# 2.0 Planning Area Description

The focus in defining flood and related resource problems and potential solutions will be primarily on lands protected by facilities of the State Plan of Flood Control (SPFC[10]), as defined in California Water Code (CWC) Section 8361. The SPFC Planning Area (SPFCPA) is generally within the Sacramento and San Joaquin valley floors. Per the legislative description, the Sacramento-San Joaquin Valley does not include lands lying within the Tulare Lake Basin.

The Sacramento River Basin covers approximately 27,246 square miles including all or a portion of 23 predominately rural Northern California counties. The basin is about 240 miles long and up to 150 miles wide, bounded by the crests of the Sierra Nevada on the east, the Coast Ranges on the west, the Cascade and Trinity mountains on the north, and the Sacramento-San Joaquin Delta (Delta) on the south (DWR, 2009e). It is drained by the Sacramento River and its major tributaries, the Feather and American rivers. Numerous smaller streams flow into the Sacramento River from both sides of the valley.

The San Joaquin River Basin covers approximately 16,700 square miles, including drainage areas from the Central Sierra rivers and streams, and the central Delta islands. The basin encompasses the southern portion of the Central Valley and lies between the crests of the Sierra Nevada on the east and the Coast Ranges on the west. It extends from the northern boundary of the Tulare Lake Basin, near Fresno, to the confluence with the Sacramento River in the Delta. Major tributaries to the San Joaquin River include the Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, and Fresno rivers. In addition, a portion of flood flows from the Kings River are diverted north through the James Bypass to the San Joaquin River during times of high water along the Kings River.

Together, the Sacramento and San Joaquin rivers convey more than 40 percent of the surface water in California, and join at their lowest elevations in the Delta. In the Sacramento and San Joaquin river basins, average annual precipitation can vary from 95 inches in the highest elevations of the Sierra Nevada and Cascade mountain ranges to 8 inches on the valley floor at Los Banos (USACE, 1999).

[10] The SPFC includes the State and federal flood control works, lands, programs, plans, conditions, and O&M mode of the SRFCP (CWC Section 8350), of flood control projects in the Sacramento and San Joaquin river basins for which the Board or DWR has provided the assurances, and of those facilities identified in CWC Section 8361.

The two major flood management systems in the Central Valley – including the Sacramento River Flood Control Project (SRFCP) and the San Joaquin River and Tributaries Project – have a combined total of approximately 1,569 miles of State of California (State)-federal project levees, 1,200 miles of designated floodways[11], several hundreds of miles of project channels, and 56 major flood control works (overflow weirs, flood relief structures, outfall gates, and pumping plants). The existing State-federal flood management system influences flooding and flood management on more than 2.2 million acres (3,400 square miles) of land within the Central Valley. Local and regional flood management facilities and projects provide additional flood damage reduction for valley lands in both urban and rural areas.

[11] Designated floodways are defined as follows: (1) the channel of the stream and that portion of the adjoining floodplain reasonably required to provide for the passage of a design flood, as indicated by floodway encroachment lines on an adopted map, or (2) the floodway between existing levees as adopted by the Board or the Legislature (23 California Code of Regulations (CCR) Section 4i).

## 2.1 Existing Conditions

The following sections present information on the existing physical conditions, infrastructure, biological conditions, social and economic conditions, cultural resources, institutional, and emergency planning, response, and recovery. As mentioned previously, the Regional Conditions Report – A Working Document (RCR) is based primarily on existing and available information. The RCR will be updated as relevant technical information is developed and as the 2012 CVFPP progresses.

### 2.1.1 Physical Conditions

This section describes the existing physical conditions in the Central Valley relevant to integrated flood management.

***Hydrology, River Hydraulics, and Flood Management in the Sacramento River Basin***

The Sacramento River Basin has been subject to floods that result from winter and spring rainfall as well as combined rainfall and snowmelt. The Sacramento River is the major source of water supply in California. The Sacramento River flows combine with tides to strongly influence water levels in the Delta. This often causes backwater effects on the San Joaquin River in and near the Delta, causing sediment deposition.

Major rivers in the Sacramento River Basin include the Sacramento, Feather, and American rivers. 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 its two largest tributaries, 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. Cottonwood Creek, entering the Sacramento River near the town of Cottonwood, is the largest tributary on the west side of the Sacramento River Basin that enters the river directly and is the only large tributary that is uncontrolled. Other significant westside tributaries include Cache, Putah, and Stony creeks, however they enter the Yolo Bypass, which discharges to the Sacramento River near Rio Vista. The eastside tributaries are influenced greatly by snowmelt, however the westside tributaries essentially have negligible influence of snowmelt on flood runoff.

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 basins 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, and at Rio Vista, downstream from Sacramento, the drainage area is approximately 26,300 square miles (USACE, 1999). 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.

Downstream from Keswick Dam in Redding, the Sacramento River flows south-southeast for 58 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 near Collinsville. Through the valley floor reach, the Sacramento River is flanked by overflow basins, two of which (the Sutter and Yolo bypasses) are leveed floodways. These floodways comprise part of the 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. Butte Basin is the northernmost of the regulated overflow basins flanking the Sacramento River. Water flows naturally over the banks into the Butte Basin downstream from Chico Landing when Sacramento River flows exceed a certain amount, as described in the Upper and Lower Butte Basin section below.

**Flow and Flood Management in the Sacramento River Basin** The historic hydrology and hydraulics of the Sacramento River have been greatly affected by the construction of flood management levees, channel modifications, bank protection placement, dam construction, hydraulic mining, and urbanization. The levees and bank protection have restricted river movement downstream from Chico and modified overflows to the natural flood basins during high flows. Overflow to the Colusa Basin was blocked by levees for protection of agricultural lands.

A number of flood management projects along the river affect the flow and operation of facilities. These facilities include dams and reservoirs, levees, and weirs. Shasta Lake collects flow in the Upper Sacramento River Region, 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 dam releases can be adjusted to accommodate uncontrolled flows, subject to storage availability and other operational constraints.

The flood management system uses five weirs and three flood relief structures located along the river to divert part of the flood flows 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 overflow basins and bypasses. The weirs were designed to begin operation in a certain order: Moulton Weir, Colusa Weir, Tisdale Weir, Fremont 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

*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 (USACE, 1999). 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 channel improvement project in Adin, near Alturas, is found in this segment of the Sacramento River.

*Sacramento River from Shasta Dam to Red Bluff*
Flows in the Sacramento River in the 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 Central Valley Project (CVP). Keswick Dam, completed in 1950 as part of the CVP, serves as an afterbay for the Shasta and Spring Creek power plants. Since 1964, some flows from the Trinity River Basin, more specifically from Whiskeytown Lake, have been exported to the Sacramento River Basin through CVP facilities.

*Sacramento River from Red Bluff to Chico Landing*

The Sacramento River enters the Sacramento River Basin about 5 miles north of Red Bluff. The stretch of river 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 east side – Antelope, Mill, Deer, Big Chico, Sycamore-Mud, Rock, and Pine creeks; from the west side – 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 partial bank protection and some channel modifications. Red Bluff Diversion Dam diverts water from the Sacramento River to the Corning and Tehama-Colusa Canals.

*Sacramento River from Chico Landing to Colusa*

In the 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. Big Chico Creek/Mud Creek drain flood waters from the east side of the valley in the Chico area. Black Butte Lake on Stony Creek is the only reservoir operated to manage flood flows in this Sacramento River reach. Floodwaters in the Sacramento River overflow the east bank at three sites in the reach, referred to by the State as the Butte Basin Overflow Area. The first points of diversion, moving downstream, are upstream from Ord Ferry (the M&T and 3Bs flood relief structures). 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 Goose Lake flood relief structure, Moulton Weir, and over the Colusa Weir into Butte Basin. In this river reach, several federal projects begin, including the SRFCP, Sacramento River Major and Minor Tributaries Project, and Sacramento River Bank Protection Project (SRBPP). Levees of the SRFCP 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. It should be noted that these levees were not all constructed to provide the same level of protection.

*Sacramento River from Colusa to Verona*
The Sacramento River meanders 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.

- **Feather River** – The Feather River has a drainage area of 5,921 square miles and contributes about 44 percent of the annual flow in the Sacramento River. The rest of the basin extends south and includes the drainage of the Yuba and Bear rivers. Annual precipitation in the Feather River Basin varies from about 20 inches in the valley near Oroville to nearly 90 inches on the ridges near the west branch of the North Fork. Of the total flow, 75 percent originates above Oroville, and about half of that comes from the North Fork. Two major tributaries to the Feather River are the Yuba River and Bear River, contributing on average about 30 percent of the total Feather River flow (Reclamation, 2005c).

*Sacramento River from Verona to Collinsville*
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.

- **American River** – The American River drains and area of 1,921 square miles in the north-central portion of the Sierra Nevada. Mean annual unimpaired runoff is estimated at 2.6 million acre feet (AF) (at Fair Oaks). Folsom and Nimbus dams regulate flow for irrigation, power,

flood control, municipal and industrial use, and other uses. The American River joins the Sacramento River about 25 miles downstream from Nimbus Dam (DWR, 1996b).

### *Hydrology, River Hydraulics, and Flood Management in the San Joaquin River Basin*

Data is presented for the San Joaquin River Basin, which includes the San Joaquin Valley. The Sacramento-San Joaquin Valley, as defined in California Government Code (CGC) Section 65007(g), encompasses any "lands in the bed or along or near the banks of the Sacramento River or San Joaquin River, or their tributaries or connected therewith, or upon any land adjacent thereto, or within the overflow basins thereof, or upon land susceptible to overflow therefrom. The Sacramento-San Joaquin Valley does not include lands lying within the Tulare Lake Basin, including the Kings River." The San Joaquin Valley is bounded by the Delta in the north, the Sierra Nevada Mountains in the east, the Coast Ranges in the west, and the northerly boundary of the Tulare Lake Basin 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 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 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.

Rivers that drain the western slope of the Sierra Nevada provide the primary sources of surface water to the San Joaquin River Basin. Many of these rivers drain large areas high in the basin that supply primarily snowmelt runoff. The basic flood management system in the San Joaquin River Basin 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 (USACE, 1999). Although less frequent than snowmelt floods, rain floods do occur in the San Joaquin River Basin and tend to have higher peak flows than the snowmelt floods. While reservoirs in the San Joaquin River Basin provide some rain flood protection, available flood management storage space can fill quickly during rain floods.

**Flow and Flood Management in the San Joaquin River Basin** The San Joaquin River Basin extends from the Delta in the north to the northerly boundary of the Tulare Lake Basin in the south, and from its headwaters

upstream from Friant Dam in the Sierra Nevada in the east to the Coast Ranges in the west. 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 (USACE, 1999). Major municipal and industrial centers in the San Joaquin River Basin include Stockton, Modesto, Merced, and Fresno. There are ongoing discussions between the City of Fresno and California Department of Water Resources (DWR) regarding the city's inclusion in the CVFPP.

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 River Basin at Friant, flows to the center of the valley floor, turns sharply northward, and flows through the San Joaquin River Basin to Vernalis. Vernalis is generally considered to represent the southern limit of the Delta. Major sections of the San Joaquin River and its minor tributaries are ephemeral.

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 (through the James Bypass), 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. Many minor tributaries are controlled through natural streams, which attenuate flood flows. Flood management facilities are found on all major tributaries except the Cosumnes River. Locations along the San Joaquin River are referenced by river mile, with RM 0 the river mouth (4.5 miles below Antioch), and RM 270 at Friant Dam.

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 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.

Basins 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 flood flows 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. Both the Chowchilla Canal Bypass and the Eastside Bypass are critical to flood management in the San Joaquin River Basin. 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, there is less channel capacity available on the San Joaquin River moving downstream due to a greater number of tributaries adding to flow upstream. The San Joaquin River levee and diversion systems are not designed to contain the objective release from each of the project reservoirs simultaneously. Channel capacity has been affected due to in-channel growth of trees, native plants, and nonnative plants. 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.

Significant urban and commercial development within the last decade in the lower portion of the San Joaquin River, between the Stockton and Tracy urban areas, has constrained the development of flood control structures. Residential areas are located in low-lying areas immediately adjacent to the levee system along much of the right bank of the San Joaquin River south of Stockton. South Delta islands that have functioned in the past as overflow areas are being considered for urban development. The flood management system in this area was originally designed to protect agricultural land uses, and so the levees were not constructed with as high a degree of reliability as those in urban areas. Consequently, the public may underestimate the risk of flooding in these areas.

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 from Friant Dam to Chowchilla Canal Bypass
- San Joaquin River from Chowchilla Canal Bypass to Merced River
- San Joaquin River from the Merced River to Vernalis

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.

*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 (USACE, 1999). Several reservoirs in the upper portion of the San Joaquin River Basin, 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, although the undersized storage capacity limits flood management operations. At the dam, water is diverted to the Madera and Friant-Kern canals to provide irrigation and municipal and industrial (M&I) water supplies to the eastern portion of the San Joaquin River Basin. Under flood conditions, flood flows can also be diverted into these canals when capacity is available and there is a place to release the flood flows. Flood flows 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 cubic feet per second (cfs) into the Fresno-Chowchilla River system (USACE, 1999). Flows from the Big Dry Creek Reservoir enter the San Joaquin River downstream from Friant Dam. The San Joaquin River downstream from Friant Dam flows westward toward the Mendota Pool.

*San Joaquin River Between Chowchilla Canal Bypass and Merced River*
Flood flows 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 flood flows from upstream from the Chowchilla Canal Bypass are diverted from the San Joaquin River to the Chowchilla Canal Bypass. Flood flows 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 the foothills of the Sierra Nevada and drains a watershed of approximately 500 square miles, as measured at the Eastside Bypass (USACE, 1999). 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 basin. 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.

- **Chowchilla River** – The Chowchilla River, a tributary to the San Joaquin River, originates in the Sierra Nevada and drains a basin of approximately 600 square miles (USACE, 1999). 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 basin. 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.

*San Joaquin River from the Merced River to 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, non-flood management flow patterns result from tributary inflows from the Merced, Tuolumne, and Stanislaus rivers. All three rivers have dams that require regional coordination that may have to overcome jurisdictional issues to be successful. The groundwater table upstream from the Merced River confluence is shallow, which can also impact flows. 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.

- **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 (USACE, 1999). 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 basin drain lands in Yosemite National Park. Significant changes have been made to the Merced River hydrologic system since the 1850s, when agricultural development began in the basin. 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 drainage basin.

- **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 basin below the 5,000-foot elevation snowline (USACE, 1999). The Tuolumne River is the largest tributary to the San Joaquin River. New Don Pedro Dam is the only facility that regulates flood flows on the Tuolumne River. Dry Creek, a tributary to the Tuolomne River, has also been historically subject to flooding. The dam's drainage area covers 1,533 square miles, or 81 percent of the drainage basin. A short distance downstream from New 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 New Don Pedro Dam. O'Shaughnessy Dam on the mainstem 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.

- **Stanislaus River** – The Stanislaus River originates in the Sierra Nevada and enters the San Joaquin River at RM 80. The river drains a basin of approximately 1,075 square miles at the town of Ripon (USACE, 1999). 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 basin. Ungaged tributaries contribute some 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 Basin. Tulloch Dam, about 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 Basin include the Tri-Dam Project, a hydroelectric generation project that consists of Donnells, Beardsley, and Tulloch dams upstream from New Melones Dam on the Middle Fork Stanislaus River. Releases from Donnells and Beardsley dams affect inflows to New Melones Dam.

*San Joaquin River from the Vernalis to Mouth*

- **Eastside Tributaries to the Delta** – The streams in the northern portion of the San Joaquin River Basin, generally between the basins of the American and Stanislaus rivers, are commonly referred to as the eastside tributaries to the Delta. The primary basins in this region include the Cosumnes, Mokelumne, and Calaveras rivers and the Littlejohns 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.

- **Littlejohns Creek Stream Group** – The Littlejohns Creek Stream Group, composed of Duck, Littlejohns, Temple, and Lone Tree creeks, is located southeast 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 Stockton. The only flood management facility, Farmington Dam, is on Littlejohns Creek. This facility manages 85 percent of the drainage basin, as measured at the town of Farmington (USACE, 1999).

- **Calaveras River** – The Calaveras River originates in the Sierra Nevada, drains approximately 470 square miles at Bellota, and enters the San Joaquin River near Stockton (USACE, 1999). The Calaveras River Basin 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 basin.

- **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 basin of approximately 661 square miles with 65 percent of the area below the snowline (USACE, 1999). 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 basin. Camanche Dam and Reservoir provide flood damage reduction on the Mokelumne River and are operated to maintain downstream water requirements.

