CHAPTER 3

CENTRAL VALLEY FLOOD MANAGEMENT SYSTEMS

US Army Corps of Engineers
Sacramento District

Post-Flood Assessment for 1983, 1986, 1995, and 1997
Central Valley, California

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INTRODUCTION

The hydrology of the Central Valley varies widely. Rivers and tributaries draining the Central Valley descend from the bordering mountain ranges, through steep channels, spilling onto the valley floor floodplains (Figure 3-1). The precipitation in the region ranges from 95 inches in the Sierra Nevada and Cascade Ranges to 5 inches on the valley floor at Bakersfield. Runoff and streamflow are affected by both rainfall and snowmelt. Flood management facilities further affect the natural hydrology, as streamflow travels through reservoirs, dams, and developed channels. The Central Valley, covers more than 60,000 square miles and is divided into two major regions, the Sacramento Valley in the north and San Joaquin Valley in the south. The Sacramento Valley is drained by the Sacramento River and the northern half of the San Joaquin Valley is drained by the San Joaquin River. The San Joaquin and Sacramento rivers flow through the Delta and join at the upper end of Suisun Bay.

The east side of the Sacramento Valley is characterized by the many rivers and large streams that drain into the Sacramento River from the western slopes of the Sierra Nevada: the Feather, Yuba, Bear, and American rivers and Butte and Big Chico creeks. The climate of the Sacramento Valley's west side is drier and contains smaller streams: Stony, Cache, and Putah creeks. Historically, large rainstorms in winter and early spring have resulted in maximum flows from December through March.

Major tributary streams on the San Joaquin Valley's east side include the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, Chowchilla, and Fresno rivers. The intermittent flows from the San Joaquin River's west side tributaries—Del Puerto, Orestimba, and Los Banos Creeks—result from the arid climate of the Coast Range and Tehachapi Mountains. Historically, snowmelt resulted in maximum flows in the San Joaquin River in May and June. The southern half of the San Joaquin Valley comprises the Tulare Lake Basin. The landlocked Tulare Lake Basin is fed by four major streams from the Sierra Nevada on the east side of the basin: the Kings, Kaweah, Tule, and Kern rivers.

This chapter describes the hydrology of the Sacramento and San Joaquin Valleys and major tributary watersheds and the development and operation of the flood management systems. After the description of the hydrology of each watershed, the major flood management facilities are described, along with an explanation of their operating constraints and objectives. Because of the large number of drainage areas that constitute the Central Valley, only those rivers, streams, creeks, canals, and other water-related facilities that significantly contribute to the flood system operation in the basin are discussed in detail.

Table 3-1 contains the project name, authorization, completion date, location, total capacity, flood management reservation, and physical characteristics for each major flood management project in the Central Valley.

TABLE 3-1
FLOOD CONTROL STORAGE IN MAJOR CENTRAL VALLEY RESERVOIRS

Project Name	Stream	Type of Dam	Storage (TAF)[A]	Maximum Flood Control Space (TAF)[A]	Length (feet)	Height (feet)	Crest Width (feet)	Owner	Year
Sacramento River Basin									
Shasta Dam (Shasta Lake)	Sacramento River	GRAV	4,552	1,300	3,500	487	30	USBR	1949
Black Butte Dam (Black Butte Lake)	Stony Creek	ERTH	136	136[C]	5,975[D]	140	20	Corps	1963
New Bullards Bar Dam (New Bullards Bar Res.)	Yuba River	VARA	966	170	2,323	635	27	YCWA	1970
Oroville Dam (Lake Oroville)	Feather River	ERTH	3,538	750	6,920	770	51	DWR	1968
Clear Lake (Clear Lake)	Cache Creek	GRAV	313	0	260	38	4	YCFCWCD	1914
Indian Valley Dam (Indian Valley Res.)	North Fork Cache Creek	ERTH	301	40	965	207	40	YCFCWCD	1976
Folsom Dam (Folsom Lake)	American River	GRAV	977	400[B]	26,670[D]	340	36	USBR	1956
Monticello Dam (Lake Berryessa)	Putah Creek	VARA	1,602	0	1,023	255	12	USBR	1957

TABLE 3-1
FLOOD CONTROL STORAGE IN MAJOR CENTRAL VALLEY RESERVOIRS

Project Name	Stream	Type of Dam	Storage (TAF)[A]	Maximum Flood Control Space (TAF)[A]	Length (feet)	Height (feet)	Crest Width (feet)	Owner	Year
San Joaquin River Basin									
Friant Dam (Millerton Lake)	San Joaquin River	GRAV	521	170[C]	3,488	319	20	USBR	1949
Los Banos Detention Dam	Los Banos Creek	ERTH	35	14	1,370	167	30	USBR	1965
Hidden Dam (Hensley Lake)	Fresno River	ERTH	90	65	5,730	163	20	Corps	1975
Buchanan Dam (Eastman Lake)	Chowchilla River	ROCK	150	45	1,800	206	20	Corps	1975
New Exchequer Dam (Lake McClure)	Merced River	ROCK	1,025	350[C]	2,720[D]	490	17	Merced ID	1967
Don Pedro Dam (Don Pedro Lake)	Tuolumne River	ROCK	2,030	340	1,900	580	40	TID/MID	1970
New Melones Dam (New Melones Lake)	Stanislaus River	ROCK	2,420	450	1,560	625	40	USBR	1978

TABLE 3-1
FLOOD CONTROL STORAGE IN MAJOR CENTRAL VALLEY RESERVOIRS

Project Name	Stream	Type of Dam	Storage (TAF)[A]	Maximum Flood Control Space (TAF)[A]	Length (feet)	Height (feet)	Crest Width (feet)	Owner	Year
Eastside Tributaries									
Pardee Dam (Pardee Reservoir)	Mokelumne River	GRAV	198	N/A[E]	1,377	345	16	EBMUD	1929
Camanche Dam (Camanche Reservoir)	Mokelumne River	ERTH	417	200[CE]	2,640	173	30	EBMUD	1963
New Hogan Dam (New Hogan Reservoir)	Calaveras River	ERTH	317	165	3,315[D]	200	20	Corps	1964
Farmington Dam (Littlejohn Creek)	Littlejohn Creek	ROCK	52	52	7,800	58	20	Corps	1951
Tulare Lake Basin									
Pine Flat Dam (Pine Flat Lake)	Kings River	GRAV	1,000	475[C]	1,820	429	32	Corps	1954
Terminus Dam (Lake Kaweah)	Kaweah River	ERTH	143	142	3,245[D]	250	25	Corps	1961
Success Dam (Success Lake)	Tule River	ERTH	82	75	11,140[D]	142	23	Corps	1961
Isabella Dam (Isabella Lake)	Kern River	ERTH	568	398[C]	4,952[D]	185	20	Corps	1953

TABLE 3-1
FLOOD CONTROL STORAGE IN MAJOR CENTRAL VALLEY RESERVOIRS

Notes:

A. Storage and flood control space values are rounded to the nearest 1,000 acre-feet.
B. Interim flood control storage exceeds this amount, which will vary depending on upstream storage regulation.
C. Maximum flood control space may vary depending on upstream storage and/or snowpack.
D. Length includes dikes, auxiliary dams, and wing dams.
E. Total flood control storage can be shared between Camanche and Pardee Reservoirs. It is reported for Camanche, the downstream reservoir.

Owners:

Corps - U.S. Army Corps of Engineers
DWR - California Department of Water Resources
EBMUD - East Bay Municipal Utilities District
FMFCD - Fresno Metropolitan Flood Control District
MercedID - Merced Irrigation District
MID - Modesto Irrigation District
TID - Turlock Irrigation District
USBR - U. S. Bureau of Reclamation
YCWA - Yuba County Water Agency
YCFCWCD - Yolo County Flood Control and Water Conservation District

Abbreviations for Type of Dam

ARCH - Arch dam
ERRK - Rock and Earth Dam
ERTH - Earth Dam
GRAV - Gravity Dam
ROCK - Rockfill Dam
VARA - Variable Radius Arch Dam

SACRAMENTO VALLEY

The Sacramento Valley contains the Sacramento, Feather, and American River basins, covering an area of more than 26,300 square miles in the northern portion of the Central Valley. The Sacramento River Basin encompasses the three major basins: the McCloud River, Pit River, and Goose Lake in the north; the Sacramento-San Joaquin River Delta in the south; the Sierra Nevada and Cascade Ranges in the east, and the Coast Range and Klamath Mountains in the west. Figure 1-1 shows the Central Valley and surrounding mountain ranges. Drainage in the northern portion of the Central Valley is provided by the Sacramento, Feather, and American rivers and other major and minor streams that drain the east and west sides of the basin. Before reaching the Pacific Ocean, the Sacramento and San Joaquin rivers pass through the largest interior Delta in the Western Hemisphere.

The Sacramento River flows generally north to south from its origin near Mount Shasta to its mouth at the Delta. As the Sacramento River travels to the Delta, it picks up additional flows from the Feather and American rivers. The Feather River flows generally north to south from its origin near Lassen Peak and joins the Sacramento River from the east at Verona. The American River originates in the Sierra Nevada, flows generally east to west, and enters the Sacramento River at the City of Sacramento.

Ground surface elevations in the northern portion of the Sacramento Valley range from about 14,000 feet in the headwaters of the Sacramento River to approximately 1,070 feet at Shasta Lake. In this area, total annual precipitation averages between 60 and 70 inches and is as high as 95 inches in the Sierra Nevada and the Cascade Range. At Lassen Peak, which exceeds 10,000 feet in the Cascade Range, as much as 90 inches of precipitation falls. Other mountainous areas bordering the valley reach elevations higher than 5,000 feet and receive an average of 42 inches of precipitation per year, with snow prevalent at higher elevations (Figure 3-2). In the southern portion of the Sacramento River Basin, the Sacramento Valley floor is relatively flat; elevations range from sea level to about 300 feet above sea level. The valley floor is characterized by hot, dry summers and mild winters. Precipitation on the valley floor occurs mostly as rain, and yearly totals range from 20 inches in the northern end of the valley to 15 inches at the Delta.

Municipal and industrial land use within the valley is concentrated in and around the California State capital, the City of Sacramento. This large metropolitan area, with approximately 1,630,000 living in the metropolitan area (U. S. Bureau of Census, 1996), provides a large employment base. Other municipal and industrial areas are on the valley floor along the major highway corridors leading out of the city and in the Solano County area. These communities include Davis, Woodland, Yuba City, Marysville, Chico, and Redding.

Agricultural land dominates in the lowland areas of the basin and helps California lead the Nation in agricultural exports. In fact, when compared with other countries, California, as a country, would be the sixth leading agricultural exporter in the world. Additionally, agricultural production supports about 30 percent of all jobs in the Central Valley. Agricultural crops in the basin include grains, pasture, rice, orchards and vineyards, and vegetables. Grains and pastures are the most abundant crops in the basin.

The agricultural products are transported through the valley via two major transportation corridors, Interstate 5 and Highway 99. These highways, oriented north to south along either side of the Sacramento River, service many small urban communities that support agriculture. Several railroads that parallel Interstate 5 also transport agricultural goods and services, and passengers, through the Sacramento Valley. In years past, flooding in the valley has caused havoc with California's agricultural production and transportation system.

Notwithstanding the extensive agricultural, municipal, and industrial land uses in the valley, natural terrestrial communities occupy most of the total land area in the Central Valley, primarily in the foothill and mountain areas.

The basic flood management system in the Sacramento Valley consists of a series of levees and bypasses, placed to protect preferred areas and take advantage of the natural overflow basins. The management system includes levees along the Sacramento River south of Ord Ferry; levees along the lower portion of the Feather, Bear, and Yuba rivers; and levees along the American River. The levees are set back along the typical streambanks to accommodate design flood capacities. Additionally, the system benefits from three natural basins, Butte, Sutter, and Yolo. These basins run parallel to the Sacramento River and receive excess flows from the Sacramento, Feather, and American rivers via natural overflow channels and over weirs. When the Sacramento River is high, the three basins form one continuous waterway connecting the Butte, Sutter, and Yolo Basins. During low stages on the Sacramento, water in these basins can reconnect with the Sacramento River at several points: the Butte Slough Outfall Gates, the terminus of the Sutter Bypass at Verona, and the east levee toe drain at the terminus of the Yolo Bypass above Rio Vista.

In addition to the levee system, the flood management system uses reserved flood storage space in selected reservoirs on the Sacramento, Feather, Yuba, and American rivers. These reservoirs help to reduce damaging rain flood peaks by holding back floodwater and, ideally, releasing water into the rivers at a slower rate.

Today, problems in the flood management system occur partly because of the way the system evolved. Early flood protection in the basin developed piecemeal in response to the most recent rainfall flood. To prevent flooding, local individuals and agencies constructed levees using available nonengineered fill materials.

However, flooding on the Sacramento River worsened; eventually, the State and Federal Government took over the work. One task included expanding the levee system coverage by dredging the streambeds and constructing new levees that tied into existing levees. The government designed narrow and deep leveed channels to serve several objectives. However, some of these objectives no longer exist, and the channel design now causes other problems. During a storm, the inherent weakness of the levee system may result in a levee break. Then, the high and deep riverflow can cause extensive flooding. Additionally, the carrying capacity of these narrow channels is inadequate to carry floodflows, and the Feather and American River basins lack natural overflow basins, which exist on the Sacramento River, to store the floodwater temporarily.

Although the State and Federal Governments constructed dams in the foothills with reserved flood storage space on the Sacramento, Feather, Yuba, and American River systems, the flood protection is inadequate to protect land uses today. The reservoirs collect and manage flows from the upper watersheds, but many tributaries enter downstream from the dams, and the flow from the downstream tributaries is mostly unregulated.

In addition to the problems caused by unregulated drainage, flood management operations are complicated by the natural delay in moving the regulated water down the system. It takes about 62 hours, almost 3 days, for water released from the Shasta Dam on the northern portion of the Sacramento River to reach the Feather River confluence at Verona, and about 70 hours, nearly 3 days, to reach the American River confluence at I Street in the City of Sacramento. These delays in the conveyance of controlled flows, combined with relatively rapid runoff of rainfall in uncontrolled streams downstream from Shasta Dam, make it difficult to maintain flood protection throughout the Sacramento River Basin. Similar time delays affect operations of Oroville, New Bullards Bar, and Folsom dams. On the Feather River, water released from Oroville Dam takes 30 hours, over a day, to reach Verona. Water released from New Bullards Bar Dam on the Yuba River reaches Yuba City in 8 hours; 8 hours faster than water released from Oroville Dam on the Feather River. The travel time from Folsom Dam on the American River to the Sacramento River at I Street is about 8 hours.

Problems arise when a storm is centered over the Feather-Yuba and/or American River basins. Sacramento River water released from Shasta Dam 2 or 3 days previously arrives at the various confluences at the same time as floodflows from the Feather-Yuba and American rivers arrive at the same confluence. Shasta operators cannot know that a major storm will occur over the Feather and/or American River basins 2 days into the future and thus cannot adjust the water released at Shasta to reduce impacts at Verona or at the City of Sacramento. Shasta operators are also constrained by the operating rule curve to make releases based on conditions in the reservoir and for a limited distance downstream. Although storms are often recognizable more than 2 days in advance, the specific location where the storm will center is not easily predicted.

SACRAMENTO RIVER BASIN

A map of the major streams tributary to the Sacramento River is shown on Figure 3-3. Tributary flows from numerous small creeks, primarily those draining the western slopes of the Cascade Range and the Sierra Nevada, feed the Sacramento River. The volume of flow increases as the river progresses generally north to south and is increased considerably by the contribution of flows from the Feather and American River watersheds as the flow travels to the Delta. At Shasta Dam, the Sacramento River drains 6,421 square miles. Downstream at Ord Ferry, the drainage area increases to 12,250 square miles, whereas at Rio Vista, downstream from Sacramento, the drainage area is approximately 26,300 square miles.

TABLE 3-2
TRAVEL TIMES ON MAJOR CENTRAL VALLEY RIVERS

Location	Travel Time (Hours)
Sacramento River	
Shasta Dam (Keswick)	0
Bend Bridge	10
Red Bluff	12
Tehama	18
Hamilton City	23
Ord Ferry	28
Butte City	36
Moulton Weir	44
Colusa Weir	45
Colusa	47
Tisdale Weir	54
Verona	62
I Street	70
American River	
Nimbus	0
H Street	6
I Street	8
Feather River	
Oroville	0
Gridley	8
Yuba City	16
Nicolaus	26
Verona	30
Yuba River	
Narrows	0
Yuba City	8
San Joaquin River	
Friant	0
Gravelly Ford	24
Mendota	36
Fremont Ford	126
Newman	132
Vernalis	168

Downstream from Shasta Dam, the Sacramento River flows south-southeast for 65 river miles, until it reaches the valley floor south of Red Bluff. Along the valley floor, the river continues to flow south-southeast for 186 river miles, to the City of Sacramento, where it changes to a southwesterly course and flows for an additional 60 river miles to its terminus at Suisun Bay in the Delta. Through the valley floor reach, the Sacramento River is flanked by overflow basins, two of which are leveed floodways. These floodways comprise part of the comprehensive flood management improvements that have been developed along the lower 175 miles of the river on the east bank, along the lower 185 miles of the west bank, and along the lower reaches of the river's major tributary streams. Downstream from Sacramento, the Sacramento River traverses the low-lying tidal area of the Delta. The Delta area is affected by tidal flow, and this tidal influence extends up the Sacramento River for 80 miles to Verona, at low river stages. Locations along the Sacramento River are referenced by River Mile (RM), with RM 0 at Collinsville, the river mouth, and RM 302 at Keswick Dam (Table 3-3).

