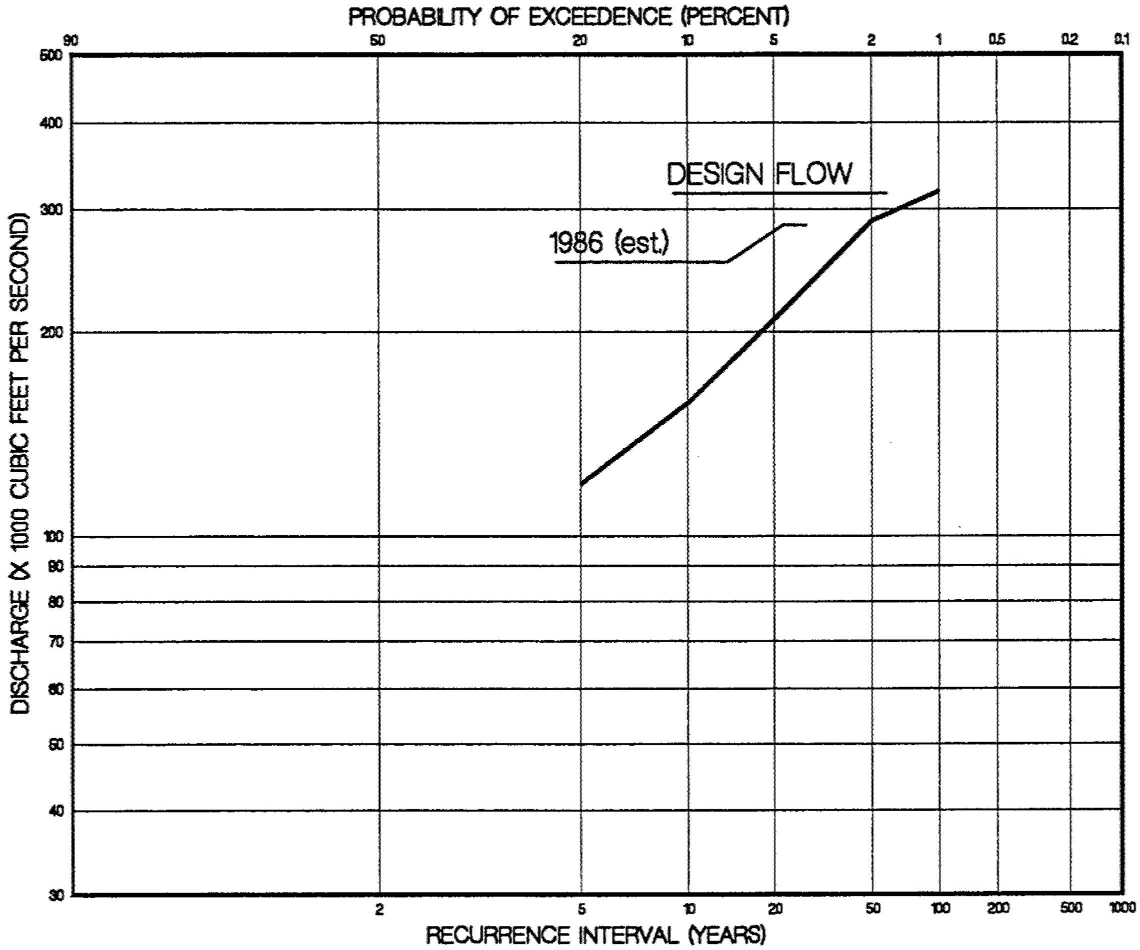
NOTE: Present condition (peak stage) stage-frequency relationship developed for this study, July 1990.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP
SUTTER BYPASS AT RD 1500

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 11



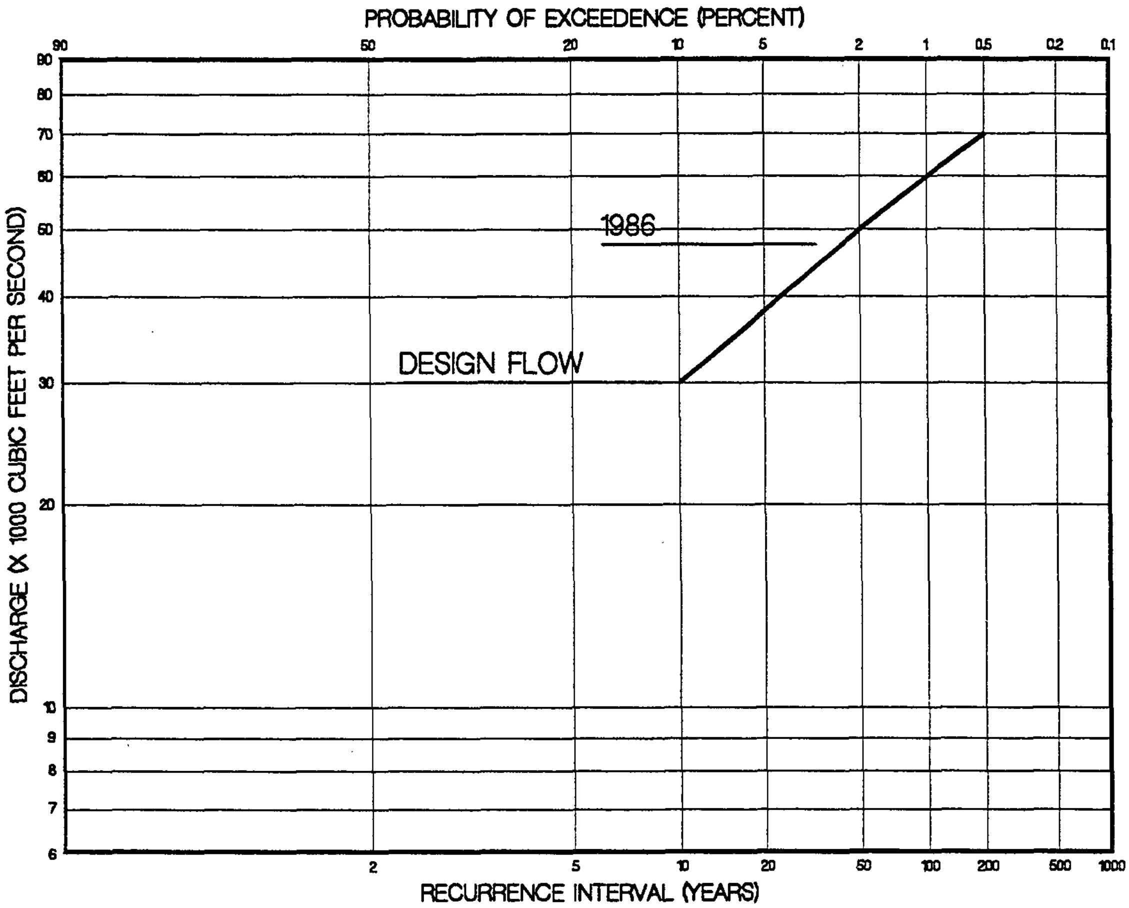
NOTE: Present condition (peak flow) discharge-frequency relationship taken from "Sacramento River Flood Control Project, Hydrology, Office Report," dated October 1993.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

DISCHARGE-FREQUENCY RELATIONSHIP FEATHER RIVER ABOVE SUTTER BYPASS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 12



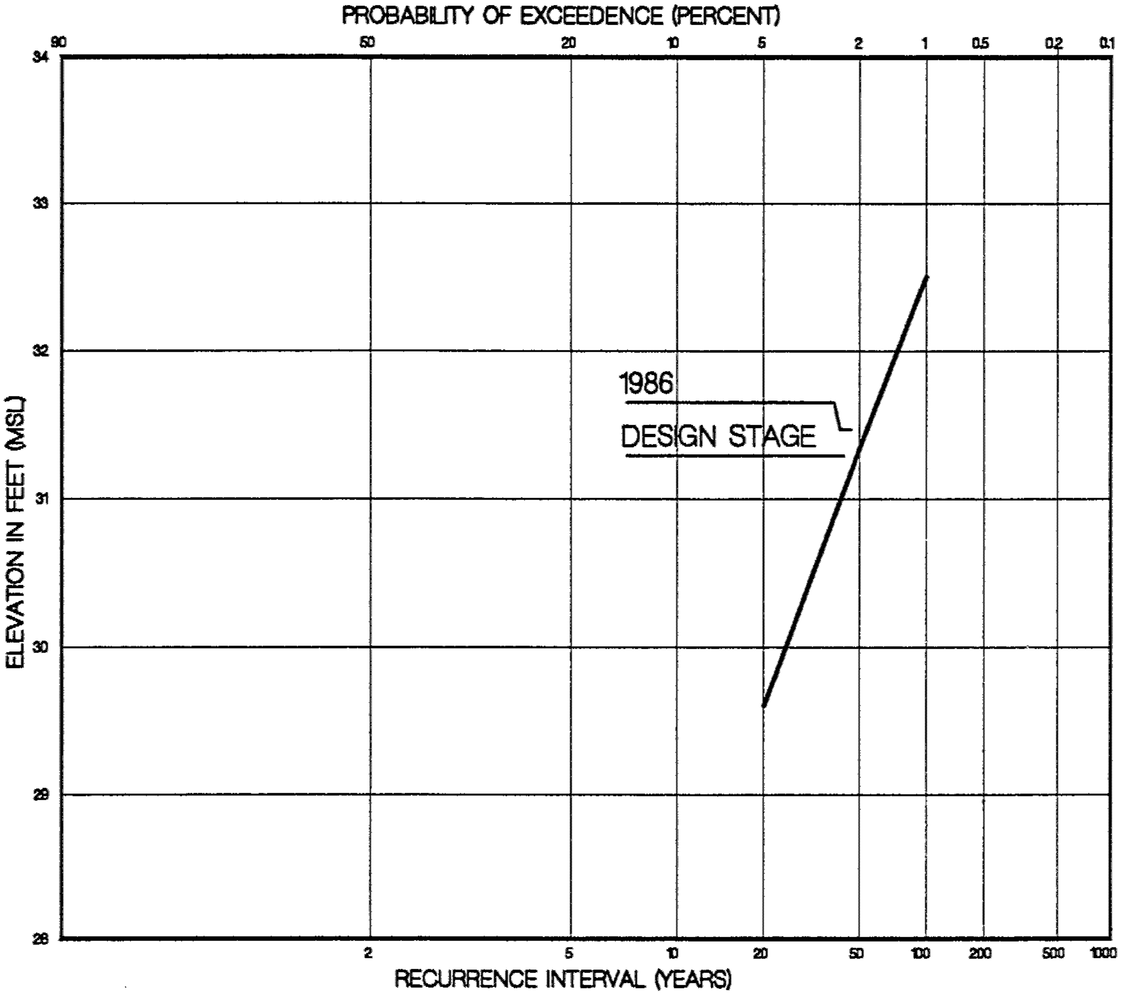
NOTE: Present condition (peak flow) discharge-frequency relationship updated by the Hydrologic Engineering Center, Corps of Engineers, July 1990.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

DISCHARGE-FREQUENCY RELATIONSHIP
BEAR RIVER AT WHEATLAND

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 13



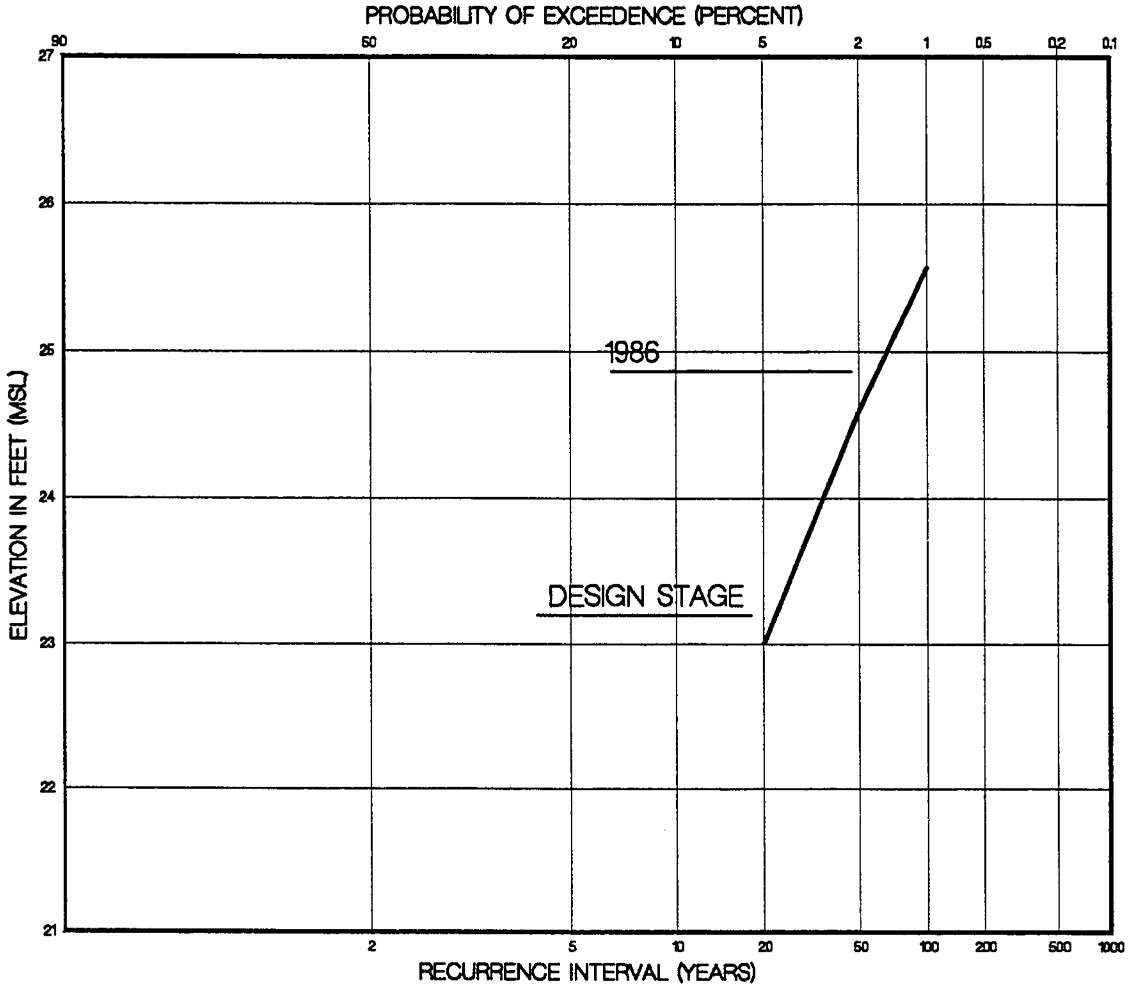
NOTE: Present condition (peak stage) stage-frequency relationship taken from the Hydrology Office Report, American River and Sacramento Metro Investigations, California," Corps of Engineers, January 1990.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP
YOLO BYPASS NEAR WOODLAND

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 14



NOTE: Present condition (peak stage) stage-frequency relationship taken from the Hydrology Office Report, American River and Sacramento Metro Investigations, California," Corps of Engineers, January 1990.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP
YOLO BYPASS NEAR LISBON

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 15

FIGURE 16

HIGH WATER MARK STAKING OF FEBRUARY 1986 FLOOD
(EAST LEVEE OF YOLO BYPASS).

The discharge and stage-frequency relationships are considered representative of existing conditions in the study area and in the Sacramento River watershed. Most of the relationships were developed in conjunction with ongoing studies for the American River Watershed and Sacramento Metropolitan Area Investigations and funded in part by the Sacramento River Flood Control System Evaluation. Hydrologic models developed and used for the American River Watershed Investigation were calibrated based on the 1983 and 1986 flood events and subsequently modified to simulate physical conditions as they now exist in the area. These models were then used to determine water surface profiles and stage-frequency relationships within the study area for recurrence intervals that encompassed the design water surfaces and February 1986 high water mark profiles.

Only partial curve segments of the discharge and stage-frequency relationships have been plotted just sufficient to adequately cover the range of recurrence intervals necessary to accomplish the economic evaluations. For the curve segments shown and for recurrence intervals equal to or less than 200 years, the following conditions apply:

- No levee breaching on the Sacramento River, Sutter Bypass, Feather River, and Yolo Bypass within and upstream from the study area.

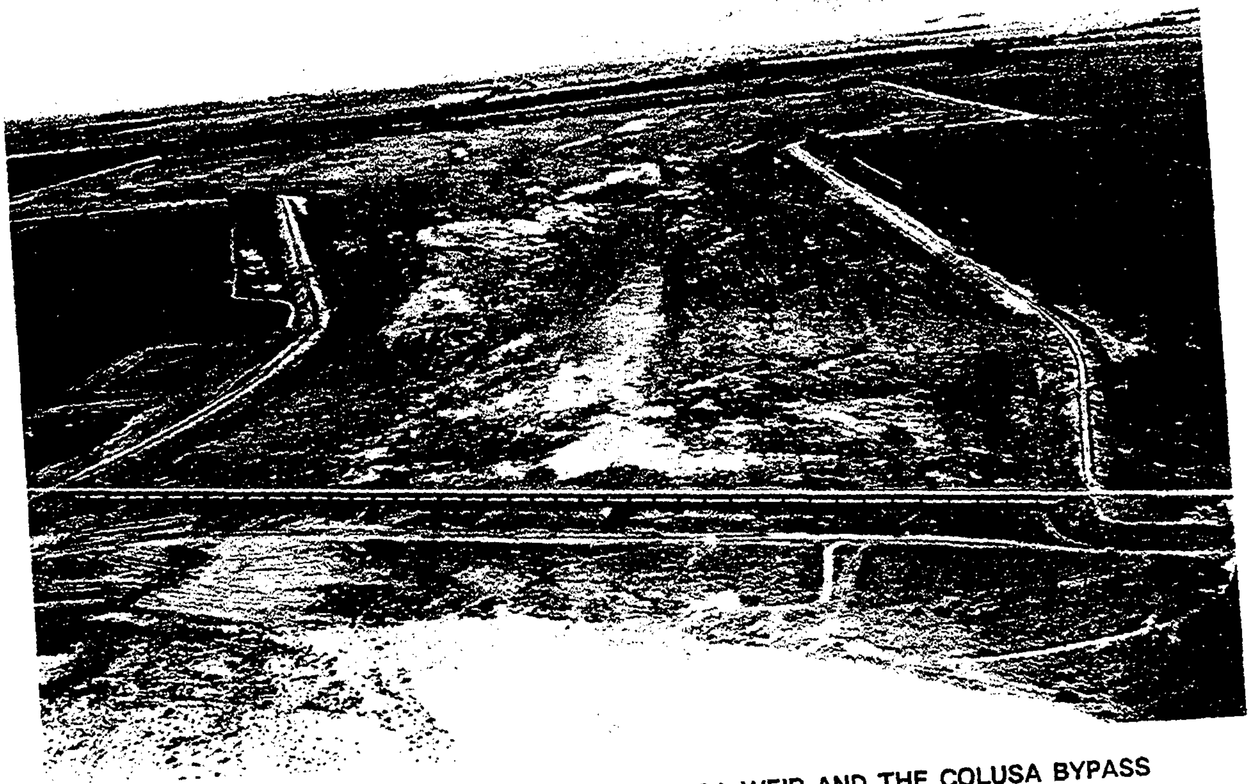
- Levee breaching on the American and Yuba Rivers according to conditions specified in the Hydrology Office Report, "American River and Sacramento Metro Investigations, California," Corps of Engineers, January 1990.

Significant physical changes have occurred and are occurring in the Sacramento River Basin, particularly in and adjacent to the study area, that have an impact on flow patterns, flow conveyance, flood stages, and direct runoff. Since the February 1986 flood event, levee embankments and floodwalls have been raised, levees repaired, new levees constructed, and flood gates installed at locations where levee overflow and flooding occurred in 1986. In addition, following the 1986 flood, accumulated sediments were removed from Colusa Bypass and Sediment Basin (an overflow structure on Sacramento River about 25 channel miles upstream from Tisdale Bypass), from Tisdale Bypass, and from Yolo Bypass just upstream and downstream from Fremont Weir (see Figures 17 through 19). If the February 1986 rainfall event were to occur under physical conditions existing today, the above changes would result in peak flood stages and floodflows within the study area different from those recorded in 1986. Because of these and other physical changes, hydrologic models were developed to simulate physical conditions that exist today in the basin. As such, recurrence intervals associated with the recorded peak flood stages and floodflows of the 1986 flood event (as shown in Figures 5 through 16) represent a hypothetical flood event resulting from a different combination of meteorological and physical conditions than actually existed in February 1986.

Peak flood stages and floodflows of the 1986 flood event were, in many cases, the maximums recorded (for the systematic record) in the study area. Maximum floodflows occurred at Bear River near Wheatland, Sacramento River below Wilkins Slough, Sacramento River at Verona, Sacramento Weir spill, and Yolo Bypass near Woodland. A comparison of the 1986 peak flows and stages of Table 3 with the design flows and stages of Table 4 indicates that the 1986 peak flows exceeded design flows in Sacramento River between Tisdale Bypass and Fremont Weir, in Sacramento Bypass (see Figure 20) and in Yolo Bypass downstream from Putah Creek, and that the 1986 peak flood stages exceeded design stages in Sacramento River near Verona and in Yolo Bypass downstream from Woodland. In addition, the 1986 high water mark profiles (which include the effect of wave action) of Plates 4 through 18 indicate minimum freeboards less than 3 feet on Sacramento River, Yolo Bypass, and Natomas Cross Canal.

3.02. Stage Hydrograph

The existing condition stage-frequency relationships indicate that the 1986 water surface elevations (the static water surface elevations plus wind setup) represent about a 40-year recurrence interval on the Sacramento River below Tisdale Bypass (Figure 5), a 60-year recurrence interval on the Sacramento River near Knights Landing (Figure 6), a 50-year recurrence interval on the Sacramento River at Fremont Weir (Figure 7), a 60-year recurrence interval on the Sacramento River near the Natomas Cross Canal (Figure 8), a 50-year recurrence interval on the Sacramento River near Sacramento Bypass (Figure 9), a 30-year recurrence interval on the Sutter Bypass near Tisdale Bypass (Figure 10), a 100-year recurrence interval on the Sutter Bypass just upstream from the

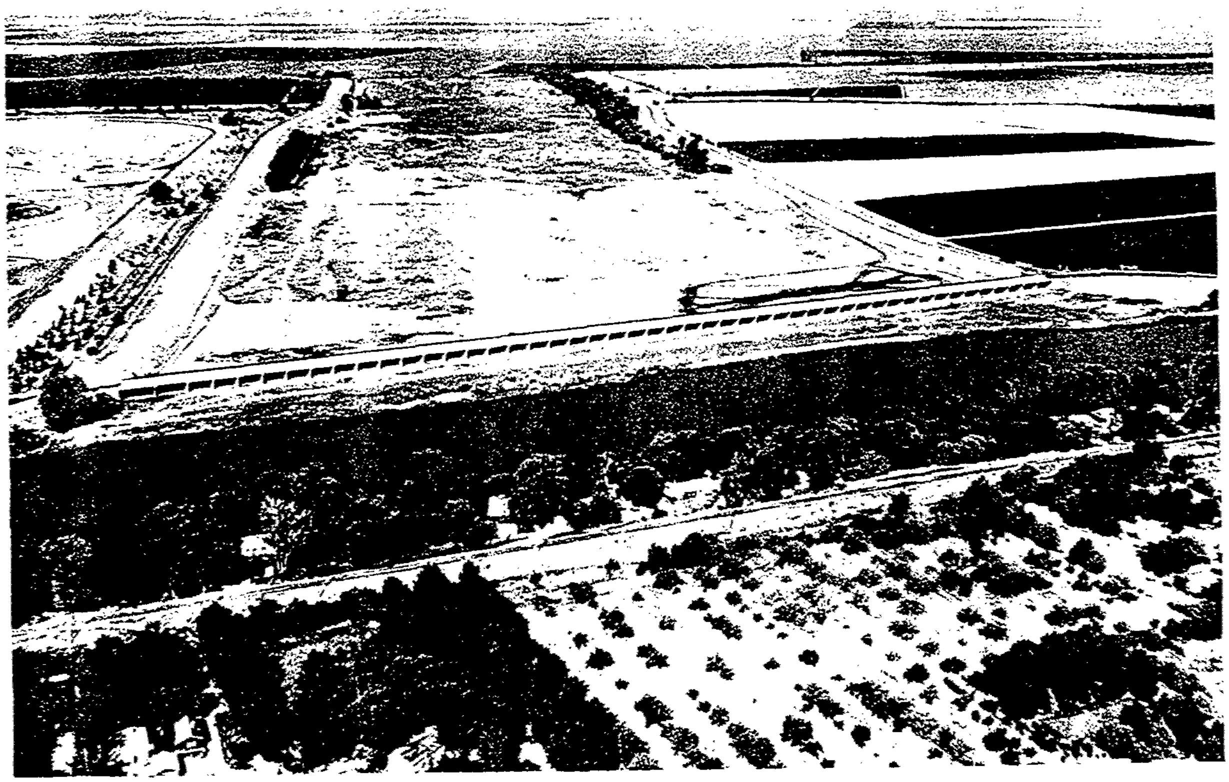


RIVER MILE 146 - ENTRANCE TO THE COLUSA WEIR AND THE COLUSA BYPASS
15 JULY 1982

RIVER MILE 118 - ENTRANCE TO THE TISDALE WEIR AND THE TISDALE BYPASS
15 JULY 1982.

FIGURE 17

RIVER MILE 82 - ENTRANCE TO THE FREMONT WEIR AND YOLO BYPASS
15 JULY 1982.

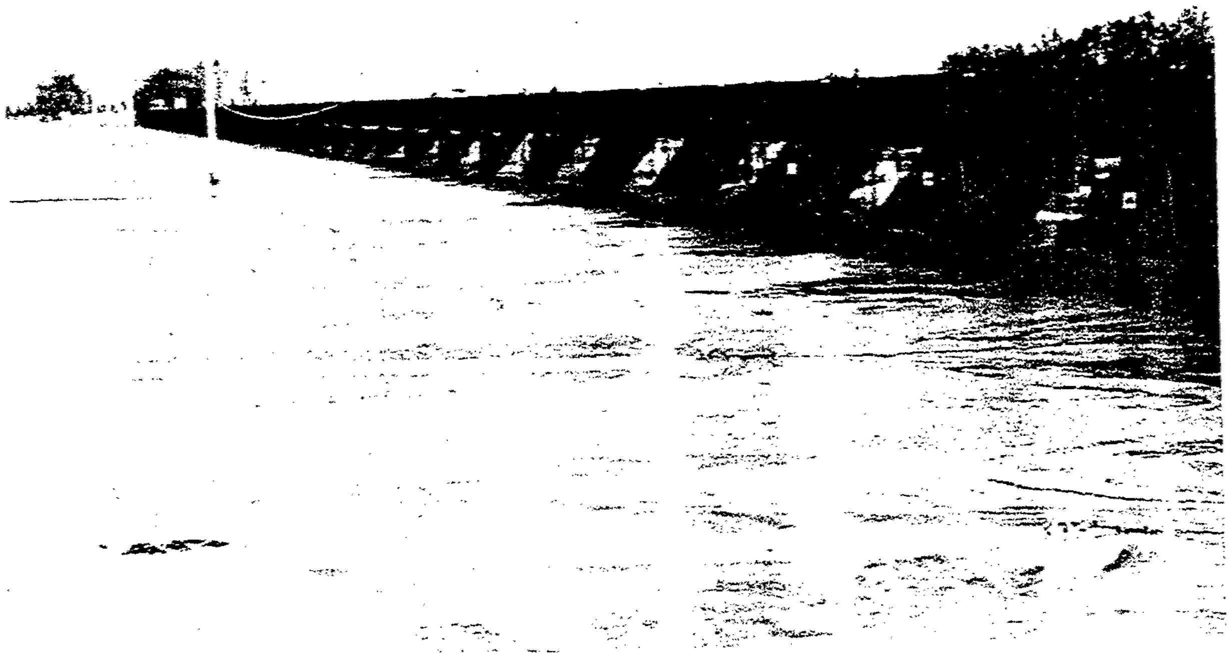


RIVER MILE 63 - ENTRANCE TO THE SACRAMENTO WEIR AND SACRAMENTO BYPASS
15 JULY 1982.

FIGURE 18

ACCUMULATED DEBRIS AND SEDIMENT IN VICINITY OF FREMONT WEIR WAS REMOVED BY STATE AFTER FEBRUARY 1986 FLOOD.

FIGURE 19



FEBRUARY 1986 FLOODFLOWS EXCEEDED DESIGN CONDITIONS
FOR SACRAMENTO WEIR AND BYPASS.

FIGURE 20

Sacramento River (Figure 11), and a 55-year recurrence interval on the Yolo Bypass just downstream from Cache Creek (Figure 14).

The published 1986 peak flow at the gaging station, Sacramento River below Wilkins Slough (about 1 mile downstream from Tisdale Bypass as shown on Plate 4, sheet 1 of 4), was 32,700 cubic feet per second. The design flow for the Sacramento River between Tisdale Bypass and Fremont Weir is 30,000 (see Table 4). The design water surface profile for this levee reach is shown on Plate 4, sheets 1, 2 and 3 of 4. A comparison of the recorded peak flood stages (gaging station locations) with nearby surveyed high water mark elevations (obtained from debris lines as shown in Figure 4) indicates little or no difference between the debris line and the static water surface elevation. (This suggests that wave action was insignificant in creating a debris line substantially different from the recorded peak flood stages.) Based on the rating curve for Sacramento River below Wilkins Slough (see Figure 21), the design flow of 30,000 cubic feet per second would be conveyed at a water surface elevation 2 feet lower than the 1986 high water mark profile. (Local inflow into the Sacramento River between Tisdale and Fremont Weirs is insignificant.) Although backwater conditions from the Feather River influence flood stages in the Sacramento River in the vicinity of the confluence of the Sacramento and Feather Rivers, the above information indicates that the design flow can be conveyed at or near the design water surface in the Sacramento River between Tisdale and Fremont Weirs.

For Sutter Bypass, the design flow between Tisdale Bypass and Feather River is 180,000 cubic feet per second (see Table 4). The 1986 peak flow for Butte Slough near Meridian (just upstream from Sutter Bypass and about 15 miles upstream from the confluence of the Sutter and Tisdale Bypasses) was 157,000 cubic feet per second on February 20 at 0600 hours. The mean daily discharge into Sutter Bypass from Wadsworth Canal (about 6 miles upstream from Tisdale Bypass) on February 20 was about 700 cubic feet per second (see Initial Appraisal Report for the Marysville/Yuba City Area). Although some attenuation of the peak flow is possible between the Butte Slough near Meridian gage location and Wadsworth Canal, the estimated peak flow in Sutter Bypass just upstream from Tisdale Bypass is probably equal to or slightly greater than the design flow (155,000 cubic feet per second). In addition, the mean daily inflow to Sutter Bypass from

Tisdale Bypass was 22,800 cubic feet per second and 19,900 cubic feet per second on February 20 and 21, respectively. The estimated peak flow in Sutter Bypass just downstream from Tisdale Bypass is 178,000 cubic feet per second. Based on the above information, Sutter Bypass conveyed a peak flow in 1986 (between Tisdale Bypass and Feather River) nearly equal to the design flow cited above. Based on a comparison of the design water surface and the 1986 high water mark profile (see Plate 5, sheet 1 of 2) and considering the impact of wave action on surveyed high water marks, Sutter Bypass can generally convey the design flow within the design water surface between Tisdale Bypass and Feather River.

3.03. Rating Curves

Measured streamflow data are not available on Bear River downstream from the confluence with Dry Creek, on Dry Creek, on Western Pacific Intercept Canal, and on Yankee Slough; however, measured streamflow data at the gaging station, Bear River near Wheatland (channel mile 10.9 on Plate 12), provide an indication of design flow capacities. The peak flow and stage at this station during the February 1986 flood event was 48,000 cubic feet per second and 93.52 feet, respectively (see Table 3). The design flow at this station is 30,000 cubic feet per second, and the corresponding design water surface elevation is about 98 feet as shown in Plate 12. Based on the above information and the extension of the rating curve for Bear River near Wheatland, Figure 22, more than 50,000 cubic feet per second can be conveyed within the design water surface near Wheatland. The design flow for Bear River just upstream from the confluence with the Feather River is 40,000 cubic feet per second. The 1986 peak flow at this location is difficult to estimate because of unknown flow contributions from Dry Creek, Western Pacific Intercept Canal, and Yankee Slough. In addition, the Western Pacific Intercept Canal acts as a relief valve during periods of high flood stages in the Bear and Feather Rivers. Although the 1986 peak flow is not known, there is 4 to 8 feet of levee freeboard above the design water surface in this reach between the Feather River and Yankee Slough (as indicated by Plate 12).

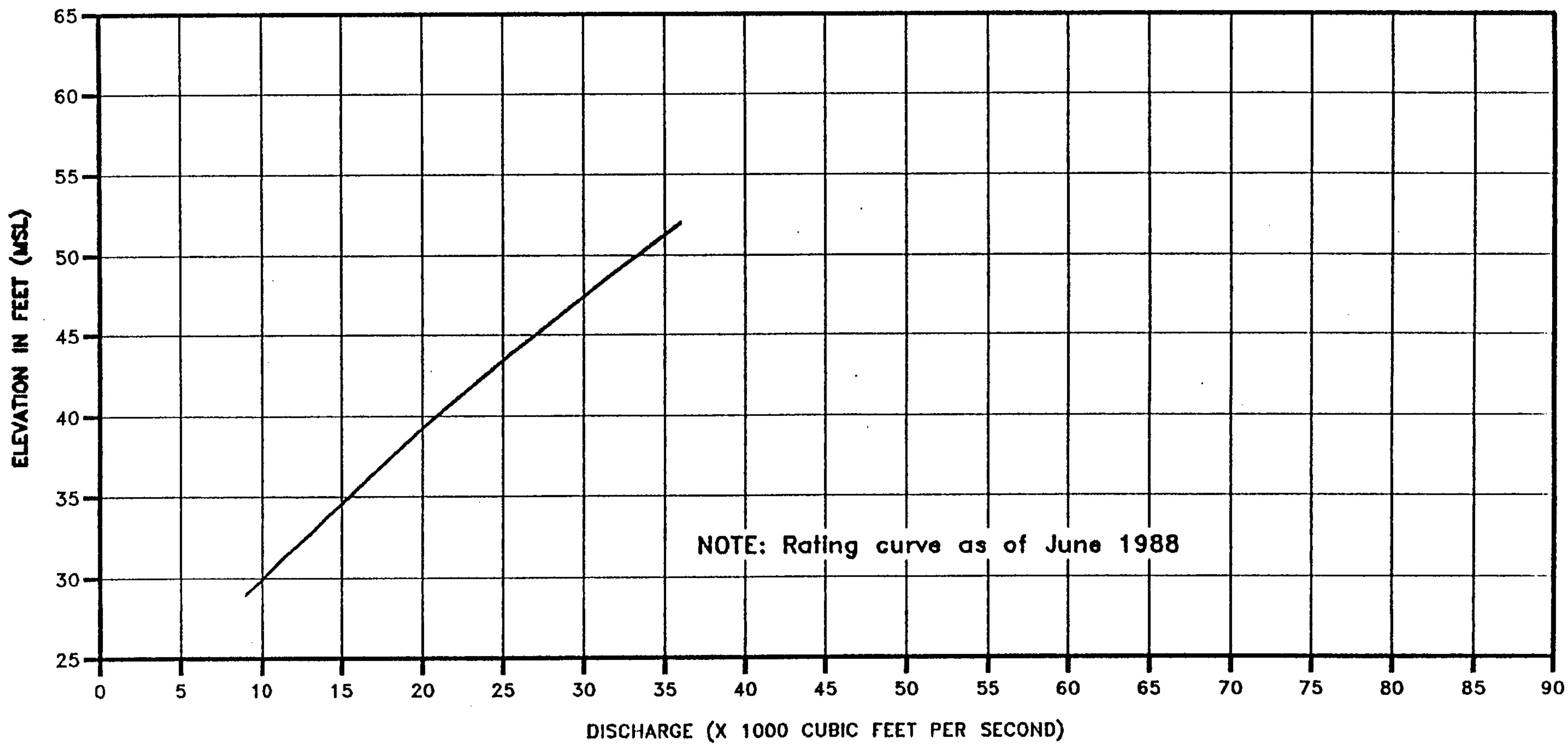
TABLE 3

DESIGN FLOWS AND STAGES

Location	Design Flow (cfs)	Design Stage (msl)
Western Pacific Intercept Canal		
at confluence with Bear River	10,000	57.8
Dry Creek		
at confluence with Bear River	9,000	62.6
Yankee Slough		
at confluence with Bear River	2,500	57.5
Bear River		
just upstream from Dry Creek	30,000	
just downstream from Dry Creek	37,000	62.6
just downstream from Western Pacific Intercept Canal	40,000	57.8
at confluence with Feather River	40,000	54.1
Tisale Bypass		
at confluence with Sacramento River	38,000	50.0
at confluence with Sutter Bypass	38,000	48.2
Sutter Bypass		
just downstream from Tisdale Bypass	180,000	48.2
just downstream from Feather River	380,000	42.6
at confluence with Sacramento River	380,000	37.8
Feather River		
just downstream from Bear River	320,000	54.1
at Nicolaus Bridge (Highway 99)	320,000	50.4
at confluence with Sutter Bypass	320,000	42.6
Natomas Cross Canal		
at confluence with Sacramento River	22,000	38.2
Coon Creek Group Interceptor		
at confluence with Natomas Cross Canal	16,000	39.1
Sacramento River		
just downsream from Tisale Bypass	30,000	50.0
at Fremont Weir	-	37.8
just downstream from Feather River	107,000	38.5
at Sacramento Bypass	-	31.5
Knights Landing Ridge Cut		
at confluence with Yolo Bypass	20,000	33.7
Cache Creek		
at Highway 113	30,000	66.6
Willow Slough Bypass		
at confluence with Yolo Bypass	6,000	25.8
Putah Creek		
at confluence with Yolo Bypass	62,000	24.1
Sacramento Bypass		
at confluence with Sacramento River	112,000	31.5
at confluence with Yolo Bypass	112,000	26.3
Yolo Bypass		
just downstream from Fremont Weir	343,000	37.3
just downstream from Knights Landing Ridge Cut	362,000	33.7
just downstream from Cache Creek	377,000	31.3
just downstream from Sacramento Bypass	480,000	26.3
just downstream from Putah Creek	490,000	24.1

As in the above case, measured streamflow data are not available on the Feather River downstream from the Bear River within the study area. Recent flood routings by the Corps of Engineers though provide estimates of the peak flow during the February 1986 flood. For Feather River at Nicolaus, the estimated peak flow was 285,000 cubic feet per second (see Table 3). Based on the discharge-frequency relationship of Figure 12, the February 1986 estimated peak flow represents a 65-year recurrence interval on the Feather River above Sutter Bypass (which includes the Nicolaus location). The design flow for Feather River between the Bear River and Sutter Bypass is 320,000 cubic feet per second (see Table 4). As indicated previously, Sutter Bypass just upstream from the confluence with Feather River conveyed a peak flow nearly equal to the design flow. If Feather River above the confluence with Sutter Bypass were conveying the design flow, the high water mark profile in the vicinity of the confluence would be about 1.0 foot higher than the 1986 high water mark profile. (The rating curve for Feather River at Nicolaus, Figure 23, indicates a change in flow of 3,500 cubic feet per second for a 0.1-foot change in water surface elevation above the 1986 peak flood stage.) Because of wave action in this area, the 1986 high water mark profile is estimated to be 1.5 feet higher than a static water surface elevation in the vicinity of the confluence of Sutter Bypass and Feather River. Based on the above information, the design flow <u>can not</u> be conveyed within the design water surface in the immediate vicinity of the confluence for both the Sutter Bypass and Feather River levees (see Plate 7, channel miles 4 to 8).

The design flow and design water surface elevation of the Sacramento River at the Fremont Weir are 343,000 cubic feet per second and 37.3 feet, respectively (see Table 4). During the February 1986 flood event, the published peak flow (by the State) over Fremont Weir was 341,000 cubic feet per second, and the peak water surface elevation at the east end of the weir crest was 37.4 feet. It appears that the weir was generally functioning as designed within the limits of accuracy of the estimated flows and stages.



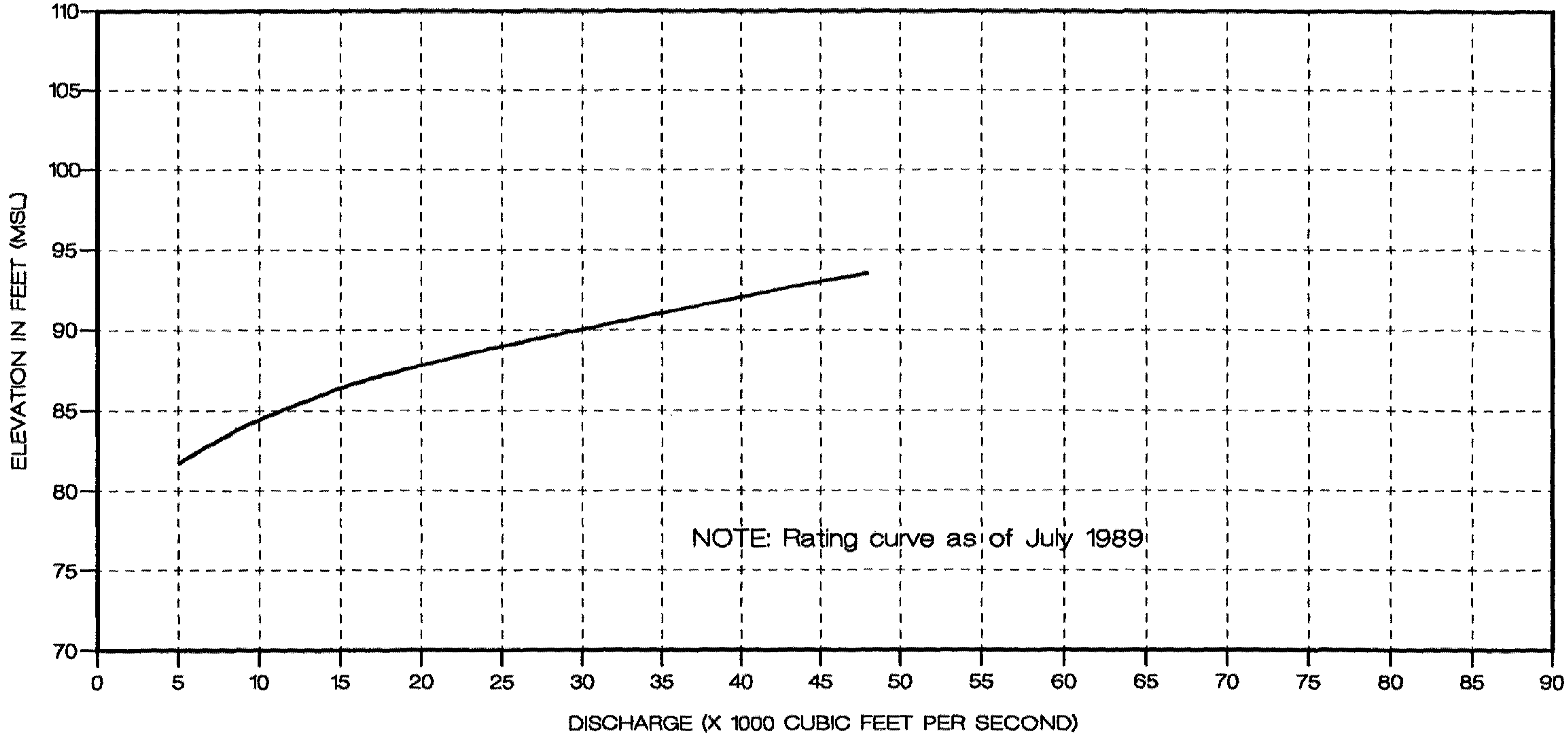
Sacramento River Flood Control
System Evaluation
Mid-Valley Area

RATING CURVE

SACRAMENTO RIVER BELOW WILKINS SLOUGH

Sacramento District, Corps of Engineers
May 1990

Figure 21



DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

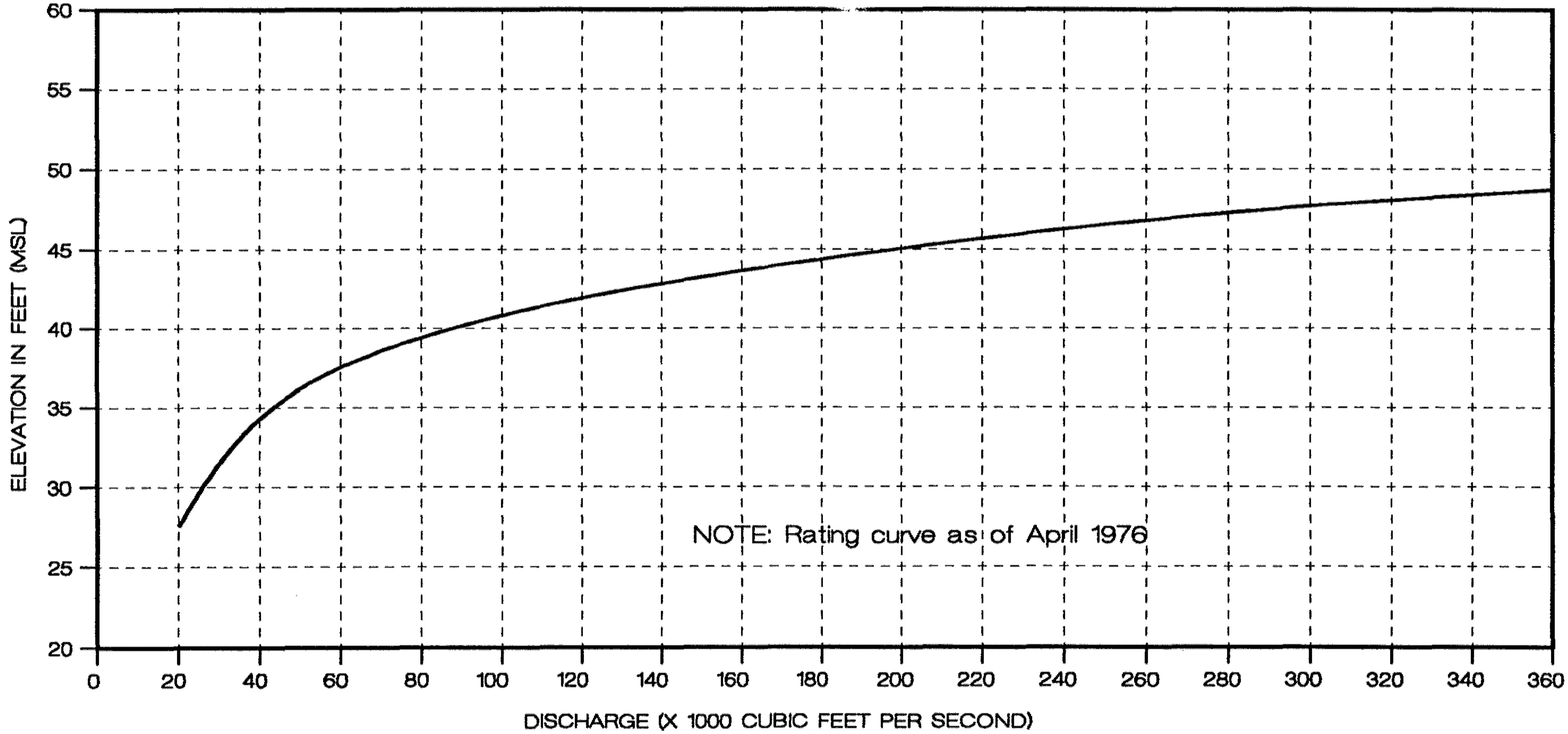
RATING CURVE
BEAR RIVER NEAR WHEATLAND

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 22

For the leveed channel reach of Sacramento River between Fremont Weir and Sacramento Weir, the design flow is 107,000 cubic feet per second. During the 1986 flood event, the peak flow determined by the U.S. Geological Survey at the Verona station (just downstream from the Natomas Cross Canal) was about 93,000 cubic feet per second (see Table 3). As indicated by Plate 4, sheets 3 and 4, the peak flow resulted in a high water mark profile higher in elevation than the design water surface for most of this reach. The rating curve of Figure 24 was applicable during the February 1986 flood event and was developed using flow measurements from the 1986 flood. Since the rating curve was developed using 1986 flow measurements, the curve should, in general, include the impacts of backwater conditions from the American River and Yolo Bypass. Based on this rating curve, only 90,000 cubic feet per second could be conveyed in this reach of the river at the design water surface.

In 1986 (following the February flood event), 1987, and 1991, the State (DWR) removed accumulated sediments near Fremont Weir (see Figure 19). Evaluations by the Corps of Engineers indicate that the sediment removal does not improve the flow conveyance over the weir during flood conditions. This is due to backwater conditions in the Yolo Bypass downstream from Fremont Weir. The hydraulic and hydrologic modeling efforts simulating existing conditions at the weir (with the sediment removed) were used in developing the stage-frequency relationships in the vicinity of and downstream from the weir. Under existing conditions, the 1986 water surface elevations correspond to a 60-year recurrence interval on Sacramento River near Knights Landing (Figure 6), a 50-year recurrence interval on the Sacramento River at Fremont Weir (Figure 7), a 60-year recurrence interval on the Sacramento River near the Natomas Cross Canal (Figure 8), a 50-year recurrence interval on the Sacramento River near Sacramento Bypass (Figure 9), and a 55-year recurrence interval on the Yolo Bypass just downstream from Cache Creek (Figure 14).

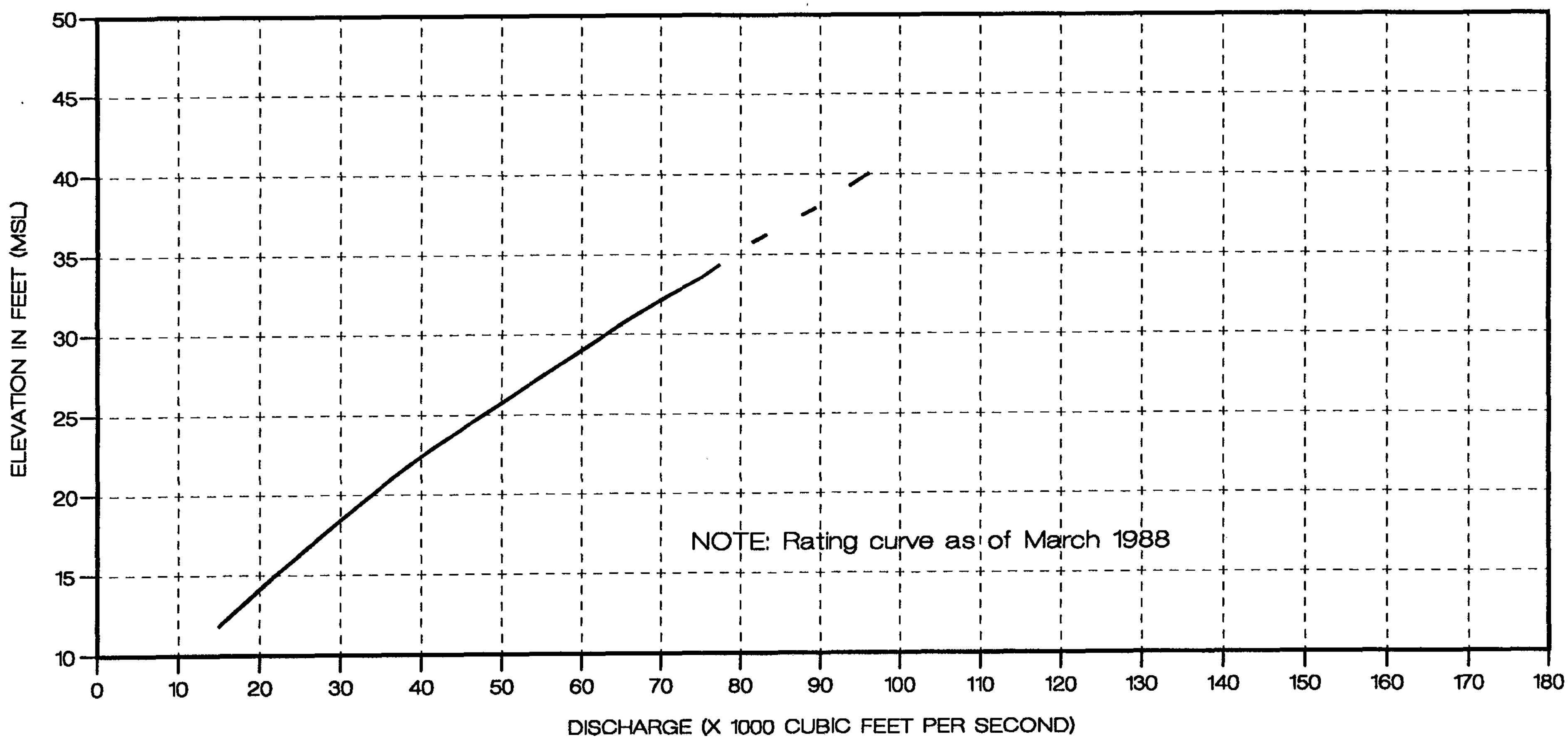


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

RATING CURVE
FEATHER RIVER AT NICOLAUS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 23



NOTE: Elevation recorded at Gage located at mouth of Natomas Cross Canal.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

RATING CURVE
SACRAMENTO RIVER AT VERONA

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 24

For the Yolo Bypass near Woodland (just downstream from the confluence with Cache Creek), the design flow and stage is 377,000 cubic feet per second and 31.3 feet, respectively. The 1986 peak flow and stage was 374,000 cubic feet per second and 31.4 feet, respectively (from published U.S. Geological Survey records), which suggests that this part of the Yolo Bypass was generally functioning as designed in February 1986 (within the limits of accuracy of the computed flows and stages). The rating curve of Figure 25 indicates that a 0.1-foot change in water surface elevation above the 1986 peak flood stage represents a change in flow rate of about 6,200 cubic feet per second in Yolo Bypass downstream from Fremont Weir. Based on the above, the computed flow rate could easily vary by 6,200 cubic feet per second with small changes in the plotted position of the rating curve.

For the gaging station Yolo Bypass near Lisbon (about 2.5 miles downstream from Putah Creek), the estimated peak flow during February 1986 was probably between 495,000 and 509,000 cubic feet per second (see Table 3), and the observed peak stage was 24.9 feet. The design flow and stage at this location are 490,000 cubic feet per second and 23.2 feet, respectively. The above suggests that Yolo Bypass in the vicinity of Lisbon conveyed between 5,000 and 19,000 cubic feet per second of floodwaters more than the design flow in 1986. Since the bypass can accommodate a significant amount of additional flow for a small increase in water surface elevation (as shown in the preceding analysis), the bypass in this reach <u>cannot</u> convey the design flow within the design water surface.

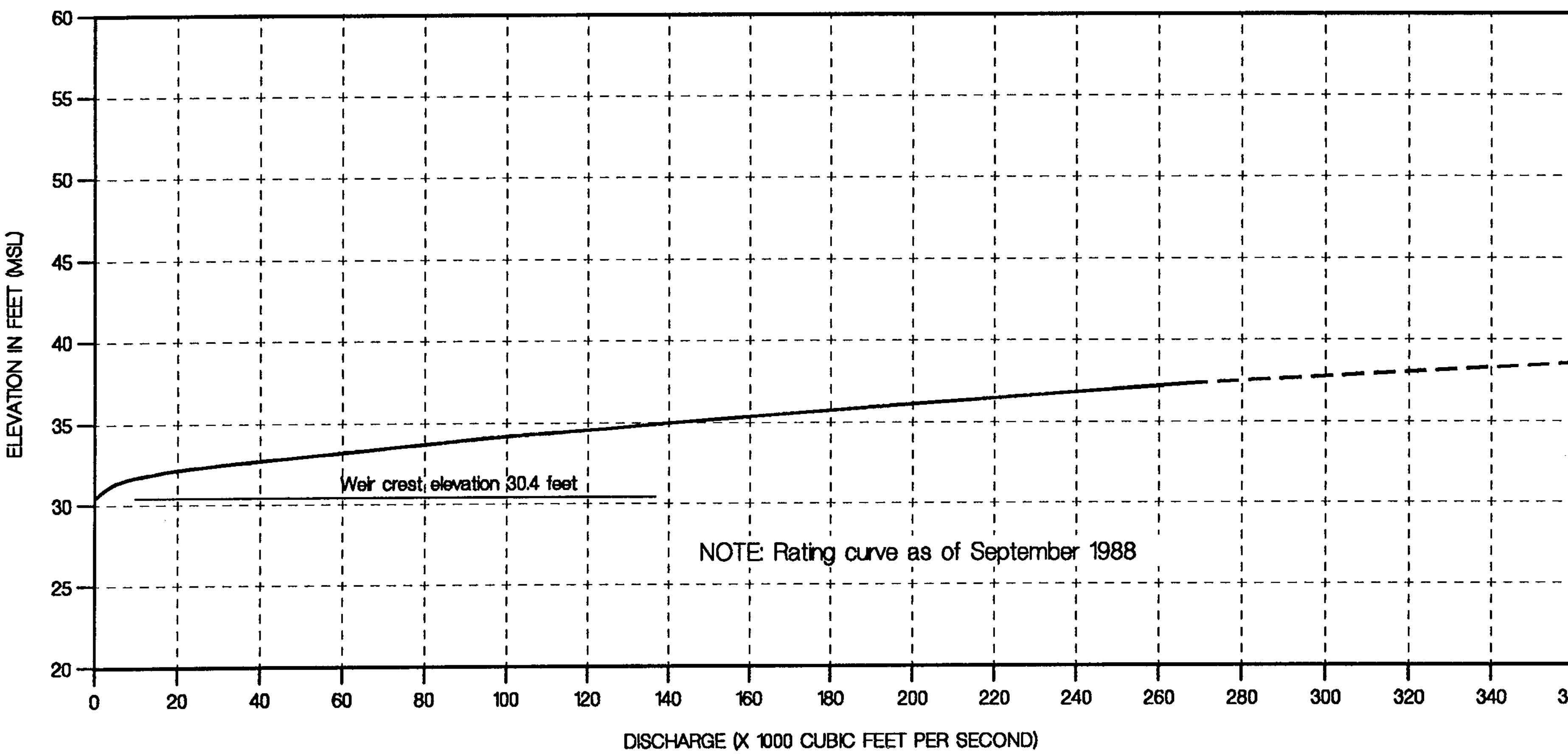
As discussed in the geotechnical reports and in the following sections, the slope stability analysis performed for selected levee cross sections was based on a peak flood stage of 3-day duration. (The phreatic surface elevations within the levee embankments were developed based on the assumption that the peak flood stage would remain at or near the design water surface for 3 days.) For the above analysis, stage hydrographs within the study area were plotted for the February 1986 flood event (see Figures 26 through 30). As indicated by the hydrographs, peak flood stages remained at or near the peak (within 1 to 3 feet depending on location) for a 3-day time interval with the exception of Bear River near Wheatland. For the Sacramento River, Sutter Bypass, and Yolo Bypass

(Figures 26, 27, 29, and 30) stage hydrographs, flood stages remained within 2 feet of the peak for a 3-day duration. Since the peak flows and stages at these locations were at or near design conditions, the 3-day duration assumption is appropriate for the Sacramento River, Sutter Bypass, and Yolo Bypass. For the Feather River above Sutter Bypass, the peak flow was less than the design flow. If the design flow existed in this reach of Feather River, a peak flood stage of 3-day duration is also considered appropriate. For the various tributary streams (such as Bear River, Dry Creek, Yankee Slough, Cache Creek, Willow Slough Bypass, Putah Creek, etc.), a design flood stage of 3-day duration is probably not warranted. If levee reconstruction is being considered for the levees on the tributary streams, phreatic surfaces would be determined based on a design flood of lesser duration. (A more detailed analysis of phreatic surfaces would be accomplished in future engineering and design efforts.)

