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Hydrology, Hydraulics, and Water Management Technical Report

Shasta Lake Water Resources Investigation, California

Prepared by:

United States Department of the Interior
Bureau of Reclamation
Mid-Pacific Region

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Abbreviations and Acronyms

ACID	Anderson-Cottonwood Irrigation District
Banks	Harvey O. Banks
BO	Biological Opinion
Cal/EPA	California Environmental Protection Agency
CCWD	Contra Costa Water District
cfs	cubic feet per second
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
Delta	Sacramento-San Joaquin Delta
DSM2	Delta Simulation Model 2
DWR	Department of Water Resources
EIS	Environmental Impact Statement
elevation xxx	elevation in feet above mean sea level
EPA	U.S. Environmental Protection Agency
Gianelli	William R. Gianelli
H&H	hydrology, hydraulics, and water management
Jones	C.W. “Bill” Jones
kW	kilowatt
M&I	municipal and industrial
MAF	million acre-feet
MCL	maximum contamination levels
mg/L	milligrams per liter
msl	mean sea level
MW	megawatt
NMFS	National Marine Fisheries Service
PG&E	Pacific Gas and Electric Company
RBDD	Red Bluff Diversion Dam
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RM	river mile
ROD	Record of Decision
SBA	South Bay Aqueduct
SLWRI	Shasta Lake Water Resources Investigation
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
TCD	temperature control device
TDS	total dissolved solids
USACE	United States Army Corps of Engineers

Chapter 1 Affected Environment

This chapter describes the affected environment related to hydrology, hydraulics, and water management (H&H) for the dam and reservoir modifications proposed under the Shasta Lake Water Resources Investigation (SLWRI).

1.1 Environmental Setting

The environmental setting section first presents background information and then describes reservoir facilities and operations, H&H, including surface water supply, groundwater resources, flood management facilities, and south Sacramento-San Joaquin Delta (Delta) water levels.

Shasta Dam and Reservoir are located on the upper Sacramento River in Northern California, about 9 miles northwest of the City of Redding in Shasta County on the Sacramento River. The Shasta Dam and Reservoir project was constructed by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), as an integral element of the Central Valley Project (CVP) for six purposes: irrigation water supply, municipal and industrial (M&I) water supply, flood management, hydropower generation, fish and wildlife conservation, and navigation.

The CVP was authorized as a Federal Reclamation project in 1935. The dam was constructed between September 1938 to June 1945, when it was put into interim operation. Storage of water in Shasta Reservoir began in December 1943. Gates, valves, and other items of finish work, deferred during the war, were completed and placed in full operation in April 1949. Shasta Reservoir delivers about 55 percent of the total annual water supply developed by the CVP.

Keswick Dam and Reservoir are an integral element of the Shasta Dam and Reservoir Project. Keswick Dam is located on the Sacramento River just north of Redding. All releases from Shasta Dam on the Sacramento River and through the Spring Creek Tunnel from Whiskeytown Reservoir on Clear Creek flow through Keswick Dam.

Below Shasta Dam, the Sacramento River flows through about 60 miles of natural channel along a low foothill area to Red Bluff. From Red Bluff, the Sacramento River flows through natural channels and leveed river reaches for another 250 miles to the Delta.

This Technical Report describes pertinent hydrologic and hydraulic conditions and water management operations for Shasta Lake, the Sacramento River, the Delta, and the CVP/State Water Project (SWP) service areas, under existing conditions, the No-Action Alternative, and the Action Alternatives for the SLWRI.

For purposes of this Technical Report, the area around Shasta Lake and along the Sacramento River from Shasta Dam to Red Bluff is considered the primary study area, as shown in Figure 1-1. The area along the Sacramento River from Red Bluff to the Delta, shown in Figure 1-2 and Figure 1-3, and CVP/SWP service areas shown in Figures 1-4 and 1-5 are considered the extended study area.