As described in Chapter 2, a number of flood management projects along the river affect the flow and operation of facilities (Figure 3-4). These facilities include dams and reservoirs, levees, and weirs. Shasta Lake collects flow in the upper Sacramento River watershed, but many uncontrolled tributaries enter the Sacramento River downstream from the dam. Stream gages have been added to the major uncontrolled tributaries entering downstream from Shasta Lake (Cow, Battle, Cottonwood, and Thomes creeks), and the operators of the dam can adjust releases to take into account this uncontrolled flow. Recently more gages were added on many other smaller tributaries. The flood management system uses five weirs located along the river to divert part of the floodflows to the overflow basins and bypasses: Butte Basin, Sutter Bypass, and Yolo Bypass. The weirs function as flow relief structures that permit high Sacramento River flows to enter the basin and bypasses. The weirs were designed to begin operation in a certain order: Tisdale Weir, Colusa Weir, Fremont Weir, Moulton Weir, and Sacramento Weir.

The Sacramento River is divided into six segments for descriptive purposes. Each segment is contained within a different drainage area, and each segment has different flow and flood management characteristics. The segments are:

- Sacramento River upstream from Shasta Dam
- Sacramento River from Shasta Dam to Red Bluff
- Sacramento River from Red Bluff to Chico Landing
- Sacramento River from Chico Landing to Colusa
- Sacramento River from Colusa to Verona
- Sacramento River from Verona to Collinsville

TABLE 3-3
RIVER MILES ON MAJOR CENTRAL VALLEY RIVERS

Location	River Mile
Sacramento River	
Keswick Dam	302
Redding	300
Balls Ferry Bridge	276
Bend Bridge	258
Red Bluff	244
Los Molinos	236
Tehama	229
Hamilton City	199
Chico Landing	194
Stony Creek	192
Ord Ferry	184
Butte City	169
Moulton Weir	158
Colusa Weir	146
Colusa	143
Meridian	134
Grimes	125
Tisdale Weir	119
Knights Landing	90
Fremont Weir	83
Feather River	80
Verona	79
Natomas Cross Canal	79
Sacramento Weir	63
American River	60
I Street Gage	59.5
Barge Canal and Lock	57
Clarksburg	42
Courtland	34
Walnut Grove	27
Isleton	18
Liberty Island	14
Rio Vista	12
Collinsville	0

Location	River Mile
Feather River	
Oroville Dam	70.4
Oroville Gaging Station	65.3
Thermalito Afterbay Outlet	58.2
Gridley Gaging Station	49.7
Honcut Creek	43.7
Yuba River	27.3
Bear River	12.0
Nicolaus Gaging Station	8.0
Mouth	0.0
Yuba River	
Narrows Dam	22.8
Deer Creek	21.8
Dry Creek	13.1
Daguerre Point Dam	11.0
Marysville Gaging Station	5.2
Highway 99 E Bridge above D Street	0.0
American River	
Folsom Dam	26
Fair Oaks Gaging Station	21.4
Sunrise Avenue Bridge	18.8
Watt Avenue Bridge	8.8
Business 80 Freeway Bridge	3.2
Interstate 5 Bridge	1.9
Mouth	0.0
San Joaquin River	
Friant	270
Gravelly Ford Canal	233
Mendota Dam / Fresno Slough	209
Merced River	124
Tuolumne River	91
Stanislaus River	80
Vernalis Gaging Station	77
Mouth (4-1/2 Miles Below Antioch)	0

Sacramento River Upstream from Shasta Dam

The most northern portion of the Sacramento River Basin, upstream from Shasta Dam, is drained by the Pit River, the McCloud River, and the headwaters of the Sacramento River. The total drainage area is about 6,700 square miles, excluding the Goose Lake drainage of the Pit River. Although Goose Lake is topographically within the Pit River Basin, it seldom contributes to the flow in the Pit River. The last outflow from Goose Lake was in 1880. Only a small Federal levee project in Alturas is found in this segment of the Sacramento River.

The Pit River originates on the western slopes of the Warner Mountains. The main stem of the Pit River is formed by the junction of its North and South Forks, near Alturas. From Alturas, the river flows southwest 170 miles to Shasta Lake. The headwaters of the McCloud River and its principal tributary, Squaw Valley Creek, are the southern slopes of Mount Shasta. These streams drain a heavily forested mountainous region of 685 square miles immediately north of Shasta Lake. The headwaters of the Sacramento River are on the southwestern slopes of Mount Shasta. These headwaters converge north of Dunsmuir to form the main stem of the Sacramento River, which flows south-southwest to Shasta Lake. Elevations in the area range from 1,070 feet at Shasta Lake to more than 14,000 feet on Mount Shasta and more than 10,000 feet in the Warner Range. The area comprises 1,500 square miles of rugged mountains and 5,200 square miles of high, arid plateau underlain by extensive lava beds and other volcanic formations.

Sacramento River Between Shasta Dam and Red Bluff

Flows in the Sacramento River in the 65-river mile reach between Shasta Dam and Red Bluff (RM 244) are regulated by Shasta Dam and reregulated downstream at Keswick Dam (RM 302). In this reach, flows are influenced by tributary inflow. Major westside tributaries to the Sacramento River in this reach of the river include Clear and Cottonwood creeks. Major eastside tributaries to the Sacramento River in this reach of the river include Battle, Bear, Churn, Cow, and Paynes creeks.

The major flood management facility in this reach of the Sacramento River is Shasta Dam, which creates Shasta Lake, the largest reservoir in the CVP. Keswick Dam, completed in 1950 as part of the CVP, serves as an afterbay for the Shasta and Spring Creek powerplants. Since 1964, some flows from the Trinity River Basin have been exported to the Sacramento River Basin through CVP facilities.

Shasta Dam and Lake. Shasta Dam and Lake, completed in 1949, are components of a multipurpose project built by the USBR and operated for flood management by the Corps of Engineers. Constructed on the Sacramento River downstream from its confluence with the Pit River, 10 miles north of Redding, the dam is a concrete gravity structure 487 feet high above the streambed and 3,500 feet long. Shasta Lake has a capacity of 4,552,100 acre-feet and a flood management reservation of 1,300,000 acre-feet. Keswick Dam is about 9 miles downstream from Shasta Dam and provides reregulation for Sacramento River flow releases. Shasta Dam provides flood protection to the nearby communities of Redding, Anderson, Red Bluff, and Tehama, as well as the agricultural lands, industrial developments, and communities downstream along the Sacramento River. Shasta Dam is operated for an objective release of 79,000 cfs at Redding and 100,000 cfs at Bend Bridge in Red Bluff, subject to consideration of the following:

- Releases are not to be increased more than 15,000 cfs or decreased more than 4,000 cfs in any 2-hour period.

- The 2,500-square mile uncontrolled drainage area between Keswick Dam and Bend Bridge can produce flows well in excess of the design channel capacity of 100,000 cfs. These high-magnitude flows can occur very rapidly, requiring release changes based on official flow forecasts and complicated by the 8- to 12-hour travel time between Keswick Dam and Bend Bridge.

- Gages on major eastside tributaries (Cow, Battle, and Cottonwood creeks) between Keswick Dam and Red Bluff are very helpful in coordinating operations of Shasta with flows from the uncontrolled downstream areas. The most critical flood forecast for the Sacramento River is that of local runoff entering the Sacramento River between Keswick Dam and Bend Bridge. As the Bend Bridge flow is projected to recede, Keswick Dam releases are increased to evacuate water stored in the flood management space at Shasta Lake while minimizing rapid fluctuations in the flow at Bend Bridge.

- In the spring, even moderate release increases can affect agricultural diversion weirs that, quite often, are in place by April. Usually, the diversion structures lower the nondamaging release value to about 15,000 cfs, less than 20 percent of the objective release of 79,000 cfs.

The following constraints are considered when making release changes at Keswick Dam.

- The maximum capacity of Shasta Powerplant is about 18,000 cfs, but varies considerably with head. Maximum powerplant release is required when Shasta Lake storage is encroached into the flood management space by 25 percent or less, with actual or forecasted inflows of 40,000 cfs or less.

- The capacity of the Keswick Powerplant is about 16,000 cfs, which represents a maximum release rate when no flood management space is being used. The Keswick Dam release must include discharge from Spring Creek Powerplant, releases from Spring Creek Debris Dam, and local flows into Keswick Reservoir.

- Flows greater than 36,000 cfs begin to cause flooding in Redding. The Keswick Dam release needs to be restricted to this level for as long as the release schedule on the Flood Control Diagram allows.

Sacramento River Between Red Bluff and Chico Landing

The Sacramento River enters the Sacramento Valley about 5 miles north of Red Bluff. Over the 52 miles between Red Bluff (RM 244) and Chico Landing (RM 194), the river meanders through alluvial deposits. Flows accumulate downstream on the Sacramento River as major tributaries enter from the eastside—Antelope, Mill, Deer, Big Chico, Rock, and Pine creeks; from the westside—Thomes, Elder, Reeds, and Red Bank creeks. These tributaries influence Sacramento River flows during storms. In this reach of the river, the Chico Landing to Red Bluff Project provides bank protection and channel modifications.

Sacramento River, Chico Landing to Red Bluff Project. The Chico Landing (RM 194) to Red Bluff Project (RM 244), authorized in 1958, extends and modifies the Sacramento River Flood Control Project. This project, sponsored by The Reclamation Board of the State of California (The Reclamation Board), provides for bank protection and incidental channel modifications along 50 miles of the Sacramento River between Chico Landing and Red Bluff. The ability to implement these channel improvements may be constrained by the presence of Valley Elderberry Longhorn Beetle habitat in the reach. The project also calls for floodplain zoning along the river upstream to Keswick Dam to limit development and maintain a floodway area to carry maximum flood management releases from Shasta Lake safely.

Sacramento River Between Chico Landing and Colusa

In the 50-mile reach between Chico Landing (RM 194) and Colusa (RM 143), the Sacramento River meanders through alluvial deposits between widely spaced levees. Stony Creek is the only major tributary in this segment of the river. Black Butte Lake on Stony Creek is the only reservoir operated to manage floodflows in this Sacramento River reach. Floodwaters in the Sacramento River overflow the east bank at three sites in a reach referred to by the State as the Butte Basin Overflow Area. The first point of diversion, moving downstream, is upstream from Ord Ferry. Floodwaters overflow the east bank of the river and flow into the Butte Basin. Under extraordinarily high river stages at Ord Ferry, floodwaters may also overflow the west bank of the river and flow into the Colusa Basin. Farther downstream, the floodwaters are diverted over the Moulton Weir and over the Colusa Weir into the Butte Basin. In this river reach, several Federal projects begin, including the Sacramento River Flood Control Project, Sacramento River Major and Minor Tributaries Project, and Sacramento River Bank Protection Project. Levees of the Sacramento River Flood Control Project begin in this reach, downstream from Ord Ferry on the west (RM 184) and downstream from RM 176 above Butte City on the east side of the river. Each of the major features that affect flow in this segment of the river is described below.

Sacramento River Flood Control Project. In 1910, Congress directed the CDC to prepare a flood management plan for the Sacramento River system. The CDC proposal made at that time incorporated the leveed bypass concept and became the basis of the present project. This major project for flood management on the Sacramento River and its tributaries was authorized by the 1917 Flood Control Act. Construction began in 1918 on this local cooperation flood management project sponsored by The Reclamation Board. It was the first flood management work Federally authorized for construction outside the Mississippi River Valley.

The Sacramento River Flood Control Project consists of a comprehensive system of 1,000 miles of levees, five major overflow weirs, two sets of outfall gates, three major drainage pumping plants, 95 miles of bypass floodways, overbank floodway areas, and channel enlargement in the lower reach of the Sacramento River. Increased flood protection is provided to about 800,000 acres of prime agricultural land; the cities of Colusa, Gridley, Live Oak, Yuba, Marysville, Sacramento, Courtland, Isleton, Rio Vista, and many smaller communities; railroads; and State and county highways.

During major floods, most floodflows in the leveed channels on the valley floor are contained because the initial surges of the runoff are detained in foothill reservoirs. The leveed channels, and bypass floodways cannot contain major floodflows without the intercepting action of the upstream reservoirs, and full benefits of the reservoirs cannot be realized unless specific downstream channel capacities are provided and maintained. Reservoir operation is coordinated not only among the various storage projects, but also concerning downstream channel and floodway capacities. Thus, each element is part of an integrated system, and its proper functioning is dependent on other elements.

A System Evaluation of the Sacramento River Flood Control Project was initiated in September 1986 to determine the extent of levee reconstruction required to bring the system to original design standards. The System Evaluation is divided into five phases or areas. The initial appraisal reports have been completed. Work on Phase I, the Sacramento Urban Area Reconstruction Project, was completed in 1993. Work on Phase II, the Marysville/Yuba City Area, is under way and scheduled for completion in September 1999. Phases III (Mid-Valley Area), IV (Lower Sacramento Area), and V (Upper Sacramento Area) are in engineering and design. Construction schedules are being developed for Phases III, IV, and V.

Sacramento River Major and Minor Tributaries Project. Initially authorized by the 1944 and 1950 Flood Control Acts and first funded in 1948, modifications on the Sacramento River and certain of its tributary streams and waterways supplement the Sacramento River Flood Control Project in providing flood protection to all major cities along the river system and to 880,000 acres of prime agricultural land. The Reclamation Board is the sponsor of this project that provided for levee construction and channel modifications on the Sacramento River from Colusa to Chico Landing and on lower reaches of its tributaries from the mouth of Butte Creek to Red Bluff, including Butte Creek, Chico and Mud creeks, Sandy Gulch, Elder Creek, Deer Creek, and Cherokee Canal. The project also protected the levees in the Sutter, Tisdale, Sacramento, and Yolo Bypasses through revetment. Current operation and maintenance of the project are the responsibility of non-Federal interests.

Sacramento River Bank Protection Project. The Sacramento River Bank Protection Project is a long-range, phased program for construction of bank erosion control work and setback levees on the main stem of the Sacramento River from Collinsville (RM 0) to Chico Landing (RM 194) and various tributary and distributary waterways. The purpose of the project is to protect levees from erosion that could cause levee failure and to thus maintain the capability of the Sacramento River Flood Control Project to furnish design protection. It also reduces the need for emergency levee repair, periodic dredging, and loss of land due to bank erosion. The Reclamation Board is the sponsor for this project.

Black Butte Dam and Lake. Black Butte Dam is owned, operated, and maintained by the Corps of Engineers and is on Stony Creek, a westside tributary of the Sacramento River (RM 192). Constructed in 1963, it consists of an earthfill dam 140 feet high above the streambed and 5,975 feet long, including six auxiliary earthfill dikes. Black Butte Lake has a capacity of 136,200 acre-feet and provides the entire capacity as flood management space reservation during the winter months. The project originally provided a minimum pool of 6,640 acre-feet for sediment and fishery values, but sediment has completely filled this reservation and now affects overall flood operations.

The specific flood management objectives of Black Butte Dam are to protect Hamilton City, the City of Orland, Interstate 5, and 64,000 acres of agricultural areas along Stony Creek from rain floods. Black Butte Dam is operated in conjunction with Stony Gorge and East Park storage reservoirs, upstream from Black Butte Lake.

Several factors that must be considered when operating Black Butte Dam are:

- Releases are not to be increased more than 2,000 cfs in any 2-hour period, and releases are to be decreased in increments of 1,000 cfs (between 15,000 cfs and 5,000 cfs) and 500 cfs (between 5,000 cfs and 50 cfs), with each release level sustained for at least 2 hours.

- If flows at Ord Ferry on the Sacramento River are forecast to be greater than 135,000 cfs, flows are to be reduced below the objective release of 15,000 cfs if possible.

- Many downstream landowners claim that sustained releases, from 2,500 cfs to 15,000 cfs, cause more erosion than the higher, short-duration floodflows that occurred before construction of Black Butte Dam. Besides channel erosion, high sustained releases erode the banks next to the powerhouse and affect the vehicular channel crossing maintained by the county.

- There is 100,000 acre-feet of storage capacity in reservoirs upstream from Black Butte Lake. None of this capacity is dedicated to flood management; however, some credit is given to space available in Stony Gorge and East Park reservoirs as defined on the Water Control Diagram. Although these reservoirs have proved beneficial in attenuating inflow into Black Butte Lake, they are not operated as a system. Real-time data for these reservoirs is sparse, adding to the difficulty of predicting inflow into Black Butte Lake during rain floods.

- Irrigation dikes and diversion dams placed downstream from Black Butte Dam at the start of the irrigation season can be severely affected by releases from Black Butte Dam in response to late season floods. Placement of these structures lowers the nondamaging release value to about 1,000 cfs, or less than 10 percent of channel capacity.

- Basin sediment rates appear to be 7 to 10 times greater than originally estimated. The latest sediment survey (1995) indicates that the gross pool storage of Black Butte Lake is now 136,200 acre-feet. This storage is 800 acre-feet less than the maximum flood management reservation of 137,000 acre-feet. Continued high sedimentation rates will affect project operation and performance.