Discharge versus elevation relationships were plotted for the gages, Sacramento River below Wilkins Slough, Bear River near Wheatland, Feather River at Nicolaus, Sacramento River at Verona, and Fremont Weir Spill to Yolo Bypass (data provided by the U.S. Geological Survey and DWR, as shown in Figures 21 through 25. Figures 21 (Sacramento River below Wilkins Slough) and 22 (Bear River near Wheatland) present rating curves generally appropriate for existing conditions as indicated by the applicable dates of June 1988 and July 1989.

These two rating curves also yield peak flows for the February 1986 flood event similar to those recorded in Table 3 for the peak flood stages observed at these locations. In addition, the tabulated rating curve data indicate that a 0.1-foot change in the water surface elevation above the peak flood stages in 1986 represents a change in flow rate of 125 cubic feet per second for Sacramento River below Wilkins Slough and 600 cubic feet per second for Bear River near Wheatland. (The above information was used as a guide in developing water surface profiles for Sacramento River downstream from Tisdale Bypass and Bear River for design conditions and for flood events greater than that which occurred in February 1986.) The last rating curve developed at the Nicolaus gage was in April 1976. That rating curve shown in Figure 23 indicates that a 0.1-foot change in water surface elevation above the 1986 peak flood stage represents a change in flow rate of about 3,500 cubic feet per second. (This curve is affected by flows in Sutter Bypass and is probably no longer applicable under existing conditions. A comparison of the rating curve value and the estimated peak flow in February 1986 suggests that channel degradation could be occurring in this levee reach.) Although the rating curves for Sacramento River at Verona, Figure 24, and Fremont Weir Spill to Yolo Bypass, Figure 25, were applicable during the February 1986 flood event, because of recent sediment removal at Fremont Weir (see Figure 19), the curves are no longer considered appropriate for the higher flood stages (flood stages at which floodwaters move over the weir).

The above information in conjunction with prior hydraulic and hydrologic models developed for the American River and Sacramento Metropolitan Area investigations was used in developing water surface profiles in the study area for design conditions and for flood events equal to or greater than that which occurred in February 1986.



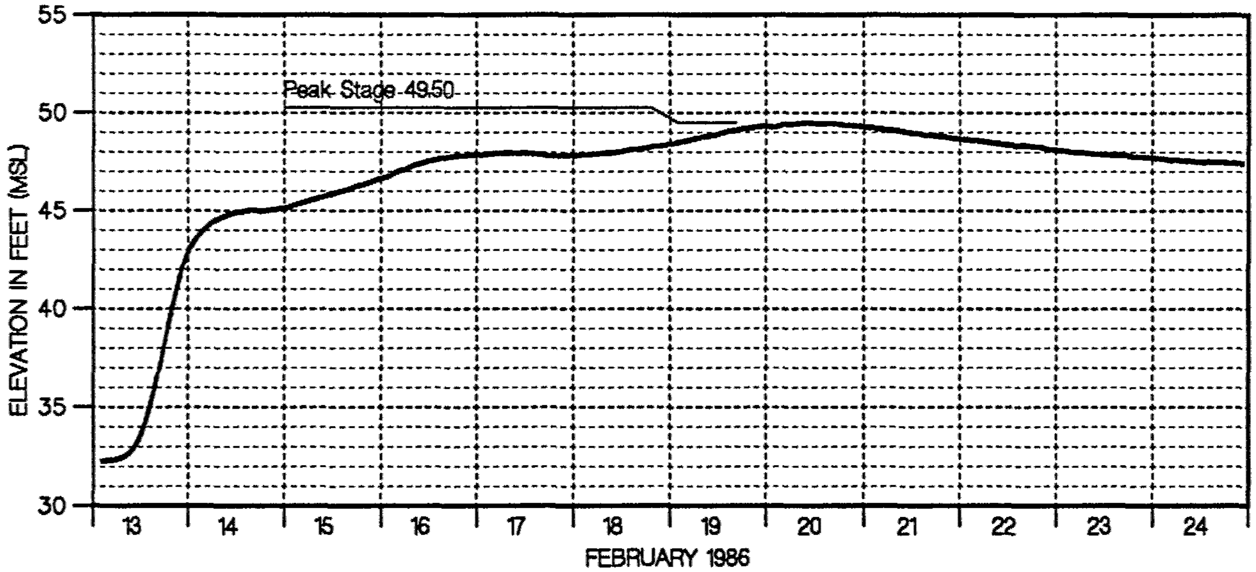
NOTE: Elevation recorded at Gage located 500 feet Upstream of West Abutment of Weir Structure.

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

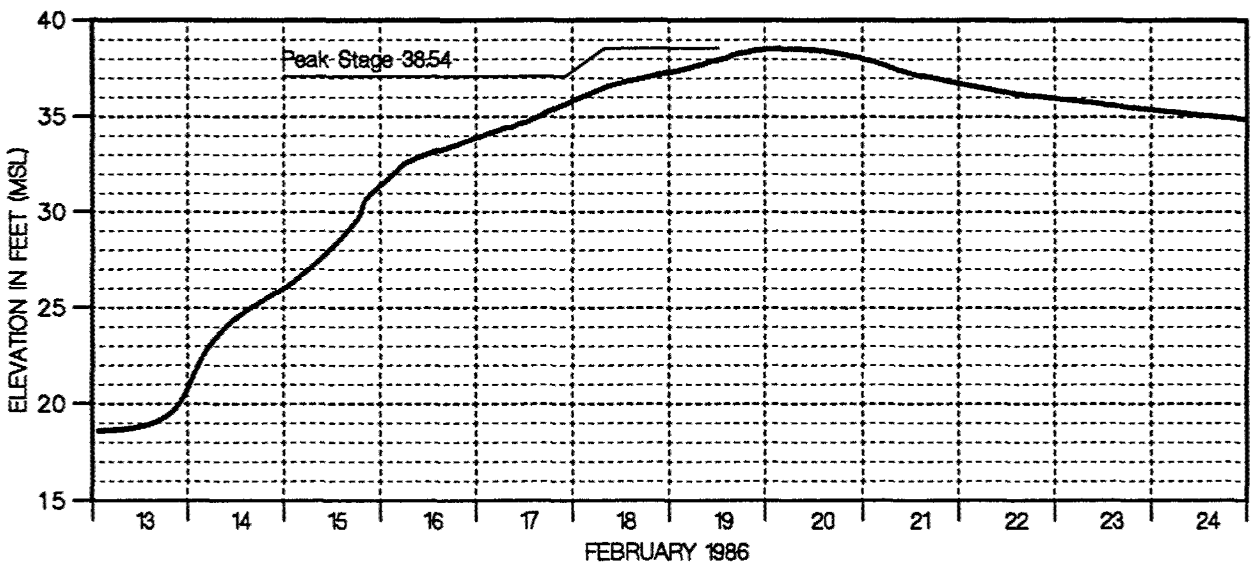
RATING CURVE
FREMONT WEIR SPILL
TO YOLO BYPASS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 25



SACRAMENTO RIVER AT WILKINS SLOUGH



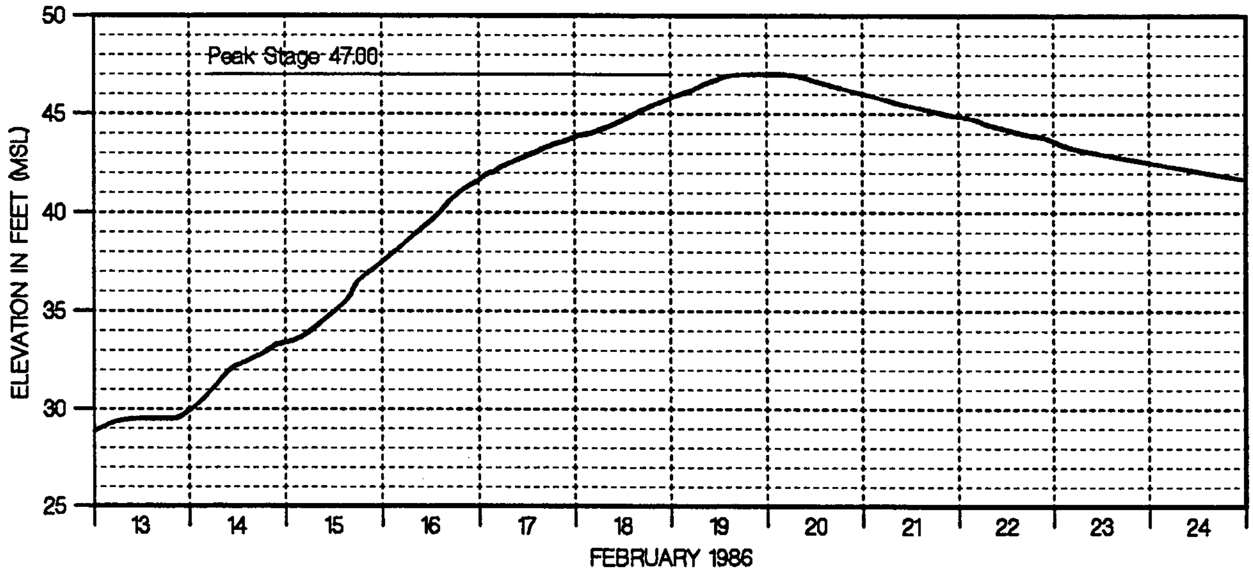
SACRAMENTO RIVER AT FREMONT WEIR (WEST END)

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

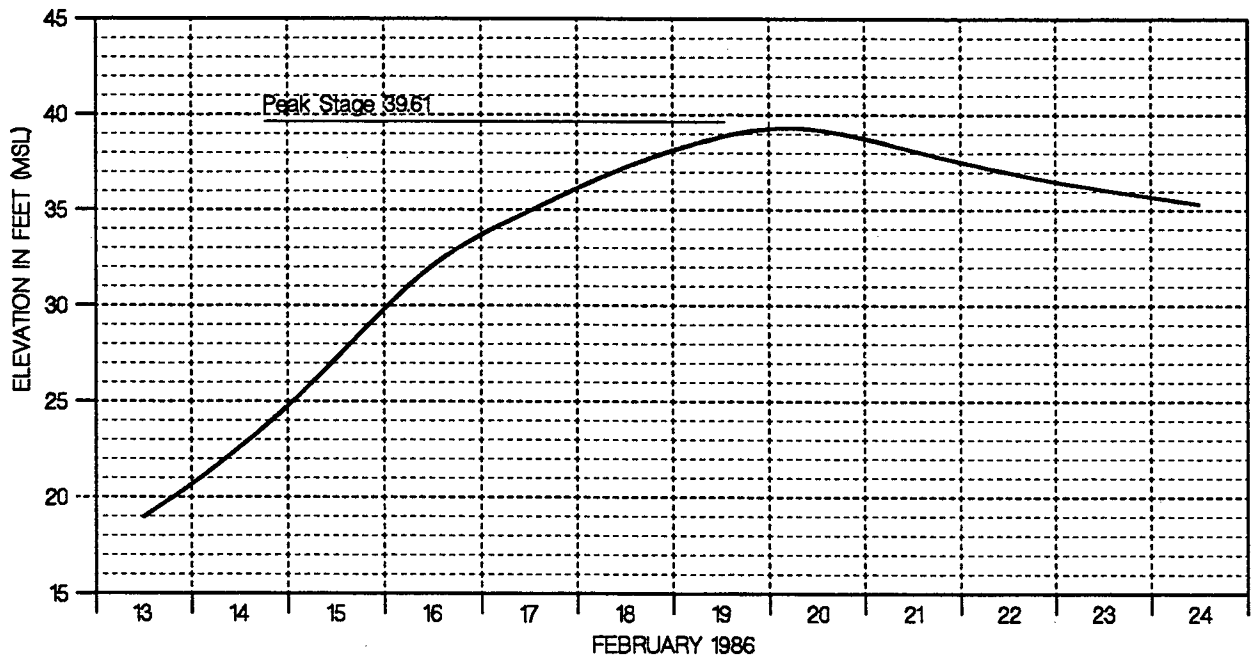
FEBRUARY 1986 FLOOD EVENT
STAGE HYDROGRAPH
SACRAMENTO RIVER AT
WILKINS SLOUGH AND FREMONT WEIR

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 26



SUTTER BYPASS AT TISDALE BYPASS



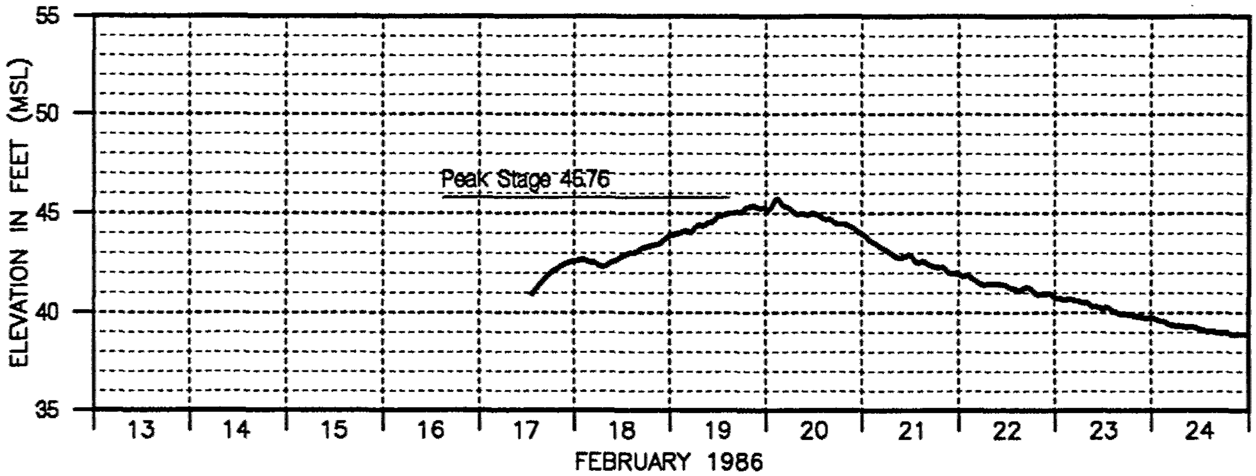
SUTTER BYPASS AT RD 1500

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

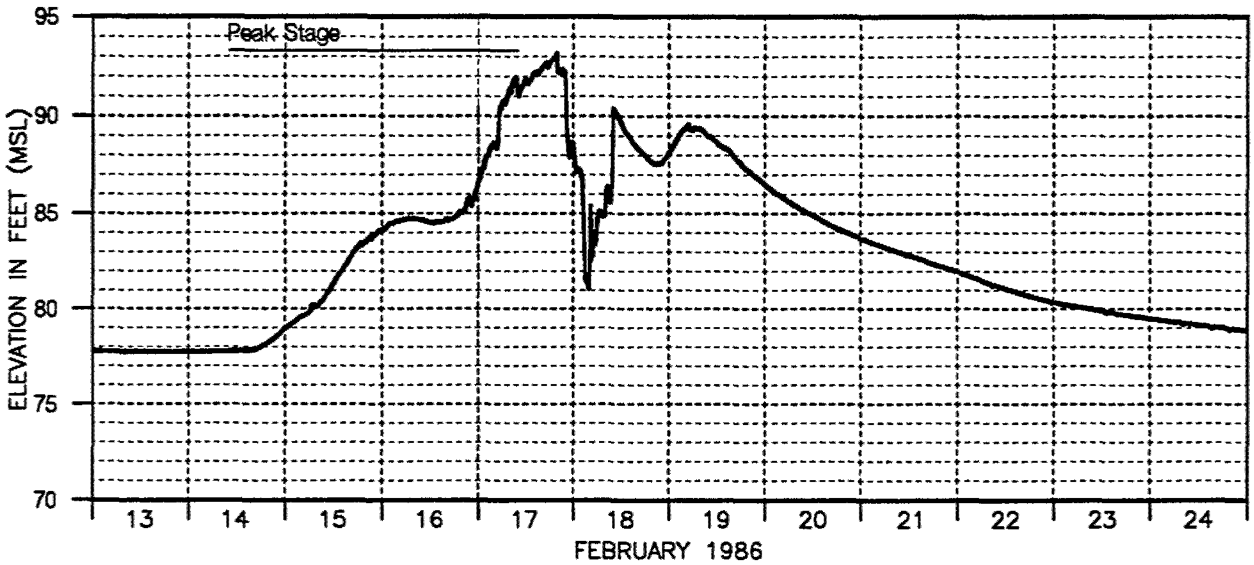
FEBRUARY 1986 FLOOD EVENT
STAGE HYDROGRAPH
SUTTER BYPASS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 27



FEATHER RIVER AT NICOLAUS



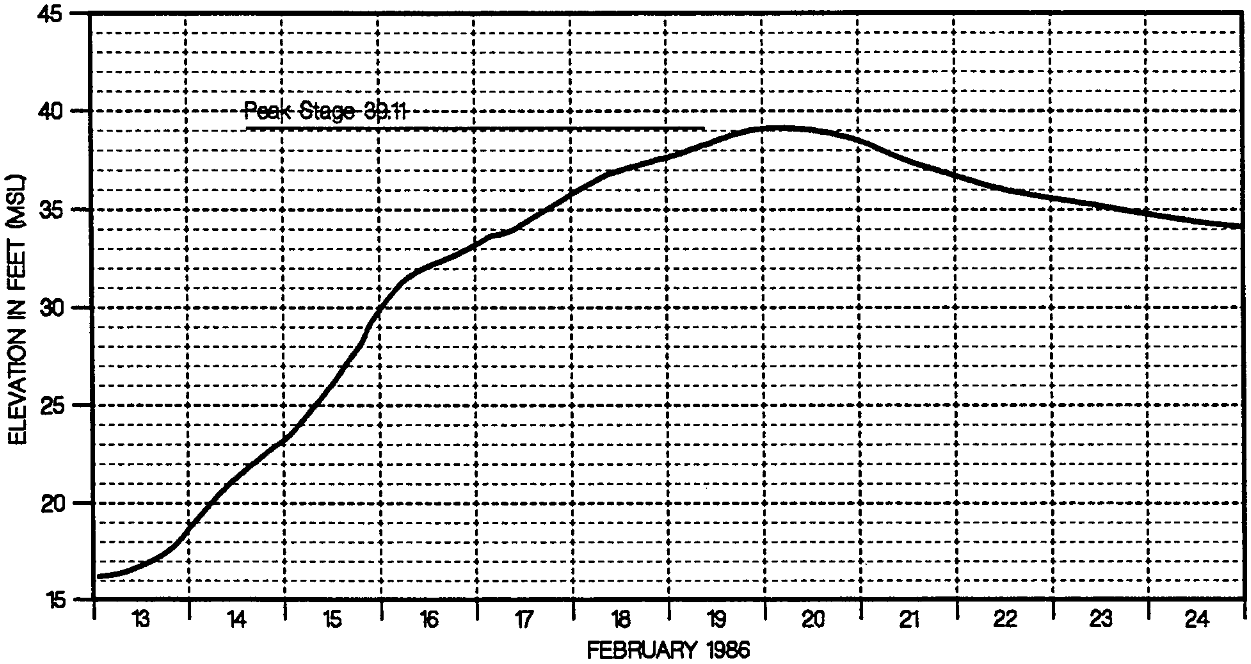
BEAR RIVER AT WHEATLAND

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

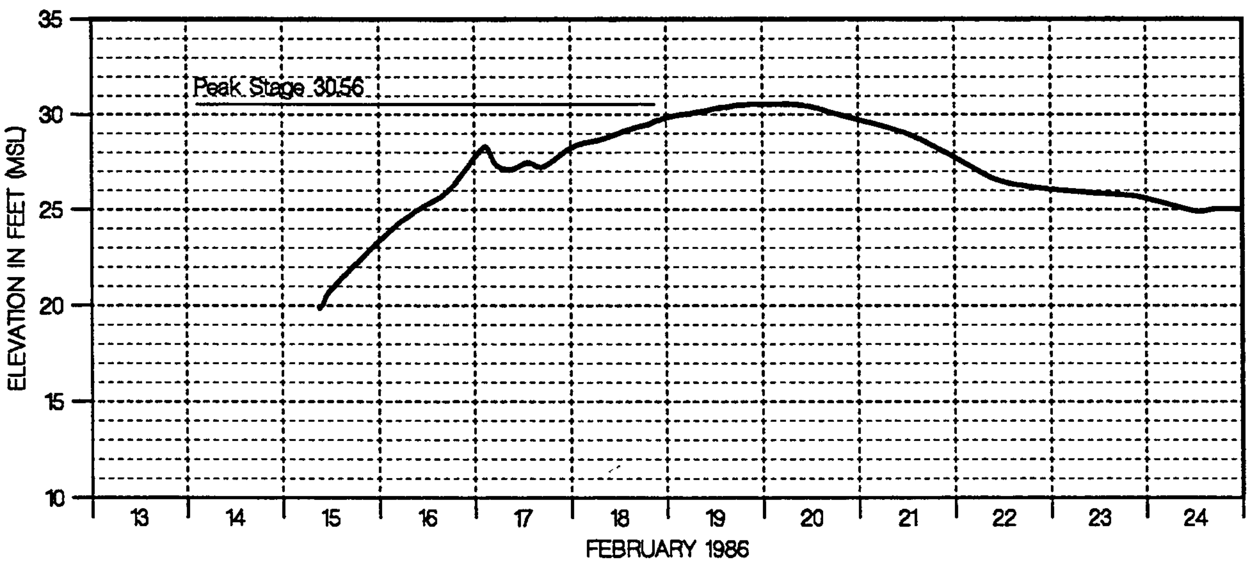
FEBRUARY 1986 FLOOD EVENT
STAGE HYDROGRAPH
BEAR AND FEATHER RIVERS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 28



SACRAMENTO RIVER AT VERONA



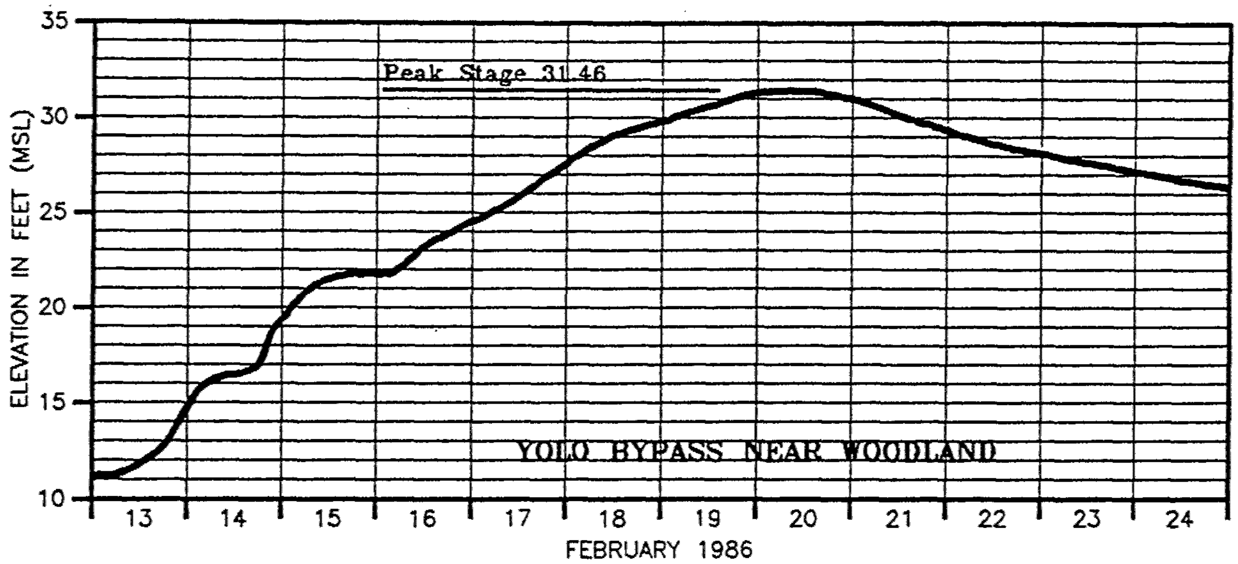
SACRAMENTO RIVER AT SACRAMENTO WEIR (NORTH WEIR)

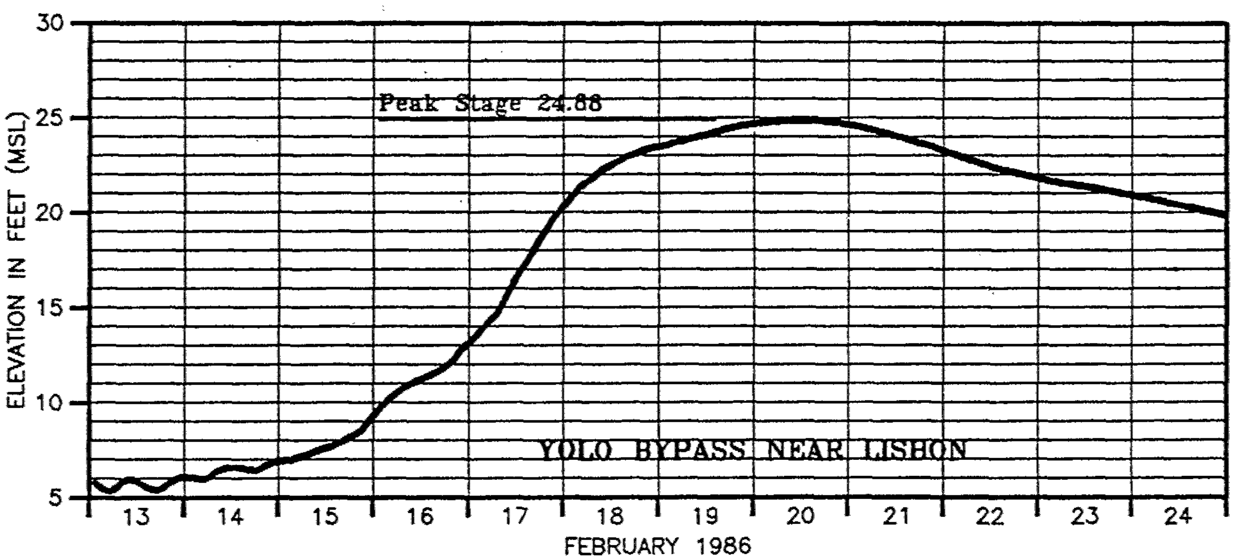
DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

FEBRUARY 1986 FLOOD EVENT STAGE HYDROGRAPH SACRAMENTO RIVER AT VERONA AND SACRAMENTO WEIR

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 29





Sacramento River Flood Control
System Evaluation
Mid-Valley Area

FEBRUARY 1986 FLOOD EVENT
STAGE HYDROGRAPHS
YOLO BYPASS

Sacramento District, Corps of Engineers
April 1990

Figure 30

CHAPTER 4 - LEVEE DESIGN CRITERIA

4.01. Levee Crown Profiles

Levee crown surveys were conducted during October and November 1989 by DWR personnel in cooperation with the Corps. Levee crown elevations are referenced to mean sea level datum. Levee crown stationing (and the design water surface profile) was based on "Levee and Channel Profiles," Corps of Engineers, March 1957.

Survey points were taken on the centerline of the levee crown every 500 feet and at breaks in the levee crown profile. Additional survey points were taken at railroad crossings, road crossings, power line crossings, Corps drill sites, and at other significant physical features. Levee crown profiles developed from the survey data are shown on Plates 4 through 14.

The profile plots indicate the non-uniformity in the levee crown surfaces in the study area. In addition, the plots indicate that many railroad and road crossings cut through the levee embankments at elevations 1 to 6 feet below the adjacent levee crown elevations.

4.02. Design Water-Surface Profiles

Design water surface profiles were developed for each levee reach of the Sacramento River Flood Control Project, as indicated by "Levee and Channel Profiles," Corps of Engineers, March 1957. Design water surface elevations were based on a specified design discharge (no recurrence interval or frequency was attached to that design discharge) and adopted concurrent conditions at the confluences of study area streams.

Project design flood planes were originally adopted by the March 1917 Flood Control Act as taken from House Document No. 81, lst Session, dated 1910. In 1923 corrections were made to House Document No. 81 where recomputation indicated changes should be made. In addition, changes were made to the recommended project because of significant increases in costs, local desires, and in an effort to utilize work which had already been done by locals in the interim. Revised values for project design flows and flood planes were established and included in the report "Flood Control in the Sacramento and San Joaquin Basins," printed as Senate Document No. 23, 69th Congress, 1st Session, 1926. This is the basic document authorizing the 1928 revision of the project. Since 1928, project design flows and water surface profiles have been reevaluated and modified based on available hydrologic information, more detailed hydraulic studies, and as various segments of the project were constructed. These revisions have been agreed to by The Reclamation Board, State of California, and the Corps of Engineers and published as "Levee and Channel Profiles, Sacramento River Flood Control Project," dated 15 March 1957.

The agreed to 1957 design water surface profiles are shown on Plates 4 through 14 and can be compared to the levee crown profile plots. As indicated in Table 2, 3 feet is the minimum authorized freeboard required on the Western Pacific Intercept Canal, Dry Creek, Yankee Slough, Bear River, Feather River (upstream from the confluence with Sutter Bypass), Natomas Cross Canal, Coon Creek Group Interceptor (East Side Canal), Sacramento River, Knights Landing Ridge Cut, Cache Creek, Willow Slough Bypass, and Putah Creek; 5 feet is the minimum freeboard required on Sutter Bypass and Tisdale Bypass; and 6 feet is the minimum freeboard required on Sacramento Bypass and Yolo Bypass to meet design requirements for the flood control project levees. An inspection of the profile plots indicates that there is not adequate design freeboard on Yolo Bypass between channel miles 44 and 50 and in the vicinity of channel mile 56 on the left bank levee. (This left bank levee of Yolo Bypass within the study area has a history of subsidence. Early reports indicate that portions of the levee embankment were constructed on tule marshes.) The west levee (right bank levee) of Yolo Bypass also has inadequate design freeboard between channel miles 50 and 52, but this portion of the levee would be modified and raised under the recently authorized Corps of Engineers project for flood control, Cache Creek Basin (see Design Memorandum No. 1, "Cache Creek Basin, California," Corps of Engineers, January 1987). In addition, there is not adequate design freeboard on Sacramento Bypass in the vicinity of channel mile 0, north side.

Although railroad and road crossings do not meet minimum design freeboard requirements, local levee maintaining agencies should have operational procedures for sandbagging or for installing flood gates at these locations during high flood stages.

4.03. February 1986 High Water Mark Profiles

During and immediately following the February 1986 flood event, personnel from the DWR staked high water marks along the levee embankments of the Feather River from the confluence with the Sacramento River to Honcut Creek (near the upstream limits of the flood control project levees) and the Bear River from the confluence with the Feather River to the Western Pacific Intercept Canal. The high water marks were surveyed by DWR personnel and referenced to the mean sea level datum. Similarly, the Corps of Engineers staked and surveyed high water marks along the east levee embankment of Yolo Bypass only and the north levee embankment of Sacramento Bypass. The U.S. Geological Survey developed a peak water-surface profile (see references included under U.S. Geological Survey in Table 1) along Sacramento River which was used for the study reach between Verona and the Sacramento Bypass. In addition, gaged data from Table 3 were also used for the study area, and other high water mark observations were obtained from various State and local entities (in particular, the Northern District Office of the DWR provided high water mark information for Knights Landing Ridge Cut, and R.D. 1500 provided flood stage data for Sacramento River and Sutter Bypass in their area of responsibility).

Based on the above information, high water mark profiles of the February 1986 flood were developed for the study area levee reaches, as shown on Plates 4 through 18. The high water mark profiles include the streamflow data from gages operated by the U.S. Geological Survey and DWR. The gaged data (because of the types of devices used, such as pressure manometers, stilling wells, etc.) generally represent a water surface elevation that would be consistent with a static water surface or a static water surface plus wind setup. The gage devices essentially dampen out any wave action that might be occurring on the water surface. High water mark stakes were generally placed where a debris line was evident on the levee embankment slopes (see Figure 4). In river reaches where wave action is not significant, the debris line elevations are probably similar to water surface elevations observed at the gaging stations. Where large expanses of floodwaters exist (such as Sutter and Yolo Bypasses) or where the wind direction generally coincides with the stream channel, wave action can be significant and can create a debris line that is significantly higher than the observed gaging station elevations. The Feather River at Nicolaus gage reading (near Highway 99) is lower than the adjacent upstream and downstream high water marks determined from debris lines (see Plate 7, about channel mile 10). This difference can probably be attributed to wave action and will be considered when making design recommendations for modifications of levee embankments on the lower reach of Feather River and on Sutter and Yolo Bypasses.

Since surveyed high water marks are available for the east levee of Yolo Bypass only, those marks may not be representative of debris lines (see Figure 4) that occurred on the west levee of the bypass. The impact of wave action on debris lines would be different between the east and west levee embankments. In addition, because of the width and alignment of the bypass, judgment was required when transferring high water marks from the east levee to the west levee and in evaluating the impact of wave action.

A comparison of the February 1986 high water marks and the design water surface profiles indicates that flood stages were about equal to or exceeded designs on Sacramento River, Sutter Bypass, Yolo Bypass, Feather River between channel miles 0 and 9, Tisdale Bypass, Knights Landing Ridge Cut between river miles 0 and 4, Natomas Cross Canal, and Sacramento Bypass. In other levee reaches of the study area, the 1986 high water marks were 1 to 12 feet below the corresponding design water surface profiles.

4.04. Design Freeboard

The freeboard specified for the Sacramento River Flood Control Project levees is the minimum vertical elevation difference required between the design water surface and top of levee. The minimum freeboard required on the Western Pacific Intercept Canal, Dry Creek, Yankee Slough, Bear River, Feather River (upstream from the confluence with Sutter Bypass), Natomas Cross Canal, Coon Creek Group Interceptor (East Side Canal), Sacramento River, and Knights Landing Ridge Cut is 3 feet; the minimum freeboard required on Sutter Bypass and Tisdale Bypass is 5 feet; and the minimum freeboard required on Sacramento Bypass and Yolo Bypass to meet design requirements for the flood control project is 6 feet (see Table 2).

About 7 miles of levee embankment have deficient design freeboard, ranging up to a maximum of 4 feet, as shown in Table 5. The reason (or reasons) the levee embankments have deficient design freeboard in the above reaches is not known. As indicated by "Levee and Channel Profiles," Corps of Engineers, March 1957, the levee crown profiles had the minimum design freeboard required at that time (1957). A comparison of the 1957 levee crown profiles and those shown in Plates 4 through 14 does indicate significant changes in the locations of grade changes, low sections, and general shape.

Levee height restoration required for Yolo Bypass, left bank, is located in levee reaches where levee embankment subsidence and slippage have occurred in the past. Early reports indicate that portions of the east levee of Yolo Bypass were constructed on tule marshes. It is possible that marsh material in the foundation has consolidated over time, resulting in lower levee crown elevations today.

4.05. Levee Height Restoration

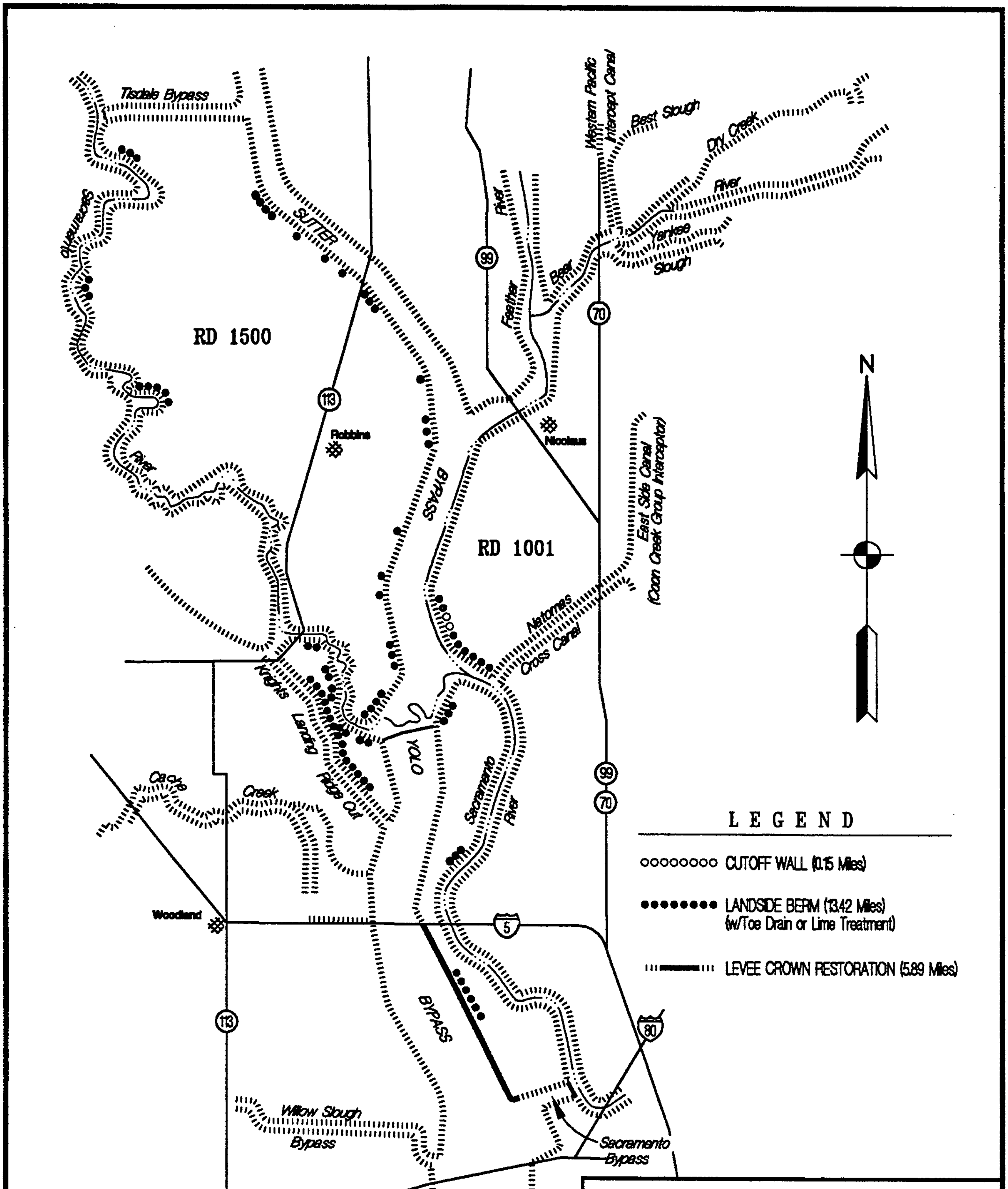
The design of the Sacramento River Flood Control Project (SRFCP) was based on surveys and data from the flood of March 1907, which was the largest general flood in the Central Valley for which measurements are recorded.

The SRFCP design was based on three criteria: (1) design discharge or channel capacity, (2) design water-surface profile, and (3) minimum freeboard above the design water-surface profile.

Table 3 - Peak Flows and Stages February 86 flood event

Location	Time (date/hours)	Elevation (msl)	Flow (cfs)
Bear River near Wheatland	Feb 17/2000	93.52	48,000
Feather River at Nicolaus	Feb 20/0230	45.76	285,000 1/
Sutter Bypass at R.D. 1500	Feb 20/0415	39.61	
Sacramento River at Tisdale Weir	Feb 20/0945	49.66	
Sacramento River below Wilkins Slough	Feb 20/1350	49.50	32,700
Sacramento River at Knights Landing	Feb 20/0800	40.39	
Colusa Basin Drain at Knights Landing	Feb 21/0300	35.94	
Sacramento River at Verona	Feb 20/0215	39.11 2/	92,900
Sacramento River Fremont Weir Spill	Feb 20/0300	38.54 3/	341,000
Yolo Bypass near Woodland	Feb 20/0745	31.46	374,000
Sacramento River Sacramento Weir Spill	Feb 20/0115	30.56 4/	127,680
Cache Creek at Yolo	Feb 17/2245	80.36	26,100
Putah Creek near Winters	Feb 20/1545		6,630
South Fork Putah Creek near Davis	Feb 20/1745	41.96	
Yolo Bypass near Lisbon	Feb 20/1330	24.88	495,000 to 509,000 (estimated)

1/ Estimate by the Corps of Engineers based on flood routing studies.
2/ Elevation recorded at mouth of Natomas Cross Canal.
3/ Elevation recorded 550 feet upstream of west end of Fremont Weir on Sacramento River.
4/ Elevation recorded 550 feet upstream of Sacramento Weir on Sacramento River.



DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

GENERAL LOCATION
LEVEE RECONSTRUCTION

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 31

"Design Levels" addressed in the SRFCP evaluation were based only on design grade and freeboard and not flow frequency. This means that the SRFCP was evaluated to determine if the project could safely pass the design flow within the design water-surface profile. Although geotechnical considerations were a major component of the evaluation, the significant hydrologic uncertainty associated with rare flood events, such as the March 1907 flood, dictated that deficiencies in design freeboard be evaluated and restored where economically justified to ensure that the SRFCP was functioning as intended.

There are several levee reaches in the study area with deficient design freeboard as authorized and approved by Congress for the SRFCP (Table 5). The freeboard is provided to ensure that the desired degree of protection will not be reduced because of wave runup on the levees and unforeseen embankment settlement (reconsolidation) and slippage as experienced along the levees in the study area in the past.

Reestablishing the minimum freeboard on the levee crown profiles (Plates 4 through 14) in the reaches identified as being deficient and comparing them with the water-surface profile plots will show that some of the levee height restoration cannot be economically justified because it will not increase the level of flood protection in the flood hazard area. Only one reach at Yolo Bypass has been identified as being in need of levee height restoration—1.2 miles, left levee between channel miles 44 to 48 .

4.06. Design Flow

As indicated below and in the section on Hydrology, the design flow <u>could not</u> be conveyed within the design water surface in the Tisdale Bypass, in the Sutter Bypass and Feather River in the vicinity of the confluence of the Feather River and Sutter Bypass, in the Natomas Cross Canal, in the Sacramento River between Fremont Weir and Sacramento Weir, and in the Yolo Bypass south of Interstate 80 (based on information available from the February 1986 flood event and information developed for this investigation and for the American River Watershed and Sacramento Metropolitan Area Investigations). Since the

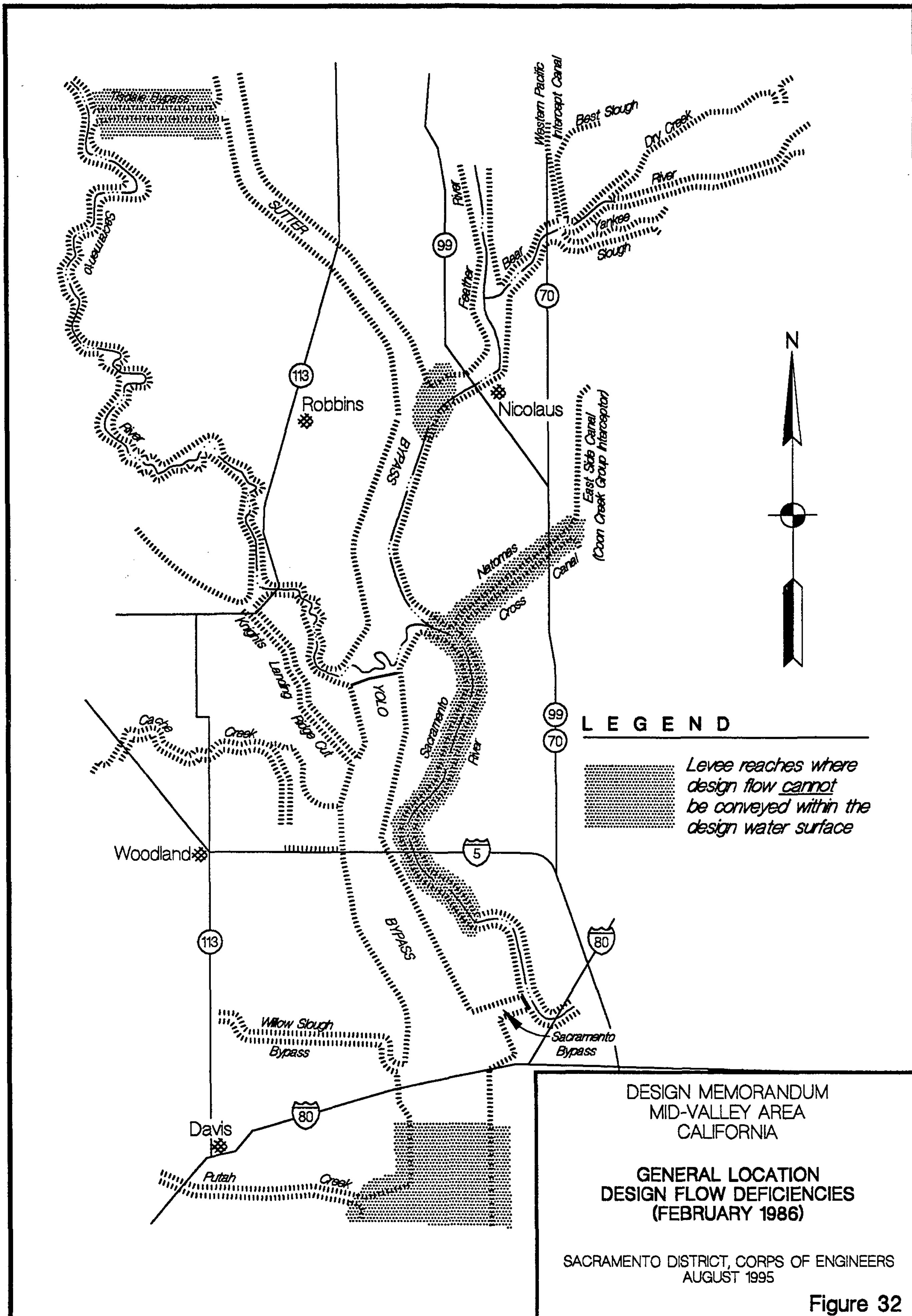
February 1986 flood event, significant physical changes have occurred that will probably eliminate or minimize the extent of the cited levee reaches with design flow deficiencies.

Levee reaches that could not convey the design flow within the design water surface in February 1986 are shown in Figure 32. For Tisdale Bypass, the computed flows during the February flood event indicate that the bypass cannot convey the design flow within the design water surface (computed flows are only approximate because rating curves for Tisdale Weir are affected by submergence and backwater from Sutter Bypass). Although the bypass was deficient in flow conveyance, both the Sacramento River and Sutter Bypass downstream from Tisdale Bypass conveyed the design flow and more within the design water surface in 1986. Since the 1986 flood event, the State (DWR) has cleared and removed about 1,500,000 cubic yards of deposited material from the bypass. Because of the sediment removal, because both the Sacramento River and Sutter Bypass downstream from Tisdale Bypass did convey the design flow within the design water surface (in February 1986), and because more than 5 feet of freeboard existed on the bypass levees during the peak 1986 flood stage (see Plate 8), no remedial measures appear necessary at this time to correct for any potential flow deficiency within Tisdale Bypass. Future efforts, though, should concentrate on monitoring and evaluating the impacts of sediment removal on flow conveyance and flood stages in the bypass.

As indicated in the "Initial Appraisal Report, Marysville/Yuba City Area," January 1990, the design flow would exceed the design water surface on the east levee of Sutter Bypass and the north levee of Feather River near the confluence of the Sutter Bypass and Feather River. Although Sutter Bypass just upstream from the confluence with the Feather River conveyed a peak flow nearly equal to the design flow (see section on Hydrology), Feather River just upstream from Sutter Bypass conveyed an estimated peak flow of 285,000 cubic feet per second (compared to a design flow of 320,000 cubic feet per second, as shown in Table 4). If Feather River were conveying the design flow, the high water mark profile in the vicinity of the confluence would be about 1.0 foot higher than the 1986 high water mark profile (the rating curve for Feather River at Nicolaus, Figure 23, indicates a change in flow of 3,500 cubic feet per second for a 0.1-foot change in water surface elevation above the 1986 peak flood stage). Because of wave action in this area, the 1986 high water mark profile is estimated to be 1.5 feet higher than that shown (1.5

feet higher than the static water surface elevation) in the vicinity of the confluence of Sutter Bypass and Feather River. Based on the above information, the design flow cannot be conveyed within the design water surface in the immediate vicinity of the confluence for both the Sutter Bypass and Feather River levees. However, the levee reaches shown on Figure 32 (which cannot convey the design flow within the design water surface) have adequate freeboard to convey design flows with the minimum required design freeboard except for one localized area as shown on Plate 7, sheet 1 of 1 (the localized area is located at the junction of the left bank levee of Feather River and Sutter Bypass).

For the leveed channel reach of Sacramento River between Fremont Weir and Sacramento Weir, the design flow is 107,000 cubic feet per second. During the 1986 flood event, the peak flow determined by the U.S. Geological Survey at the Verona station just downstream from the Natomas Cross Canal was about 93,000 cubic feet per second (see Table 3). As indicated by Plate 4, sheets 3 and 4, the peak flow resulted in a high water mark profile higher in elevation than the design water surface for most of this reach. (Backwater conditions from the American River and Yolo Bypass can influence stages in the Sacramento River upstream from the Sacramento Bypass. In 1986, though, peak flood stages in the American River were less than the specified design conditions, and in Yolo Bypass in the vicinity of Sacramento Bypass the design flow was conveyed at the design water surface.) The rating curve of Figure 24 was applicable during the February 1986 flood event and was developed using flow measurements from the 1986 flood. The highest flow measurement in 1986 was about 75,000 cubic feet per second. Since the rating curve was developed using 1986 flow measurements, the curve should, in general, include the impacts of backwater conditions from the American River and Yolo Bypass. Based on this rating curve, about 90,000 cubic feet per second could be conveyed in this reach of the river at the design water surface elevation. For the design flow of 107,000 cubic feet per second, the extension of the rating curve indicates that this flow would overtop the levee embankment system on both the west and east levees of the Sacramento River in the vicinity of the rating cross section (the rating cross section is located about 2,700 feet downstream from the confluence with the Natomas Cross Canal).



DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

GENERAL LOCATION
DESIGN FLOW DEFICIENCIES
(FEBRUARY 1986)

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 32

Because this reach of the Sacramento River between Fremont Weir and Sacramento Weir could not convey the design flow within the design water surface in 1986, it is possible that the channel has been aggrading (sediments accumulating on the channel bottom over time), thereby reducing the conveyance capacity. A comparison of the rating curves developed by the U.S. Geological Survey for the Sacramento River at Verona over time (see Figure 33) indicates a trend in which the rating curve has continually shifted to the right. This trend is apparent throughout the range of observed flows and reveals that the conveyance capacity in this area has increased over the time interval indicated in the legend. The increased capacity is attributed to channel degradation, probably a combination of bottom scour and channel enlargement. The trend has been significant when considering a flow of 70,000 cubic feet per second, as shown in Table 4. The rating curve data indicate that in 1956 this section of the river had significantly less capacity than it does now.

TABLE 4

RATING CURVE DATA
SACRAMENTO RIVER AT VERONA

Rating Curve (years)	Stage (feet above mean sea level)	Flow (cfs)
1956-68	35.3	70,000
1968-69	34.6	70,000
1970-76	33.3	70,000
1986	32.4	70,000

Since flow in the Natomas Cross Canal is influenced by flood stages in the Sacramento River in the vicinity of the Verona station, the canal cannot function as designed, either. Hydrologic modeling efforts under the American River Watershed Investigation estimated peak flows in the canal in 1986 to be significantly less than the design flow of 22,000 cubic feet per second shown in Table 4. (The 1986 high water mark profile is shown on Plate 10.)

In 1986 (following the February flood event), 1987, and 1991, the State (DWR) removed accumulated sediments near Fremont Weir (see Figure 19). Evaluations by the DWR and Corps of Engineers indicate that the sediment removal would improve flow conveyance over the weir and could significantly reduce flood stages along the Sacramento River from the Fremont Weir downstream to the Sacramento Weir. Because of the sediment removal at Fremont Weir (in addition to other physical changes including sediment removal in Colusa Bypass and Sediment Basin and Tisdale Bypass), new rating curves need to be developed by the U.S. Geological Survey for the gaging station on the Sacramento River at Verona and by DWR for the Fremont Weir spill. (The new rating curves need to be developed from frequent flow measurements during a period in which there is a significant and sustained flow over the weir.) A comparison of these rating curves with those shown in Figures 24 and 25 should indicate the changes in the flow regime resulting from sediment removal at the weir. (Since no significant floodwaters have been conveyed over Fremont Weir since the flood event of February 1986, no new rating curves have been developed at the above stations.) Once the new rating curves have been developed, the DWR in cooperation with the Corps should make the necessary evaluations to determine whether or not design flow deficiencies still exist in the Sacramento River between the Fremont Weir and Sacramento Weir and in the Natomas Cross Canal.

For the gaging station Yolo Bypass near Lisbon (about 2.5 miles downstream from Putah Creek), the estimated peak flow during February 1986 was probably between 495,000 and 509,000 cubic feet per second (see Reconnaissance Report, "Sacramento Metropolitan Area, California" Corps of Engineers, February 1986 for the computation of peak flow), and the observed peak stage was 24.9 feet. The design flow and stage at this location are 490,000 cubic feet per second and 23.2 feet, respectively. The above suggests that the Yolo Bypass in the vicinity of Lisbon conveyed between 5,000 and 19,000 cubic feet per second more than the design flow in 1986. The bypass can accommodate a significant amount of additional flow for a small increase in water surface elevation, indicating that Yolo Bypass in this reach <u>cannot</u> convey the design flow within the design water surface elevation. As shown on Plate 6, sheet 2 of 2, the high marks plot above the design water surface, but these high water marks (surveyed debris lines) are impacted by wave action. The high water marks shown between the locations of the

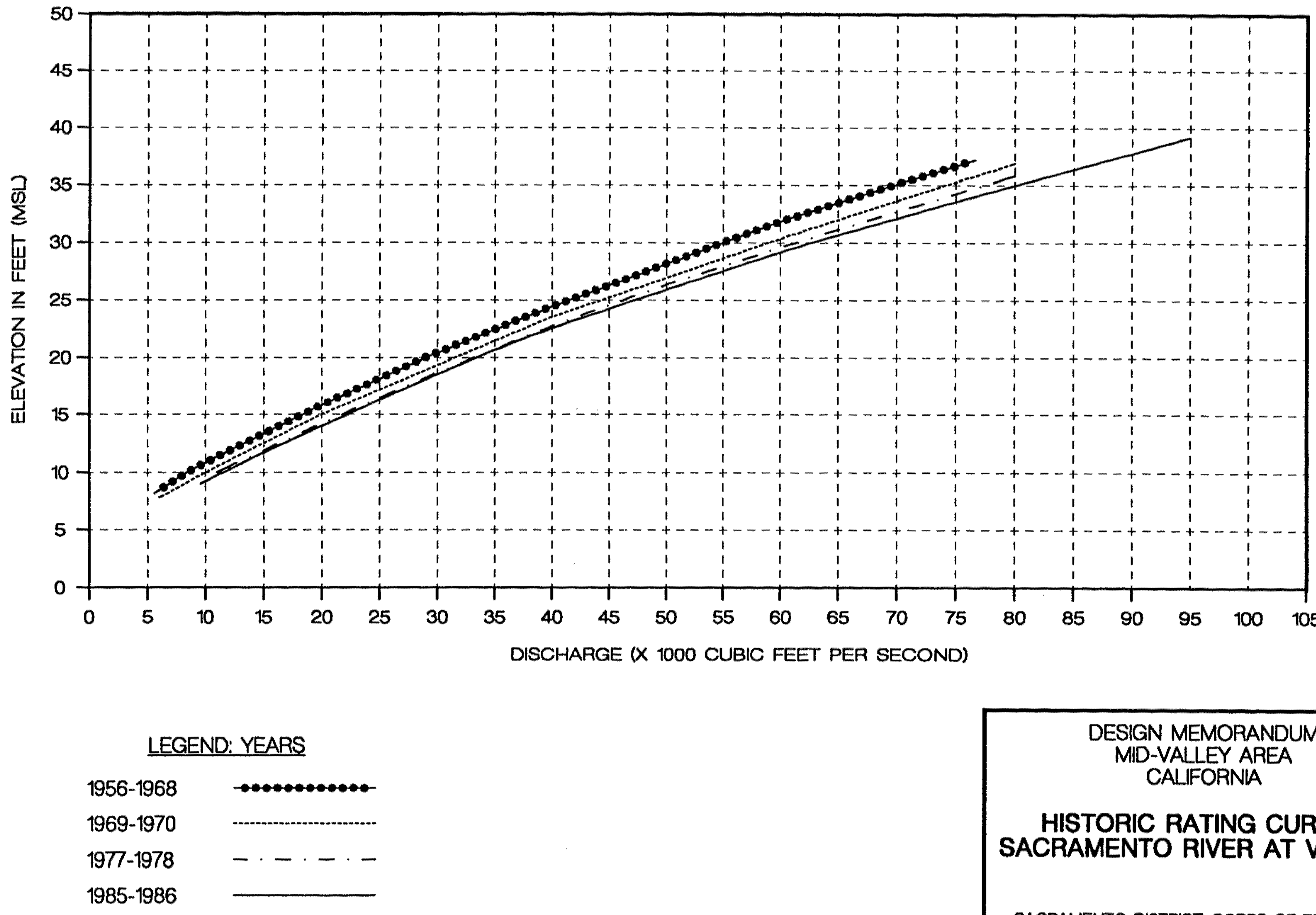
Southern Pacific Railroad and Interstate 80 were located in an area that observers agreed had little or no wave action that would impact debris line observations. These high water marks are probably more representative of a static water surface than the others shown. Since the 1986 peak stage observation of 24.9 feet at Lisbon represented a static water surface plus wind setup (wind setup estimated at 0.1 to 0.3 feet), the 1986 peak stage at this location (for a static water surface) would probably be between 1.0 and 2.0 feet above the design water surface, depending on the wind direction at the time of observation. The high water mark observations between the Southern Pacific Railroad and Interstate 80 suggest that only a small elevation difference might exist between the 1986 peak stages (for a static water surface) and the design water surface. Based on previous flow measurements, hydrologic modeling efforts, and the rating curve shown in Figure 25, about 8,000 cubic feet per second of additional flow can be conveyed in this reach of the bypass with a 0.1-foot rise in water surface elevation above the 1986 peak flood stage. Based on the above, the design flow <u>cannot</u> be conveyed within the design water surface in the Yolo Bypass between Interstate 80 and the downstream limit of the study.

4.07. Recurrence Intervals

Levels of flood protection provided by a levee embankment are difficult to estimate. The physical condition of a levee can change with time based on past forces acting on the embankment. Major flood events can alter surface and subsurface conditions because of erosion, seepage, and piping. Maintenance practices can alter surface conditions. Development and agricultural practices can modify adjacent land surface and subsurface conditions. Many other factors can modify the existing condition of the levee embankment, including high ground water levels, prior soil saturation due to rainfall and wave action, and levee embankment erosion.

As discussed in the Initial Appraisal Report for the Marysville-Yuba City Area, peak flood stages on the Yuba River in the vicinity of the 1986 levee break were higher for the 1955 and 1964 flood events when there were no levee breaks in this area. Although the peak flood stage of the 1955 flood event was higher than in 1986, the shapes of the stage hydrographs were similar. What physical conditions of the levee embankment were different in 1986 (than in 1955 and 1964) to cause a levee break is not fully known. The Yuba River levee break occurred after floodwaters started to recede and with 8 to 10 feet of freeboard. At the time of the levee break, the flood stage was about 8 feet above the adjacent land surface (landward of the levee embankment). In the case of Yankee Slough, the north levee failed during the 1986 flood event with 7 to 8 feet of freeboard and a relatively low level of water on the levee embankment. The failure was a sudden blowout which widened to about 200 feet. Many similarities exist between the levee embankments on this stream and adjacent levees evaluated in this investigation.