- **Cosumnes River** – The Cosumnes River originates in the lower elevations of the Sierra Nevada, drains a basin of approximately 537 square miles, and enters the Mokelumne River within the Delta near the Town of Thornton (USACE, 1999). Because there are no flood management projects in the basin, flood flows 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 basin 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 Basin 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.

***Hydrology, River Hydraulics, and Flood Management in the Delta***

The Delta comprises the West Coast's largest estuary, encompassing approximately 1,153 square miles of waterways and draining more than 40 percent of the fresh water in California. Most of California's major rivers provide flow to the Delta as tributaries of the Sacramento, California's largest river, or the San Joaquin River (DFG, 2007). In the estuary, the Sacramento and San Joaquin rivers flow from low-lying inland valleys into the Delta – a labyrinth of islands, sloughs, canals, and channels – continuing through Grizzly Bay, Suisun Bay, and San Pablo Bay, before emptying into San Francisco Bay and then the Pacific Ocean. Entering the Delta separately and becoming tributary within the region are the Cosumnes, Mokelumne, and Calaveras rivers, the Yolo Bypass, and numerous smaller creeks and sloughs. The largest source of water for the Delta is the Sacramento River, which transports about 18.3 million acre-feet (MAF) into the Delta in an average year. Additional flows from the Yolo Bypass and the San Joaquin River bring in an average of 5.8 MAF, with precipitation adding about another 1 MAF (DWR, 2009e).

Fresh water from the rivers mixes with salt water from ocean tides, creating a rich and diverse aquatic ecosystem. Because of its geographical position, the Delta serves as the collection point for much of the runoff and resulting water supplies of Northern California. It is through the channels of the Delta that this water must pass to satisfy the needs of the Delta, San Francisco Bay Area (Bay Area), agricultural lands of the San Joaquin River Basin, and densely populated southlands.

Before 1850, the Delta was essentially a broad expanse of water-dependent habitat and natural channels. Large-scale reclamation of the Delta for agriculture resulted in approximately 700 miles of meandering waterways and 1,100 miles of levees protecting more than 538,000 acres of farmland, homes, and other structures (USACE, 2003).

About 65 major islands and tracts in the Delta rely on the levee system to hold back river and tidal waters. There are a few small islands without levees, and a few open water areas that were formerly islands. Most original Delta levees were built from soils dredged from nearby channels

during early reclamation efforts. There are approximately 1,115 miles of levees protecting 700,000 acres of lowland in the Delta. The levee system generally provides low levels of protection for adjoining lands. Most levees were never engineered and have been locally built and maintained. They have been improved in various locations using a variety of methods, resulting in a system of levees with variations in the ability to withstand natural forces.

Flooding is a near-annual event in the Delta and can cause overtopping and erosion of levees. Delta floods originate from levee failure, often caused by the combination of high river inflows, high tide, and high winds, but also occurring in fair weather due to rodent damage, piping, foundation movement, or other causes. Because many of the Delta islands are below sea level, any levee failure carries with it the almost certain potential for deep flooding.

The Delta lies near major faults. On the basis of research conducted by the U.S. Geological Survey (USGS) and other scientists, there is a high probability of an earthquake striking the Bay Area region before 2032 (DWR, 2009g). Catastrophic levee failures from an earthquake could cause water to rush into the lower-than-sea-level islands, pulling salt water into the Delta and contaminating water exports from the Delta, affecting transportation, energy, and water transmission infrastructure, and agricultural and other local economic activities. Potential sea-level rise from future climate change could also strain existing levees that are protecting lower-than-sea-level islands. Windblown sediment losses and degradation of peat soils add further strain to the levee system by lowering the ground surface of many of the islands.

**Tidal Effects** Downstream from Sacramento, the Sacramento River traverses the low-lying tidal area of the Delta. The Delta is a convergence of ocean tides and river flows from the Sacramento River, the San Joaquin River, and several eastside tributaries. The river stage at any point in the Delta is a result of hydraulic balance among these controlling factors. This Delta tidal flow influence extends up the Sacramento River for 80 miles to Verona, at low-river stages, inducing backwater into the Yolo Bypass. This interaction between the Delta and the Lower Sacramento River Region poses flood management constraints because any increase in river flood stage has the potential to impact hundreds of miles of Delta levees. The tidal effects on the river stage typically exhibit a frequency of approximately two cycles per day, and a larger tidal effect is observed roughly twice each month.

In the San Francisco Bay, tides are semidiurnal (two high and low tides per day). The tides have a 14-day spring-neap cycle. The typical daily high

tides over a 24-hour cycle in summer conditions are generally around elevation +5 feet (North American Vertical Datum 1988 (NAVD88)) in the central-west Delta, and about +5.6 feet in Suisun Marsh (DWR, 1995). The normal tidal cycle is about 24 hours and 50 minutes. Coastal floods, which can also affect water levels in rivers, can be caused by severe sea storms, or as a result of another hazard (e.g., tsunami or hurricane, although neither is likely in the Delta).

#### *Topography and Bathymetry*

Ground surface elevations in the northern portion of the Sacramento River Basin range from more than 14,000 feet at Mount Shasta in the headwaters of the Sacramento River to approximately 1,070 feet at Shasta Lake. At Lassen Peak in the Cascade Range, elevation exceeds 10,000 feet. Other mountainous areas bordering the valley reach elevations higher than 5,000 feet. The Sacramento River Basin floor is relatively flat, with elevations ranging from sea level to about 300 feet above sea level. The Sacramento River average slope is about 1 foot/mile for the river reach below Shasta Dam to the Delta. The elevations in the Feather and American rivers range from about sea level to near 10,000 feet at the upper reaches in the Sierra. The main tributaries for the Sacramento River are the Feather and American rivers (USACE, 2001).

The San Joaquin River originates in the Sierra Nevada at an elevation of more than 10,000 feet, flows west into the San Joaquin River Basin at Friant Dam, flows to the center of the valley floor, turns north, and flows through the San Joaquin River Basin to the Delta. The San Joaquin River joins the Sacramento River at the upper end of Suisun Bay. Floodplain elevations range from about 10 feet near Old River to 70 feet above sea level at Hills Ferry. The main tributaries for the San Joaquin River are the Stanislaus, Tuolumne, Merced, Fresno, and Chowchilla rivers (USACE, 2001).

Land elevations in the Delta generally range from 25 feet below to 35 feet above mean sea level (DWR, 2009g). The Delta's main tributaries are the Cosumnes, Mokelumne, Calaveras, Sacramento, and San Joaquin rivers, and the Yolo Bypass.

#### *Soils and Geology*

Soil cover in the Sacramento River Basin ranges from metasedimentary granitic and basaltic rock in the upper elevations to alluvial deposits in the valley areas. There is also volcanic rock in the northern area of the Sacramento River Basin. The Sacramento River Basin is moderately deep with soil classifications varying from sands, silts, and clays in the valley areas to porous volcanic areas in the northern end of the basin. Delta soils range from highly mineralized soils similar to those described for the

Sacramento River Basin to deep peats. The exposure of bare peat soils to air causes oxidation, which results in subsidence, or a loss of soil, on some Delta islands. Wind can also cause sediment losses. In addition, loading from levees induces consolidation that can occur over many years.

The east side of the San Joaquin River Basin, composed of a series of coalesced alluvial fans that have formed at the base of the Sierras, comprises primarily intrusive rocks, including granite and granodiorite, with some metamorphosed granite and granite gneiss (CGS, 2002). The alluvial fans of the larger rivers include those of the Kings, San Joaquin, Merced, Tuolumne, and Stanislaus rivers. Each of the fans has significantly affected the distribution of historic flood flows. The western margin of the valley along the San Joaquin River is also composed of alluvial fans at the base of the Coast Ranges. Relatively unconsolidated water-bearing sediments are confined by the impermeable clay underlying the valley floor on the west side. The valley is interrupted by two major surface cross structures, the Stockton Fault in the Stockton Arch and the White Wolf Fault in the south near Bakersfield. Geologically driven subsidence of the valley is ongoing and is on the order of 0.01 inch/year. Collapsible soils in the San Joaquin River Basin complicate the construction of new flood control structures (USACE, 2001). In addition, groundwater overdraft contributes to subsidence.

***Geomorphology***

The geomorphology of the Sacramento River varies throughout the region. From the base of Mount Shasta for about 75 miles downstream to Elevation 300 near the town of Red Bluff, the river is generally constrained from moving laterally by erosion-resistant volcanic and sedimentary formations. The river in this area, the Sacramento Canyon, is generally narrow and deep, and the floodplain is similarly narrow. From here, the river emerges onto the broad alluvial floodplain of the Sacramento River Basin (USACE, 2001).

For about the next 50 river miles, the Sacramento River historically meandered, over time, across a wide floodplain. By eroding and depositing sediment, the river migrated across deep alluvial soils from the Red Bluff area to about Hamilton City and Chico Landing. At RM 190, Stony Creek joins from the west, and flows from the Big Chico Creek approach from the east at RM 193. From this point downstream, flood flows along the Sacramento River were split between the main stem and the adjacent flood basins separated from the main stem by natural levees. Because of the natural geomorphic processes associated with valley basins such as the Sacramento, the size and capacity of the main stem decreased in the downstream direction and topographically, the river banks are higher than the connecting floodplains. The sheer magnitude of flood flows resulted in

several distributary flood paths across the flat valley floor into which main stem flows spilled (USACE, 2001). Both base flows and flood peak flows have been regulated to the extent that they limit natural geomorphic and ecosystem functions.

Most of the surface runoff in the San Joaquin River Basin flows from the Sierra Nevada Mountains to the floor of the valley, with very little surface drainage from the west. This has moved large quantities of eroded material out of the eastern mountains and foothills into the valley as alluvial fans. For the larger waterways, such as the Merced River, these alluvial fans have progressed far onto the valley floor, displacing the main stem river channel toward the west and flattening the river slope. The flat topography of the San Joaquin River at the valley floor tends to slow down and attenuate river flows.

The San Joaquin River changes from a multi-channel system above the Merced River to a single-channel system below. As the San Joaquin River merges with the Merced River, a much larger, single channel is formed. The San Joaquin River carries year-round flow to the Delta, with summer flows being contributed to by the three main tributaries. In the reach from the Merced River to the Tuolumne River, the floodplain of the San Joaquin River is constricted by natural topography. Project levees are intermittent, protecting specific areas of the floodplain and then tying back into high ground away from the river. As the San Joaquin River approaches the Tuolumne and Stanislaus rivers, the floodplain widens to form broad triangular-shaped confluences.

Downstream from the Stanislaus River confluence, the San Joaquin River passes the Vernalis gaging station, the general area where the river becomes tidally influenced. At Paradise Cut, the San Joaquin River becomes a distributary system, dividing its flows between several channels as it winds through the Delta. During a flood event, concurrent high flows from the Sacramento, Cosumnes, and Mokelumne rivers physically limit the amount of flow that can drain out of the San Joaquin River.

Hydrologic changes, combined with gold and gravel mining disturbances, levee and bypass construction, and dam-related modifications of sediment continuity have caused a significant change in the geomorphology of the San Joaquin River. In addition to these changes, because of the arid climate in the San Joaquin River Basin, there is rarely enough water to satisfy natural, agricultural, and municipal demands and much of the upper reaches of the San Joaquin River have run dry. Both base flows and flood peak flows have been regulated to the extent that they no longer support natural geomorphic and ecosystem functions.

The area generally referred to as "the Delta" actually represents the merging of two distinct river deltas which, like the rivers that formed them (Sacramento and San Joaquin), had somewhat distinctive characteristics. The Sacramento River was characterized by comparatively high flows and sediment loads. During large floods, silts and sands were deposited adjacent to the river channels forming high and wide natural levees that tended to somewhat isolate the river from the low-lying wetlands beyond. In contrast, San Joaquin River flood flows were smaller, carrying and depositing less sediment. As a result, natural levees in the south-central Delta were lower and narrower, and high water was distributed over a flatter topography. This led to many of the systematic differences in the extent and character of the wetlands in the northern versus south-central Delta described above. The soils of the Delta were formed from a combination of peat and inorganic sediments. Throughout the south-central Delta, the main natural accretionary mechanism has been peat formation. Here, peat soils up to 40 feet thick overlay layers of marine sedimentary muds, sands, shales, and rock. Soils are typically at least 90 percent peat by wet volume. In the northern Delta, the layer of primarily peat soils is considerably thinner, and the inorganic fraction also typically higher (The Bay Institute, 1998).

Most of the inorganic sediment delivered to the estuary as a whole was in the form of suspended alluvial deposits provided by the Sacramento River. A portion of the bed load was funneled into the northern Delta channels through distributary channels, while some of the suspended load was captured in the back swamps of the northern Delta when levees overtopped. Lower volumes of inorganic alluvial sediments were delivered to the estuary from San Joaquin River discharge. The amount of this captured by intertidal wetlands of the southern and central Delta appears to have been minimal. Most appears to have been resuspended by wind-driven turbulence, and eventually passed through the Delta and to the lower estuary before settling out. Through equilibrial mechanisms not well understood, the plane of the swamps and marshes was maintained at a level closely approximating mean high tide. This is a generally "typical" condition for such environments, and presumably represents the net results of processes that equilibrate deposition, erosion, and subsidence in tidal marshes (The Bay Institute, 1998).

Two of the most ecologically influential factors in estuarine environments – water movement and salinity gradient – are primarily determined by the complex interactions of tides, topography, and freshwater discharge from the riverine system. Under normal outflow conditions, tides exert a strong influence on water movement in the Delta. Tides affect two aspects of water movement – changes in surface level and changes in direction and volume of flow. Two high and low tides of unequal magnitude (mixed

semidiurnal) exchange water between the Delta and the San Francisco Bay each day. At the Delta-Suisun Bay junction, typical summer tidal flows are on the order of 330,000 cfs. As rivers discharge into the zone of tidal influence, high flows (i.e., greater than 60,000 cfs, depending on the location in the Delta) may negate changes in water surface level that would otherwise follow the change in tides, while under low outflow conditions, unidirectional flow in the large river channels may cease, becoming bidirectional in response to the tides. When high freshwater outflows block salinity incursion at Carquinez Strait and Suisun Bay, the Delta becomes further isolated from the saline conditions that typify the lower part of the estuary (The Bay Institute, 1998).

The geomorphology of Delta is influenced by interactions among the Sacramento River, San Joaquin River, and the tidal action from the west. The Delta's natural geomorphic conditions have been substantially modified as the tidal marsh was reclaimed and the natural tidal and distributary channel system was extensively modified to provide for navigable access to farms and by excavation to build up levees. The result was the creation of a series of agricultural islands protected by levees and separated by a network of natural and created channels through which the freshwater flows from the Sacramento and San Joaquin rivers. Possibly more important to the Delta region, during the period of 1913 to 1938, the Sacramento River below Grand Island to Collinsville was enlarged as part of the flood control project (USACE and Board, 1953). The scope of this project was unprecedented with new channels and landforms created, and old channels widened and deepened to accommodate the project design flood. The geomorphology of the Delta dictates major physical characteristics such as tidal prism, tidal range, salinity, and residence times that drive the estuarine processes. These physical characteristics and processes, in turn, affect ecosystem functions, flood hazards, water diversions, and the extent of wetland habitats.

**Mining Legacy** Hydraulic mining had a major influence on the flow carrying capacity of the Sacramento River system and especially the eastside tributaries beginning in 1853. Hydraulic mining consisted of excavating hillside areas with high-pressure water cannons or "monitors" to get to the gold-bearing materials, resulting in the generation of more than 1.1 billion cubic yards of mining debris and sediment that flowed downstream to the valley floor during high-flow events. The Yuba, Bear, and Feather rivers received the highest mining sediment loads. Accordingly, these rivers and the Sacramento River downstream from the confluence with the Feather River were severely impacted by the large sediment loads in the late nineteenth and early twentieth centuries. These changes to channels resulted in increased flood stages, repeated bank and levee failures, and severe flood damages (James and Singer, 2008).

Hydraulic mining had an influence on the flow carrying capacity of the San Joaquin River Basin, but on a smaller scale than the Sacramento River system. Most of the mining in the San Joaquin River Basin was placer mining rather than hydraulic mining. Placer mining was more prevalent because the gold was a very fine texture, and mixed with the sand and gravel at the bottom of the streams (Friant Water Users Authority, 2008).

**Sedimentation and Erosion** Under natural conditions, the channels of the Sacramento and San Joaquin rivers had insufficient capacity to carry the heavy winter and spring flows generated by wet season precipitation and/or snowmelt (USACE, 1999). The rivers overflowed onto the surrounding countryside as they exceeded the channel capacity. The flow velocity in the overbank areas would be greatly reduced from that in the channel. Thus, the sediment carrying capacity would also be reduced, allowing much of the material naturally eroded from mountain and foothill areas and carried in the streams to drop out of suspension. The Sacramento and San Joaquin rivers built up their beds and formed natural levees composed of the heavier, coarser material carried by the flood flows each year. The finer material stayed in suspension much longer and would drop out when the overflow water ponded in the basins that developed east and west of the rivers. The flow regime and the sediment supply have changed significantly from natural conditions in the Sacramento and San Joaquin rivers because of human activities.