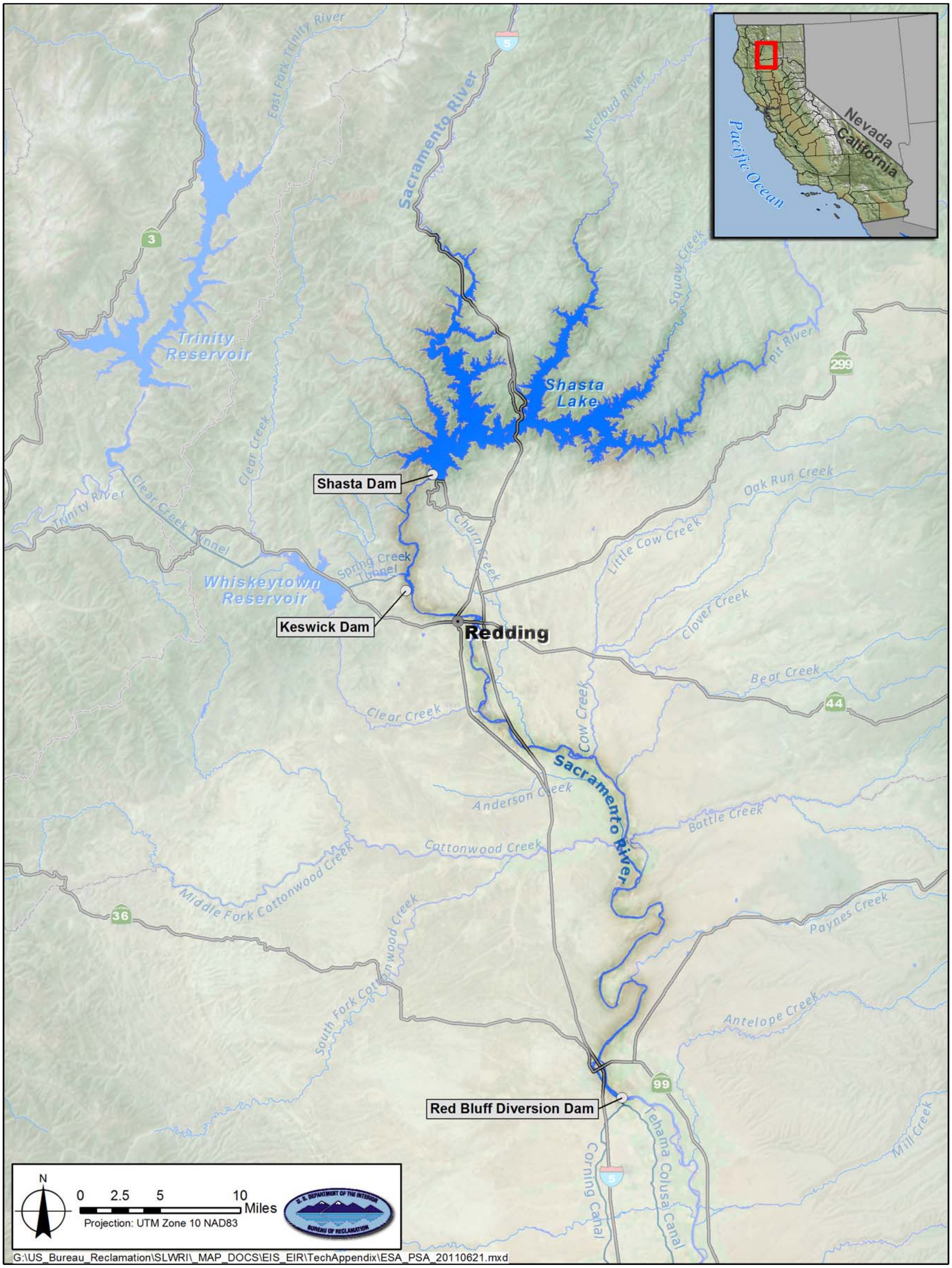

Figure 1-1. Shasta Lake Water Resources Investigation Primary Study Area, Shasta Lake Area and Shasta Dam to Red Bluff Diversion Dam

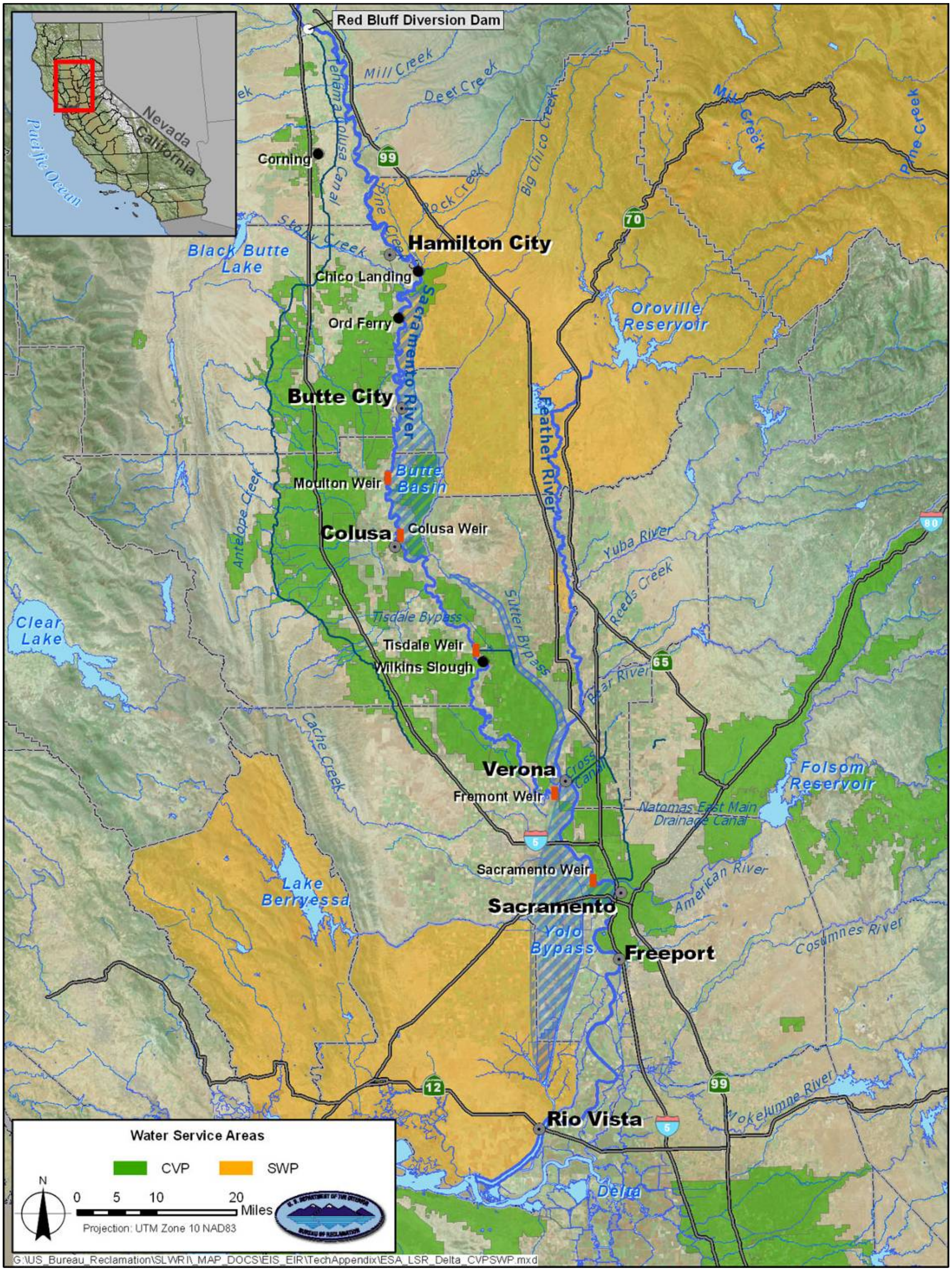

Figure 1-2. Shasta Lake Water Resources Investigation Extended Study Area, Lower Sacramento River to the Delta