In addition to the above, flood fight efforts were required during the February 1986 flood to prevent potential failure of the west levee of Sutter Bypass (see Figure 3 and Plate 3) just downstream from the confluence with the Feather River. The problem began suddenly as a blowout of levee embankment material near the landside toe of the levee. Seepage and erosion continued until the levee subsided at this location. Seepage then appeared immediately downstream where seepage and erosion progressed until the levee settled at this location. This process continued downstream for about 200 feet. The problem area was located about channel mile 63 and, as shown on Plate 5, sheet 1 of 2, where the high water mark profile for Sutter Bypass was less than the design water surface. (Plate 5 indicates that the high water mark profile was between 0.5 and 1.0 foot below the design water surface at this location. If the impact of wave action on the observed 1986 high water marks is also considered, the above difference would be even greater.) As in the other examples, many similarities exist between the above-cited levee embankment problem area and adjacent levees on Sutter Bypass that provide additional information on potential problem areas currently being evaluated.



DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

HISTORIC RATING CURVES
SACRAMENTO RIVER AT VERONA

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 33

Personnel from DWR provided a report on levee embankment areas where problems have occurred in the past, particularly during the 1986 flood event. Some of these problem areas were discussed in the section on Historic Levee Embankment Problem Areas (see Plate 3 also), and others are presented in reports cited in this investigation. Because of the difficulties of accurately predicting when, where, and under what conditions levee embankment problem areas will occur (as noted by the information presented above), levels of flood protection are estimated based on the extent and relative significance of hydraulic and geotechnical considerations. (Only those levee embankment-problem areas that have not been modified or repaired since 1986 were considered.)

To determine existing levels of flood protection, the recurrence intervals were estimated for the February 1986 peak flood stages (see Table 5) for the levee reaches in which the Corps is recommending levee reconstruction (see Figure 31 and Table 5). Based on an evaluation of the levee embankment problem areas, freeboard, and geotechnical considerations, levee breaks are expected for the following:

(1) Flood events with peak flood stages similar to the February 1986 flood event but with slightly longer durations.

(2) Flood events with peak flood stages slightly higher than the February 1986 flood event but with similar durations.

The 1986 levee failure on Yankee Slough could have occurred at flood stages less than the 1986 high water mark profile. This levee embankment was subsequently reconstructed by the Corps of Engineers during the summer of 1986. In addition, the west levee of Sutter Bypass east of Robbins could have failed during the flood of 1986 at flood stages less than the peak flood stages observed at this location if flood fight efforts had not been implemented. (Although flood fight efforts can and have prevented levee failures in the past, such efforts cannot be depended on during major flood events. In this evaluation, flood fight efforts are assumed ineffective in increasing the levels of flood protection.

TABLE 5

RECURRENCE INTERVALS
FOR
FEBRUARY 1986 PEAK FLOOD STAGES 1/

Location	Recurrence Interval (years)
Sacramento River	
below Wilkins Slough (channel mile 117.6)	40
at Knights Landing (channel mile 89.7	60
at Fremont Weir (channel mile 84.1)	100
at Verona (channel mile 78.8)	120
at Sacramento Weir (channel mile 63.5)	50
Sutter Bypass	
at Tisdale Bypass (channel mile 76.0)	30
at R.D. 1500 (channel mile 57.9)	100
Yolo Bypass	
near Woodland (channel mile 50.3)	55
near Lisbon (channel mile 35.3)	65

1 Recurrence intervals specified for the different locations represent gaging station elevations (static water surface elevations plus wind setup) and may differ from high water mark elevations shown in Plates 4 through 18 because of the impact of wave action. The recurrence intervals also represent existing conditions and assume no levee breaching.

Railroad, road crossings, and localized depressed areas of the levee embankment crown with flood gates or other means of closure during high flood stages, though, are assumed in place in this analysis when determining levels of flood protection.) A 600-foot-long section of this damaged Sutter Bypass levee was reconstructed following the flood event. Several other sections of levee embankments that experienced problems during the 1986 flood have also been repaired either by the Corps of Engineers, State, or local entities. Based on the above remedial repairs and adequate future maintenance, it appears reasonable to assume that the study area levee embankments would not fail for peak flood stages and durations less than that which occurred in 1986. (Although deterioration or physical changes of the levee embankments, levee foundations, and adjacent land surfaces is possible over time, such changing conditions are not easily analyzed, and are assumed to have little or no impact on levels of flood protection used in the following economic analysis.)

Soil samples taken of the levee embankment and foundation at and near problem area locations on Sutter Bypass indicate levee soils consisting of silts and clays over clean sand deposits. Seepage analyses through such sand layers (see attached geotechnical evaluation) show that factors of safety are less than recommended for design of levee embankments at flood levels equal to or greater than the design water surface (on Sutter Bypass there is very little elevation difference between the design water surface and the 1986 high water mark profile). Based on the above analysis, the consultant's geotechnical studies (see Table 1), and past performance, the potential for failure is high on the Sutter Bypass levee (at locations where levee reconstruction is proposed) for flood levels equal to or greater than the 1986 flood levels.

For problem area locations along the Sacramento and Feather Rivers, the levee embankments generally consist of clean, poorly graded sand. These reaches of levee were constructed in part of dredged material taken from the channel bottom, which was predominantly silt and sand. Slope stability analyses were performed for typical sections (see attached geotechnical evaluation) and indicate factors of safety less than current design requirements at the design water surface and for 2- to 3-day flood durations. Based on this information, the potential for structural instability is high at the levee reconstruction locations shown on Figure 31 for flood levels equal to or greater than the 1986 flood levels.

A similar analysis was performed for the east levee of Yolo Bypass by the geotechnical consultant (Roger Foote Associates, Inc.) and also indicated factors of safety less than required under current design requirements.

Based on the information presented in this section, the 1986 high water mark profile (static water surface plus wind setup) will be used as the reference water surface elevation at which piping and structural instability problems would be expected at the proposed levee reconstruction locations shown in Figure 31. Recurrence intervals have been determined for these water surface elevations and tabulated for specific locations in

Table 7. The recurrence intervals represent existing conditions (including the removal of accumulated sediments at Fremont Weir) and assume no levee breaching within or adjacent to the study area. If levee breaching does occur, either within or adjacent to the study area, the recurrence intervals specified in Table 7 would be increased accordingly to accomplish the economic analysis.

CHAPTER 5 - GEOTECHNICAL

5.01. Introduction

The geotechnical investigation/design for the Design Memorandum was accomplished in two phases. Phase 1 was completed by an A-E, Roger Foott Associates, and phase 2 by Corps of Engineers Sacramento District's Geotechnical Branch.

Roger Foott Associates, Inc., was contracted by the Corps of Engineers, Sacramento District, to provide geotechnical engineering services for the study area. The work effort included subsurface exploration, soil sampling, and stability assessments over 238 miles of project levees (Sacramento River Flood Control Project levees) in Placer, Solano, Sutter, Yolo, and Yuba Counties.

For the geotechnical program, 55 electric cone penetration tests (CPT's) and 20 exploratory borings were drilled to evaluate subsurface conditions at predetermined locations of the levee embankments (information contained in the July 7 and December 21, 1989, reports by Roger Foott Associates, Inc.). The CPT's extended to depths ranging between 20 and 50 feet below the levee crown, and the exploratory borings were drilled to depths ranging from 30 to 46 feet below the levee crown. The above information was also supplemented with boring logs from previous investigations by the Corps of Engineers, other geotechnical firms, and Caltrans and with data from past levee repairs. Soil samples collected from the borings were delivered to the Corps South Pacific Division Laboratory in Sausalito for classification and analysis. In addition, soil maps and aerial photographs were reviewed to identify subdued topographic and geologic features, and engineering analyses were performed to evaluate slope stability of the levee embankments and the potential for damage due to seepage and piping. Where levee improvements (or reconstruction) are warranted, recommendations for repair of the levees were made and applicable design concepts developed.

Cross-section information obtained by Roger Foott Associates, Inc., and DWR indicate levee heights within the study area range between 5 and 35 feet above the landside ground surface. Crown widths are from 10 to 45 feet. In addition, Roger Foott Associates, Inc., encountered wide variations in the levee embankment and foundation soil conditions. These variations occur both between study sites and within individual sites studied (and frequently occur over short vertical and lateral distances). The variable soil types ranged from soft to very stiff clayey silts (such as found in levee embankment materials on Dry Creek and Yankee Slough) to loose to medium dense sandy soils (such as found in levee embankment materials on Sacramento River).

The slope stability analyses were performed in two phases because of the wide range of levee embankment types and foundation conditions. In the first phase, a set of chart solutions (detailed information contained in Appendix B and December 21, 1989, reports by Roger Foott Associates, Inc.) encompassing the general range of levee embankments and foundations was developed and used to screen each levee reach and to identify the levees which required a more detailed stability assessment. The chart solutions were based on a flood peak 3 to 6 feet below the levee crown, depending on the design freeboard and a steady-state seepage condition. Factors considered included levee embankment height and slope, soil unit weight, shear strength, and depth of tension cracks. The levee embankments with indicated factors of safety of 1.6 or greater were considered adequate to meet existing Corps requirements. In the second phase, the remaining levee embankments, with indicated factors of safety of less than 1.6, were evaluated in more detail. In addition to the above factors used in the chart solutions, the detailed evaluation considered site-specific variations in shear strengths (shear strengths were modified to simulate physical changes with depth and location within the levee embankment and foundation) and in the phreatic surface. Results of the above analyses indicate that only the left bank of the Yolo Bypass has potential factors of safety less than 1.4. (As shown in the attachment, Office Report, "Geotechnical Portion of the Initial Appraisal Report for the Sacramento River Flood Control System Evaluation, Mid-Valley Area," Corps of Engineers, June 1990, this levee embankment has a history of settlement and slumping. Many of these historic problem areas have been repaired by the Corps of Engineers, as shown on Figure 10 of the attached geotechnical report.)

Results from the geotechnical studies indicate that the primary concern related to levee embankment integrity in the study area is the susceptibility of levee embankment and foundation soils to seepage and piping. Potential slope stability problems result from water seeping through a permeable levee and exiting on the landside slope. If the energy of the exiting seepage waters is sufficient and of long enough duration, local slumping and progressive failure back into the levee embankment can occur. This condition is most likely to occur with sandy levees having only small percentages of silt and clay particles. The problem is also a function of levee geometry (steep levee embankment slopes and small cross section widths would increase the potential for this type of seepage condition) and the existence and location of landside drainage ditches.

Potential problems also result from seepage waters moving through permeable levee foundation soils. As in the above case, if the energy of the seepage waters is great enough, sand boils (Figure 2-4) and piping can occur landward of the levee embankment. Seepage evaluations involved the determination of levee embankment and foundation characteristics which could lead to the development of seepage problems (information was generally obtained from borings and field surveys), a review of historic problem areas and field observations during high flood stages, and the computation of potential seepage exit gradients (as done in the Initial Appraisal Report for the Marysville/Yuba City Area). Based on the above, potential problem areas exist along the Sacramento and Feather Rivers because of sandy levee embankments and along Sutter Bypass because of a sand foundation stratum. In general, levee embankments adjacent to the Sacramento and Feather River channels were constructed with dredged material from the channel bed which contained high percentages of sand particles. In addition, unique problem areas exist along Sacramento River where levee segments cross old channel meanders (between channel miles 100 and 110 and channel miles 80 and 90) filled with sand or clay and organic deposits. Along the west levee of Sutter Bypass, foundation seepage has been a problem in the past. Landward of the levee embankment in the vicinity of channel mile 70, seepage has resulted in many clear water boils during past high water levels. In fact, the local Reclamation District responsible for levee maintenance has marked their locations with numbered posts. The district has also reported seepage in farmland a distance of 1 to 2 miles from the levee. During the 1986 flood event, piping in the foundation sand layer of the west levee of Sutter Bypass near Robbins removed enough material to cause about 200 feet of levee to drop suddenly (see Figures 1 and 3). This area was subsequently repaired by removal and replacement of most of the levee embankment (about 700 feet in length) and by excavating and constructing a cutoff key to the bottom of the sand layer.

Rapid drawdown was evaluated in relation to levee embankment stability. The evaluations indicated that, under expected flood conditions (assuming no levee breaching at design conditions), drainage from the levee embankment would be adequate even in fine-grained soils (such as the Yolo and Sutter Bypass levees) and would preclude the likelihood of a stability problem due to water entrapment.

Levee height restoration and its impact on stability was also evaluated for those areas with deficient design freeboard (Table 5-1). Levee height restoration was based on maintaining existing side slopes and top widths. The tributary levees on Cache Creek, Willow Slough Bypass, and Putah Creek have slope stability factors of 3.0 and greater and would remain very stable under an additional 5 feet of fill. Yolo Bypass levees with present stability factors greater than 2.0 will maintain a factor of safety above 1.5 when raised up to 5 feet. The bypass levees with present stability factors of less than 2.0 have clayey foundations and would have estimated reductions in factors of safety from 0.2 to 0.3 when raised 5 feet (a reduction in factor of safety of about 0.05 for each foot of additional levee height). As shown in Table 5, the east levee embankment of Yolo Bypass would require height restoration to a maximum of 2 feet and could potentially have an adverse impact on slope stability. Levee height restoration in this area would require additional explorations and analysis to insure slope stability and integrity in the final design.

Geotechnical staff from the Corps of Engineers (Sacramento District) provided a technical review of the reports by Roger Foott Associates, Inc. In addition, the geotechnical staff prepared a report which summarizes information and evaluations to date (see Office Report, "Geotechnical Portion of the Initial Appraisal Report for the Sacramento River Flood Control System Evaluation, Mid-Valley Area," Corps of Engineers, June 1990, included as Attachment B in the Sacramento River Flod Control System Evaluation, Initial Appraisal Report—Mid-Valley Area, December 1991). Included in this geotechnical evaluation are the Corps preliminary recommendations for levee repairs based on the design water surface profiles shown in Plates 4 through 18 and a flood peak duration of 3 days. (As noted previously, Roger Foott Associates, Inc., made their analyses based on a water surface elevation that was 3 to 6 feet below the existing levee crown, depending on the design freeboard. The 3 to 6 feet of freeboard was used by the consultant because levee crown and design water surface profiles were not available at that time. In addition, the consultant used variable phreatic surfaces in the evaluations of slope stability and seepage that generally provided higher factors of safety and design requirements). The types of evaluations made by the Corps in developing recommendations for levee reconstruction are similar to those used in Phases I and II of the Sacramento River Flood Control System Evaluation (see Initial Appraisal Reports for the Sacramento Urban and the Marysville/Yuba City Areas).

The Corps preliminary recommendations for levee reconstruction, general locations, and lengths are shown in Figure 31 (a more detailed description is presented in the attached geotechnical report). The repairs proposed (excluding levee height restoration) would generally involve the construction of a cutoff wall or toe berm with drain to correct for areas of seepage, piping, and stability. (Preliminary designs for the repairs considered are similar to those shown on Figure 13 of the attached geotechnical report.) Final designs and lengths of levee modifications will be dependent on additional foundation explorations and evaluations.

5.02. Phase I Investigations

The work effort included subsurface explorations, soil sampling, laboratory analyses, and stability assessments of over 238 miles of project levees in Placer, Solano, Sutter, Butte, and Yuba Counties.

TABLE 6

LEVEE REACHES
WITH
DEFICIENT DESIGN FREEBOARD

Location (channel miles)	Length of Levee Reach [1] (miles)	Design Freeboard Deficiency (feet)
Yolo Bypass		
44.1 to 50.0 left bank (intermittent)	4.5	0 to 2
50.3 to 51.7 right bank [2]	1.4	N/A
52.6 to 56.2 left bank (intermittent)	0.6	0 to 1
Sacramento Bypass		
0.0 to 0.1 right bank	0.1	0 to 1
Cache Creek		
5.1 to 9.6 right bank	4.5	0 to 4
5.1 to 9.5 left bank	4.4	0 to 4
Willow Slough Bypass		
3.5 to 6.1 right bank	2.6	0 to 2
3.5 to 6.1 left bank	2.6	0 to 2
Putah Creek		
3.9 to 5.0 right bank	1.1	0 to 2
3.9 to 5.2 left bank	1.3	0 to 2
6.2 to 6.8 right bank	0.6	0 to 1

1 Levee reach miles are measured along the centerline of the levee embankment crown and do not necessarily correspond to the difference indicated by the channel mile locations.

2 Levee embankment and weir would be modified under the recently authorized Corps of Engineers project for flood control, Cache Creek Basin (see Design Memorandum No. 1, "Cache Creek Basin, California," Corps of Engineers, January 1987).

The initial phase of the geotechnical investigation commenced with field explorations of the project levees. A site reconnaissance was performed by the Sacramento District, the A/E, and representatives from the local levee maintenance agencies to investigate the existing conditions of the levees and to select exploration sites. Schematic cross sections of the levees showing relative elevations were developed at the completion of the field reconnaissance. The field exploration program began with electric cone penetration testing (CPT), exploratory borings with Standard Penetration Tests (SPT), and soil samples obtained and delivered to the Corps' South Pacific Division Laboratory. The data from the field explorations and previous exploration programs accomplished by the Corps of Engineers and other consultants in the study area were analyzed and the following recommendations were made:

> Conduct explorations at 24 sites to evaluate typical sections, weak foundations, boils, and seepage. The explorations consisted of SPT borings at the levee toe and backhoe test pits to evaluate the limits of sandy soils susceptible to boils or seepage.
>
> Conduct a laboratory testing program on the soil samples consisting of evaluation of moisture content and dry density; Atterberg Limits; grain size distribution using mechanical and/or hydrometer methods; and consolidated-undrained, unconsolidated-undrained, and consolidated-drained triaxial strength tests.
>
> Analyze slope stability and/or susceptibility to seepage or boils at the explorations.
>
> Obtain and review aerial photographs of the levee reaches to evaluate topographic conditions, such as river meanders, which may affect levee foundations.

The A-E continued with the technical evaluation of the levees with a second increment of explorations and analyses based on the recommendations listed above. Ultimately, 24 sites were selected for further evaluation to assess levee embankment conditions. To make these assessments, the additional exploratory borings and trenches were made and soil samples collected. Soil samples were delivered to the Corps South Pacific Division Laboratory in Sausalito for testing. In addition, aerial photographs were reviewed to identify subdued topographic and geologic features, and engineering analyses were performed to evaluate slope stability of the levee embankments and the potential for damage due to seepage and piping. Recommendations for reconstruction of the levees were made and applicable design concepts developed.

Cross-section information indicates levee heights within the study area range from 5 to 35 feet. In addition, wide variations in the levee embankment and foundation soil conditions were identified. These variations occur both between sites and within the individual sites studied and frequently occur over short vertical and lateral distances. The variable soil types ranged from soft to very stiff clayey soils to loose to very dense sandy soils.

The slope stability analyses for the levee cross sections (24 selected sites) were based on a flood peak of 3-day duration and 3 to 6 feet of freeboard below the crown of the levee embankments. Subsequent analysis by the Corps geotechnical staff evaluated underseepage piping potential and stability of the landside slopes using the computer program UTEXAS3. The susceptibility of the levee to damage due to foundation seepage and piping was evaluated based on the general soil types encountered at the explored sites. Also assessed were the potential effects on levee stability due to increased embankment heights.

Based on the results of their evaluation, the A/E recommended that reconstruction be undertaken over some reaches of levee in the study area. The primary problems to be addressed are potential embankment instability due to a high phreatic surface that could develop within the levee embankment and the related potential for instability or internal erosion (piping) of the levee section due to subsurface seepage. To improve unsatisfactory conditions related to potential slope instability and seepage, the A/E recommended the following design concepts:

- Internal chimney/blanket drain
- Drained stability berm
- Internal chimney/blanket drain with landside reverse filter berm or seepage cutoff trench
- Seepage cutoff trench

- Slurry trench cutoff wall.

In regard to the other conditions analyzed that could affect the integrity of the levees, the following conclusions were reached:

- Maintaining a low phreatic surface within the levee embankment, particularly where sandy soils are present, can significantly enhance slope stability and minimize instability.

- The levee bearing capacities will not be adversely affected with respect to their ability to support additional loading due to levee crown restoration. Consolidation test results indicate that the levee foundations soils are predominantly overconsolidated. Based on that data, settlements resulting from modest increases in levee height would be insignificant. In general, increases in levee heights in the study area in the order of 2 to 3 feet should not affect the overall foundation support or slope stability. However, prior to final designs and levee raising, additional investigations and stability computations will be made.

5.03. Phase II Investigations

The Geotechnical Branch of the Corps of Engineers, Sacramento District, provided a technical review of the reports prepared by the A/E. A need was identified for additional explorations in the questionable reaches prior to making final reconstruction recommendations and establishing the limits of the reconstruction. The primary emphasis of the additional explorations was to provide additional data to support the A/E's conclusion that levee stability and integrity in the study area were related to the susceptibility of the embankment and foundation soils to seepage.

Landside seepage and sand boils have occurred in several locations along both the Sutter Bypass and Feather River during past high river stages. Although seepage in itself is not necessarily cause for major concern, when the seepage energy is high enough, soil particles near the seepage exit point can be displaced. This phenomenon, known as piping, is generally manifested in the form of sand boils. Uncontrolled, sand boils can become progressively larger as the seepage path is shortened due to loss of material at the exit point. This condition is extremely dangerous and can lead to total levee failure. Sandbag rings can and have been used to stop piping when detected at an early stage. However, the rate at which the piping worsens is unpredictable. Piping can progress rapidly and cause complete levee failure before emergency measures can be taken.

Seepage flow net analyses were performed for typical levee sections along the Sutter Bypass and Feather River where the foundation is sand to predict the potential for piping. The potential for piping was determined by calculating typical seepage exit gradients from foundation seepage beneath the levees. The calculated seepage exit gradient was compared to the theoretical critical exit gradient at which piping would occur. The seepage exit gradient is defined as the rate of energy loss per unit length at the seepage exit point. The critical exit gradient is that gradient at which flotation of soil particles begin. The factor of safety against piping is defined as the ratio of the critical exit gradient to the actual exit gradient as determined by a flow net analysis. Engineering Manual 1110-2-1901 (Seepage Analysis and Control for Dams) suggests a minimum acceptable factor of safety against piping between 2.5 and 3.0 (Cedergren) or between 4.0 and 5.0 (Harr). Since the actual levee profiles and topography are irregular and the foundation sand deposits are highly variable, a good deal of judgment must be used in determining the need for seepage control measures. With this in mind, a conservative factor of safety of 4.0 against piping was selected. Where the analyses indicates a factor of safety less than 4, there is a good potential for piping. The results indicate that for the design flood, sand layers greater than about 12 feet thick are susceptible to piping. In some areas, the deposits extend to at least 25 feet.

Foundation seepage analyses were performed to estimate the potential for foundation piping during the design flood. The analyses made no attempt to model the many possible foundation anomalies that may actually exist. These anomalies or irregularities include varying levee base widths; potentially higher horizontal to vertical permeability ratios; thick sand layers which may narrow near the landside toe; and anomalies in the foundation such as animal holes or voids left by decayed tree roots or broken pipes. The reports by the A/E and the Corps include a review of remedial levee repairs constructed by local entities since the 1986 flood to correct for stability, seepage, and piping (see Figures 1 and 2). In addition, the Corps also reviewed plans for reconstruction currently under consideration for implementation by locals (see attached geotechnical report for locations).

The Corps made final reconstruction recommendations based on information provided in the A/E's reports, Corps 1993 explorations, reports by other geotechnical consultants, past levee performance, flow net analyses, and discussions with representatives of various levee districts. The reaches identified for reconstruction include only the reaches that are in need of structural repairs from a stability standpoint and do not include reaches that need to be raised due to inadequate freeboard. Of the 240 miles of levee studies, it is concluded that a total of 18.27 miles need structural reconstruction generally as a result of pervious levee and/or foundation soils. Where the foundation soil is highly pervious, the repair selected is generally a toe trench. The toe trench will collect and provide a safe outlet for underseepage while preventing piping near the levee toe. Where the levee materials are highly pervious as well, the choice is generally a toe trench and landside seepage berm or a cutoff wall through the levee and into the foundation. The attached Basis of Design in Appendix C provides detailed descriptions of the geotechnical evaluation of the levees. Table 1 provides a summary of the recommended structural reconstruction in each of the levee reaches identified for reconstruction.

5.04. Construction Materials

a. Borrow Areas. The immediate source of required fill material will be from the excavation of the toe drains and the cutoff walls within the project. Additional fill material for the levee raising would be obtained from the sediment removal stockpile areas of the Tisdale Bypass and Fremont Weir.

b. Borrow Materials. Materials to be excavated from the borrow areas are predominantly sandy clays (CL). Prior to excavation of borrow material, the top 6 inches of material shall be stripped and wasted.

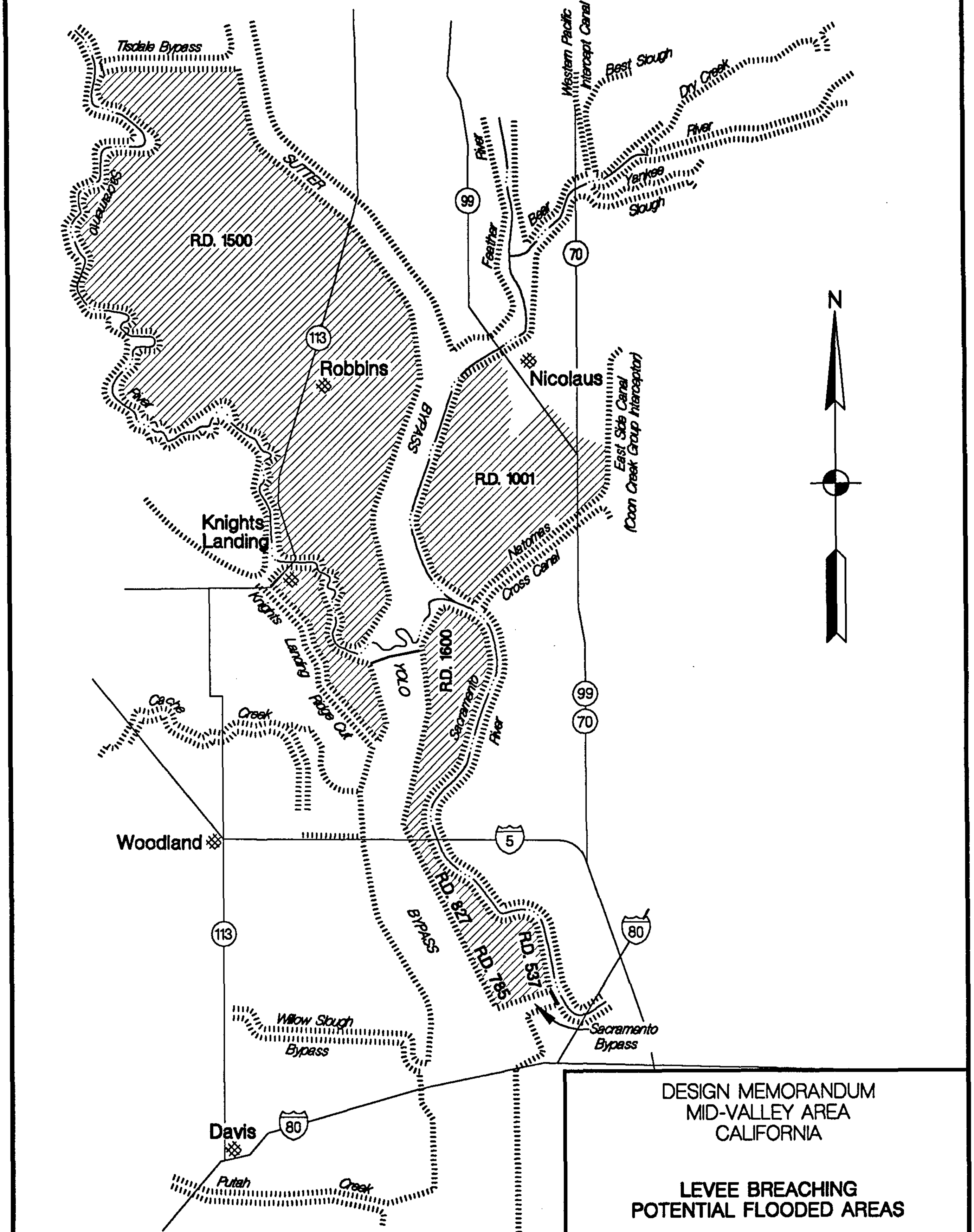
c. Drain Rock. Drain rock for the toe drains can be obtained from the following local suppliers in the Marysville/Yuba City areas:

(1) Bangor Quarry near Marysville. Rock was tested by the SPD laboratory in September 1986. The contractor is required to identify the material that is suitable for the toe drain.

(2) Yuba River Sand & Gravel at Dantoni Road, Linda.

(3) Parks Bar Quarry near Marysville. The contractor is required to verify that the material is suitable for the toe drain.

(4) Western Aggregates, Inc., at 7516 Hammonton Road, Marysville. The contractor needs to report the test results on the material that will be used for the toe drain.



DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE BREACHING
POTENTIAL FLOODED AREAS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

Figure 34

CHAPTER 6 - PROJECT RECONSTRUCTION PLAN

6.01. Introduction

The reconstruction plans were developed such that the project levees could safely pass the design flow (according to existing Corps criteria and guidance) at the design water surface. The reconstruction will be along 30 separate levee reaches in the study area. Geotechnical investigations have found that 30 reaches of levee within the study area have structural deficiencies related to seepage, piping and cracking. The 3 Construction Contract Areas and the 30 reconstruction sites within each contract are shown on Plates 2 and 3 and described below:

a. Contract #1/Area #1 and Area #3 (Robbins/Knights Landing area): This area is composed of Reclamation District 1500 and Knights Landing Ridge Cut east levee. Reconstruction sites 1, 2, 2-1 to 2-10, 3, 4, 5, 6, 7, 9, 10, 11, 12, 12A, and 13 are within this area. About 54 miles of levees are maintained by RD 1500 and 13 miles of Knights Landing Ridge Cut levee are maintained by Westside Levee District. There are 9.44 miles of levee reconstruction within this area.

b. Contract #2/Area #2 (Verona Area): This area is composed of Reclamation District 1001, which includes a total of 11 miles of Feather River left levees. Reconstruction Sites 17, 18, 19, and 20 are within this area. The total reconstruction site is 1.02 miles.

c. Contract #3/Area #4 (Elkhorn Area): This area is composed of Reclamation Districts 1600, 827, 785, and 537, approximately 31 miles of Sacramento River Flood Control Project levees which include Sacramento River right levee and Yolo Bypass west levee. Reconstruction sites 14, 15A, and 15B are 6.6 miles within this area.

6.02. Reconstruction Plans

Based on the geotechnical studies and engineering evaluations, levee reconstruction recommended for the 30 reconstruction sites in the 3 Construction Contract areas are as follows:

A. CONTRACT #1

(1) Site 1: This site is located on the right (west) bank of the Sutter Bypass, about 3-½ miles downstream from the Tisdale Bypass, from levee mile (LM) 17.9 to LM 18.6. It comprises a 3,700-foot-long reach of levee which has had a history of boils during high water. Past exploration has consisted of three auger borings—two through the levee and into the foundation, and one in natural ground a short distance beyond the landside toe. The levee soils consist primarily of soft to very stiff, low plasticity sandy clay, with isolated fill consisting of clayey sand. The borings at this site did not encounter clean sand deposits within the foundation. However, several borings at Site 2 (discussed below) revealed that clean sand deposits do exist about 10 to 12 feet beneath ground surface, as did a number of other borings along the right bank of the Sutter Bypass. This sand is a feature of the Pleistocene alluvium, which underlies the basin clay and is made up of alternating layers of clay, silt, and sand. Given the history of boils at Site 1, it must be assumed that, although not encountered in the borings, sand deposits do exist in the foundation. For purposes of developing a remedial solution, it seems reasonable to assume that these deposits exist at about the same depth as at Site 2.

The landside levee slope is flat (approximately 2.9H to 1V, horizontal to vertical). Piping of foundation sands, not levee slope instability, is the main concern at this site. Seepage could be controlled either by (1) cutting off or lengthening the seepage path or (2) safely controlling exit conditions by filtered drainage on the landward side. Alternatives evaluated embraced both the above methods. For reasons discussed below, the solution recommended is a toe drain installed near the landside toe of the levee.

Because the levee consists of fine-grained materials, it is not considered necessary to install a seepage barrier through the levee itself, nor does an impervious blanket on the waterside slope appear to be required. The waterside levee slope is quite flat (about 3.6H to 1V) and, at the waterside toe, there is an elevated bench that is a few feet higher in elevation than the landside toe. The recommended Type IB slurry wall would be installed from this bench. It is assumed that a 35-foot-deep slurry wall (similar to that at Site 2) would be necessary to satisfactorily reduce seepage gradients (see further discussion under Site 2, below). A low clay blanket would cap the slurry wall to protect against "short-circuiting" seepage through the levee at the waterside toe to possibly undetected upper foundation sands. Since the slurry wall scheme would be a waterside control measure, the length would have to be increased to account for end-around seepage. A 200-foot extension of the wall at each end of the site is recommended at this time. For preparation of plans and specifications, the required extension should be confirmed by analyses to determine its impact on reduction of exit gradients. The 200-foot extension at each end would increase the length of Site 1 (for the slurry wall type of solution) to 4,100 feet.

A deep landside interceptor trench drain installed at the landside toe was evaluated as an alternative. Assuming that foundation sands known to exist at Site 2 (below) also exist at similar depths in Site 1, it is estimated that the trench depth would be about 15 feet, although it is possible that the trench may have to be somewhat deeper, depending on at what levels sands are encountered. If landside seepage control could be achieved with a relatively shallow seepage interceptor trench, a trench would be a cheaper and better solution than the slurry wall. However, it is considered that installation of an interceptor trench to depths of 15 or more feet, in clean sands subject to caving, could be fraught with problems. Moreover, effectively encapsulating gravel drain material in filter fabric to such great depths would be extremely difficult. It is considered that constructibility problems would make this alternative expensive and undesirable; in any case, very sophisticated techniques involving specialized equipment would have to be worked out.

A second possible landside control alternative which might be considered for the conditions at this site would be the installation of relief wells near the levee toe. However, to estimate the design layout and cost of this alternative would require more subsurface information than is currently available.

(2) Site 2: This site is located on the right bank of the Sutter Bypass, about 7 miles downstream from the Tisdale Bypass, from LM 13.75 to LM 14.75. It comprises a 5,300-foot-long reach of levee which has had a history of boils during high water. In fact, Site 2 contains seven documented boil locations. Past exploration has consisted of six auger borings (four through the levee and into the foundation, and two in natural ground a short distance beyond the landside toe) and one cone penetration test (CPT) exploration through the levee and into the foundation. The levee soils consist primarily of soft to very stiff, low plasticity clay, with isolated fill consisting of clayey sand. Soils in the upper 10 to 15 feet of the foundation are predominantly low plasticity clays and clayey sands. Those soils are underlain by sand deposits, some of which are clean sands (less than 5 percent fines) and others which contain up to 10 or 11 percent fines (according to gradation test results). The thickness of these sand deposits is unknown, because several borings were terminated above the bottom of the sand. However, several boring logs indicated the deposits are quite thick (at least 10 feet in one boring and at least 17 feet in another).

The landside levee slope is flat (approximately 3.2H to 1V). Consequently, piping of foundation sands, not levee slope instability, is the main concern at this site. As at Site 1 (above), seepage could be controlled either on the waterside (by a slurry wall) or on the landward side (by filtered drainage). Alternatives evaluated embraced both methods. For reasons discussed below, the recommended solution is a toe drain installed near the landside toe of the levee.

Because the levee consists of fine-grained materials, it is not considered necessary to install a seepage barrier through the levee itself, nor does an impervious blanket on the waterside slope appear to be required. The waterside levee slope is quite flat (about 4H to 1V) and, at the waterside toe, there is an elevated bench or berm that is several feet higher in elevation than the landside toe. The recommended toe drain would be installed from this bench. The bottom of the sand deposits was not located in several borings. It is possible, therefore, that a complete cutoff cannot be achieved at any practical depth of slurry wall. It is assumed that a partial cutoff will be achieved, which will have the effect of lengthening the seepage path through the sands and reducing the exit gradient at the landside toe to an acceptable value. It is estimated that a 35-foot-deep slurry wall will be required. As at Site 1, a low clay blanket would cap the slurry wall to protect against "short-circuiting" seepage to possibly undetected upper foundation sands. Also as at Site 1, a 200-foot extension of the slurry wall at each end of the site is recommended to account for end-around seepage. The extension would increase the length of Site 2 (for the slurry wall type of solution) to 5,700 feet.

A deep landside slurry cutoff wall installed at the landside toe was evaluated as an alternative. Based on the depth of sands as revealed by the borings, it is estimated that the required trench depth would be about 15 feet, although it is possible that the trench may have to be somewhat deeper in areas, depending on at what levels sands are actually encountered. As at Site 1, it is considered that constructibility problems associated with such a deep drain trench would make this alternative expensive and undesirable.

As at Site 1, the installation of relief wells near the landside toe is another possible alternative at this site. However, to estimate the design layout and cost of this alternative would require more subsurface information than is currently available.

(3) Sites 2-1 through 2-10: These sites are all located on the right bank of the Sutter Bypass and represent documented individual boil site locations in addition to the more extensive Sites 1 and 2. Most of these sand boils have occurred in the landside irrigation ditch near the levee. Locations and lengths of the sites to be treated are presented in the tabulation on the following page.

In addition to the exploration at Sites 1 and 2 (above), past exploration has included a number of borings at various other locations along the right bank of the Sutter Bypass. These locations do not often coincide with the locations of Sites 2-1 through 2-10, but some are located reasonably close. Discussions of site conditions presented herein are based on reasonably projecting subsurface information from boring locations. However, for most of the length of the Sutter Bypass, the upper natural basin deposits are clays and clayey sands. These materials were used in constructing the levees. Therefore, it is reasonable to assume that levee materials at Sites 2-1 through

Site No.	Location	Length(Ft)
2-1	LM 4.22	250
2-2	LM 4.89	250
2-3	LM 7.67	250
2-4	LM 9.13	250
2-5	LM 9.53-9.60	400
2-6	LM 10.32-10.38	400
2-7	LM 12.09	250
2-8	LM 15.45	250
2-9	LM 16.12	250
2-10	LM 17.14	250

2-10 are clays and clayey sands, generally similar in nature to those at Sites 1 and 2. This assumption is reinforced by the fact that the problems have been related to foundation seepage, not seepage through the levee. One boring log, located near Site 2-5, where the levee is founded on distributary channels of Nelson Slough, does indicate sand in the levee, but here also the reported problem is foundation seepage. The borings in natural ground along the bypass levee indicate that the foundation at the individual sites would probably be similar to Site 2—the upper portion consisting of fine-grained deposits, and these underlain by sand deposits. Exploration to obtain specific details of the foundation at each site will be necessary before plans and specifications for reconstruction are prepared.

Historically, piping of foundation sands, not levee slope instability, has been the problem at these sites. As at Sites 1 and 2, seepage could be controlled either on the waterside (by a slurry wall) or on the landward side (by filtered drainage). Alternatives evaluated embraced both methods. Because of the severe constructibility problems associated with a deep landside interceptor trench drain, the recommended solution is a toe drain installed near the landside toe of the levee.

The recommended toe drain for a deep landside interceptor trench drain would be the same as at Sites 1 and 2. Thus, it is estimated that a 15-foot-deep trench will be required.

Relief wells could be considered as a second landside seepage control alternative at these sites. However, the design layouts and costs for this alternative cannot be estimated without more subsurface information.

(4) Site 3: This site is located on the right bank of the Sutter Bypass about 2 miles north of the Sacramento River, from LM 2.0 to LM 3.0. It is a 5,300-foot-long site where levee landside slope instability has historically been a problem. Landside slope failures occurred in this area in 1980 and 1983. Public Law 84-99 repairs included removing the slide material and blending and recompacting the levee fill and foundation material. No slope failures have been reported in this reach since 1983. Past exploration has consisted of two auger borings and three CPT explorations, all through the levee and into the foundation. The levee and foundation soils to a depth of at least 20 feet below the natural ground surface consist predominantly of high plasticity clay (CH). The three CPT borings, which extended slightly deeper than the auger borings, intercepted sand at depths of 20 to 22 feet below the natural ground surface. Plasticity Indices (PI) of samples tested from borings at this site range from 34 percent to 42 percent and average 38 percent. Clay soils with a PI greater than 30 percent in arid to semiarid regions are known to have a high potential for developing shrinkage cracks and for swelling upon wetting.

The levee in this reach of the bypass is characterized by desiccation cracks on the levee slopes, particularly on the landside, and longitudinal cracks typically on the upper portion of the slope and on the levee crown paralleling the levee. The shrinkage cracks typically extend to depths of 3 to 5 feet. Slides are triggered when heavy rainfall in the winter follows the long dry summer. The extensive cracking of near-surface material results in an increase in the mass permeability of the embankment. Consequently, the upper portion of the embankment becomes saturated and shallow failures develop, typically in the upper 5 to 7 feet of the embankment. When failures develop on the lower portion of the landside slope, there is a tendency for progressive failure toward the levee crown. Although the failures to date have been relatively shallow and have not yet resulted in total breaching of the levee, it is possible that progressive sloughing and loss of levee crown elevation could result in a complete breach of the levee during high water in the bypass. It is recommended that corrective measures be taken to improve this condition. Alternatives evaluated included chemical stabilization of the clay in the outer portion of the levee and removal and replacement of the clay in the outer portion with low-plasticity material. Chemical stabilization of the clay is recommended on the basis of lower cost. A landside berm against the lower levee slope is another possible alternative that could preclude progressive failures from encompassing the entire height of levee. However, this alternative was rejected because it would leave substantial portions of the upper slope subject to a similar (though not as deep-seated) progressive failure and would still require constant maintenance.

The alternative solution consists of chemically stabilizing the clay material using hydrated lime, Ca $(OH)^2$, stabilization techniques. This technique has been successfully used by the Corps in the St. Louis and Memphis Districts for similar levee soil conditions. The slides to date at Site 3 have occurred on the landside slope of the levee. This may be explained by the fact that the slope on the bypass side is flatter (4H to 1V) than the landside slope (3H to 1V), and by the stabilizing effect of the water against the waterside slope. It is also possible that riprap on the waterside slope may partially protect that slope from moisture changes. In any event, because of where the problems have historically occurred, the treatment would encompass the levee crown, the landside slope, and a portion of the natural ground beyond the landside toe, as shown in the typical design. Lime stabilization would involve blending and compacting approximately 4 percent lime into the outer 4 feet of the levee slope, and to a depth of 4 feet on the levee crown and landward of the levee toe. This procedure will reduce the PI of the clay to well below 20 percent. Shrinkage cracks in the outer slope will be virtually eliminated with a significant increase in shear strength. The lime-treated levee material will act as a cap, preventing large moisture changes in the underlying levee material, and will be resistant to shrinkage and swelling cycles. The recommended technique is to excavate the outer 4 feet of the levee slope and crown, and the upper 4 feet of natural ground at the toe, blending with lime and moisture conditioning in stockpiles, and then recompacting the blended material in approximate 9-inch loose lifts. For most of this reach of levee, the landside irrigation ditch is located at least 35 feet from the levee toe. Near the northernmost end of the site, the ditch alignment veers slightly toward the levee and is approximately 30 feet from the levee toe for a distance of perhaps 200 feet. This situation was examined in the field, and it appears that the ditch here would have no adverse impact on the levee. Therefore, ditch relocation is not considered necessary. The reconstruction will be approximately 5,300 feet long.

The recommended solution would replace the same outer portions of the levee and natural ground near the landside toe with compacted, imported clay of low plasticity. This would essentially accomplish the same end result as the lime stabilization scheme. However, it would require finding an adequate, consistent source of lean clay and hauling the material to the site. It would also require disposing of the excavated high-plasticity clay at a suitable site.

(5) Site 4: This site is located on the left bank of the Sacramento River, from river mile (RM) 116.2 to RM 117.2. It comprises a 5,300-foot-long reach of levee where generalized seepage, including through-levee seepage, has been reported during high river stages. Sand boils have not been reported. Past exploration has consisted of four auger borings (two through the levee and into the foundation and two in natural ground a short distance beyond the landside toe) and one CPT exploration through the levee and into the foundation. The exploration indicates that both levee and foundation soils typically consist of alternating layers of sandy clay, clayey sand, and clay. However, there are also scattered layers of clean sand in the levee and lower foundation.

It does not appear that the levee and foundation soils should be particularly vulnerable to seepage-related problems such as piping. However, the landside slope is very steep (1.6H to 1V), and some sand layers do exist. Given the history of through-levee seepage and the steep landside slope, instability during high river stages is considered very possible. Alternative solutions evaluated included a landside seepage/stability berm and an impervious cutoff. The seepage/ stability berm is recommended based on cost and reliability of performance.

The recommended solution is a Type IIA seepage/stability berm along the entire site. The landside levee slope is about 21 feet high, so the berm would average about 7 feet in height. Two or three residential structures exist fairly close to the levee along this reach. Construction around or otherwise dealing with this situation will be evaluated during final design. Localized omission of the berm or a localized alternative design may be considered. The berm will not prevent nuisance seepage in the farmland beyond the levee toe. It will, however, sufficiently improve levee stability. Its encapsulated horizontal blanket drain will also minimize the potential for future development of sand boils near the landside toe of the levee during high river stages. The reconstruction will be approximately 5,300 feet long.

An impervious slurry cutoff wall was evaluated as an alternative. A slurry wall installed from the crown of the levee is not favored because it would interrupt traffic on a traveled roadway and would require restoration of the road pavement. At the toe of the waterside slope there is a broad berm which is some 9 feet higher in elevation than the landside toe. A 15-foot-deep slurry wall installed from this berm would cut off seepage through the lower portion of the levee and through any sands existing in the upper foundation (a sand layer was revealed in one boring, about 4 feet into the foundation). Seepage through the upper portion of the levee would be cut off by an impervious clay blanket, constructed on the waterside slope from the top of the slurry wall to above the design water surface. Thus, the alternate solution would be a Type IC slurry wall. A 200-foot extension of the wall and blanket at each end of the site is recommended to mitigate end-around seepage. The extensions would increase the length of the site for the alternate solution to 5,700 feet. The higher cost and less assurance as to performance make this alternative less favorable than the seepage/stability berm. Should the slurry wall fail to cut off all foundation sands that might crop out near the landside toe, the intent of the reconstruction might not be achieved.

(6) Site 5: This site is located near Poffenbergers Landing on the left bank of the Sacramento River, from RM 109.9 to RM 110.5. It comprises a 3,200-foot-long reach of levee where seepage in the farmland beyond the levee toe has been reported during high river stages. Past exploration has consisted of two auger borings and one CPT exploration, all through the levee and into the foundation. The data indicate that the levee

and at least the upper 20 feet of foundation consist of relatively fine-grained soils. One boring encountered clean sand deposits at a depth of about 20 feet beneath the natural ground surface. This could not be verified in the other borings because they terminated several feet above that level.

Since the sand deposits here apparently are relatively deep, it does not appear that shallow foundation seepage leading to piping is a major concern at this site. Rather, the problem is considered to be primarily nuisance seepage, during high river stages, that could interfere with farming activities. The levee landside slope is relatively flat at 2.3H to 1V, and seepage through the relatively fine-grained levee at high river stages does not appear likely. Consequently, inherent levee instability is not a serious concern. However, localized steepening near the landside toe of the levee, resulting from the proximity of an irrigation ditch at this site, is of concern. This condition could cause shallow sloughing during high river stages, which in turn could lead to a more serious problem such as progressive failure of the landside slope. It is recommended that the irrigation ditch in this reach be backfilled and the levee slope be regraded to a uniform slope in areas that have been steepened near the landside toe. It is further recommended that the irrigation ditch be relocated to a distance of at least 35 feet from the levee toe. The recommended solution will not reduce seepage in the interior farmland. It will, however, improve overall stability of the levee and minimize the potential that undetected near-surface sand lenses in the foundation could cause sand boils in a ditch near the levee toe. An approximately 3,200-foot-long reach of ditch will be relocated.

It is considered that the above recommended solution is the only one warranted at this site. It does not appear necessary to evaluate any alternatives.

(7) Site 6: This site is located near Kirkville on the left bank of the Sacramento River, from RM 104.8 to RM 105.7. It comprises a 4,600-foot-long reach of levee. Past exploration has consisted of three auger borings and one CPT exploration, all through the levee and into the foundation. Exploration and laboratory testing indicated that the levee at Site 6 consists of clean sand with fines content ranging from only 3 to 6 percent. Standard penetration test blow counts (N) ranged from 3 to 8 and averaged about 4. This indicates that much of the levee would be of very loose density and the sands would

exhibit a fairly low shear strength. A shear strength of 28 degrees was assumed in stability analyses performed on this levee. The foundation consists predominantly of finer grained material (lean clay, sandy clay, silty sand, or sandy silt) to a depth of about 25 feet. One boring extended below this depth and encountered clean sand between depths of 25 and 30 feet (the depth of the boring).

Because the foundation materials contain significant percentages of fines (the only clean sands encountered were at least 25 feet deep), foundation seepage is not considered a major concern. However, the levee soils are highly permeable and susceptible to seepage-related landside slope instability during high river stages. This was confirmed by a slope stability analysis which yielded a factor of safety of 1.2 on a slip circle which encompasses the entire landside slope. This factor of safety is below the Corps criterion of 1.4. Alternative solutions evaluated included a landside seepage/stability berm and an impervious cutoff. The seepage/stability berm is recommended based on cost and reliability.

The recommended solution is a Type IIA seepage/stability berm along the entire site. The landside levee slope is about 13 feet high, so the berm would average 4 to 5 feet in height. Stability analyses assuming a berm of this nature resulted in a minimum factor of safety of 1.78 on the landside slope. This berm will not prevent seepage through the levee, but its internal drain will collect and control the seepage, and the berm will sufficiently improve levee stability. Its encapsulated horizontal blanket drain will also minimize the potential for future development of sand boils near the landside toe of the levee, should there be any undetected upper-foundation sand layers. The reconstruction will be approximately 4,600 feet long.

An impervious slurry cutoff wall was evaluated as an alternative. A slurry wall installed from the crown of the levee to fine-grained foundation soils would cut off seepage through the levee. Since there is no frequently traveled public roadway along the levee crown, this alternative (Type IA) is favored over a waterside Type IC slurry wall and blanket, with its requirement for borrowing impervious blanket material. A 20-foot-deep Type IA slurry wall is assumed to be required to extend into fine-grained foundation materials. A 200-foot extension of the slurry wall at each end of the site is recommended to mitigate end-around seepage. The extensions would increase the length of the site for the alternate solution to 5,000 feet. The higher cost and less assurance as to performance make this alternative less favorable than the seepage/stability berm. Should there be undetected sands in the upper foundation that are not cut off by the slurry wall, a potential for sand boils would still exist at the landside toe.

(8) Site 7: This site is located on the left bank of the Sacramento River, southwest of Karnak, from RM 85.2 to RM 85.9. It comprises a 3,700-foot-long reach of levee where seepage and landside slope slippage have been reported in the past. Past exploration has consisted of three auger borings (two through the levee and into the foundation, and one in natural ground beyond the levee toe) and one CPT exploration through the levee and into the foundation. The two auger borings through the levee indicate that the levee in those locations consists predominantly of very loose to loose sand (SP). These materials are highly permeable and susceptible to seepage. The CPT data and another boring a short distance downstream from the site indicate levee soils comprised of firm to stiff clayey sand (SC). Given the variability of possible borrow sources, this variation in levee material is not unusual. However, the history of seepage and slope instability along this reach of levee warrants basing the reconstruction at this site on the most unfavorable conditions encountered (i.e., the loose, clean levee sands). The exploratory data also indicate some variation in foundation conditions over the site. At two locations within the site, the upper 15 feet is predominantly soft clay and clayey sand, and this is then underlain by thick sand deposits. Near RM 85.7, however, the upper foundation consists of sand to a depth of at least 11 feet (the maximum depth explored).

As recounted above, seepage and landside slope instability has been experienced within the limits of this site. Moreover, the loose, clean levee fill makes future stability in this area questionable. This was confirmed by a landside slope stability analysis which yielded a factor of safety of 1.15, well below the Corps criterion of 1.4. Alternative solutions evaluated included a landside seepage/stability berm and an impervious slurry wall. The seepage/stability berm is recommended based on cost and reliability.

The recommended solution is a Type IIA seepage/stability berm along the entire site. The landside levee slope is about 15 feet high, so the berm would average 5 feet in height. Stability analyses assuming a berm of this nature resulted in a minimum factor of safety of 1.63 on the landside slope. This berm will not prevent seepage through the levee, but its internal drain will collect and control the seepage, and the berm will sufficiently improve levee stability. Its encapsulated horizontal blanket drain will also minimize the potential for future development of sand boils near the landside toe of the levee by controlling any seepage emanating there from the upper foundation sands. There is an extensive orchard adjacent to the levee on the landward side, and it appears that the first row of trees along the site will be impacted by berm construction. Clearing and grubbing will be required prior to berm placement. The reconstruction will be approximately 3,700 feet long.

An impervious slurry wall was evaluated as an alternative. A slurry wall installed from the crown of the levee to fine-grained foundation soils would cut off seepage through the levee, where those fine-grained soils exist at reachable depths. However, as noted above, a significant thickness of sand deposits exists over at least part of the site. It is not presently known whether those deposits can be cut off by a slurry wall. A partially-penetrating wall would, however, lengthen the seepage path and thus reduce gradients and pore water pressures in the landward portion of the levee and foundation, improving stability to some extent. Since there is no frequently traveled public roadway along the levee crown, a slurry wall installed from this level (Type IA) is favored over a waterside Type IC slurry wall and blanket. It is assumed that the slurry wall would average 25 feet in depth over the site. A 200-foot extension of the wall at each end of the site is recommended to mitigate end-around seepage. The extensions would increase the length of the site for the alternate solution to 4,100 feet. The higher cost and less assurance as to performance make this alternative less favorable than the seepage/stability berm. Unless the upper foundation sands can be cut off, this solution relies on the partially penetrating wall to adequately reduce gradients and pore pressures.

(9) Site 9: Site 9 is a 700-foot-long reach of levee located on the right (west) bank of the Sacramento River, about 2 miles south of Knight's Landing. This levee is reportedly maintained by Yolo County. According to county personnel, this is a location

where clear seepage emerged from the lower levee slope and toe during the 1986 flood. There is a waterside pond surrounded by lush vegetation, including trees, immediately adjacent to this site. It is speculated that the pond is likely the result of a past levee break or old river meander.

This reach of the Sacramento River levee is characterized by predominantly loose, clean, sandy levee material, which was dredged from the river, usually overlying a fine-grained foundation. One boring was drilled at this site in 1993 by the Corps of Engineers, because of the past history of seepage in 1986. The boring encountered loose, clean sand to a depth of about 12 feet overlying sandy clay to 20 feet deep and clay to the bottom of the boring at about 35 feet deep.

The levee at this site has been measured at a height of only about 11.5 feet and a relatively flat slope of about 2.8H to 1V. In addition, the levee crown is over 50 feet wide over half the site length and about 24 feet wide over the other half of the reach. In spite of the loose, clean sand in the levee, the favorable levee geometry precludes concerns about stability. However, given the reports of seepage at this location, through-levee seepage and piping is a concern. Alternative solutions evaluated included a landside seepage/stability berm with toe drain and an impervious cutoff. The seepage/stability berm with toe drain is recommended based on cost and reliability.

To minimize the potential for more serious problems at this site, a Type IIB seepage/stability berm (with internal drain) and toe drain are recommended to control any future seepage. The drain, which is wrapped with filter fabric, does not prevent seepage, but rather attracts seepage passing through or beneath the levee, in a controlled manner, so as to reduce the potential for the development of sand boils, piping, and progressive internal erosion. The 5-foot-deep toe drain is considered adequate to attract underseepage based on a review of the boring which indicated that the sand may extend slightly below the toe of the levee. The repair will be about 700 feet long at approximately River Mile 87.2.

As an alternative, a Type IA slurry cutoff wall through the levee crown could be constructed. The cutoff wall should be keyed several feet into the finer-grained foundation soil to an estimated total depth of about 15 feet to provide an effective seepage cutoff. The length of the cutoff wall would need to be increased to account for end-around seepage. An estimated 200-foot extension of the wall on each end is recommended, thus increasing the length of Site 9 to about 1,100 feet for this alternative.

(10) Site 10: Site 10 is a 500-foot-long reach of levee on the right (west) bank of the Sacramento River, about 0.3 mile downstream from Site 9. Maintained by Yolo County, at least one sand boil at this site required sandbagging during the 1986 flood.

As at Site 9, this reach of the Sacramento River levee is characterized by predominantly loose, clean, sandy levee material, dredged from the river, overlying fine-grained foundation. One boring and one CPT sounding, drilled by the Corps in 1989, indicate that the levee materials range from clean sand to silty sand. The foundation consists of firm clay (CL) and sandy clay (CL) or silt (ML) deposits to a depth of about 40 feet, below which a layer of loose, clean sand was encountered to a depth of about 50 feet.

The levee at Site 10 is only 7.5 feet high, and the landside slope of 4.4H to 1V is very flat. Although the favorable geometry and the low head make it seem unlikely that significant through-levee or upper foundation seepage would develop, the history of seepage and boils at the site are reason for concern. Alternative solutions evaluated included a landside toe drain and an impervious cutoff. The landside toe drain is recommended based on cost and reliability.

To control seepage, a Type IIIA toe drain (5 feet deep) is recommended. The toe drain will not prevent seepage, but rather is designed to safely attract seepage passing through or beneath the levee, so as to reduce the risk of development of sand boils, piping, and progressive internal erosion. The 5-foot depth of the toe drain is considered adequate to attract underseepage, based on our review of the borings and the depths of the sand layers in the upper foundation. Because of the very low levee height, a higher inclined drain (and berm) on the levee slope was not considered necessary. The repair will be about 500 feet long, located at approximately River Mile 86.8. There appears to be an orchard and associated residence adjacent to the levee on the landward side. Thus it appears that some trees will need to be removed for berm construction. Clearing and grubbing will be required prior to stripping and berm placement.

As an alternative, a Type IA slurry cutoff wall through the levee crown could be constructed. The cutoff wall should be keyed several feet into the fine-grained foundation to an estimated total depth of about 20 feet. As discussed previously, the length of the cutoff wall would need to be extended about 200 feet on each end of the wall, thus increasing the length of Site 10 to about 900 feet. In addition, a road on the levee crown would require restoration.

(11) Site 11: Site 11 is a 2,000-foot-long reach of levee on the right bank of the Sacramento River about 2 miles upstream from the Fremont Weir. Maintained by Yolo County, this reach has been reported as having had seepage emerge from the levee landside toe and into the field during flooding.

As at Sites 9 and 10, this reach of the Sacramento River levee is characterized by predominantly loose, clean, sandy levee material dredged from the river, overlying fine-grained foundation. Two borings were drilled at this site in 1993 by the Corps of Engineers because of the history of seepage. These explorations show that significant portions of the levee section consist of very loose to loose sand (SP). The foundation soils are predominantly fine-grained, consisting of clay (CL) and sandy clay (CL) or clayey sand (SC) to at least 20 feet below the ground surface, the depth of the explorations.