Many levees were originally designed to narrow the channel to promote high velocities and resultant scouring in order to move the large amounts of sediments from hydraulic mining and to deepen the channel for navigation. The narrow channel design after the mining era contributed to the self-eroding phenomena of the levees, which now adds significantly to maintenance costs. To protect the banks from erosion, levees are armored with large boulders (riprap), which is expensive and has ecological impacts on riparian habitat in the channel. Today, the optimal design for a self sustaining channel is regarded as a wide, meandering channel that is compatible with natural geomorphic processes, allows riparian habitat, and has the capacity to carry flood flows.

*Upper Sacramento River*

From the base on Mount Shasta for about 75 miles downstream to near Elevation 300 near the town of Red Bluff, the Sacramento River is constrained by erosion-resistant volcanic and sedimentary formations. The Chico Landing to Red Bluff Project, authorized in 1958, provides for bank protection (erosion protection) and incidental channel modifications along 50 miles of the Sacramento River between Chico Landing and Red Bluff. In this reach, 21.5 miles of bank protection have been installed to hold the

river in place and prevent meandering of the channel (USACE, 1999). Erosion from meandering channels damages adjacent agricultural lands.

*Feather River*

Deposition of mining sediments transformed the Feather River into a wide and shallow channel characterized by sandbars and low sinuosity. The Feather River still receives significant sediment from the Yuba and Bear rivers during flood events, but sediment inputs from the Bear River and other tributaries are declining, which could result in increased bank erosion and channel migration in the future. The lower Feather River experiences sediment deposition primarily caused by backwater from the Sacramento River and flow area expansion at the confluence with the Sutter Bypass.

*Yuba and Bear Rivers*

Rivers in the foothill and lower basin areas have been severely affected by rapid aggradation caused by hydraulic mining activities. Since the ban of hydraulic mining in 1893, many channels have since incised into the debris (USACE, 1999). Natural and constructed debris impoundments remain both within the channels and in overbank areas. The lower Bear River is a single-channel river characterized by low sinuosity and channel degradation over the last century. The lower Yuba River, which received significantly more mining debris than the Bear River, is characterized by high terraces of mining sediment alongside a degrading river channel with a steep gradient. Degradation has been accelerated along the lower Yuba River by dam construction and the gradual movement of sediment and mining debris down the Feather River. Also, aggregate mining in the Gold Fields is altering the channel location.

*Cache and Putah Creeks*

High velocities of water carry larger sediments down from upstream hill locations. As water slows either from flow rates dropping or flows overtopping banks, aggregates settle out in concentrated deposits. The 16-mile stretch of Cache Creek between the towns of Capay and Yolo has been extensively mined for aggregates, which has changed the sediment balance in the waterway, thereby increasing the erosion potential downstream. The Cache Creek Settling Basin is where waters from Cache Creek are impounded over a broad area to allow sediment to settle out so that the adjacent Yolo Bypass, which must carry away Sacramento River flood water, does not clog.

*Lower Sacramento River*

The lower Sacramento River is a single-channel watercourse with moderate to low sinuosity that is confined by levees located immediately adjacent to the riverbanks. The gradient of the river channel is relatively low and flat and becomes more so as it approaches the Delta. Sediment is generated

from upstream reaches of the Sacramento River, tributaries, and bank erosion. Sediment deposition occurs most notably in the Yolo Bypass and Delta. The lower Sacramento River is a perched system, meaning that ground elevation generally decreases with distance from the river. This is due in part to historic (before hydraulic mining) sediment deposition that occurred more rapidly alongside the river than in the adjacent floodplains, forming natural levees and gradually elevating the river channel.

*Delta*

Sediment supply from the Sacramento, San Joaquin, Mokelumne, and Calaveras rivers, and Bear Creek greatly influences sedimentation in the Delta. The Sacramento River is the dominant source of sedimentation to the Delta. The majority of the sediment entering the Delta from the Sacramento River watershed either deposits along the Sacramento River or moves past Mallard Island and into Suisun Bay and San Francisco Bay, leaving less than 20 percent of sediment load to move through the complex network of Delta channels (USACE, 1999). It is also possible to transport sediment from Suisun Bay landward into the Delta due to complex hydrodynamics in Suisun Bay and the western Delta. Flood tides transport sediment from Suisun Bay into the Delta and ebb tides reverse sediment transport.

Major floods export large quantities of sediment and cause net erosion within the Delta and Suisun Bay. Natural climatic events such as large storms may initiate the sediment suspensions as well. Moving water within the Delta transports suspended sediment and affects erosion and deposition over long time periods (decades) causing changes in the land surface elevation and geomorphology of the Delta. Water in the Delta moves primarily because of tides, waves, river flows, and export pumping in the south Delta. Waves generated by boats can also induce erosion from the bed and bank. To prevent erosion, riprap is often placed on levees and the sides of channels. Armoring increases bed particle size and decreases erosion, but can adversely impact ecological health. However, methods exist that can sometimes mitigate these adverse impacts, such as allowing vegetation on levees. Dredging deepens channels and can suspend bottom sediment.

Exterior slopes of levees are often protected by erosion-resistant riprap, but the interior levee slopes are not protected. Wind-generated waves in the Delta can lead to overtopping and erosion along the interior of levees protecting Delta islands. The erosion can weaken levees resulting in conditions that make them more susceptible to failure and breaching during storm events. In the event of a levee failure, winds blowing over the length of a flooded island would generate waves that could erode the inner slope (inboard side) of the levee. Inboard levee erosion could cause secondary

levee breaches to form, adding to the damage. To help prevent this erosion, plastic sheeting is sometimes placed on the inboard side of the levee as a temporary repair alternative.

*San Joaquin River*

Between 1914 and 1998, there was a general trend of degradation (increase in channel depth) in the San Joaquin River downstream from the Merced River, with some channel aggradation downstream from the Tuolumne to the southern Delta. Also, there has been some channel narrowing between the Merced and Tuolumne rivers since 1914. Bank erosion is occurring (between 14 and 31 percent of bank) downstream from the Merced River, which will maintain sediment supply to downstream areas (USACE, 1999). Bank erosion is the primary source of sediment upstream from the Chowchilla Bypass and aggradation is occurring upstream from Mendota Dam. General bed degradation is occurring downstream from Mendota Dam. Considerable sediment has accumulated in the Eastside Bypass downstream from the Sand Slough Control Structure from gully erosion in the bypass near the State Route (SR) 152 crossing. Upstream diversions on the San Joaquin River and tributaries have reduced the frequency of flooding, thereby reducing the opportunity to flush the accumulated sediment out of the river system.

In the lower San Joaquin River, past farming practices directed sediment-laden agricultural drainage from surrounding fields into low-lying areas near the river. These practices were to assist farmers in those areas who were attempting to fill in and grade flood terraces and oxbow lakes to make them suitable for farming. Additionally, imported irrigation water from both State and federal projects contributed to the sediment loading by also directing agricultural return flows to the river through “wasteways.” These wasteways were originally intended to carry excess flows from the canals back to the river. Since the wasteways cut off older drainage ditches, agreements were made to allow the farmers to discharge their agricultural tailwater into them. This has caused substantial sedimentation to occur, both in the “wasteways” themselves and in the receiving river channel. Current practices are attempting to retain agricultural tailwater on site.

The accumulation of sediment over time has flattened the northern downstream reaches of the San Joaquin River, increasing travel time and decreasing channel capacities. Because of this, operators of the Merced, Tuolumne, and Stanislaus river reservoirs need to consider downstream conditions before evacuating their flood management reservation storage (USACE, 2001).

*Anthropogenic Modifications*

Since the beginning of civilization, river systems have been changed due to anthropogenic or human activities. Urbanization has increased impervious surfaces such as pavement and buildings, which do not allow percolation of water to the aquifer. Instead, the water flows to stormwater runoff drains, where erosion (which can reduce crop productivity) and siltation, as well as flooding can be major problems. Pollutants on impervious surfaces of urban areas are carried by runoff and contribute to water contamination in the receiving waters. All of these activities change the natural process of flooding. Other human activities such as farming, overgrazing, logging, and mining have increased sediment loads to rivers. The average residence time of rivers (the average time a water molecule will spend within a reach) has increased due to river flow being dammed or diverted. River characteristics such as temperature, stratification, turbulence, turbidity, and reduction-oxidation conditions have also been altered due to human activities.

***Mercury/Heavy Metals Transport***

Mercury contamination from historic gold mines and natural cinnabar deposits represents a potential risk to human health and the environment. Total mercury production in California between 1850 and 1981 was more than 220,000 tons (Alpers and Hunerlach, 2000). Although most of this mercury was exported around the Pacific Rim or transported to Nevada and other western states, a significant portion (about 12 percent, or 26,000 tons) was used for gold recovery in California, mostly in the Sierra Nevada and Klamath-Trinity Mountains. The northwestern Sierra Nevada region has been mined extensively for both its hardrock-gold and placer-gold deposits. Currently the highest levels of mercury bioaccumulation occur in the Bear River and South Yuba River basins. In soil, each mercury component is subject to leaching and runoff of the dissolved phase, erosion of the particulate phase, and volatilization of the gas phase.

Streambed sediment of Cache and Putah creeks are significant sources of mercury and methylmercury to downstream receiving bodies of water. Much of the mercury in these sediments is the result of deposition over the last 100 to 150 years by either stormwater runoff, from abandoned mines, or continuous discharges from geothermal activity in areas of natural mercury deposits. Fish from lower Cache Creek have elevated mercury levels. During periods of high runoff, large loads of mercury come down Cache Creek and enter the Yolo Bypass. Smaller amounts of mercury are also released into the Yolo Bypass during low summer flows. Mercury from the Cache Creek Basin appears to be a major source of mercury entering the Delta.

### *Groundwater Recharge and Flood Management*

Traditional urban flood management focused on constructing networks of concrete conveyance channels that funnel and transfer urban stormwater runoff into the closest receiving waterbody (e.g., bays, ocean, rivers, lakes). Traditional urban flood management structural water quality management practices include detention basins and other devices used to store volumes of runoff to reduce peak flows. These methods reduce infiltration and groundwater recharge. Alternative methods of urban flood management include reducing impervious surfaces throughout a watershed and flooding groundwater recharge areas within the watershed, thereby reducing peak storm volumes. In addition, setting back levees to allow rivers and streams access to their natural floodplains can enhance recharge while reducing flood stages (SWRCB, 2009).

Rates of groundwater extraction in the Central Valley have the ability to impact flows in rivers and streams. Under current conditions, most areas of the northern Sacramento River Basin are full and discharge excess recharge to streams. If pumping increases, the volumetric rate of discharge to streams will decrease, but the groundwater basins will remain essentially full unless groundwater pumping rates exceed the volumetric rate of groundwater recharge (DWR, 1978). In the southern portions of the Sacramento River Basin, in areas such as the Sacramento Metropolitan Area and eastern Yolo County, cones of depression resulted because of intensive agricultural and municipal groundwater production. In these areas, the cones of depression extend beneath streams. As a result, some of these streams no longer receive groundwater discharge and instead leak surface water to the underlying aquifer.

The San Joaquin River Basin is heavily reliant on groundwater. Groundwater accounts for 30 percent of water use in the San Joaquin River Basin. The extensive use of groundwater in the San Joaquin River Basin has historically caused subsidence of the land surface, primarily along the west side and south end of the river basin (DWR, 2003a).

#### *Subsidence of Land Surface*

Subsidence of the land surface resulting from compaction of underlying formations affected by the decline of groundwater surface elevations, as well as by inundation of collapsible soils, is a well-documented concern throughout much of the Central Valley. Historically, land subsidence has occurred at higher rates in the San Joaquin River Basin than in the Sacramento River Basin. Differential subsidence of land surfaces has adverse impacts on the performance of flood control facilities. In the Sacramento River Basin, subsidence, along with other factors, has increased the extent of flooding along the Colusa Basin Drain and reduced

the capacity of the Knights Landing Ridge Cut, which conveys drainage from the Colusa Basin into the Yolo Bypass (USACE, 2002a).

Within the southern part of the San Joaquin River Basin, groundwater-withdrawal and hydrocompaction of the soils by irrigation has led to accelerated subsidence since the 1920s. Differential subsidence due to groundwater overdraft has adversely affected the performance of the flood management system in the upper region. A maximum of about 30 feet of subsidence occurred in the Los Banos-Kettleman City area, but 1 to 10 feet of subsidence occurred along portions of the San Joaquin River between Mendota and Los Banos, at an average rate of 1.4 inches/year, depending on the rainfall (USACE, 1999). Upstream from the area of greatest subsidence, the stream gradient has steepened, increasing downcutting of the channel and threatening the stability of levees and flow-management structures. The eroded material is deposited in the subsided section, reducing its conveyance capacity. A specific example of this problem is in the Chowchilla Canal – Eastside Bypass, where subsidence has caused increased sedimentation that has reduced conveyance capacity. Downstream from the subsided section, the stream gradient becomes flatter, also decreasing conveyance capacity.

Subsidence of land surfaces due to the loss of topsoil is an important concern in the Delta, placing much of the Delta below sea level. The Delta used to be waterlogged and anaerobic, and the organic soils accumulated faster than they could decompose. With the reclamation of the Delta, more peat soils are exposed to the atmosphere and are subject to an increased rate of microbial oxidation. In addition, compaction of organic-rich soils due to farming activity and loss of peat soils by wind are also primary causes of Delta subsidence. The rate of loss of peat soils from the Delta islands varied by location and averages 0.5 to 1.5 inches of soil loss per year (USACE, 1999).

#### *Floodplains*

Historically, natural floodplains attenuated floods by storing water on the plains and letting it seep slowly back into the ground. Table 2-1 shows the natural and beneficial functions of floodplains. Most of the rivers in the Sacramento and San Joaquin river basins have now been confined to leveed channels, cutting them off from their historic floodplains, resulting in alterations of natural hydrologic and hydraulic processes. Some of the natural floodplains are used as bypasses for flood flows for flood management. These bypasses also provide an important habitat function.

**Table 2-1. Natural and Beneficial Functions of Floodplains**

| Water Functions | Biological Functions | Societal Functions |
|---|---|---|
| **Natural Flood and Erosion Control**<br>• Flood storage and conveyance<br>• Reduces flood velocities and peak floods<br>• Reduces sedimentation<br>**Maintenance of Water Quality**<br>• Filters nutrients and impurities from runoff<br>• Processes organic wastes<br>• Moderates water temperature fluctuations<br>**Groundwater Recharge**<br>• Promotes infiltration and aquifer recharge<br>• Reduces frequency and duration of low flows | • Provides essential life history features (breeding, rearing, migratory) for many species, including waterfowl, sensitive species, and highly productive habitats<br>• Provides natural habitat renewal processes, including sediment transport, channel migration, and vegetation recruitment | • Replenishes soil fertility with nutrients<br>• Provides open space and visually pleasing landscapes<br>• Protects important historical and archaeological features |

Figure 2-1 shows the Federal Emergency Management Agency (FEMA) Q3 and DFIRM data for the 500-year floodplain in the Central Valley.