Figure 1-3. Shasta Lake Water Resources Investigation Extended Study Area, Delta

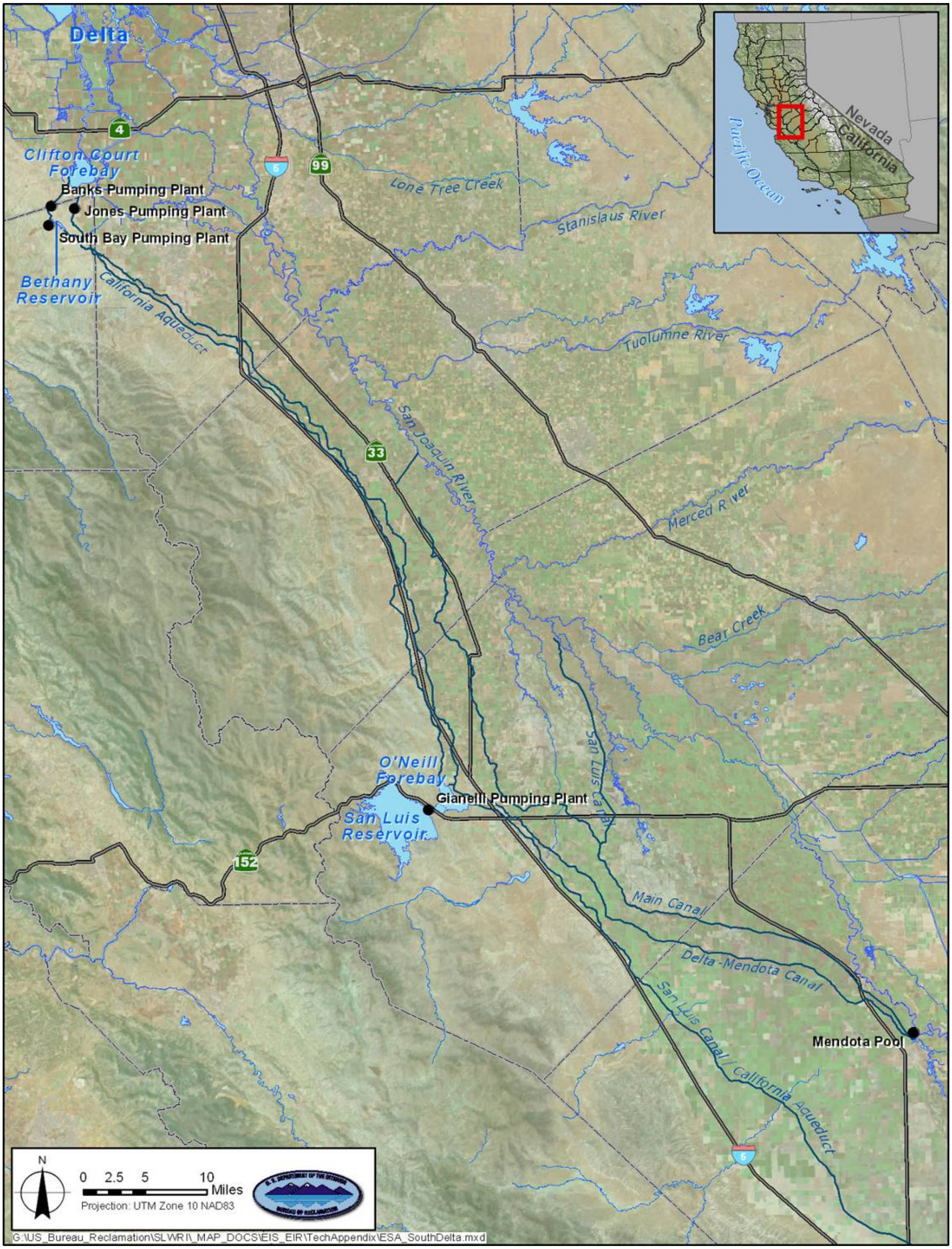

Figure 1-4. Shasta Lake Water Resources Investigation Extended Study Area, South-of-the-Delta

Figure 1-5. Shasta Lake Water Resources Investigation Extended Study Area, CVP/SWP Service Areas

1.1.1 Storage and Diversion Facilities

Facilities described below include Shasta Dam and Powerplant, Keswick Dam and Powerplant, Anderson-Cottonwood Irrigation District (ACID) Diversion Dam, and Red Bluff Diversion Dam (RBDD).

Shasta Lake and Vicinity

This section describes storage and diversion facilities in the Shasta Lake area.

Shasta Dam and Powerplant Shasta Dam is a curved, gravity-type, concrete structure that rises 533 feet above the streambed with a total height above the foundation of 602 feet. The dam has a crest width of about 41 feet and a length of 3,460 feet. Shasta Reservoir has a storage capacity of 4,550,000 acre-feet, and water surface area at full pool of 29,600 acres. Maximum seasonal flood management storage space in Shasta Reservoir is 1.3 million acre-feet (MAF). The Shasta Powerplant consists of five main generating units and two station service units with a combined capacity of 663,000 kilowatts (kW).

Releases from Shasta Dam can be made through the powerplant, over the spillway, or through the river outlets. The powerplant has a maximum release capacity of nearly 20,000 cubic feet per second (cfs), the river outlets can release a maximum of 81,800 cfs at full pool, and the maximum release over the drum-gated spillway is 186,000 cfs.

The existing temperature control device (TCD) at Shasta Dam, constructed from 1996 to 1998, is a multilevel water intake structure located on the upstream face of the dam. The TCD allows operators to draw water from the top of the reservoir during the winter and spring when surface water temperatures are cool and from deeper in the reservoir in the summer and fall when surface water is warm. It also improves oxygen and sediment levels in downstream river water.

The TCD has improved cold-water management for the benefit of fish, as outlined in the Central Valley Project Improvement Act (CVPIA) and State Water Resources Control Board (SWRCB) water right permits, while concurrently producing water for contract deliveries and power generation.

The Shasta Powerplant is located just below Shasta Dam. Water from the dam is released through five 15-foot penstocks leading to the five main generating units and two station service units. Units 1, 2, and 3 are rated at 125 megawatts (MW); Units 4 and 5 were uprated from 125 MW to 142 MW in 1998 and 1999, respectively.

Table 1-1 summarizes pertinent engineering data for and features of the existing Shasta Dam and Reservoir.

Table 1-1. Pertinent Data – Shasta Dam and Reservoir

General			
Drainage Areas (excluding Goose Lake Basin)		**Mean Annual Runoff (1908 – 2006)**	
Sacramento R. at Shasta Dam	6,421 sq-mi	Sacramento R. at Shasta Dam	5,737,000 acre-feet
Sacramento R. at Keswick	6,468 sq-mi	Sacramento R. near Red Bluff	8,421,000 acre-feet
Bridge near Red Bluff	8,900 sq-mi	**Sacramento River Maximum Flows**	
Sacramento R. near Ord Ferry	12,250 sq-mi	At Shasta Lake 16 Jan 1974	216,000 cfs
Pit R. at Big Bend	4,710 sq-mi	Near Red Bluff 28 Feb 1940	291,000 cfs
McCloud R. above Shasta Lake	604 sq-mi	At Ord Ferry 28 Feb 1940	370,000 cfs
Sacramento R. at Delta above Shasta Lake	425 sq-mi		
Shasta Dam and Reservoir			
Shasta Dam (concrete gravity)		**Shasta Reservoir**	
Crest elevation	1,077.5 feet	Full pool elevation (msl)	1,067.0 feet
Freeboard above full pool	9.5 feet	Minimum operating level	840.0 feet
Height above foundations	602 feet	Taking line	Irregular
Height above streambed	487 feet	Surface Area	
Length of crest	3,500 feet	Minimum operating level	6,700 acres
Width of crest	30 feet	Full pool	29,500 acres
Slope, upstream	Vertical	Taking line	90,000 acres
Slope, downstream	1 on 0.8	Storage capacity	
Volume	8,430,000 cy	Minimum operating level	587,000 acre-feet
Normal tailwater elevation	585 feet	Full pool	4,552,000 acre-feet
Spillway (gated ogee)		**Shasta Powerplant**	
Crest length		Main units	
Gross	360 feet	5 turbines, Francis type	515,000 hp (total)
Net	330 feet	5 units @ 142 MW	710 MW (total)
Crest gates (drum type)		Station units	
Number and size	3 @ 110 feet x 28 feet	2 generators, 2,000 kW each	4,000 kW (total)
Top elevation when lowered	1037.0 feet	Elevation centerline turbines	586 feet
Top elevation when raised	1065.0 feet	Maximum tailwater elevation	632.5 feet
Discharge capacity at pool (1,065 feet)	186,000 cfs	Total discharge at pool (1,065 feet)	14,500 cfs
Flashboard gates	3 @ 110 feet x 2 feet	Total discharge at pool (827.7 feet)	16,000 cfs
Top elevation when lowered	1,067.0 feet	Power outlets (15-foot-diameter steel penstocks)	
Bottom elevation when raised	1,069.5 feet	5 with invert elev. of intake	807.5 feet
Outlets 102-inch-diameter conduit with 96-inch-diameter wheel-type gate			
4 with invert elevation	737.75 feet	Capacity at Elevation 1,065 feet	81,800 cfs
8 with invert elevation	837.75 feet	Capacity at Elevation 827.7 feet	12,200 cfs
6 with invert elevation	937.75 feet		