The levee at this site is about 16 feet in height above the landside toe, has a crown approximately 31 feet wide, and a very steep 1.4H to 1V landside slope. Stability analysis performed by the Corps of Engineers on a levee section at Site 6, which is comprised of similar levee and foundation materials, but has a much flatter landside slope (2.5H to 1V) and lower height (13 feet), indicated substandard levee stability during high river stages. Therefore, levee stability at Site 11 is a significant concern.

To improve the overall stability and to control internal seepage and the potential for piping, a Type IIA seepage/stability berm is recommended. Based on comparison with the stability analysis of the levee with berm at Site 6, it is anticipated that the proposed berm will improve the stability of Site 11 to above project standards for stability. Although the seepage/stability berm will not prevent seepage into the field, it will minimize the potential for sand boils, which can lead to piping and internal erosion, in the vicinity of the toe. The repair will be approximately 2,000 feet long, located approximately between River Mile 85.2 and 85.6.

No other alternative considered, including a slurry cutoff wall, seems likely to provide as technically effective, or as cost effective, a solution to the problems of this particular site. Therefore, no other alternatives were evaluated, and no cost comparison of other methods of reconstruction has been made.

(12) Sites 12, 12A and 13: Sites 12, 12A, and 13 comprise three contiguous reaches of the left (east) bank levee of the Knight's Landing Ridge Cut (KLRC), which extends from the Colusa Basin Drain southeasterly to the Yolo Bypass. The combined length of the sites is about 3.4 miles of the approximately 6.4-mile-long KLRC east levee, exclusive of about one and one-half miles on each end.

The KLRC was constructed at the turn of the century by local interests to convey irrigation water to nearby fields and to provide drainage during the flood season. The KLRC consists of two parallel channels excavated using a clamshell dredge. The dredged material was deposited in piles along the levee alignment without grubbing or removal of the surficial organic matter.

The KLRC levees have a long history of stability problems. Records dating to 1951 have described levee deformation, slippage, and partial collapse. Levee damage has resulted from a combination of four conditions: (1) loss of strength and cracking of the near-surface weathered fat clay (CH) soils (similar to Yolo Bypass east levee), (2) precipitation and possible through-levee seepage creating water forces within the levee, (3) a weak layer of foundation organic clay, and (4) oversteepened levee geometry. Many of the failures have been on the landside slope and are often shallow, involving approximately the upper 5 feet of the levee. Deeper slides, sometimes resulting in significant slumping of the crown, have also occurred. Similar to slides that occur on the left bank of the Yolo bypass discussed later in Section C.(2), the slides along KLRC tend to come to equilibrium after the slide mass forms a crude buttress at the toe of the slide, sometimes "pinching off" the adjacent irrigation ditch. However, before this occurs, typically a 4- to 7-foot vertical escarpment will develop in the crown which can be anywhere from 200 to 1,000 feet long. Past repairs have included removal and recompaction of the failed material to flatter slopes with the inclusion of a stabilizing berm to counterbalance the tendency for rotational failures of the levee fill. A total of 67 levee repair and reconstruction sites have been noted in Corps' documents since 1956.

Three separate explorations of the east levee of the KLRC were conducted in 1951, 1989, and 1990 by the Corps of Engineers or their consultants. In the site areas, a total of 11 borings and 2 CPT soundings were drilled. The levee and foundation materials are classified predominantly as fat clay (CH) and lean clay (CL) with occurrences of organics identified in most of the explorations. Excavations of failed reaches have also revealed layers of organic material. Organic material encountered near the foundation contact consists of decayed and partially decayed tule reeds, carbon chunks, and roots. Pockets and seams of sand are also encountered to a depth of about 15 to 20 feet below the ground surface.

Levee geometry varies over the length of the three sites. An evaluation of about 12 cross-sections within the site reaches indicates that the crown width is generally about 15 to 20 feet and the height above the landside toe generally varies from about 15 feet to 20 feet. The levee height is up to as much as 30 feet where the irrigation ditch, which is about 5 to 10 feet deep, is close to or contiguous with the toe of the levee. The ditch is located at the levee toe approximately from Channel Mile (CM) 2.8 to the northern (upstream) end of the sites at CM 5.0. In this reach, identified as Site 12, the landside slope typically has a characteristic break in slope below mid-slope, where the slope steepens down into the irrigation ditch. In spite of its oversteepened appearance at the toe, the cross-sections indicate that the average landside slope, from edge of crown to toe, is generally a relatively flat 3H to 1V or flatter.

From CM 2.8 to the southern (downstream) end of the sites, at about CM 1.6, the levee seems to have a more regular, or unbroken landside slope which varies from about 2.5H: 1V to 3H to 1V. Site 12A is identified as the reach from about CM 2.8 to CM 2.0

where the irrigation ditch is at least 35 feet from the landside toe. Site 13 is identified as the reach from about CM 2.0 to CM 1.6, where the irrigation ditch is closer than 35 feet from the toe.

Most of the reaches are characterized by numerous random cracks on the slopes, and in some areas longitudinal cracks are prevalent along the levee shoulder and extend 5 to 7 feet beneath the surface.

Because of the history of landside slope failures in this reach of the levee, stability of the levee is a major concern. Therefore, a stability analysis of the landside slope of a typical levee section was performed. The analysis included (1) a relatively weak organic clay layer at the base of the levee; (2) a cracked and weakened (due to shrink-swell) surficial layer of fat clay; and (3) an 8-foot-deep irrigation ditch at the landside toe.

Strength parameters of the organic clay, fat clay, and weakened fat clay materials were assigned based on the results of a laboratory testing program performed on samples obtained from the explorations.

Stability of the waterside slopes has not been evaluated because it is generally assumed that during flood stages the water against the waterside slope has a stabilizing effect. Waterside slope failures typically occur after receding floodwaters and do not pose the same threat of sudden release of floodwater as do landside slope failures. Waterside slope repairs can usually be made after the floodwaters recede.

The results of the landside slope stability analysis indicate that the factor of safety for the existing levee condition is 1.02. Therefore, it is recommended that corrective measures be taken to improve this condition. Based on the results of the stability analyses and consideration of a combination of alternatives, including ditch relocation, slope flattening, and soil treatment or lime stabilization, it was determined that a combination of all of the above would be required. Therefore, the recommended repair consists of construction of the following:

1) Backfill the existing irrigation ditch where it is closer than 35 feet from the levee toe and relocate to at least 35 feet from the toe (Sites 12 and 13);

2) Flatten the landside slope to 3H to 1V where the slope has an oversteepened section at the toe and treat soil or lime stabilize (Site 12); and

3) Stabilize with lime all levee reaches to a depth of 4 feet, the levee crown, landside slope and landside toe material (Sites 12, 12A, and 13).

To summarize the identification of the sites, as discussed previously, Site 12 is the northern reach of the KLRC levee approximately from CM 5.0 downstream to CM 2.8 where the irrigation ditch is adjacent or close to the toe of the levee. Site 12A is the middle reach of the levee from CM 2.8 to CM 2.0 where the ditch is located at least 35 feet from the levee toe. And finally, Site 13 is at the southern end of the KLRC levee from CM 2.0 to CM 1.6. In this reach the ditch is also closer than 35 feet from the levee toe.

The following is a summary of the recommended repairs for the three sites:

Site 12	Backfill and relocate ditch - Type VI and flatten and treat soil or lime stabilize surface - Type V.
Site 12A	Treat soil or lime stabilize surface - Type IVA.
Site 13	Backfill and relocate ditch - Type VI and treat soil or lime stabilize surface - Type IVA.

The repairs to Sites 12 are about 11,500 feet long; 12A, 4,500 feet long; and 13, 2,000 feet long.

Stability was reevaluated using a landslide slope of 3H to 1V, a backfilled and relocated irrigation ditch, but no change in the cracked and weakened surface layer. The resulting minimum factor of safety for deep sliding surfaces was 1.54, but only 1.27 for shallow slides, which was still less than the criterion of 1.4. Although an analysis with a lime-stabilized surface was not performed, it was concluded that lime stabilization would increase the stability against shallow slides to acceptable project standards.

Lime stabilization for this purpose has been successfully used by the Corps of Engineers in the St. Louis and Memphis Districts on similar soils (see the discussion regarding Site 3). In addition, a laboratory testing program was developed specifically for this project to evaluate the suitability of using lime as a soil stabilizing agent. It was concluded that a reduction in the Plasticity Index (PI) of the native CH soils of about 50 percent could be achieved with about 4 percent lime admixture. The objective of the lime stabilization is to change the soil's behavior from highly expansive (typically PI greater than 30) to non-expansive (typically PI less than 15), thereby resisting shrinkage leading to cracking.

Lime stabilization helps to increase the levee stability in a number of ways. The lime-treated levee material will be shrink-swell resistant; therefore, it will be less likely to crack, which has three main advantages: (1) cracked levee material tends to increase the mass permeability of the clay, especially vertically, leading to saturation of underlying levee materials, thus increased weight and increased loading. Lime treatment, by resisting cracking, therefore tends to preserve the impermeability of the clay and act as a cap against infiltration of water and saturation; (2) cycles of shrink-swell over the years are known to significantly reduce the strength of the clay and, in effect, reduce or eliminate cohesive strength. The strength of weathered fat clay has been estimated at $\phi = 23°$ and $c = 0$ based on laboratory testing. Lime treatment not only resists the loss of strength due to shrink-swell cycles, but actually hardens the clay, thus adding strength, especially cohesion; and (3) a continuous length of open crack on the crown of a levee has a very negative impact on the mechanics of stability because the open crack not only has no strength, but is likely to fill with water and thus add a very large, destabilizing hydrostatic force to the top of the levee. This can seriously contribute to reduction of levee stability in either shallow or deep landslide modes.

As an alternative to the Type IVA lime stabilization method, the surface layer could be removed and replaced with compacted, nonexpansive clay (Type IVB). Use of nonexpansive clay has some of the same advantages as lime treatment with regard to resisting cracking and preventing increased vertical permeability, reduction of shear strength, and addition of destabilizing levee forces. However, nonexpansive clay will not add strength by hardening as does lime treatment. Good, dependable sources of suitable material are also often difficult to obtain, and material requires hauling to the site. Disposal of the excavated expansive clay will also be required. For these reasons, lime treatment is the preferred alternative.

B. CONTRACT #2

(1) Site 17: This site is located on the left bank of the Feather River along the Garden Highway south of its intersection with West Catlett Road, approximately at RM 2.3. It is the site of an apparently undocumented old levee break. The resulting landside scour hole is now a stagnant pond, which is lush with vegetation and surrounded by large trees. According to a representative of Reclamation District 1001, the pond becomes deeper during high river stages, implying significant seepage. The length of the scour hole parallel to the levee is approximately 400 feet. and the site has therefore been assigned that length. An auger boring from the levee crown indicates the levee, which is a maximum of 24 feet high, consists of very loose (SPT N values of 3), clean sand for its entire height. The foundation consists of similar material with comparable properties.

The nature of the levee and foundation materials and the configuration of the levee raise concerns about both levee stability and the potential for piping of levee and foundation soils during high river stages. The landside slope is steep (1.6H to 1V), and the sand would exhibit a relatively low shear strength (friction angle less than 30 degrees). Landside slope stability analyses yielded an extremely low minimum factor of safety of 0.75, implying an unstable slope under high river stage conditions. It is possible that slope failure has been avoided during recent floods only because they were of insufficient duration to fully saturate the levee section. Foundation piping potential was also evaluated using a flow net. Factor of safety against piping was calculated to be about 2.3, below the desired minimum of 4.0. It is obvious that reconstruction is needed to improve stability and foundation piping resistance. Alternative solutions evaluated included waterside and landside control measures. Given the potential threat to slope stability and the possibility of foundation piping, the traditional recommendation would be a landside seepage/stability berm. However, as discussed later, this solution has a potentially significant environmental impact at this site, and there is also some question whether there is room to construct an adequate berm here. Therefore, a waterside slurry wall and blanket are recommended.

Installation of a slurry wall from the levee crown would involve disruption of traffic on the Garden Highway and restoration of the paved roadway. The recommended solution is a Type IC slurry wall installed from an existing waterside berm. Seepage through the upper portion of the levee would be cut off by an impervious clay blanket constructed on the waterside slope from the top of the slurry wall to above the design water surface. It is probably not feasible to completely cut off seepage through the foundation, as clean sands are known to extend to a depth of at least 30 feet below ground level (the maximum depth explored) and perhaps much more. Therefore, this solution relies on the partially penetrating slurry wall to reduce exit gradients and pore water pressures in the landside portion of the levee and its foundation by significantly increasing the length of the seepage path. A flow-net analysis was performed to determine the underseepage piping potential with a 25-foot-deep slurry wall installed from the waterside berm. This arrangement improved the factor of safety against piping at the landside toe to 4.2. Admittedly, the results of flow-net analyses are sensitive to adjustment and interpretation in the slope of the flow net. Nevertheless, the analysis does provide a good approximation of the factor of safety as well as the relative change in the factor of safety using a slurry wall compared to the existing condition. To provide some additional comfort, recognizing the approximate nature of the analysis, a slurry wall depth of 30 feet is recommended. A 200-foot extension of the wall at each end of the site is recommended to account for end-around seepage. This would double the site length to 800 feet for this alternative. Because this is a very short site, the unit cost of a slurry wall for the small quantity involved would be very high. However, adopting the slurry wall solution at several sites in Contract Area 2 would reduce the unit cost.

A Type IIA landside seepage/stability berm was evaluated as an alternative. A stability analysis conducted on a section including a sizable berm at the landside toe yielded a marginal factor of safety of 1.38 on a rather deep slip circle that extends into the foundation and beyond the toe of the berm. The pond near the toe of the levee is classified as wetlands, and no draining to lower its water surface or encroachment within its limits would be allowed. Very little room exists between the levee toe and the pond as it now exists to construct a berm of Type IIA dimensions without severely impacting the pond. Furthermore, it is possible that more detailed final design studies would show that an even larger berm is required. It is questionable whether a seepage/stability berm of adequate size to sufficiently improve stability can be constructed, given the constraints at this site. Moreover, the removal of vegetation and large trees that would be required to construct a berm would have significant environmental impact.

(2) Site 18: This site is also located along the Garden Highway on the left bank of the Feather River and is about 1-1/2 miles south of Site 17 at approximate RM 0.85. The site is about 400 feet long and may also be the location of an old levee break. Adjacent to the levee toe is a shallow depression about 300 feet long which is overgrown by dense vegetation. According to a local reclamation district representative, although no sand boils or slope failures are known to have occurred in this location in the past, seepage emerges near the landside toe during high river stages. Moreover, it was noted during the field reconnaissance of this site that the toe area was damp, apparently from river seepage. Exploration by an auger hole at the site indicates that the upper half of the levee consists of a very loose to loose (N=2 to 6) silty sand, and the lower half consists of a very loose to loose clean sand. The foundation to the 30-foot-depth explored consists of soft to firm (N=4 to 8) sandy clay.

Because the foundation apparently consists entirely of sandy clay, it does not appear that shallow foundation seepage leading to piping is a concern at this site. However, the levee is about 25 feet high, and its landside slope is fairly steep at 2H to 1V. Sands in the lower half of the levee are highly permeable, and the levee is therefore susceptible to seepage-related landside slope instability during high river stages. Alternative solutions evaluated included a landside seepage/stability berm and an impervious cutoff. Based on lower cost, the seepage/stability berm is recommended. However, if slurry wall solutions are adopted at the other three sites in Contract Area #2, the economics may change, and it may be more advantageous contractually to adopt a slurry wall solution here.

The recommended solution is a Type IIA seepage/stability berm about 8 feet high along the entire site. The dense vegetation will require clearing and grubbing over the entire site of the berm. The berm will not prevent seepage through the levee, but its internal drain will collect and control the seepage, and the berm will sufficiently improve levee stability. Its encapsulated horizontal blanket drain will also minimize the potential for future development of sand boils near the landside toe of the levee, should there be any undetected upper foundation sand layers (not considered likely given the clayey nature of all the foundation materials encountered). The reconstruction will be approximately 400 feet long.

An impervious slurry cutoff wall was evaluated as an alternative. To avoid disruption of traffic on the Garden Highway, a Type IC slurry wall would be installed from an existing waterside berm to the underlying foundation clays. This would be supplemented by an impervious clay blanket on the waterside slope to completely cut off seepage through the levee, thus sufficiently improving levee stability. The exploratory data suggest that virtual seepage cutoff could be attained at a relatively shallow depth of about 12 feet beneath the waterside berm. Seating the base of the slurry wall 15 feet below the berm would provide some reserve depth to cut off any undetected upper-foundation sands, in the unlikely event that they exist here. Thus, a 15-foot-deep slurry wall is assumed. A 200-foot extension of the slurry wall and blanket at each end of the site is recommended to account for end-around seepage. The extension would increase the length of the site (for the slurry wall solution) to 800 feet.

(3) <u>Site 19</u>: This site is located along the Garden Highway on the left bank of the Feather River, from RM 0.35 to RM 0.55. It comprises an approximately 1,000-foot-long reach of levee which is the site of the "Verona cut." That intentional cut in the levee was made in early 1956 to drain the floodwaters created by an upstream levee break in December 1955. The Verona cut was subsequently repaired by the Corps of Engineers. The levee at this site is 22 feet high, with slopes 2.5H to 1V landside and 3H to 1V waterside. No exploration was conducted in this reach, so levee and foundation materials have not been confirmed. However, when the Corps closed the cut, the material used was obtained from the adjacent Feather River. Therefore, it is believed the levee consists of relatively clean sand. Reclamation District 1001 records indicate the cut was

approximately 800 feet wide. According to a representative of that district, a gravel or rock core used to armor the base and sides of the cut was left in place prior to closure of the section. This may partially explain why this reach of levee is reported to seep part way up the landside slope during high river stages. To date, there have been no reports of slope failure or internal erosion of the levee material.

Since the landside slope is relatively flat, slope stability is probably not a major concern at this site. However, the presence of a continuous blanket of rock or gravel through the levee, and the likelihood that the levee is composed predominantly of relatively clean sands, makes this reach vulnerable to through-levee seepage and possible internal erosion. Consequently, corrective action is recommended at this site. Alternatives considered include a seepage/stability berm against the landside slope and a slurry wall with blanket at the waterside slope. The seepage/stability berm is recommended because of probable lower cost and the potential difficulty in constructing a slurry wall if site conditions are as presently understood.

The recommended solution is a Type IIA seepage/stability berm along the entire site. Based on what is known of site conditions at this time, a berm 7 to 8 feet high is anticipated. The berm will not prevent seepage through the levee, but its encapsulated internal drain will collect and safely control the seepage exiting the lower slope, and as an added benefit will improve levee stability. Its horizontal blanket drain will also minimize the potential for sand boils near the landside toe, should there be any presently unknown upper-foundation sand layers. The reconstruction will be approximately 1,000 feet long.

Because of the existence of the Garden Highway on the crown of the levee, the alternative solution would consist of a Type IC slurry wall with blanket. The slurry wall would be installed from an existing berm that is part way up the waterside slope and would extend into the foundation. It is assumed that a slurry wall depth of 20 feet would cut off seepage through the foundation, but no information exists on the foundation materials at this time. An impervious clay blanket would cover the waterside slope from the top of the slurry wall to above the design water surface. A 200-foot extension of the slurry wall at each end of the site is recommended to account for end-around seepage. The extensions would increase the length of the site for the alternative solution to

1,400 feet. The constructibility of a slurry wall at this site hinges totally on conditions within the levee, and those conditions are not well understood at this time. The extent of the reported blanket of rock armor over the old Verona cut will influence whether a slurry wall is practical at this site. If a rock blanket extends completely through the section, excavation of a slurry trench through the blanket could be difficult if not impossible. Therefore, if this alternative is considered further, exploration will be required to confirm site conditions. Exploration is necessary, in any case, to define the nature of the embankment and foundation conditions.

(4) Site 20: This site is located along the Garden Highway on the left bank of the Feather River between Verona and the Natomas Cross Canal, from approximate RM 79.0 to RM 79.5. It constitutes a 2,800-foot-long reach of levee where seepage and small sand boils have occurred during high flows in the Sacramento River. Past exploration has consisted of four auger borings—two through the levee and into the foundation and two in natural ground near the landside toe of the levee. This exploration indicates the levee consists of very loose to loose (N=2 to 6) relatively clean sand. Most of the foundation to the explored depth of 23 feet consists of finer-grained, soft to firm sandy clay (CL) to sandy silt (ML) deposits. However, two of the borings indicate that portions of the upper few feet of the foundation may contain continuous sand deposits.

The landside slope of the levee is relatively steep at 1.9H to 1V. The relatively clean and loose sand in the levee, the apparent continuity of sand layers in the upper foundation, and the relatively steep landside slope indicate the levee in this reach is susceptible to failure by instability or foundation piping during high river stages. The seepage and small boils that have occurred here in the past reinforce that conclusion. Stability analyses were performed on a typical section of the levee, utilizing shear strengths based on a 30-degree friction angle for the sand and a 28-degree friction angle with 500 pounds per square foot cohesion for the fine-grained foundation material. The analyses yielded a minimum factor of safety of 1.06 on a shallow circle at the landside toe, well below the Corps criterion of 1.4. This indicates the potential for progressive failure starting from the toe and also indicates that many other potential slip circles, encompassing larger portions of the levee, would exhibit factors of safety below the Corps criterion. The potential for slope instability or foundation piping warrants corrective action at this site. Alternative solutions evaluated include a landside seepage/stability berm and an impervious cutoff. The impervious cutoff is recommended based on lower cost.

The recommended solution is a Type IC slurry wall with waterside slope blanket. The wall would be installed from what appears to be an elevated berm or bench at the waterside toe. A depth of about 12 feet would put the bottom of the cutoff wall below the foundation sands encountered in borings. However, because the borings here have identified significant amounts of sand in the upper foundation, it is considered that additional depth is warranted to allow for the possibility of somewhat lower seepage-bearing sands. Therefore, a slurry wall depth of 20 feet is estimated. The impervious clay blanket would extend up the waterside slope from the top of the slurry wall to above the design water surface. A 200-foot extension of the wall at each end of the site is recommended to account for end-around seepage. The extensions would increase the length of the site for the slurry wall alternative to 3,200 feet.

A seepage/stability berm at the landside toe was evaluated as an alternative. In this case, because the upper several feet of foundation is known to contain sand layers, a 5-foot-deep toe drain would be incorporated in the design. Thus, a Type IIB berm is recommended. This solution will not prevent seepage through the levee or upper foundation, but its drain system will collect and safely control that seepage near the landside toe, and the berm will sufficiently improve levee stability. This was confirmed by stability analyses on the modified levee section, which yielded a minimum factor of safety of 1.89, well above the Corps criterion.

C. CONTRACT #3

(1) Site 14: Site 14 is a 3,700-foot reach of levee on the right bank of the Sacramento River, just downstream from the Fremont Weir. This reach of levee is maintained by Reclamation District 1600 (R.D. 1600). It is noted in the R.D. 1600 inspection log that an apparent old levee break, referred to as the Caffaro break, occurred near the downstream end of this site. Reclamation district personnel have also reported seepage at the toe of the levee at this site during the 1986 flood. A Public Law 84-99

repair was subsequently constructed, consisting of a 600-foot-long gravel seepage berm at the landside toe designed to minimize potential for future sand boils. However, the berm has apparently been obliterated by farming activities.

As at Sites 9, 10, and 11, this reach of the Sacramento River levee is characterized by predominantly loose, clean, sandy levee material dredged from the river, overlying finer-grained foundation materials. One boring was drilled at this site in 1987 as part of the Public Law 84-99 levee investigation following the 1986 floods, and two more borings were drilled in 1993 by the Corps of Engineers because of the history of problems. These explorations show that the levee and the upper 3 to 5 feet of the foundation consist mainly of clean, very loose to loose fine sand (SP), overlying firm sandy clay (CL) or silty sand (SM) foundation materials.

The levee at this site has a 36-foot-wide crest and is typically about 16 feet high on the landside with a relatively steep landside slope of 2H to 1V, which is locally oversteepened at the landside toe due to farming operations.

Based on past performance and site conditions, this site is believed to be vulnerable to underseepage and piping failure. In addition, stability analyses performed by the Corps of Engineers at Site 6, which is comprised of similar levee and foundation conditions but has even more favorable levee geometry, indicated substandard levee stability during high river stages. Therefore, levee stability at Site 14 is also a concern. Alternative solutions evaluated included a landside seepage/stability berm with toe drain and an impervious cutoff. The seepage/stability berm with toe drain is recommended based on cost and reliability.

To improve the overall stability and to control internal seepage and the potential for piping, a Type IIB seepage/stability berm with toe drain is recommended. The drain, which is wrapped with filter fabric, does not prevent seepage, but rather attracts seepage passing through or beneath the levee in a controlled manner, so as to reduce the potential for the development of sand boils, piping, and progressive internal erosion. The 5-foot-deep toe drain is considered adequate to attract underseepage based on a review of the borings which indicated that the sand may extend slightly below the toe of the levee.

Based on comparison with the stability analysis of the levee with berm at Site 6, it is anticipated that the proposed berm will improve the stability of Site 14 to above project standards for stability, while also minimizing the potential for seepage and piping near the levee toe during high river stages. The repair will be approximately 3,700 feet long, approximately between River Miles 80.8 and 81.5.

As an alternative, a Type IIA slurry cutoff wall through the levee crown could be constructed. The cutoff wall should be keyed several feet into the finer-grained foundation soil to a total depth of about 20 to 23 feet. As discussed previously, the length of the cutoff wall would need to be extended about 200 feet on each end of the wall, thus increasing the length of Site 14 to about 4,100 feet. In addition, the gravel surface on the levee crown would require restoration.

(2) Sites 15A and 15B: Sites 15A and 15B comprise contiguous reaches of the left (east) bank levee of the Yolo Bypass and extend from the upstream end at River Road (Highway 16), which is just north of the I-5 crossing, to the north bank levee of the Sacramento Bypass. Reclamation District 827 (R.D. 827) maintains the upstream 2.8 miles, and Reclamation District 785 (R.D. 785) maintains the downstream 3.1 miles. The two reclamation districts are separated by County Road 124.

This reach of levee has been plagued with landside slope failures (sloughing). Recent failures in R.D. 827 include three in 1983 and three in 1986. Four slope failures occurred in R.D. 785 in 1983. The failures have generally been only 75 to 150 feet wide and have occurred following periods of heavy rainfall and flooding in the Yolo Bypass. Major slides typically start out as small slides at the landside toe or quite often at the edge of the nearby irrigation ditch. Characteristically, the slide progresses up the levee slope and deeper into the levee section, sometimes involving the levee crest. The slides also tend to be somewhat self-stabilizing. After significant movement has taken place, the lower portion of the slide mass tends to serve as a stabilizing berm. In recent years, plastic sheeting has been placed on the failed slope by emergency flood fighting crews to minimize saturation and possible enlargement of the slide. Following past flood events, the Corps of Engineers has routinely repaired the slides under Public Law 84-99 authority by removing the slide material to below the slide plane and reconstructing the damaged portion of the levee using the same levee material as excavated. In some instances, the adjacent landside ditch has been relocated as part of the repair. Historically, failures involving the adjacent irrigation ditch have been a significant problem near the southern half of R.D. 827 where the irrigation ditch was adjacent to the levee toe. After 1986, a little over 1 mile of ditch was relocated to between 75 and 100 feet from the levee toe.

Four separate explorations have been conducted in 1956, 1987, 1989 and 1993 by the Corps of Engineers or their consultants. A total of 11 borings and 1 CPT sounding were drilled. Laboratory testing included primarily soils classification testing and triaxial shear strength testing of samples from the 1993 exploration. The borings and laboratory data indicate that the levee material consists mainly of firm to stiff fat clay (CH), with between 2 and 24 percent sand and an average Plasticity Index (PI) of 36. The foundation soils are similar except that some of the foundation soils classify as low plasticity clay (CL) with liquid Limits (LL) slightly below 50, and some portions of the upper foundation contain deposits of organic clay and some decaying vegetable matter.

The levee in this reach varies from approximately 15 to 20 feet in height, and the crown width is generally about 20 feet. The landside slopes are irregular, apparently as a result of past surface slides. In general, however, the slopes are about 2.5H to 1V, with some slopes slightly flatter at about 3H to 1V near the upstream third of the reach. The crown is gravel surfaced throughout. Surface shrinkage cracks are a predominant feature of this entire reach. In the summer, the levee soils are characterized by numerous cracks on the crown and sideslopes.

Because of the history of landside slope failures in this reach, stability of the levee is a major concern. Stability of the waterside slopes has not been evaluated, because it is generally assumed that during flood stages the water against the waterside slope has a stabilizing effect. Waterside slope failures typically occur after receding floodwaters and do not pose the same threat of sudden release of floodwater as do landside slope failures. Waterside slope repairs can usually be made after the floodwaters recede. Therefore, it is recommended that corrective measures be taken to improve the landside levee stability. Two main factors seem to contribute to the landside slope stability problems at these sites: 1) cracking due to shrinkage of the predominantly highly plastic clays, leading to

(a) increased vertical permeability of the levee, (b) decrease in shear strength of the surficial levee materials, and (c) added hydrostatic driving forces in water-filled cracks; and 2) the presence of an irrigation ditch directly adjacent to the landside toe. The problem with the toe ditch is that it usually has the effect of oversteepening the levee slope at the toe and increasing the overall slope height, thereby reducing stability by increasing driving forces. In addition, the presence of weak, organic clays near the foundation contact in some cases also likely contributes to levee instability.

The recommended repair consists of construction of the following:

1) Backfill the existing irrigation ditch, where it is closer than 35 feet from the levee toe, and relocate to at least 35 feet from the toe (Site 15A); and

2) Lime stabilize to a depth of 4 feet the levee crown, landside slope, and landside toe material (Sites 15A and 15B).

Along most of the levee, the landside irrigation ditch is located at least 35 feet from the levee toe. It appears, however, that at the northern end of the site, from R.D. 827 Levee Mile (LM) 0.0 to about R.D. 827 LM 1.3, the ditch is immediately adjacent, or very close, to the levee toe. This subreach of the levee is identified as Site 15A.

The remaining part of the levee from R.D. 827 LM 1.3 to the southern end of the site at the Sacramento Bypass (R.D. 785 LM 3.3) is identified hereafter as Site 15B.

The following is a summary of the recommended repairs at the two sites:

Site 15A	-	Backfill & relocate ditch - Type VI and treat soil or lime stabilize surface. - Type IVA.
Site 15B	-	Treat soil or lime stabilize surface - Type IVA.

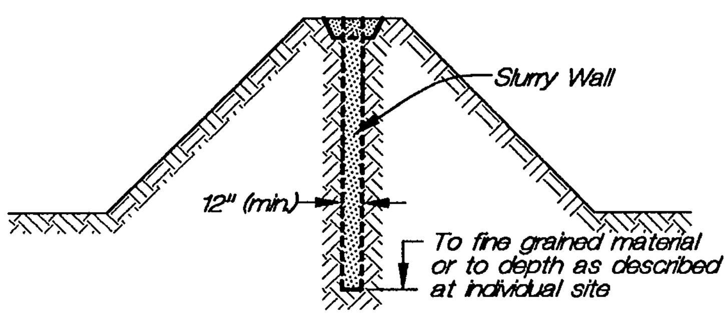
It is suspected that the levee is slightly deficient in freeboard in some sections. Adding minor amounts of fill to the levee crown to take care of these deficiencies can be incorporated into the recommended repairs during final design.

No stability analyses were specifically performed for these sites; however, the anticipated improvement in stability can be reasonably inferred from the results of the analysis of the Knight's Landing Ridge Cut (KLRC) levee (Sites 12, 12A, 13). The writeup for those sites also contains a thorough discussion of the purpose and advantages of using lime stabilization to repair the levees.

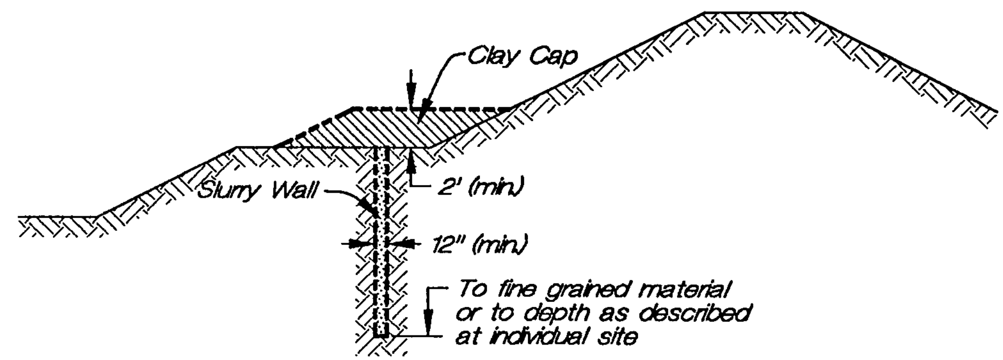
As at the KLRC levee sites, an alternative to the lime-stabilization method could consist of removal and replacement of the surface layer with compacted, nonexpansive clay (Type IVB).

6.03. Construction Considerations

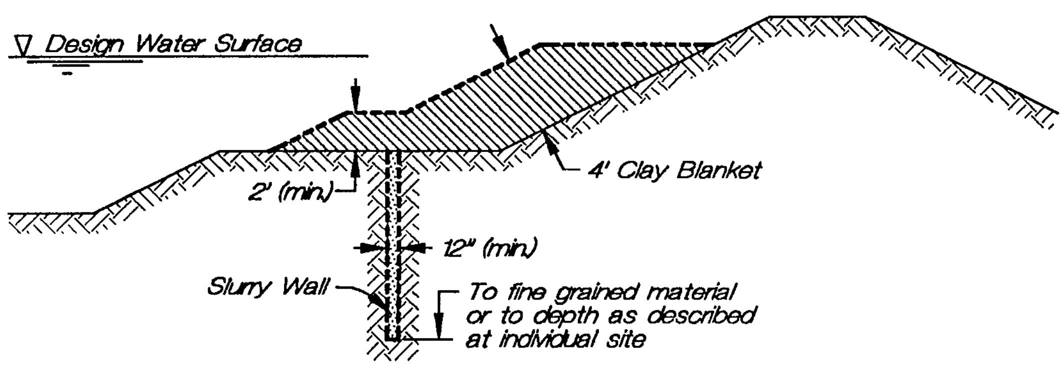
For the reconstruction work proposed, the Sacramento River Flood Control Project levee design is for a 20-foot crown width, a 3:1 waterside slope, and a 2:1 landside slope. The project design standards were used for the remedial reconstruction plans, except where minor transitions were required between the proposed and the existing levee embankments. The toe drain would be constructed at the landside toe of the existing levee embankment. The Lime treatment, the pH ratio of this mixture material, cannot be larger than 12. The relocated ditch should meet the minimum distance from levee toe requirement.



SLURRY WALL - TYPE 1A



SLURRY WALL - TYPE 1B



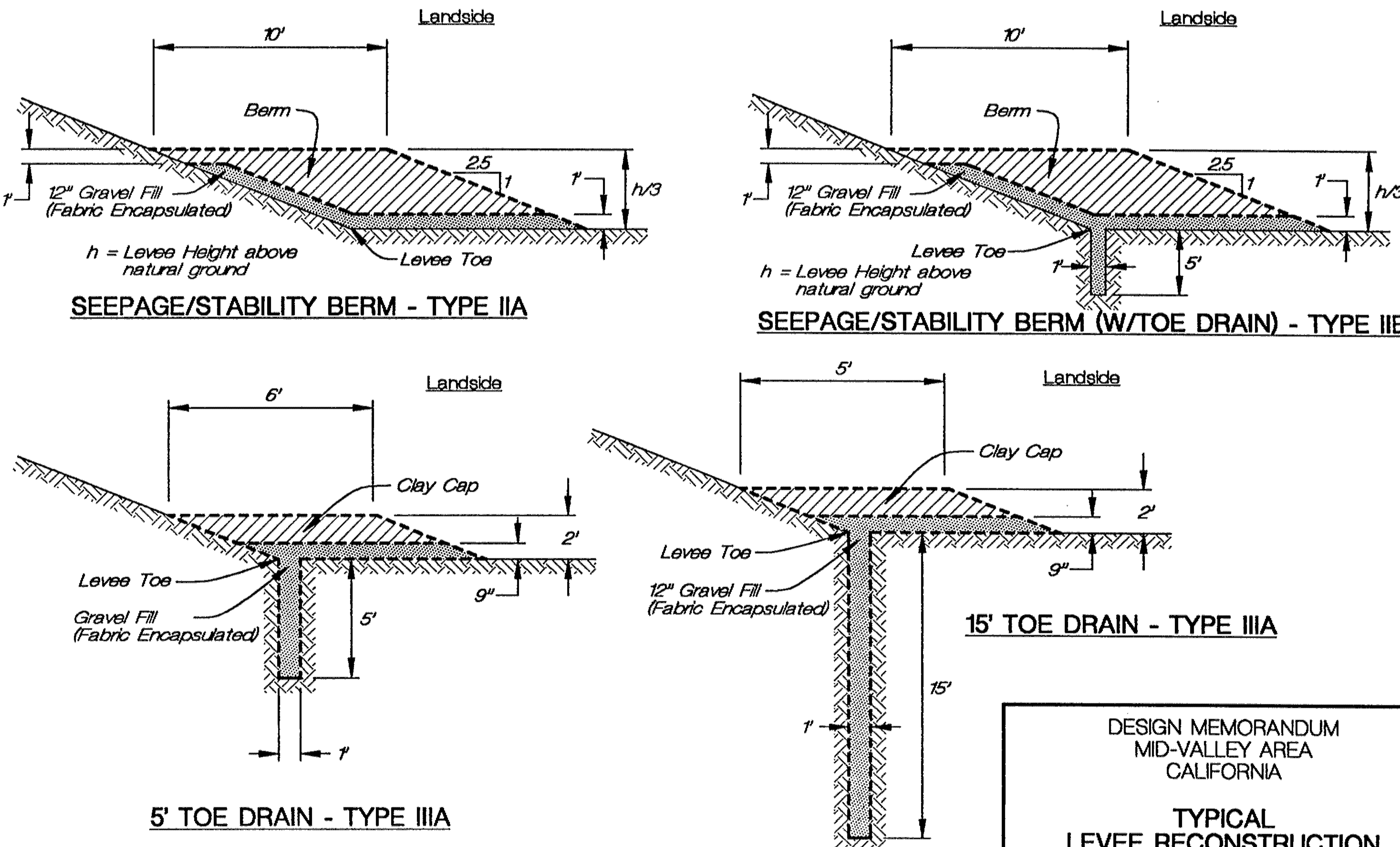
SLURRY WALL - TYPE 1C

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

TYPICAL
LEVEE RECONSTRUCTION
CROSS SECTIONS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
JULY 1995

Figure 35

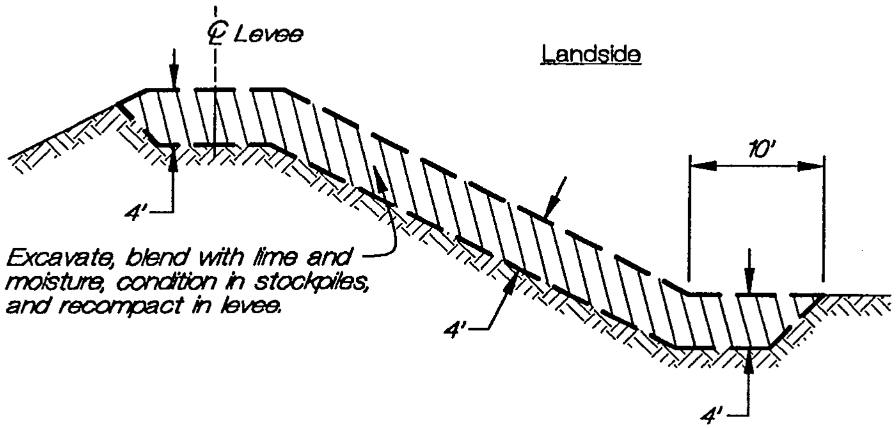


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

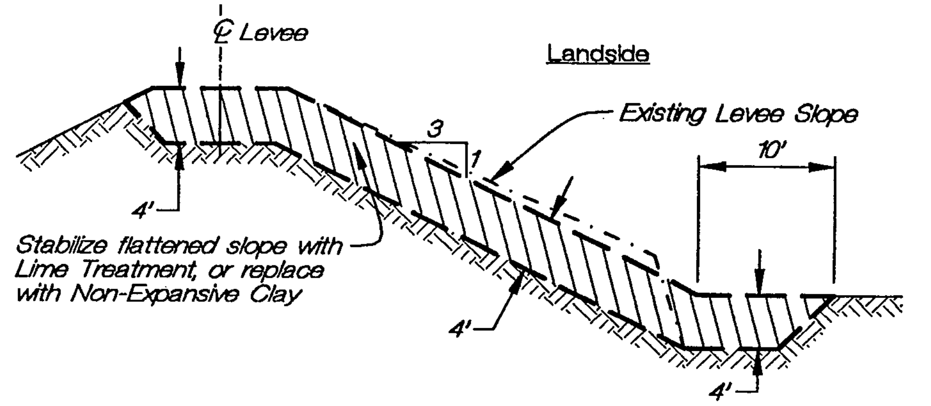
TYPICAL
LEVEE RECONSTRUCTION
CROSS SECTIONS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
JULY 1995

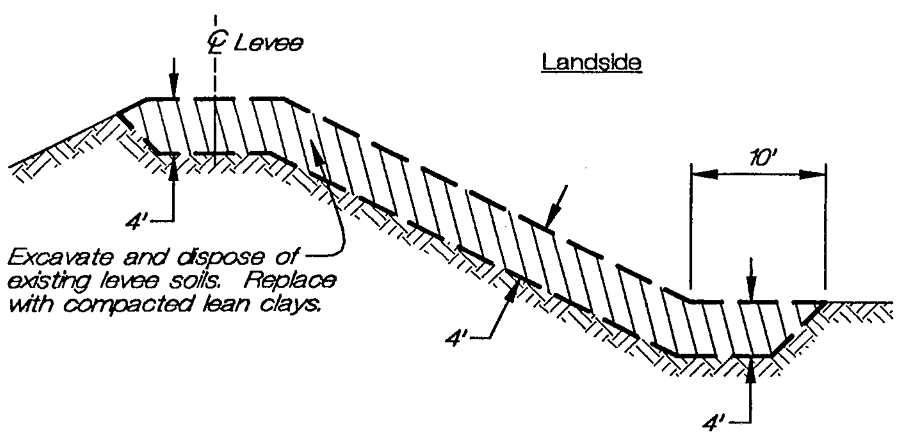
Figure 36



LIME STABILIZATION OF LANDSIDE
SLOPE AND CROWN - TYPE IVA

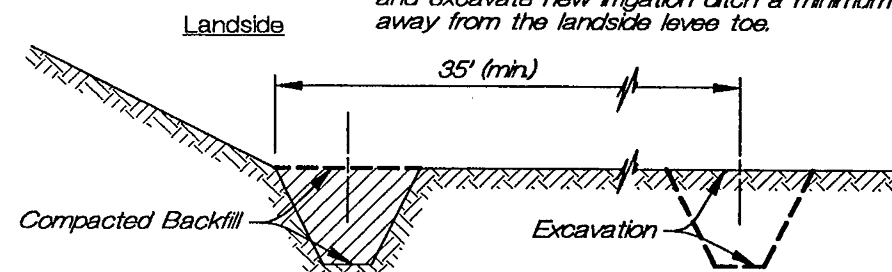


STABILIZATION OF LANDSIDE SLOPE AND CROWN
BY REPLACEMENT W/NON-EXPANSIVE CLAY - TYPE IVB



SLOPE FLATTENING AND STABILIZATION - TYPE V

Fill existing irrigation ditch with compacted backfill and excavate new irrigation ditch a minimum 35' away from the landside levee toe.



EXISTING IRRIGATION DITCH RELOCATION - TYPE VI

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

**TYPICAL
LEVEE RECONSTRUCTION
CROSS SECTIONS**

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
JULY 1995

Figure 37

6.04. Relocations

The levee reconstruction work will affect existing roads; overhead and underground power and telephone lines, poles, and towers; irrigation canals or pipelines; pipe (or cable, metal drive) gates on the levee crown; and pump stations and irrigation concrete structures—distribution boxes with slide gates or headwalls with slide gates. Most relocations are either replacements or modifications. The relocations are only being considered at the landside of the levee.

The Reclamation Board, State of California, is the local project sponsor. The Board is responsible for relocations necessitated by the proposed flood control reconstruction in this project. The Reclamation Board will task the Corps of Engineers with the design and construction of the relocations.

The following tabulations summarize the relocations required because of the recommended reconstruction. The utility relocations listed are described in detail in the tabulations of relocations by three contracts. All details and designs will be developed in the plans and specifications.

RELOCATIONS - CONTRACT #1

ITEM	DESCRIPTION	LOCATION	ACTION
SITE # 1			
1.	40' Irrigation Canal	LM 18.00 - 18.50	Remain in place
SITE # 2			
1.	40' Irrigation Canal	LM 13.75 - 14.75	Remain in place
SITE # 2-1			
1.	Irrigation Canal	LM 4.22	Remain in place

SITE # 2-2		
1. Irrigation Canal	LM 4.89	Remain in place
SITE # 2-3		
1. Irrigation Canal	LM 7.67	Remain in place
SITE # 2-4		
1. Irrigation Canal	LM 9.13	Remain in place
SITE # 2-5		
1. Irrigation Canal	LM 9.53 - 9.60	Remain in place
SITE # 2-6		
1. Irrigation Canal	LM 10.32 - 10.38	Remain in place
SITE # 2-7		
1. Irrigation Canal	LM 12.09	Remain in place
SITE # 2-8		
1. Irrigation Canal	LM 15.45	Remain in place
SITE # 2-9		
1. Irrigation Canal	LM 16.12	Remain in place
SITE # 2-10		
1. Irrigation Canal	LM 17.14	Remain in place
SITE # 3		
1. 40' Irrigation Canal	LM 2 - 3	Remain in place
SITE # 4		
1. Pump w/pipe thru levee (w/s)	LM 31.15	Remain in place
2. 4'x6' Conc Water Dist. Box (w/s levee toe)	LM 31.15	Relocate
3. Head Wall w/Culvert thru levee	LM 31.6	Remain in place
4. Power Pole (14 each)	LM 116.2 - 117.2	Remain in place

SITE # 5			
1.	Irrigation Ditch (V shape)	LM 24.6 - 25.1	Relocate
2.	Dirt Road	LM 24.6 - 25.1	Relocate
3.	Power Pole (3 each)	LM 25.1	Remain in place
SITE # 6			
1.	Irrigation Ditch	LM 18.8 - 19.7	Relocate
Site # 7			
1.	Power Pole (3 each)	LM 0.6 - 0.85	Remain in place
2.	High Voltage Pole w/guys	LM 0.75	Remain in place
3.	Irrigation ditch (V shape)	LM 0.6 - 1.3	Relocate
Site # 8 DELETED			
Site # 9			
1.	Conc Water Diversion Pipe (40" dia x 2' high)	LM 2.9	Modify
2.	Irrigation Ditch (V shape)	LM 2.78 - 2.92	Relocate
Site # 10			
1.	Levee Overgrown	LM 3.19 - 3.28	Clear
2.	Orchard	LM 3.19 - 3.28	Clear
3.	Chicken Coop (100' from levee)	LM 3.24	Remain in place
4.	Small House	LM 3.27	Remain in place
Site # 11			
1.	Ramp	LM 4.88	Remain
2.	Pipe (2-24") thru levee Pump (w/s)	LM 4.68	Remain in place
3.	Distribution Well (toe of levee)	LM 4.68	Relocate
4.	Power Pole (3 each) (toe of levee)	LM 4.62	Remain in place
5.	Tree (3 each)	LM 4.77	Remain
6.	Radio Tower (50' from toe)	LM 4.77	Remain
Site # 12			
1.	Power Poles (5 each)	Sta 255+00 - 265+56	Remain in place
2.	Trees along toe	STA 276+10	Remain in place
3.	Irrigation Ditch	STA 276+10 - 375+00	Relocate

4.	Irrigation Well (4 each)	STA 299+88	Remain in place
	" "	STA 307+80	"
	" "	STA 315+72	"
	" "	STA 321+00	"
5.	Conc Box w/s (5'x 5')	STA 307+80	Remain in place
6.	Brush in Ditch	STA 307+80	Remove
7.	Trees in Ditch	STA 331+50 - 334+20	Remain in place
8.	Trees in Ditch	STA 352+70 - 368+50	Remain in place
9.	Pump House w/2 Pipes thru Levee (12" & 24")	STA 321+00	Remain in place

SITE # 12A

1.	Power Pole (2each)	STA 210+00 - 255+00	Remain in place

SITE # 13

1.	Irrigation Ditch	STA 190+00 - 210+00	Relocate
2.	Ramp	STA 191+52	Remain

RELOCATIONS - CONTRACT 3

ITEM	DESCRIPTION	LOCATION	ACTION
SITE # 14			
1.	Pump next to Access Road	LM 9.65	Remain in place
2.	Pump on w/s (pipe thru levee ?)	LM 9.75	Remain in place
SITES # 15 and 15A			
1.	Underground Phone Line (along levee toe)	LM 1.32 - 2.34 & LM 0.00 - 3.30	Remain in place
2.	Underground Phone Line thru Levee	LM 0.20	Remain in place
3.	Power Pole	LM 2.00	Remain in place

RELOCATIONS - CONTRACT #2

ITEM	DESCRIPTION	LOCATION	ACTION
SITE # 16	DELETE		
SITE # 17	884		
1.	Pond	LM 10.15 - 10.38	Remain in place
2.	Trees at toe of levee	LM 10.15 - 10.38	Remain in place
3.	Power Pole	LM 10.25	Remain in place
4.	Pump w/Pipe thru Levee	LM 10.25	Remain in place
SITE # 18			
1.	Power Poles	LM 11.68	Remain in place
2.	Ramp	LM 11.64	Remain in place
3.	Trees on Levee	LM 11.48 - 11.68	Remain in place
SITE # 19			
1.	Power Pole (2 each)	LM 11.2 - 11.6	Remain in place
SITE # 20			
1.	Power Pole on Levee	LM 12.79	Remain in place
2.	Conc Box (3'x4') & Pole	LM 12.79	Remain in place
3.	Ramp	LM 12.89	Remain in place
4.	House & Trees	LM 12.89 - 12.94	Remain
5.	Power Pole on Levee	LM 12.98	Remain in place
6.	Walnut & Oak Trees	LM 12.98 - 13.00	Remain in place
7.	Elderberries	LM 13.17	Relocate
8.	Big Tree (3 each)	LM 13.21	Remain

6.05. Environmental Impacts

Environmental impacts of the project are analyzed in the Environmental Assessment/Initial Study (EA/IS) (Appendix D). For a complete description of the environmental impacts of this study, the EA/IS should be consulted. The EA/IS presents guidelines to be used by the contractor during construction to avoid adverse environmental impacts, such as removal of habitat for the Federally listed threatened valley elderberry longhorn beetle. The EA/IS shall be consulted prior to construction to ensure that unnecessary impacts are avoided.

A detailed report analyzing the effects of the project on fish and wildlife resources has been prepared by the U.S. Fish and Wildlife Service (FWS). FWS identified 73 trees that would be removed during construction. By applying its Habitat Evaluation Procedure (HEP) to terrestrial resources, FWS determined that the project would adversely affect 224.28 acres of terrestrial habitats, including 199.69 acres of grassland/agriculture, 13.08 acres of emergent marsh, 8.24 acres of riparian woodland, 3.22 acres of scrub-shrub, and .05 acre of permanent wetland.

The mitigation acreage required to compensate for impacts to emergent marsh, riparian woodland, scrub-shrub, and permanent wetland will be 29.66 acres: 13.28 acres will be reestablished as emergent marsh, 11.74 acres will be planted as riparian woodland, 4.59 acres will be planted as scrub-shrub, and .05 acres will be reestablished as permanent wetland habitat.

All woody vegetation at the construction staging areas will be fenced and field-inspected by FWS and the Department of Fish and Game (DFG) prior to construction. All contractors will be given oral and written instruction to avoid these areas and made aware of the significant value of these areas to wildlife. Any woody vegetation inadvertently destroyed at the staging areas will be replaced onsite at a ratio of 5:1. Watering and monitoring of replanting success would be required until the replanted areas are self-sustaining, as determined by DFG.

A list of endangered and threatened species that may be present in the project area was provided to the Corps on April 12, 1994, and was updated on April 18, 1995. A Biological Data Report and Biological Assessment was prepared by the Corps and submitted to the FWS Endangered Species Office for a Biological Opinion. There are 1,333 elderberry stems greater than or equal to 1 inch in diameter that will be adversely affected by project construction. The loss of this beetle habitat will be mitigated by replanting 3,999 elderberry seedlings on 53.3 acres of land, in accordance with FWS compensation guidelines. One State-listed threatened Swainson's hawk was sighted in the construction area during a field visit; however, no nests were sighted. If a nest is sighted prior to or during construction, construction will be restricted within 1/4 mile until the young have fledged.

A total of 3.22 acres of scrub-shrub habitat will be affected by project construction. Of that, 3.22 acres, or 100 percent, is covered by beetle habitat (elderberry shrubs). The total compensation for impacted scrub-shrub habitat is 4.59 acres. Of this acreage, 100 percent, or 4.59 acres, will be credited as mitigation for the loss of habitat for the valley elderberry longhorn beetle. These calculations are based on FWS policy for determining how wildlife mitigation credits can be applied toward beetle mitigation. FWS allows credit for wildlife mitigation to be applied towards beetle mitigation. The credit is determined by calculating the percentage of habitat covered by elderberry shrubs. This percentage is multiplied by the acreage of compensation for the habitat affected. The resulting figure is the acreage that can be applied toward beetle mitigation. The total mitigation required for both wildlife (29.66 acres) and beetle mitigation (53.3 acres), minus the credit (4.59 acres) equals 78.37 acres.

A portion of the 78.37 acres required for mitigation will be reestablished in the irrigation ditches: 13.28 acres of compensation for emergent marsh habitat and .05 acre of permanent wetland habitat.

Habitat for the giant garter snake was found in the irrigation ditches at Sites 3, 5, 12, 13, 15A, and 19, but no garter snakes were found. Preproject surveys will be conducted at Sites 3, 5, 12, 13, 15A, and 19 to determine if the giant garter snake is present within the project area. If surveys determine that the giant garter snake is present, specific mitigation requirements would be implemented to avoid or reduce the potential for adverse effects to this species.

The FWS, California Reclamation Board, and the California Department of Fish and Game have been consulted, both formally and informally, throughout the NEPA process. FWS was consulted with regard to the giant garter snake and valley elderberry longhorn beetle. DFG was consulted regarding the Swainson's hawk, bank swallow, and giant garter snake. Elderberry shrubs at sites 12, 12A, 20 and throughout the project area will be avoided during construction. In response to FWS findings that construction work on the waterside of the levees is more damaging to valuable habitats, most construction work will be done on the landside of the levees or on the levee crown. Also, in accordance with the DFG biological opinion, construction near nests of the Swainson's hawks or bank swallows will be avoided until the young have fledged.

6.06. Mitigation Planting Design

Project design addresses all effort necessary to plant and establish vegetation for lost habitat due to levee construction work. Revegetation sites have been targeted to show a typical site that is acceptable for this effort. The targeted sites are considered "offsite" mitigation and are representative of riparian sites conducive to this type of plant growth.

Mitigation work will be accomplished under one contract, provided suitable land is available and approved by FWS. Mitigation work will commence prior to or concurrent with the first levee reconstruction contract. The total mitigation area will be 65.04 acres. An additional 199.69 acres of land disturbed as a result of construction work will be seeded with a cover crop.

Plant material will be native to the habitat and will be genetically compatible to the sites selected. Terrestrial plants will be installed as either seedlings, direct seed, and/or pole cuttings, depending on the species. Existing elderberries will be removed and transplanted from the affected levees prior to levee work. All terrestrial plants will be installed with browse/rodent guards. Selected species will be protected with wire cages from beavers.

Establishment will include the replacement of all plants that have died beyond the specified acceptable mortality rates. The Establishment Period will continue for 3 years after the Installation Acceptance has been given. Establishment will include weed control and an irrigation system to systematically water the plants with the required amount of water. A cover crop will be planted to suppress weed competition. Records and yearly reports will be required.

A monitoring program will systematically monitor the progress of the sites. The program will help determine plant progress. It will also determine if the targeted habitats are being met as specified in the EA-IS.

Operation and maintenance manuals will be developed for use by the local sponsor to protect and preserve the planting following the establishment period.

See Appendix E for detailed description of the Mitigation Planting Design.

6.07. Cultural Resources

A review of records held by the Information Center of the California Archeological Survey at California State University, Chico, revealed that no properties that are listed or eligible for the National Register of Historic Places lie within the proposed project areas of potential effect. Information records did reveal, however, that a single prehistoric site (CA-Sut-11) exists within this area, and three additional prehistoric sites (CA-Sut-1, 2, and 16) lie within 1 mile of the project area. Site CA-Sut-11 is a prehistoric burial mound recorded in 1934 by R.F. Heizer. He noted that this mound could be "a key mound to Sacramento archeology." The three prehistoric archeological sites lying outside the project area are also burial mounds.

Two separate cultural resources surveys covered the entire project area. A 1990 archeological survey (Far Western Anthropological Research Group, Inc.) confirmed the presence of archeological site CA-Sut-11 within the project area of potential effects in Site 19. Auguring at the site revealed a subsurface deposit of cultural materials at least 40 centimeters in depth which would suggest that the site retains a certain degree of integrity from the time it was first recorded in 1934. No additional cultural resources sites or values were located within the project area by the 1990 survey.

A 1992 cultural resources survey (Par Environmental Services, Inc.) identified a single cultural value within the project area of potential effects at Site 12A. This was a historic period site (receiving the temporary site number AC-S-2) on the east side of the Knights Landing Ridge Cut in Yolo County. The resource was noted to consist of a surface distribution of farming and ranching equipment and domestic debris, probably associated with agricultural use in the surrounding region during the first half of the 20th century. This survey identified no additional cultural resources within the project area.

Further cultural resource investigations are necessary to document historic values, determine adverse effects, and recommend appropriate mitigation for historic sites within the project area. Cultural resources surveys would be conducted by a qualified archeologist in the project area to determine precise adverse effects and mitigation for historic sites. The results of these surveys would be reported to the State Historic Preservation Office prior to the finalization of this document.

6.08. Hazardous and Toxic Waste

A Preliminary Assessment and Report of the project area for Hazardous and Toxic Waste was completed by the Sacramento District. The 30 reconstruction sites are along the Feather River, Sutter Bypass, Sacramento River, Knights Landing Ridge Cut, and Yolo Bypass; the staging areas and borrow areas which are considered feasible at this time were surveyed for any materials which are causing or have a potential to cause contamination of the levees with hazardous, toxic, or radiological wastes (HTRW).

A site reconnaissance for Environmental Site Assessment (ESA) was conducted for the Sacramento River Flood Control System, Phase III Mid-Valley Project. This proposed project will improve 30 sites along various levees by constructing slurry cutoff walls, adding a berm, installing a drain, restoring the levee crown, and/or relocating a ditch at the base of the levee.

No known contamination was discovered within the right-of-way of the various project sites. Five areas with potential contamination were located outside the rights-of-way (ROW) of the project sites, but within 1/4 mile of the project. Further investigation of the five areas with potential contamination is recommended to confirm the absence of contamination.

An additional consideration is that all the project sites are adjacent to farming areas and/or orchards and may contain soil and ground water with concentrations of petroleum hydrocarbons or agricultural chemicals.