- Outflows greater than 10,000 cfs cause closure of the Highway 32 bridge in Orland. Flows of 40,000 cfs will damage banks and levees by erosion and flood about 21,000 acres of agricultural land. Flows greater than 40,000 cfs would enter the towns of Orland and Hamilton City and damage highways and railroads.

Upper and Lower Butte Basin. Butte Basin is the northernmost of the natural overflow basins flanking the Sacramento River. Located east of the Sacramento River, it extends from northwest of Chico to the mouth of Butte Slough, north of Meridian. Its eastern boundary is an indefinite line along the gently sloping lands rising from the trough of the basin toward the Sierra Nevada foothills. The Glenn and Colusa County line divides Butte Basin into an upper basin and a lower basin.

When Sacramento River flows exceed between 90,000 and 100,000 cfs at Ord Ferry, water flows naturally over the banks into the Butte Basin. In addition to the Sacramento River overbank flows at Ord Ferry, the basin receives inflow over the Colusa and Moulton Weirs and from tributary streams draining from the northeast, principally Cherokee Canal and Butte Creek. Before construction of the Feather River levees, Butte Basin also received overflows from the Feather River north of the Sutter Buttes. Outflows from Butte Basin move through the Sutter Bypass when the Sacramento River is high, or through the Butte Slough Outfall Gates (RM 139) into the Sacramento River when the river is low.

The Butte Basin has a significant attenuation effect on flows before discharging them into the Sutter Bypass downstream from Colusa. The Butte Basin holds more than 1 million acre-feet when it is flowing full and has a travel time of about 2 days from its upper end to the Sutter Bypass.

Colusa Basin and Drain. The Colusa Basin, a natural overflow basin on the west side of the Sacramento River, extends from south of Stony Creek to Knights Landing. Historically, the area within the basin was subject to periodic flooding from the Sacramento River. Flows in the basin generally discharged southeast to the river through a series of sloughs ending at Knights Landing above Fremont Weir. Agricultural land reclamation begun during the 1850's eventually drained much of the wetland area.

The Colusa Drain, a leveed channel completed in the 1930's, intercepts all drainage on the west side of the Sacramento River between Colusa and Knights Landing, where the drain releases flows to the Sacramento River. Levees along the west bank of the Sacramento River block flooding from the Sacramento River.

Inflow into the basin comes from approximately 11 streams. Additionally, extremely high flows, higher than 300,000 cfs in the Sacramento River at Ord Ferry, would result in flows entering the Colusa Drain at that location. The Knights Landing Ridge Cut, on the southern end of the Colusa Drain, provides an outlet for floodflows (up to 20,000 cfs) to the Yolo Bypass when the outfall gates to the Sacramento River are closed. Flows to the Yolo Bypass through the Knights Landing Ridge Cut are limited to around 16,000 to 17,000 cfs when the Yolo Bypass is full. Flows from the Colusa Drain enter the Sacramento River via outfall gates at Knights Landing when the river is low.

Moulton Weir. In 1932 the Corps of Engineers constructed the Moulton Weir (RM 158), an ungated weir between the towns of Butte City and Colusa. The weir has a 535-foot crest length, 13-foot crest height, and 49-foot crest width. The weir begins operation automatically, sending excess flows from the Sacramento River into the Butte Basin when flows in the Sacramento River at the weir exceed 60,000 cfs. The California Department of Water Resources now maintains and operates the weir.

Colusa Weir. The Colusa Weir (RM 146), completed in 1933, is an ungated weir with a 1,650-foot crest length, 0.75-foot crest height, and 20-foot crest width. The weir operates automatically to send excess flows from the Sacramento River into the Butte Basin. Located on the Sacramento River between the Moulton Weir and the town of Colusa, the weir begins operation when flows in the river at the weir exceed 30,000 cfs. During a sharp rise on the Sacramento River, this weir usually begins to pass flows before either the Moulton or Tisdale Weirs, approximately 2 hours before the Colusa gage exceeds 59.8 feet (32,000 cfs). Like the Moulton Weir, the Corps of Engineers constructed the Colusa Weir, and the Department of Water Resources now maintains and operates the weir.

Sacramento River Between Colusa and Verona

The Sacramento River meanders through the 65 miles between Colusa (RM 143) and Verona (RM 79). The levees, which began upstream, continue in this river reach. The levee spacing, east to west, is wider between the upstream sections, from RM 176 to RM 143 at Colusa, than the levee spacing downstream from Colusa. The Feather River, the largest eastside tributary to the Sacramento River, enters the river just above Verona. Flood management diversions occur at two places in this segment of the river. The first point of diversion, moving downstream, is at the Tisdale Weir. Floodwaters flow over the Tisdale Weir into the Tisdale Bypass, which routes the water into the Sutter Bypass. Farther downstream, floodwaters from the Sacramento River, Sutter Bypass, and Feather River combine and flow over the Fremont Weir into the Yolo Bypass. The major features that affect flow in this segment of the river are described below.

Tisdale Weir. In 1932, the Corps of Engineers built the Tisdale Weir, south of Colusa and just downstream from Grimes (RM 119). This ungated weir, with a 1,150-foot crest length, 11-foot crest height, and 38-foot crest width, operates automatically to send excess flows from the Sacramento River into the Tisdale Bypass that sends the flows to the Sutter Bypass. The weir begins operation when flows in the Sacramento River exceed 23,000 cfs. During a slow rise on the river, this weir begins to pass flows before the Moulton and Colusa Weirs, 8 to 10 hours after the upstream Colusa gage exceeds 55.0 feet (23,000 cfs). When flows are larger in the Sutter Bypass and the Sacramento River stage is sufficiently lower, flows may leave the bypass and rejoin the river over the Tisdale Weir via the Tisdale Bypass. The California Department of Water Resources maintains and operates the weir.

Tisdale Bypass. The Tisdale Bypass (RM 119), a leveed channel, conveys water that has spilled over the Tisdale Weir to the Sutter Bypass. As described in the Tisdale Weir section, extremely high flows in the Sutter Bypass may flow back into the Sacramento River over the Tisdale Weir via the Tisdale Bypass.

Sutter Bypass. The Sutter Bypass, which began operation in the 1930's, is a leveed portion of the natural floodway in the Sutter Basin. The bypass is south of the Sutter Buttes from Colusa (RM 143) to Verona (RM 79) between the Sacramento and Feather rivers. Flows enter the Sutter Bypass from the Butte Basin at its upper end near Colusa at the Butte Slough. Other flows enter from Wadsworth Canal, interior drainage from pumping plants, and the Sacramento River by way of the Tisdale Weir and Bypass. Flows exit the Sutter Bypass and combine with the Sacramento River, Feather River, Natomas Cross Canal, and Yolo Bypass upstream from the Fremont Weir near the town of Verona.

Fremont Weir. The Fremont Weir (RM 83), completed in 1924 by the Corps of Engineers, is an ungated weir with a 9,518-foot crest length, 6-foot crest height, and 35-foot crest width. The Fremont Weir is on the west bank of the Sacramento River where the Sutter Bypass, Yolo Bypass, Feather River, and Sacramento River meet near Verona. Excess flows from the Sacramento River, Sutter Bypass, and Feather River automatically flow over the weir into the Yolo Bypass when flows in the Sacramento River at Verona exceed 62,000 cfs. The California Department of Water Resources maintains and operates the weir.

Sacramento River Between Verona and Collinsville

Over the 79 miles between Verona (RM 79) and Collinsville (RM 0), the Sacramento River flows past the City of Sacramento to the Delta. The Yolo Bypass parallels this river reach to the west. Flows enter this river reach at various points. First, flows from the Natomas Cross Canal enter the Sacramento River approximately 1 mile downstream from the Feather River mouth (RM 80). The American River (RM 60), the southernmost major Sacramento River tributary, enters the river in the City of Sacramento. The flows in the Yolo Bypass reenter the river near Rio Vista (RM 12). As the river enters the Delta, the Georgiana Slough branches off from the main stem of the river, routing flows into the central Delta. The one diversion point for flood management is at the Sacramento Weir, where floodwaters are diverted from the Sacramento River through the Sacramento Bypass to the Yolo Bypass. The major features that affect flow in this segment of the river are described below.

Sacramento Weir. In 1916 the City of Sacramento began construction of the Sacramento Weir (RM 63) upstream from the Sacramento-American River confluence, immediately west of Sacramento. This weir has a variable crest with 48 removable gates. When the gates are in place, the crest height is 9 feet; without the gates, the crest height is 3 feet. The weir has a net crest length of 1,830 feet. The weir diverts high flows from the Sacramento River into the Yolo Bypass via the Sacramento Bypass. When flows from the American River are high enough, some of the American River water flows upstream through the Sacramento River channel to the weir. The California Department of Water Resources maintains and operates the weir.

This is the only weir in the Sacramento system with gates that allow it to be operated during floods. The weir is operated to limit the flood stages in the Sacramento River to project design levels, to reduce the sediment in the Sacramento River channel downstream from the weir, to prevent flooding of agricultural lands in the Yolo Bypass until after those lands have been wet by flows over the Fremont Weir, and to make maximum use of the flood carrying capacity of the Sacramento River channel downstream from the weir.

DWR operates the weir under rules specified by the Corps of Engineers to achieve the objectives described above. The rules have been in effect since 1940, except the years 1963-75 when a higher initial opening level was specified. Where the Corps' rules allow flexibility, DWR opens the gates at the minimum stage permitted.

Weir opening begins when the stage at the I Street gage is 27.5 feet. The procedure for continued operation is to open as many gates as necessary to maintain the stage at the I Street gage at or below 27.5 feet, until all the gates are open.

Yolo Bypass. The Yolo Bypass is a leveed floodway through the natural overflow Yolo Basin on the west side of the Sacramento River between Verona and Rio Vista near Suisun Bay and immediately west of the metropolitan area of Sacramento. The bypass lies generally north to south and extends from the Fremont Weir (RM 83) downstream to Liberty Island (RM 14). The bypass is a feature of the Sacramento River Flood Control Project that began operation in the 1930's.

During high flows in the Sacramento River, water enters the Yolo Bypass over the Fremont Weir and over the Sacramento Weir and Bypass and is conveyed south around the metropolitan area of Sacramento. From the west, Cache Creek enters the Cache Creek Settling Basin, where sediment is deposited, and then enters the Yolo Bypass. Additional flows enter the bypass from the westside tributaries, including Putah Creek, Knights Landing Ridge Cut, Willow Slough, and the Willow Slough Bypass. Floodwaters reenter the Sacramento River upstream from Rio Vista.

The bypass floods approximately once every 3 years, generally during the winter months of December, January, and February. However, in 1998, water entered the bypass in June. Non-floodwaters exit the bypass primarily through the east levee toe drain.

Natomas Cross Canal. The Natomas Cross Canal (RM 79), downstream from the Feather-Sacramento River confluence, collects flows from Coon, Markham, and Pleasant Grove creeks and Auburn Ravine and routes the flows to the Sacramento River. Levees line the canal and split north and south to border the west side of the Natomas East Canal. The levees protect the North Natomas area.

Indian Valley Dam and Reservoir. In 1976, the Yolo County Flood Control and Water Conservation District completed the Indian Valley Dam and Reservoir on North Fork Cache Creek about 11 miles upstream from its confluence with Cache Creek. This facility, about 50 miles northwest of the City of Woodland, is owned, operated, and maintained by the Yolo County Flood Control and Water Conservation District. The project includes the 207-foot-high and 965-foot-long main dam, a gated spillway, and outlet works. Indian Valley Reservoir capacity at gross pool is 300,600 acre-feet, which includes 40,000 acre-feet of flood management reservation.

The project's primary purpose is to protect agricultural, residential, and industrial areas along Cache Creek near the town of Rumsey by limiting flows to the objective release of 20,000 cfs. A large portion of the reach downstream from the dam lies in the Capay Valley, a highly developed agricultural area. Indian Valley Dam uses its 40,000 acre-feet of flood management reservation to reduce flows on Cache Creek at Rumsey to the objective release of 20,000 cfs, with consideration of the following:

- Releases are not to be increased or decreased by more than 2,500 cfs in any 2-hour period.
- Operating to respond to flows at the control point on Cache Creek at Rumsey is difficult because the largely uncontrolled drainage area (843 square miles) between Indian Valley Dam and Rumsey can produce flows greater than the channel capacity. These high-magnitude flows can occur very rapidly, requiring release changes based on official flow forecasts and complicated by the travel time between Indian Valley Dam and Rumsey.
- The remoteness of the project can potentially affect operation and real-time data collection.
- Downstream channel capacities vary considerably from Indian Valley Dam to the City of Woodland. Annual removal of large amounts of sand and gravel affects the Cache Creek channel capacities even further. From Indian Valley Dam to the mouth of North Fork, the maximum nondamaging channel capacity is about 10,000 cfs. At the vicinity of Rumsey, the channel capacity of Cache Creek is about 20,000 cfs; at Capay the channel capacity is about 21,000 cfs; downstream of Yolo (I-5) crossing channel capacity is about 30,000 cfs.

Cache Creek and Cache Creek Settling Basin. This project includes the Clear Lake Dam and Outlet Channel and the Cache Creek Settling Basin and levees, authorized by the Flood Control Act of 1917 as modified by the Acts of 1928, 1937, and 1941. Cache Creek drains part of the eastern slope of the Coast Range in Lake and Yolo Counties. Cache Creek originates at the east end of Clear Lake about 110 miles north of San Francisco, flows southeast through Cache Creek Canyon and across the valley floor just north of Woodland, and discharges into the Yolo Bypass, a unit of the Sacramento River Flood Control Project. The basin is naturally divided into an upper drainage area that includes Clear Lake and its tributaries and a lower drainage area that includes Cache Creek and its tributaries.

In the upper basin, the major water resources-related problem is flooding around Clear Lake caused by inadequate discharge capacity of the lake's 5-mile-long outlet channel. The Yolo County Flood Control and Water Conservation District built Clear Lake Dam on Cache Creek near the town of Clear Lake in 1914. Although flooding was significant in 1970, 1983, 1986, and 1998, design studies conducted by the Corps of Engineers in 1990 indicated that the benefits from the Clear Lake Outlet Channel improvements were insufficient to justify construction.

Because of the large volume of sediment transported by Cache Creek in the lower basin, the Cache Creek Settling Basin was constructed in the 1930's to prevent sediment from being carried into and deposited in the Yolo Bypass. This deposition affects the floodflow capacity of the bypass. In 1993, the Corps of Engineers and The Reclamation Board enlarged the capacity of the basin by raising the perimeter levees 12 feet, constructed a roller-compacted concrete weir, and degraded the training levee and rebuilt it next to the western perimeter levee to allow the entire basin to be used for sediment deposition. Facilities constructed in the first phase were transferred to The Reclamation Board in December 1993 for operation, maintenance, repair, rehabilitation, and replacement.

FEATHER RIVER BASIN

The Feather River Basin, in the eastern portion of the Sacramento Valley, flows southwest and enters the Sacramento River at RM 80, just north of Verona. The largest tributary to the Sacramento River downstream from Shasta Dam, the Feather River has two major tributaries, the Yuba and Bear rivers.

Lake Oroville provides flood protection to the upper Feather River watershed. However, downstream from the Oroville Dam, floodflows on the Feather River and its two major tributaries, the Yuba and Bear rivers, are mostly unregulated. Two-thirds of the Yuba River watershed and all of the Bear River watershed are unregulated for flood management.

For the discussion of the flood management projects that affect the flow and operation of facilities, the Feather River Basin is divided into three sections: the Feather River, the Yuba River, and the Bear River.

Feather River

The Feather River Basin drains an area of 5,921 square miles as measured at Nicolaus. Of this area, 25 percent is above the snowline. Flooding on this river affects the towns of Oroville, Marysville, and Yuba City and agricultural lands.

The lowermost dam on the Feather River, Oroville Dam regulates upstream flows on the Feather River and is located at the confluence of the West Branch and the North, Middle, and South Forks of the Feather River, upstream from the Yuba and Bear tributaries. The upper Feather River Basin drains an area of 3,611 square miles as measured at Oroville Dam, which is 60 percent of the total watershed area. Besides this dam, several dams upstream from Lake Oroville affect flows in the upper Feather River. The largest of these is Lake Almanor on the

North Fork Feather River, with a storage capacity of 1.3 million acre-feet (usable capacity is 1.143 million acre-feet). Other impoundments in the Feather River watershed upstream from Oroville Dam include Mountain Meadows Reservoir, Bucks Lake, Little Grass Valley Reservoir, Lake Davis, Frenchman Lake, Butt Valley Reservoir, Sly Creek Reservoir, Philbrook Reservoir, and Antelope Lake; these provide a combined storage capacity of approximately 500,000 acre-feet. Only one reservoir on the Feather River, Lake Oroville, has reserved flood management space.

In addition to impoundments, levees direct the floodflows along the Feather River and its tributaries. The Feather River levees and Oroville Dam and Lake, the major features affecting flow in this segment of the river, are described below. Locations along the Feather River are referenced by River Mile (RM), with RM 0 at the river mouth, and RM 70 at Oroville Dam.