Notes:
Elevations given are in vertical datum NGVD 1929.
Key:
cfs = cubic feet per second
cy = cubic yard
elevation = elevation in feet above msl
hp = horsepower
kW = kilowatt
msl = mean sea level
MW = megawatt
R = river
sq-mi = square mile

Keswick Dam and Powerplant Keswick Dam is about 9 miles downstream from Shasta Dam. In addition to regulating outflow from the dam, Keswick Dam controls runoff from 45 square miles of drainage area. Keswick Dam is a concrete, gravity-type structure with a spillway over the center of the dam. The spillway has four 50-foot by 50-foot fixed wheel gates with a combined discharge capacity of 248,000 cfs at full or full pool elevation (elevation in feet above mean sea level) (587 feet). Storage capacity below the top of the spillway gates at full pool is 23,800 acre-feet. The powerplant has a nameplate generating capacity of 75,000 kW and can pass about 15,000 cfs at full pool.

Diversion Facilities Below Keswick Dam, two diversion dams regulate flows on the Sacramento River, the ACID Diversion Dam and RBDD. The primary purpose of these two facilities is to divert water into canals for local agricultural use.

Anderson-Cottonwood Irrigation District Diversion Dam Since 1916, water has been diverted into the ACID canal for irrigation along the west side of the Sacramento River between Redding and Cottonwood. Reclamation and ACID have signed a settlement agreement quantifying the amount of water ACID could divert from the Sacramento River. ACID diverts to its main canal on the right bank of the river from a diversion dam in Redding about 5 miles downstream from Keswick Dam. The diversion dam consists of boards supported by a pinned steel superstructure anchored to a concrete foundation across the river. The boards are manually set from a walkway supported by the steel superstructure. The number of boards set in the dam varies depending on the flow in the river and the desired head in the canal.

Because this dam is a flashboard dam installed for seasonal use only, close coordination is required between Reclamation and ACID for regulation of river flows to allow safe installation and removal of the flashboards. The contract between Reclamation and ACID allows for ACID to notify Reclamation as far in advance as is reasonably possible each time ACID intends to install or remove boards from its diversion dam. Reclamation will similarly notify ACID each time it intends to change releases at Keswick Dam. In addition, during the irrigation season, ACID will notify Reclamation of the maximum flow that it believes the diversion dam, with the current setting of boards, can safely accommodate. Reclamation will notify ACID at least 24 hours in advance of a change in releases at Keswick Dam that exceed such maximum flow designated by ACID.

The irrigation season for ACID runs from April through October. Therefore, around April 1 each year, ACID erects the diversion dam. This consists of raising the steel superstructure, and installing the walkway and setting boards. Around November 1 each year, the diversion dam is removed. The dates of installation and removal can vary depending on hydrologic conditions. Removal and installation of the dam cannot be done safely at flows greater than 6,000 cfs. ACID usually requests Reclamation to limit the Keswick release to a

5,000 cfs maximum for 5 days to accomplish the installation or removal of the dam. As indicated previously, there may be times during the irrigation season when the setting of boards must be changed because of changes in releases at Keswick Dam. When boards must be removed because of an increase at Keswick Dam, the release may initially have to be decreased to allow work to be done safely. If an emergency exists, personnel from Reclamation's Northern California Area Office can be dispatched to assist ACID in removing the boards.

Keswick Dam release rate ramping required for ACID operations is limited to 15 percent in a 24-hour period and 2.5 percent in a 1-hour period. Therefore, advance notification is important when scheduling decreases to allow installation or removal of the ACID dam. Since 2001, ACID has completed improvements to the ACID Diversion Dam fish ladder, improving passage for winter-run Chinook salmon, and to the ACID diversion canal fish screen.

Red Bluff Diversion Dam The RBDD, located on the Sacramento River approximately 2 miles southeast of Red Bluff, is a gated structure with fish ladders at each abutment. Construction of the RBDD was completed in 1967, coincidentally with startup of the SWP pumps in the Delta. When the gates are lowered, the impounded water rises about 13 feet, creating Lake Red Bluff, and allowing gravity diversions through a set of drum screens into a stilling basin servicing the Tehama-Colusa and Corning canals.

The Tehama-Colusa Canal is a lined canal extending 111 miles south from the RBDD to provide irrigation service on the west side of the Sacramento Valley in Tehama, Glenn, Colusa, and northern Yolo counties. Construction on the Tehama-Colusa Canal began in 1965, with enlargement approved in 1967, first operation in 1976, and completion in 1980.

The Corning Pumping Plant lifts water approximately 56 feet from the screened portion of the settling basin into the unlined, 21-mile-long Corning Canal. The Corning Canal first began to serve water to CVP contractors in Tehama County who cannot be served by gravity from the Tehama-Colusa Canal in 1966. Both canals are operated by the Tehama-Colusa Canal Authority.

Since 1986, the RBDD gates have been raised during the winter to allow passage of winter-run Chinook salmon. The National Marine Fisheries Service (NMFS) issued a Biological Opinion (BO) on winter-run Chinook salmon in 1993 mandating the gates to be raised from September 15 through May 14 each year (NMFS 1993). This 8-month gates-up operation has eliminated passage impedance of upstream migration for species that migrate above the RBDD to spawn, with the exception of 70 percent of the spring-run Chinook, and an estimated 35 percent of the green sturgeon migrants (Tehama-Colusa Canal Authority and Reclamation 2002).