According to Sutter County Environmental Health, the State Water Resources Control Board tested a sediment sample taken under the South Bridge on Highway 113 at the Sutter Bypass, north of Site 2. The test results indicate that the sample polynuclear aromatic hydrocarbons are at a concentration of 0.6 part per million (ppm).

Construction of the slurry cutoff walls into shallow ground water and ditch relocation are concerns. Construction workers at those sites may be exposed to contamination if the soil or ground water is contaminated.

6.09. Real Estate Requirements

For the reconstruction plan proposed, 10 feet of permanent easement would be required for the construction of the toe drain facilities, plus easements for drain systems to existing ditches or conveyance channels. Up to a maximum of 50 feet of permanent easement would be required for the levee reconstruction. In addition, construction would require another 20 feet of temporary easement landward of the permanent easement limit. Permanent or construction easements will not be required for the construction of the slurry cutoff walls because the work will be on the levee waterside berm, and a temporary construction easement 15 feet from the permanent easement limit will be required on the waterside of the levee.

Area #1 (RD 1500 and Knights Landing) lies entirely within Yolo and Sutter Counties. There appear to be no adverse impacts on the adjacent property owners. This area will require the acquisition of approximately 54.4 acres of land for levee easements and 29.6 acres for temporary work area easements (2 years).

Area #2 (Verona Area) lies entirely within Sutter County. This area will require the acquisition of approximately 6.6 acres of land for levee easements and 4.0 acres of land for temporary work area easements.

Area #3 (Elkhorn Area) lies in Sacramento and Placer Counties. About 41.6 acres of land for levee easements and 16 acres of land for temporary work area easements will be needed.

In addition, approximately 75 acres of land will be acquired in fee for fish and wildlife mitigation.

The real estate baseline cost estimate, which is at October 1995 price levels, is shown in Appendix F. The baseline cost estimate includes acquisition and administrative costs. The non-Federal acquisition costs were estimated by the non-Federal sponsor. The Federal costs of monitoring the acquisitions, certifying for construction, and crediting the sponsor were estimated by the Sacramento District Real Estate Division.

Detailed descriptions of the real estate requirements are contained in the Real Estate Plan (Appendix F). An acquisition schedule prepared by the non-Federal sponsor is shown in this Real Estate Plan.

6.10. Surveys

Horizontal and vertical controls were established for the levees in the project area. Horizontal control was tied into the California coordinate system, Zone 2. The U.S. Army Corps of Engineers, Louisville District, established Geodetic Control along the top of the levees on the Feather River using the Global Positioning System (GPS). The check between the existing control checked very well. Vertical control was tied into the National

Geodetic Vertical Datum of 1929 N.G.V.D. The Sacramento District ran conventional primary levels along the levee crowns of the Feather River from Richvale to Knights Landing and back to Richvale. A secondary control line was run to Wheatland for checking. Slight differences in elevations were found when compared to previous California Department of Water Resources Surveys. But since the differences were small (0.4 to 0.6 feet) and of the same magnitude throughout, it was concluded that the differences were due to adjustments of the base datum and not subsidence.

Topographic surveys of all 30 reconstruction sites will be completed in September 1995. The Sacramento District completed the survey by conventional ground control methods, shooting break points along reference lines running perpendicular to the levees at approximately 50-foot intervals. The field information was transferred to computer data (ASCII file) and copied to the Intergraph System. The Intergraph System creates a Digital Terrain Model from which contours and cross sections are developed.

CHAPTER 7 - PROJECT COSTS

7.01. General

The total project cost estimate is shown in Table 7. The cost estimate includes construction costs; planning, engineering design, and construction management costs; riparian mitigation costs; real estate costs; and relocation costs. The M-CACES cost estimate is included in Appendix G.

7.02. Basis of Costs

7.2.1 General. The project cost estimate is based on 1 October 1995 price levels. The project will be constructed in three construction contracts (Contract 1, Robbins/Knights Landing area; Contract 2, Verona area; and Contract 3, Elkhorn area) during a 3-year period from May 1997 to September 1999. Riparian mitigation will be done under a separate construction contract during a 3-year period from January 1996 to September 1998, including a 3-year maintenance period. The apportionment of Federal and non-Federal costs is based on the criteria contained in the Project Cooperation Agreement (PCA) and the Water Resources Development Act of 1986. The estimated construction costs were developed using M-CACES software, Unit Price Book database, and production rates based on similar projects. The basis of cost by features was derived from the following considerations and assumptions:

7.2.2 Real Estate. The costs for lands and Federal and non-Federal administrative activities are supplied by Real Estate Division. The estimated land costs are based on comparable sales data in the general vicinity of the project and real property valuations.

7.2.3 Relocation. Irrigation ditches will be relocated within the contracts. The cost for relocation is the responsibility of the non-Federal sponsor.

7.2.4 Construction.

a. Clearing and grubbing involves the removal of trees, stumps, and vegetation. Equipment will include dozer, front-end loader, trucks, and miscellaneous equipment. The wasted material will be hauled to a local dump site about 10 miles away. The costs include the dumping fee.

b. Stripping involves the removal and disposal of the top 6 inches of soil in areas to be excavated. Equipment will include dozer, front-end loader, dump trucks, and water trucks. The stripped material will be hauled to a local dump site about 10 miles away.

c. Excavation involves the removal of unclassified soil. Excavated material will be stockpiled for use in constructing the embankment, and excess excavated material will be disposed of in the same manner as the stripped material. Equipment to be used would be the same as that for stripping.

d. Embankment involves the placement of stockpiled material from excavation. Equipment will include dozer, roller compactor, grader, and water trucks.

e. Soil treatment involves importing borrow material and mixing with existing clay soil. Equipment would be the same as for excavation and embankment operations.

f. Slurry cutoff wall involves mixing in place a 2-foot-wide by 30-foot-deep wall with a slurry mix consisting of bentonite, water softener, other additives, and existing soil. Equipment will include hydraulic excavator, crane, concrete pumps, loader, transit mixer, water trucks, and miscellaneous equipment.

g. For other construction items, drainage material, geotextile, and erosion control, cost includes material delivered onsite and placed by common methods.

7.2.5 Riparian Mitigation. Estimated mitigation planting costs are based on requirements described in Appendix E.

7.2.6 Cultural Resources. The estimated cost for cultural resources is based on 1 percent of the total Federal cost.

7.2.7 Planning, Engineering and Design (PED), and Construction Management. Costs for PED and construction management were based on expenditures to date and itemized estimates of requirements for future engineering, design, supervision, and inspection required to complete the project.

7.2.8 Contingencies. A contingency of 15 percent was applied to all construction items to provide for potential adjustment in quantities which could result from more complete survey and exploration work and pricing which could result from more detailed design based on the final plans and specifications.

TABLE 7

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN

SUMMARY OF ANNUAL COST Total Effective Price Date (EPD) 1 Oct 95 7.750%	
Item	**Cost ($)**
A. INVESTMENT COST	
1. FEDERAL	
TOTAL	27,456,000
2. NON-FEDERAL	
TOTAL	8,689,000
TOTAL PROJECT INVESTMENT	36,145,000
B. ANNUAL COSTS	
1. FEDERAL	
TOTAL	2,130,000
2. NON-FEDERAL	
TOTAL	674,000
TOTAL PROJECT ANNUAL COST	2,804,000

ESTIMATED COST (CONSTRUCTION PROJECTS)
FIRST COSTS

	Contract 1	Contract 2	Contract 3	Mitigation
Federal	19,750,000	3,937,000	1,001,000	2,768,000
Non-Federal	6,126,000	1,236,000	546,000	781,000
Total First Costs	25,876,000	5,173,000	1,547,000	3,549,000

TABLE 7, continued

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN

DETAILED ESTIMATE OF ANNUAL COST Total Effective Price Date (EPD) 1 Oct 95 7.750%		
A. INVESTMENT COST		
1. FEDERAL		
a. First Cost		24,030,000
Less 18. Cultural Resources Presrvation		(241,000)
b. Interest During Construction		3,667,000
TOTAL		27,456,000
2. NON-FEDERAL		8,130,000
a. First Cost		559,000
b. Interest During Construction		
TOTAL		8,689,000
TOTAL PROJECT INVESTMENT		36,145,000
B. ANNUAL COSTS		
1. FEDERAL		
a. Interest and Amortization:		
Interest @	7.750%	2,129,000
Amortization @	0.004%	1,000
Amortization Period	100	
Total		2,130,000
2. NON-FEDERAL		
Total		674,000
TOTAL PROJECT ANNUAL COST		2,804,000

TABLE 7, continued

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN
CONTRACT 1

SUMMARY OF ANNUAL COST
Area 1
Effective Price Date (EPD) 1 Oct 95
7.750%

Item	Cost ($)
A. INVESTMENT COST	
1. FEDERAL	
TOTAL	19,750,000
2. NON-FEDERAL	
TOTAL	6,126,000
TOTAL PROJECT INVESTMENT	25,876,000
B. ANNUAL COSTS	
1. FEDERAL	
TOTAL	1,532,000
2. NON-FEDERAL	
TOTAL	475,000
TOTAL PROJECT ANNUAL COST	2,007,000

TABLE 7, continued

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN
CONTRACT 1

DETAILED ESTIMATE OF ANNUAL COST Area 1 Effective Price Date (EPD) 1 Oct 95 7.750%		
A. INVESTMENT COST		
1. FEDERAL		
a. First Cost		17,470,000
Less 18. Cultural Resources Presrvation		(175,000)
b. Interest During Construction		2,455,000
TOTAL		19,750,000
2. NON-FEDERAL		5,770,000
a. First Cost		356,000
b. Interest During Construction		
TOTAL		6,126,000
TOTAL PROJECT INVESTMENT		25,876,000
B. ANNUAL COSTS		
1. FEDERAL		
a. Interest and Amortization:		
Interest @	7.750%	1,531,000
Amortization @	0.004%	1,000
Amortization Period	100	
Total		1,532,000
2. NON-FEDERAL		
Total		475,000
TOTAL PROJECT ANNUAL COST		2,007,000

TABLE 7, continued

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN
CONTRACT 2

SUMMARY OF ANNUAL COST Area 2 Effective Price Date (EPD) 1 Oct 95 7.750%	
Item	**Cost ($)**
A. INVESTMENT COST	
1. FEDERAL	
TOTAL	3,937,000
2. NON-FEDERAL	
TOTAL	1,236,000
TOTAL PROJECT INVESTMENT	5,173,000
B. ANNUAL COSTS	
1. FEDERAL	
TOTAL	305,000
2. NON-FEDERAL	
TOTAL	96,000
TOTAL PROJECT ANNUAL COST	401,000

TABLE 7, continued

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN
CONTRACT 2

DETAILED ESTIMATE OF ANNUAL COST Area 2 Effective Price Date (EPD) 1 Oct 95 7.750%		
A. INVESTMENT COST		
1. FEDERAL		
a. First Cost		3,580,000
Less 18. Cultural Resources Presrvation		(36,000)
b. Interest During Construction		393,000
TOTAL		3,937,000
2. NON-FEDERAL		1,180,000
a. First Cost		56,000
b. Interest During Construction		
TOTAL		1,236,000
TOTAL PROJECT INVESTMENT		5,173,000
B. ANNUAL COSTS		
1. FEDERAL		
a. Interest and Amortization:		
Interest @	7.750%	305,000
Amortization @	0.004%	0
Amortization Period	100	
Total		305,000
2. NON-FEDERAL		
Total		96,000
TOTAL PROJECT ANNUAL COST		401,000

TABLE 7, continued

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN
CONTRACT 3

SUMMARY OF ANNUAL COST Area 4 Effective Price Date (EPD) 1 Oct 95 7.750%	
Item	**Cost ($)**
A. INVESTMENT COST	
1. FEDERAL	
TOTAL	1,001,000
2. NON-FEDERAL	
TOTAL	546,000
TOTAL PROJECT INVESTMENT	1,547,000
B. ANNUAL COSTS	
1. FEDERAL	
TOTAL	78,000
2. NON-FEDERAL	
TOTAL	42,000
TOTAL PROJECT ANNUAL COST	120,000

TABLE 7, continued

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN
CONTRACT 3

DETAILED ESTIMATE OF ANNUAL COST Area 4 Effective Price Date (EPD) 1 Oct 95 7.750%		
A. INVESTMENT COST		
1. FEDERAL		
a. First Cost		880,000
Less 18. Cultural Resources Preservation		(9,000)
b. Interest During Construction		130,000
TOTAL		1,001,000
2. NON-FEDERAL		490,000
a. First Cost		56,000
b. Interest During Construction		
TOTAL		546,000
TOTAL PROJECT INVESTMENT		1,547,000
B. ANNUAL COSTS		
1. FEDERAL		
a. Interest and Amortization:		
Interest @	7.750%	78,000
Amortization @	0.004%	0
Amortization Period	100	
Total		78,000
2. NON-FEDERAL		
Total		42,000
TOTAL PROJECT ANNUAL COST		120,000

TABLE 7, continued

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN
MITIGATION CONTRACT

SUMMARY OF ANNUAL COST Effective Price Date (EPD) 1 Oct 95 7.750%	
Item	**Cost ($)**
A. INVESTMENT COST	
1. FEDERAL	
TOTAL	2,768,000
2. NON-FEDERAL	
TOTAL	781,000
TOTAL PROJECT INVESTMENT	3,549,000
B. ANNUAL COSTS	
1. FEDERAL	
TOTAL	215,000
2. NON-FEDERAL	
TOTAL	61,000
TOTAL PROJECT ANNUAL COST	276,000

TABLE 7, continued

MID-VALLEY AREA LEVEE RECONSTRUCTION
COST ESTIMATE, RECONSTRUCTION PLAN
MITIGATION CONTRACT

DETAILED ESTIMATE OF ANNUAL COST Effective Price Date (EPD) 1 Oct 95 7.750%		
A. INVESTMENT COST		
1. FEDERAL		
a. First Cost		2,100,000
Less 18. Cultural Resources Presrvation		(21,000)
b. Interest During Construction		689,000
TOTAL		2,768,000
2. NON-FEDERAL		
a. First Cost		690,000
b. Interest During Construction		91,000
TOTAL		781,000
TOTAL PROJECT INVESTMENT		3,549,000
B. ANNUAL COSTS		
1. FEDERAL		
a. Interest and Amortization:		
Interest @	7.750%	215,000
Amortization @	0.004%	0
Amortization Period	100	
Total		215,000
2. NON-FEDERAL		
Total		61,000
TOTAL PROJECT ANNUAL COST		276,000

COST ESTIMATE

SACRAMENTO RIVER FLOOD CONTROL PROJECT,
MID-VALLEY, PHASE III
SACRAMENTO, CALIFORNIA.

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To the best of my knowledge the cost estimate was prepared in full compliance with ER 1110-2-1302 dated 31 March 1994 and ER-5-7-1(FR) dated 20 September 1992.

TOTAL - ALL CONTRACTS **** TOTAL PROJECT COST SUMMARY ****

PROJECT: MID-VALLEY PROJECT
LOCATION: CALIFORNIA

DISTRICT: SACRAMENTO
P.O.C. FRANK Y.F. FONG, CHIEF, COST ENGINEERING

ACCOUNT NO.	FEATURE DESCRIPTION	CURRENT MCACES ESTIMATE PREPARED: 1-OCT-95 EFFECTIVE PRICING LEVEL (EPL): 1-OCT-95 COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	AUTHORIZ./BUDGET YR: 1996 EFF PRICING LEVEL: 1-OCT-95 COST ($K)	CNTG ($K)	TOTAL ($K)	........FULLY FUNDED ESTIMATE....(3. COST ($K)	CNTG ($K)	FULL ($K)
	FEDERAL COSTS										
06	FISH & WILDLIFE										
	Mitigation Contract	1,830	271	15%	2,101				1,923	285	2,208
11	LEVEES & FLOODWALLS	18,859	2,844	15%	21,703				20,381	3,075	23,456
	Contract 1	15,205	2,283	15%	17,488				16,419	2,466	18,885
	Contract 2	3,032	462	15%	3,494				3,272	499	3,771
	Contract 3	622	99	16%	721				690	110	800
18	CULTURAL RESOURCE (1 PRESERVATION	208	33	16%	241				223	35	258
	Contract 1	151	24	16%	175				161	26	187
	Contract 2	31	5	16%	36				34	5	39
	Contract 3	8	1	13%	9				9	1	10
	Mitigation Contract	18	3	17%	21				19	3	22
	SUBTOTAL FEDERAL & NON-FEDERAL CONSTRUCTION COSTS	20,897	3,148		24,045				22,527	3,395	25,922
01	LANDS AND DAMAGES (2	225	28	12%	253				239	23	262
	Contract 1	122	15	12%	137				129	12	141
	Contract 2	51	7	14%	58				54	6	60
	Contract 3	52	6	12%	58				56	5	61
30	PLANNING ENGINEERING AND DESIGN	3,115	485	16%	3,600				3,149	493	3,642
	Contract 1	2,308	356	24%	2,664				2,315	357	2,672
	Contract 2	465	71	24%	536				476	74	550
	Contract 3	86	15	25%	101				94	17	111
	Mitigation Contract	256	43	24%	299				264	45	309
31	CONSTRUCTION MANAGEMENT	1,759	263	15%	2,022				1,917	287	2,204
	Contract 1	1,292	194	15%	1,486				1,405	210	1,615
	Contract 2	258	38	15%	296				287	43	330
	Contract 3	53	8	15%	61				59	9	68
	Mitigation Contract	156	23	15%	179				166	25	191
	SUBTOTAL FEDERAL & NON-FEDERAL CONTRIBUTION	25,996	3,924		29,920				27,832	4,198	32,030
	NON-FEDERAL CONTRIBUTION	5,217	673		5,890				5,610	720	6,330
	TOTAL FEDERAL COSTS	**20,779**	**3,251**		**24,030**				**22,222**	**3,478**	**25,700**
	NON-FEDERAL COSTS										
01	LANDS AND DAMAGES	1,770	445	25%	2,215				1,873	470	2,343
	Contract 1	1,000	268	27%	1,268				1,054	282	1,336
	Contract 2	274	63	23%	337				298	69	367
	Contract 3	344	76	22%	420				369	81	450
	Mitigation Contract	152	38	25%	190				152	38	190
02	RELOCATIONS	22	3	14%	25				24	3	27
	Contract 1	19	3	16%	22				21	3	24
	Contract 2	3	0	0%	3				3	0	3
	SUBTOTAL NON-FEDERAL	1,792	448		2,240				1,897	473	2,370
	NON-FEDERAL CONTRIBUTION	5,217	673		5,890				5,610	720	6,330
	TOTAL NON-FEDERAL COSTS	**7,009**	**1,121**		**8,130**				**7,507**	**1,193**	**8,700**
	TOTAL FEDERAL & NON-FEDERAL COSTS	**27,788**	**4,372**		**32,160**				**29,729**	**4,671**	**34,400**

GENERAL NOTES

(1 Cultural Resources Preservation costs associated with mitigation and/or data recovery up to one percent
(2 Federal administrative costs for non-Federal land acquisition.
of the total Federal cost are not subject to cost sharing.
(3 The Fully Funded cost estimate was prepared in compliance with EC 11-2-163 published in March 1995.

DISTRICT APPROVED:

CHIEF, COST ENGINEERING
CHIEF, REAL ESTATE
Walter Yep CHIEF, PLANNING
for CHIEF ENGINEERING
CHIEF, CON-OPS
CHIEF, PROGRAMS MANAGEMENT
PROJECT MANAGER
DDE (PM)

DIVISION APPROVED:

________ CHIEF, COST ENGINEERING
________ CHIEF, REAL ESTATE
________ CHIEF, PROGRAMS MANAGEMENT
________ DIRECTOR OF PPMD

APPROVED DATE: ________

CONTRACT 1

		CURRENT MCACES ESTIMATE PREPARED: 1-OCT-95 EFFECTIVE PRICING LEVEL (EPL): 1-OCT-95				AUTHORIZ./BUDGET YR: 1996 EFF PRICING LEVEL: 1-OCT-95				........FULLY FUNDED ESTIMATE.......				
ACCOUNT NO.	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
	FEDERAL COSTS													
11	LEVEES & FLOODWALLS	15,205	2,283	15%	17,488							16,419	2,466	18,885
	Area 1	4,158	624	15%	4,782					MAR-98	7.8%	4,484	673	5,157
	Area 3	11,047	1,659	15%	12,706					MAR-98	8.0%	11,935	1,793	13,728
18	CULTURAL RESOURCE (1 PRESERVATION	151	24	16%	175						6.9%	161	26	187
	SUBTOTAL FEDERAL & NON-FEDERAL CONSTRUCTION COSTS	15,356	2,307		17,663							16,580	2,492	19,072
01	LANDS AND DAMAGES (2	122	15	12%	137					JUN-96	2.9%	129	12	141
30	PLANNING ENGINEERING AND DESIGN	2,308	356	24%	2,664					JUN-95	0.3%	2,315	357	2,672
31	CONSTRUCTION MANAGEMENT	1,292	194	15%	1,486					AUG-97	8.7%	1,405	210	1,615
	SUBTOTAL FEDERAL & NON-FEDERAL CONTRIBUTION	19,078	2,872		21,950							20,429	3,071	23,500
	NON-FEDERAL CONTRIBUTION	3,968	512		4,480							4,280	550	4,830
	TOTAL FEDERAL COSTS	15,110	2,360		17,470							16,149	2,521	18,670
	NON-FEDERAL COSTS													
01	LANDS AND DAMAGES	1,000	268	27%	1,268							1,054	282	1,336
02	RELOCATIONS Constr Activities													
03	CEMETERIES UTILITIES AND STRUCTURES	19	3	16%	22							21	3	24
	SUBTOTAL NON-FEDERAL	1,019	271		1,290							1,075	285	1,360
	NON-FEDERAL CONTRIBUTION	3,968	512		4,480							4,280	550	4,830
	TOTAL NON-FEDERAL COSTS	4,987	783		5,770							5,355	835	6,190
	TOTAL FEDERAL AND NON-FEDERAL COSTS	20,097	3,143		23,240							21,504	3,356	24,860

CONTRACT 2

ACCOUNT NO.	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
	CURRENT MCACES ESTIMATE PREPARED: 1-OCT-95 EFFECTIVE PRICING LEVEL (EPL): 1-OCT-95					AUTHORIZ./BUDGET YR: 1996 EFF PRICING LEVEL: 1-OCT-95				........FULLY FUNDED ESTIMATE.......				
	FEDERAL COSTS													
11	LEVEES & FLOODWALLS AREA 2	3,032	462	15%	3,494					May-98	7.9%	3,272	499	3,771
18	CULTURAL RESOURCE (1 PRESERVATION	31	5	16%	36						8.3%	34	5	39
	SUBTOTAL FEDERAL & NON-FEDERAL CONSTRUCTION COSTS	3,063	467		3,530							3,306	504	3,810
01	LANDS AND DAMAGES (2	51	7	14%	58					Oct-98	3.4%	54	6	60
30	PLANNING ENGINEERING AND DESIGN	465	71	24%	536					Mar-96	2.6%	476	74	550
31	CONSTRUCTION MANAGEMENT	258	38	15%	296					Feb-98	11.5%	287	43	330
	SUBTOTAL FEDERAL & NON-FEDERAL CONTRIBUTION	3,837	583	15%	4,420							4,123	627	4,750
	NON-FEDERAL CONTRIBUTION	744	96		840							800	100	900
	TOTAL FEDERAL COSTS	**3,093**	**487**		**3,580**							**3,323**	**527**	**3,850**
	NON-FEDERAL COSTS													
01	LANDS AND DAMAGES	274	63	23%	337							298	69	367
02	RELOCATIONS													
03	CEMETERIES UTILITIES AND STRUCTURES	3	0	0%	3							3	0	3
	SUBTOTAL NON-FEDERAL	277	63		340							301	69	370
	NON-FEDERAL CONTRIBUTION	744	96		840							800	100	900
	TOTAL NON-FEDERAL COSTS	**1,021**	**159**		**1,180**							**1,101**	**169**	**1,270**
	TOTAL FEDERAL AND NON-FEDERAL COSTS	**4,114**	**646**		**4,760**							**4,424**	**696**	**5,120**

CONTRACT 3

ACCOUNT NO.	FEATURE DESCRIPTION	CURRENT MCACES ESTIMATE PREPARED: 1-OCT-95 EFFECTIVE PRICING LEVEL (EPL): 1-OCT-95 COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	AUTHORIZ./BUDGET YR: 1996 EFF PRICING LEVEL: 1-OCT-95 OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	........FULLY FUNDED ESTIMATE....... FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
	FEDERAL COSTS													
11	LEVEES & FLOODWALLS AREA 4	622	99	16%	721					Mar-99	11.0%	690	110	800
18	CULTURAL RESOURCE (1 PRESERVATION	8	1	13%	9						11.1%	9	1	10
	SUBTOTAL FEDERAL & NON-FEDERAL CONSTRUCTION COSTS	630	100		730							699	111	810
01	LANDS AND DAMAGES (2	52	6	12%	58					Mar-99	5.2%	56	5	61
30	PLANNING ENGINEERING AND DESIGN	86	15	25%	101					Jun-97	9.9%	94	17	111
31	CONSTRUCTION MANAGEMENT	53	8	15%	61					Mar-99	11.5%	59	9	68
	SUBTOTAL FEDERAL & NON-FEDERAL CONTRIBUTION	821	129	16%	950							908	142	1,050
	NON-FEDERAL CONTRIBUTION	58	12	21%	70							60	10	70
	TOTAL FEDERAL COSTS	**763**	**117**	**15%**	**880**							**848**	**132**	**980**
	NON-FEDERAL COSTS													
01	LANDS AND DAMAGES	344	76	22%	420							369	81	450
	SUBTOTAL NON-FEDERAL	344	76		420							369	81	450
	NON-FEDERAL CONTRIBUTION	58	12		70							60	10	70
	TOTAL NON-FEDERAL COSTS	**402**	**88**		**490**							**429**	**91**	**520**
	TOTAL FEDERAL AND NON-FEDERAL COSTS	1,165	205		1,370							1,277	223	1,500

MITIGATION CONTRACT

ACCOUNT NO.	FEATURE DESCRIPTION	CURRENT MCACES ESTIMATE PREPARED: 1-OCT-95 EFFECTIVE PRICING LEVEL (EPL): 1-OCT-95 COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	AUTHORIZ./BUDGET YR: 1996 EFF PRICING LEVEL: 1-OCT-95 OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	........FULLY FUNDED ESTIMATE....... FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
	FEDERAL COSTS													
06	FISH & WILDLIFE	1,830	271	15%	2,101					May-98	5.1%	1,923	285	2,208
18	CULTURAL RESOURCE (1 PRESERVATION	18	3	17%	21						4.8%	19	3	22
SUBTOTAL FEDERAL & NON-FEDERAL CONSTRUCTION COSTS		1,848	274		2,122							1,942	288	2,230
30	PLANNING ENGINEERING AND DESIGN	256	43	24%	299					Aug-96	3.3%	264	45	309
31	CONSTRUCTION MANAGEMENT	156	23	15%	179					Jun-97	6.7%	166	25	191
SUBTOTAL FEDERAL & NON-FEDERAL CONTRIBUTION		2,260	340		2,600							2,372	358	2,730
NON-FEDERAL CONTRIBUTION		447	53		500							470	60	530
TOTAL FEDERAL COSTS		1,813	287	16%	2,100							1,902	298	2,200
	NON-FEDERAL COSTS													
01	LANDS AND DAMAGES	152	38	25%	190							152	38	190
SUBTOTAL NON-FEDERAL		152	38		190							152	38	190
NON-FEDERAL CONTRIBUTION		447	53		500							470	60	530
TOTAL NON-FEDERAL COSTS		599	91		690							622	98	720
TOTAL FEDERAL AND NON-FEDERAL COSTS		2,412	378		2,790							2,524	396	2,920

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
	FEDERAL							
	CONTRACT 1							
01------	LANDS AND DAMAGES							
01------	SUNK COSTS							
	Planning				16,800	0	0.0	-
	Appraisal				8,900	0	0.0	-
012303--	CONSTRUCTION CONTRACT(S) DOCUMENTS							
01230301	Real Estate Planning Documents	160	WH		11,000	1,700	15.5	-
01230302	Real Estate Acquisition Documents	464	WH		30,300	4,500	14.9	-
01230303	Real Estate Condemnation Documents	48	WH		2,400	400	16.7	-
01230305	Real Estate Appraisal Documents	72	WH		5,600	800	14.3	-
01230307	Real Estate Rts of Entry/TempPermt	216	WH		14,800	2,200	14.9	-
01230317	Real Estate LERRD Crediting Docs	496	WH		32,200	5,400	16.8	-
	Subtotal, Construction Costs:			$	122,000			
	Contingencies @ average of	15.6 % +/- *			$	15,000		A
01------	LANDS AND DAMAGES			TOTAL:	$	137,000		
	AREA 1							
11------	LEVEES AND FLOODWALLS							
1101----	LEVEES							
110199--	Asssociated General Items:							
11019902	Site Work							
	Clearing and Grubbing	28.5	ACR	12,500	356,250	53,400	15.0	-
	Stripping	15110	CY	6.75	101,993	15,300	15.0	-
	Excavation	97300	CY	2.50	243,250	36,500	15.0	-
	Embankment	82800	CY	2.00	165,600	24,800	15.0	-
	Soil Treatment	99720	CY	10.60	1,057,032	158,600	15.0	-
	Drainage Material	97100	TN	17.60	1,708,960	256,300	15.0	-
	Geotextile	264000	SY	1.80	475,200	71,300	15.0	-
	Erosion Control Seeding	28.5	ACR	1,750	49,875	7,500	15.0	-
	Subtotal, Construction Costs:			$	4,158,160			
	Contingencies @ average of	15.0 % +/- *			$	623,840		A
1101----	LEVEES			TOTAL:	$	4,782,000		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
	AREA 3							
11------	LEVEES AND FLOODWALLS							
1101----	LEVEES							
110199--	Asssociated General Items:							
11019902	Site Work							
	Clearing and Grubbing	83.6	ACR	11,300	944,680	141,700	15.0 -	
	Stripping	9970	CY	5.10	50,847	7,600	14.9 -	
	Excavation	585830	CY	4.35	2,548,361	382,300	15.0 -	
	Embankment	127140	CY	1.95	247,923	37,200	15.0 -	
	Soil Treatment	606600	CY	10.50	6,369,300	956,400	15.0 -	
	Drainage Material	18170	TN	17.70	321,609	48,200	15.0 -	
	Geotextile	232000	SY	1.80	417,600	62,600	15.0 -	
	Erosion Control Seeding	83.6	ACR	1,760	147,136	22,100	15.0 -	
	Subtotal, Construction Costs:			$	11,047,456			
	Contingencies @ average of 15.0 % +/- *					$ 1,658,544		A
1101----	LEVEES		TOTAL:			$ 12,706,000		
18------	CULTURAL RESOURCE PRESERVATION				151,000	24,000		
	Subtotal, Construction Costs:			$	151,000			
	Contingencies @ average of 15.9 % +/- *					$ 24,000		A
18------	CULTURAL RESOURCE PRESERVATION		TOTAL:			$ 175,000		
30.-.-.-	**PLANNING, ENGINEERING & DESIGN Federal**							
30.B.-.-	ENGINEERING AND DESIGN PRIOR THRU 30 SEP 1995				827,200			
30.D.-.-	ENVIRONMENTAL AND REGULATORY ACTIVITIES							
30.D.C.-	Supplemental EIS				20,800	0	0.0 -	
30.D.2.-	401, 404, & ROD				1,640	0	0.0 -	
30.D.Z.-	Contingencies					12,590	-	
30.E.-.-	DESIGN RELATED ENGINEERING							
30.E.1.-	Subsurface Explorations				34,120	0	0.0 -	
30.E.2.-	Sampling, Testing, & Analysis				97,610	0	0.0 -	
30.E.Z.-	Contingencies					46,530	-	
30.F.-.-	GENERAL DESIGN MEMORANDUM (GDM)							
30.F.A.-	Draft Design Document				437,170	0	0.0 -	
30.F.B.-	Finial Design Document				131,920	0	0.0 -	
30.F.F.-	Value Engineering (VE) Studies				10,760	0	0.0 -	
30.F.Z.-	Contingencies					121,940	-	
30.H.-.-	PLANS AND SPECIFICATIONS							
30.H.A.-	Premliminary Design				267,630	0	0.0 -	
30.H.B.-	Final Design				78,210	0	0.0 -	
30.H.C.-	Design Revisions				14,300	0	0.0 -	
30.H.E.-	Bidability, Constructability & Operability Review				9,330	0	0.0 -	
30.H.Z.-	Contingencies					65,330	-	
30.J.-.-	ENGINEERING DURING CONSTRUCTION							
30.J.H.-	Value Engineering Change Proposals (VECP)				11,850	0	0.0 -	
30.J.1.-	Review of E&D Effort by Construction Contractor				1,080	0	0.0 -	
30.J.2.-	Periodic Inspections				3,770	0	0.0 -	
30.J.9.-	All Other Engineering During Construction				5,400	0	0.0 -	
30.J.Z.-	Contingencies					12,380	-	

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
30.M.-.-	COST ENGINEERING				82,840	0	0.0	-
30.M.Z.-	Contingencies					12,430		-
30.P.-.-	PROJECT MANAGEMENT				218,040	0	0.0	-
30.P.Z.-	Contingencies					75,220		-
30.Z.-.-	MISCELLANEOUS ACTIVITIES							
30.Z.1.-	FWS Support				32,120	0	0.0	-
30.Z.1.-	Surveys (Topographical)				14,600	0	0.0	-
30.Z.1.-	Surveys (Cultural)				7,930	0	0.0	-
30.Z.Z.-	Contingencies					9,220		-
	Subtotal			$	2,308,320			
	Contingencies @ average of	24.0 % +/- *			$	355,680		
30.-.-.-	PLANNING, ENGINEERING & DESIGN Federal		TOTAL:		$	2,664,000		
31.-.-.-	CONSTRUCTION MANAGEMENT (S & I)							
31.B.-.-	CONTRACT ADMINISTRATION							
31.B.1.-	Pre-award Activities							
31.B.1.1	Resident Office				5,770	866	15.0	-
31.B.1.2	District Office				11,060	1,659	15.0	-
31.B.2.-	Award Activities				2,760	414	15.0	-
31.B.3.-	Review & Approval of Contract Payment				34,620	5,193	15.0	-
31.B.4.-	Contract Modifications							
31.B.4.1	Resident Office				230,820	34,623	15.0	-
31.B.4.2	District Office				13,820	2,073	15.0	-
31.B.5.-	Progress and Completion Reports				23,080	3,462	15.0	-
31.C.-.-	BENCHMARKS AND BASELINES				9,970	1,496	15.0	-
31.D.-.-	REVIEW OF SHOP DRAWINGS							
31.D.1.1	Resident Office				115,410	17,312	15.0	-
31.D.1.2	District Office				13,820	2,073	15.0	-
31.E.-.-	INSPECTION AND QUALITY ASSURANCE							
31.E.1.-	Schedule Compliance				23,080	3,462	15.0	-
31.E.2.-	Compliance Sampling & Testing							
31.E.2.1	Resident Office				86,560	12,984	15.0	-
31.E.2.2	Laboratory Charges				86,560	12,984	15.0	-
31.E.9.-	Q. A. Personnel				294,290	43,844	14.9	-
31.F.-.-	PROJECT OFFICE OPERATION							
31.F.-.1	Resident Office				23,080	3,462	15.0	-
31.F.-.2	Vehicles and Equipment				220,980	33,147	15.0	-
31.H.-.-	CONTRACTOR INITIATED CLAIMS AND LITIGATIONS				48,370	7,256	15.0	-
31.P.-.-	PROJECT MANAGEMENT				48,370	7,256	15.0	-
	Subtotal			$	1,292,420			
	Contingencies @ average of	15.0 % +/- *			$	193,580		
31.-.-.-	CONSTRUCTION MANAGEMENT (S & I)		TOTAL:		$	1,486,000		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
	CONTRACT 2							
01------	LANDS AND DAMAGES							
01------	SUNK COSTS							
	Planning				7,100	0	0.0 -	
	Appraisal				3,700	0	0.0 -	
012303--	CONSTRUCTION CONTRACT(S) DOCUMENTS							
01230301	Real Estate Planning Documents	128	WH		9,000	1,400	15.6 -	
01230302	Real Estate Acquisition Documents	72	WH		4,400	700	15.9 -	
01230303	Real Estate Condemnation Documents	16	WH		800	100	12.5 -	
01230305	Real Estate Appraisal Documents	40	WH		3,300	500	15.2 -	
01230307	Real Estate Rts of Entry/TempPermt	120	WH		8,000	1,200	15.0 -	
01230317	Real Estate LERRD Crediting Docs	224	WH		15,000	2,800	18.7 -	
	Subtotal, Construction Costs:			$	51,300			
	Contingencies @ average of 16.5 % +/- *				$	6,700		A
01------	LANDS AND DAMAGES		TOTAL:		$	58,000		
	AREA 2							
11------	LEVEES AND FLOODWALLS							
1101----	LEVEES							
110199--	Asssociated General Items:							
11019902	Site Work							
	Clearing and Grubbing	24.4	ACR	11,200	273,280	41,000	15.0 -	
	Stripping	5210	CY	5.10	26,571	4,000	15.1 -	
	Excavation	122900	CY	2.60	319,540	47,900	15.0 -	
	Embankment	88120	CY	2.00	176,240	26,400	15.0 -	
	Soil Treatment	159000	CY	10.60	1,685,400	259,800	15.4 -	
	Drainage Material	20550	TN	17.70	363,735	54,600	15.0 -	
	Geotextile	80110	SY	1.80	144,198	21,600	15.0 -	
	Erosion Control Seeding	24.4	ACR	1,780	43,432	6,500	15.0 -	
	Subtotal, Construction Costs:			$	3,032,396			
	Contingencies @ average of 15.2 % +/- *				$	461,604		A
1101----	LEVEES		TOTAL:		$	3,494,000		
18------	CULTURAL RESOURCE PRESERVATION				31,000	5,000		
	Subtotal, Construction Costs:			$	31,000			
	Contingencies @ average of 16.1 % +/- *				$	5,000		A
18------	CULTURAL RESOURCE PRESERVATION		TOTAL:		$	36,000		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
30.-.-.-	**PLANNING, ENGINEERING & DESIGN Federal**							
30.B.-.-	ENGINEERING AND DESIGN PRIOR THRU 30 SEP 1995				169,400			
30.D.-.-	ENVIRONMENTAL AND REGULATORY ACTIVITIES							
30.D.C.-	Supplemental EIS				4,150	0	0.0	-
30.D.2.-	401, 404, & ROD				330	0	0.0	-
30.D.Z.-	Contingencies					2,510		-
30.E.-.-	DESIGN RELATED ENGINEERING							
30.E.1.-	Subsurface Explorations				6,810	0	0.0	-
30.E.2.-	Sampling, Testing, & Analysis				19,470	0	0.0	-
30.E.Z.-	Contingencies					9,280		-
30.F.-.-	GENERAL DESIGN MEMORANDUM (GDM)							
30.F.A.-	Draft Design Document				87,180	0	0.0	-
30.F.B.-	Finial Design Document				26,310	0	0.0	-
30.F.F.-	Value Engineering (VE) Studies				2,150	0	0.0	-
30.F.Z.-	Contingencies					24,580		-
30.H.-.-	PLANS AND SPECIFICATIONS							
30.H.A.-	Premliminary Design				53,370	0	0.0	-
30.H.B.-	Final Design				15,600	0	0.0	-
30.H.C.-	Design Revisions				2,850	0	0.0	-
30.H.E.-	Bidability, Constructability & Operability Review				1,860	0	0.0	-
30.H.Z.-	Contingencies					13,030		-
30.J.-.-	ENGINEERING DURING CONSTRUCTION							
30.J.H.-	Value Engineering Change Proposals (VECP)				2,360	0	0.0	-
30.J.1.-	Review of E&D Effort by Construction Contractor				220	0	0.0	-
30.J.2.-	Periodic Inspections				750	0	0.0	-
30.J.9.-	All Other Engineering During Construction				1,080	0	0.0	-
30.J.Z.-	Contingencies					2,470		-
30.M.-.-	COST ENGINEERING				16,520	0	0.0	-
30.M.Z.-	Contingencies					2,480		-
30.P.-.-	PROJECT MANAGEMENT				43,480	0	0.0	-
30.P.Z.-	Contingencies					15,000		-
30.Z.-.-	MISCELLANEOUS ACTIVITIES							
30.Z.1.-	FWS Support				6,400	0	0.0	-
30.Z.1.-	Surveys (Topographical)				2,910	0	0.0	-
30.Z.1.-	Surveys (Cultural)				1,580	0	0.0	-
30.Z.Z.-	Contingencies					1,840		-
	Subtotal			$	464,780			
	Contingencies @ average of	24.1 % +/- *			$	71,220		
30.-.-.-	**PLANNING, ENGINEERING & DESIGN Federal**		TOTAL:		$	536,000		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
31.-.-.-	CONSTRUCTION MANAGEMENT (S & I)							
31.B.-.-	CONTRACT ADMINISTRATION							
31.B.1.-	Pre-award Activities							
31.B.1.1	Resident Office				1,150	173	15.0	-
31.B.1.2	District Office				2,210	332	15.0	-
31.B.2.-	Award Activities				550	83	15.1	-
31.B.3.-	Review & Approval of Contract Payment				6,900	1,035	15.0	-
31.B.4.-	Contract Modifications							
31.B.4.1	Resident Office				46,030	6,905	15.0	-
31.B.4.2	District Office				2,760	414	15.0	-
31.B.5.-	Progress and Completion Reports				4,600	690	15.0	-
31.C.-.-	BENCHMARKS AND BASELINES				1,990	299	15.0	-
31.D.-.-	REVIEW OF SHOP DRAWINGS							
31.D.1.1	Resident Office				23,010	3,452	15.0	-
31.D.1.2	District Office				2,760	414	15.0	-
31.E.-.-	INSPECTION AND QUALITY ASSURANCE							
31.E.1.-	Schedule Compliance				4,600	690	15.0	-
31.E.2.-	Compliance Sampling & Testing							
31.E.2.1	Resident Office				17,260	2,589	15.0	-
31.E.2.2	Laboratory Charges				17,260	2,589	15.0	-
31.E.9.-	Q. A. Personnel				58,680	8,402	14.3	-
31.F.-.-	PROJECT OFFICE OPERATION							
31.F.-.1	Resident Office				4,600	690	15.0	-
31.F.-.2	Vehicles and Equipment				44,060	6,609	15.0	-
31.H.-.-	CONTRACTOR INITIATED CLAIMS AND LITIGATIONS				9,650	1,448	15.0	-
31.P.-.-	PROJECT MANAGEMENT				9,650	1,448	15.0	-
	Subtotal			$	257,720			
	Contingencies @ average of	14.9 % +/- *			$	38,280		
31.-.-.-	CONSTRUCTION MANAGEMENT (S & I)		TOTAL:		$	296,000		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
	CONTRACT 3							
01------	LANDS AND DAMAGES							
01------	SUNK COSTS							
	Planning				7,200	0	0.0	-
	Appraisal				3,800	0	0.0	-
012303--	CONSTRUCTION CONTRACT(S) DOCUMENTS							
01230301	Real Estate Planning Documents	16	WH		1,100	200	18.2	-
01230302	Real Estate Acquisition Documents	192	WH		12,700	1,900	15.0	-
01230303	Real Estate Condemnation Documents	16	WH		800	100	12.5	-
01230305	Real Estate Appraisal Documents	40	WH		3,300	500	15.2	-
01230307	Real Estate Rts of Entry/TempPermt	120	WH		8,000	1,200	15.0	-
01230317	Real Estate LERRD Crediting Docs	224	WH		15,000	2,200	14.7	-
	Subtotal, Construction Costs:			$	51,900			
	Contingencies @ average of 14.9 % +/- *				$	6,100		A
01------	LANDS AND DAMAGES		TOTAL:		$	58,000		
11------	LEVEES AND FLOODWALLS							
1101----	LEVEES							
110199--	Asssociated General Items:							
11019902	Site Work							
	Clearing and Grubbing	3.8	ACR	14,200	53,960	8,100	15.0	-
	Stripping	1700	CY	14.00	23,800	3,600	15.1	-
	Excavation	3410	CY	2.20	7,502	1,100	14.7	-
	Embankment	23600	CY	8.10	191,160	31,700	16.6	-
	Drainage Material	8650	TN	17.70	153,105	26,000	17.0	-
	Geotextile	33800	SY	1.90	64,220	9,600	14.9	-
	Erosion Control Seeding	3.8	ACR	1,920	7,296	1,100	15.1	-
	Slurry Cutoff Wall	18000	SF	6.70	120,600	18,100	15.0	-
	Subtotal, Construction Costs:			$	621,643			
	Contingencies @ average of 16.0 % +/- *				$	99,357		A
1101----	LEVEES		TOTAL:		$	721,000		
18------	CULTURAL RESOURCE PRESERVATION				8,000	1,000		
	Subtotal, Construction Costs:			$	8,000			
	Contingencies @ average of 12.5 % +/- *				$	1,000		A
18------	CULTURAL RESOURCE PRESERVATION		TOTAL:		$	9,000		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
30.-.-.-	**PLANNING, ENGINEERING & DESIGN Federal**							
30.B.-.-	ENGINEERING AND DESIGN PRIOR THRU 30 SEP 1995				25,300			
30.D.-.-	ENVIRONMENTAL AND REGULATORY ACTIVITIES							
30.D.C.-	Supplemental EIS				850	0	0.0	-
30.D.2.-	401, 404, & ROD				70	0	0.0	-
30.D.Z.-	Contingencies					510		-
30.E.-.-	DESIGN RELATED ENGINEERING							
30.E.1.-	Subsurface Explorations				1,400	0	0.0	-
30.E.2.-	Sampling, Testing, & Analysis				3,990	0	0.0	-
30.E.Z.-	Contingencies					1,900		-
30.F.-.-	GENERAL DESIGN MEMORANDUM (GDM)							
30.F.A.-	Draft Design Document				17,880	0	0.0	-
30.F.B.-	Finial Design Document				5,400	0	0.0	-
30.F.F.-	Value Engineering (VE) Studies				440	0	0.0	-
30.F.Z.-	Contingencies					5,600		-
30.H.-.-	PLANS AND SPECIFICATIONS							
30.H.A.-	Premliminary Design				10,950	0	0.0	-
30.H.B.-	Final Design				3,200	0	0.0	-
30.H.C.-	Design Revisions				580	0	0.0	-
30.H.E.-	Bidability, Constructability & Operability Review				380	0	0.0	-
30.H.Z.-	Contingencies					2,670		-
30.J.-.-	ENGINEERING DURING CONSTRUCTION							
30.J.H.-	Value Engineering Change Proposals (VECP)				480	0	0.0	-
30.J.1.-	Review of E&D Effort by Construction Contractor				40	0	0.0	-
30.J.2.-	Periodic Inspections				150	0	0.0	-
30.J.9.-	All Other Engineering During Construction				220	0	0.0	-
30.J.Z.-	Contingencies					510		-
30.M.-.-	COST ENGINEERING				3,390	0	0.0	-
30.M.Z.-	Contingencies					510		-
30.P.-.-	PROJECT MANAGEMENT				8,920	0	0.0	-
30.P.Z.-	Contingencies					3,080		-
30.Z.-.-	MISCELLANEOUS ACTIVITIES							
30.Z.1.-	FWS Support				1,310	0	0.0	-
30.Z.1.-	Surveys (Topographical)				600	0	0.0	-
30.Z.1.-	Surveys (Cultural)				320	0	0.0	-
30.Z.Z.-	Contingencies					380		-
	Subtotal			$	85,870			
	Contingencies @ average of 25.0 % +/- *				$	15,130		
30.-.-.-	**PLANNING, ENGINEERING & DESIGN Federal**		TOTAL:		$	101,000		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
31.-.-.-	**CONSTRUCTION MANAGEMENT (S & I)**							
31.B.-.-	CONTRACT ADMINISTRATION							
31.B.1.-	Pre-award Activities							
31.B.1.1	Resident Office				240	36	15.0	-
31.B.1.2	District Office				450	68	15.1	-
31.B.2.-	Award Activities				110	17	15.5	-
31.B.3.-	Review & Approval of Contract Payment				1,420	213	15.0	-
31.B.4.-	Contract Modifications							
31.B.4.1	Resident Office				9,440	1,416	15.0	-
31.B.4.2	District Office				570	86	15.1	-
31.B.5.-	Progress and Completion Reports				940	141	15.0	-
31.C.-.-	BENCHMARKS AND BASELINES				410	62	15.1	-
31.D.-.-	REVIEW OF SHOP DRAWINGS							
31.D.1.1	Resident Office				4,720	708	15.0	-
31.D.1.2	District Office				570	86	15.1	-
31.E.-.-	INSPECTION AND QUALITY ASSURANCE							
31.E.1.-	Schedule Compliance				940	141	15.0	-
31.E.2.-	Compliance Sampling & Testing							
31.E.2.1	Resident Office				3,540	531	15.0	-
31.E.2.2	Laboratory Charges				3,540	531	15.0	-
31.E.9.-	Q. A. Personnel				12,040	2,006	16.7	-
31.F.-.-	PROJECT OFFICE OPERATION							
31.F.-.1	Resident Office				940	141	15.0	-
31.F.-.2	Vehicles and Equipment				9,040	1,356	15.0	-
31.H.-.-	CONTRACTOR INITIATED CLAIMS AND LITIGATIONS				1,980	297	15.0	-
31.P.-.-	PROJECT MANAGEMENT				1,980	297	15.0	-
	Subtotal			$	52,870			
	Contingencies @ average of	15.4 % +/- *			$	8,130		
31.-.-.-	**CONSTRUCTION MANAGEMENT (S & I)**		**TOTAL:**		$	61,000		
	MITIGATION CONTRACT							
06------	FISH AND WILDLIFE FACILITIES							
0603----	**WILDLIFE FACILITIES AND SANCTUARIES**							
060373--	Habitat and Feeding Facilities:							
06037302	Site Work							
	Mitigation	75	ACR	24,400	1,830,000	271,400	14.8	-
	Subtotal, Construction Costs:			$	1,830,000			
	Contingencies @ average of	14.8 % +/- *			$	271,400		A
0603----	**WILDLIFE FACILITIES AND SANCTUARIES**		**TOTAL:**		$	2,101,400		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
18------	CULTURAL RESOURCE PRESERVATION				18,000	3,000		
	Subtotal, Construction Costs:			$	18,000			
	Contingencies @ average of 16.7 % +/- *				$	3,000		A
18------	CULTURAL RESOURCE PRESERVATION		TOTAL:		$	21,000		
30.-.-.-	**PLANNING, ENGINEERING & DESIGN Federal**							
30.B.-.-	ENGINEERING AND DESIGN PRIOR THRU 30 SEP 1995				78,100			
30.D.-.-	ENVIRONMENTAL AND REGULATORY ACTIVITIES							
30.D.C.-	Supplemental EIS				2,510	0	0.0	-
30.D.2.-	401, 404, & ROD				200	0	0.0	-
30.D.Z.-	Contingencies					1,520		-
30.E.-.-	DESIGN RELATED ENGINEERING							
30.E.1.-	Subsurface Explorations				4,110	0	0.0	-
30.E.2.-	Sampling, Testing, & Analysis				11,750	0	0.0	-
30.E.Z.-	Contingencies					5,600		-
30.F.-.-	GENERAL DESIGN MEMORANDUM (GDM)							
30.F.A.-	Draft Design Document				52,610	0	0.0	-
30.F.B.-	Finial Design Document				15,880	0	0.0	-
30.F.F.-	Value Engineering (VE) Studies				1,290	0	0.0	-
30.F.Z.-	Contingencies					14,410		-
30.H.-.-	PLANS AND SPECIFICATIONS							
30.H.A.-	Premliminary Design				32,210	0	0.0	-
30.H.B.-	Final Design				9,410	0	0.0	-
30.H.C.-	Design Revisions				1,720	0	0.0	-
30.H.E.-	Bidability, Constructability & Operability Review				1,120	0	0.0	-
30.H.Z.-	Contingencies					7,860		-
30.J.-.-	ENGINEERING DURING CONSTRUCTION							
30.J.H.-	Value Engineering Change Proposals (VECP)				1,430	0	0.0	-
30.J.1.-	Review of E&D Effort by Construction Contractor				130	0	0.0	-
30.J.2.-	Periodic Inspections				450	0	0.0	-
30.J.9.-	All Other Engineering During Construction				650	0	0.0	-
30.J.Z.-	Contingencies					1,490		-
30.M.-.-	COST ENGINEERING				9,970	0	0.0	-
30.M.Z.-	Contingencies					1,500		-
30.P.-.-	PROJECT MANAGEMENT				26,240	0	0.0	-
30.P.Z.-	Contingencies					9,050		-

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
30.Z.-.-	MISCELLANEOUS ACTIVITIES							
30.Z.1.-	FWS Support				3,870	0	0.0 -	
30.Z.1.-	Surveys (Topographical)				1,760	0	0.0 -	
30.Z.1.-	Surveys (Cultural)				960	0	0.0 -	
30.Z.Z.-	Contingencies					1,110	-	
	Subtotal			$	256,370			
	Contingencies @ average of	23.9 % +/- *			$	42,530		
30.-.-.-	**PLANNING, ENGINEERING & DESIGN Federal**			**TOTAL:**	**$**	**298,900**		
31.-.-.-	**CONSTRUCTION MANAGEMENT (S & I)**							
31.B.-.-	CONTRACT ADMINISTRATION							
31.B.1.-	Pre-award Activities							
31.B.1.1	Resident Office				690	104	15.1 -	
31.B.1.2	District Office				1,330	200	15.0 -	
31.B.2.-	Award Activities				330	50	15.2 -	
31.B.3.-	Review & Approval of Contract Payment				4,170	626	15.0 -	
31.B.4.-	Contract Modifications							
31.B.4.1	Resident Office				27,780	4,167	15.0 -	
31.B.4.2	District Office				1,660	249	15.0 -	
31.B.5.-	Progress and Completion Reports				2,780	417	15.0 -	
31.C.-.-	BENCHMARKS AND BASELINES				1,200	180	15.0 -	
31.D.-.-	REVIEW OF SHOP DRAWINGS							
31.D.1.1	Resident Office				13,890	2,084	15.0 -	
31.D.1.2	District Office				1,660	249	15.0 -	
31.E.-.-	INSPECTION AND QUALITY ASSURANCE							
31.E.1.-	Schedule Compliance				2,780	417	15.0 -	
31.E.2.-	Compliance Sampling & Testing							
31.E.2.1	Resident Office				10,420	1,563	15.0 -	
31.E.2.2	Laboratory Charges				10,420	1,563	15.0 -	
31.E.9.-	Q. A. Personnel				35,420	5,113	14.4 -	
31.F.-.-	PROJECT OFFICE OPERATION							
31.F.-.1	Resident Office				2,780	417	15.0 -	
31.F.-.2	Vehicles and Equipment				26,600	3,990	15.0 -	
31.H.-.-	CONTRACTOR INITIATED CLAIMS AND LITIGATIONS				5,820	873	15.0 -	
31.P.-.-	PROJECT MANAGEMENT				5,820	873	15.0 -	
	Subtotal			$	155,550			
	Contingencies @ average of	14.9 % +/- *			$	23,150		
31.-.-.-	**CONSTRUCTION MANAGEMENT (S & I)**			**TOTAL:**	**$**	**178,700**		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
	NON-FEDERAL							
	CONTRACT 1							
01------	LANDS AND DAMAGES							
012303--	CONSTRUCTION CONTRACT(S) DOCUMENTS							
01230301	Real Estate Planning Documents	160	WH		40,000	12,000	30.0 -	
01230302	Real Estate Acquisition Documents	1,008	WH		460,000	144,000	31.3 -	
01230303	Real Estate Condemnation Documents	1,008	WH		150,000	45,000	30.0 -	
01230305	Real Estate Appraisal Documents	672	WH		120,000	18,000	15.0 -	
01230307	Real Estate Rts of Entry/TempPermt	504	WH		35,000	5,300	15.1 -	
01230315	Real Estate Payment Documents				194,700	44,000	22.6 -	
	Subtotal, Construction Costs:			$	999,700			
	Contingencies @ average of 26.8 % +/- *				$	268,300		A
01------	LANDS AND DAMAGES			TOTAL:	$	1,268,000		
	AREA 1							
02------	RELOCATIONS							
0203----	CEMETERIES, UTILITIES, AND STRUCTURES Construction Activities							
020399--	Associate General Item							
02039902	Site Work							
	Relocate 4'x6'x6' Concr. Distr. Box	1	JOB	LS	3,320	500	15.1 -	
	Relocate V Shape Irrig. Ditch	11,000	LF	1.40	15,400	2,300	14.9 -	
	Subtotal, Construction Costs:			$	18,720			
	Contingencies @ average of 14.9 % +/- *				$	2,780		A
0203----	CEMETERIES, UTILITIES, AND STRUCTURES			TOTAL:	$	21,500		
	CONTRACT 2							
01------	LANDS AND DAMAGES							
012303--	CONSTRUCTION CONTRACT(S) DOCUMENTS							
01230301	Real Estate Planning Documents	80	WH		20,000	6,000	30.0 -	
01230302	Real Estate Acquisition Documents	840	WH		100,000	28,500	28.5 -	
01230303	Real Estate Condemnation Documents	1,008	WH		50,000	10,000	20.0 -	
01230305	Real Estate Appraisal Documents	504	WH		48,000	7,200	15.0 -	
01230307	Real Estate Rts of Entry/TempPermt	168	WH		20,000	3,000	15.0 -	
01230315	Real Estate Payment Documents				36,100	8,200	22.7 -	
	Subtotal, Construction Costs:			$	274,100			
	Contingencies @ average of 22.9 % +/- *				$	62,900		A
01------	LANDS AND DAMAGES			TOTAL:	$	337,000		

DETAILED ESTIMATE OF FIRST COST

ACCOUNT NUMBER	ITEM	QUANTITY	UNIT	UNIT PRICE $	AMOUNT $	CONTINGENCY $ *	CONTINGENCY % *	REASON
	Effective Price Level (EPL) 1-OCT-95							
	AREA 2							
02------	RELOCATIONS							
0203----	CEMETERIES, UTILITIES, AND STRUCTURES Construction Activities							
020399--	Associate General Item							
02039902	Site Work							
	Relocate V Shape Irrig. Ditch	700	LF	3.60	2,520	500	19.8 -	
	Subtotal, Construction Costs:			$	2,520			
	Contingencies @ average of 19.0 % +/- *				$	480		A
0203----	CEMETERIES, UTILITIES, AND STRUCTURES			TOTAL:	$	3,000		
	CONTRACT 3							
01------	LANDS AND DAMAGES							
012303--	CONSTRUCTION CONTRACT(S) DOCUMENTS							
01230301	Real Estate Planning Documents	80	WH		20,000	6,000	30.0 -	
01230302	Real Estate Acquisition Documents	840	WH		100,000	27,000	27.0 -	
01230303	Real Estate Condemnation Documents	1,008	WH		50,000	10,000	20.0 -	
01230305	Real Estate Appraisal Documents	504	WH		48,000	7,200	15.0 -	
01230307	Real Estate Rts of Entry/TempPermt	168	WH		20,000	3,000	15.0 -	
01230315	Real Estate Payment Documents				105,500	22,900	21.7 -	
	Subtotal, Construction Costs:			$	343,500			
	Contingencies @ average of 22.2 % +/- *				$	76,100		A
01------	LANDS AND DAMAGES			TOTAL:	$	419,600		
	MITIGATION CONTRACT							
01------	LANDS AND DAMAGES							
012303--	CONSTRUCTION CONTRACT(S) DOCUMENTS							
01230315	Real Estate Payment Documents				152,000	38,000	25.0 -	
	Subtotal, Construction Costs:			$	152,000			
	Contingencies @ average of 25.0 % +/- *				$	38,000		A
01------	LANDS AND DAMAGES			TOTAL:	$	190,000		

CHAPTER 8 - ECONOMIC ANALYSIS

8.01. Introduction

The economic analysis (see Appendix H) is to determine the damages assessment and benefits from levee reconstruction in the study area. The economic justification for implementing the proposed reconstruction within the study area is based on incremental analysis in accordance with ER 1165-2-119 and as instructed by the 1 March 1994 Headquarters 2d Endorsement of the Limited Evaluation Report submittal (CESPK-PD-S/29 Oct 93). Appendix I, Benefit Determination Involving Existing Levees for Sacramento River Flood Control System Evaluation, has been prepared to assist in the economic evaluation of risk and uncertainty. The increments (flood hazard areas) as defined by contract area are as follows: Contract 1, Robbins Area/Knights Landing Area; Contract 2, Verona Area; and Contract 3, Elkhorn Area.