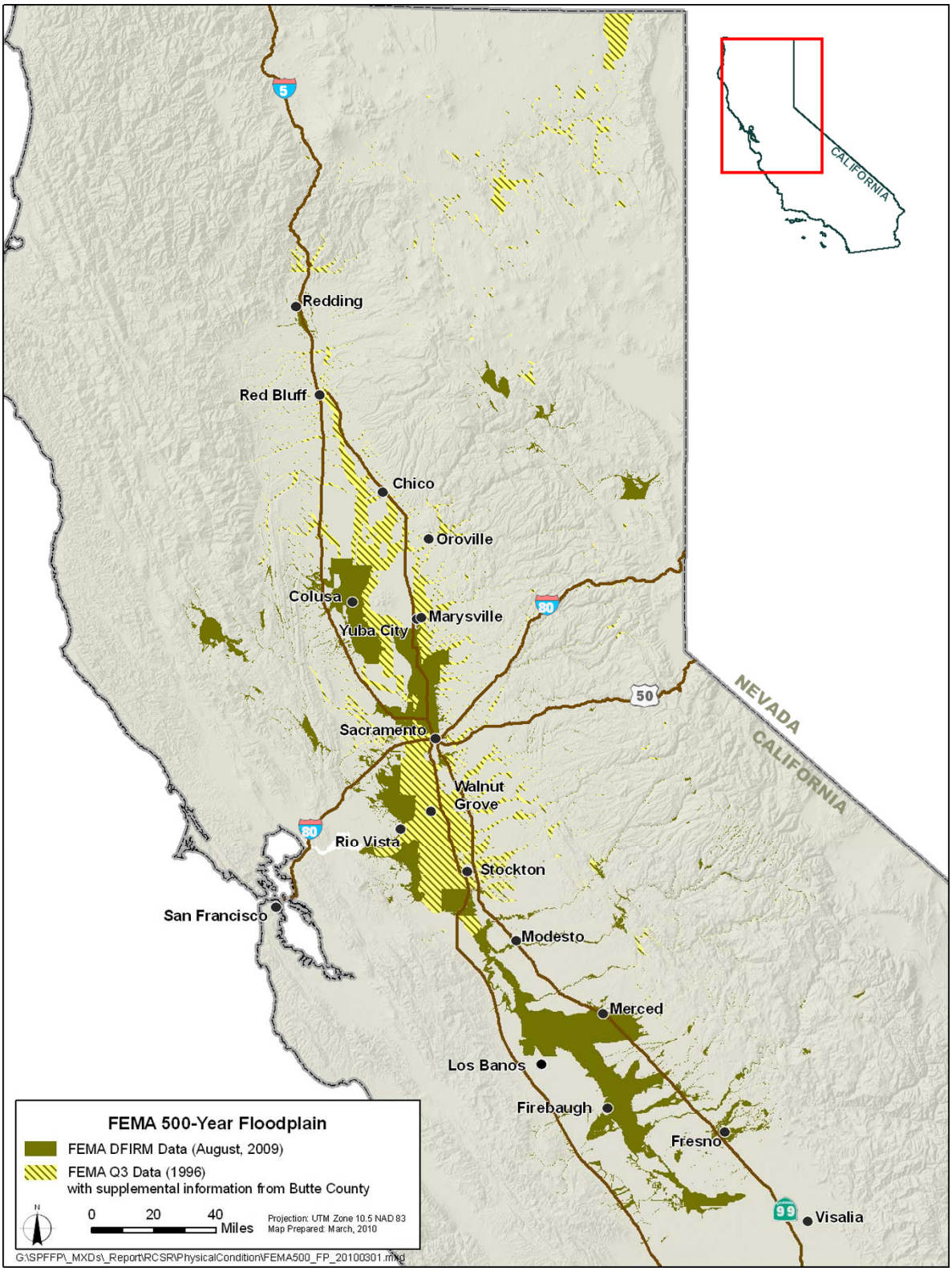


**Figure 2-1. FEMA 500-Year Floodplain in the Sacramento and San Joaquin River Basins**

**Yolo Basin** 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 Yolo Bypass consists of a 59,000-acre, mostly leveed, floodplain within the greater Yolo Basin (USACE, 1999). The existing east levee of the Yolo Bypass downstream from West Sacramento is a levee that protects the Sacramento Deep Water Ship Channel. The original levee, the project levee, is now the east levee for the Sacramento Deep Water Ship Channel. 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 SRFCP that began operation in the 1930s. The construction of the Sacramento Deep Water Ship Channel encroached into the Yolo Bypass, thus reducing its capacity from West Sacramento to the Delta.

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 to help maintain the flood flow capacity of the bypass. The water then flows over a 1,740-foot concrete weir into the Yolo Bypass (USACE, 1999). The Yolo Bypass also receives flow from westside tributaries Putah Creek and Willow Slough, as well as from the Knights Landing Ridge Cut. Monticello Dam, which forms Lake Berryessa and individually provides major flood control, is on Putah Creek.

Water in the Yolo Bypass results from seasonal flooding in the winter and spring, agricultural return drainage, and tidal backwater in the lower half of the bypass. Spills over the Fremont Weir, when the water surface in the Sacramento River at the weir exceeds 40.3 feet above mean sea level (msl), are the principal cause of widespread inundation of the bypass. Historically, spills at the Sacramento Weir have only occurred during those times when flow is also spilling over the Fremont Weir. Contribution from the four main tributaries, Cache Creek, Putah Creek, Willow Slough Bypass, and the Knights Landing Ridge Cut, is relatively small in comparison to flows over the Fremont and Sacramento weirs. While complete inundation is nearly always attributed to the weirs, the tributaries themselves can cause inundation of portions of the bypass.

Water entering the bypass from the Fremont Weir initially travels along the eastern margin of the bypass due to the natural slope of the land. Overland flow from the weir travels about 40 miles before reentering the Sacramento River near Rio Vista. Non-floodwaters exit the bypass primarily through the east levee toe drain. Numerous distributaries flow through the low-lying tidal area of the Delta.

The bypass floods approximately once every 2 to 3 years, as dictated by the operations of the Fremont Weir, generally during the winter months of December, January, and February. However, in 1998, water entered the bypass in June. Flow depth in the bypass ranges from 6 feet in a normal year to 10 feet in a heavy water year (USACE, 1999). High stages in the Yolo Bypass can affect flows/stages in the Knights Landing Ridge Cut, Colusa Basin Drain, Putah Creek, Willow Slough, and other tributaries.

**Upper and Lower Butte Basin** Butte Basin is the northernmost of the regulated overflow basins flanking the Sacramento River. Located east of the Sacramento River, it extends from southwest 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-Colusa county line divides Butte Basin into an upper basin and a lower basin.

The purpose of the Butte Basin overflow areas is to provide an orderly three-way split of flood flows between the basin and the Sacramento River channel such that flows in the river do not exceed channel capacity. 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 downstream from Chico Landing, through three State-regulated weir locations (USACE, 1999). The three overflow locations are M&T Weir, 3Bs, and Goose Lake Weir. In 1964, the Reclamation Board (now the Central Valley Flood Protection Board) (Board) adopted a plan of flood control for Butte Basin. This plan permits the orderly development of lands within the basin while maintaining the integrity of the SRFCP. DWR will maintain and operate units or portions of the works of the SRFCP, on behalf of the state, and the Operations and Maintenance (O&M) costs will be defrayed by the State. This includes flood relief structures or weirs, and other structures or facilities essential for the proper functioning of Glenn County Levee District (LD) 3 in the vicinity of the Sacramento River between Big Chico Creek and the north boundary. The Phelan Levee, on the east bank of the Sacramento River between the M&T Weir and Big Chico Creek, although not a federal project structure, is a structure or facility essential for the proper functioning of the Butte Basin Overflow Area, as designed in 1964 and included in CWC Section 8361.

The Phelan Levee is a component of the flood control measures that maintain the proper flow split among the SRFCP levees and the overflow areas east of the river. If the Phelan Levee is lost due to continued erosion, an excessive amount of flow could overflow Angel Slough. The flooding would be disastrous for the Butte Basin and could endanger the integrity of the SRFCP levees (Water Engineering and Technology, Inc., 1989).

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 MAF when it is flowing full and has a travel time of about 2 days from its upper end to the Sutter Bypass (USACE, 1999). Sedimentation at the 3Bs overflow flood relief structure may affect the storage and conveyance capacity of the basin.

The federal flood management project envisioned in the 1950s included a flood bypass through the Butte Basin. This component was not included due to economic impacts.

**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 1850s eventually drained much of the wetland area.

The Colusa Drain, a leveed channel completed in the 1930s, 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 (USACE, 1999). The Knights Landing Ridge Cut, on the southern end of the Colusa Drain, provides an outlet for flood flows (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. The Ridge Cut is an artificial channel that allows some drainage of flood water from the Colusa Basin Drain when the Sacramento River level is high. Flows from the Colusa Drain enter the Sacramento River via outfall gates

at Knights Landing when the river is low. The Knights Landing Outfall Structure controls the direction of flows out of the Colusa Basin Drain and also prevents the backwater from the Sacramento River entering into the drain.

**Upper Lake Valley** Middle and Scotts creeks, the two largest tributaries to Clear Lake, had extensive floodplains. Historically, Middle and Clover creeks frequently flooded downtown Upper Lake and adjacent areas with depths of 1 to 3 feet (USACE, 1999). Clover Creek flowed through the center of town and had a limited channel capacity.

The project consists of 14.6 miles of levees, two diversion structures, and a flood water pumping station. Project levees protect the community of Upper Lake, SR 20 and SR 29, and nearby agricultural land from flooding from Middle, Scotts, and Clover creeks. Levees contain the flows of Middle and Scotts creeks within the channels, while a majority of the flows of Clover Creek are diverted around the northern side of Upper Lake to Middle Creek. The levee system contains flows, however the lack of interior drainage facilities in and west of Upper Lake has resulted in localized flooding, causing flood damage and closing both SR 20 and SR 29.

Approximately 3.5 miles of the levees, one pump station, and one diversion structure protect 1,650 acres from flooding by Clear Lake. These levees were constructed on top of old Reclamation District (RD) levees and have significant foundation problems. Review of historical records indicates the levees were not constructed to U.S. Army Corps of Engineers (USACE) standards. The levees were conditionally accepted by the State in 1961. High-water years in 1983 and 1986 showed the levees were significantly below design grade and properties were at an elevated risk of flooding.

**Sutter Basin** Before construction of the flood management system, the Feather River historically overflowed toward the west during major flood events, mingling with flood flows in the Butte and Sutter basins. The Sutter Bypass conveys flows to the lower Sacramento River at the Fremont Weir near the confluence with the Feather River and into the Sacramento River and the Yolo Bypass. The Sutter Basin is enclosed by the Sutter Bypass levee on the east, the Sacramento River levee on the west, and the Tisdale Weir levee on the north.

**San Joaquin River Basin** The San Joaquin River Basin extends from the Delta in the north to the Kings River in the south, and from its headwaters upstream from Friant Dam in the Sierra Nevada in the east to the Coast Ranges in the west. The river basin encompasses about 13,500 square

miles at the southern boundary of the Delta, and a total drainage area of 16,700 square miles (USACE, 1999).

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.

Basins 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 often 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 flood flows reached the valley floor, they spread out over the lowlands, creating several hundred thousand acres of permanent tule marshes and seasonally flooded wetlands.

#### *Channel Geometry/Capacity*

O&M manuals were developed for all levees, channels, and flood control facilities comprising the SPFC. The O&M manuals provided the design capacity of each facility. Other design capacities were available for some facilities from other studies or maps, and were also gathered. The design capacities for reaches of the Sacramento River and tributaries are referenced in the O&M manuals. Estimates of channel design capacities obtained from O&M manuals and from other sources do not always agree.

#### *Routing of Flood Waters*

The volume of flow in the Sacramento River system generally increases as it moves south toward the Delta as the number of tributaries feeding the river increases as the flow continues further downstream. The size and capacity of the Sacramento River generally decreases in the downstream direction due to increased sediment deposition. Historically, flood flows spilled into adjacent flood basins that were separated from the main stem by natural levees. The sheer magnitude of flood flows that entered these adjacent flood basins created several distributary flood paths across the flat valley floor into which the main stem would spill. The Yolo Basin, west of

Sacramento, and the American Basin, northeast of the confluence of the Sacramento and American rivers, are two of these historic overflow basins. These overflow basins are extremely sensitive to changes upstream in land use and local flood runoff.

The lower end of the Yolo Bypass and the Sacramento Deep Water Ship Channel, which runs along the east levee of the Yolo Bypass, are controlled by tidal backwater. Minor tributaries flowing into the west side of the Yolo Bypass include Cache Creek, Willow Slough, and Putah Creek. Knights Landing Ridge Cut enters the Yolo Bypass near the north end and redirects water from the Colusa Basin Drain into the Yolo Bypass. Numerous distributaries flow through the low-lying tidal area of the Delta.

Flood management operations are complicated by the natural delay in moving the regulated water down the system and the propensity to pass all floodwaters down to the Delta, rather than routing water to upstream floodplains or bypasses. It takes about 62 hours for water released from 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 (USACE, 1999). 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 to reach Verona, however, 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 flood flows from the Feather-Yuba and American rivers arrive at the same confluence. It is hard for Shasta operators to predict that a major storm will occur over the Feather and/or American river basins 2 days into the future and 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 and the storm intensity are not easily predicted.

For the San Joaquin River, the travel time for moving flood flows down the river system also 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 (USACE, 1999). 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 New 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 basins, 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 flood flows from the other rivers. Because the San Joaquin River water may have been 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 (USACE, 2001). The operators of the Merced, Tuolumne, and Stanislaus river reservoirs need to consider downstream conditions before evacuating their flood management reservation storage.

#### *Water Quality*

In general, water quality in the Sacramento River is good; however, there is concern about the possible effects associated with metal contamination from abandoned mercury and other hard-rock mining activities. As described previously, elevated mercury levels are detected in sediment in the Yuba and Bear rivers and in Cache, Putah, and Stony creeks, as well as in the sediments of other streams and rivers in the Sacramento River Basin. Another source of pollutants in the rivers is from the agriculture water returned to the river after the irrigation season, and from dewatered rice fields. Wastewater treatment effluents, ammonia, and storm drains are another source of pollutants to the rivers from urban areas.

Surface water quality in the San Joaquin River Basin is affected by several factors, including natural runoff, agricultural return flows, biostimulation, construction, logging, grazing, operations of flow-regulating facilities, urbanization, and recreation. In addition, irrigated crops grown in the western portion of the San Joaquin River Basin have accelerated the leaching of minerals from soils, altering water quality conditions in the San Joaquin River system.

The upper reaches of the rivers draining to the San Joaquin River Basin originate in large drainage areas high on the west side of the Sierra Nevada. The water in these rivers is generally soft, with low mineral concentrations. As these streams flow from the Sierra Nevada foothills across the eastern valley floor, their mineral concentrations steadily increase. This increase is fairly uniform for each of the eastside streams as in the Sacramento River Basin.

In the western part of the San Joaquin River Basin, soils are derived mainly from the marine sediments that make up the Coast Ranges and are high in salts and trace elements, such as asbestos, selenium, molybdenum, arsenic, and boron. As the San Joaquin River Basin has undergone extensive land development, erosion and drainage patterns have been altered, accelerating the rate at which these trace elements have been dissolved from the soil to accumulate in shallow groundwater, streams, and the San Joaquin River.

Water quality challenges in the Delta include mercury methylation, salinity levels, dissolved oxygen levels, and pesticide and herbicide runoff. Episodes of oxygen depletion in some parts of the Delta are caused by operation of upstream facilities that cause relatively low river flows, algae growth fueled by high nutrient concentrations, and waste discharges.

The entire Delta is on the State Water Resources Control Board (SWRCB) list for impaired water bodies for mercury. Delta areas that are intermittently flooded, such as tidally influenced shallow water, can be primary sites for mercury methylation. The methylation process converts inorganic mercury found in sediment deposits into methylmercury, which is a toxic substance affecting wildlife and human health.

Delta salinity is influenced by tidal action and from return flows from agricultural and urbanized lands. Before the construction of today's water supply and flood control facilities in the Delta, salinities were lower in the winter and spring and higher in the summer and fall. Today, the Water Right Decision 1641 (D-1641) mandates the implementation of water quality objectives for the Bay-Delta for municipal and industrial beneficial uses, agricultural uses, and fish and wildlife beneficial uses. These objectives include chloride concentration at Delta intakes and pumping plants, electrical conductivity for western Delta, San Joaquin River, interior Delta, southern Delta, and Suisun Marsh.

Saline water flows into the western Delta through tidal influence. When the export pumps draw Sacramento River water from the northern Delta into the southern Delta, some of that salt water is exported to Southern California by the State Water Project (SWP) pumps via the California Aqueduct, or into the San Joaquin River watershed by the CVP pumps via

the Delta-Mendota Canal. This salt is concentrated by farm crop and wetland water consumption. Some salt then accumulates in valley soils and groundwater, but several thousand tons of salt each year seeps, drains, or gets discharged into the San Joaquin River.

#### *Air Quality*

The Sacramento River Basin is within the Sacramento Valley Air Basin. During the summer, the Pacific high-pressure system can create inversion layers in the lower elevations that prevent the vertical dispersion of air in most of the Sacramento Valley Air Basin. As a result, air pollutants in this portion of the region can become concentrated during summer, lowering air quality. During the winter, when the Pacific high-pressure system moves south, stormy, rainy weather intermittently dominates the region and also winter inversions are very persistent. Prevailing winter winds from the southeast disperse pollutants, often resulting in clear, sunny weather and better air quality over most of this portion of the region. Much of the Sacramento Valley Air Basin is designated as a nonattainment area with respect to the national and State ozone and particulate matter standards, and the urban Sacramento and Marysville/Yuba City areas are designated as nonattainment for national and State carbon monoxide standards.