Monitoring associated with the operation of the Red Bluff research pumping plant has shown the 8-month gates-up operation also substantially reduced or eliminated losses of juvenile salmonids attributable to predatory fish. In addition, the studies demonstrated that juveniles pass safely under the gates when predators are absent (Gaines and Martin, 2002). Concurrently, experiments have shown both types of pumps tested at the research pumping plant pass juvenile fish with less than 1.8 percent sublethal injury rates during 24-hour trials (Borthwick and Corwin 2001).

Reclamation has continued to operate the RBDD using the 8-month gates-up procedures since 1993. Reclamation also continues to use rediversions of CVP water stored in Black Butte Reservoir to supplement water pumped at the RBDD during the gates-out period. This water is rediverted with the aid of temporary gravel berms through an unscreened, constant head orifice into the Tehama-Colusa Canal.

This arrangement has successfully met water demand since 1993, but the delivery has consistently been limited. Thus far, Reclamation has rarely had to use the provision of the Reasonable and Prudent Alternative of the 1993 Winter-Run BO, which allows up to one closure per year for the gates for up to 10 days. While mandatory use of this temporary gates closure has been avoided, with the exception of 1997 and 2007, its use in another year was only avoided by an exceptionally heavy, late storm. Reclamation is in the process of implementing with NMFS a decision-making protocol to ensure such gate closure decisions can be made on short notice.

The Red Bluff Diversion Dam is scheduled to be taken out of service in 2012 after the completion of a new pumping plant that will provide water supply to contractors off of the Tehama-Colusa Canal.

1.1.2 Hydrology and Hydraulics

The Sacramento Valley contains the Sacramento, Feather, and American river basins, covering an area of more than 24,000 square miles in the northern portion of the Central Valley. The Sacramento Valley also encompasses three major drainage basins: the McCloud River, Pit River, and the Sacramento River in the north; the Delta in the south; the Sierra Nevada Mountains and Cascade Ranges in the east; and the Coast Range and Klamath Mountains in the west. Drainage in the northern portion of the Central Valley is provided by the Sacramento, Feather, and American rivers, and major and minor streams and rivers that drain the east and west sides of the valley.

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

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

Table 1-2. Historical Average Monthly Precipitation in the Primary Study Area

Month	Mount Shasta City[1] Elevation 3,544 ft-msl		Redding[2] Approximate Elevation 500 ft-msl		Sacramento[3] Approximate Elevation 20 ft-msl	
	(inches)	(% of annual)	(inches)	(% of annual)	(inches)	(% of annual)
October	2.2	5.5	2.2	5.6	0.9	5.2
November	5.3	13.2	4.7	11.9	2.1	12.1
December	6.7	16.7	7.0	17.7	3.0	17.2
January	7.1	17.7	8.0	20.2	3.6	20.7
February	6.2	15.4	5.9	14.9	3.1	17.8
March	5.3	13.2	5.0	12.6	2.4	13.8
April	2.9	7.2	3.0	7.6	1.2	6.9
May	1.9	4.7	1.5	3.8	0.5	2.9
June	1.0	2.5	1.0	2.5	0.2	1.1
July	0.4	1.0	0.2	0.5	0.0	0.0
August	0.4	1.0	0.3	0.8	0.1	0.6
September	0.8	2.0	0.8	2.0	0.3	1.7
Total	40.2	100	39.6	100	17.4	100

Source: Western Regional Climate Center

Notes:
[1] Period of Record (1948-present)
[2] Period of Record (1931-1979)
[3] Period of Record (1948-present)
Key:
ft-msl = feet above mean sea level

The Sacramento River system is complex. There are numerous Federal, State, local, and private dams in the foothills with reserved flood storage space on the Sacramento, Feather, and American river systems. These reservoirs collect and manage flows from the upper watersheds, but many tributaries enter downstream from the dams, and the flow from the downstream tributaries is mostly unregulated. It takes about 70 hours (almost 3 days) for water released from Shasta Dam on the northern portion of the Sacramento River to reach the Feather River confluence at Verona, and about 78 hours (more than 3 days) to reach the American River confluence at I Street in the City of Sacramento. Table 1-3 shows the estimated travel times of high flows in the Sacramento River and major tributaries.

Table 1-3. Travel Times of Major Sacramento Valley Rivers

Location	Travel Time (hours)
Sacramento River	
Shasta Dam	0
Keswick Dam	8
Bend Bridge	18
Red Bluff	20
Tehama	26
Hamilton City	31
Ord Ferry	36
Butte City	44
Moulton Weir	52
Colusa Weir	53
Colusa	55
Tisdale Weir	62
Verona	70
I Street Gage	78
American River	
Nimbus	0
I Street	8
Feather River	
Oroville	0
Verona	30
Yuba River	
Narrows	0
Yuba City	8

Source: USACE 1999

Downstream from Shasta Dam, the Sacramento River flows south-southeast for 65 river miles, until it reaches the valley floor south of Red Bluff. Along the valley floor, the river continues to flow south-southeast for 186 river miles to the City of Sacramento, where it changes to a southwesterly course and flows for an additional 60 river miles to its terminus at Suisun Bay in the Delta. Through the valley floor reach, the Sacramento River is flanked by overflow basins, two of which are leveed floodways. These floodways comprise part of the comprehensive flood management improvements that have been developed along the lower 175 miles of the river on the east bank, along the lower 185 miles of the west bank, and along the lower reaches of the river's major tributary streams. These floodways intercept all Sacramento River tributaries for more than 100 miles downstream from Stony Creek and Big Chico Creek to the Feather River. Downstream from Sacramento, the Sacramento River traverses the low-lying tidal area of the Delta. The Delta area is affected by tidal flow, and this tidal influence extends up the Sacramento River for up to 80 miles (or as far as Verona), during periods of low river flow. 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, as shown in Table 1-4.

Table 1-4. Key Locations Along Major Central Valley Rivers

Location	River Mile
Sacramento River	
Keswick Dam	299
Redding	296
Balls Ferry Bridge	273
Bend Bridge	255
Red Bluff	241
Los Molinos	236
Tehama	226
Hamilton City	199
Chico Landing	194
Stony Creek	192
Ord Ferry	184
Butte City	169
Moulton Weir	158
Colusa Weir	146
Colusa	143
Meridian	134
Grimes	125
Tisdale Weir	119
Knights Landing	90
Fremont Weir	83
Feather River	80
Verona	79
Natomas Cross Canal	79
Sacramento Weir	63
American River	60
I Street Gage	59.5
Deep Water Ship Channel (north end)	57
Clarksburg	42
Courtland	34
Walnut Grove	27
Isleton	18
Liberty Island	14
Rio Vista	12
Collinsville	0
Feather River	
Oroville Dam	70.4
Oroville Gaging Station	65.3
Mouth	0.0
Yuba River	
Englebright Dam	22.8
Mouth	0.0
American River	
Folsom Dam	26
Mouth	0.0

Source: USACE 1999

Shasta Lake and Vicinity

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

The four major tributaries to Shasta Lake are the Sacramento River, McCloud River, Pit River, and Squaw Creek, in addition to numerous minor tributary creeks and streams. The combined historical average monthly inflows to Shasta Lake from three major tributaries (Sacramento, McCloud, and Pit rivers) are shown in Table 1-5.