8.02. Flood Damage Determination

Flooded areas were developed for various flood events in the flood hazard areas established above. Flooded areas were based in part on historic flood events. In any particular flood event, floodwaters discharged through a breach in the levee were deducted from flows conveyed downstream within the project levees. In all cases, flooded areas were determined only for those areas landward of the project levees that would be flooded due to a levee break.

Sources used to determine the magnitude of flood damages included assessors rolls from Sacramento, Sutter, and Yolo Counties which were field verified and inventoried for typical land use areas and historical flood reports developed by the Corps of Engineers for the 1950, 1955, 1969, 1970, and 1986 floods. Damages were generally divided into commercial, industrial, agricultural (crop and noncrop), public (public structures and contents and road damages and levee repairs), and emergency categories.

Due to the complex nature of the Sacramento River Flood Control Project, a simplified scenario is used to determine how and when levees will break in each incrementally independent area, as shown in Figure 34 (page 5-13). There are four separate areas—Robbins, Knights Landing, Verona, and Elkhorn. Each area has multiple sites which have been identified as deficient and which had problems in passing the 1986 floodflows.

A 3-day duration was used for design proposes. Stage and duration are important for defining a levee-breaching scenario under existing or without-project conditions. Levee breaks that result from seepage or stability problems are dependent on the levee embankment and foundation soils, levee geometry, peak flood stages, and duration of peak flood stages. The phreatic water surface within the levee embankment is important in determining potential locations where levees could fail. Higher phreatic water surfaces at a specific location increase the potential for seepage and stability problems, and higher phreatic water surfaces are generally associated with coarser soil materials and longer flood durations. Because of these conditions, a sensitivity analysis was performed by Economics staff from the Corps of Engineers (Sacramento District) to determine the potential costs of levee reconstruction which is economically justified on an incremental basis.

a. **Contract 1 Area—Robbins/Knights Landing.** For the R.D. 1500 area, the low level of flood protection and the number of acres which could be flooded suggest that incremental justification is possible. Based on the location of proposed levee reconstruction shown in Figure 31, levee breaching could occur on Sutter Bypass and Sacramento River just downstream from Tisdale Bypass. The estimated existing levels of flood protection for Sutter Bypass and Sacramento River are 30 and 40 years, respectively (assuming no levee breaching upstream). If a levee breached on Sutter Bypass, it is possible that the level of flood protection estimated for the Sacramento River side would increase. It is also possible that multiple breaching could occur. Since there is only a 0.3-foot difference in water surface elevation between a 30-year and 40-year recurrence interval for Sacramento River below Wilkins Slough (Figure 5), multiple breaching appears likely. With two levee breaks, the damages shown in Figure 34 for R.D. 1500 would be increased by $400,000 (the cost of repairing a levee break) for a particular water surface elevation. Based on the stage hydrograph of Figure 26 for Sacramento River below

Wilkins Slough (which is about 1 mile upstream from the northernmost levee reconstruction location), flood stages could remain within 1 or 2 feet of the peak flood stage for 6 to 8 days. The stage hydrograph for Sutter Bypass at Tisdale Bypass, Figure 27, indicates that flood stages are probably of shorter duration than on the Sacramento River side. (The east levee of Sutter Bypass between Wadsworth Canal and the Feather River is being considered for reconstruction under Phase II of the Sacramento River Flood Control System Evaluation, Marysville/Yuba City Area. In the Marysville/Yuba City Area report, floodwaters discharged through a breach in the levee were permanently deducted from flows conveyed downstream within the project levees. In that report, a single breach was assumed on both the east and west levee of Sutter Bypass in the vicinity of Highway 113. If the east levee is repaired, then a single breach of the west levee might be expected for a 30-year event assuming no levee breaches upstream). A single breach could occur at either of the locations shown on Figure 31, but, depending on breach width, location, and duration of the peak flood stages, floodwaters discharging through the breach would probably yield 100,000 acre-feet to 150,000 acre-feet of water. This volume would be equivalent to a water surface elevation of about 25 feet and about $30 million in damages based on the elevation-damage relationship of Figure 34. For a 40-year flood event and two levee breaches, one on the Sacramento River and one on the Sutter Bypass, about $50 million in damages would probably result. For larger flood events, probably greater damages would result but would be dependent on possible levee breaching upstream or adjacent to the study area. Average annual damages under without-project conditions could range between $1.6 million and $1.7 million with a present worth of about $18 million. If an incremental analysis is required for economic justification, then the maximum possible cost of repairs which could be supported would be $18 million. If the stage-frequency relationship for Sacramento River below Wilkins Slough Bypass, Figure 5, is valid and if half the benefits within the freeboard range are attributable to project conditions, then average annual benefits under project conditions would be about $1.2 million (with a present worth of $13 million). In reality, if levee breaching were to occur adjacent to or upstream from the R.D. 1500 area, then average annual benefits would be less than the $1.6 to $1.7 million maximum values. Based on the above and the costs presented in the section on Design and Construction Costs, levee reconstruction for the area that includes R.D. 1500 is incrementally justified.

For the Knights Landing area, the damage versus elevation relationship, Figure 37, is based on existing conditions and October 1989 price levels. The damages shown also include the cost of repairing one levee break. As shown by Figure 31, levee reconstruction is proposed along the west side of Sacramento River between the Colusa Basin Drainage Canal (Knights Landing) and Fremont Weir. The existing level of flood protection near Knights Landing is estimated at a 60-year recurrence interval (see Table 5). If a single levee break were to occur in this area at one of the problem locations and if the peak flood stage and duration were similar to but slightly greater than that which occurred during the 1986 flood event, floodwaters that could pass through the levee breach and accumulate within the levee embankments would probably be adequate to fill the area to an elevation of about 38 feet. (At this elevation, floodwaters would be flowing out of the area over the levee embankment and into the Knights Landing Ridge Cut near the confluence with Yolo Bypass.) Flood damages attributable to this occurrence would be about $16.5 million. For flood events larger than the 1986 flood event, flood depths would probably not be significantly greater than that cited above, particularly if levee breaching is occurring adjacent to and upstream from the Knights Landing area. (As shown by Figure 6, the stage frequency relationship indicates less than a 1.0-foot difference in water surface elevation on Sacramento River at Knights Landing between the 60-year and 200-year recurrence intervals with no levee breaching within the study area.) Based on the expectation that flood damages would be similar for all flood events greater than a 60-year recurrence interval, average annual flood damages under without-project conditions would be equivalent to about $1 million. The present worth of a uniform annual series of $1 million at an interest rate of 7-3/4 percent and for a period of analysis of 50 years (a 50-year project life) is about $3.1 million. Since incremental analysis is required for economic justification, then the maximum possible cost of levee reconstruction that the flood damages would be $3.1 million. The proposed levee reconstruction would not prevent levee breaching in the Knights Landing area for the larger flood events since the minimum freeboard during the 1986 flood event was between 1 and 2 feet on the Sacramento River side (see Plate 4, sheet 3 of 4). Information presented later in the section on Design and Construction Costs indicates that the costs involved in the reconstruction of levees for the Knights Landing area are about $2 million. From this analysis, levee reconstruction for the Knights Landing area is incrementally justified.

b. Contract 2 Area—Verona. An analysis similar to the above was used in the evaluation of R.D. 1001 (Nicolaus). The results indicated potential average annual flood damages under without-project conditions of about $952,000 for an existing 100-year level of flood protection (see Table 8, Contract 2). As in the preceding case, levee reconstruction for this area is incrementally justified.

c. **Contract 3 Area—Elkhorn.** For the flood hazard area which includes R.D. 1600, R.D. 827, R.D. 785, and R.D. 537 (see Figure 34), the estimated maximum flood damage expected is $11 million. This damage estimate includes the cost of repairing two levee breaks, damages to the Union Pacific Railroad embankment, and railroad transportation losses. The existing level of flood protection is about a 55-year recurrence interval (see Table 7, Yolo Bypass near Woodland) based on potential levee breaching on the Yolo Bypass side in the vicinity of Interstate 5 and assuming no levee breaching upstream from this area. If the maximum potential flood damages cited above occur for flood events equal to or greater than a 55-year recurrence interval, average annual flood damages under without-project conditions would be equivalent to about $553,600. The present worth of this uniform series is about $2.3 million. As in the preceding evaluation, an incremental analysis is required for economic justification. Based on the costs presented in the section on Design and Construction Costs, levee reconstruction for this area is incrementally justified.

8.03. Benefit Determination

For the Phase II, Marysville/Yuba City Area, Initial Appraisal Report and the Yuba River Basin Investigation Reconnaissance Report, HQUSACE directed the Sacramento District to use the benefit evaluation procedure and sensitivity analysis described in the DRAFT Policy Guidance Letter No. 26, Benefit Determination Involving Existing Levees, dated 21 May 1991, to develop a BCR for levee reconstruction in the study area. This procedure was also used for the Mid-Valley economic analysis.

Benefits attributable to the project were determined using estimates for without-project damages that are based on judgments of existing levee reliability. A simplified linear relationship was used for relating water surface on the levee (in feet above adjacent land surface) to probability of levee failure. Although the relationship is an approximation, it does incorporate the reasonable assumption that as the levee becomes more stressed with higher water surface on the levee, it is more likely to fail.

The average annual benefits attributable to the levee reconstruction using judgments of levee reliability were developed in accordance with the methodology described in the Policy Guidance Letter and is as follows. (See Appendix H for details on average annual benefits.)

As a total system (a combination of the three contract areas cited above), about $3,150,800 million in average annual benefits are attributable to the proposed levee reconstruction plan using a benefit determination based on judgment of existing levee reliability.

8.04. Project Justification

A comparison of the average annual benefits with the average annual costs for the recommended levee reconstruction plan is shown in Table 8. Contract 4 is the Mitigation Contract, which has been split into Contracts 1, 2, and 3. The benefit-to-cost ratio for each of the flood hazard areas and the total project is also shown.

TABLE 8

ECONOMIC JUSTIFICATION
FLOOD HAZARD AREAS
Equivalent Annual Costs
(50-year economic life and 7-3/4 percent interest rate)

Flood Hazard Area	Contract 1	Contract 2	Contract 3	Total [1]
Total Annual Costs	2,062,200	566,800	175,200	2,804,200
Average Annual Benefit	2,286,100	634,300	230,400	3,150,800
Benefit-Cost Ratio	1.1	1.12	1.32	1.18

[1] Mitigation Contract costs are distributed in Contracts 1, 2, and 3 and are therefore included in the total.

CHAPTER 9 - PROJECT RESPONSIBILITIES OF SPONSORS

9.01. Local Maintenance and Repairs

As described in Chapter 4, Design Flow, design flow deficiencies exist in the system. As shown on Figure 32, localized areas of the flood control project cannot convey the design flow within the design water surface. Since The Reclamation Board is the local entity responsible for the maintenance and operation of the existing Sacramento River Flood Control Project (SRFCP), it is the State's obligation to ensure that the design flow can be conveyed within the design water surface (assuming that the levee embankments can convey the design flow without levee failure). The Reclamation Board will be required, under the existing SRFCP operation and maintenance requirements, to evaluate each of the levee reaches cited above to determine potential causes of the design flow deficiencies and to develop measures for eliminating any deficiencies. In order to ensure that the design flow can be conveyed safely within the project levees at the design water surface, The Reclamation Board will be required to implement corrective measures (such as dredging, clearing, levee modifications, etc.) at its expense in conjunction with reconstruction plans proposed by the Corps.

9.02. Local Flood Fighting

Railroad and road crossings that encroach into the design freeboard and/or design water surface (crossings that create localized depressed areas in the levee crown as shown on Plates 1 through 14), in general, were incorporated or approved as part of the Sacramento River Flood Control Project. In many cases, flood gates have been installed at the crossings and can be effectively closed during high flood stages. At other crossings, sandbags (or different methods) have been used to provide a temporary barrier against floodwaters that could potentially flow over the levee embankment.

To ensure that the design flow can be conveyed safely within the project levees at the design water surface, all railroad and road crossings that encroach into the design freeboard should have an operation schedule specified for installing flood barriers. As part of the proposed reconstruction recommended in this DM, The Corps, in coordination with The Reclamation Board, will define procedures for installing flood barriers at each crossing with deficient design freeboard. During reconstruction of the levees, the procedures will be developed and included as an addendum or modification to the Operation and Maintenance Manual for the SRFCP levees. Flood barriers would provide the necessary design freeboard above the design water surface. Installation of a flood barrier would be based on actual and projected flood stages at the crossing location and would be the responsibility of The Reclamation Board.

9.03. Hazardous and Toxic Wastes

The project's 30 sites are located on or adjacent to levees along the Sacramento River, Feather River, Sutter Bypass, Knights Landing Ridge Cut East Levee, and Yolo Bypass east side. No evidence of HTRW (hazardous, toxic, or radiological waste) was observed at these sites.

CHAPTER 10 - OPERATION AND MAINTENANCE

10.01. General

The Reclamation Board will provide the assurances of local cooperation for the project by signing the Project Cooperation Agreement (PCA). Under these assurances, it will be the responsibility of The Reclamation Board to accept the project after completion of construction and ensure that all operation and maintenance is in accordance with directions and procedures established by the Corps of Engineers. Currently, the levees are operated and maintained by the State of California, Department of Water Resources, and local reclamation, levee, and drainage districts and municipalities (responsible agencies are described in Chapter 6).

10.02. Operation and Maintenance History

To secure a uniform degree of operation and maintenance on Federal flood control projects throughout the Nation, the Corps of Engineers on 17 August 1944 promulgated regulations (Title 33, Part 208, Flood Control Regulations) governing the maintenance and operation of flood control works and establishing a high standard of maintenance. The Reclamation Board is the local sponsor for the Sacramento River Flood Control Project and is required by State law to transfer the actual O&M to local entities such as municipalities and flood control districts and/or reclamation districts. The State retained supervisory powers and responsibility over these entities to ensure that O&M was accomplished properly. However, with only supervisory powers over the local agencies, the State lacked specific authority to enforce compliance with the O&M regulations. This led to revisions of the State Water Code relating to operation and maintenance of the Sacramento River Flood Control Project. The State Water Code, as amended by Chapter 1528, Statutes of 1947, sets forth a procedure which is available when necessary to secure adequate and uniform maintenance throughout the Sacramento River Flood Control Project. In substance, when The Reclamation Board finds that local agencies have failed to properly maintain the project, The Reclamation Board is empowered after a hearing to form a "maintenance area." Thereafter, the State Department of Water Resources (DWR) maintains that particular unit of the project works, and The Reclamation Board apportions the cost thereof, under the property benefited. DWR has inspected the condition of all project levees twice each year since 1948. DWR produces detailed "Levee Inspection Log" sheets for each project levee inspected. Copies of those sheets are given to the owners, trustees, or other responsible officials in each of the respective areas, and their attention is called to the portions of levee in need of maintenance or repair. In addition, these sheets are summarized into an annual report on the project's levees, channels, and other structures. Copies of both the inspection sheets and summary reports are provided to flood control agencies, including The Reclamation Board and the Corps. The Corps also reports on any areas where maintenance is considered deficient in accordance with Engineer Regulation 1130-2-339.

10.03. Operation and Maintenance Requirements

a. Maintenance. The reconstruction work proposed for the SRFCP levees in this project will not require additional maintenance procedures from those described in the existing operation and maintenance manual. Maintenance requirements will continue as part of the requirements of local cooperation of the original project. Maintenance activities will consist of the routine inspection and repair of all project features, including selective vegetation removal and weed abatement, repair of eroded levee sections, protection of levee slopes, repair and resurfacing of patrol and maintenance roads, and inspection and periodic repair and replacement of security fencing and gates.

b. Operations. In conjunction with railroad and road crossings that encroach into the design freeboard, the Corps, in coordination with The Reclamation Board, will define an operation for installing flood barriers at each crossing with deficient design freeboard. At the time remedial repairs are constructed, the operations developed would be included as an addendum or modification to the Corps current Operation and Maintenance Manuals for project levees. Flood barriers would provide the necessary design freeboard above the design water surface. Installation of a flood barrier would be based on actual and projected flood stages at the crossing location and would be the responsibility of The Reclamation Board.

10.04. Environmental Mitigation

The construction of the mitigation areas will include a 3-year establishment period as part of the construction contract. After the establishment period, the operation, maintenance, and replacement of riparian mitigation areas will follow the procedures outlined in the mitigation management plan (included within the Environmental Assessment). The mitigation management plan has been coordinated with the California Department of Fish and Game, U.S. Fish and Wildlife Service, and the California Reclamation Board. The estimated annual cost for monitoring the study is $10,000. The mitigation management plan will be included in the flood control operation and maintenance manual.

10.05. Operation and Maintenance Manual

After the project is completed, the Sacramento District will revise the operation and maintenance manual of the project area. The revisions will be furnished to The Reclamation Board.

CHAPTER 11 - DESIGN AND CONSTRUCTION SCHEDULE

11.01. General

Project construction will consist of three general construction contracts and one design/construct mitigation contract. The limits of each of the three construction contracts are shown on Plate 2.

Three construction contracts will be conbined into one set of plans and specifications. The preparation of plans and specifications will be coordinated with the required real estate transactions because the construction contracts cannot be advertised until all real estate acquisitions are completed for that contract. The preparation of plans and specifications for the first contract will follow completion of this Design Memorandum because this project has been approved for an FY 97 New Start. The plans and specifications for the second contract are scheduled to start in September 1997 and the third in February 1998.

Contract 1 is scheduled to be awarded in early May 1997 with construction completed in September 1998. Contract 2 will be awarded in September 1997 and completed in September 1998. Contract 3 will be awarded in February 1998 and completed in September 1999.

The mitigation contract is scheduled to start in January 1996 with the preparation of the Request for Proposal (RFP). Mitigation planting will take place in the fall of 1996. The collection of plant materials will be accomplished in the fall preceding the mitigation planting under a separate procurement. A 3-year maintenance period will follow the completion of the planting.

The project schedule listing all the major activities, including mitigation, is shown on page 11-3.

11.02. Work by Federal Government

The Federal contracts will include all the levee reconstruction work, consisting of the toe drains, cutoff walls, and levee height restoration and the mitigation planting and maintenance.

11.03. Work by Others

The Reclamation Board will be responsible for acquiring all project lands, relocations, alteration of all overhead power and telephone lines and miscellaneous surface and subsurface utilities affected by project construction, and subsequent operation and maintenance of the levees. The Reclamation Board has informally requested that the Federal Government prepare the design and complete construction of all relocations and alterations of utilities affected by the project. The work will be accomplished with funds contributed by The Reclamation Board. (See Chapter 6.04 for list of relocations.)

MID-VALLEY RECONSTRUCTION SCHEDULE

JUNE 1995

Task Name	Duratn (Days)	Start Date	End Date
Design Memorandum (DM)	621	1-Oct-93	30-Oct-95
Design	103	1-Sep-94	1-Feb-95
Draft DM	229	1-Sep-94	1-Aug-95
SPK Review	8	17-Jul-95	26-Jul-95
Revise DM	44	26-Jul-95	26-Sep-95
Submit DM to SPD	23	27-Sep-95	30-Oct-95
Submit DM to HQ	23	27-Sep-95	30-Oct-95
Revise & Approval	23	27-Sep-95	30-Oct-95
Geotechnical Report	251	1-Oct-93	30-Sep-94
Hydrology	80	3-Oct-94	30-Jan-95
Economics	163	1-Dec-94	25-Jul-95
Surveys	314	1-Jul-94	29-Sep-95
HTRW Investigation	151	1-Mar-94	30-Sep-94
Environmental Assessment Rept	273	1-Aug-94	30-Aug-95
Real Estate	227	1-Sep-94	28-Jul-95
Cost Estimate	63	19-Jun-95	15-Sep-95
Mitigation	197	3-Oct-94	17-Jul-95
Cultural Resources	207	3-Oct-94	31-Jul-95
VE Study	24	2-Oct-95	3-Nov-95
Plans & Specification:	272	30-Oct-95	27-Nov-96
Establish Take Line	22	30-Oct-95	30-Nov-95
Draft P&S	169	30-Oct-95	1-Jul-96
SPK/DWR Review P&S	14	1-Jul-96	19-Jul-96
Revise P&S (SPK)	23	22-Jul-96	21-Aug-96
Submit P&S for SPD Review	31	3-Sep-96	16-Oct-96
Revise P&S (SPD)	16	16-Oct-96	6-Nov-96
P&S for BCO Review	22	3-Sep-96	2-Oct-96
Revise P&S (BCO)	25	2-Oct-96	6-Nov-96
Reproduce P&S	15	6-Nov-96	27-Nov-96
FY97 Construction Appropriatio	0	1-Oct-96	1-Oct-96
Submit PCA/Fin Plan to SPD	0	1-Oct-96	1-Oct-96
Submit PCA/Fin Plan to HQUSACE	0	1-Oct-96	1-Oct-96
Submit PCA/Fin Plan to ASA(CW)	0	1-Nov-96	1-Nov-96
ASA Approve PCA	0	2-Dec-96	2-Dec-96
PCA Executed	0	2-Jan-97	2-Jan-97
Prepare Synopsis	3	27-Nov-96	2-Dec-96
Advertise	20	3-Feb-97	3-Mar-97
Bid Opening	0	7-Apr-97	7-Apr-97
Award Contract	8	21-Apr-97	30-Apr-97
Notice to Proceed	0	1-May-97	1-May-97
Construction	608	1-May-97	30-Sep-99
Contract 1	357	1-May-97	30-Sep-98
Contract 2	272	2-Sep-97	30-Sep-98
Contract 3	419	3-Feb-98	30-Sep-99
Local Sponsor Acceptance	0	15-Sep-99	15-Sep-99
Real Estate Acquisition:	354	6-Nov-96	7-Apr-98
Establish RE Take Lines	15	6-Nov-96	27-Nov-96
Prepare Legal Description	47	27-Nov-96	5-Feb-97
Appraisal	121	27-Nov-96	21-May-97
Negotiate/Acquisition	53	2-Jun-97	14-Aug-97
State Certify	0	2-Mar-98	2-Mar-98
Corps Certify	5	1-Apr-98	7-Apr-98
O&M Manual:	421	2-Jan-98	2-Sep-99
Draft O&M Manual	52	16-Oct-98	31-Dec-98
SPK & Sponsor Review	22	2-Jan-98	3-Feb-98
Revise O&M Manual	18	3-Feb-98	27-Feb-98
Submit to SPD for Review	45	27-Feb-98	30-Apr-98
Revise & Reproduce	20	1-May-98	29-May-98
Transmit Interim to Sponsor	0	7-Jun-99	7-Jun-99
Transfer Final to Sponsor	63	7-Jun-99	2-Sep-99
Mitigation Contract:	692	2-Jan-96	30-Sep-98
-RFP	148	2-Jan-96	31-Jul-96
-Award Contract	12	1-Aug-96	16-Aug-96
-Collect Seeds (Propagate)	21	2-Oct-96	31-Oct-96
-Install Plants	40	3-Nov-97	31-Dec-97

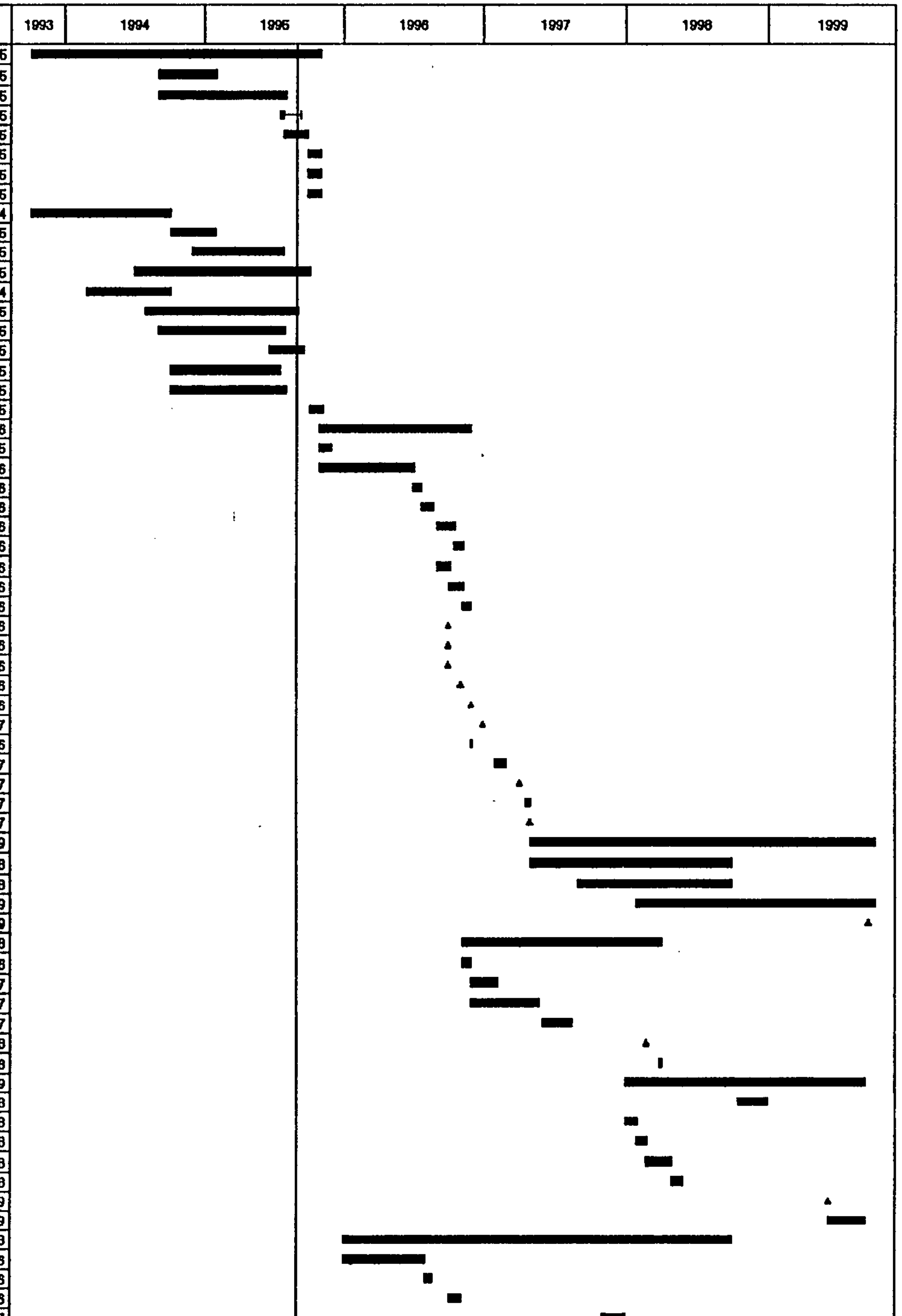


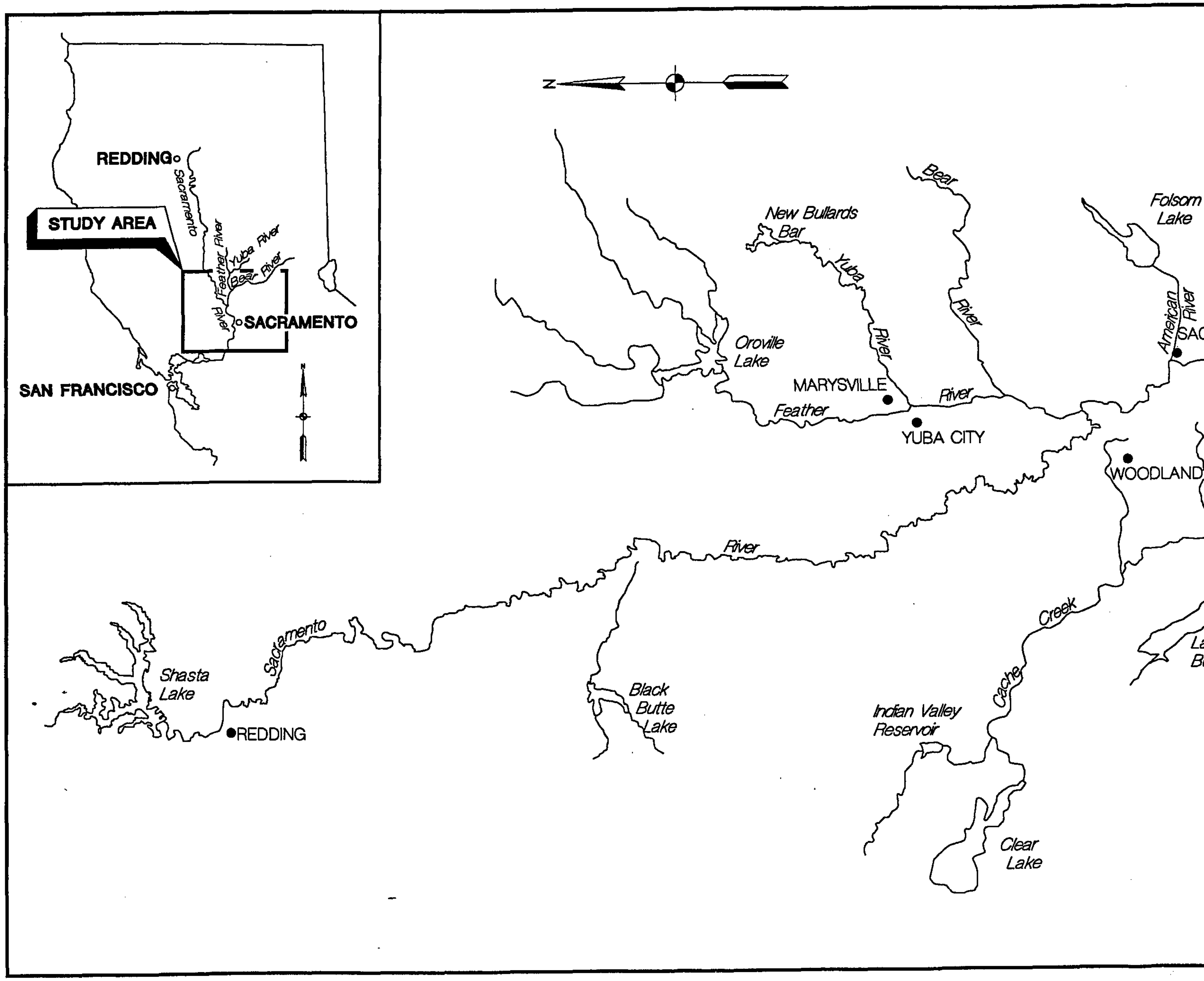
FIGURE 38

CHAPTER 12 - RECOMMENDATIONS

12.01. Recommendations

It is recommended that this Design memorandum be approved as the basis for preparing contract plans and specifications for the Sacramento River Flood Control System at Mid-Valley Area Levee Reconstruction project.

PLATES

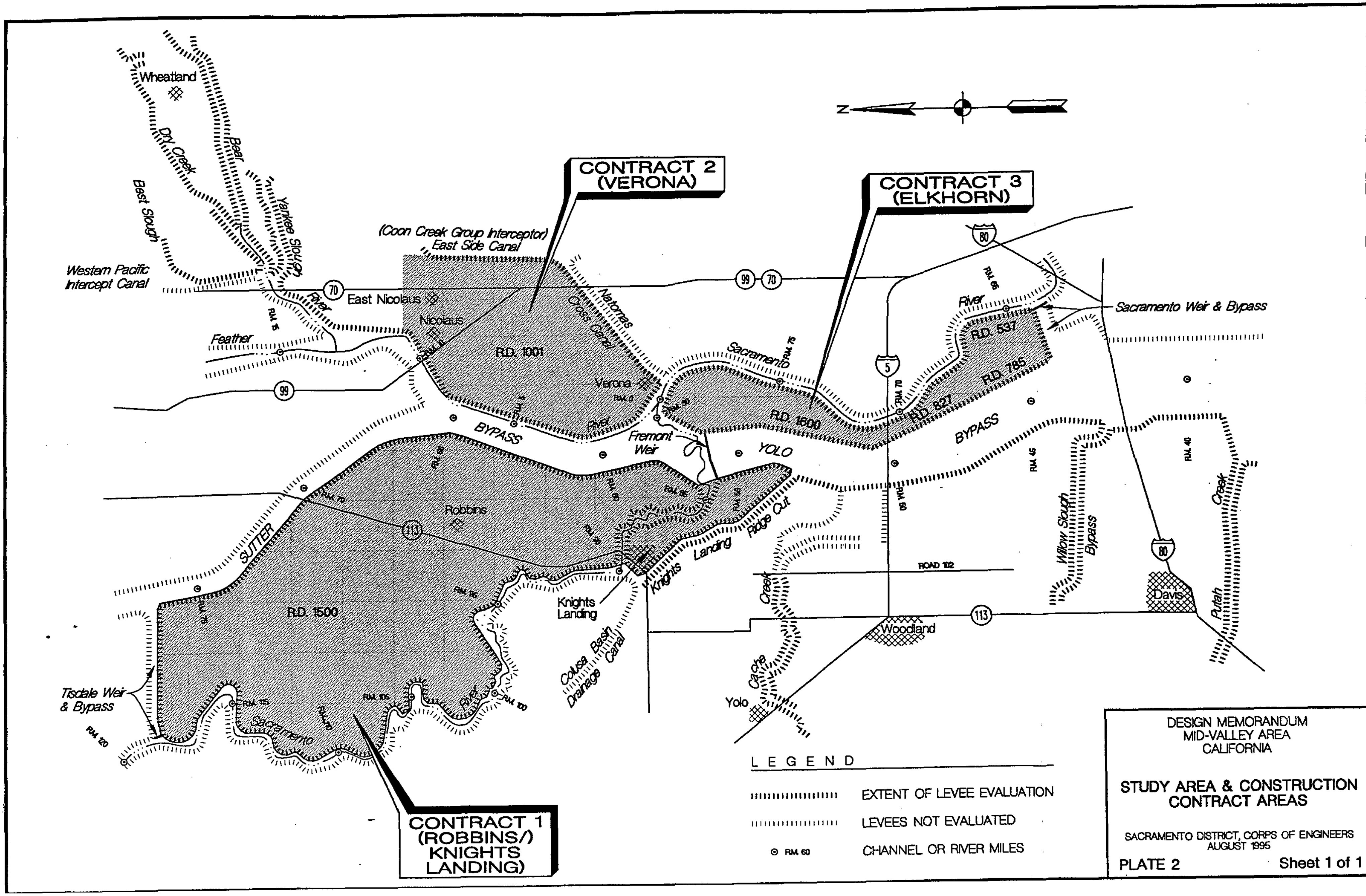


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

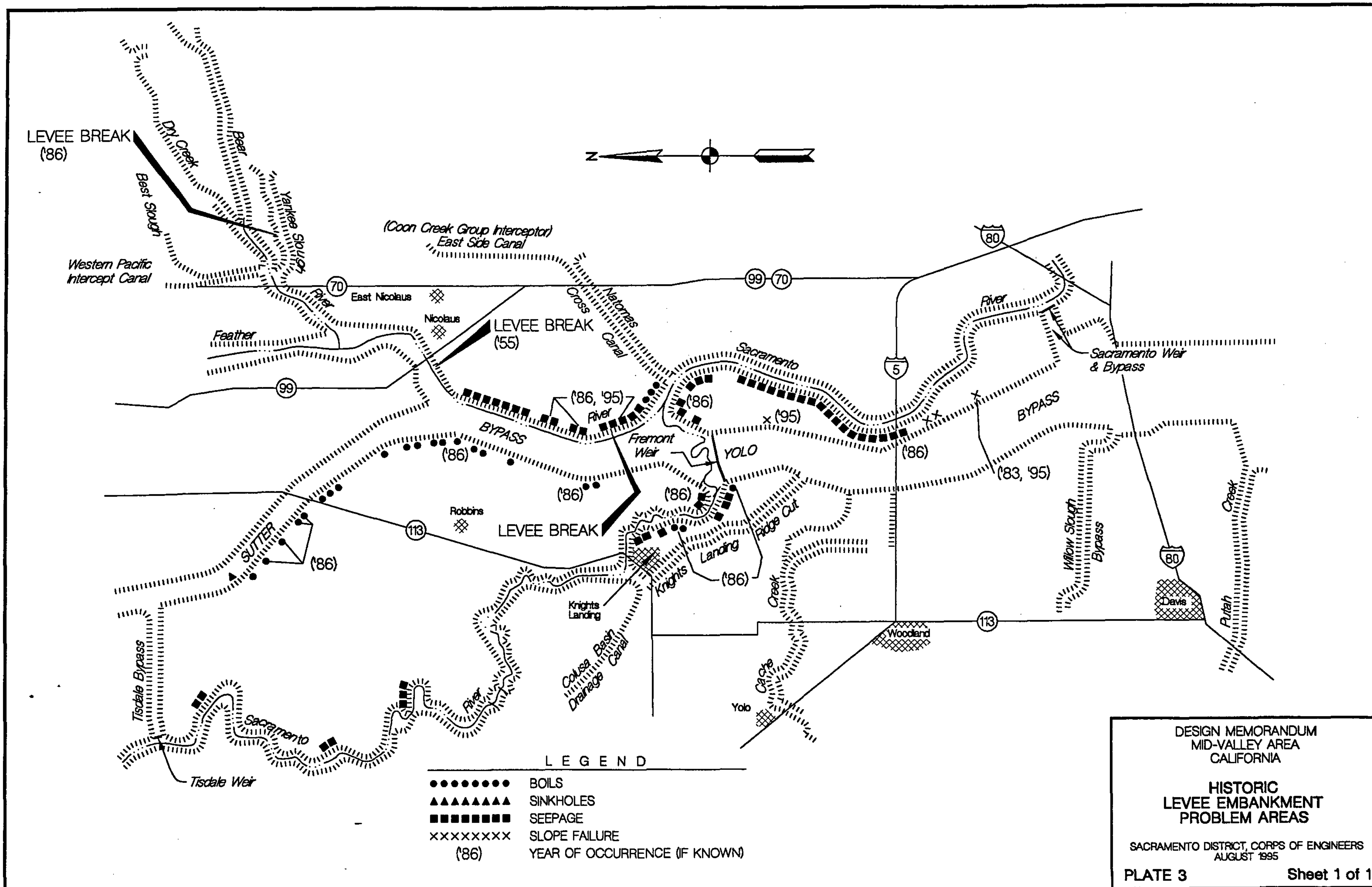
GENERAL MAP

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 1 Sheet 1 of 1



CONTRACT 1 (ROBBINS/) KNIGHTS LANDING)
CONTRACT 2 (VERONA)
CONTRACT 3 (ELKHORN)
N
Wheatland
Dry Creek
Bear
Yankee Slough
Best Slough
Western Pacific Intercept Canal
(Coon Creek Group Interceptor) East Side Canal
East Nicolaus
Nicolaus
Feather
River
R.D. 1001
Natomas Cross Canal
Verona
River
BYPASS
SUTTER
Robbins
R.D. 1500
Sacramento
River
Tisdale Weir & Bypass
Fremont Weir
YOLO
BYPASS
R.D. 1600
R.D. 827
R.D. 785
R.D. 537
Sacramento Weir & Bypass
Knights Landing
Knights Landing Ridge Cut
Colusa Basin Drainage Canal
Cache Creek
Yolo
Woodland
ROAD 102
Willow Slough Bypass
Davis
Putah Creek
LEGEND
EXTENT OF LEVEE EVALUATION
LEVEES NOT EVALUATED
R.M. 60 CHANNEL OR RIVER MILES
DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA
STUDY AREA & CONSTRUCTION CONTRACT AREAS
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995
PLATE 2
Sheet 1 of 1



LEGEND

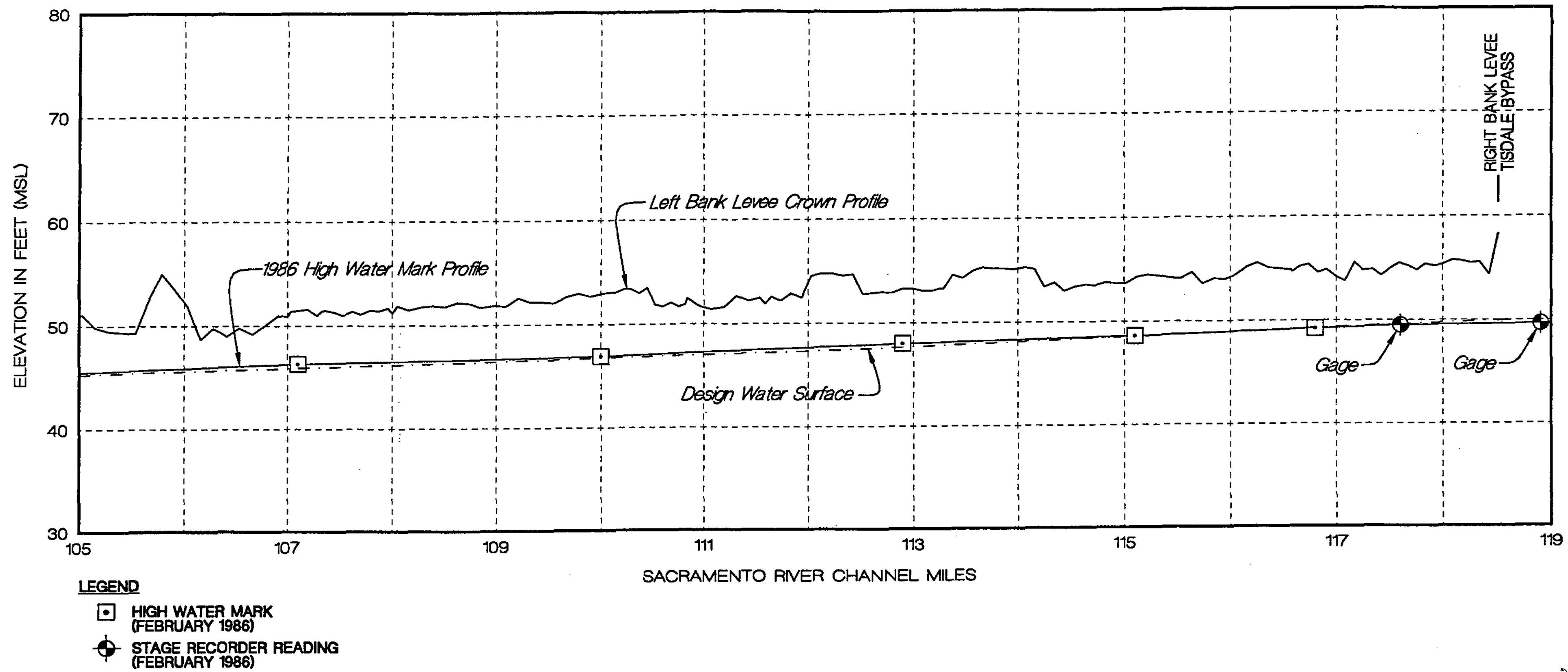
- ●●●●●●●● BOILS
- ▲▲▲▲▲▲▲▲ SINKHOLES
- ■■■■■■■■ SEEPAGE
- ×××××××× SLOPE FAILURE
- ('86) YEAR OF OCCURRENCE (IF KNOWN)

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

**HISTORIC
LEVEE EMBANKMENT
PROBLEM AREAS**

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 3 **Sheet 1 of 1**

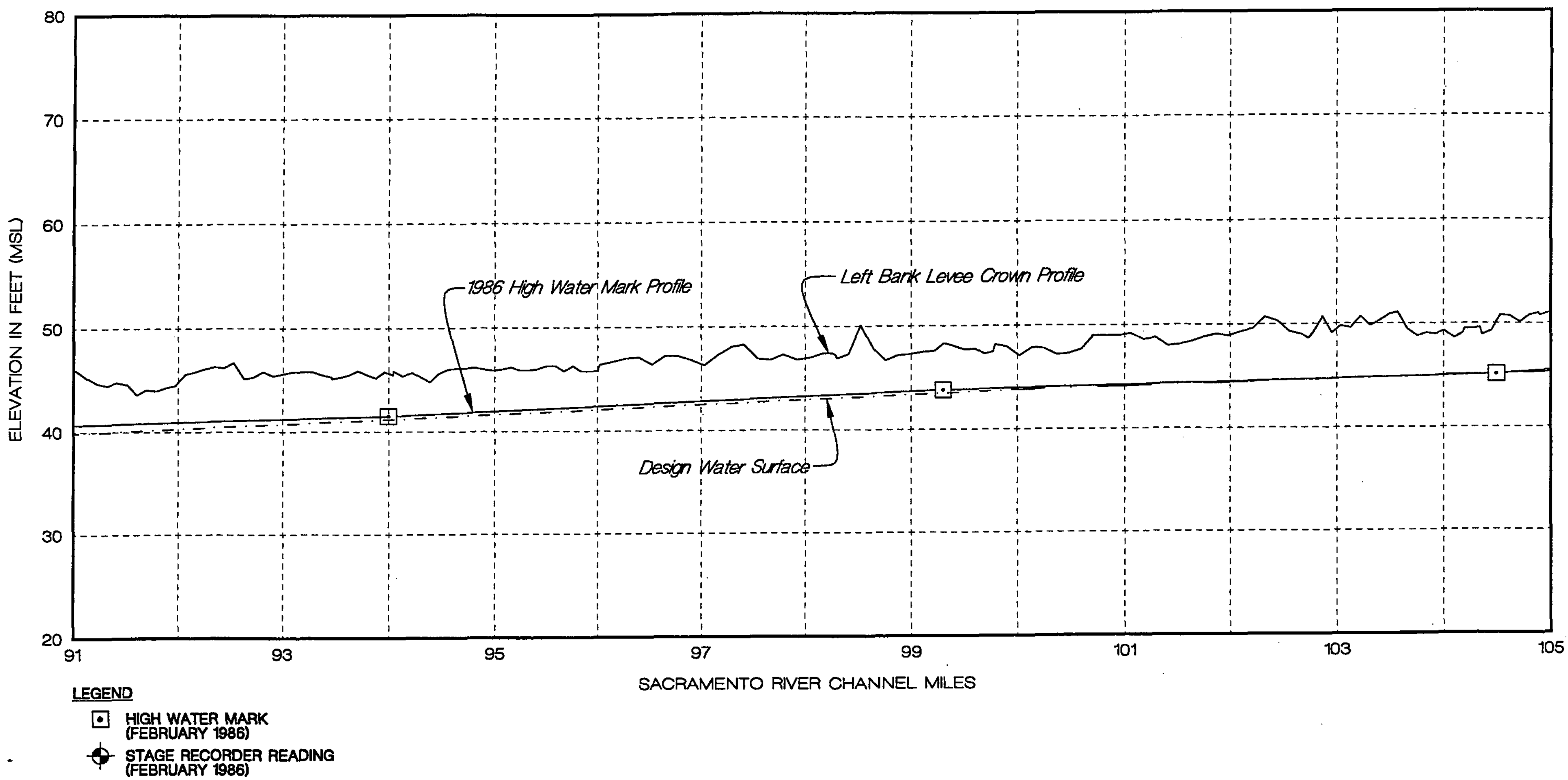


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES SACRAMENTO RIVER

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 4 **Sheet 1 of 4**

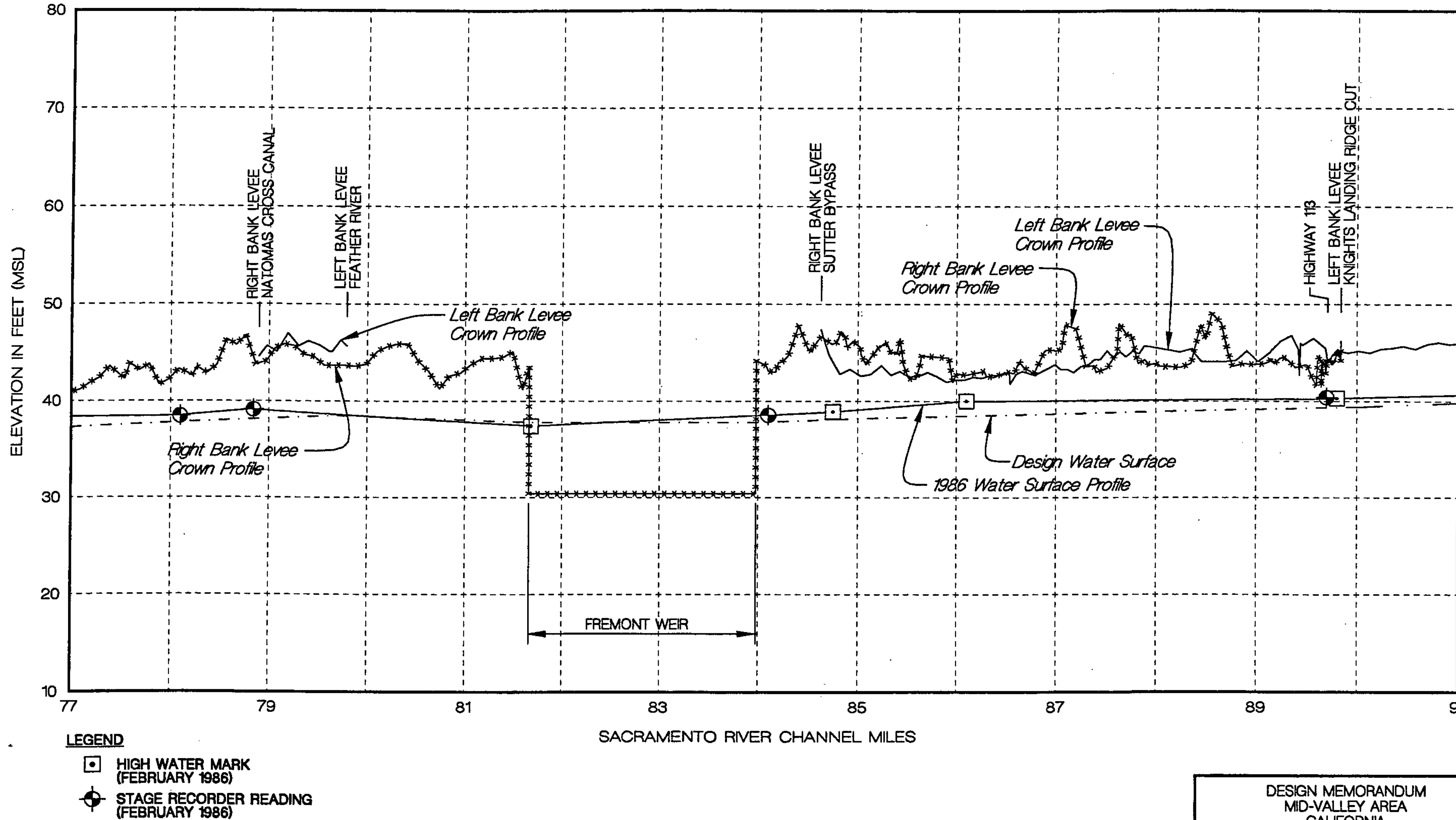


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES SACRAMENTO RIVER

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 4 **Sheet 2 of 4**

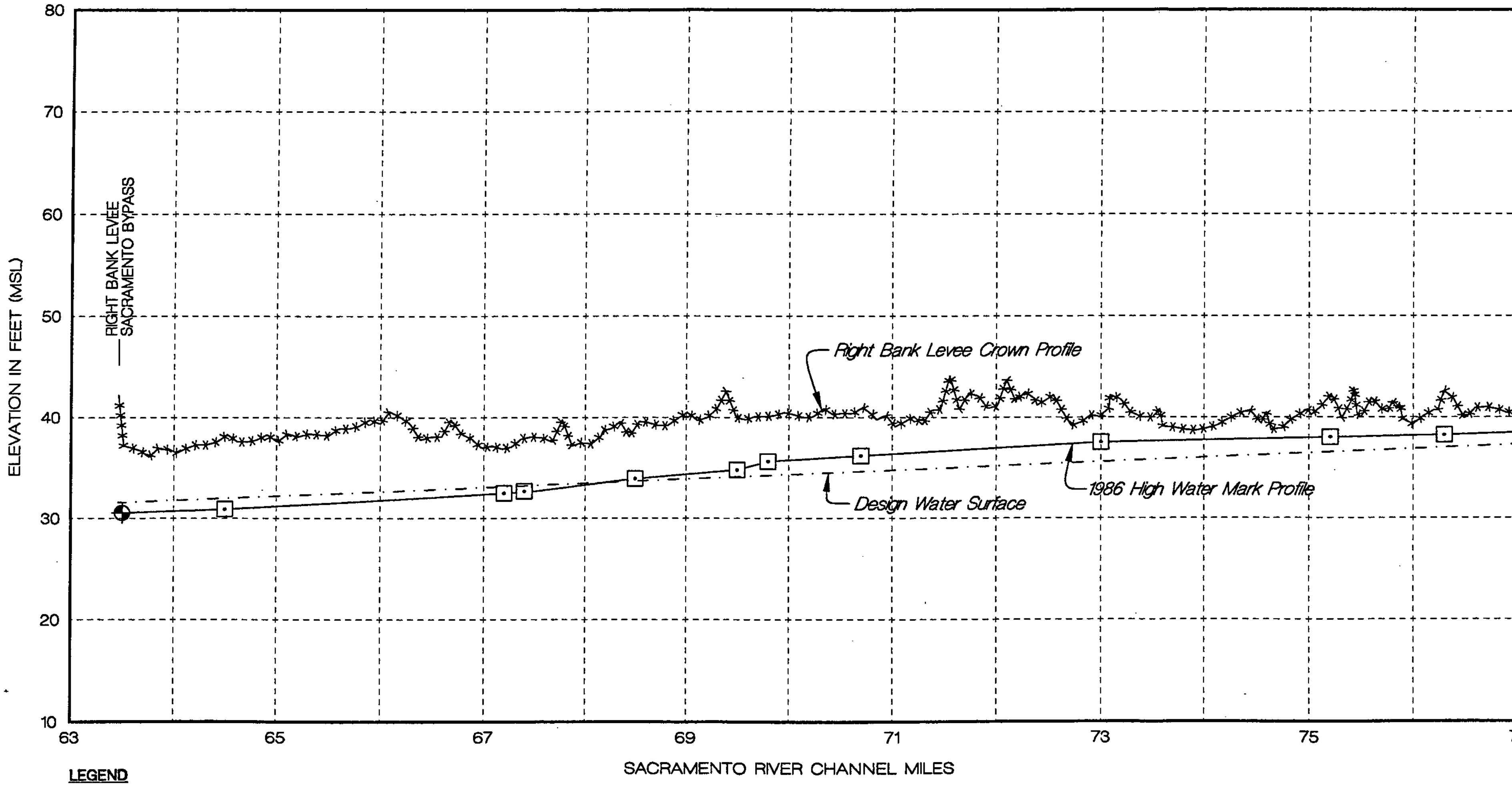


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES SACRAMENTO RIVER

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 4 **Sheet 3 of 4**



LEGEND

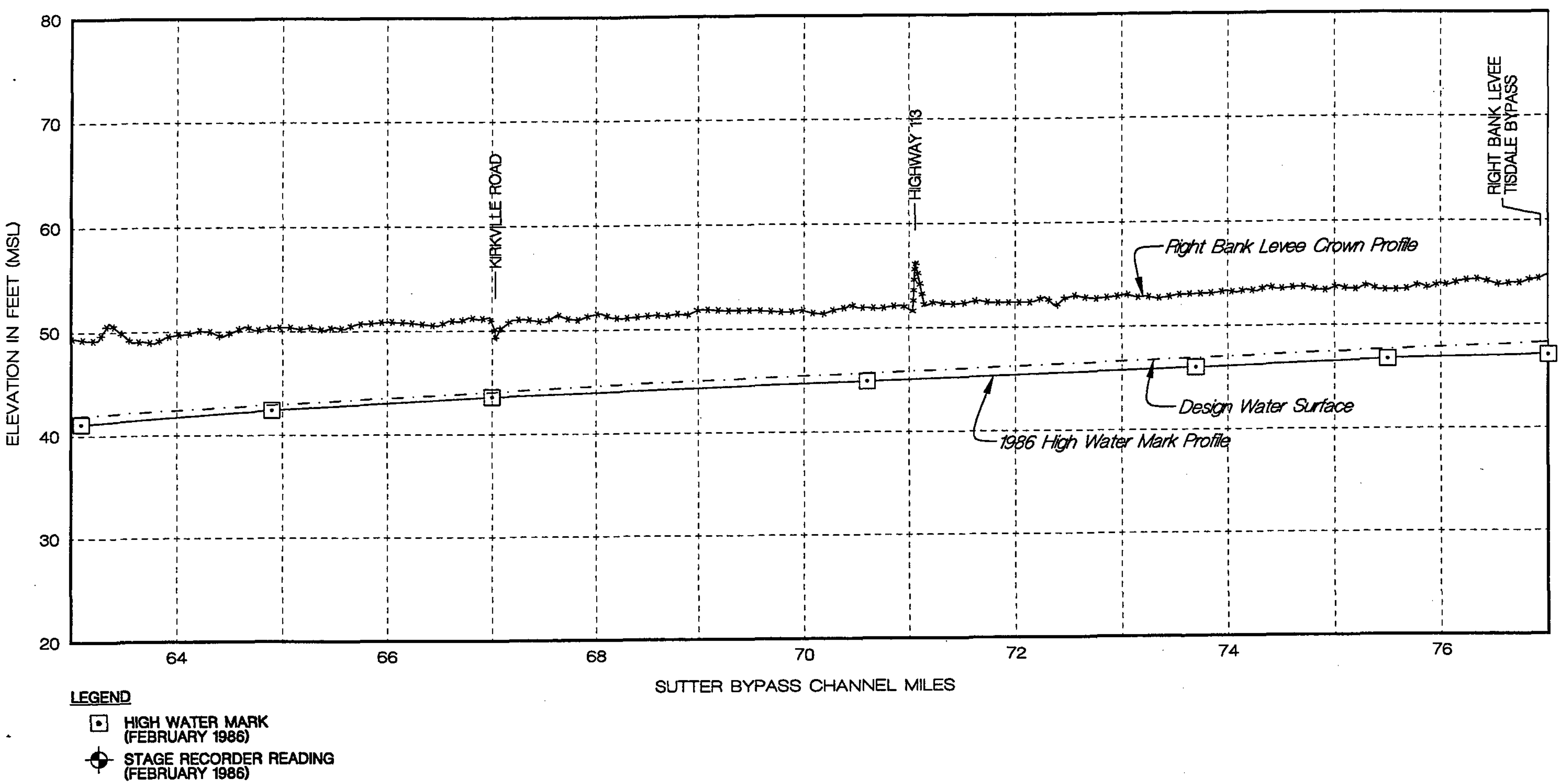
- HIGH WATER MARK (FEBRUARY 1986)
- STAGE RECORDER READING (FEBRUARY 1986)