The San Joaquin River Basin is within the San Joaquin Valley Air Basin, which is designated as nonattainment with respect to the national and State ozone and particulate matter standards; the urban areas of Fresno, Modesto, and Stockton are designated as nonattainment for national and State carbon monoxide standards. Several variables other than land uses can affect air quality conditions, and these variables may change over time. Air quality problems result from the region's geographic location, topography, climate, population growth, and economic activities. The San Joaquin Valley Air Basin is affected by air pollution from the Sacramento and San Francisco Bay metropolitan areas, as well as Stockton, Modesto, and Fresno.

#### *Climate and Meteorology*

A dominating factor in the weather of California is the semipermanent high-pressure area of the northern Pacific Ocean. This pressure center moves northward in summer, holding storm tracks well to the north and, as a result, California receives little or no precipitation from such storms during summer. In winter, the Pacific High retreats southward permitting storm centers to swing into and across California. These storms bring widespread, moderate precipitation to the State. Some of them travel far enough to the south to spread moisture beyond the Mexican border. When changes in the circulation pattern permit storm centers to approach the California coast from a southwesterly direction, copious amounts of moisture are carried by the northeastward streaming air. This results in heavy rains and often produces widespread flooding during the winter

months. Precipitation in the Coast Ranges is higher at a given elevation and the region is much less dependent on snowfall (approximately 95 percent or more of precipitation falls as rain).

The surface of the ocean also responds to changes in atmospheric pressure and winds. When a storm moves into a costal location the air pressure is usually low, which causes the water level to rise. If the wind is also blowing across the ocean toward land, water is pushed in that direction. This combination can cause the water level to rise several feet, causing as much damage as the other effects of the storm. The storm tides are of course not regular and periodic, as are the gravitational tides. While tidal forces can be accurately calculated and predicted from astronomical observation, the response of the ocean to those forces depends on the shape of the shore line and the topography of the ocean bottom. These tidal storms affect water levels and flood stage conditions in Suisun Bay and the Delta.

In the northern portion of the Sacramento River Basin, 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.

In the southern portion of the Sacramento River Basin, the Sacramento River Basin floor is relatively flat. 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. The wet season runs from October to April but it is not unusual for precipitation to occur in September or May.

Weather patterns in the San Joaquin River Basin are similar to those in Sacramento River Basin, although the humidity and precipitation tend to be lower. Except at the highest altitudes, the climate of the San Joaquin River Basin is characterized as semiarid to arid with hot, dry summers and mild winters. The annual precipitation in the San Joaquin River Basin ranges from about 6 inches on the valley floor at Mendota to about 70 inches in the Sierra Nevada. Precipitation in the valley occurs primarily from November to April. The basins on the west side of the valley that drain the Coast Ranges lie in a rain shadow and receive less precipitation than those on the east side of the valley that drain the Sierra Nevada. Snowpack accumulates on the east side of the basin above 5,000 feet, and the snowmelt generally begins to run off by April. On the valley floor,

precipitation decreases from north to south, ranging from 15 inches at Stockton to 5 inches at Bakersfield.

**Prevailing Wind Patterns** California lies within the zone of the Prevailing Westerlies and on the east side of the semipermanent high-pressure area of the northeast Pacific Ocean. The basic flow in the free air above the State, therefore, is from the west or northwest during most of the year. The Coast and the Sierra Nevada mountain ranges deflect winds, making wind direction in the Central Valley dependant on local terrain more than the prevailing regional circulation.

The Carquinez Strait, a major gap in the Coast Ranges at the northeastern end of the San Pablo Bay and extending eastward to the Delta, is a critical feature controlling the wind flow patterns in the Sacramento and San Joaquin river basins. Marine air flows through the Carquinez Strait, moves east through the Delta, and then splits to flow north into the Sacramento River Basin or south into the San Joaquin River Basin. The intensity of the marine air penetration varies with a diurnal cycle, being strongest in the afternoon and evening, with wind speeds of 15 to 20 miles per hour. Wind patterns are also characterized by the upslope flow over the Sierra Nevada. The southerly and northerly wind patterns in the Sacramento and San Joaquin river basins are prevailing directions year-round due to the north-south orientation of the Central Valley. Occasionally, a strong high-pressure region moves inland to the north or northeast, forcing strong northerly winds through the Sacramento River Basin.

Winds in the Delta are predominantly westerly and follow a diurnal pattern in strength, with highest speeds during the afternoon and evening. Wind gusts in the Delta can reach up to 45 miles per hour. Open water bodies in the Delta experience high wave actions during strong wind conditions. These wave actions can lead to overtopping and erosion along Delta levees, especially during high-stage conditions.

#### *Seismic Conditions*

The Delta lies near six major faults that are capable of generating moderate-to-strong ground shaking, particularly in the western Delta. The three most active faults are the San Andreas, Hayward, and Calaveras faults. Liquefaction of foundation sands under some levees during a moderate-to-strong earthquake has the potential to cause failures of miles of Delta levees.

However, no Delta levee has ever failed from an earthquake. The San Francisco earthquake in 1906 with a 7.8 magnitude was a significant event, but levees were much lower then. Since the mid-1990s, levees have been built higher due to increasing concerns for land subsidence and flooding. These levees now are likely to fail during a major earthquake, such as the one in 1906 (Lund et. al., 2008). Levees in Suisun Marsh are not as high as those in the Delta, but they are much closer to several fault lines.

Relatively lower seismic activity characterizes both the Sacramento and San Joaquin river basins. The potential to cause levee failures is also lower because most levees in this area only hold water back during significant flood events.

### 2.1.2 Infrastructure

This section describes the existing flood management and related infrastructure in the Sacramento and San Joaquin river basins.

#### *History of Flood Management Facility Construction, and Operations and Maintenance*

This section summarizes the history of construction and subsequent O&M of SPFC facilities. Components of flood management in the Central Valley, with emphasis on components of the SPFC, are also described. The facilities discussed include the early flood management system in the Central Valley, non-project levees (briefly described as they tie into, and affect performance of, the SPFC), flood management-specific projects, and multipurpose projects. Figure 2-2 shows the locations of federal-State flood damage reduction projects within the Sacramento and San Joaquin river basins that comprise the SPFC.

In the late nineteenth century, individual landowners and local governments built the first flood management facilities in the Central Valley, usually levees. Farmers often worked with (or against) their neighbors to build levees to protect their own crops and property. Cities built levees to ensure public safety in urban areas. As part of the Arkansas Act, prospective landowners could acquire land throughout the Central Valley for $1 per acre if they paid to construct levees to "reclaim" land for agricultural production, some of which exists as islands in the Delta today. Landowners often created levee maintenance districts, reclamation districts, or other entities that were charged with maintaining the levees (Assembly, 2007).

In 1911, the State adopted the federal government’s plan for the SRFCP from the California Debris Commission and created the Board (formerly

known as the Reclamation Board)[12] to implement the plan, in conjunction with the federal government. The State's adoption of a valley-wide flood management plan was meant to resolve conflicting local flood management projects. Six years later, the State gained federal authorization for USACE to collaborate with the State in constructing and maintaining the SRFCP. The flood management system in the San Joaquin River Basin continued to be constructed and operated and maintained in the older, piecemeal fashion.

After construction began on the SRFCP in 1918, the State and federal governments shared responsibility for building and repairing new and locally built levees, weirs, and bypasses to increase conveyance of flood waters downstream. During construction of the SRFCP beginning in 1918, and construction of the Lower San Joaquin River and Tributaries Project (LSJRTP) beginning in the 1950s, USACE often constructed the federal "project levees" in both the Sacramento and San Joaquin river basins from existing locally built levees (Assembly, 2007).

[12] The Reclamation Board became the Central Valley Flood Protection Board in 2007.

**Figure 2-2. Approximate Locations of Federal/State Flood Damage Reduction Projects Within the Sacramento and San Joaquin River Basins that Comprise the State Plan of Flood Control**

Current responsibility for SPFC O&M is spread among multiple agencies at all three levels of government: local, State, and federal. Consistent with the U.S. Constitution's Commerce Clause, USACE has primary responsibility for regulating flows (including floodwaters) in "waters of the United States," which include the Sacramento and San Joaquin rivers. Some of the federal reservoirs in the Central Valley with reserved flood management space are operated by U.S. Department of the Interior, Bureau of Reclamation (Reclamation) under direction from USACE (Assembly, 2007). Other reservoirs are owned and operated by USACE or owned and operated by State and local interests with flood management space managed by USACE (e.g., Lake Oroville).

The State – through the Board – shares in the costs of construction, assumes responsibility for O&M of the flood management facilities, and indemnifies the federal government for liability. The Board has the legal responsibility for oversight of the entire Central Valley flood management system, although responsibility resides, administratively, with DWR or local flood agencies and LDs (Assembly, 2007). DWR's primary responsibilities lie in the Sacramento River Basin, while local agencies have most of the responsibility in the San Joaquin River Basin.

DWR plays a significant role in the SPFC, with field staff maintaining approximately 300 miles of levees and other flood management facilities, according to the statute. DWR inspects and evaluates the maintenance of approximately 1,600 miles of the State's federally designated project levees and channels. DWR does levee maintenance for parts of the Sacramento River system according to statute. While most project levees are maintained by local agencies, DWR performs some levee maintenance by forming maintenance areas that abide by the assurances that the State provided to the USACE where local interests are unable to perform satisfactory maintenance. In those cases, DWR assesses the property owners for the cost of carrying out the maintenance. DWR primarily maintains the system channels on the Sacramento River, while local agencies primarily maintain San Joaquin River system channels (Assembly, 2007).

Local agencies, including levee maintenance districts and RDs, counties, cities, and water districts, also play a significant role in flood management. In many areas, local agencies maintain and operate project levees and other flood management facilities on the State's behalf (Assembly, 2007). In 1996, State and federal law shifted greater financial responsibility for flood management facility construction to local agencies, which today typically pay 35 percent of construction or rehabilitation costs for State-federal project facilities. In other cases, local agencies pay the entire cost of flood

management, but remain subject to Board and USACE oversight (Assembly, 2007).

**Early Flood Management System** The early flood management systems in the Sacramento and San Joaquin river basins was constructed, operated, and maintained in a piecemeal fashion by local interests settling along the rivers and their tributaries. The first levee was built around the City of Sacramento in 1850, and was 3 feet high by 26 feet wide. It was constructed, operated, and maintained by the City of Sacramento. Early levees were also constructed by individual farmers to protect their agricultural lands and farmsteads from frequent flooding. The early levees along the Sacramento River were built with shovel and wheelbarrow, using soil from the land side of the levee because it was impossible to get the sand from the river, and the sand was considered poor material for levee building. The earliest dredges were dipper dredges, first recorded in use in 1871 on Webb tract in the Delta (Oakland Daily News, 1871). The clamshell dredger was first used in 1889 along the Sacramento River near Courtland, and employed subsequently to build much of the rest of the early levee system in the Sacramento River Basin. A clamshell dredger was a large piece of equipment that excavated sediment from the river bottom and piled it along the banks for levee building (Evans, 1912).

As LDs and RDs were formed along the Sacramento River, those districts built their own levees to “reclaim” their agricultural land and protect property from frequent flooding (Kelley, 1989).

**Federal Authorizations for Existing State-Federal Flood Protection Projects** This section shows the federal authorizations for each of the existing State-federal flood protection projects included in the SPFC. The projects are organized as Sacramento River Basin projects, San Joaquin River Basin projects, and other facilities with State assurances. While each authorization covers one major project, such as the SRFCP, implementation of the projects generally occurred over time with the construction of various units of the projects. Some levees are physically disconnected from the larger system and were constructed to provide local benefits while others were constructed to provide system benefits.

*Sacramento River Basin Projects*

The majority of the State-federal flood protection projects that constitute the SPFC are located in the Sacramento River Basin. Federal authorizations for projects described below began in 1917 and extended into the 1980s. Some projects authorized by later federal authorizations may eventually become part of the SPFC.

- **Sacramento River Flood Control Project –** The SRFCP is the core of the flood system along the Sacramento River and tributaries. It includes most of the levees, weirs, control structures, bypass channels, and river channels that make up the SPFC. About 980 miles of levees were involved in the project. Portions of these levees were originally constructed by local interests and either included directly in the project without modification or modified to meet USACE project standards. The project was originally authorized by the Flood Control Act of 1917 and subsequently modified and extended by the Acts of 1928, 1937, and 1941. Cost changes over time are reflected in these acts along with rectification, additions, and deletions.

  - **Flood Control Act of 1917** – Public Law 64-367 (64th Congress) is the Flood Control Act of 1917. The authorized project was in accordance with plans contained in the California Debris Commission report submitted on August 10, 1910, and printed as House Document (HD) 81 (62nd Congress), as modified by the California Debris Commission report submitted on February 8, 1913, and printed in Rivers and Harbors Committee Document No. 5 (63rd Congress). The 1913 document provides for the rectification and enlargement of river channels and the construction of weirs.

  - **Flood Control Act of 1928** – Public Law 70-391 (70th Congress) is the Flood Control Act of 1928. The 1928 act modified the Flood Control Act of 1917 in accordance with the California Debris Commission report submitted on May 1, 1924, and printed in Senate Document (SD) 23 (69th Congress). Some significant changes made by the act include the following:

    - Elimination of reclamation works in Butte Basin
    - Construction of a weir above Colusa
    - Elimination of two of the four proposed cutoffs in the stretch of river between Colusa and the mouth of the Feather River
    - Use of the existing Tisdale Weir instead of construction of a new weir
    - Relocation of certain levee lines on the Feather River and Yolo Bypass
    - Settling basin at the mouth of Cache Creek
    - Three sloughs in the Delta to be left open instead of closed

- Increase in levee cross-section dimensions
- Conclusion that San Joaquin River Basin flood problems are different from those of the Sacramento River Basin, and that flood control in the San Joaquin River Basin should be considered in a separate report, if deemed advisable
- Federal government to carry some maintenance responsibility (enlarged channels, of weirs, and of certain gages)
- Increase in the project cost
- Change of the cost share between the federal government and nonfederal interests
- Set design capacities

- **Rivers and Harbors Act of 1937** – Public Law 75-332 (75th Congress) is the Rivers and Harbors Act of 1937. The prior 1917 and 1928 flood control acts were modified in accordance with a Senate Commerce Committee Document (75th Congress). The document concluded that maintenance by the federal government was not consistent with policies of the Flood Control Act of 1936 (Public Law 74-738, 74th Congress). Additional work was required on revetment for eroding levees, and the project cost was adjusted. Requirements were added for local interests to provide rights-of-way and hold the federal government harmless from damage claims.

- **Flood Control Act of 1941** – Public Law 77-228 (77th Congress) is the Flood Control Act of 1941. The 1941 act modified previous acts in accordance with HD 205 (77th Congress). The act authorized federal expenditures for completion of the project, and required the following local cooperation:
  - Furnish all rights-of-way, including railway, highway, and all other utility modifications
  - Hold and save the United States free from damage claims
  - Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army

Construction of the SRFCP began in 1918 and continued for decades. By 1944, the project was regarded as being about 90 percent complete. The plan for completing the project was presented in the November 30, 1953,

"MOU Respecting the Sacramento River Flood Control Project" between USACE and The Reclamation Board (see reference DVD) (USACE and The Reclamation Board, 1953). This Memorandum of Understanding (MOU) included levee construction standards for river project levees and bypass levees, and outlined maintenance responsibilities. The plan included no difference in levee standards for urban versus agricultural levees. By 1961, the project was essentially completed (Kelley, 1989).

Some documents refer to the project from these authorizations as the "Old" Sacramento River Flood Control Project.

- **Sacramento River and Major and Minor Tributaries Project –** The Sacramento River and Major and Minor Tributaries Project was initially authorized by the federal government in the Flood Control Act of 1944 (Public Law 78-534, 78th Congress), and was further amended by the Flood Control Act of 1950 (Public Law 81-516, 81st Congress). The project was a modification and extension of the SRFCP, and was to supplement reservoir storage by reducing the flooding potential to certain areas along the Sacramento River.

  The project provided for levee construction and/or channel enlargement of the following minor tributaries of the Sacramento River: Chico and Mud creeks and Sandy Gulch, Butte and Little Chico creeks, Cherokee Canal, Elder Creek, and Deer Creek (Tehama County). In addition, the project also included revetment of levees for the Sutter, Tisdale, Sacramento, and Yolo bypasses. Minor tributary improvements were to reduce flood risk to about 80,000 acres of agricultural land important to the economy of the region and to the City of Chico and other smaller communities. Bypass levee revetment features of the project were to reduce flood risk to floodplain lands adjacent to the bypasses, and ideally would decrease requirements for levee repairs under emergency conditions (USACE, 1999).