Table 1-5. Historical Inflows to Shasta Lake

	Average Monthly Inflow (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Sacramento River at Delta[1]	340	727	1,359	1,900	2,331	2,275	2,051	1,768	857	349	240	233	870
Pit River[1]	3,092	3,615	4,404	5,696	6,445	6,868	6,154	5,036	3,693	2,972	2,795	2,819	3,239
McCloud River[2]	587	777	1,266	1,629	1,861	1,770	1,470	1,120	765	590	531	521	766
Total	4,020	5,119	7,028	9,226	10,637	10,913	9,676	7,924	5,314	3,911	3,566	3,574	4,875

Source: USGS Gaging Stations 11342000, 11365000, 11368000

Notes:
[1] Period of record WY 1945 – 2010
[2] Period of record WY 1946 – 2010

Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = United States Geological Survey
WY = water year

The Sacramento Arm above Shasta Lake drains an area of roughly 430 square miles. Its headwaters include portions of Mount Shasta and the Trinity and Klamath Mountains. It flows south for approximately 40 miles before entering Shasta Lake below the town of Delta.

McCloud River The McCloud River drainage basin covers approximately 627 square miles of Siskiyou and Shasta counties. The McCloud River originates as Moosehead Creek southeast of Mount Shasta, at an elevation of approximately 5,500. From there, it flows approximately 59 miles in a southwesterly direction through McCloud Reservoir before entering Shasta Lake and joining the Sacramento River. The McCloud Reservoir watershed includes the entire basin draining into McCloud Reservoir and has a drainage area of 403 square miles. The lower McCloud River watershed begins at Pacific Gas and Electric

Company's (PG&E) McCloud Dam, extends down the McCloud River into Shasta Lake, and encompasses approximately 224 square miles.

Pit River The Pit River watershed is located in northeastern California and southeastern Oregon. The north and south forks of the Pit River drain the northern portion of the watershed. The north fork of the Pit River originates at the outlet of Goose Lake and the south fork originates in the south Warner Mountains at Moon Lake in Lassen County. The Pit River is joined by the Fall River in Shasta County. The Pit River has 21 named tributaries, totaling about 1,050 miles of perennial stream and encompassing approximately 4,700 square miles. PG&E has several dams and reservoirs within the Pit River watershed, including Iron Canyon Reservoir, and Pit 4, 5, 6, and 7 dams. Pit 7 Dam and Powerhouse are located immediately upstream from Shasta Reservoir's current high-water level on the Pit River.

Squaw Creek The Squaw Creek watershed is located east of Shasta Lake and drains 103 square miles. It flows to the southwest through generally steep terrain.

Shasta Lake Shasta Lake reservoir storage is typically at its highest in April and May and at its lowest in October and November. Table 1-6 shows the historical average end-of-month reservoir storage at Shasta Lake since 1954 by year type. Table 1-7 shows historical average end-of-month Shasta Lake reservoir water surface elevations since 1992 by year type.

Table 1-6. Historical End-of-Month Shasta Lake Storage by Year Type

Year Type	Average End-of-Month Storage (TAF)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	2,462	2,475	2,717	3,055	3,384	3,683	3,935	3,956	3,675	3,204	2,831	2,625
Wet	2,796	2,853	3,152	3,513	3,641	3,813	4,131	4,311	4,125	3,696	3,293	3,085
Above Normal	2,387	2,389	2,739	3,208	3,527	3,869	4,290	4,372	4,113	3,604	3,251	3,070
Below Normal	2,399	2,382	2,562	3,102	3,635	3,887	4,225	4,164	3,820	3,313	2,951	2,751
Dry	2,378	2,407	2,648	2,836	3,289	3,746	3,804	3,656	3,225	2,676	2,305	2,103
Critical	2,048	1,990	2,016	2,193	2,638	2,958	3,053	2,951	2,693	2,315	1,968	1,723

Source: DWR CDEC Gage SHA (2008)

Notes:

Period of record WY 1992 – 2010

Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index

Key:
CDEC = California Data Exchange Center
TAF = thousand acre-feet
WY = water year

Table 1-7. Historical End-of-Month Shasta Lake Reservoir Water Surface Elevations by Year Type

Year Type	Average End-of-Month Water Surface Elevation (ft-msl)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	979	980	994	1,007	1,023	1,035	1,045	1,045	1,033	1,014	996	986
Wet	997	1,000	1,015	1,030	1,034	1,041	1,053	1,059	1,051	1,035	1,018	1,010
Above Normal	976	977	1,006	1,016	1,030	1,043	1,058	1,061	1,051	1,032	1,018	1,010
Below Normal	975	975	984	1,011	1,033	1,044	1,056	1,053	1,040	1,020	1,004	994
Dry	974	976	988	996	1,019	1,038	1,040	1,034	1,016	992	973	962
Critical	956	952	954	964	990	1,005	1,009	1,005	992	973	954	927

Source: DWR CDEC Gage SHA (2010)

Notes:
Period of record WY 1992 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CDEC = California Data Exchange Center
ft-msl = feet above mean sea level
WY = water year

As previously described, releases from Shasta Lake to the Sacramento River can be made through either the Shasta Lake Powerplant, with a maximum capacity of about 16,000 cfs; through the river outlets, with a maximum capacity of about 81,000 cfs; or over the dam crest, through the spillway, with a maximum capacity of about 186,000 cfs. Table 1-8 shows historical monthly average releases from Shasta Lake by year type.