Oroville Dam and Lake. Oroville Dam (RM 70) on the Feather River is 6 miles upstream from the town of Oroville and is 770 feet high and 6,920 feet long. The State of California owns, operates, and maintains this key unit of the State Water Project. Since its completion in 1967, it has been the highest earthfill dam in the United States and impounds a 3,538,000 acre-foot reservoir. The flood management reservation of 750,000 acre-feet is used to reduce flows downstream from the dam to the objective release of 150,000 cfs and to reduce flows below the confluence with the Yuba River, in conjunction with flood management flows from New Bullards Bar Dam, to 300,000 cfs. The flood management operation provides flood protection to Marysville, Yuba City, Oroville, and many smaller communities. It also provides protection to about 283,000 acres of highly developed agricultural lands and to important highway and railroad routes.

Oroville Dam operates in accordance with the approved Water Control Plan, with consideration of the following:

- Releases are not to be increased more than 10,000 cfs or decreased more than 5,000 cfs in any 2-hour period.

- Operating to respond to flows at the control points on the Feather River below the Yuba River is made more difficult by the largely uncontrolled drainage area (1,200 square miles) between Oroville Dam and the confluence with the Yuba River. This uncontrolled drainage area can produce high-magnitude flows that peak very quickly, requiring release changes to be made at Oroville to meet the objective flows. These releases must be based on official flow forecasts and are complicated by the 16-hour travel time between Oroville Dam and Marysville-Yuba City.

- Coordinated operation with New Bullards Bar Dam (North Fork Yuba River) to meet the downstream objective flow of 300,000 cfs below the confluence with the Yuba River, has been complicated in the past by the uncontrolled drainage, travel time, and lack of streamflow gages below both projects. Recently installed real-time flow gages now track flows in the Yuba and Bear rivers, increasing the information available when making control decisions. New Bullards Bar has objective flows at Marysville of 120,000 cfs and 180,000 cfs for high and low flows in the Feather River, respectively.

- There is more than 1.8 million acre-feet of storage capacity in reservoirs upstream from Lake Oroville; however, none of the capacity is dedicated to flood management. While these reservoirs have proved beneficial in attenuating inflow into Lake Oroville, they are not operated as a system. Real-time data for these reservoirs are sparse, adding to the difficulty of predicting inflow into Lake Oroville during rain floods.

- In spring, even moderate increases in release can affect landowners downstream. Orchards adjacent to the river are influenced by induced seepage during the growing season. Usually, seepage effects can begin at flows of about 20,000 cfs, less than 15 percent of the objective release of 150,000 cfs.

Feather River Levees. The Feather River is leveed from its Sacramento River confluence up to Hamilton Bend near the City of Oroville (RM 63) on the right bank and from its confluence up to Honcut Creek (RM 44) on the left bank. In addition, levees lie along the lower reaches of the Bear and Yuba rivers, around the City of Marysville, and around a local reclamation district. Units of the Sacramento River Flood Control Project, the levees provide flood damage reduction protection to approximately 530 square miles. Design channel capacities of the leveed sections increase in the downstream direction.

Yuba River

The Yuba River originates in the Sierra Nevada where the North, Middle, and South Forks of the Yuba River drain the upper Yuba River watershed. The Yuba River drains approximately 1,339 square miles of the eastern Sacramento Valley and flows into the Feather River near the City of Marysville. Elevations in the watershed range from up to 7,000 feet at the headwaters to 57 feet at the Feather-Yuba River confluence; approximately 75 percent of the drainage area is below the snowline. Yuba River flooding affects Marysville, Yuba City, and Olivehurst, as well as other small communities and agricultural lands. Locations along the Yuba River are referenced by River Mile (RM), with RM 0 at U.S. Highway 99 E Bridge above D Street and RM 23 at Englebright Dam.

Most of the total flow in the Yuba River is unregulated for flood management. In fact, New Bullards Bar Dam and Reservoir on the North Fork Yuba River is the only reservoir in the watershed with reserved flood management capacity. Unfortunately, New Bullards Bar Dam regulates only a third of the flow in the Yuba watershed. Other small to medium impoundments in the watershed include Lake Spaulding, Bowman Lake, Jackson Meadows Reservoir, Englebright Lake, Lake Fordyce, and Scotts Flat Reservoir that provide a combined storage capacity over 400,000 acre-feet. Englebright Reservoir is impounded by Narrows Dam, which was constructed by the Federal Government in 1941 as part of the Sacramento River Debris Control Project. The South Fork Yuba River does not have any flood management facilities. As mentioned in the Feather River section, the lower reach of the Yuba River, as well as the City of Marysville, is leveed.

New Bullards Bar Dam and Reservoir. New Bullards Bar Dam, completed in 1967, is owned, operated, and maintained by the Yuba County Water Agency. The project is on the North Fork of the Yuba River about 30 miles northeast of the City of Marysville and provides flood protection to Marysville and Yuba City, as well as to 60,000 acres of agricultural land along the Yuba River. The dam is a concrete arch 635 feet high and 2,323 feet long at the crest, impounding a 966,000 acre-foot capacity reservoir. The flood management reservation of 170,000 acre-feet is used to reduce flows to the following objective releases:

- 50,000 cfs at the damsite
- 120,000 cfs at Marysville if the Feather River is high
- 180,000 cfs at Marysville if the Feather River is low

New Bullards Bar Dam is operated in accordance with the approved Water Control Manual, taking into account the following:

- Releases are not to be increased or decreased by more than 5,000 cfs per hour.

- Operating to respond to flows at the control point on the Yuba River at Marysville is made more difficult by the uncontrolled drainage area (850 square miles) between New Bullards Bar Dam and Marysville. The high-magnitude flows produced by this uncontrolled drainage area can occur very rapidly, requiring release changes based on official flow forecasts and complicated by the 8-hour travel time between New Bullards Bar Dam and Marysville. Coordinated operation with Oroville Dam is also complicated by the uncontrolled drainage and travel time.

- The objective release of 50,000 cfs at the Dam cannot be made until the flood management space is 30 percent encroached. The maximum release is limited by the combined spillway/outlet capacity of the dam. This limitation can potentially affect the rate of evacuation of storage in the flood management pool.

Narrows Dam and Englebright Lake. Englebright Lake is impounded by Narrows Dam (RM 23) on the Yuba River downstream from New Bullards Bar Dam. The dam was constructed by the Federal Government in 1941 as part of the Sacramento River Debris Control Project. The reservoir has a capacity of 70,000 acre-feet with no flood management reservation.

Bear River

The Bear River originates in the Sierra Nevada, drains an area of about 292 square miles, and flows southwest until it enters the Feather River approximately 3 miles north of the town of Nicolaus. Bear River, the second largest tributary to the Feather River, has no flood management facilities in the watershed. Floodflows are mainly from rain, because the entire watershed is below the 5,000 foot snowline. Ground elevations in the watershed range from around 5,000 feet in the Sierra Nevada to 40 feet near the town of Nicolaus. Flooding on the Bear River affects Nicolaus, other small communities, and agricultural lands.

The South Sutter Water District operates the largest reservoir in the watershed, Camp Far West Reservoir. Although the reservoir has 104,000 acre-feet of storage, no space is reserved for flood management. Other smaller impoundments, including Rollins Reservoir and Lake Combie, provide an additional storage capacity of approximately 70,000 acre-feet. Eleven powerplants and their associated forebays and afterbays also regulate Bear River flow. Like the Yuba River, levees direct flows in the lower reach of the Bear River.

AMERICAN RIVER BASIN

The American River originates in the Sierra Nevada and continues southwest to Folsom Lake, north and east of the City of Sacramento. Downstream from Folsom Lake, the American River travels through the Sacramento metropolitan area and enters the Sacramento River (RM 60) in the City of Sacramento. Locations along the American River are referenced by River Mile (RM), with RM 0 at the river mouth, and RM 26 at Folsom Dam. The American River drains a watershed of about 2,100 square miles. The watershed ranges in elevation from 10,000 feet to near sea level at the Sacramento River confluence. With 40 percent of the drainage area above the 5,000-foot snowline, 60 percent of the American River watershed is subject to rain floods. Flooding usually occurs during heavy warm rainstorms when freezing levels are above 8,000 feet.

The City of Sacramento and areas in Sacramento County are affected by American River flooding. Downstream from Folsom Dam, two minor tributaries, Dry and Arcade creeks, draining approximately 239 square miles, are uncontrolled. Thus, only 11 percent of the American River watershed is unregulated.

Folsom Lake is the only flood management reservoir on the American River. This facility regulates 1,861 square miles, or more than 88 percent of the total watershed area. Besides Folsom Dam, the flood management system includes levees along the American River. Several reservoirs in the upper basin provide hydroelectric generation and water supply with no specific flood management responsibilities. Although the upper portion of the basin has 54 reservoirs, approximately 90 percent of the storage capacity is provided by five: French Meadows, Hell Hole, Loon Lake, Union Valley, and Ice House reservoirs.

Discussion of the major flood management facilities on the river, as well as the North Fork Dam, a part of the Sacramento River Debris Control Project, follows.

North Fork Dam and Lake Clementine. North Fork Dam was constructed on the North Fork of the American River upstream from Folsom Dam in 1939, as part of the Sacramento River Debris Control Project. The dam is a 155-foot-high concrete arch dam. Lake Clementine has a capacity of 14,700 acre-feet and no flood management reservation.

Folsom Dam and Lake. Folsom Dam (RM 26), a unit of the CVP, is on the main stem of the American River 26 miles upstream from the City of Sacramento near the City of Folsom. The project, completed in 1956 by the Corps of Engineers, consists of a concrete gravity main dam with earthfill wing dams: total crest length, 10,200 feet; maximum height, 340 feet; and eight earthfill dikes (total crest length 16,470 feet) along the perimeter of the lake. Folsom Lake has a capacity of 977,000 acre-feet with a variable flood management reservation. This flood management reservation provides flood protection to areas below the dam, including the cities of Sacramento and Folsom and the metropolitan area between them. Releases from Folsom Dam flow to Nimbus Dam, about 7 miles downstream.

In 1994 the Sacramento Area Flood Control Agency (SAFCA) and the USBR signed a 5-year agreement in which the USBR agreed to operate Folsom Dam according to a new Flood Control Diagram. This agreement, which expires in 1999, is intended to be in effect until a long-term project is implemented in the basin. The diagram defines the flood management reservation required (from 400,000 acre-feet to 670,000 acre-feet) in Folsom Lake based on crediting space in the upstream non-Federal reservoir projects. Operation of Folsom Dam is governed by the approved Flood Control Diagram to limit downstream flows to the objective release of 115,000 cfs, with consideration of the following:

- Releases will not be increased more than 15,000 cfs or decreased more than 10,000 cfs during any 2-hour period.

- The objective release of 115,000 cfs cannot be made until the flood management space is about 45 percent encroached. The maximum release is limited by the combined spillway/outlet capacity of the dam. This limitation affects the ability of project operators to make required releases and thus affects the rate of evacuation of storage in the flood management pool.

- Areas in the American River below Folsom Dam can be damaged at flows much less than channel capacity (115,000 cfs). At 20,000 cfs, the Campus Commons Golf Course is inundated; at 45,000 cfs, the Sacramento County bike bridge crossing the American River is inundated and damaged; at 65,000 cfs, bike trails in the American River Parkway are damaged; and at 115,000 cfs, the Nimbus Fish Hatchery is damaged and banks are eroded in many places along the channel.

- There are more than 800,000 acre-feet of storage capacity in reservoirs upstream from Folsom Lake. None of the capacity is dedicated to flood management; however, some credit is given to space available in the three largest reservoirs as defined in the SAFCA/USBR Water Control Diagram. Although these reservoirs have proved beneficial in attenuating inflow into Folsom Lake, they are not operated as a system. Real-time data for these reservoirs are sparse, adding to the difficulty of predicting inflow into Folsom Lake during rain floods.

- Flood management requirements override other operational considerations in the fall and winter. Consequently, short-duration changes may be made in river releases. The USBR attempts to plan operations to avoid major fluctuations in flow and to maximize the water that can be released for hydropower generation.

The Folsom Project is related to the Sacramento River Flood Control Project in that flows from the lake can affect stages in the Sacramento River. Because of the effects of both lake releases and upstream Sacramento River flows, when the stage at the I Street Bridge, downstream from the American River confluence, exceeds 27.5 feet, gates are opened at the Sacramento Weir. The weir provides floodwaters a route to the Yolo Bypass by way of the Sacramento Bypass.

American River Levees. Levees along the lower American River have been constructed, modified, and maintained over many years as part of both Federal and non-Federal projects. In 1958, the Corps of Engineers constructed Federal levees under the Sacramento River Flood Control Project. These levees extend from the mouth of the American River up to the Mayhew Drain on the south bank. The Corps then extended the north bank levee from the Mayhew Drain up to Carmichael Bluffs through the American River Flood Control Project, also in the 1950's. On the south bank of the American River, non-Federal levees, constructed by local developers, extend upstream from the Mayhew Drain to Sunrise Boulevard (RM 19).

The American River project levees are considered safe, with proper maintenance and patrol, for sustained flows up to the design release of 115,000 cfs and for short-duration flows greater than 115,000 cfs (up to 130,000 cfs as released in 1986). In the lower reaches of the system, from the Sacramento River upstream about 4.75 miles on the right bank, the levees are designed to pass a peak of 180,000 cfs.

SAN JOAQUIN VALLEY

The 250-mile-long San Joaquin Valley comprises the southern two thirds of the Central Valley and includes the San Joaquin River Basin, the Eastside Tributaries to the Delta, and the Tulare Lake Basin, covering an area of more than 34,100 square miles. The San Joaquin Valley encompasses the two major basins; the San Joaquin River in the north, and Tulare Lake in the south. The San Joaquin Valley is bounded by the Sacramento-San Joaquin River Delta in the north, the Sierra Nevada Mountains in the east, the Coast Range in the west, and the Tehachapi Mountains in the south. Drainage in the Valley is provided by the San Joaquin River and major and minor streams and rivers that drain the east and west sides of the basin and ultimately flow into the Delta. The Tulare Lake Basin watershed includes lands that drain to interior basins in the Tulare and Buena Vista Lakes.

In the south, the Kings, Kaweah, Tule, and Kern rivers flow into the landlocked Tulare Lake Basin. These rivers flow generally east to west. The San Joaquin River flows generally northward from the Sierra Nevada headwaters to its mouth in the Delta. As the San Joaquin River travels north to the Delta, it picks up additional flows from tributaries that generally flow east to west from their origins in the Sierra Nevada.

Except at the highest altitudes, the climate of the San Joaquin Valley is semiarid, characterized by hot, dry summers and mild winters with distinct wet and dry seasons. Most of the precipitation falls from November to April, with rain at the lower elevations and snow in the higher regions. On the valley floor, precipitation decreases from north to south, ranging from 15 inches at Stockton to 5 inches at Bakersfield.

Municipal and industrial centers in the San Joaquin Valley include the cities of Fresno, Stockton, Modesto, Bakersfield, Manteca, Merced, Tracy, and Visalia. These cities are industrial hubs for food and grain processing. Fresno, one of the largest cities in the State, is larger than the City of Sacramento. The cities of Tracy and Stockton have grown recently, fed by growth trends in the San Francisco Bay region.

In the lowland areas of the basin agricultural land use, including pasture, orchards and vineyards, vegetables, cotton, grains, and rice, dominates. In fact, based on 1995 U.S. Commerce Department data, 6 out of the 10 top farm counties in California are in the San Joaquin Valley. Of these, five counties lead the Nation.

As in the Sacramento Valley, agricultural products are transported through the San Joaquin Valley via two major transportation corridors, Interstate 5 and Highway 99. Interstate 5 traverses the west side of the valley, and Highway 99 traverses the east side of the valley along with several railroads that transport agricultural products. In the valley alongside the highways, several urban centers, including Stockton, Fresno, Tulare, and Bakersfield, among others, support the agricultural industry.

Agricultural land use dominates the lowland areas of the San Joaquin Valley. Primary crop types include pasture, orchards and vineyards, vegetables, cotton, grains, and rice. Based on 1995 U.S. Commerce Department data, 6 out of the 10 top farm counties in California are in the San Joaquin Valley. Of these, five counties lead the Nation. These include Fresno, Tulare, Kern, Merced, and San Joaquin counties.

Rivers that drain the western slope of the Sierra Nevada provide the primary sources of surface water to the San Joaquin Valley. Many of these rivers drain large areas high in the watershed that supply primarily snowmelt runoff. The basic flood management system in the San Joaquin Valley includes reservoirs with reserved flood storage space to help regulate snowmelt from areas above the 5,000-foot level, while conserving water supplies for multiple purposes. Although less frequent than snowmelt floods, rain floods do occur in the San Joaquin Valley and tend to have higher peak flows than the snowmelt floods. While reservoirs in the San Joaquin Valley provide some rain flood protection, available flood management storage space can fill quickly during rain floods.

SAN JOAQUIN RIVER BASIN

The San Joaquin River Basin extends from the Delta in the north to the Kings River North in the south, and from its headwaters upstream from Friant Dam in the Sierra Nevada in the east to the Coast Range in the west (Figure 3-5). The river basin encompasses about 13,500 square miles at the southern boundary of the Delta, and a total watershed area of 16,700 square miles. The City of Fresno is the major municipal and industrial center in the San Joaquin River Basin. Other cities include Stockton, Modesto, and Merced.

The San Joaquin River flows approximately 270 miles from Friant Dam to the river mouth, 4.5 miles below Antioch. The San Joaquin River originates in the Sierra Nevada at an elevation of more than 10,000 feet, flows west into the San Joaquin Valley at Friant, flows to the center of the valley floor, turns sharply northward, and flows through the San Joaquin Valley to Vernalis. Vernalis is generally considered to represent the southern limit of the Delta.