- **American River Flood Control Project –** The American River Flood Control Project was authorized by the federal government in the Flood Control Act of 1954 to reduce flood risk along the lower American River. The project was constructed in 1958 by USACE, and includes approximately 8 miles of levee along the north bank of the American River between Carmichael Bluffs and the terminus of the SRFCP levee near the State Fairgrounds.

- **Sacramento River – Chico Landing to Red Bluff –** The Sacramento River project for bank protection and channel improvements from Chico Landing to Red Bluff was authorized by

the federal government in the Flood Control Act of 1950, as amended by the Flood Control Act of 1958 (Public Law 85-500, 85th Congress). The project was authorized in accordance with recommendations by the USACE Chief of Engineers in HD 272 (84th Congress). The project was a modification and extension of the SRFCP, and was to increase bank protection along the Sacramento River from Chico Landing to Red Bluff and lower portions of its principal tributaries to reduce flood risk with discharges modified by Shasta Dam and Black Butte Reservoir. This reservoir was planned to be constructed soon after the project. The area encompassed by the project included the Sacramento River from Chico Landing to Red Bluff, and lower portions of Antelope, Mill, Deer, Pine, Elder, Thomes, and Stony creeks (USACE, 1999).

- **Middle Creek Project –** The Middle Creek Project, upstream from Clear Lake, was authorized by the Flood Control Act of 1954, Section 203. The authorized project was in accordance with recommendations by the USACE Chief of Engineers in HD 367 (81st Congress). Authorizing legislation by the State of California is contained in Section 12656.5 of the CWC and was enacted under the California Statutes of 1955. This project reduces local flood risk.

- **Lake Oroville Project –** Federal participation in the construction of Oroville Dam was authorized by the Flood Control Act of 1958 (Public Law 500, 85th Congress). The federal interest was flood control provided by the flood control storage reservation of 750 thousand acre-feet (TAF). This authorization also included the non-SPFC New Bullards Bar and the Marysville Dam (not constructed at the time of this writing).

- **Sacramento River Bank Protection Project –** The SRBPP was authorized by the Flood Control Act of 1960 (Public Law 86-645, 86th Congress) to repair eroding levees along levee reaches of the Sacramento River. The project modifies the existing SRFCP through a program for bank erosion control works and setback levees within the limits of the existing levee system. Phases I and II have modified the SRFCP through construction of more than 835,000 linear feet of bank protection and setback levees. USACE and the Board will begin investigation of a Phase III in 2010.

- **North Fork Feather River Project –** The North Fork Feather River Project at Chester was authorized by Section 203 of the Flood Control Act of 1968 (Public Law 90-483, 90th Congress). The

authorized local project was in accordance with recommendations by the USACE Chief of Engineers in HD 314 (90th Congress). This project, consisting of a diversion dam, channel, and levees, reduces local flood risk.

- **Snagging and Clearing Projects –** The Continuing Authorities Program allows USACE to respond to a variety of flood problems without the need to obtain specific Congressional authorization for each project. Section 208 of the 1954 Flood Control Act, as amended, allows work to remove accumulated snags and other debris, and to clear and straighten stream channels. Three projects in the Sacramento River Basin are snagging and clearing projects:

  - **Adin Project** – A flood control project was authorized by the federal government for Ash and Dry creeks at Adin in Modoc County in the Flood Control Act of 1937, and modified by the Flood Control Act of 1954. Ash and Dry creeks are tributary streams to the Pit River above Shasta Dam. This project reduces local flood risk.

  - **Salt Creek Project** – The Salt Creek Project was authorized by Section 2 of the Flood Control Act of 1937, as amended by Section 208 of the Flood Control Act of 1954. This project reduces local flood risk.

  - **McClure Creek Project** – The McClure Creek Project was authorized by Section 2 of the Flood Control Act of 1937, as amended by Section 208 of the Flood Control Act of 1950. This project reduces local flood risk.

*San Joaquin River Basin Projects*

Components of the SPFC located in the San Joaquin River Basin include the LSJRTP, Littlejohns Creek and Calaveras River Stream Group Project, including the New Hogan and Farmington projects, and the Merced County Stream Group Project.

- **Lower San Joaquin River and Tributaries Project –** Improvement of lower reaches of the San Joaquin River and tributaries was authorized by the federal government in the Flood Control Act of 1944 (Public Law 78-534). The project provided for improvement by the federal government of the existing channel and levee system on the San Joaquin River from the Delta upstream to the mouth of the Merced River, and the lower reaches of the Stanislaus and Tuolumne rivers, by raising and strengthening existing levees, constructing new levees, constructing revetments on riverbanks where required, and removing

accumulated snags in the main river channel. The project also reduces flood risk for areas above the mouth of the Merced River through State construction of levee and channel improvements, authorized by the federal government in the Emergency Flood Control Funds Act of 1955. The project includes a State-designed and -constructed bypass system in the upper reaches of the project area. Project construction was completed in 1972.

- **Buchanan Dam and Eastman Lake Project –** The Buchanan Dam, Eastman Lake Project, was authorized by the Flood Control Act of 1962 (Public Law 87-874, 87th Congress) in accordance with recommendations by the USACE Chief of Engineers in SD 98. The dam and reservoir are not part of the SPFC, but the channel improvements downstream from Buchanan Dam on the Chowchilla River and tributaries are included in the SPFC.

- **Hidden Dam and Hensley Lake Project –** The Hidden Dam and the Hensley Lake Project were authorized by the Flood Control Act of 1962 (Public Law 87-874, 87th Congress) substantially in accordance with recommendations by the USACE Chief of Engineers in SD 37 (87th Congress). The dam and reservoir are not part of the SPFC, but the channel improvements downstream from Hidden Dam on the Fresno River are included in the SPFC.

- **Merced County Stream Group Project –** Improvement of the Merced County Stream Group was authorized by the Flood Control Act of 1944 (Public Law 78-534, 78th Congress). The authorization was based on HD 473 (78th Congress). The project includes a diversion from Black Rascal Creek to Bear Creek, a diversion between Owens Creek and Mariposa Creek, channel improvements and levees, and one retarding-type reservoir east of the City of Merced. The project reduces flood risk to agricultural areas, the City of Merced, and the towns of Planada and Le Grand and other smaller communities. Of the five authorized reservoirs, the State provided assurances to the federal government for only one reservoir, Castle Dam, authorized by the Flood Control Act of 1970 (Public Law 91-611, Section 201, Statute 1824).

- **Bear Creek Project –** The Bear Creek Project was authorized by the Flood Control Act of 1944 (Public Law 78-534, 78th Congress). Bear Creek is a tributary to the San Joaquin River in the Delta near Stockton. The Bear Creek channel and levee improvements are included in USACE Chief of Engineers recommendations to the Secretary of the Army in HD 545.

- **Littlejohns Creek and Calaveras River Stream Group Project –** The Littlejohns Creek and Calaveras River Stream Group Project was authorized by the Flood Control Act of 1944 (Public Law 78-534, 78th Congress). This act authorized improvement of Littlejohns Creek and Calaveras River and tributaries in accordance with recommendations by the USACE Chief of Engineers in HD 545. The project included a diversion from Duck Creek to Littlejohns Creek and other channel improvements and levees.

- **Farmington Dam Project –** The Farmington Dam Project was authorized by the Flood Control Act of 1944 (Public Law 78-534, 78th Congress). This act authorized improvement of Littlejohns Creek and tributaries in accordance with recommendations by the USACE Chief of Engineers in HD 545. Farmington Dam is not part of the SPFC, but channel improvements along South Littlejohns Creek and its north and south branches are included in the SPFC.

- **Mormon Slough Project –** The Mormon Slough Project was authorized by the Flood Control Act of 1962 (Public Law 87-874, 87th Congress). The authorization was in accordance with recommendations in HD 574. The USACE Chief of Engineers concurred with these recommendations in his 1962 report. The project includes channel improvements, levees, and pumping plants.

**Existing Federal Participation in Other Non-SPFC Flood Protection Projects** In addition to SPFC facilities, USACE has an interest and role in other flood management projects in the Central Valley. While these are not part of the SPFC, operation of these projects influences operation of the SPFC, especially in reducing flood peak flows through the SPFC levee system. The following information is provided in an overview level of detail to show other projects that function along with the SPFC as a flood protection system.

*Multipurpose Reservoir Projects*

Many of the storage facilities that contribute to flood management in the Sacramento and San Joaquin river basins are also operated for other purposes, such as water supply and power generation, but are not part of the SPFC because they include no State assurances to the federal government. Debris dams in the upper Yuba River Basin contribute in a minor way to flood management in the Sacramento River Basin, and hydroelectric reservoirs in the Upper Sacramento River Region provide credit space for larger downstream multipurpose reservoirs. Major multipurpose storage projects that contribute significantly to flood management are listed in Table 2-2 in chronological order of construction. USACE has participated in each of these reservoirs by establishing

(funding in most cases) seasonal flood reservation storage and developing rules for operation of flood storage. Note that Oroville Dam is the only major multipurpose project listed that is part of the SPFC. Multipurpose reservoirs within the Sacramento and San Joaquin river basins are shown on Figure 2-3. Further information about these reservoirs such as construction date and capacity are tabulated in the Draft SPFC Descriptive Document (DWR, 2010b).

During high-water periods, reservoir operators coordinate with DWR and USACE during daily operations conferences at the State-federal Flood Operations Center in Sacramento. These conferences lead to voluntary modifications of individual reservoir operating rules to improve overall system operation. In total, these reservoir operations significantly reduce flood flows to the downstream levee system.

**Figure 2-3. Multipurpose Reservoirs Within the Sacramento and San Joaquin River Basins**

**Table 2-2. Major Multipurpose Reservoir Project Summary**

| Reservoir | Dam | Date Constructed | Total Reservoir Capacity (thousand acre-feet) | Flood Storage Capacity (thousand acre-feet) | Owner/Operator |
|---|---|---|---|---|---|
| **Sacramento River Basin** | | | | | |
| Shasta Lake | Shasta Dam | 1949 | 4,550 | 1,300 | Reclamation |
| Black Butte Lake | Black Butte Dam | 1963 | 160 | 137 | USACE |
| Folsom Lake | Folsom Dam | 1956 | 1,000 | 400[2] | Reclamation |
| Lake Oroville | Oroville Dam[1] | 1967 | 3,540 | 750 | DWR |
| New Bullards Bar Reservoir | New Bullards Bar Dam | 1967 | 960 | 170 | Yuba County Water Agency |
| Indian Valley Reservoir | Indian Valley Dam | 1976 | 301 | 40 | Yolo County Flood Control and Water Conservation District |
| **San Joaquin River Basin** | | | | | |
| Millerton Lake | Friant Dam | 1949 | 521 | 390 | Reclamation |
| Lake McClure | New Exchequer Dam | 1967 | 1,025 | 400 | Merced Irrigation District |
| New Don Pedro Reservoir | New Don Pedro Dam | 1970 | 2,030 | 340 | Turlock and Modesto Irrigation Districts |
| Hensley Lake | Hidden Dam | 1975 | 90 | 65 | USACE |
| Eastman Lake | Buchanan Dam | 1975 | 150 | 45 | USACE |
| New Melones Lake | New Melones Dam | 1978 | 2,420 | 450 | Reclamation |

**Table 2-2. Major Multipurpose Reservoir Project Summary (Contd.)**

| Reservoir | Dam | Date Constructed | Total Reservoir Capacity (thousand acre-feet) | Flood Storage Capacity (thousand acre-feet) | Owner/Operator |
|---|---|---|---|---|---|
| Los Banos Reservoir | Los Banos Detention Dam | 1965 | 34.6 | 14 | Reclamation/DWR |
| Pardee Reservoir | Pardee Dam | 1963 | 198 | 200[3] | East Bay Municipal Utilities District |
| Camanche Reservoir | Camanche Dam | 1963 | 431 | | |
| New Hogan Reservoir | New Hogan Dam | 1964 | 325 | 165 | USACE |

*Source: USACE, 1997*

Notes:
[1] Oroville Dam is part of the State Plan of Flood Control as is the smaller single purpose Castle Dam in the San Joaquin River Basin. All other dams in this table are non-SPFC.
[2] Folsom Dam is operated with variable flood storage between 400 TAF and 670 TAF to take credit for seasonally available storage in upstream reservoirs.
[3] Camanche Dam operated in conjunction with Pardee Dam and upstream reservoirs.

Key:
DWR = California Department of Water Resources
Reclamation = U.S. Department of the Interior, Bureau of Reclamation
TAF = thousand acre-feet
USACE = U.S. Army Corps of Engineers

*Local and Regional Projects*

The federal government has an interest in local projects for which local or regional entities, rather than the State, provided assurances.

- **Yuba River Goldfields –** The Yuba River gravel training walls constructed by the California Debris Commission provide substantial flood benefits to the Yuba River Basin inhabitants. These facilities are maintained by the federal government.

- **Chico Landing and Kesswick Dam –** As discussed above, the bank protection projects from Chico Landing to Red Bluff are part of the SPFC. However, the authorizing legislation provided in the Flood Control Act of 1958 recognized the encroachment of development into the floodplain of the Sacramento River below Keswick Dam – development would ultimately prevent Shasta Dam from being operated to provide the benefits for which it was authorized. Accordingly, HD 272 (84th Congress) required local interests to enact and enforce adequate zoning regulations to prevent construction of permanent improvements within the floodplain.

Glenn, Butte, Tehama, and Shasta counties are involved in the zoning requirement from Chico Landing to Keswick Dam. Glenn, Butte, and Tehama counties adopted ordinances in 1972, 1971, and 1974, respectively, to control development within the 100-year floodplain. O&M Manual SAC512 mentions that these ordinances together with the State's Designated Floodway Program (see Section 2.1.6) satisfy the floodplain zoning requirement. Shasta County has a Designated Floodway (FI) District that includes the Sacramento River from Keswick Dam to the Shasta-Tehama county line, but the O&M manual makes no mention of when this was first instituted.

- **Big Dry Creek Dam and Diversion Project –** Big Dry Creek Dam was authorized by the federal government in the Flood Control Act of 1941 (Public Law 77-288, 77th Congress). The project includes an earth-fill dam across the channel of Big Dry Creek, creating a reservoir with a maximum capacity of 16,250 acre-feet and all storage space reserved for flood management. The project also includes accompanying diversion facilities both upstream and downstream from the dam. Flows from the dam in excess of downstream capacities are diverted to the San Joaquin River downstream from Friant Dam.

This project, located about 10 miles northwest of Fresno, reduces flood risk for the cities of Fresno and Clovis and the surrounding areas. Modification of the Big Dry Creek Dam and Diversion Project was included as one of the component features of the Redbank and Fancher Creeks Flood Control Project authorized by the Water Resources Development Act (WRDA) of 1986. Although the State originally provided assurances to the federal government for the project in 1947, the 1987 Local Cooperation Agreement signed between USACE and the Fresno Metropolitan Flood Control District superseded the 1947 agreement – assurances are now provided by the district. The capacity of the Big Dry Creek Dam and Diversion Project was increased from 16,250 acre-feet to 30,200 acre-feet as part of the 1986 project (USACE, 1997).

- **Duck Creek Project -** The Duck Creek Project was authorized by the Flood Control Act of 1944 (Public Law 78-534, 78th Congress). This act authorized improvement of Littlejohns Creek and tributaries in accordance with recommendations by the USACE Chief of Engineers in HD 545. The San Joaquin County Board of Supervisors, on behalf of the San Joaquin County Flood Control and Water Conservation District, provided assurances to the federal government for lands, holding the federal government free from damages, and for O&M.

- **Stanislaus River Local Interest Project Levees -** Improvements for the Stanislaus River channel (New Melones Project) and local interest project levees (LIPL) below Goodwin Dam were authorized by the federal government in the Flood Control Act of 1962 (Public Law 87-874). USACE was given responsibility for maintenance if local interests agreed to prevent encroachment of the existing channel and floodway and maintain private levees. In 1963, The Reclamation Board (now the Central Valley Flood Protection Board, or Board) accepted responsibility as the nonfederal sponsor.

On June 19, 1981, The Reclamation Board adopted the Stanislaus River Designated Floodway, including the existing channel and LIPL along the Stanislaus River between Goodwin Dam and the San Joaquin River confluence. In Resolution 81-33, the Board accepted USACE's offer for the Board to exercise USACE property rights in the designated floodway and project floodway. The Board also delegated control of encroachments in those areas to the USACE Sacramento District.

The Board provided assurances to USACE that if the LIPLs are not satisfactorily maintained, the Board will extend the encroachment lines of the designated floodway to include the area that would be flooded during a design flood if those levees did not exist.