Table 1-8. Historical Shasta Lake Releases by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	4,691	4,492	5,307	8,446	10,167	9,881	7,135	9,329	10,610	11,519	9,427	6,826	5,917
Wet	4,791	5,010	8,111	17,104	19,395	17,663	10,990	10,327	11,108	11,714	10,583	7,450	8,109
Above Normal	4,524	3,954	3,739	5,826	9,371	11,073	5,828	10,845	11,035	12,259	9,142	6,623	5,702
Below Normal	4,873	4,252	5,085	4,123	10,322	7,591	4,629	8,451	11,729	11,874	9,020	6,619	5,351
Dry	4,794	4,521	3,681	4,111	2,822	3,440	6,023	8,717	11,109	12,300	9,097	6,302	4,663
Critical	4,458	4,294	4,111	3,282	2,467	2,841	4,319	6,717	7,639	8,866	8,209	6,682	3,873

Source: DWR CDEC Gage SHA (2008)

Notes:
Period of record WY 1992 – 2007
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
TAF = thousand acre-feet
WY = water year

Upper Sacramento River (Shasta Dam to Red Bluff)

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

Imports from the Trinity River Watershed Since 1964, Trinity River water has been imported into the Sacramento River basin through the Clear Creek and Spring Creek tunnels (capacity 3,300 and 4,200 cfs, respectively). After meeting the monthly minimum instream flow requirement below Lewiston Dam,[1] and the Trinity Reservoir end-of-September minimum storage target of 600 thousand acre-feet (TAF), Trinity River water is diverted into Whiskeytown Reservoir. Monthly diversions are based on the beginning-of-month storage in Shasta Reservoir and Trinity Reservoir. For example, imports can be as much as 3,000 cfs for July to September when Trinity Reservoir storage is high and Shasta Reservoir storage is low. Whiskeytown Reservoir receives inflow from Clear Creek. After making releases to meet the minimum flow requirement downstream from Whiskeytown Dam,[2] water is diverted through Spring Creek Tunnel to Keswick Reservoir. Based on the December 19, 2000, Trinity River Mainstem Record of Decision (ROD) (Reclamation 2000), 368.6 TAF to 815 TAF are allocated annually for Trinity River flows. After several challenges and injunctions, on July 13, 2004, the Ninth Circuit Court upheld the ROD flows for the Trinity River. Historical monthly Spring Creek Tunnel flows to Keswick Reservoir between 1964 and 2004 are shown in Table 1-9. Flows from Clear Creek join the Sacramento River below Keswick Dam. Historical monthly Clear Creek Tunnel flows to the Sacramento River between 1964 and 2004 are shown in Table 1-10 by year type. Since the implementation of the ROD in 2004, flows in the Spring Creek Tunnel and in Clear Creek have followed a substantially different pattern. Due to the limited available hydrology, average monthly flows since 2004 are also shown in Tables 1-9 and 1-10.

[1] This minimum requirement, an annual amount of 369 to 815 TAF per the Trinity Environmental Impact Statement Preferred Alternative, is a lookup value that varies by month and the Trinity index; the Trinity index changes in April.

[2] This requirement is a lookup value that varies with the month and the Shasta Index.

Table 1-9. Historical Spring Creek Tunnel Flow to Keswick Reservoir by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	1,559	1,179	1,063	1,337	1,638	1,659	1,370	1,524	1,987	2,419	2,318	2,150	1,217
All Years[1]	1,354	738	658	726	1,077	1,000	664	1,187	1,248	1,579	1,601	1,470	805
Wet	1,386	1,320	1,512	2,082	2,552	2,200	2,109	2,105	2,527	2,681	2,464	2,215	1,520
Above Normal	994	847	826	1,550	1,941	2,111	1,343	1,426	1,654	1,621	2,032	1,945	1,105
Below Normal	1,790	1,472	1,425	912	1,252	1,800	1,687	1,767	2,198	2,830	2,409	1,956	1,302
Dry	1,420	971	605	621	799	992	446	619	1,218	2,255	2,098	2,337	845
Critical	2,393	1,109	372	470	406	604	401	1,013	1,658	2,374	2,383	2,127	929

Source: USGS Gaging Station 11371600

Notes:
[1] Period of Record is WY 2004 – 2010
Period of record WY 1964 – 2004 unless otherwise indicated,
Year- types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

Table 1-10. Historical Clear Creek Flow to the Sacramento River by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	122	181	243	319	343	340	217	124	83	63	63	97	133
All Years[1]	218	223	287	345	355	342	337	301	194	125	98	143	179
Wet	92	161	285	457	504	557	343	140	80	70	72	142	175
Above Normal	145	175	247	385	342	290	216	186	114	60	59	73	138
Below Normal	88	157	157	168	254	166	117	98	78	57	54	66	88
Dry	264	336	326	264	248	214	118	97	88	61	59	78	130
Critical	56	98	118	90	112	103	83	80	62	55	54	51	58

Source: USGS Gaging Station 11372000

Notes:
[1] Period of Record is WY 2004 – 2010
Period of record WY 1964 – 2004 unless otherwise indicated
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

Tributary Inflows Major tributaries to the Sacramento River between Keswick Dam and the RBDD include Cow, Battle, and Cottonwood creeks. Inflows from these creeks typically play a large role in Shasta Lake flood management operations due to their uncontrolled nature. Historical average annual flows from these four creeks to the Sacramento River are shown in Table 1-11.

Table 1-11. Historical Major Tributary Inflows to the Sacramento River Between Keswick Dam and Red Bluff Diversion Dam

Tributary	Average Monthly Inflow (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Cow Creek	119	449	1,146	1,698	1,652	1,399	888	566	222	63	38	46	500
Cottonwood Creek	115	369	1,210	2,239	2,441	2,078	1,221	718	330	124	74	79	663
Battle Creek	291	388	543	724	724	721	643	625	483	330	263	258	362

Source: USGS Gaging Stations11374000, 11376000, 11376550

Notes:
Period of record 1962 – 2010
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
WY = water year

Above Red Bluff Diversion Dam at Bend Bridge The RBDD forms an impoundment for gravity flow for diversion to the Tehama-Colusa Canal. Table 1-12 shows the historical average monthly Sacramento River flow above the RBDD at Bend Bridge by year type, and Table 1-13 shows the average monthly historical diversions to the Tehama-Colusa Canal by year type.

Table 1-12. Historical Sacramento River Flow Above Red Bluff Diversion Dam at Bend Bridge by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	6,810	6,694	10,552	17,512	20,236	18,105	12,210	13,459	13,657	14,024	11,750	8,855	9,298
Wet	6,720	7,696	14,857	32,159	33,606	30,445	19,629	16,175	15,490	15,137	13,362	10,037	13,001
Above Normal	6,874	6,243	10,108	15,173	18,685	19,856	11,165	17,013	14,360	14,159	11,468	8,747	9,305
Below Normal	6,985	6,095	10,055	12,859	23,001	14,935	9,746	11,122	14,382	14,242	10,914	8,376	8,607
Dry	7,018	6,589	8,280	8,318	8,789	8,193	7,781	10,554	12,850	14,545	11,429	8,257	6,818
Critical	6,509	5,832	5,894	6,699	8,981	6,420	6,316	8,718	9,646	10,777	9,885	7,751	5,650

Source: USGS Gaging Station 11377100

Notes:
Period of record WY 1992 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
WY = Water year

Table 1-13. Historical Diversions to the Tehama-Colusa Canal from Red Bluff Diversion Dam by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	134	17	7	16	33	85	191	534	949	998	867	313	252
Wet	123	18	2	7	45	67	114	450	902	1,093	1,059	331	257
Above Normal	145	18	4	24	14	58	215	521	1,026	1,004	817	329	254
Below Normal	190	12	0	2	34	80	272	749	1,046	914	543	291	245
Dry	143	14	12	35	34	165	332	693	1,035	916	616	303	264
Critical	90	22	43	10	14	42	82	384	648	734	944	204	192

Source: Reclamation Central Valley Project Operations Records (2008)

Notes:
Period of record WY 1992 – 2007
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
WY = water year

Lower Sacramento River and Delta

The hydrology and hydraulics of the Sacramento River below Red Bluff and the Delta are described below.