The river receives flows from the Fresno and Chowchilla rivers; Bear and Owens creeks; and Ash and Berenda sloughs through the Chowchilla and Eastside Bypasses. Flows from Big Dry Creek are diverted by Big Dry Creek Reservoir into Little Dry Creek and then flow into the San Joaquin River below Friant Dam. Along the valley floor, the San Joaquin River receives additional flow from the Kings, Merced, Tuolumne, and Stanislaus rivers. Within the Delta, the San Joaquin River receives flows from the Eastside Tributaries to the Delta, the Calaveras, Cosumnes, and Mokelumne rivers. Streams on the west side of the basin, including Los Banos, Orestimba, and Del Puerto creeks, are intermittent, and their flows rarely reach the San Joaquin River except during large floods. Flood management facilities are found on all major tributaries except the Cosumnes River. Locations along the San Joaquin River are referenced by River Mile (RM), with RM 0 the river mouth (4.5 miles below Antioch), and RM 270 at Friant Dam (Table 3-2).

The San Joaquin River Basin and the Tulare Lake Basin are hydrologically connected through the Kings River. In the past, water in the Kings River naturally drained into the Tulare Lakebed. When the Tulare Lake exceeded capacity, water would overflow into the Fresno Slough and make its way to the San Joaquin River. Today, these basins are connected when part of the Kings River flow is diverted to the Kings River North, then through the James Bypass, Fresno Slough, Mendota Pool, and into the San Joaquin River.

Watersheds of the San Joaquin, Merced, Tuolumne, Stanislaus, Calaveras, and Mokelumne rivers include large areas of high elevation along the western slope of the Sierra Nevada. As a result, these rivers experience significant snowmelt runoff during the late spring and early summer. Before construction of water supply and flood management facilities, flows typically peaked in May and June, and snowmelt runoff caused flooding in most years along all the major rivers. When these snowmelt floodflows reached the valley floor, they spread out over the lowlands, creating several hundred thousand acres of permanent tule marshes and seasonally flooded wetlands.

The flood management system includes levees along the lower portions of Ash and Berenda sloughs; Bear Creek; Fresno, Stanislaus, and Calaveras rivers; and leveed sections along the San Joaquin River. The Chowchilla Canal Bypass diverts excess San Joaquin River flow and sends it to the Eastside Bypass. In addition to the Chowchilla Canal Bypass flow, the Eastside Bypass intercepts flows from minor tributaries and rejoins the San Joaquin River between Fremont Ford and Bear Creek. However, the channel capacity on the San Joaquin River decreases moving downstream. The San Joaquin River levee and diversion systems are not designed to contain the objective release from each of the project reservoirs simultaneously. Flows in the San Joaquin River that are less than the design flow may cause damage. These flows may damage land inside the levee system or may seep through the levees and damage adjacent areas.

The travel time for moving floodflows down the river system complicates the management of the flood system. The travel time for water released from Friant Dam on the San Joaquin River is more than 5 days to the Merced River confluence at Newman and 7 days to reach Vernalis. On the Merced River, water released from New Exchequer Dam takes 42 hours to reach the San Joaquin River confluence at Newman. The travel time from Don Pedro Dam on the Tuolumne River to Vernalis is almost 2 days. Flow released from New Melones Dam on the Stanislaus River takes just over a day to reach Vernalis.

Flows from rainstorms, centered over the Merced, Tuolumne, and/or Stanislaus River watersheds, take from 1 to 2 days to reach their confluences with the San Joaquin River. It is possible for San Joaquin River water released from Friant Dam 4 to 6 days previously to arrive at the various confluences at the same time as the floodflows from the other rivers. Because the San Joaquin water was released before the other storms arrived, Friant operators could not modify releases to have any impact at Newman or Vernalis. The accumulation of sediment over time has flattened the northern downstream reaches of the San Joaquin River, increasing travel time and decreasing channel capacities. The operators of the Merced, Tuolumne, and Stanislaus River reservoirs need to consider downstream conditions before evacuating their flood management reservation storage.

For descriptive purposes, the San Joaquin River is divided into four segments, listed below. Each segment is contained within a different drainage area, and each segment has different flow and flood management characteristics.

- San Joaquin River Upstream from Friant Dam
- San Joaquin River Between Friant Dam and Chowchilla Canal Bypass
- San Joaquin River Between Chowchilla Canal Bypass and Merced River
- San Joaquin River Between the Merced River and Vernalis

As described previously in the history of the flood management system, Chapter 2, each of the major San Joaquin River tributaries and several minor ones have projects with flood management components. These projects are discussed in more detail in the respective river segments. Additionally, the major Central Valley flood management facilities are listed in Table 3-1.

San Joaquin River Upstream From Friant Dam

Upstream from Friant Dam (RM 270), the San Joaquin River drains approximately 1,676 square miles. With about 70 percent of the land area upstream from Friant Dam above the 5,000-foot level, the drainage area receives precipitation primarily as snow. Several reservoirs in the upper portion of the San Joaquin River watershed, including Mammoth Pool and Shaver Lake, are primarily used for hydroelectric power generation. The operation of these reservoirs affects the inflow to Millerton Lake. Except for the incidental flood damage reduction from these reservoirs, there are no major flood management facilities in this segment of the river.

San Joaquin River Between Friant Dam and Chowchilla Canal Bypass

The CVP Friant Dam on the San Joaquin River creates Millerton Lake. Friant Dam is operated for water supply and flood management. At the dam, water is diverted to the Madera and Friant-Kern canals to provide irrigation and municipal and industrial water supplies to the eastern portion of the San Joaquin Valley. Under flood conditions, floodflows can also be diverted into these canals when capacity is available and there is a place to release the floodflows. Floodflows in the Friant-Kern Canal may be carried to the Kern River, through the Kern River Intertie to the California Aqueduct. Typically, during high snowmelt the Madera Canal can be used to convey up to 1,200 cfs into the Fresno-Chowchilla River system. Flows from the Big Dry Creek Reservoir enter the San Joaquin River at two locations downstream from Friant Dam. The San Joaquin River downstream from Friant Dam flows westward toward the Mendota Pool.

Friant Dam and Millerton Lake. Friant Dam (RM 270) and Millerton Lake were completed in 1949 and are owned, operated, and maintained by the USBR as part of the CVP. Friant Dam is a 319-foot-high and 3,488-foot-long concrete gravity dam on the San Joaquin River about 25 miles northeast of Fresno and 25 miles east of Madera. Millerton Lake, formed by Friant Dam, has a gross storage capacity of 520,500 acre-feet and a flood management reservation of 170,000 acre-feet. It protects hundreds of square miles of leveed agricultural land, infrastructure, and some limited urbanized areas (Firebaugh and Mendota) along the San Joaquin River.

The Southern California Edison Company operates six major storage reservoirs upstream from Friant Dam aggregating about 560,000 acre-feet of reservoir storage. These reservoirs are Florence Lake, Huntington Lake, Mammoth Pool, Shaver Lake, Redinger Lake, and Lake Thomas A. Edison. These reservoirs have considerable influence in reducing rain and snowmelt floods, but have no flood management storage reservation.

The San Joaquin River channel between Friant Dam and the "near Mendota" gage (the farthest downstream control point used in flood management operation of Millerton Lake), is typical of semiarid streams in the southern Sierra Nevada. The natural channel of the San Joaquin River is largest at the foothill line and decreases in capacity as it extends onto the valley floor. Due to encroachments into the natural flood channel, objective flow criteria are sometimes smaller than the channel capacity.

Friant Dam is operated independently of the upstream reservoirs on the San Joaquin River, but flood storage space credit may be allowed, at certain times, for available upstream storage. Use of the 170,000 acre-foot flood management reservation, as directed by the Water Control Manual, provides for an objective release of 8,000 cfs with consideration of the following:

- Downstream flow changes are limited to 500 cfs per hour for the safety of recreation users along the river and to minimize damage to riverbanks from sloughing and erosion.

- Downstream property owners would prefer that releases to evacuate flood management storage be made at less than objective flow rates to avoid damage to their property that has encroached into the floodplain, as well as to the river channel.

- Flows from Friant Dam must be adjusted to account for uncontrolled flows that enter the San Joaquin River below the dam to avoid exceeding the channel capacity downstream (8,000 cfs). These local peak flows can easily exceed channel capacity. When Big Dry Creek Dam is diverting floodflows (700 cfs) into Little Dry Creek, Friant Dam outflow is limited to 7,300 cfs or less (other local flow would further limit Friant outflows to the river).

- Flows from Friant Dam entering the Chowchilla Canal Bypass 51 miles downstream from Friant Dam should be controlled to a maximum 5,500 cfs. Flow continuing down the San Joaquin River to Mendota Dam should be controlled to 2,500 cfs or less. These objective flows are directly affected by Kings River North flood discharges that may reach 4,750 cfs below Mendota Dam, leaving only 1,750 cfs of the 6,500 cfs (below Mendota Dam) channel capacity for upper San Joaquin flows and Friant Dam releases. Coordination between Friant Dam and Pine Flat Dam releases is critical to the proper operation of the control structures in and around Mendota Dam and the Chowchilla Canal Bypass.

- All floodflows to the river can cause seepage problems for leveed agricultural property in the lower San Joaquin River, especially when combined with the other major contributing rivers (Fresno, Chowchilla, Merced, Tuolumne, and Stanislaus).

- Flood releases may also be made to the Friant-Kern Canal and Madera Canal if all parties agree. These irrigation canals have a combined peak capacity, at their diversion points, of about 6,000 cfs, which diminishes to zero or the capacity of the irrigation distribution systems using the floodwater. Once filled, canal reduction must be slow and programmed over a period of days to prevent damage to canal walls from groundwater return pressures.

- Friant Dam is part of a large system of reservoirs contributing water to the San Joaquin River. Whenever possible, releases from the dam should consider conditions in all downstream channels and the operation of the other projects in the system.

Redbank and Fancher Creeks Project. The Redbank and Fancher Creeks Flood Control Project includes five facilities. The project was constructed from 1948 to 1991 for the single purpose of flood management for the Fresno-Clovis Metropolitan area and nearby agricultural land. The project is owned and operated by the Fresno Metropolitan Flood Control District. The five features of the project are Big Dry Creek Dam and Diversion, Alluvial Drain Detention Basin, Fancher Creek Dam and Reservoir, Pup Creek Detention Basin, and Redbank Creek Detention Basin. Flows from the Big Dry Creek Reservoir enter the San Joaquin River through the Little Dry Creek Diversion downstream from Friant Dam. Additional flows enter the San

Joaquin River through the Herndon Canal, upstream from Gravelly Ford. The only project feature subject to formal flood management regulation is Big Dry Creek Dam and Diversion.

Built in 1948 by the Corps of Engineers, the Big Dry Creek Dam and Diversion are now owned, operated, and maintained by the Fresno Metropolitan Flood Control District. The flood management capacity of Big Dry Creek Dam and Diversion is 30,200 acre-feet, created by an earthfill dam 45 feet high and 25,250 feet long. The dam has a flood management outlet into Little Dry Creek. The maximum release during a flood is limited to 700 cfs through the Little Dry Creek Outlet only. Flows in Little Dry Creek end up in the San Joaquin River and must be accounted for in the operation of Friant Dam.

The other four facilities have the following storage capacities and unregulated maximum release rates:

- Alluvial Drain Detention Basin - 314 acre-feet of storage; 25 cfs maximum release rate
- Fancher Creek Dam and Reservoir - 9,712 acre-feet of storage; 100 cfs maximum release rate
- Pup Creek Detention Basin - 556 acre-feet of storage; 25 cfs maximum release rate
- Redbank Creek Detention Basin - 940 acre-feet of storage; 200 cfs maximum release rate

San Joaquin River Between Chowchilla Canal Bypass and Merced River

Floodflows are diverted from the San Joaquin River at the Chowchilla Canal Bypass (RM 233). The reach of the river from Chowchilla Canal Bypass to the Mendota Pool is generally dry unless releases are made from Friant Dam for flood management. During flood management operations, most floodflows from upstream from the Chowchilla Canal Bypass are diverted from the San Joaquin River to the Chowchilla Canal Bypass. Floodflows that exceed the capacity of the Chowchilla Canal Bypass continue down the San Joaquin River to the Mendota Pool. This river segment receives flow from the Fresno and Chowchilla rivers and the Eastside Bypass.

Fresno River. The Fresno River, a tributary to the San Joaquin River, originates in foothills of the Sierra Nevada and drains a watershed of approximately 500 square miles, as measured at the Eastside Bypass. Because of the relatively low elevation of the watershed, most of the flow in the Fresno River results from rainfall. The Fresno River ultimately discharges into the Eastside Bypass. The only regulating dam on the Fresno River is Hidden Dam, which forms Hensley Lake. With a drainage area of 237 square miles, this dam regulates almost half the watershed. The Madera Canal, which conveys water northwest from Friant Dam, crosses the Fresno River approximately 3 miles downstream from Hidden Dam. If all responsible parties agree, a relatively small portion of the flood management releases from Friant Dam can be directed to the Fresno River via the Madera Canal.

Hidden Dam and Hensley Lake. Hidden Dam, completed in 1975, is on the Fresno River about 15 miles northeast of the City of Madera and is owned, operated, and maintained by the Corps of Engineers. It provides flood protection to the city of Madera and agricultural lands downstream. Hensley Lake, formed by the 163-foot-high and 5,730-foot-long earthfill dam, has a gross pool of 90,000 acre-feet and a flood management reservation of 65,000 acre-feet. Hidden Dam is operated to reduce flows in the Fresno River at Madera to the objective flow of 5,000 cfs, with consideration of the following:

- Releases are not to be increased or decreased by more than 500 cfs per hour.

- When release decisions are made, consideration must be given to the fact that water released from Hidden Dam is passed downstream through the Chowchilla Canal Bypass and the Eastside Bypass. These two channels are also used to convey water released from Friant Dam. Close coordination is needed to maintain the flows in these two channels within their stated channel capacities.

- During flood management operations, floodwaters can be routed to the Fresno River via the Madera Canal.

- Although Hidden Dam is operated for flows on the Fresno River, it is part of a large system of reservoirs contributing water to the San Joaquin River. Whenever possible, releases from the dam should consider conditions in all downstream channels and the operation of the other projects in the system.

Chowchilla River. The Chowchilla River, a tributary to the San Joaquin River, originates in the Sierra Nevada and drains a watershed of approximately 600 square miles. Because of the low elevation of the watershed, with 95 percent below the snowline, most of the flow in the Chowchilla River results from rainfall. The Chowchilla River ultimately discharges into the San Joaquin River via the Eastside Bypass. The only regulating dam on the Chowchilla River is Buchanan Dam forming H. V. Eastman Lake. This dam encompasses a drainage area of 235 square miles, regulating about 40 percent of the watershed. During flood management operations and with the agreement of all responsible parties, flows from the Madera Canal can be directed down Ash (5,000 cfs) and Berenda (2,000 cfs) sloughs, about 10 miles downstream from Buchanan Dam.

Buchanan Dam and H. V. Eastman Lake. Buchanan Dam, completed in 1975, is owned, operated, and maintained by the Corps of Engineers to provide flood protection to the City of Chowchilla and the highly developed agricultural areas below the dam. The project is on the Chowchilla River about 16 miles northeast of the City of Chowchilla. The 206-foot-high and 1,800-foot-long rockfill dam, with a gross pool of 150,000 acre-feet, is operated with a 45,000 acre-foot flood management reservation and a combined downstream objective release of 7,000 cfs via Ash (5,000 cfs) and Berenda (2,000 cfs) sloughs. The following are to be considered during flood management operations:

- Releases are not to be increased or decreased by more than 1,000 cfs in any 2-hour period.

- Flows released from Buchanan Dam are conveyed in the Eastside Bypass and therefore must be carefully coordinated with other flood management operations to avoid exceeding the capacity of the canal.

- Although Buchanan Dam is operated for flows on the Chowchilla River, it is part of a large system of reservoirs contributing water to the San Joaquin River. Whenever possible, releases from the dam should consider conditions in all downstream channels and the operation of the other projects in the system.

Chowchilla Canal Bypass. The Chowchilla Canal Bypass is a component of the Lower San Joaquin River and Tributaries Project. The bypass begins at the San Joaquin River downstream from Gravelly Ford (RM 233), picks up San Joaquin River flows, runs northwest to the Fresno River, and ends at the Eastside Bypass. The bypass provides flood damage reduction for downstream agricultural lands. Flows from Friant Dam (San Joaquin River) are diverted to the canal through the Chowchilla Canal Bypass Control Structure. The stated channel capacity of the Chowchilla Canal Bypass is 5,500 cfs. The bypass is constructed in highly permeable soils, and much of the initial floodflows recharge groundwater. When flows in the Chowchilla Canal Bypass reach its capacity of 5,500 cfs, remaining water in the San Joaquin River enters the Mendota Pool.

Eastside Bypass. The Eastside Bypass begins at the Fresno River, runs northwest, and ends at the San Joaquin River between Fremont Ford and Bear Creek. A component of the Lower San Joaquin River and Tributaries Project, the bypass intercepts flows from the Chowchilla Canal Bypass, Fresno and Chowchilla rivers, Berenda and Ash sloughs, and Merced County Streams, including Bear Creek, and carries them to the San Joaquin River.