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES SACRAMENTO RIVER

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 4 **Sheet 4 of 4**

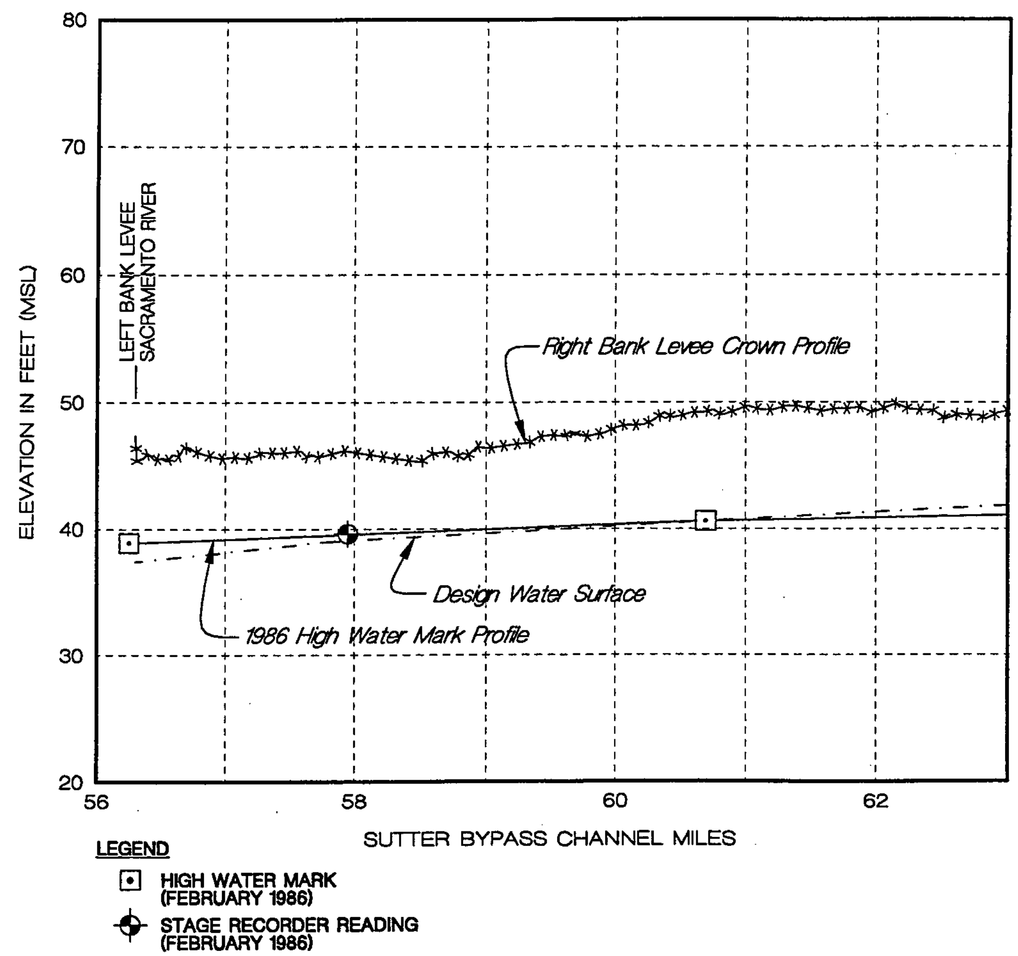


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES SUTTER BYPASS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 5 Sheet 1 of 2

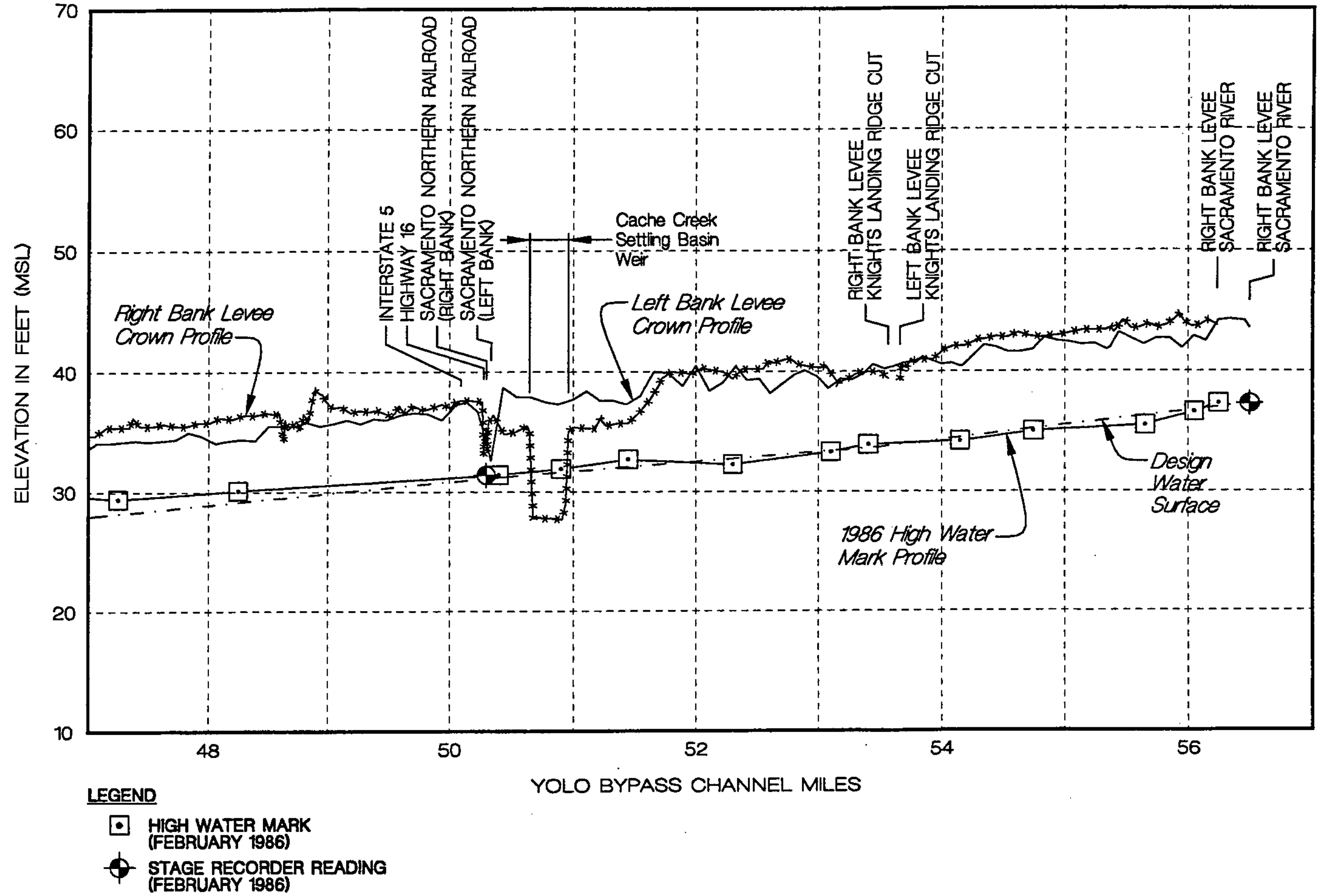


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES SUTTER BYPASS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 5 **Sheet 2 of 2**

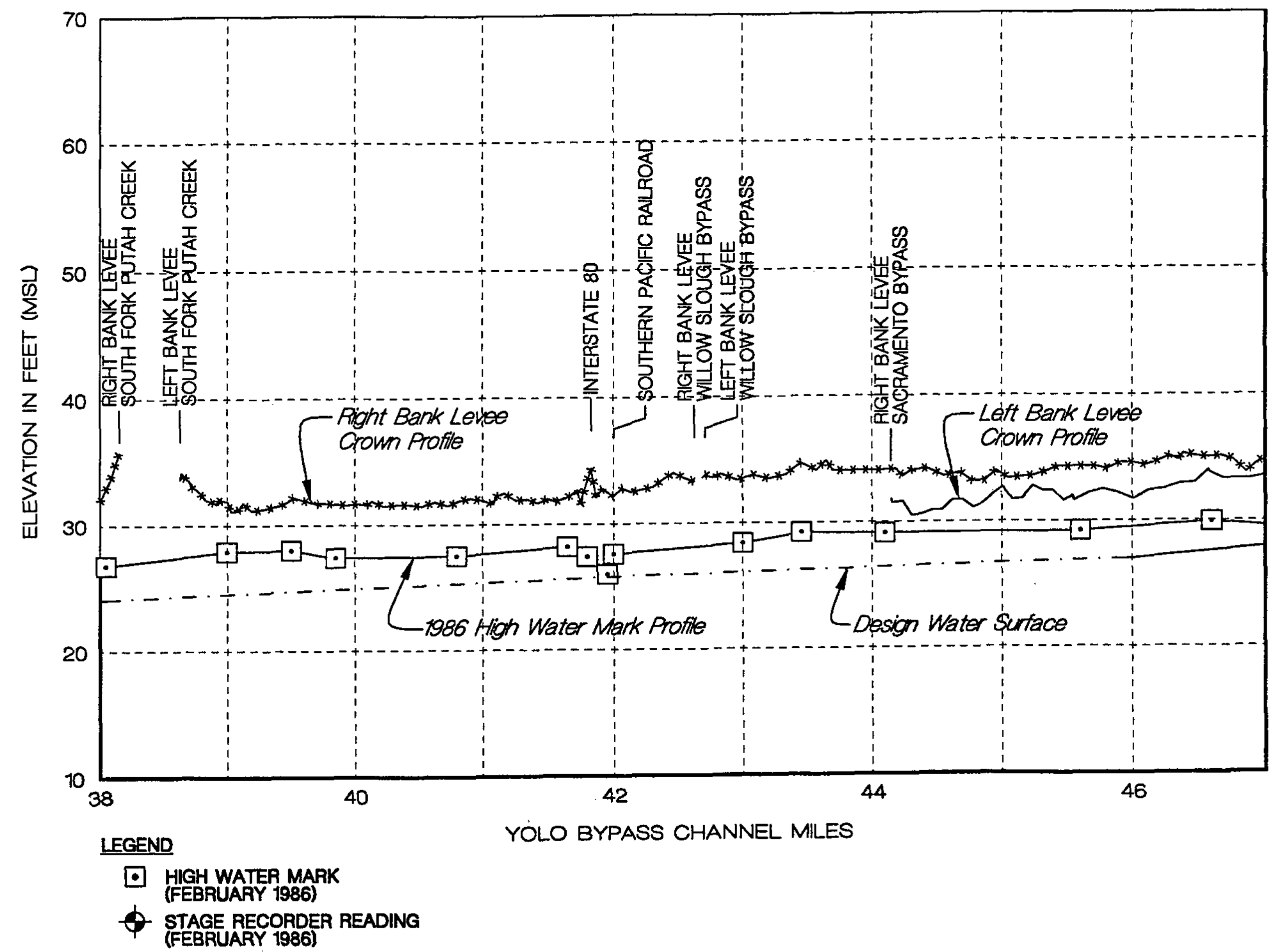


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES YOLO BYPASS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 6 **Sheet 1 of 2**

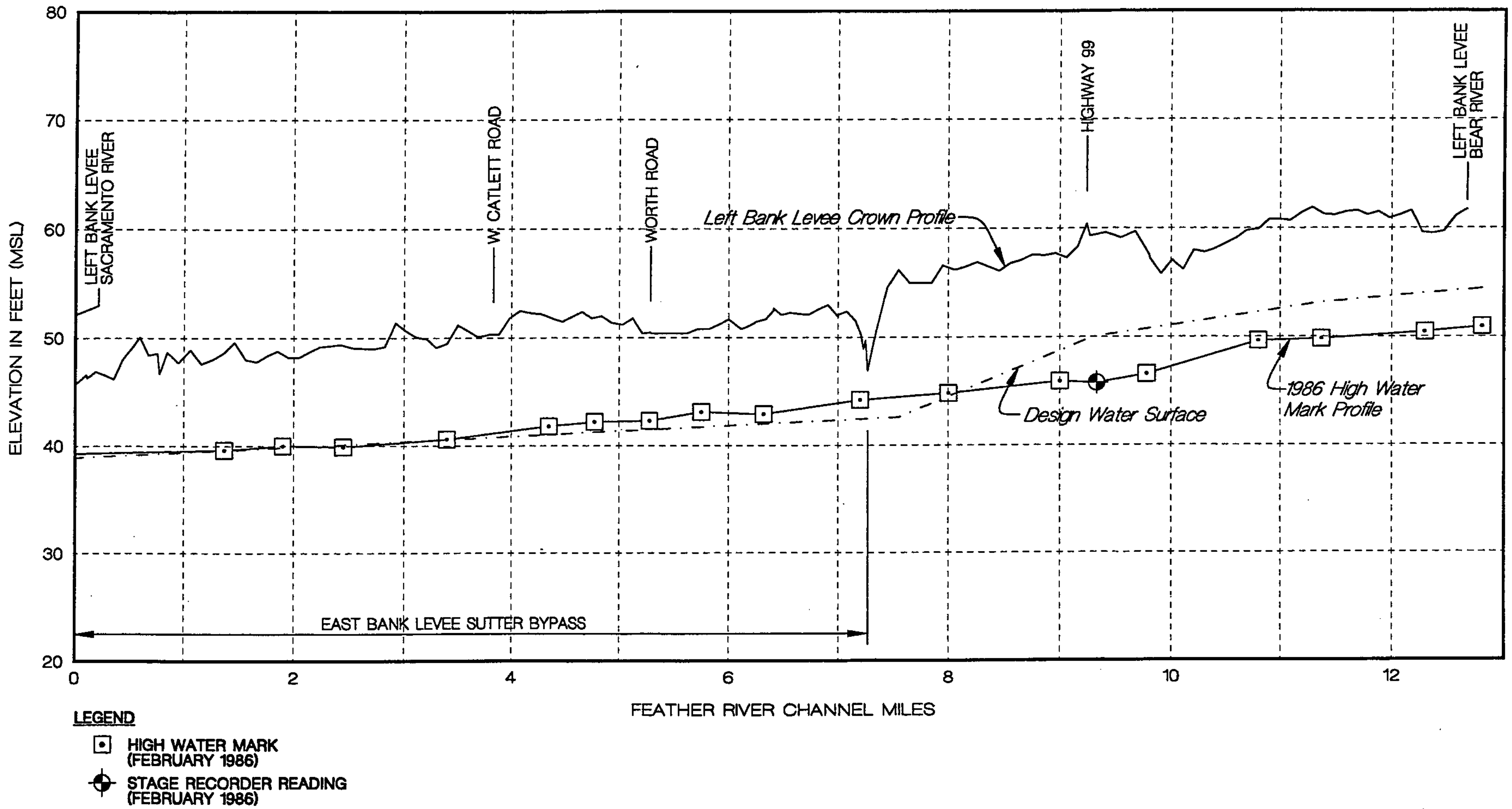


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES YOLO BYPASS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 6 Sheet 2 of 2

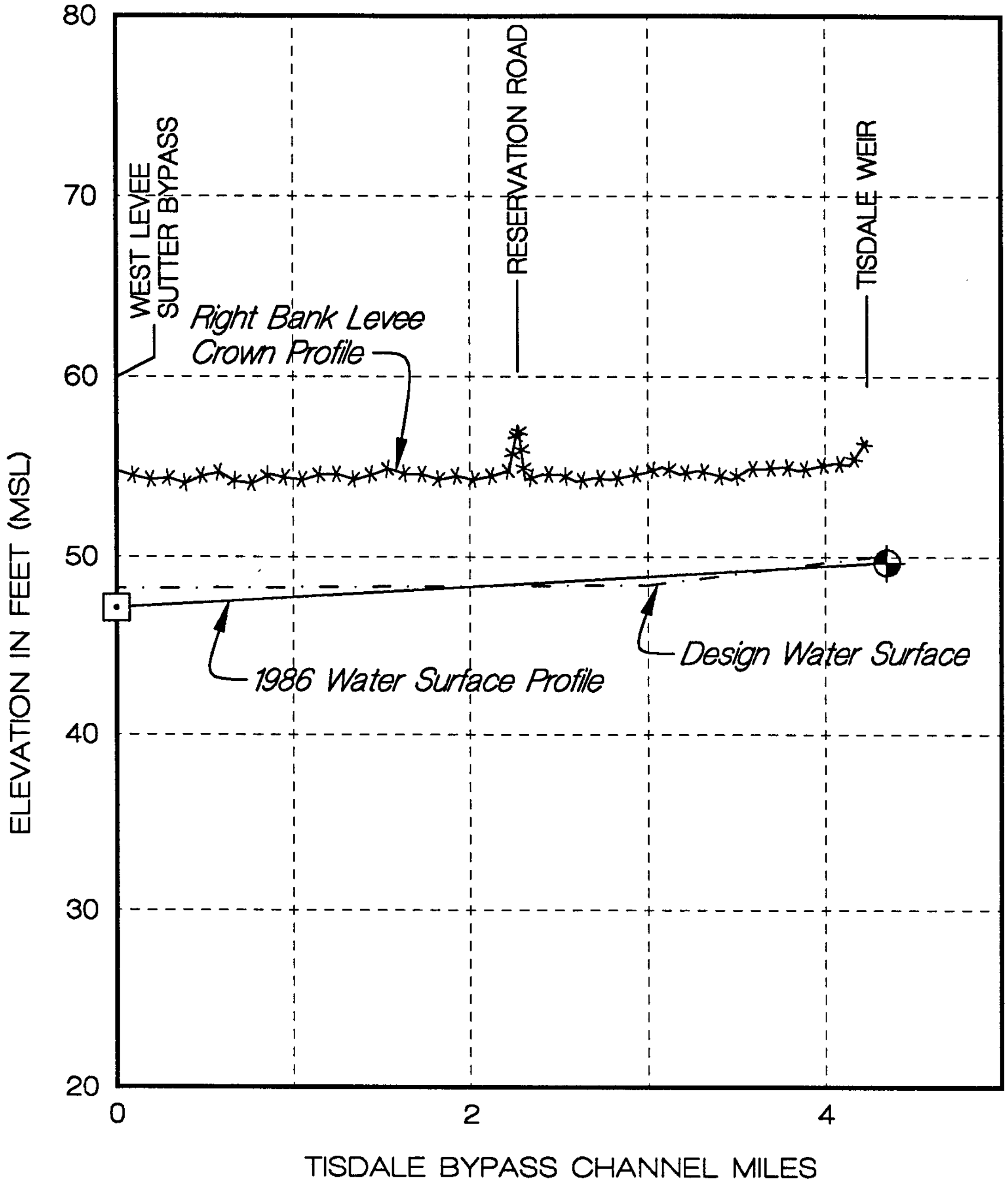


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

**LEVEE CROWN AND DESIGN
WATER SURFACE PROFILES
FEATHER RIVER**

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 7 **Sheet 1 of 1**



LEGEND

HIGH WATER MARK
(FEBRUARY 1986)

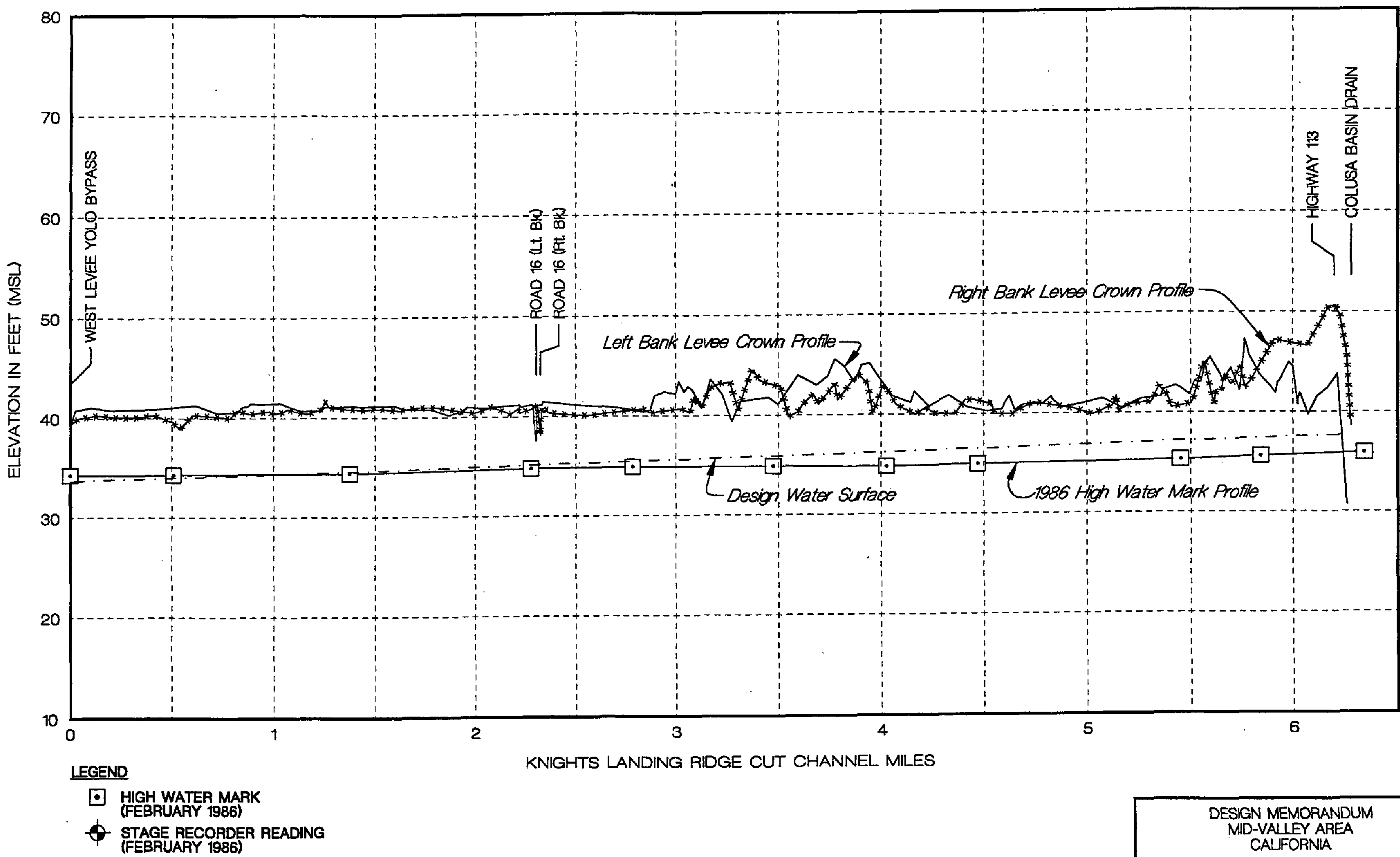
STAGE RECORDER READING
(FEBRUARY 1986)

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN
WATER SURFACE PROFILES
TISDALE BYPASS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 8 **Sheet 1 of 1**

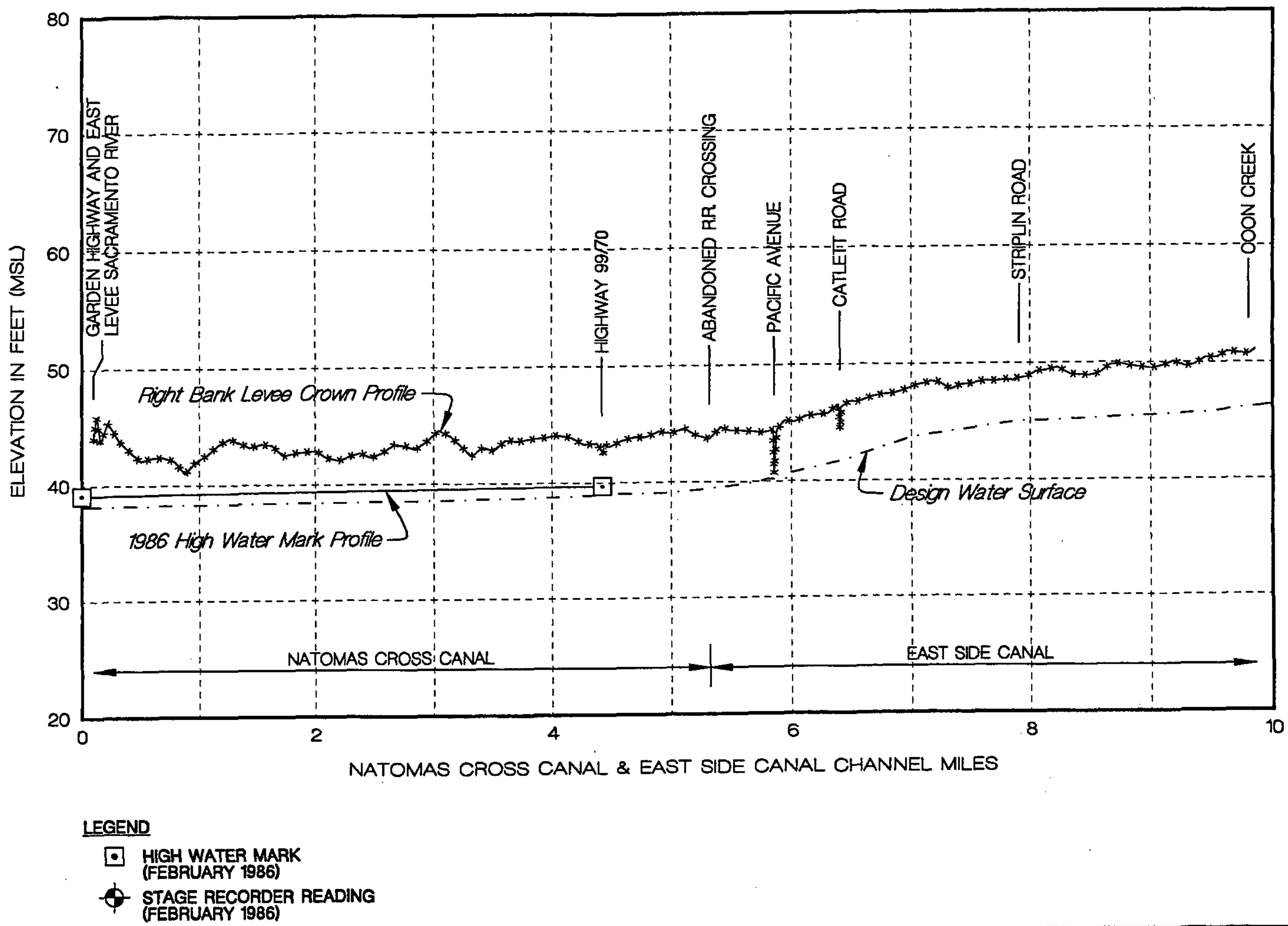


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES KNIGHTS LANDING RIDGE CUT

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 9 **Sheet 1 of 1**

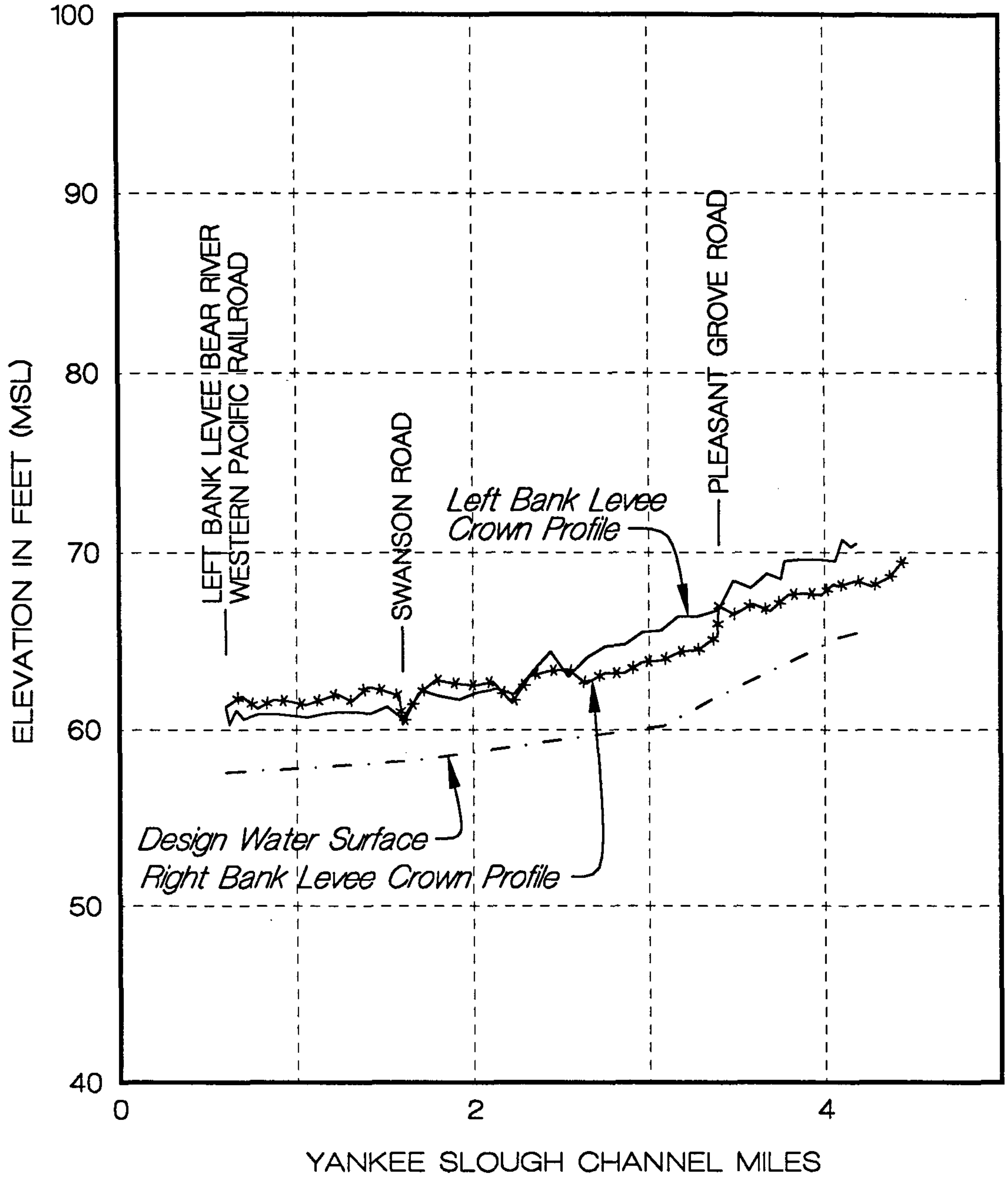


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES NATOMAS CROSS CANAL AND EAST SIDE CANAL

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 10 | **Sheet 1 of 1**



LEGEND

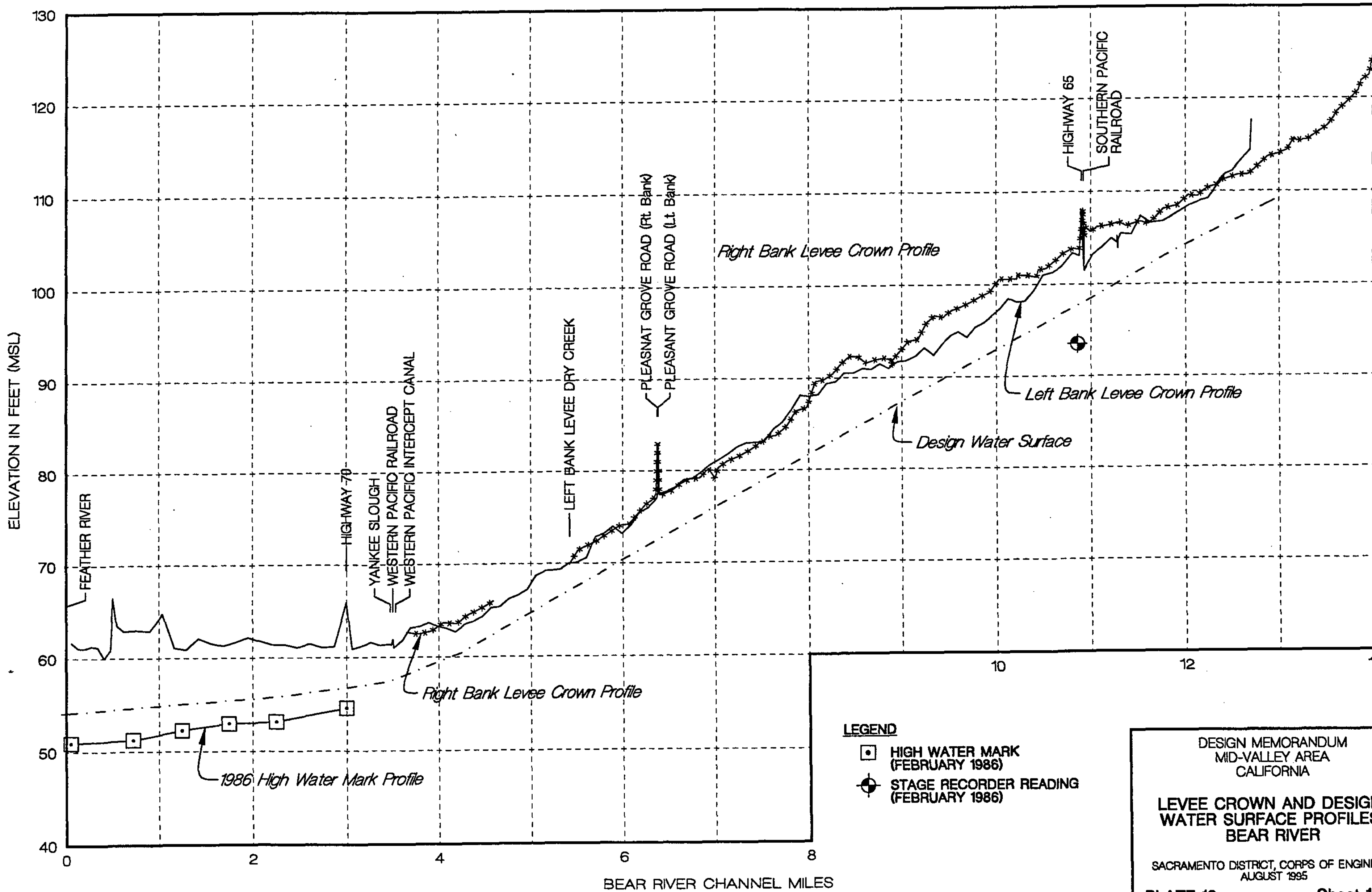
- HIGH WATER MARK (FEBRUARY 1986)
- STAGE RECORDER READING (FEBRUARY 1986)

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES YANKEE SLOUGH

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 11 **Sheet 1 of 1**

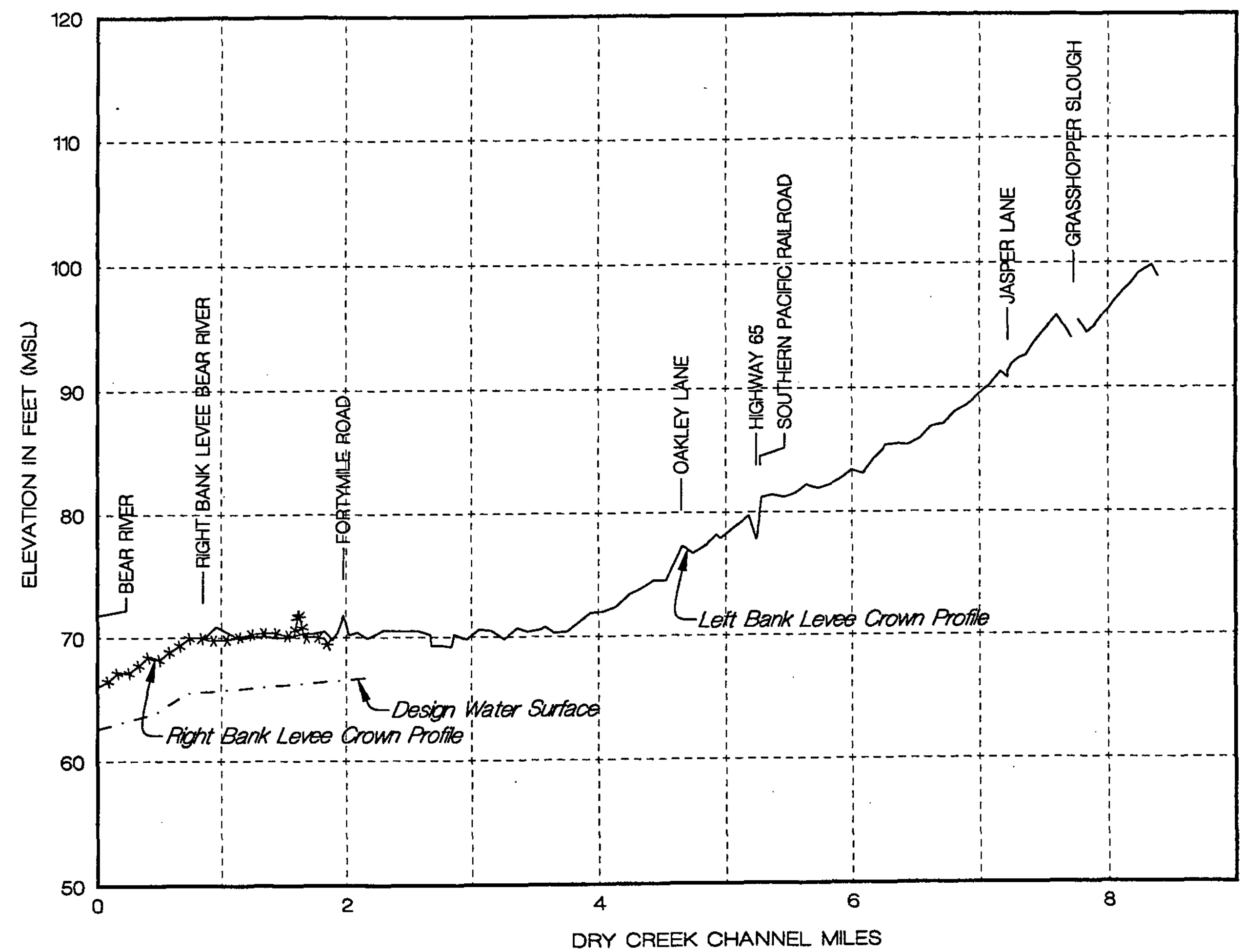


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES BEAR RIVER

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 12 Sheet 1 of 1

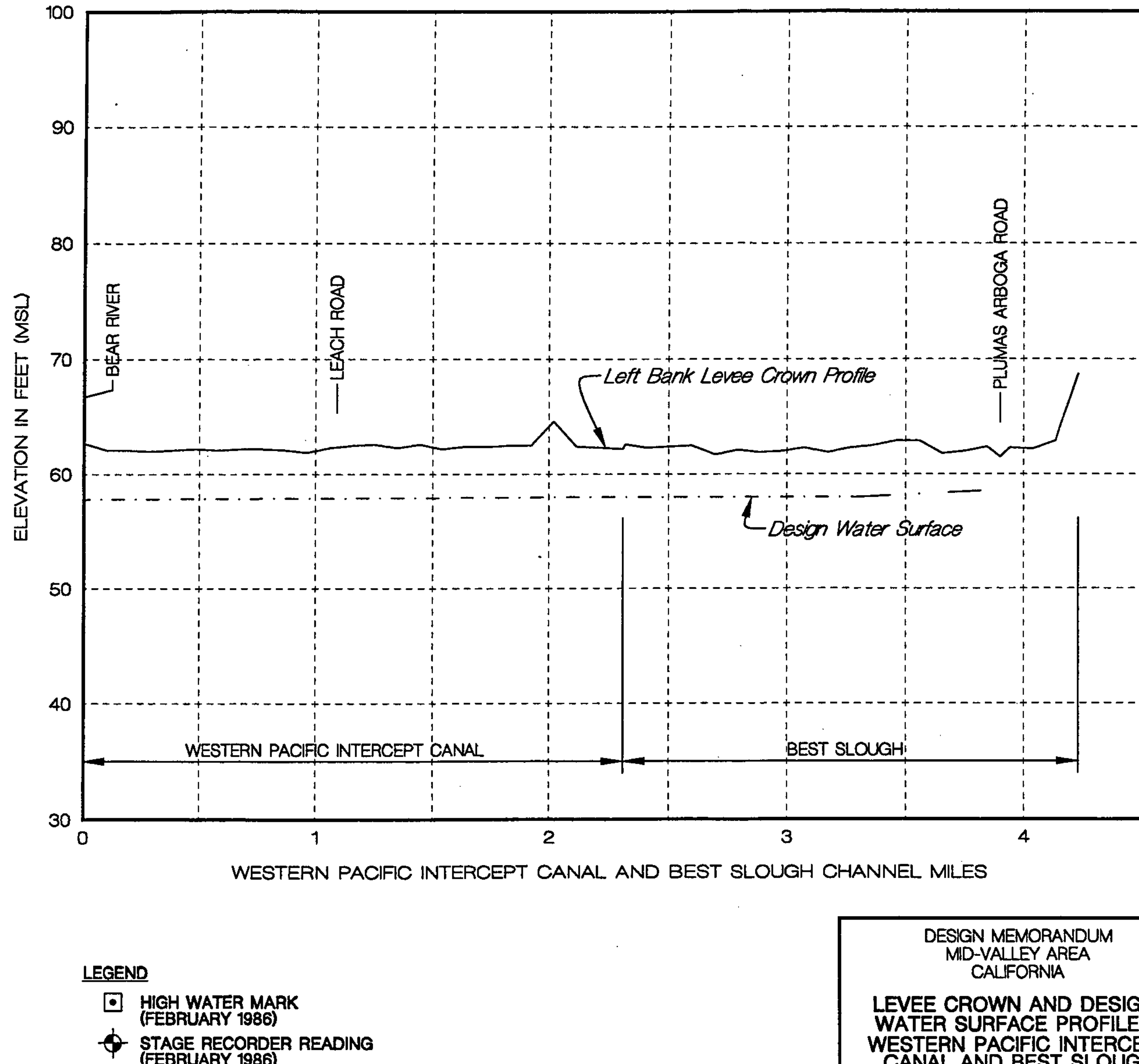


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES DRY CREEK

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 13 **Sheet 1 of 1**

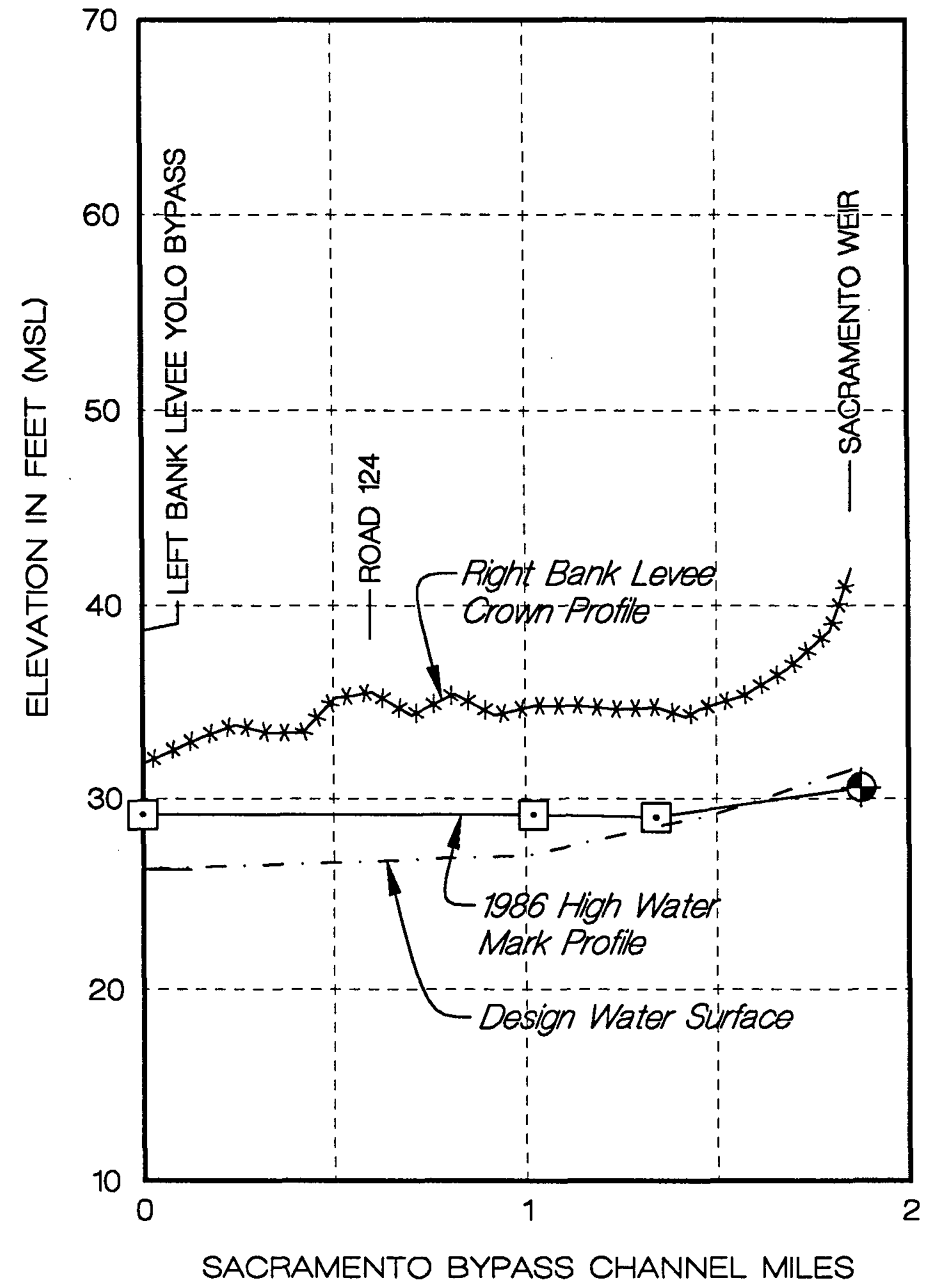


DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES WESTERN PACIFIC INTERCEPT CANAL AND BEST SLOUGH

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1995

PLATE 14 **Sheet 1 of 1**



LEGEND

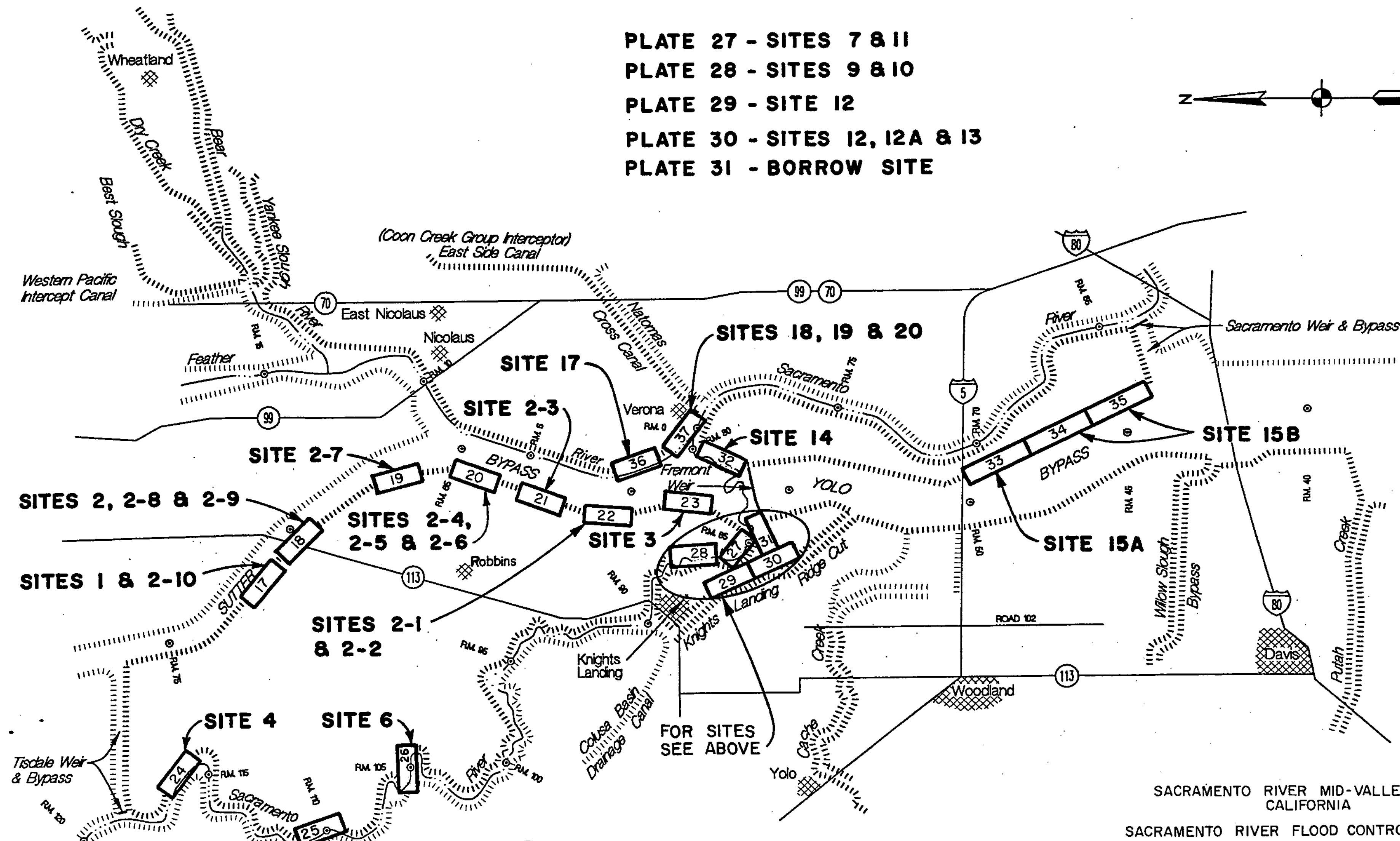
- HIGH WATER MARK (FEBRUARY 1986)
- STAGE RECORDER READING (FEBRUARY 1986)

DESIGN MEMORANDUM
MID-VALLEY AREA
CALIFORNIA

LEVEE CROWN AND DESIGN WATER SURFACE PROFILES SACRAMENTO BYPASS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS

PLATE 15 **Sheet 1 of 1**



LEGEND

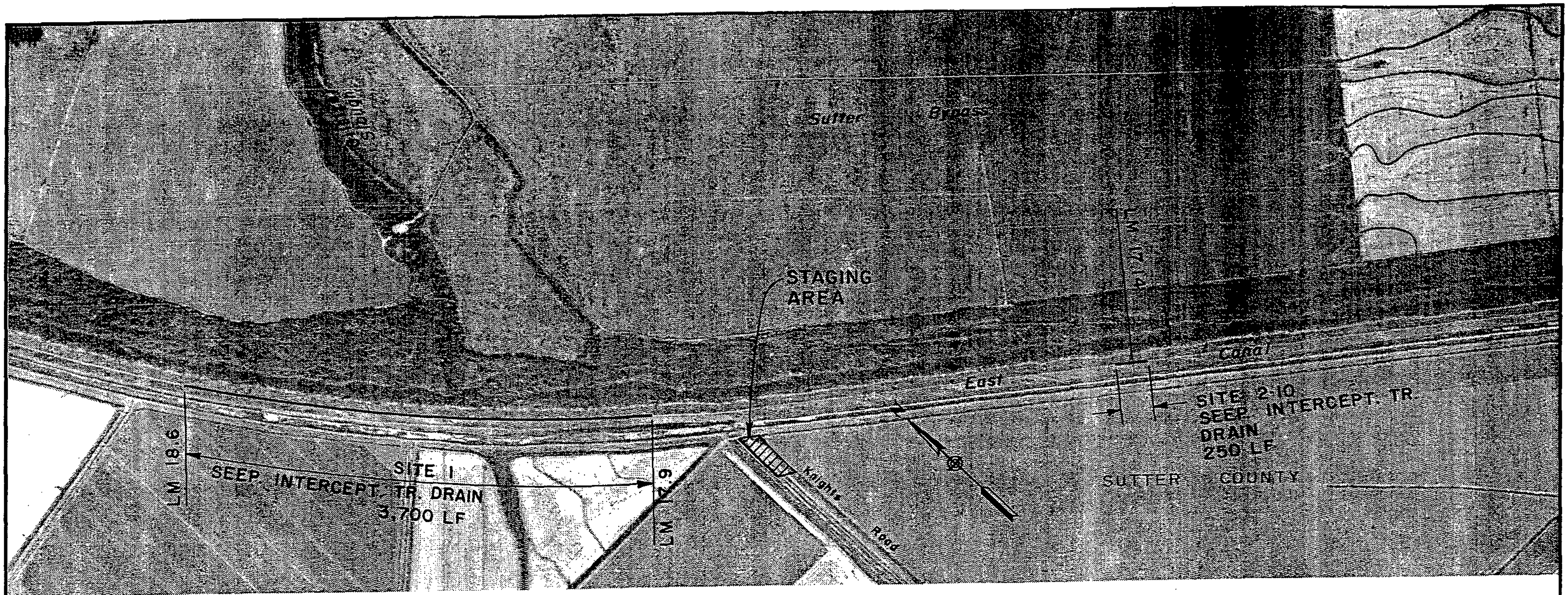
17	SITE LOCATION & PLATE NUMBER
'''''''''''''''''	LEVEES
⊙ RM 60	CHANNEL OR RIVER MILES

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION INDEX

PLATE 16



SITES 1 & 2-10

SCALE 1"= 800'

LEGEND

LM LEVEE MILE

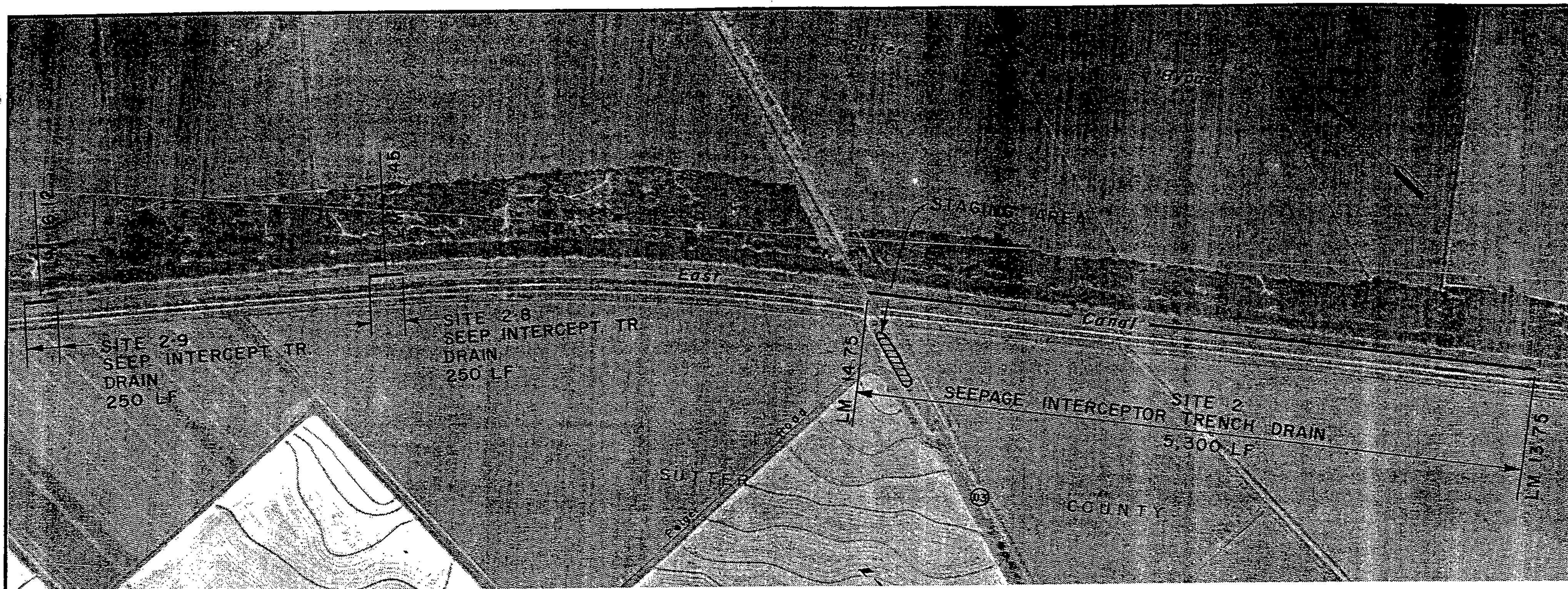
——— SEEPAGE INTERCEPTOR TRENCH DRAIN

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITES 1 & 2-10

PLATE 17



SITES 2, 2·8 & 2·9

SCALE 1" = 800'

LEGEND

LM LEVEE MILE

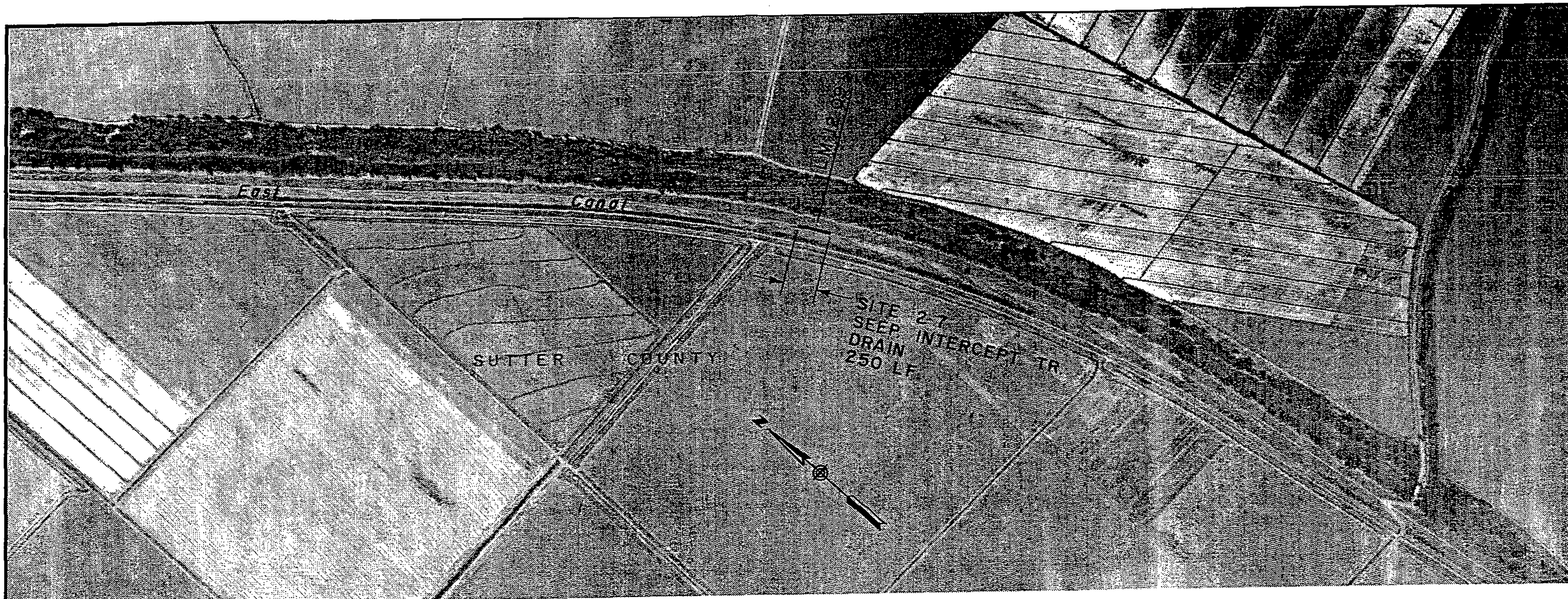
——— SEEPAGE INTERCEPTOR TRENCH DRAIN

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITES 2, 2-8 & 2·9

PLATE 18



SITE 2-7
SCALE 1" = 800'