- **Kings River and Tulare Basin Project -** The Kings River and Tulare Lake Basin Project was adopted and authorized by the Flood Control Act of 1944 (Public Law 78-534, 78th Congress). The authorization was substantially in accordance with the recommendations by the USACE Chief of Engineers in HD Number 630 (76th Congress, Third Session) and as modified by data in Design Memorandum No. 3, Kings River and Tulare Lake, California, Kings River Channel Improvement, General Design, dated April 20, 1959, and by Letter Supplement No. 1 to Design Memorandum No. 3, by the District Engineer, USACE Sacramento District. The Kings River Conservation District gave assurances for cooperation with the federal government instead of the State providing assurances. During flood times, the project discharges water (up to 4,750 cfs) through the James Bypass to the Fresno Slough, a tributary of the San Joaquin River. This discharge directly affects operation of the Chowchilla Canal Bypass and San Joaquin River Control Structures (see O&M Manual SJR601B, Sections 3.2.6 and 3.2.7).

- **Merced County Stream Group Project -** The State provided assurances to the federal government for portions of the Merced County Stream Group Project (see Section 2.1.2). In addition, USACE built and operates four retention-type reservoirs:

- Mariposa Dam (completed in 1948) is located on Mariposa Creek, about 18 miles east of Merced. Mariposa Reservoir has 15 TAF of flood management space, which is equal to the gross storage. The dam is owned, operated, and maintained by USACE.

- Owens Dam (completed in 1949) is located on Owens Creek about 16 miles east of Merced. Owens Reservoir has 3.6 TAF of flood management space, which is equal to the gross storage. The dam is owned, operated, and maintained by USACE.

- Burns Dam (completed in 1950) is located on Burns Creek, about 13 miles northeast of Merced. Burns Reservoir has 6.8 TAF of flood management space, which is equal to the gross storage. The dam is owned, operated, and maintained by USACE.

- Bear Dam (completed in 1954) is located on Bear Creek about 16 miles northeast of Merced. Bear Reservoir has 7.7 TAF of flood management space, which is equal to the gross storage. The dam is owned, operated, and maintained by USACE.

- **In Progress Projects -** Several projects are in planning, design, or construction phases, and other projects have been completed. The Bear River setback levee, and improvements to Dry Creek and Stockton levees are examples of completed projects. Examples of projects that are in progress are the Hamilton City Flood Damage Reduction and Ecosystem Restoration Project, Folsom Dam Modifications Project, and early implementation projects including those that have been underway with State bond funding since 2006. Some of these in progress and completed projects are expected to eventually become part of the SPFC, but some may not. These projects can only become part of the SPFC after construction is completed and they are accepted by USACE, USACE prepares the O&M manuals, the projects are transferred to the State, and the State accepts the projects. All or portions of some projects like the Middle Creek Project may be deauthorized and removed from the SPFC.

**Other Non-SPFC Flood Protection Facilities** In addition to the projects described in the previous section, the flood protection system in the Central Valley includes other facilities that are not part of the SPFC. They are briefly discussed here.

*Nonproject Levees*

Nonproject, or local, levees and related facilities have been constructed by local agencies along many of the rivers, creeks, and streams in the Central Valley. Many of these facilities are operated and maintained similar to

project facilities and connect to project facilities. By definition, they are not part of the SPFC, however, it is important to recognize that these nonproject levees affect the performance of the SPFC as part of the flood protection system. In addition, the levee system in the Delta downstream from Collinsville on the Sacramento River and downstream from the Stockton area on the San Joaquin River is composed entirely of nonproject levees maintained by USACE (e.g., levees of the Sacramento and Stockton ship channels) or local interests. Some of these levees have O&M manuals, but not SPFC manuals.

*Other Nonproject Facilities*
Numerous other flood protection facilities are owned and operated by local entities that are not part of the SPFC. These include the following:

- Local levees and floodwalls within SPFC-levee-protected areas.
- Local pumping plants that discharge drainage water into SPFC-leveed channels. Examples include a number of pumping plants owned and operated by local RDs and LDs and communities to pump interior storm runoff into the larger waterways.

*Designated Floodways*
Designated floodways are not part of the SPFC facilities, as defined in the Public Resources Code (PRC) Section 5096.805e because they are State-designated without assurances to, or participation of, the federal government. However, these floodways provide an important management tool to help the State meet its requirement for passing project design flows (see Section 6.8 for designated floodways as a condition of project operation).

Designated floodways are the primary nonstructural flood management program employed by the State of California. The program was started in 1968 to control encroachments and preserve the flow regimes of floodways to protect public improvements, lives, and land-use values (CWC Section 8609). Designated floodways are defined as follows: (1) the channel of the stream and that portion of the adjoining floodplain reasonably required to provide for the passage of a design flood, as indicated by floodway encroachment lines on an adopted map, or (2) the floodway between existing levees, as adopted by the Board or the Legislature.

Designated floodways serve a critical function in protecting life and property from flood risks. The designated floodway system includes more than 60 designated floodways covering more than 1,300 miles of stream length. There are designated floodways along the Sacramento and San

Joaquin rivers as well as major tributaries. There are additional designated floodways in the Tulare Lake Basin.

To designate a floodway, the Board usually completes a detailed hydraulic study to determine the design discharge associated with the design flood (usually 100-year recurrence interval) and the area of flooding that would result from the design flood. The findings of the study are then used to delineate floodway maps and, in some cases, determine areas of shallow flooding. In other cases, floodway boundaries are developed using analytical methods based on engineering judgment and review of historical floods. In proposing or revising designated floodways, the Board must also consider (1) flood control improvements and regulations affecting the floodplain, (2) the degree of danger from flooding to life, property, and public health and welfare, and (3) rate and type of development taking place on the floodplain (23 CCR Section 102).

Land uses within an adopted designated floodway are restricted to not impede the free flow of water in the floodway or jeopardize public safety (23 CCR Section 107). In general, activities such as agriculture, grazing, and recreation are allowed, as are structures and activities that can be quickly and easily removed or pose little impedance to river flow. The Board has the authority to determine additional permitted uses within the floodplain on a case-by-case basis.

#### *Flood Management Facilities*

The flood management system includes both project and non-project (local) facilities. Project facilities are under the assurances of cooperation provided by the State to the federal government[13,14] and are eligible for USACE rehabilitation under Public Law 84-99. Non-project levees and related facilities have been constructed and maintained by local agencies along many of the rivers, creeks, and streams in the Central Valley. By definition they are not a part of the State-federal system or the SPFC, but these non-project facilities may affect the performance of project facilities as part of the greater Sacramento-San Joaquin Flood Management System.

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[13] "State Plan of Flood Control" means the State and federal flood control works, lands, programs, plans, conditions, and mode of O&M of the SRFCP described in CWC Section 8350, and of flood control projects in the Sacramento and San Joaquin river basins authorized pursuant to Article 2 (commencing with CWC Section 12648) of Chapter 2 of Part 6 of Division 6 for which the Board or DWR has provided the assurances of nonfederal cooperation to the United States, which will be updated by DWR and compiled into a single document entitled "The State Plan of Flood Control."

[14] The assurances (satisfactory to the Secretary of War) are that the State will provide, without cost to the United States, all lands, easements and rights-of-way necessary for the completion of the project; bear the expense of necessary highway, railroad, and bridge alterations; hold and save the United States free from claims for damages resulting from construction of the works; and maintain and operate all works, after completion.

**Sacramento River Basin** The basic flood management system in the Sacramento River Basin consists of a series of levees and bypasses placed to protect selected areas and take advantage of some of the natural overflow basins. The management system includes non-project levees along the east bank of the Sacramento River; on the east bank south of Big Chico Creek; levees south of Ord Ferry; levees along the lower portion of the Feather, Bear, and Yuba rivers; and levees along the American River. 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 attenuate flood flow by holding back floodwater and, ideally, releasing water into the rivers at a slower rate.

**San Joaquin River Basin** The flood management system in the San Joaquin River Basin consists of levees (both project and non-project), bypasses, and associated control structures. Project levees are located along the lower portions of Ash and Berenda sloughs, Bear Creek, Fresno, Stanislaus, and Calaveras rivers, and along sections of the San Joaquin River. The Chowchilla Canal Bypass diverts excess San Joaquin River flow to the Eastside Bypass. The Eastside Bypass also collects flows from minor tributaries and rejoins the San Joaquin River between Fremont Ford and Bear Creek. In addition to the levees and bypasses, the flood management system uses reserved flood storage space in selected reservoirs on the San Joaquin River and major tributaries (as discussed in the “Multipurpose Dams and Reservoirs” section) to reduce peak flood discharges.

**The Delta** The Delta is downstream from the flood control systems of the Sacramento and San Joaquin rivers. Therefore, flood control and multipurpose reservoirs of the Sacramento and San Joaquin river systems contribute to flood protection in the Delta. On the other hand, some flood protection infrastructure exacerbate flood risk in the Delta by channeling upstream flood waters directly to the Delta, which under more natural conditions, would have been attenuated by upstream floodplains. The Delta

relies on a network of levees for protection. The levees generally do not provide 100-year flood protection for adjoining lands (100-year flood protection represents protection against a flood that has a 1 percent probability of occurring each year). The Harvey O. Banks Delta Pumping Plant and Tracy Pumping Plant are the primary southern Delta pumping facilities located in the Clifton Court Forebay. These pumping facilities are primarily used for water supply, but can be used to provide emergency flood relief for the southern Delta. During the 1997 flood event, pumping at the Banks Pumping Plant exceeded inflows to the Clifton Court Forebay to relieve southern Delta flooding and provide emergency flood control space (USACE, 2002b). This reduced water surface in the forebay to the minimum operational level. In addition, the Delta Cross Channel conveys water from the Sacramento River to the Tracy Pumping Plant, designed to combat salt water intrusion in the Delta and dilute local pollution from the San Joaquin River. The control gates of the Delta Cross Channel are closed during high water to lower Mokelumne River flood stages in the eastern Delta.

The following sections describe the flood management facilities in the Sacramento and San Joaquin river basins. The sections describe project facilities and non-project facilities, shown on Figure 2-4. Figures 2-5 through 2-9 show project and non-project facilities for each of the five smaller planning regions within the Sacramento and San Joaquin river basins.