The stated capacity of the Eastside Bypass begins at 10,000 cfs at its bifurcation from the Fresno River and increases in increments to a maximum of 17,000 cfs after crossing Ash Slough. However, the actual capacities may be less due to subsidence under sections of the Eastside Bypass levees. Flows at the downstream end of the bypass are controlled by the Eastside and Mariposa Bypass Control Structures that split the flows to either continue down the Eastside Bypass or enter the San Joaquin River through the Mariposa Bypass. During October 1996 to March 1997, flows greater than the stated capacities for the Eastside Bypass were successfully passed, largely due to sandbagging efforts along the tops of subsided levee sections.

Los Banos Detention Dam. Los Banos Detention Dam, completed in 1965, is on Los Banos Creek, a westside tributary to the San Joaquin River. The 167-foot-high and 1,370-foot-long earthfill dam is about 7 miles southwest of Los Banos. The dam is owned by the USBR, but operated by the State of California to provide flood protection to the San Luis and Delta-Mendota canals, the community of Los Banos, and the agricultural lands downstream. Los Banos Dam has a storage capacity of 34,600 acre-feet, with a flood management reservation of 14,000 acre-feet used to control downstream releases, based on the Water Control Diagram, to a maximum of 1,000 cfs.

Merced County Stream Group Project. The Merced County Stream Group Project consists of five dry dams (Bear, Burns, Owens, Mariposa, and Castle) and two diversion structures with a total flood storage capacity of 39,500 acre-feet. All the dams are in the foothills east of Merced on tributaries of the San Joaquin River and provide flood protection to the City of Merced. The two diversions are the Black Rascal Creek to Bear Creek diversion and the Owens Creek to Mariposa Creek diversion. The project objective is to restrict the floodflows of several streams in the Merced County Stream Group to the nondamaging capacity of the valley floor channels from the foothill line to the city of Merced. The storage, inflow and outflow, and basin precipitation of these projects are monitored via real-time telemetry transmitted from the damsites and additional basin precipitation gages. These data are analyzed to assess the likely impacts of the flood management releases on the downstream floodplain.

The Corps of Engineers owns and maintains Bear, Burns, Owens, and Mariposa dams, on creeks with the same names. The operation of each of these dams is entirely automatic, since the reservoir outlets are ungated. These four dams protect developed areas, including agricultural land and the City of Merced.

- Bear Dam, constructed in 1954, is on Bear Creek, about 16 miles northeast of Merced, and is rolled earthfill, 92 feet high and 1,830 feet long, with a gross pool of 7,700 acre-feet and a maximum release of 1,800 cfs.

- Burns Dam, built in 1950, is on Burns Creek, 13 miles northeast of Merced, and is rolled earthfill, 53 feet high and 4,070 feet long, with a gross pool of 6,800 acre-feet and a maximum release of 1,860 cfs.

- Owens Dam, completed in 1949, is on Owens Creek, 16 miles east of Merced, and is rolled earthfill 75 feet high and 790 feet long, with a gross pool of 3,600 acre-feet and a maximum release of 185 cfs.

- Mariposa Dam, constructed in 1948, is on Mariposa Creek, 18 miles east of Merced, and is rolled earthfill 88 feet high and 1,330 feet long, with a gross pool of 15,000 acre-feet and a maximum release of 1,000 cfs.

Castle Dam, completed in 1991, is owned by the State of California and Merced County and is operated and maintained by the Merced Irrigation District. The dam, on Canal Creek about 6 miles northeast of Merced, is zoned earthfill 51 feet high and 2,075 feet long, with a gross pool of 6,400 acre-feet and a maximum release of 420 cfs. The reservoir outlet gate is adjusted seasonally to meet irrigation requirements, but the flood management operation of Castle Dam is entirely automatic, since the outlet gate remains in a fixed position during flood management season. Castle Dam provides flood protection to agricultural areas along Canal Creek.

San Joaquin River Between the Merced River and Vernalis

The San Joaquin River downstream from the Merced River (RM 124) comprises the segment of river from the confluence with the Merced River, downstream from Fremont Ford, to Vernalis (RM 77). Because little water is contributed from the upper San Joaquin River, except during floods, nonflood management flow patterns result from tributary inflows from the Merced, Tuolumne, and Stanislaus rivers. During major floods, this segment of the river receives flow from the upstream portion of the San Joaquin, Merced, Tuolumne, Stanislaus, and Fresno rivers; Ash and Berenda sloughs; and several smaller tributaries. There are several flood management projects on this river reach.

San Joaquin River Levees. Levees have been constructed from the Delta upstream on the San Joaquin River to the mouth of the Merced River (RM 124) and along several San Joaquin River tributaries. The Federally authorized and constructed portions of the project consist of about 100 miles of intermittent levees along the San Joaquin River, Paradise Cut, Old River, and the lower reaches of the Stanislaus and Tuolumne rivers. Besides the Federal Lower San Joaquin River and Tributaries Project, an intricate series of minor levees and channel modifications have been constructed; these are owned, operated, and maintained by local interests throughout the natural river system. These modifications significantly reduce the threat of flood-related damages to the primarily agricultural lands next to the river.

Merced River. The Merced River originates in the Sierra Nevada, drains an area of approximately 1,276 square miles east of the San Joaquin River, and enters the San Joaquin River near Hills Ferry. More than 50 percent of the drainage area is below the 5,000-foot elevation snowline, resulting in rain floods in the basin. Portions of the upper Merced watershed drain lands in Yosemite National Park. Significant changes have been made to the Merced River hydrologic system since the 1850's, when agricultural development began in the watershed. The enlarged New Exchequer Dam, forming Lake McClure, regulates releases to the lower Merced River. New Exchequer Dam is operated for flood management, power production, and irrigation. The dam's 1,037 square mile drainage area encompasses more than 80 percent of the watershed.

New Exchequer Dam and Lake McClure. New Exchequer Dam is on the Merced River about 25 miles northeast of the City of Merced. The dam, completed in 1966, is a 1,220-foot-long and 490-foot-high rockfill dam, with a 1,500-foot-long and 62-foot-high rock and earthfill dike. The dam and lake, which are owned, operated, and maintained by the Merced Irrigation District, provide flood protection to prime agricultural lands below the dam and to the communities of Livingston, Snelling, Cressy, and Atwater. New Exchequer Dam has a gross pool capacity of 1,024,600 acre-feet and a flood management reservation of 350,000 acre-feet, with a downstream objective release of 6,000 cfs in the Merced River at Stevinson. The following are considered when making operations decisions:

- Dry Creek, the major uncontrolled tributary to the Merced River below New Exchequer Dam, can produce flows that exceed the objective release, requiring rapid release changes from the dam to maintain flows at specified levels.

- Although New Exchequer Dam is operated for flows on the Merced River, it is part of a large system or reservoirs contributing water to the San Joaquin River. Whenever possible, conditions in all downstream channels and the operation of the other projects in the system should be considered when releases are made from the dam.

Tuolumne River. The Tuolumne River originates in the Sierra Nevada and enters the San Joaquin River at RM 91. The river drains a watershed of approximately 1,900 square miles with about 60 percent of the watershed below the 5,000-foot elevation snowline. The Tuolumne River is the largest tributary to the San Joaquin River. Don Pedro Dam is the only facility that regulates floodflows on the Tuolumne River. The dam's drainage area covers 1,533 square miles, or 81 percent of the drainage basin. A short distance downstream from Don Pedro Dam at La Grange Dam, the water is diverted to the Modesto Main Canal and the Turlock Main Canal.

The City and County of San Francisco operate several water supply and hydroelectric facilities within the Tuolumne River Basin upstream from Don Pedro Dam. O'Shaughnessy Dam on the main stem of the Tuolumne River, completed in 1923, forms Hetch Hetchy Reservoir. The 460-square-mile drainage area is entirely within the boundaries of Yosemite National Park. Water from Hetch Hetchy is used primarily to meet the municipal and industrial water needs of the City and County of San Francisco. Two other storage facilities upstream from Don Pedro Reservoir, Lake Eleanor and Cherry Lake, are operated for hydropower and water supply. Because these reservoirs are just below 5,000 feet in elevation, the reservoirs mainly receive snowmelt runoff and provide little management for rain floods at lower elevations.

Don Pedro Dam and Lake. The new Don Pedro Dam is on the Tuolumne River, about 28 miles west of Modesto. The dam was constructed in 1971 jointly by Turlock Irrigation District (TID) and Modesto Irrigation District (MID) with participation by the City and County of San Francisco. However, only Turlock Irrigation District operates and maintains the dam. An earth and rockfill dam 580 feet high and 1,900 feet long, Don Pedro Dam impounds more than 2,030,000 acre-feet of water, with a maximum flood management reservation of 340,000 acre-feet. This dam provides flood management for agricultural property, infrastructure, and some low areas in suburban Modesto by controlling rain and snowmelt floods to the downstream objective release of 9,000 cfs. Several factors that should be considered when operating Don Pedro Dam for floods are discussed below:

- Releases are not to be increased more than 2,000 cfs or decreased more than 1,000 cfs in any 2-hour period.

- High, sustained releases, near or at channel capacity (9,000 cfs), flood Morton Road alongside Dry Creek and under La Loma Avenue Bridge inside the city of Modesto.

- Flow releases from the dam to the Tuolumne River pass the city of Modesto and must be adjusted lower for flows into Dry Creek and other local runoff.

- Flows greater than 6,000 cfs in the Tuolumne River affect improvements inside the channel floodway. These improvements encroach into normal flow areas and consist of boat docks, pumps, recreation facilities, and agriculture.

- Flows greater than 4,000 cfs start seepage problems for leveed agricultural property mainly downstream from Modesto. This flow, when combined with high-flow backwater from the San Joaquin River and other contributing rivers, could cause major seepage damage.

- Spillway flows of 1,000 cfs or more will wash out Bond Flat Road Bridge and the road fill immediately below the spillway.

Stanislaus River. The Stanislaus River originates in the Sierra Nevada and enters the San Joaquin River at RM 80. The river drains a watershed of approximately 1,075 square miles at the town of Ripon. About 40 percent of the drainage area is above the snowline. Thus, although snowmelt contributes a large portion of the flows and the highest runoff is in May and June, rain floods do occur in this watershed. Ungaged tributaries contribute flow to the lower portion of the Stanislaus River, downstream from the Goodwin diversion dam.

Currently, flooding in the lower Stanislaus River is primarily regulated by New Melones Dam, approximately 60 miles upstream from the confluence of the Stanislaus River and the San Joaquin River. The dam sits at the bottom of the 904 square-mile drainage basin, accounting for 84 percent of the Stanislaus River watershed. Tulloch Dam, which is around 9 miles downstream from New Melones Dam on the main stem Stanislaus River, provides flood protection through reserved flood space. Other water storage facilities in the Stanislaus River watershed include the Tri-Dam Project, a hydroelectric generation project that consists of Donnells and Beardsley dams upstream from New Melones Dam on the Middle Fork Stanislaus River. Releases from Donnells and Beardsley dams affect inflows to New Melones Dam.

New Melones Dam and Lake. New Melones Dam replaced the original Melones Dam and was completed by the Corps of Engineers in 1978 and approved to begin operation in 1983. It is on the Stanislaus River, 35 miles northeast of Modesto. New Melones Dam and Lake are owned, operated, and maintained by the USBR as a unit of the CVP. The dam is an earth and rockfill structure 625 feet high and 1,560 feet long, creating a lake with a capacity of 2,420,000 acre-feet, 450,000 acre-feet of which is reserved for flood management. Flood management, following the Water Control Manual prepared by the Corps of Engineers, protects more than 35,000 acres of leveed agricultural land, infrastructure, and some limited urbanized areas in Oakdale, Riverbank, and Ripon along the Stanislaus and San Joaquin rivers. The flood management reservation of 450,000 acre-feet in New Melones is used to regulate to a downstream objective release of 8,000 cfs with consideration of the following:

- Flood releases from New Melones are modified by Tulloch Dam, 9 miles downstream, which provides reregulation and 10,000 acre-feet of additional flood management reservation.

- After an event, any major release to evacuate flood management storage can potentially affect downstream property owners as well as the river channel. Releases must balance the potential damage and the need to evacuate flood management storage.

- Flood releases from New Melones Dam must be adjusted to account for local flows from the 116-square-mile area below the dam to avoid exceeding the channel capacity (8,000 cfs) at the control point (Orange Blossom Bridge). Although the design channel capacity at Orange Blossom Bridge is 8,000 cfs, experience in 1998 showed that the actual channel capacity may be 10 percent less. Tulloch Reservoir provides some flood management for 76 square miles, but the remaining 40 square miles of drainage area are uncontrolled.

- Moderate flood releases from New Melones Dam also affect agricultural land inside the normal Stanislaus River flood management channel. These improvements have encroached into established floodplains. Flows at and above 1,500 cfs start to wet crop root systems. Higher flows flood additional improved acreage and cause agricultural damage.

- All floodflows to the river can also cause seepage problems for leveed agricultural property in the lower Stanislaus and San Joaquin rivers, especially when combined with the other major contributing rivers (Kings, San Joaquin, Fresno, Chowchilla, Merced, and Tuolumne).

- Flood releases may be diverted to the irrigation canals at Goodwin Dam. These canals have a combined peak capacity of about 1,800 cfs at the dam, but diversion during the winter or wet season is near zero.

EASTSIDE TRIBUTARIES TO THE DELTA

The streams in the northern portion of the San Joaquin River Basin, generally between the watersheds of the American and Stanislaus rivers, are commonly referred to as the Eastside Tributaries to the Delta. The primary watersheds in this region include the Cosumnes, Mokelumne, and Calaveras rivers and the Littlejohn Creek stream group. These rivers flow into the San Joaquin River within the boundaries of the Delta. The hydrologic setting for this area is similar to that described for the northern portion of the San Joaquin River Basin and the eastern portion of the Delta.

Littlejohn Creek Stream Group

The Littlejohn Creek Stream Group, comprised of Duck, Littlejohn, Temple, and Lone Tree creeks, is located southeast of the City of Stockton in San Joaquin and Stanislaus Counties. The basin is bounded on the south and southeast by the Stanislaus River and is about 15 miles wide from north to south and about 40 miles long from east to west. These streams drain the west slope foothill areas of the Sierra Nevada, and all of the drainage area is below the snowline. Most of the area of the basin is devoted primarily to farming and ranching. However, urban and commercial development has taken place in several areas near the City of Stockton. The only flood management facility, Farmington Dam, is on Littlejohn Creek. This facility manages 85 percent of the drainage basin, as measured at the town of Farmington.

Farmington Dam and Reservoir. Farmington Dam, completed in 1951, is on Littlejohn Creek, approximately 20 miles east of Stockton and 3.5 miles east of Farmington. The Corps of Engineers owns, operates, and maintains the dam and reservoir. Farmington Dam is operated remotely to restrict downstream floodflows to nondamaging levels throughout the network of channels along the lower reaches of Littlejohn and Rock creeks, tributaries to the San Joaquin River. The dam is an earthfill structure 58 feet high and 7,800 feet long; the reservoir has the capacity to temporarily store up to 52,000 acre-feet of floodwater. The project also includes a diversion channel from Duck Creek to Littlejohn Creek, some channel modification work on selected streams, some cutoff dikes, and a small diversion dam to confine floodflows to the main channel of Littlejohn Creek. By reducing flows to the downstream objective release of 2,000 cfs, the dam provides flood protection to 58,000 acres of intensely developed agricultural lands below the dam, the City of Stockton, and the rural towns of Farmington and French Camp.

The entire 52,000 acre-foot pool of Farmington Dam is reserved for flood management, with the following considered during operation:

- The 36-square-mile uncontrolled drainage area between Farmington Dam and the town of Farmington (including Duck Creek) can produce flows greater than the downstream design capacity (2,000 cfs). These flows can take place very rapidly, requiring an immediate operational response.

- If there were a power or communication outage at Farmington Dam, remote gate operation would not be possible. Remote operation of the outlet gates is also complicated by the presence of a diversion structure in the channel just below the stilling basin.

Calaveras River

The Calaveras River originates in the Sierra Nevada, drains approximately 470 square miles at Bellota, and enters the San Joaquin River near the City of Stockton. The Calaveras River watershed is entirely below the effective average snowline (5,000 feet), and receives nearly all of its flow from rainfall. The major water management facility on the Calaveras River, New Hogan Dam and Lake, is operated for flood management, and, if possible, for water supply and power generation. With a drainage area of 393 square miles, the lake regulates 83 percent of the watershed.

New Hogan Dam and Lake. New Hogan Dam, completed in 1964, is owned, operated, and maintained by the Corps of Engineers. The dam, constructed of rock and earthfill, is 200 feet high and 1,960 feet long and includes four earthfill dikes with total crest length of 1,355 feet. Flood management operations at New Hogan Dam protect about 46,000 acres of agricultural land and 14,000 acres of urban and suburban land along the Calaveras River, Mormon Slough, and the Stockton Diverting Canal. The project is on the Calaveras River about 28 miles northeast of

Stockton and provides protection to Stockton and the smaller cities of Linden, Waterloo, and Bellota. With a gross pool of 317,000 acre-feet and a flood management reservation of 165,000 acre-feet, New Hogan Dam is operated to meet a 12,500 cfs objective release downstream in Mormon Slough with consideration of the following:

- Releases are not to be increased or decreased more than 2,000 cfs in any 2-hour period.