LEGEND

LM LEVEE MILE

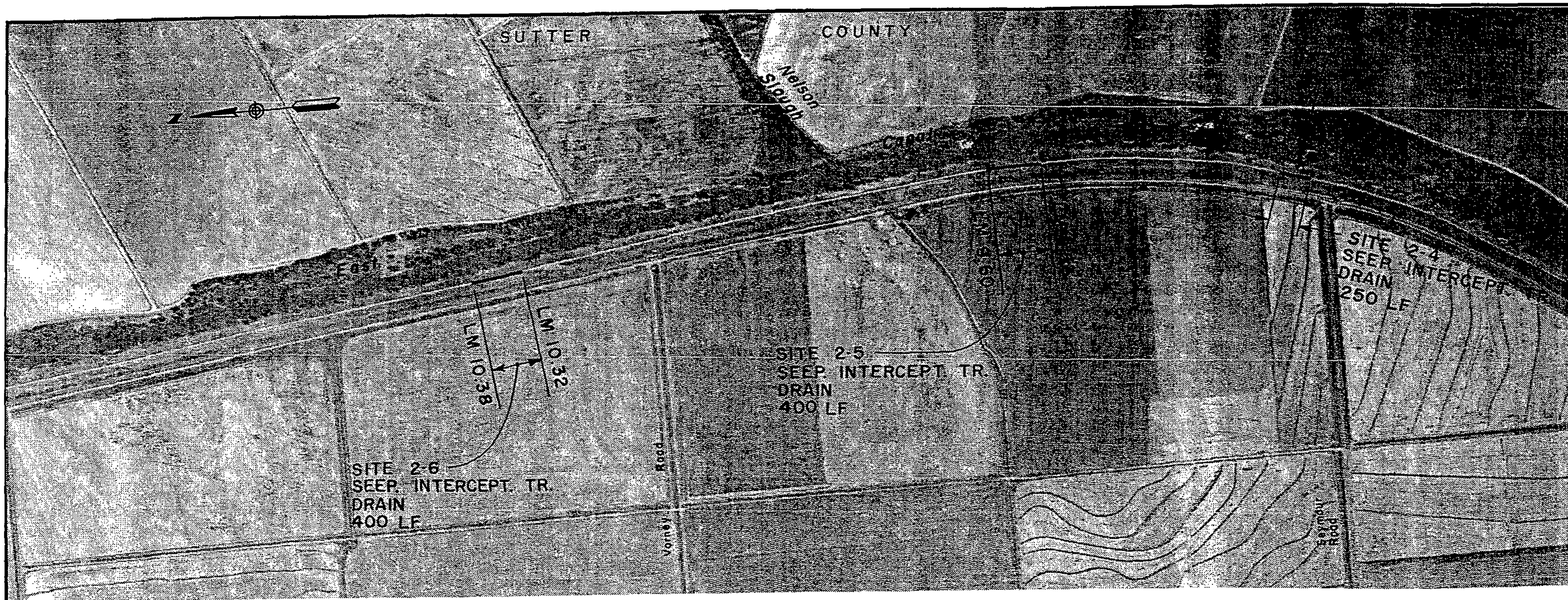
SEEPAGE INTERCEPTOR TRENCH DRAIN

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 2-7

PLATE 19



SITES 2-4, 2-5 & 2-6

SCALE 1"=800'

LEGEND

LM LEVEE MILE

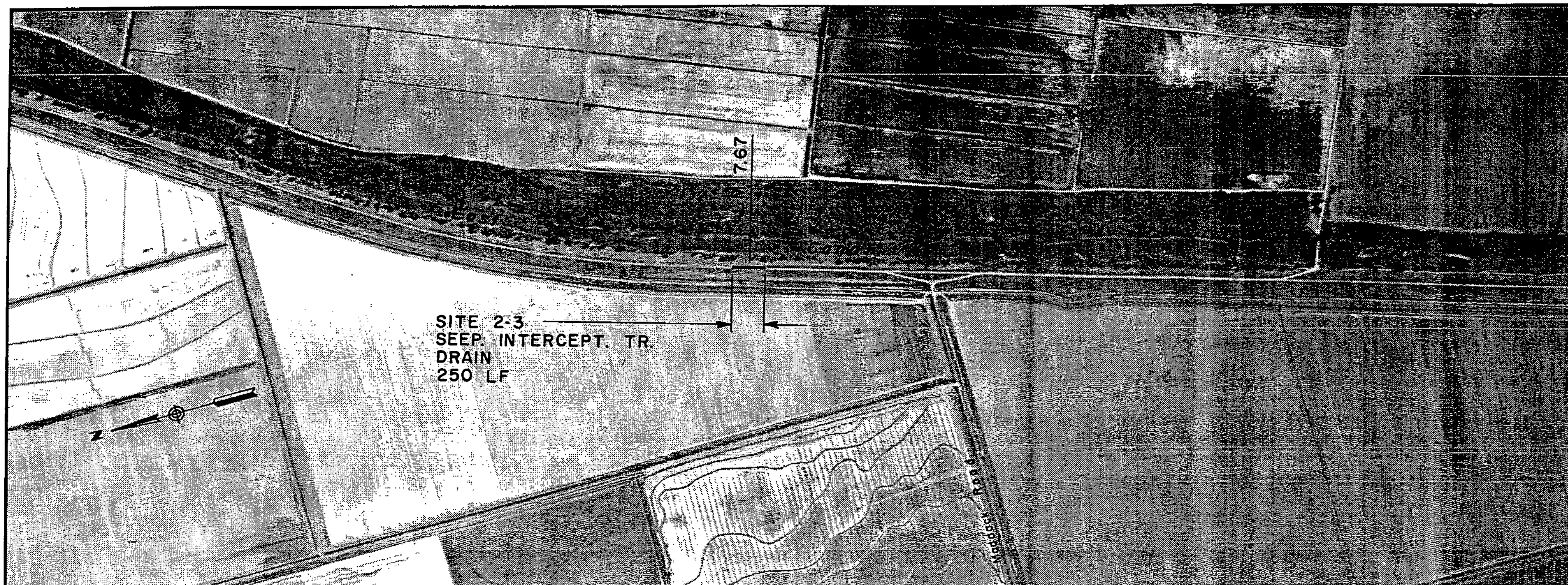
——— SEEPAGE INTERCEPTOR TRENCH DRAIN

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITES 2-4, 2-5 & 2-6

PLATE 20



SITE 2-3

SCALE 1" = 800'

LEGEND

LM LEVEE MILE

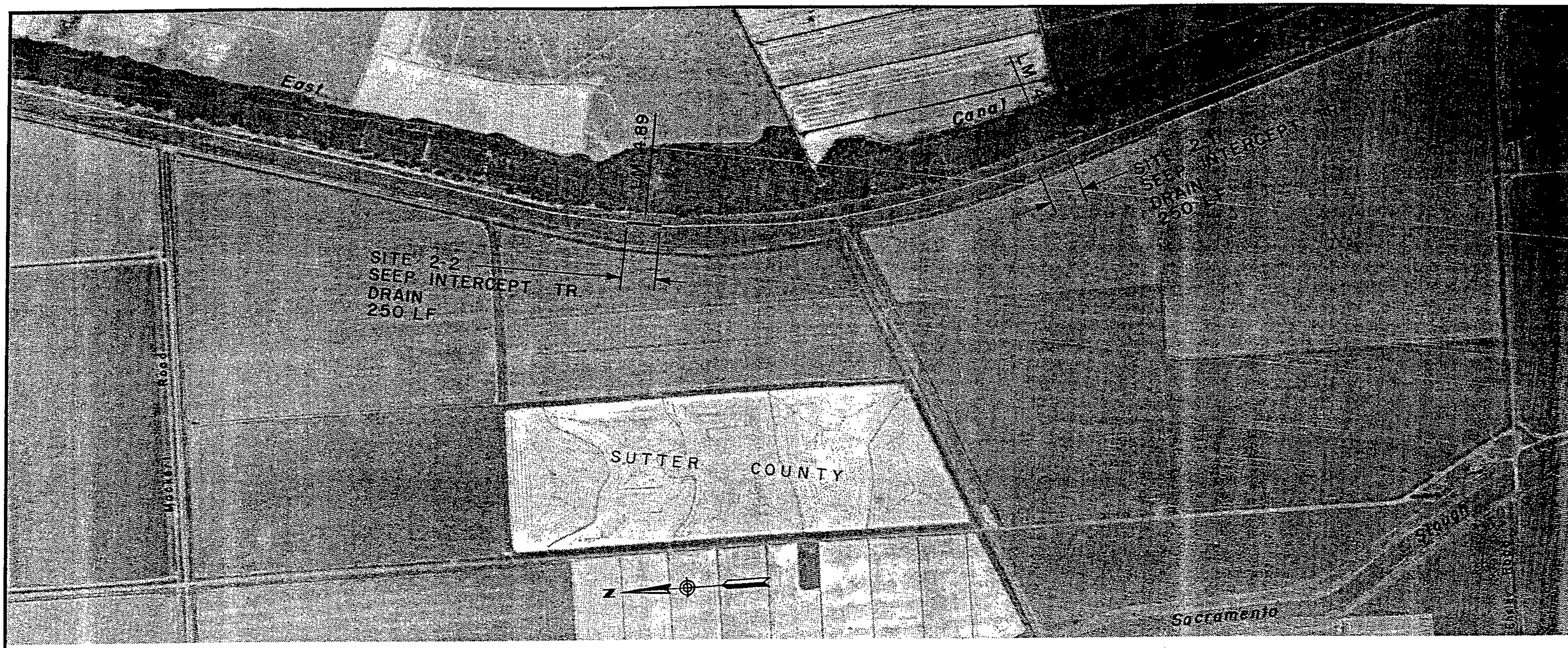
——— SEEPAGE INTERCEPTOR TRENCH DRAIN

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 2-3

PLATE 21



SITES 2-1 & 2-2
SCALE 1" = 800'

LEGEND

LM LEVEE MILE

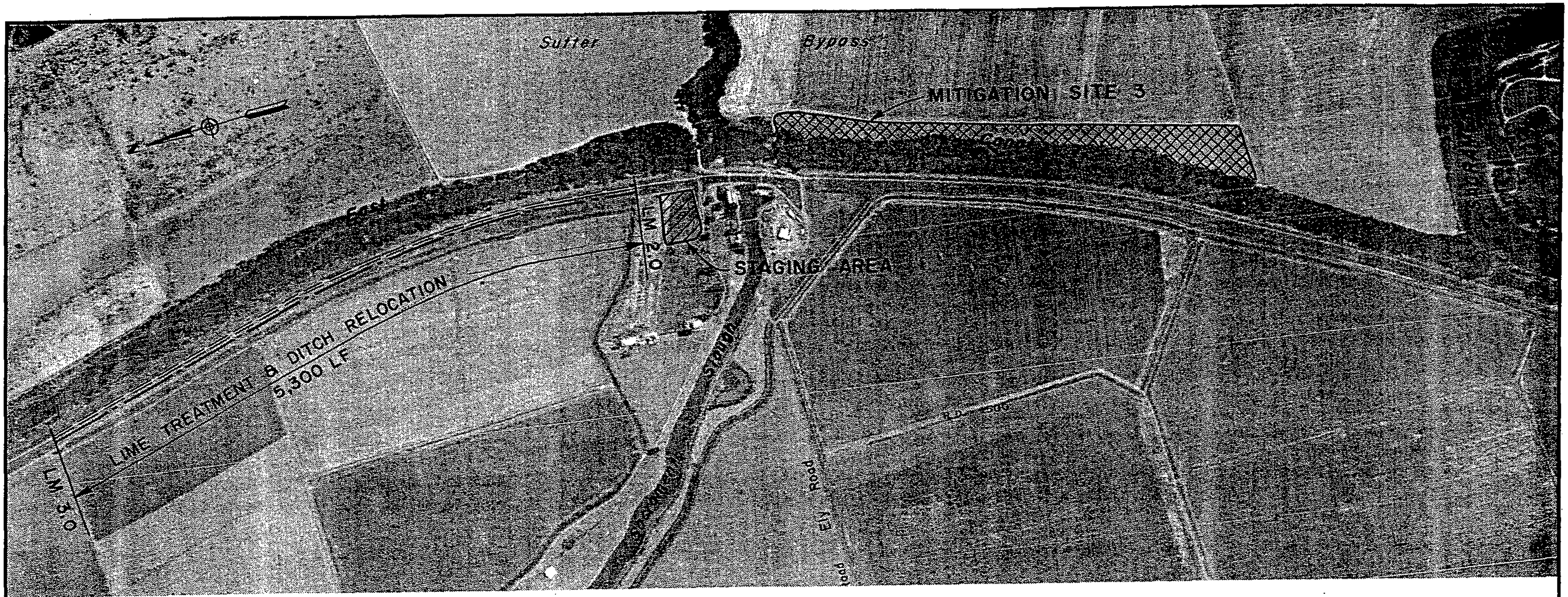
SEEPAGE INTERCEPTOR TRENCH DRAIN

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITES 2-1 & 2-2

PLATE 22



LEGEND

LM LEVEE MILE

=== LIME TREATMENT (OR SOIL TREATMENT)

—·— DITCH RELOCATION

STAGING AREA

MITIGATION

SITE 3

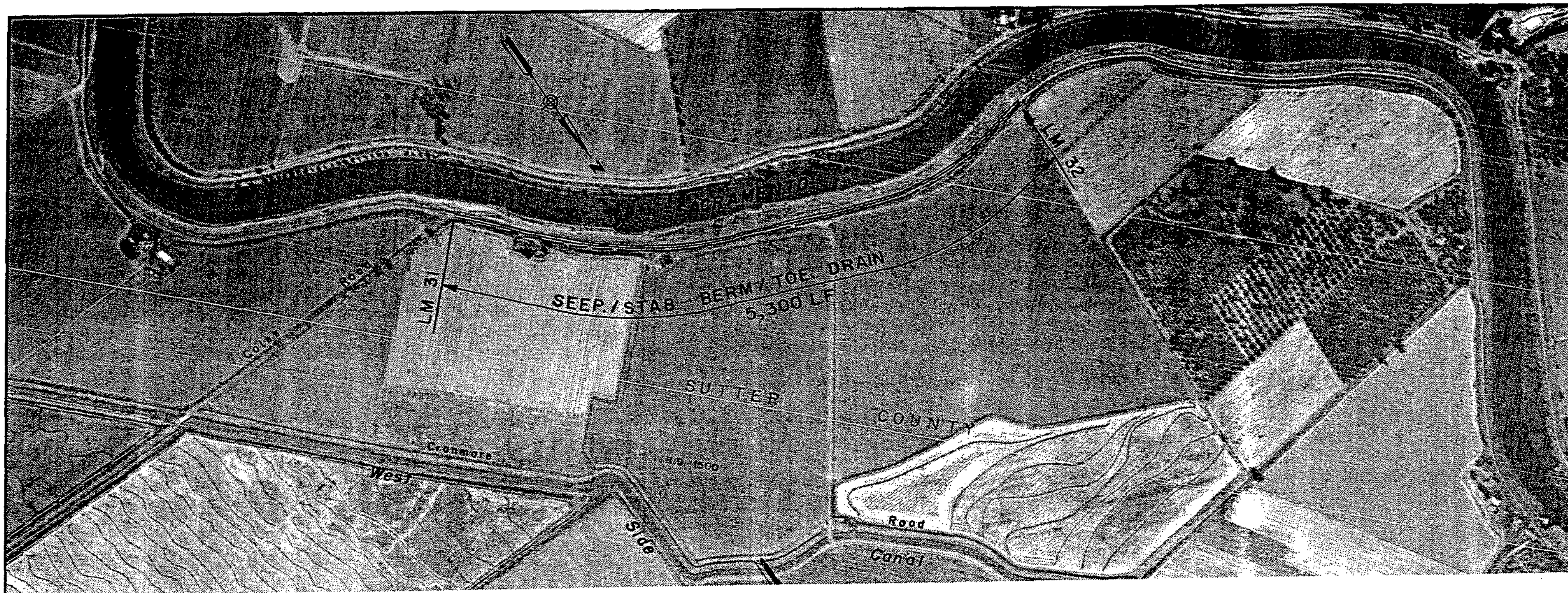
SCALE 1"=800'

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 3

PLATE 23



SITE 4

SCALE 1" = 800'

LEGEND

LM LEVEE MILE

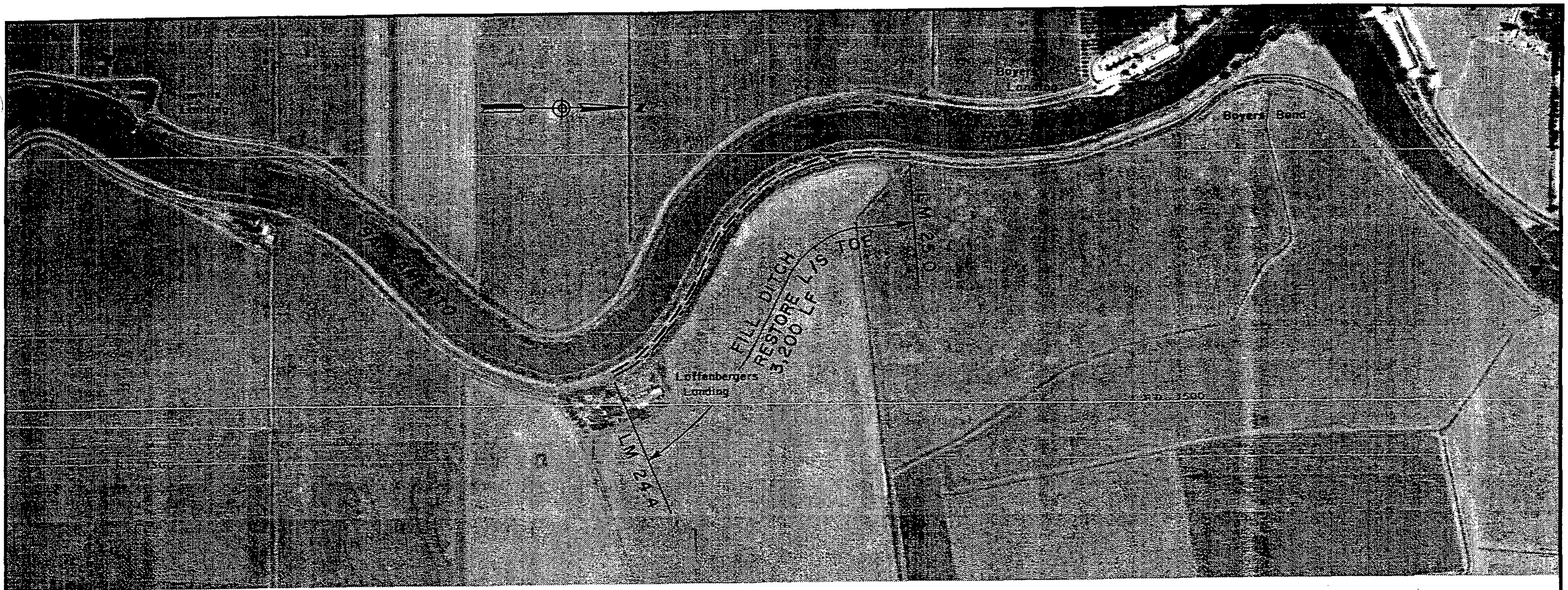
SEEPAGE / STABILITY BERM WITH TOE DRAIN

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 4

PLATE 24



SITE 5
SCALE 1" = 800'

LEGEND

LM LEVEE MILE

-·-·- FILL DITCH

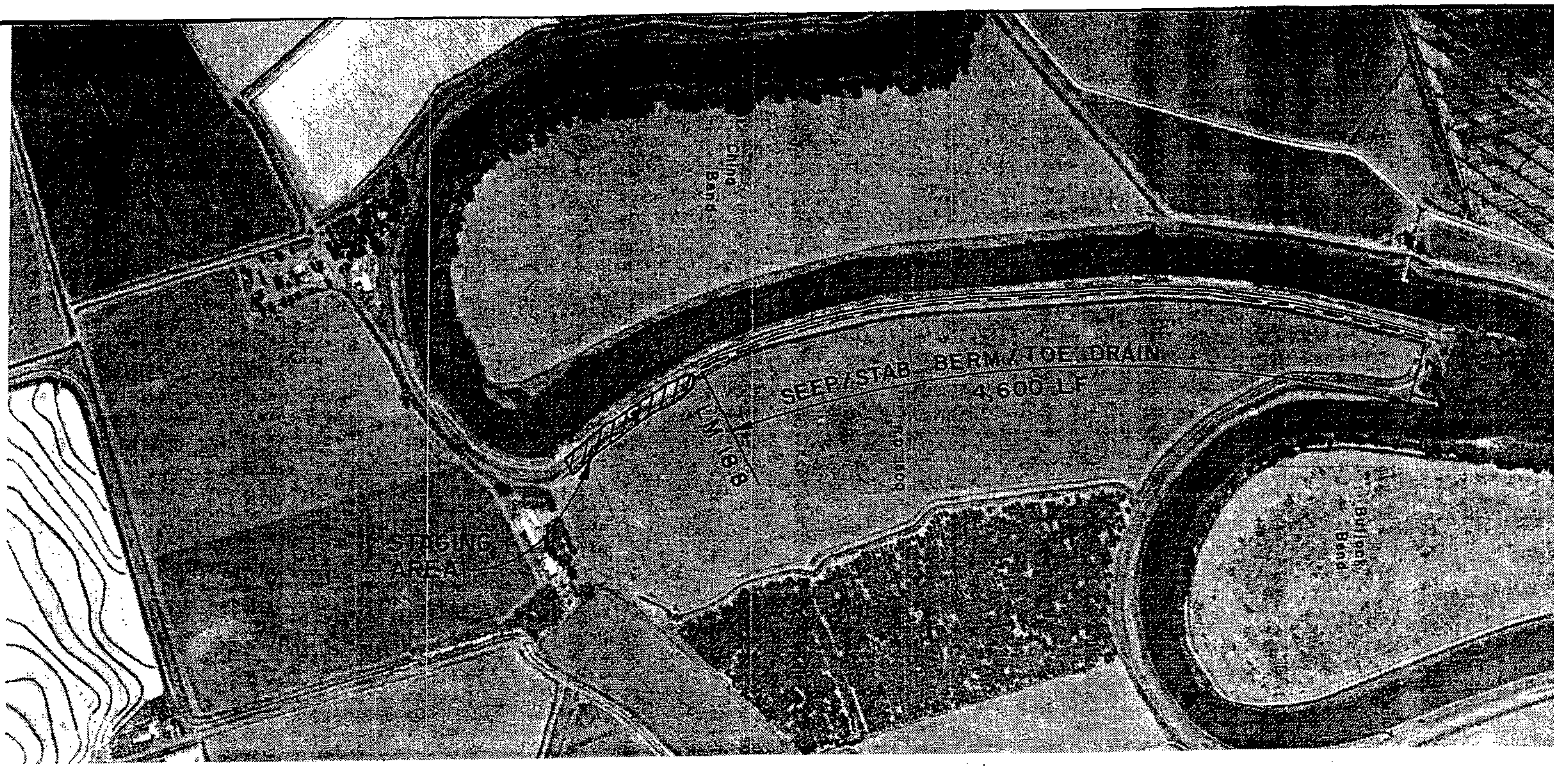
— — — RESTORE LANDSIDE TOE

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 5

PLATE 25



SITE 6

SCALE 1"= 800'

LEGEND

LM LEVEE MILE

SEEPAGE / STABILITY BERM WITH TOE DRAIN

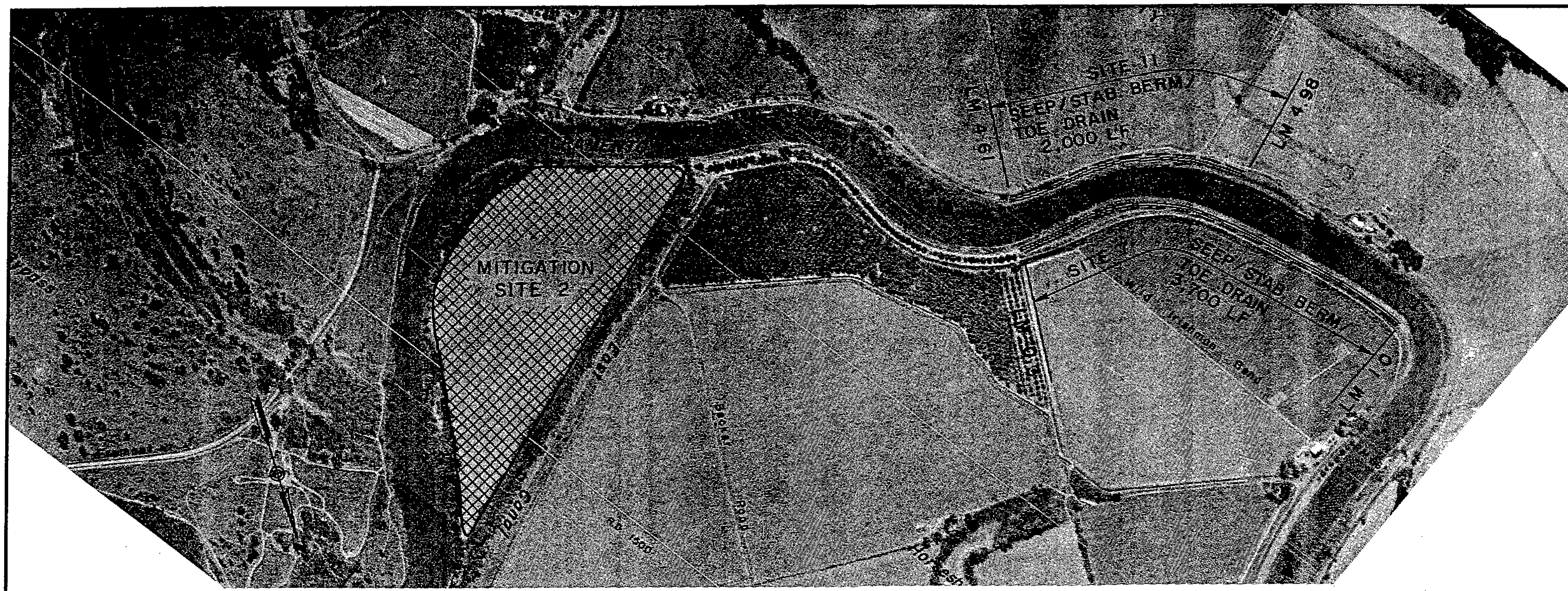
STAGING AREA

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 6

PLATE 26



SITES 7 & 11

SCALE 1" = 800'

LEGEND

LM LEVEE MILE

SEEPAGE/STABILITY BERM WITH TOE DRAIN

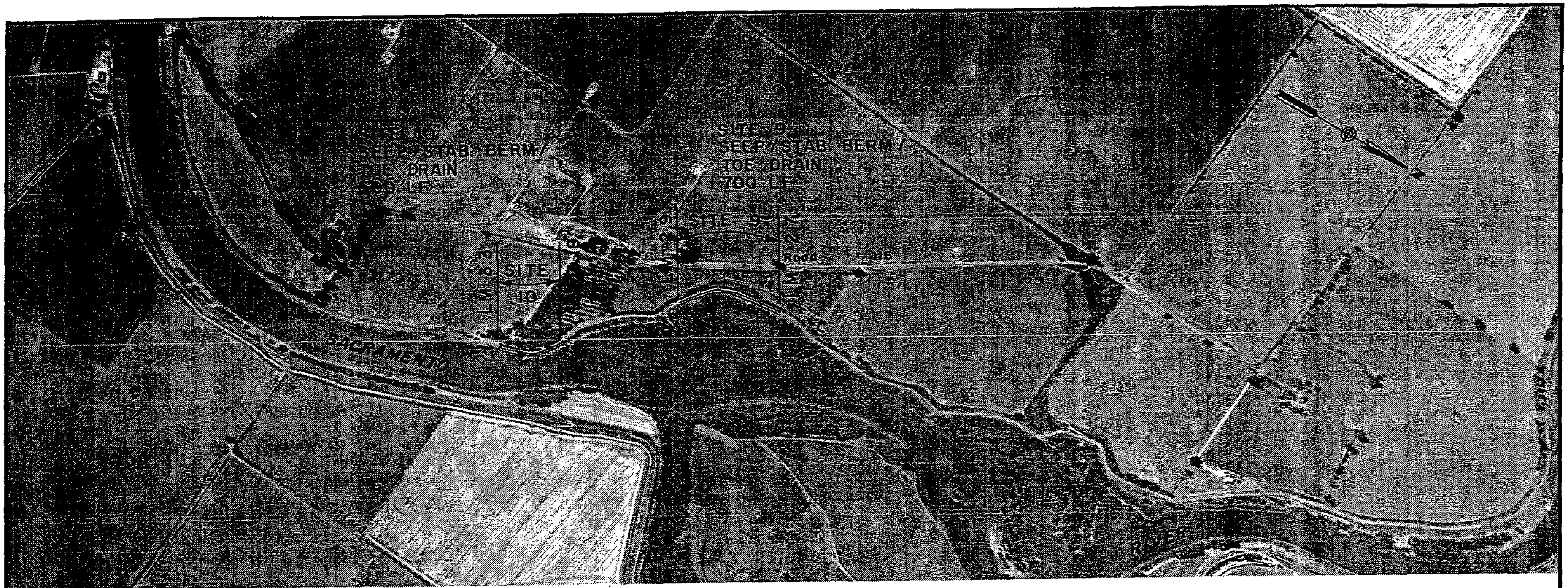
MITIGATION

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITES 7 & 11

PLATE 27



SITES 9 & 10

SCALE 1" = 800'

LEGEND

LM LEVEE MILE

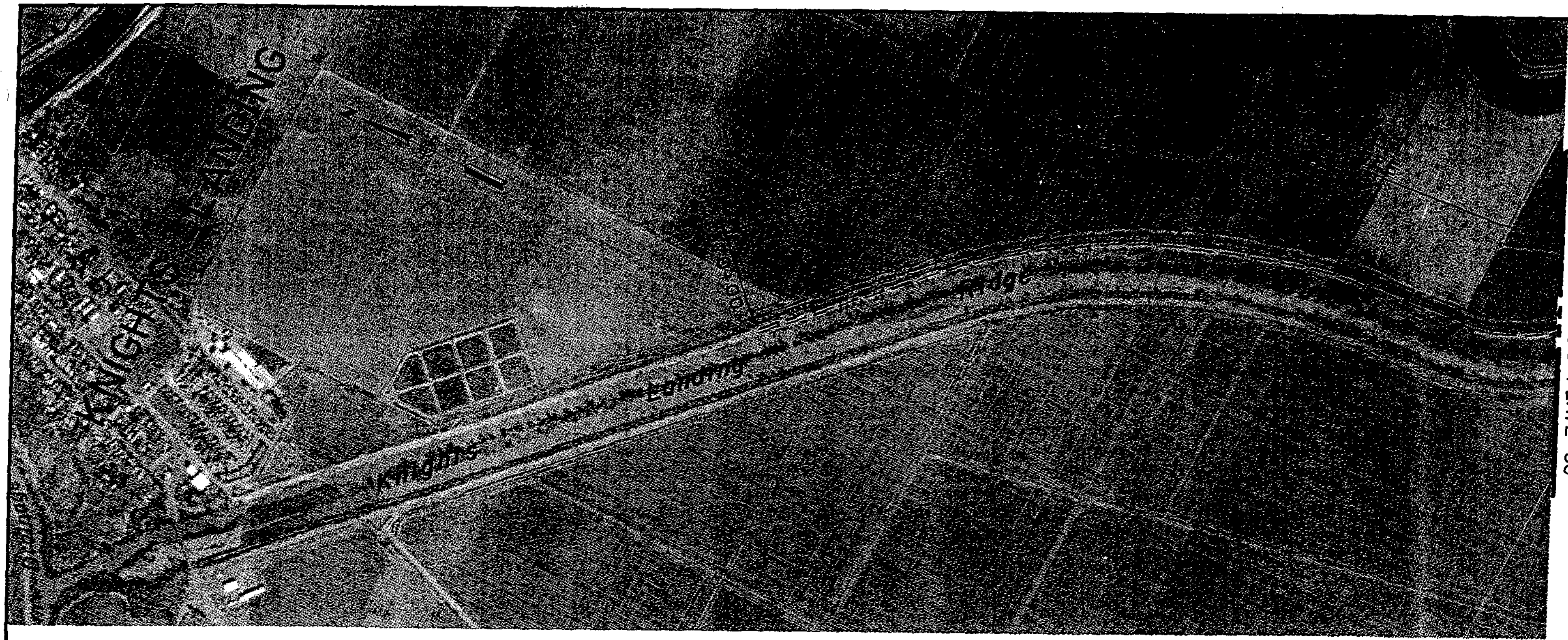
SEEPAGE / STABILITY BERM WITH TOE DRAIN

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITES 9 & 10

PLATE 28



SITE 12

SCALE 1" = 1000'

LEGEND

STA STATION

═══ LIME TREATMENT (OR SOIL TREATMENT)

— - — DITCH RELOCATION

—ooo— RESHAPE LEVEE

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

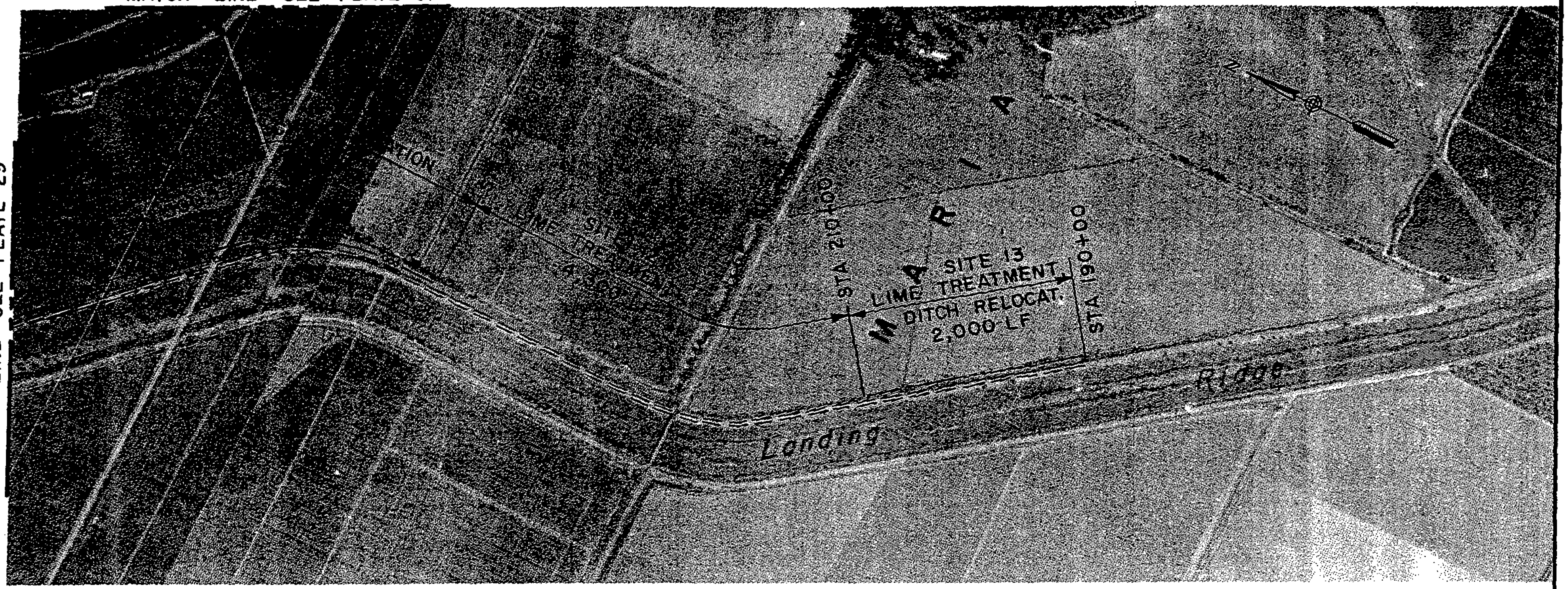
SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 12

PLATE 29

MATCH LINE SEE PLATE 31

MATCH LINE SEE PLATE 29



SITES 12, 12A & 13

SCALE 1" = 1000'

LEGEND

STA STATION

=== LIME TREATMENT (OR SOIL TREATMENT)

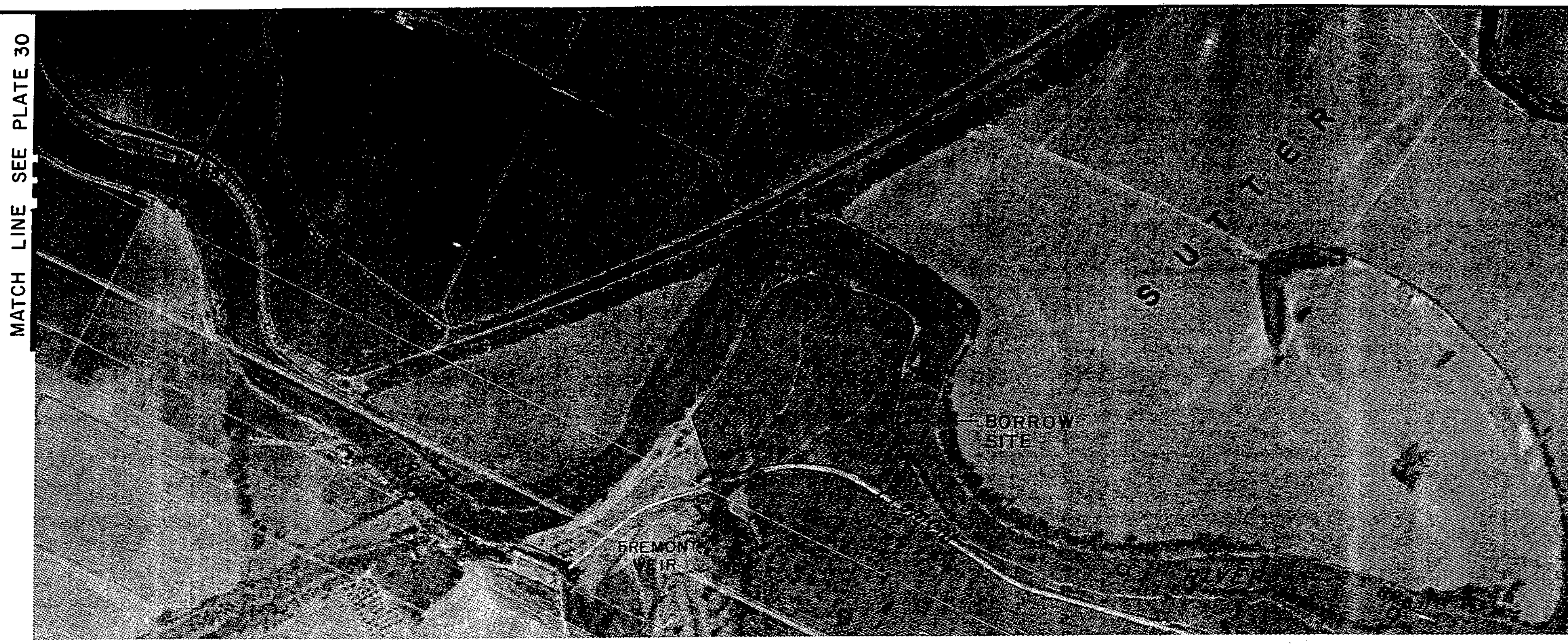
—·— DITCH RELOCATION

—ooo— RESHAPE LEVEE

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITES 12, 12A & 13



BORROW SITE

SCALE 1" = 1000'

LEGEND

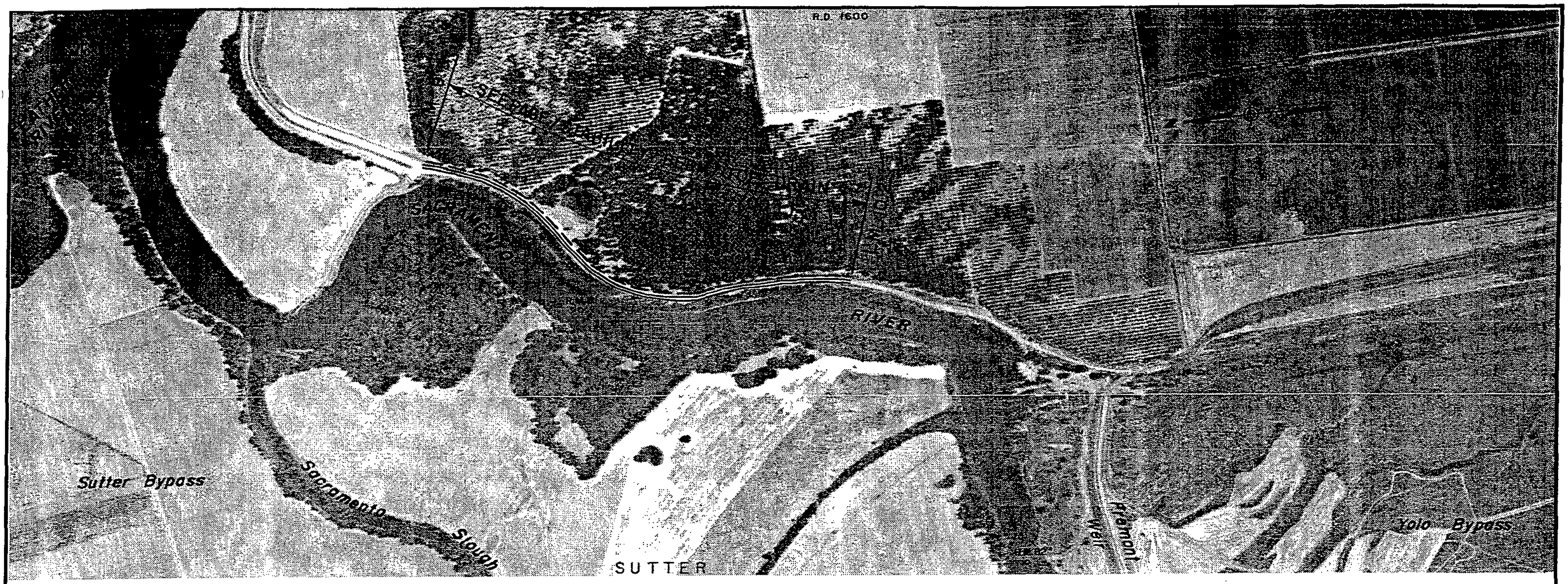
BORROW SITE

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
BORROW SITE

PLATE 31



SITE 14

SCALE 1"= 800'

LEGEND

LM LEVEE MILE

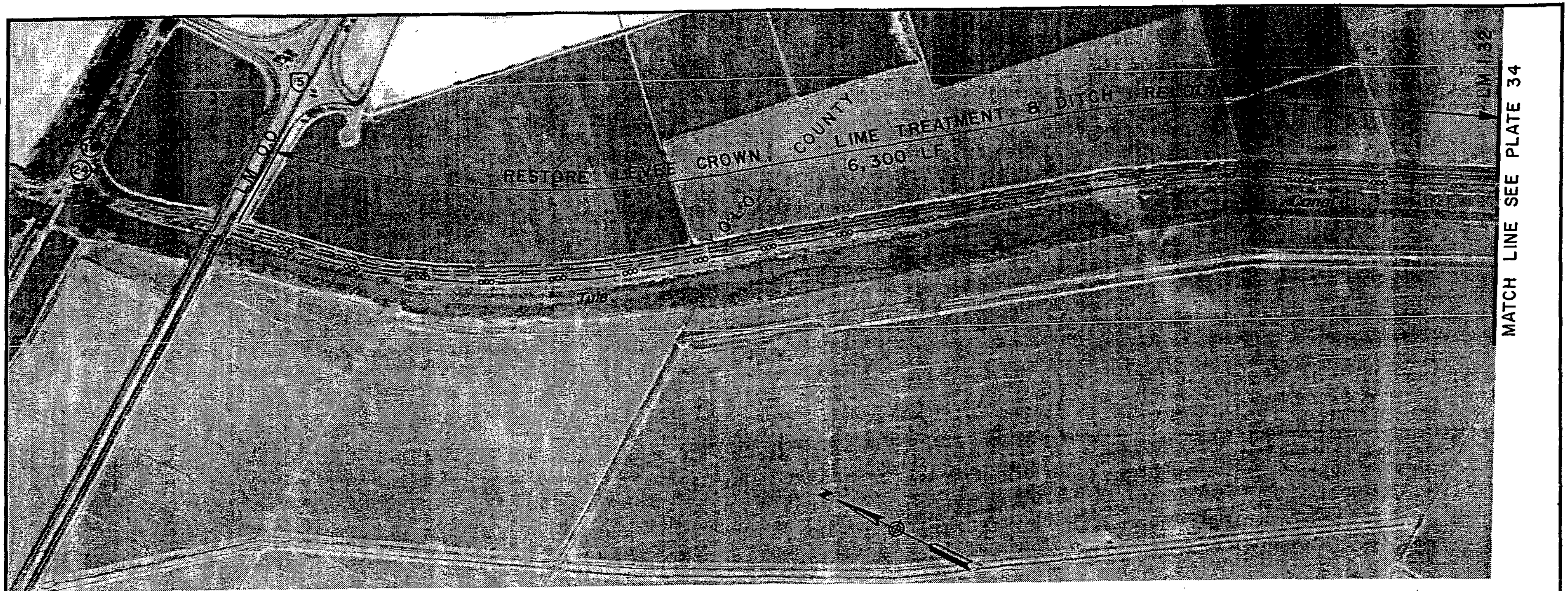
SEEPAGE / STABILITY BERM WITH TOE DRAIN

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 14

PLATE 32



SITE 15A

SCALE 1" = 800'

LEGEND

LM LEVEE MILE

—∘∘∘— RESTORE LEVEE CROWN

═══ LIME TREATMENT
(OR SOIL TREATMENT)

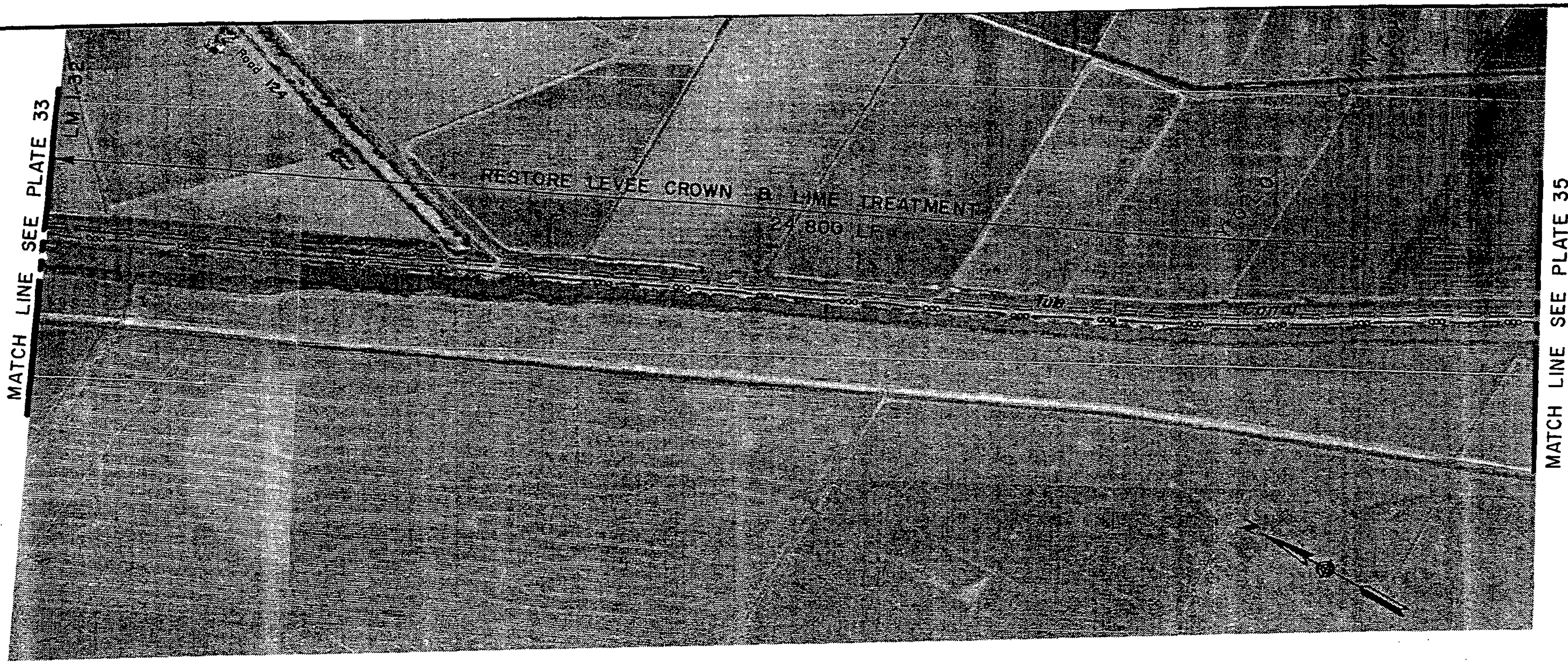
— - — DITCH RELOCATION

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 15A

PLATE 33



SITE 15B

SCALE 1"= 800'

LEGEND

LM LEVEE MILE

—∞∞— RESTORE LEVEE CROWN

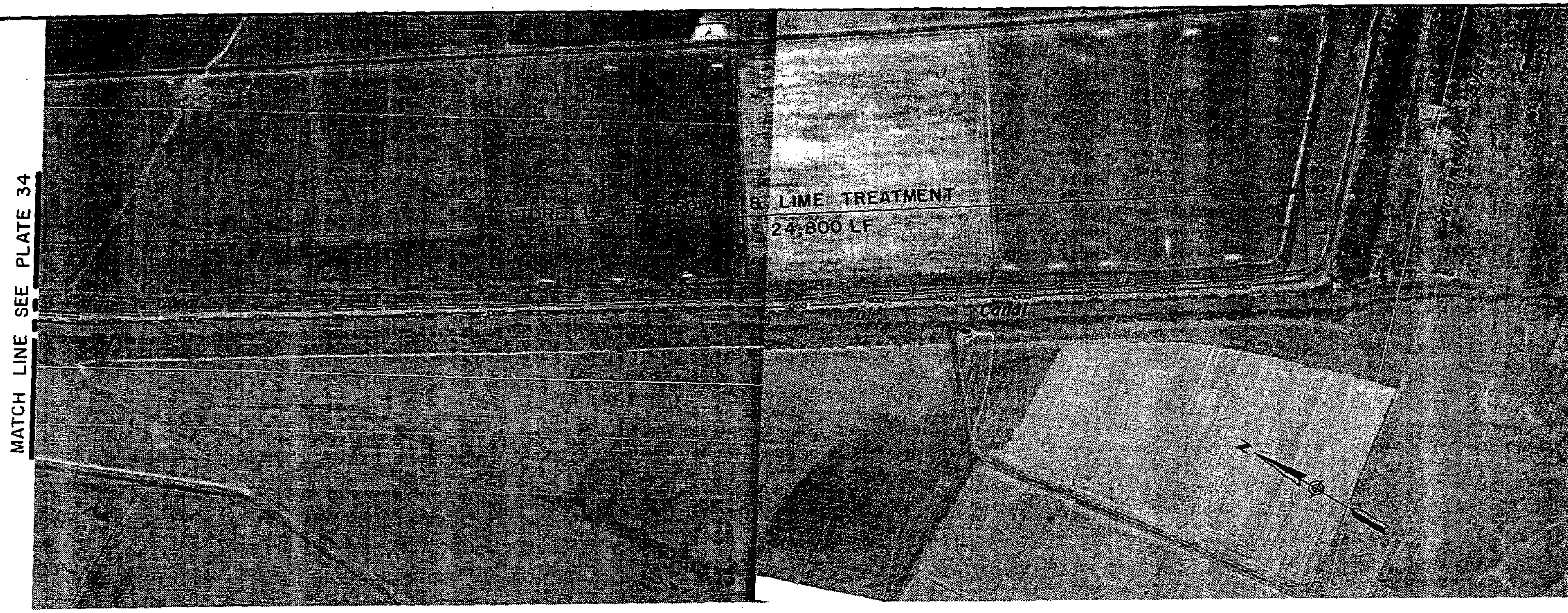
=== LIME TREATMENT (OR SOIL TREATMENT)

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 15B

PLATE 34



SITE 15B

SCALE 1" = 800'

LEGEND

LM LEVEE MILE

—∘∘∘— RESTORE LEVEE CROWN

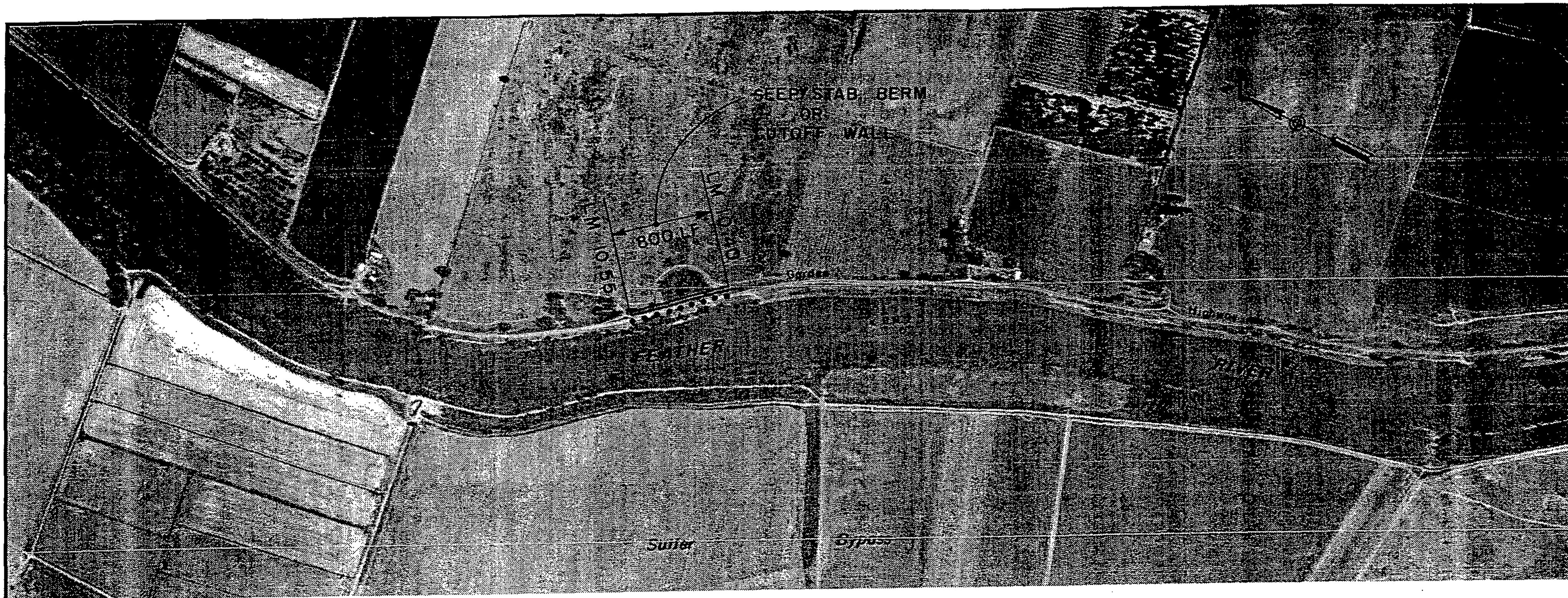
═══ LIME TREATMENT (OR SOIL TREATMENT)

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 15B

PLATE 35



SITE 17

SCALE 1" = 800'

LEGEND

LM LEVEE MILE

═══ SEEPAGE / STABILITY BERM

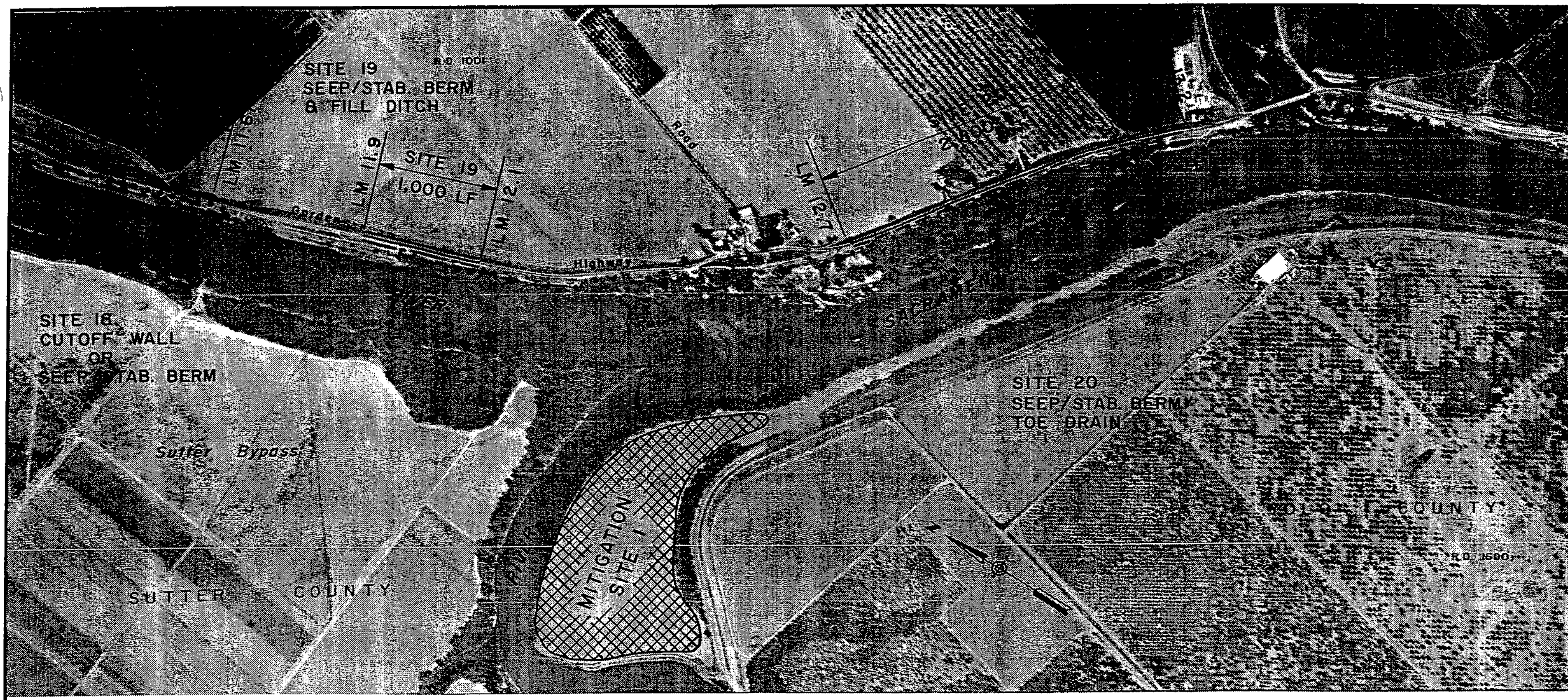
• • • • • CUTOFF WALL

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITE 17

PLATE 36



SITES 18, 19 & 20

LEGEND

LM LEVEE MILE

SEEPAGE / STABILITY BERM WITH TOE DRAIN

SEEPAGE / STABILITY BERM

CUTOFF WALL

FILL DITCH

MITIGATION

SACRAMENTO RIVER MID-VALLEY AREA
CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL PROJECT
PHASE III

LEVEE RECONSTRUCTION
SITES 18, 19 & 20

PLATE 37