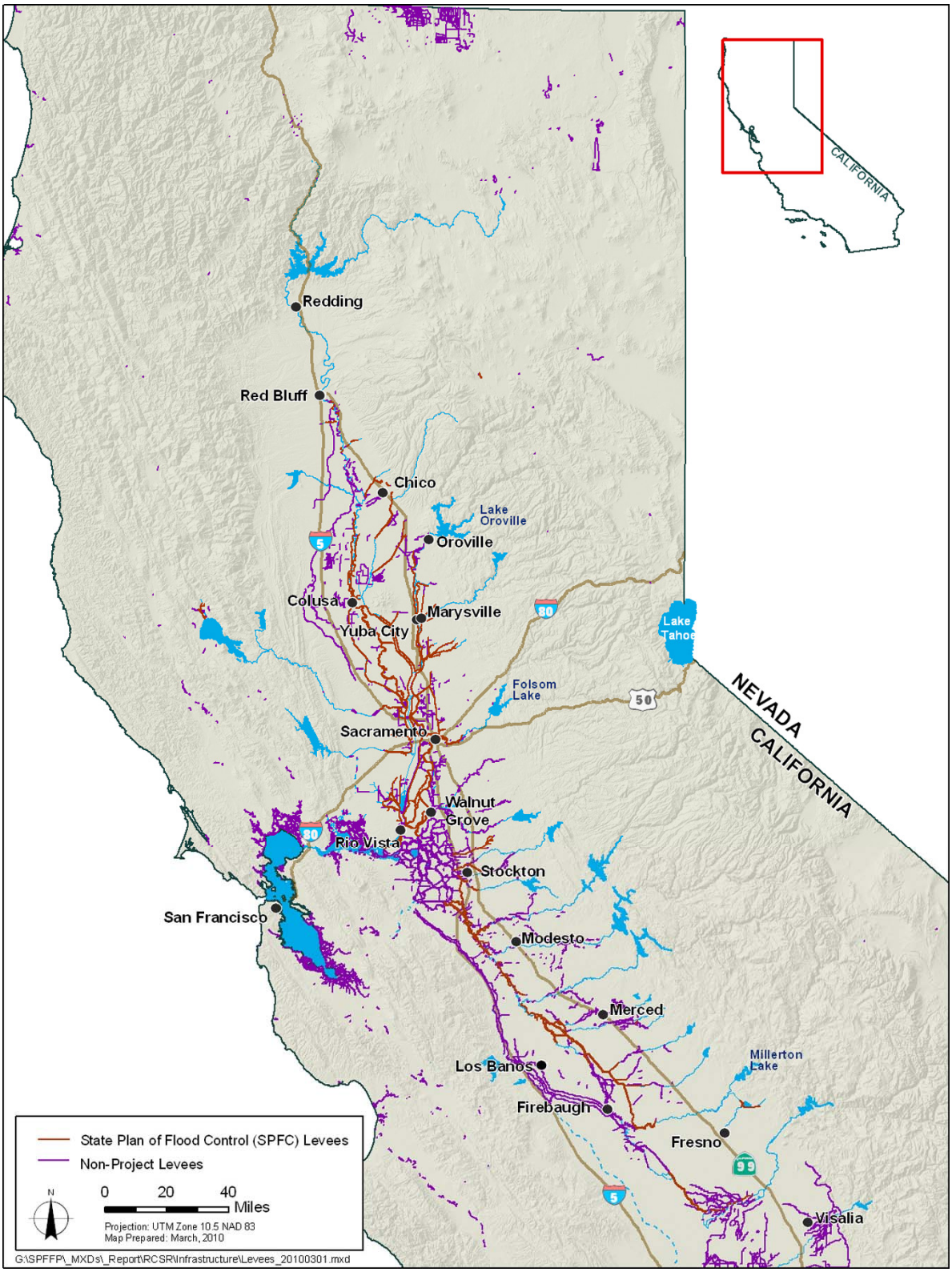


**Figure 2-4. Project and Non-Project Levees within the Sacramento and San Joaquin River Basins**

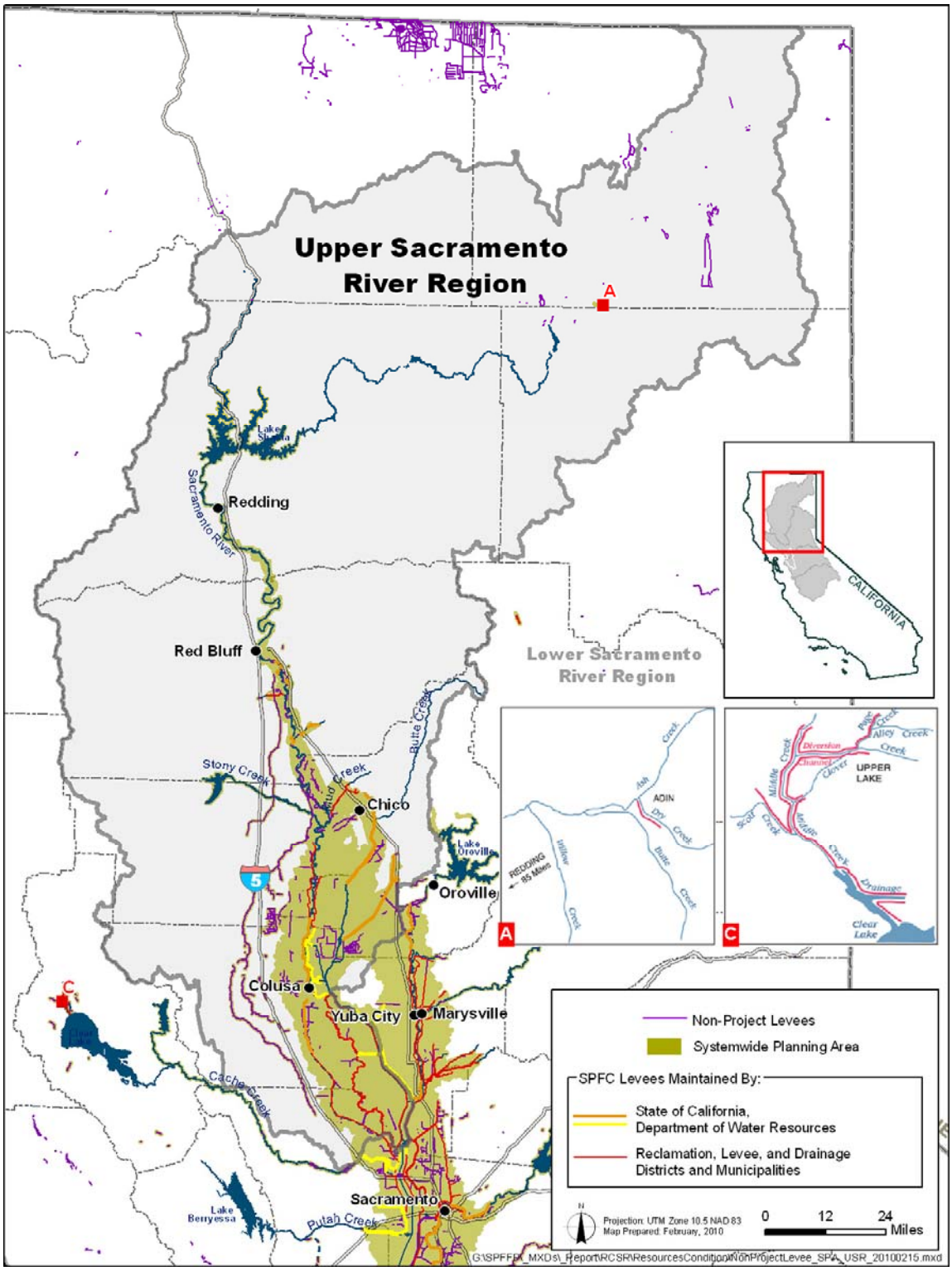


**Figure 2-5. Central Valley Flood Protection Plan, Upper Sacramento River Region**

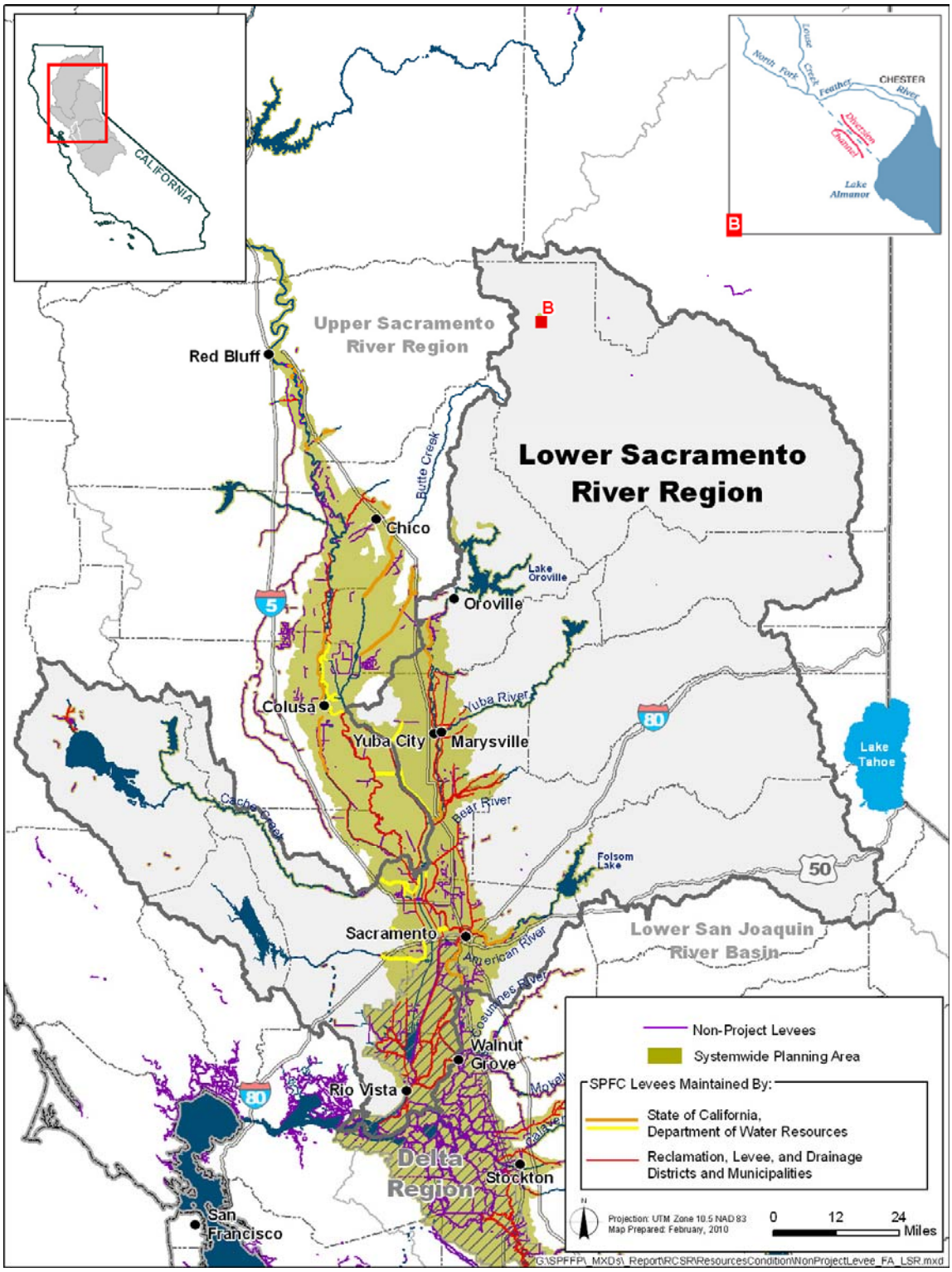


**Figure 2-6. Central Valley Flood Protection Plan, Lower Sacramento River Region**

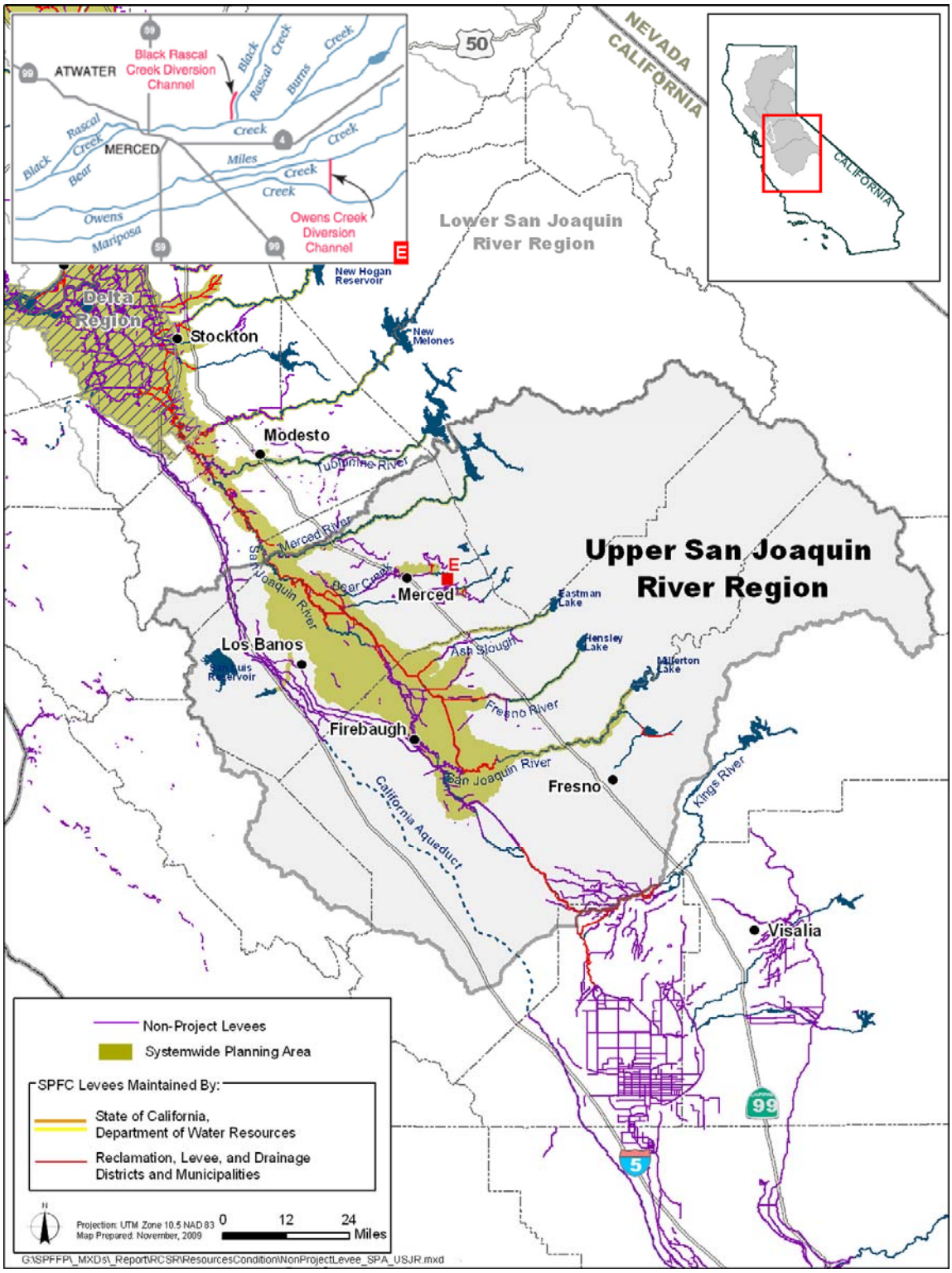


**Figure 2-7. Central Valley Flood Protection Plan, Upper San Joaquin River Region**

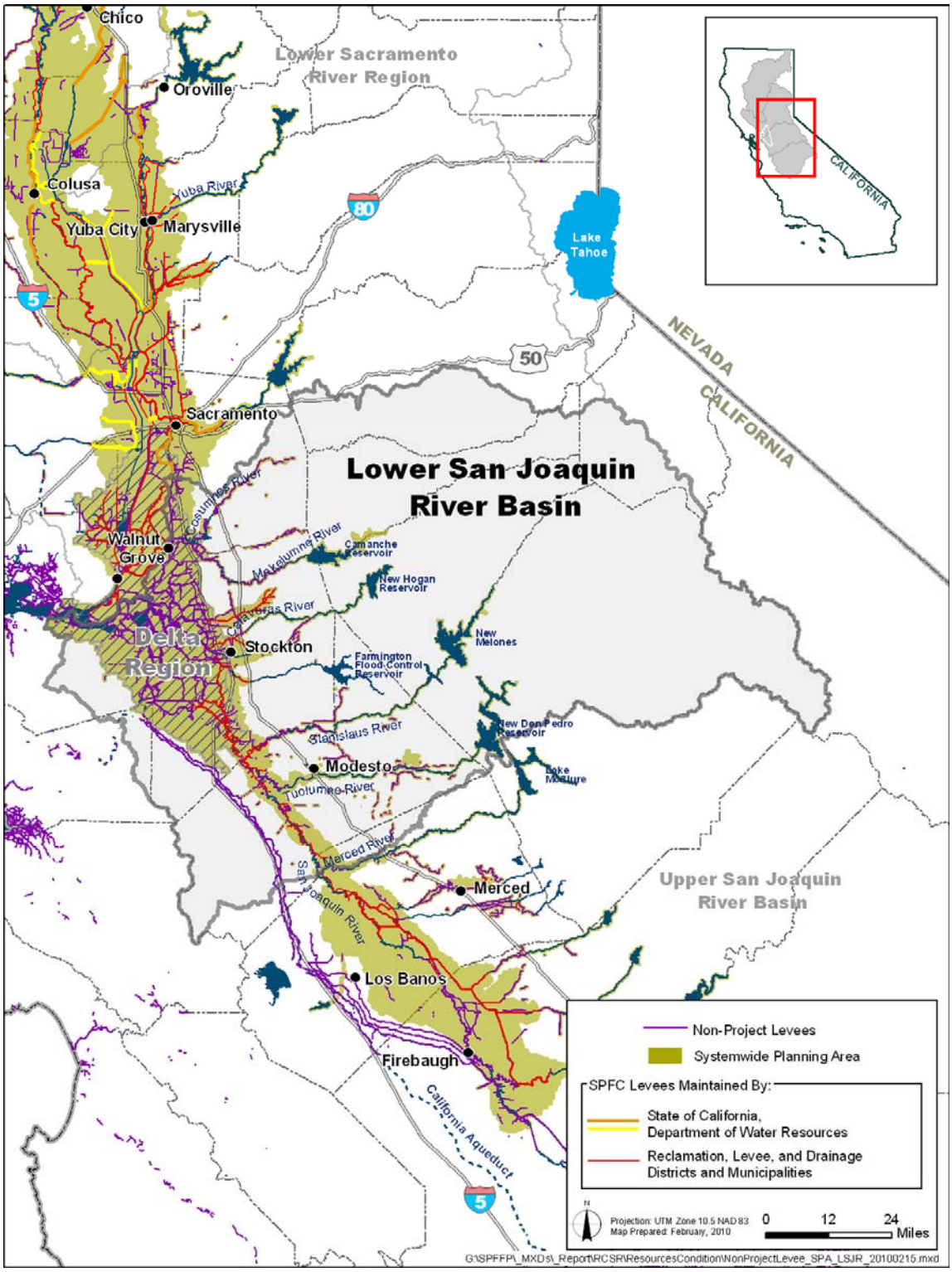


**Figure 2-8. Central Valley Flood Protection Plan, Lower San Joaquin River Region**

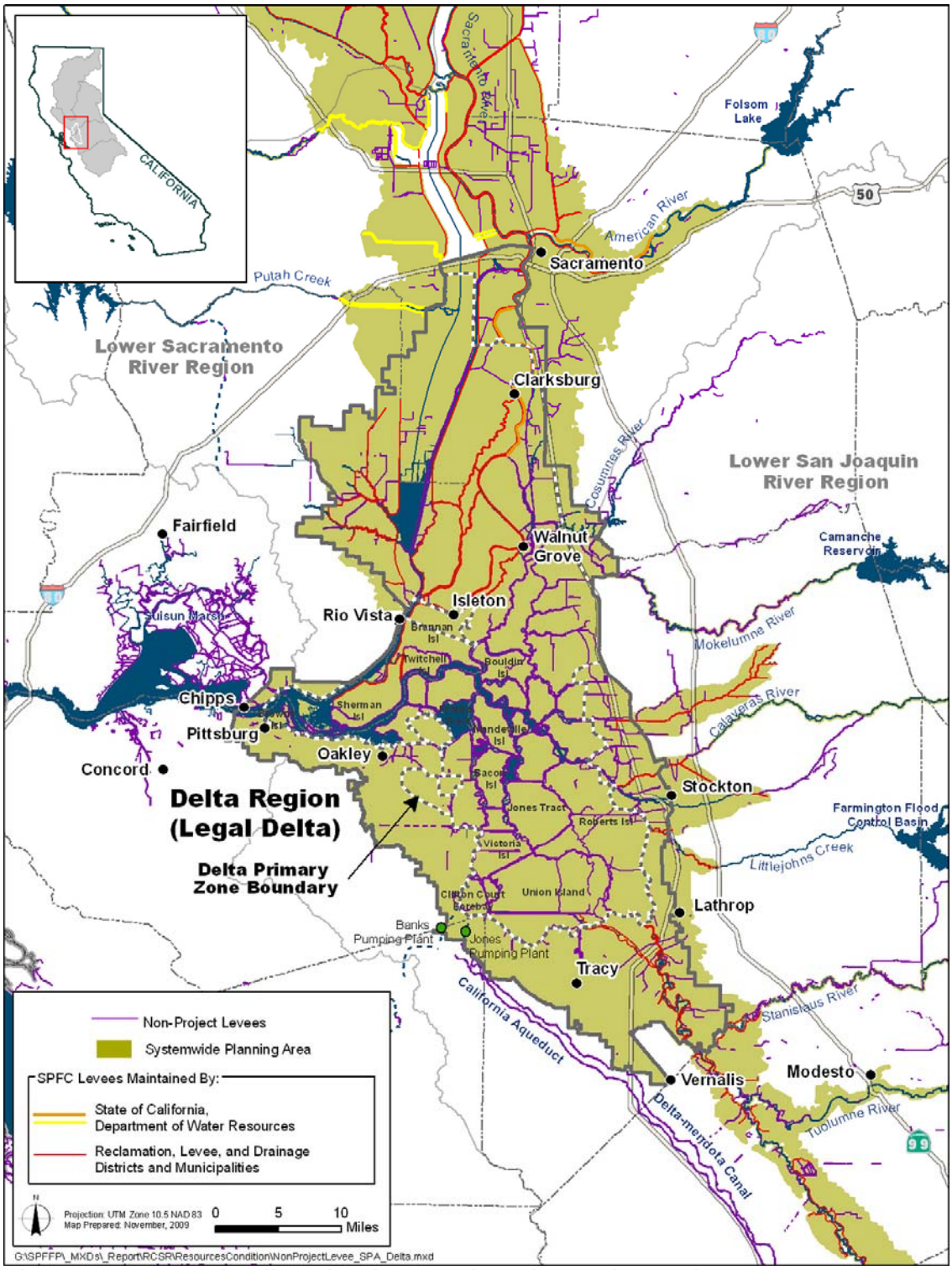


**Figure 2-9. Central Valley Flood Protection Plan, Delta Region**

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