- After an event, any major release to evacuate flood management storage can potentially affect downstream property owners, as well as the river channel. Releases must balance the potential damage and the need to evacuate flood management storage.

Mokelumne River

A major tributary to the San Joaquin River in the Delta region, the Mokelumne River originates at an elevation of approximately 10,000 feet in the Sierra Nevada and enters the lower San Joaquin River northwest of Stockton. This river drains a watershed of approximately 661 square miles with 65 percent of the area below the snowline. Although Salt Springs, Pardee, and Camanche reservoirs influence streamflow in the Mokelumne River, only Camanche has flood management reservation. The uppermost, Salt Springs Reservoir owned by the Pacific Gas and Electric Company (PG&E), is on the North Fork of the Mokelumne River and began operation in 1963. Pardee and Camanche reservoirs, both on the main stem of the Mokelumne River, are owned and operated by the East Bay Municipal Utility District (EBMUD). Pardee Reservoir was completed in 1929. Water is exported from the Mokelumne River watershed to the EBMUD service area via the Mokelumne River Aqueduct, which receives water directly from Pardee Reservoir. Camanche Dam is downstream from Pardee Dam and has a 627-square-mile drainage area accounting for about 95 percent of the watershed. Camanche Dam and Reservoir provide flood damage reduction on the Mokelumne River and are operated to maintain downstream water requirements.

Camanche Dam and Reservoir. Camanche Dam was constructed in 1963 and is owned, operated, and maintained by East Bay Municipal Utilities District (EBMUD). The 173-foot-high and 2,640-foot-long dam is on the Mokelumne River about 10 miles downstream from Pardee Dam, near the town of Jackson. Its primary objective is to provide flood protection to the lower Mokelumne River Basin, including Lodi, Woodbridge, Thornton, and 69,000 acres of agricultural land, by reducing Mokelumne River flows to the downstream objective release of 5,000 cfs. Camanche Reservoir has a capacity of 417,000 acre-feet at gross pool and a maximum flood management reservation of 200,000 acre-feet, which can be distributed between Pardee and Camanche reservoirs in any fashion. Camanche Dam is operated in conjunction with Pardee Dam (198,000 acre-foot gross pool, EBMUD), and Salt Springs and Lower Bear reservoirs (PG&E), located upstream from Camanche Dam. Required flood management reservation can be exchanged between Camanche and Pardee Reservoir.

Factors to be considered when operating Camanche Dam for flood management are:

- Releases from Camanche Dam are not to be increased or decreased more than 1,000 cfs in any 2-hour period.

- Conditional flood management reservation is determined by space available in reservoirs upstream from Camanche and by the snowmelt forecast, when applicable.

- The lack of channel maintenance and encroachment into the floodway below Camanche Dam have reduced the nondamaging flows to about one-half the design capacity of 5,000 cfs. Due to environmental concerns, channels are no longer cleared. Encroachments into the floodway have resulted from the construction of nonproject levees by agricultural interests in the basin.

Cosumnes River

The Cosumnes River originates in the lower elevations of the Sierra Nevada, drains a watershed of approximately 537 square miles, and enters the Mokelumne River within the Delta near the Town of Thornton. Because there are no flood management projects in the watershed, floodflows are uncontrolled on this river. Flooding on the Cosumnes River affects the towns of Thornton and Wilton, as well as adjacent agricultural communities. About 90 percent of the watershed drained by the Cosumnes River is below the snowline. Because of the low elevation of its headwaters, the Cosumnes River receives most of its water from rainfall. The only major water supply facilities in the Cosumnes River watershed are components of the Sly Park Unit of the CVP. The Sly Park Unit includes Jenkinson Lake, formed by Sly Park Dam on Sly Park Creek.

TULARE LAKE BASIN

The Tulare Lake Basin, which is in the southern San Joaquin Valley, extends from the southern limit of the San Joaquin River Basin in the north to the Tehachapi Mountains in the south, and from the Sierra Nevada in the east to the Coast Range in the west (Figure 3-6). Along with the cities of Fresno, Bakersfield, Hanford, and Visalia, several smaller communities are on the eastern side of the valley. The total watershed encompasses approximately 17,400 square miles with approximately 80 percent below the snowline.

The basin's major rivers—Kings, Kaweah, Tule, and Kern—originate in the Sierra Nevada, flow generally west into the San Joaquin Valley, and end in either lakes or sinks. The four flood management projects on these rivers are operated for flows in the respective rivers. All the projects are part of a system contributing water to the Tulare Lakebed. The Tulare Lakebed has an extensive levee and diversion system designed to manage irrigation flows and minor floodflows from the four projects and the surrounding uncontrolled drainage area. However, flows in the system that are less than the design flows, combined with large uncontrolled runoff, may cause damage in the Tulare Lakebed area. The size of flows may exceed the diversion system capacity and damage land protected by the levee system.

A flood management system consisting of levees, bypasses, and weirs is in place to direct floodflows and minimize flooding in the lowlands. The Kings River Weirs divert floodflows north via the Kings River North, James Bypass, Fresno Slough, and Mendota Pool system into the San Joaquin River Basin. Flows greater than the flood management operating policies are sent into Tulare Lake Basin via Kings River South. Floodflows on the Kern River may be diverted to the California State Aqueduct via the Kern River Intertie.

Kings River

The Kings River originates in the southern Sierra Nevada. The upper watershed includes the North, Middle, and South Forks of the Kings River, all of which converge in the foothills upstream from Pine Flat Dam. Downstream from the dam, the river bifurcates at Island and Army Weirs into the Kings River South, flowing into Tulare Lake, and the Kings River North/James Bypass/Fresno Slough, flowing north into Mendota Pool. The Kings River drainage area upstream from Pine Flat Dam covers approximately 1,545 square miles, about 60 percent of which is above the snowline. The main flow-regulating facility on the Kings River—Pine Flat Dam—is used for flood management, water supply, and power generation. Four reservoirs upstream from Pine Flat Dam supply water to hydropower projects on the North Fork. The largest of these reservoirs are Courtright and Wishon. The Friant-Kern Canal crosses the Kings River downstream from Pine Flat Dam.

Pine Flat Dam and Lake. Pine Flat Dam, completed in 1954, is owned, operated, and maintained by the Corps of Engineers. It is on the Kings River about 28 miles northeast of Fresno and provides flood protection to 200,000 acres of agricultural land in the Tulare Lake area. Pine Flat Dam is a 429-foot-high and 1,820-foot-long concrete gravity dam with a gross pool of 1,000,000 acre-feet and a flood management reservation of 475,000 acre-feet. The major goal of the flood operation of Pine Flat Dam and objective release of 4,750 cfs below Crescent Weir is to prevent flooding of farmland along the 100 plus miles of the Kings River (in the Tulare Lakebed) and on the San Joaquin River. However, coordination between project and nonproject dams may be a problem. The following factors need to be considered when making flood management decisions:

- After an event, any major release to evacuate flood management storage can potentially affect downstream property owners, as well as the river channel. Releases must balance the potential damage and the need to evacuate flood management storage.
- Generally, any flow greater than normal irrigation demands may damage improvements inside the channel floodway near Highway 99 and the cities of Kingsburg and Reedley.
- Mill Creek (near Pine Flat Dam), along with several other small local creeks below the dam, can produce damaging floodflows even with no flow from Pine Flat Dam. Consequently, local flows must be accounted for when making any release from Pine Flat Dam.

- Pine Flat Dam flood releases are measured 60 miles downstream at structures designed to divert floodflows north to the San Joaquin River and south to the Tulare Lakebed. This distance from the dam to the diversion points magnifies operational problems by lengthening the time for floodflows to actually enter the controlling flood channels. During the 60 miles of travel, flows may be modified by local uncontrolled runoff, diversions, and channel losses.

- Flood releases are complicated by having two levels of normal flood releases. The first level is to maximize releases, up to channel capacity (4,750 cfs), north to the San Joaquin River. The second level is to add flood releases (up to 3,200 cfs) to the south. Floodflows greater than 7,950 cfs in the Kings River are divided equally to maximize flood releases both north and south.

Army Weir. The Army Weir, constructed in 1943, controls the flow split between Kings River South (south to Tulare Lakebed) and Kings River North (north to San Joaquin River). Although constructed by and under the jurisdiction of the Corps of Engineers, permission was granted to the Kings River Water Association (KRWA) to operate the structure according to agreements among the water users. Accordingly, the KRWA is the operating agency until the Corps of Engineers, on its own initiative or at the request of the Kings River Water Association, again assumes direct responsibility for operation.

The Army Weir is equipped with six electrically operated gates along with eight other openings with flashboards. The KRWA operates the weir to maximize the flow north into the San Joaquin River up to a total of 4,750 cfs to partially relieve flooding within the Tulare Lakebed to the south. When flows exceed 4,750 cfs, the excess, up to 1,200 cfs, is diverted to the south. All flows over 5,950 cfs are sent north until maximum diversions at Crescent Weir are reached.

Crescent Weir. The Crescent Weir began operation in 1939; it is maintained and operated by the Crescent Canal Company under an agreement with the Zalda Reclamation District. The concrete weir has 18 openings and uses flashboards for flow control. The flow in the Kings River North is controlled by the Army Weir first, then by the Crescent Weir. The reclamation district controls flows greater than 4,750 cfs, at the Crescent Weir, by sending the first 4,750 cfs north and the excess, up to a maximum of 2,000 cfs, to the south. Flows greater than 7,950 cfs in the Kings River North (4,750 cfs north, 1,200 cfs south from the Army Weir, and 2,000 cfs south from the Crescent Weir) are divided by the Army and Crescent Weirs equally between north and south with consideration for existing levee and channel conditions.

Kings River North. The design flood management portion of the channel capacity of Kings River North, which feeds into Fresno Slough, Fish Slough, and James Bypass, is 4,750 cfs. This is the first level of flood releases. It is possible, at times, that irrigation flows are added to this floodflow. The broad flood channels of Kings River North are farmed in the spring, and the property owners have requested notification when flood releases are planned to be sent north. Flow changes must be coordinated with operators of Mendota Pool to enable weir changes, repairs, and operation to prevent local flooding.

James Bypass and Fresno Slough. The James Bypass, a leveed channel, begins in the lower Kings River Basin at the end of the Kings River North, runs northwest, and ends at the Fresno Slough. The Fresno Slough transports overflows from the Kings River from the James Bypass to the Mendota Pool. Excess water in the Mendota Pool overflows into the San Joaquin River.

Kings River South (Clarks Fork, Kings River South, and Crescent Bypass). In addition to the design floodflow channel capacity to the north, there is a flood channel capacity of 3,200 cfs going south to Tulare Lakebed. This capacity is used after capacity to the north has been attained and rain flood space is encroached in Pine Flat Lake, or greater than 4,750 cfs of supplemental flood releases are mandated by the snowmelt volume runoff forecast. The channel to Tulare Lakebed, via the Kings River South, includes Clarks Fork, Kings River South, and Crescent Bypass.

Kaweah River

The headwaters of the Kaweah River lie in the southern Sierra Nevada. The upper watershed includes the North, Marble, Middle, East, and South Forks of the Kaweah River, all of which converge in the foothills upstream from Lake Kaweah. Downstream from the lake, the main stem of the Kaweah River meanders southwest past Visalia and onto the valley floor. The Kaweah River drainage area covers 647 square miles at McKay Point east of Visalia where the river bifurcates. The drainage area upstream from Terminus Dam covers approximately 561 square miles, or 86 percent of the total watershed. Approximately 30 percent of the basin upstream from the dam is above the snowline. The main regulating facility on the Kaweah River, Terminus Dam, is used for flood management, water supply, and power generation. Approximately 12 diversions downstream from Lake Kaweah divert water for agriculture.

Terminus Dam and Lake Kaweah. Terminus Dam, completed in 1961, is owned, operated, and maintained by the Corps of Engineers. The dam is on the Kaweah River about 2 miles northeast of Lemoncove and provides flood protection for the communities of Visalia, Tulare, Farmersville, Ivanhoe, Goshen, and the Tulare Lakebed. The 250-foot-high and 870-foot-long earthfill dam, with a 130-foot-high and 870-foot-long auxiliary dam, has a rain flood management reservation of 142,000 acre-feet that uses nearly the entire 143,000 acre-foot volume of the lake. Because Lake Kaweah flood management reservations are small compared with the drainage area tributary to the lake, it must be kept practically dry each winter. The lake provides little protection from rain floods and filled and emptied twice during the flood of 1997. The downstream objective release of 5,500 cfs is met by adherence to the approved Water Control Plan with consideration of several factors discussed below:

- Dry Creek and Yokohl Creek are the major uncontrolled tributaries to the Kaweah River below Terminus Dam. These tributaries can produce high-magnitude flows requiring rapid release changes from the dam. Because the objective flow below the two creeks is 5,500 cfs, the releases from Terminus Dam must be reduced to accommodate the flows from the creeks.

- Although Terminus Dam is operated for flows in the Kaweah River, it is part of a four-reservoir system contributing water to the Tulare Lakebed area. Since the Kaweah River has no outlet to the ocean, all floodflows not stored in Lake Kaweah must be used or disposed of within the service area; otherwise they enter Tulare Lakebed and can be damaging. When flood management releases must be made from Lake Kaweah, all possible diversions to irrigation uses are made. Whenever possible, releases from the reservoir should reflect consideration of the conditions in all downstream channels and the operation of the other three projects.

A project to raise the spillway elevation of the dam by approximately 21 feet, increasing maximum reservoir storage to 186,000 acre-feet, has been authorized. This project would increase the level of flood protection downstream and provide greater operational flexibility in the Tulare Lakebed flood management system.

Tule River

The Tule River originates in the southern Sierra Nevada. The upper watershed includes the North, Middle, and South Forks of the Tule River, which converge in the foothills upstream from Success Dam. Downstream from the dam, the main stem of the Tule meanders west through Porterville and across the valley floor until it drains into Tulare Lakebed. The Tule River drainage area upstream from Success Dam covers approximately 393 square miles; 10 percent is above the snowline. The main regulating facility on the Tule River is Success Dam, which is used for flood management, water supply, and power generation.

Success Dam and Lake. Success Dam, completed in 1961, is owned, operated, and maintained by the Corps of Engineers. The dam is on the Tule River about 6 miles east of Porterville and is operated to provide flood management to agricultural areas along the Tule River, the Tulare Lakebed area, and the City of Porterville. The 142-foot-high and 3,490-foot-long earthfill dam, with a 7,650-foot-long and 42-foot-high auxiliary dike, creates a lake with a total capacity of 82,300 acre-feet. The flood management reservation of 75,000 acre-feet requires that the reservoir be nearly dry each winter. The reservoir filled and emptied twice during the flood of 1997. Decisions on flood management operations are made to meet requirements of the approved Water Control Plan that specifies maximum downstream objective releases of 3,200 cfs with consideration of the following:

- Although Success Dam is operated for flows in the Tule River, it is part of a four-reservoir system contributing water to the Tulare Lakebed area. Since the Tule River has no outlet to the ocean, all floodflows not stored in Lake Success must be used or disposed of within the service area; otherwise they enter Tulare Lakebed and can be damaging. Flows in the Tule River that are less than the design flows, coupled with large uncontrolled runoff, may cause damage in the Tulare Lakebed area. Whenever possible, releases from the reservoir should reflect consideration of the conditions in all downstream channels and the operation of the other three projects.

Kern River

The headwaters of the Kern River are high in the southern Sierra Nevada. The upper watershed includes the South Fork of the Kern River and the main stem of the Kern River. The main stem flows south through the mountains and directly into Isabella Lake. Downstream from the lake, the river flows southwest toward Bakersfield, where it enters the valley floor and continues to the Buena Vista lakebed. The main regulating facility on the Kern River is Isabella Dam. The drainage area upstream from Isabella Dam is approximately 2,074 square miles, which accounts for 86 percent of the total watershed as measured near Bakersfield. About 75 percent of the watershed upstream from the dam is above the snowline. Isabella Lake, created by Isabella Dam, is used for flood management, water supply, and power generation. Additionally, the Friant-Kern Canal ends at the Kern River west of Bakersfield.

Isabella Dam and Lake. Isabella Dam, completed in 1953, is a 185-foot-high and 1,695-foot-long earthfill dam on the Kern River, about 35 miles northeast of Bakersfield. The dam has an auxiliary dam 100-feet high and 3,257-feet long that is operated to reduce floodflows to a downstream objective release of 4,600 cfs. The Corps of Engineers owns, operates, and maintains Isabella Dam. The dam was built with a gross pool capacity of 568,000 acre-feet and a flood management reservation of 398,000 acre-feet. Isabella Dam provides flood protection to the city of Bakersfield, the highly developed agricultural areas downstream from the dam, and the Tulare Lakebed area. The following are considered when making operations decisions:

- Significant efforts by the water user agencies served by Isabella Lake have made it possible to release the total objective flow of 4,600 cfs downstream without any of the flow reaching the Kern River Intertie. The efforts of the water users have centered on the expansion of the groundwater recharge in the area.

- Although Isabella Dam is operated for flows in the Kern River, it is part of a four-reservoir system contributing water to the Tulare Lakebed area. Since the Kern River has no outlet to the ocean, all floodflows not stored in Lake Isabella must be used or disposed of within the service area; otherwise they enter Tulare Lakebed and can be damaging. Flows in the Kern River that are less than the design flows may cause damage in the Tulare Lakebed area. Whenever possible, releases from the reservoir should reflect consideration of the conditions in all downstream channels and the operation of the other three projects.

Kern River Intertie. The Kern River Intertie, completed in 1977, is operated to provide flood protection to Tulare Lakebed. It diverts Kern River rain and snowmelt floodflows to the California Aqueduct if space allows. The Intertie is on the Kern River just downstream from the Buena Vista inlet and consists of a sedimentation basin, a gated concrete-lined diversion channel from the sedimentation basin to the State Aqueduct, and an emergency bypass channel from the sedimentation basin to the Buena Vista Outlet Canal. The Kern River Intertie has also been used to divert floodwaters from the State Aqueduct into the Buena Vista Outlet Canal and into Lake Buena Vista.

POST FLOOD ASSESSMENT FOR
1983, 1986, 1995, and 1997

FIGURE 3-1
MAJOR FLOOD
MANAGEMENT RESERVOIRS

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LEGEND

- Reservoirs with Flood Control Storage
- Other Major Water Bodies
- Rivers
- Area Above 5,000 ft Elevation
- Areas of Runoff for Major Flood Control Dams

POST FLOOD ASSESSMENT FOR
1983, 1986, 1995, and 1997

FIGURE 3-2
WATERSHED AREAS ABOVE
MAJOR CENTRAL VALLEY FLOOD
MANAGEMENT DAMS

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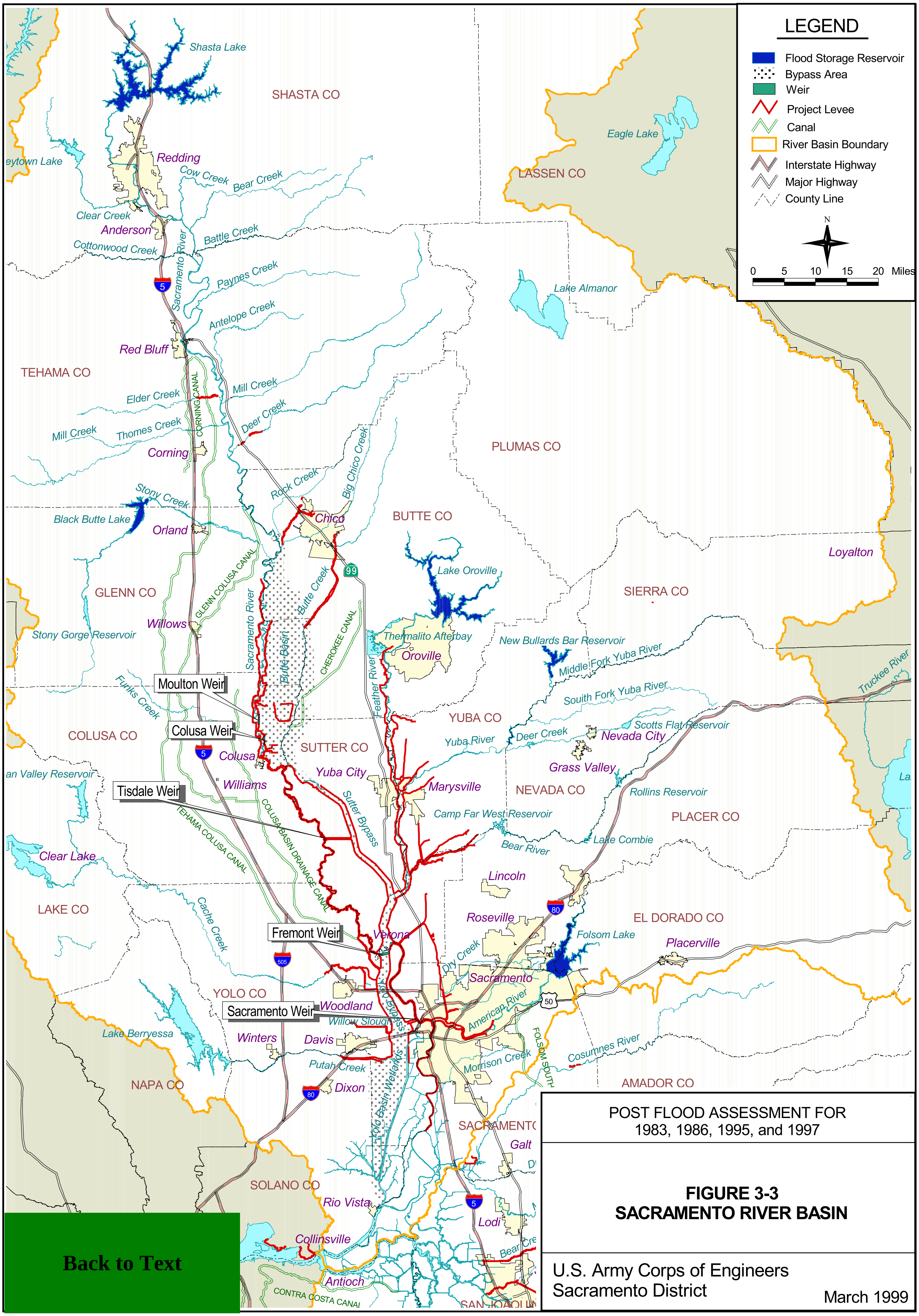

POST FLOOD ASSESSMENT FOR
1983, 1986, 1995, and 1997

FIGURE 3-3
SACRAMENTO RIVER BASIN

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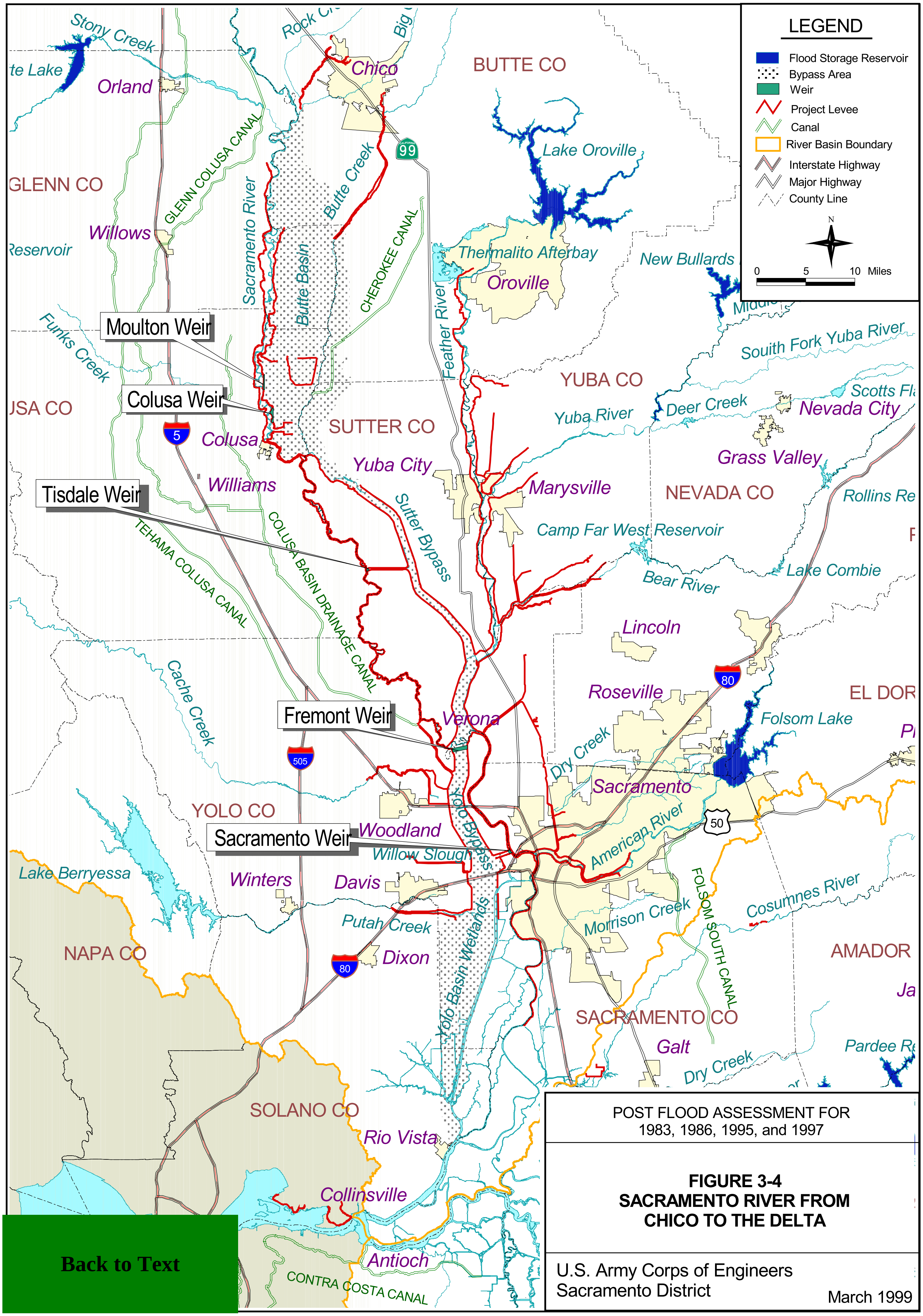

POST FLOOD ASSESSMENT FOR
1983, 1986, 1995, and 1997

FIGURE 3-4
SACRAMENTO RIVER FROM CHICO TO THE DELTA

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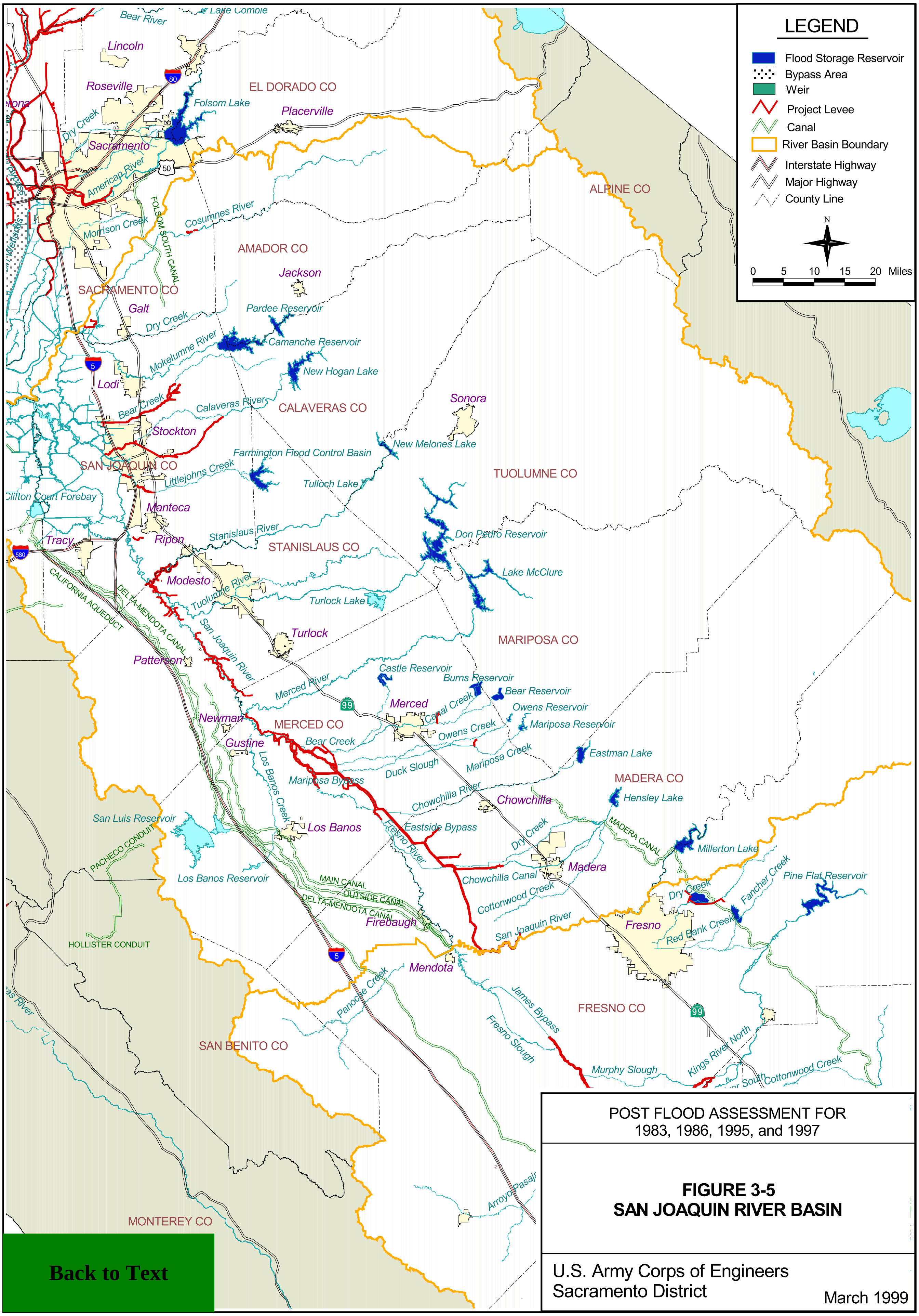

POST FLOOD ASSESSMENT FOR
1983, 1986, 1995, and 1997

FIGURE 3-5
SAN JOAQUIN RIVER BASIN

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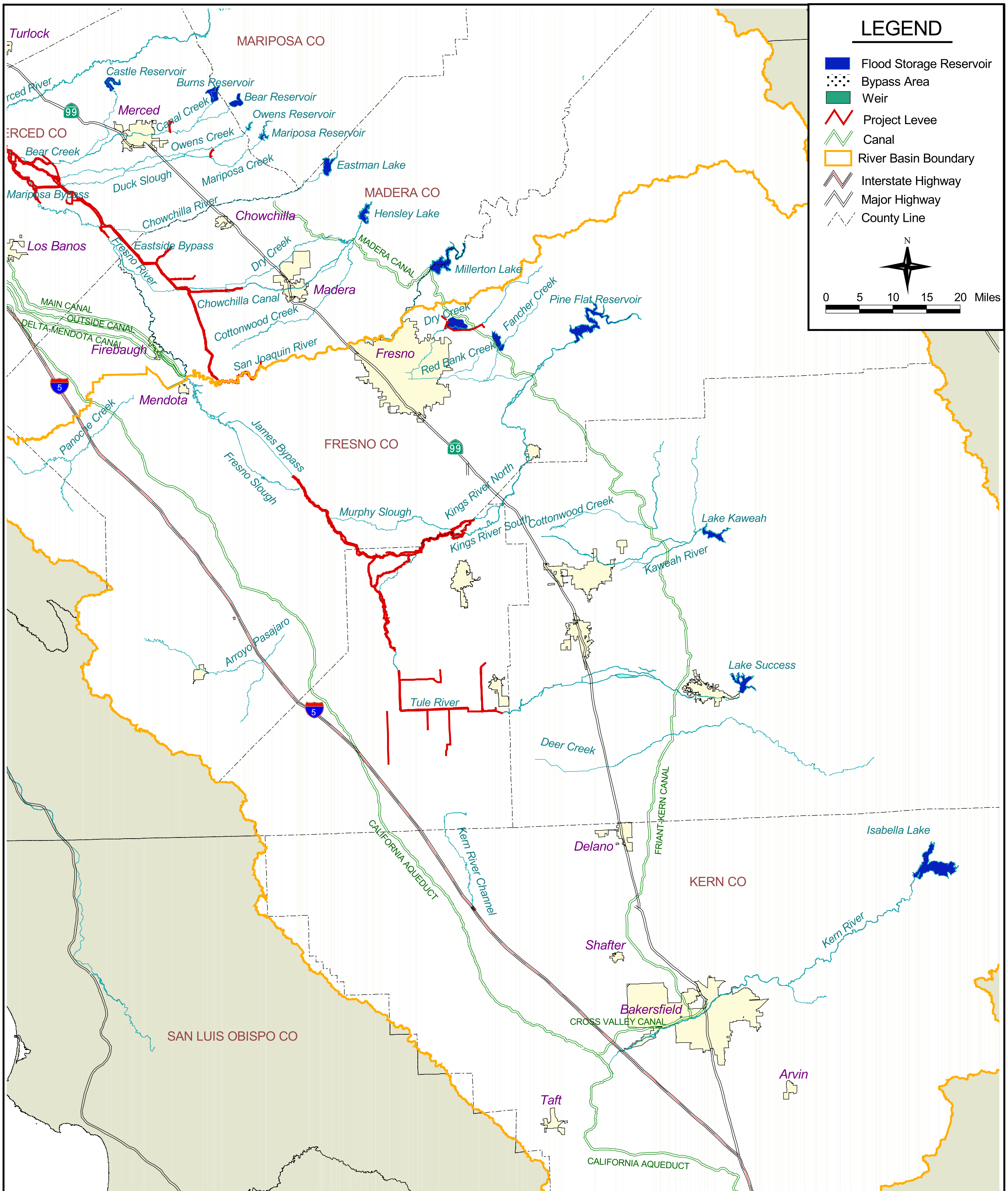
March 1999



POST FLOOD ASSESSMENT FOR
1983, 1986, 1995, and 1997

FIGURE 3-6
TULARE LAKE BASIN

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