Lower Sacramento River The Sacramento River enters the Sacramento Valley about 5 miles north of Red Bluff. Over the 244 miles between Red Bluff downstream to the Delta, the river goes through a series of changes. From Red Bluff to Chico Landing (52 miles), the river meanders through alluvial deposits and receives flows from Antelope, Mill, Deer, Big Chico, Rock, and Pine creeks on the east side and Thomes, Elder, Reeds, and Red Bank creeks on the west side. From Chico Landing to Colusa (50 miles) the Sacramento River meanders through alluvial deposits between widely spaced levees. Stony Creek is the only major tributary in this segment of the river. There are no tributaries entering the Sacramento River between Stoney Creek and its confluence with the Feather River.

Floodwaters in the Sacramento River overflow the east bank at three sites in a reach referred to by the State as the Butte Basin Overflow Area. In this river reach, several Federal projects begin, including the Sacramento River Flood Control Project, Sacramento River Major and Minor Tributaries Project, and Sacramento River Bank Protection Project. Levees of the Sacramento River Flood Control Project begin in this reach, downstream from Ord Ferry on the west (RM 184), and downstream from RM 176 above Butte City on the east side of the river. Historical monthly average Sacramento River flows at Colusa are shown in Table 1-14 by year type.

Shasta Lake is also operated to meet a flow requirement in the Sacramento River, at Wilkins Slough near Grimes (RM 125). This compliance location is also known as the Navigation Control Point, and is discussed in detail in the Regulatory Setting section. Historical monthly average Sacramento River flows below Wilkins Slough are shown in Table 1-15 by year type.

Table 1-14. Historical Sacramento River Flows at Colusa by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	5,576	5,914	11,606	19,010	21,149	18,836	13,109	12,022	10,756	10,051	8,744	7,798	8,731
Wet	5,914	7,224	15,759	28,317	29,762	27,691	20,909	16,178	13,788	11,387	10,229	8,949	11,839
Above Normal	5,307	5,195	11,657	21,913	21,802	20,311	13,534	16,178	11,771	9,968	8,628	7,684	9,304
Below Normal	5,232	4,971	11,658	17,703	22,672	18,185	11,646	9,112	10,729	9,749	7,802	7,425	8,258
Dry	5,306	5,826	9,419	10,567	12,163	11,558	6,932	7,347	8,406	10,133	8,281	7,041	6,228
Critical	5,850	4,996	6,116	8,654	14,022	9,298	6,150	6,343	6,491	7,582	7,172	6,907	5,404

Source: USGS Gaging Station 11389500

Notes:
Period of record WY 1992 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

Table 1-15. Historical Sacramento River Flows Below Wilkins Slough, near Grimes by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	5,561	5,828	10,848	16,110	18,141	15,976	11,751	10,383	9,378	8,580	7,663	7,690	7,724
Wet	5,770	6,842	14,214	21,438	23,171	20,967	17,403	14,317	12,319	10,013	9,133	8,759	9,923
Above Normal	5,331	5,361	10,434	19,333	19,164	17,390	13,117	14,070	10,738	8,486	7,434	7,536	8,360
Below Normal	5,234	4,771	10,649	16,138	19,067	16,049	11,467	8,069	9,417	8,093	6,768	7,431	7,431
Dry	5,483	6,011	9,635	10,309	11,976	11,638	6,598	6,098	6,915	8,585	7,345	7,050	5,904
Critical	5,774	4,883	6,421	8,872	14,321	9,845	5,686	4,853	4,944	6,158	6,047	6,781	5,100

Source: USGS Gaging Station 11390500

Notes:
Period of record WY 1992 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

Downstream from Wilkins Slough, the Feather River, the largest east side tributary to the Sacramento River, enters the river just above Verona. Between Wilkins Slough and Verona, floodwater is diverted at two places in this segment of the river – Tisdale Weir into the Tisdale Bypass and Fremont Weir into the Yolo Bypass. The bypass system routes floodwater away from the mainstem Sacramento River to discharge into the Delta. Historical average monthly Sacramento River flows at Verona are shown in Table 1-16 by year type.

Table 1-16. Historical Sacramento River Flows at Verona by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	9,572	10,310	19,344	31,500	35,742	31,995	22,835	19,731	16,597	15,794	15,059	14,008	14,642
Wet	10,461	11,751	27,901	47,558	54,255	48,686	38,499	30,837	23,876	18,344	17,281	16,259	20,862
Above Normal	8,911	9,480	16,691	34,688	35,514	33,792	23,702	25,529	19,283	17,135	16,331	14,099	15,416
Below Normal	9,314	9,617	17,717	29,729	33,565	29,934	18,284	12,214	14,910	16,229	15,974	14,775	13,419
Dry	8,955	10,442	15,141	17,850	19,059	19,377	11,364	10,308	11,014	15,560	14,218	12,369	10,021
Critical	9,674	8,822	12,457	14,515	22,718	14,418	8,679	7,366	7,024	8,926	9,428	11,057	8,145

Source: USGS Gaging Station 11425500

Notes:
[1] Period of record WY 1992 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

Below Verona, the Sacramento River flows 79 miles to the Delta, passing the City of Sacramento. 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. The American River flows into the Sacramento River in the City of Sacramento. When Sacramento River system flood flows are the highest, a portion of the flow is diverted into the Yolo Bypass at the Sacramento Weir about 3 miles upstream from the American River confluence in downtown Sacramento. At the downstream end, Yolo Bypass flows reenter the Sacramento River near Rio Vista. As the river enters the Delta, Georgiana Slough branches off from the mainstem of the Sacramento River, routing a portion of the flow into the central Delta. Historical monthly average Sacramento River flows in Rio Vista are shown in Table 1-17 by year type.

Table 1-17. Average Monthly Historical Sacramento River Flows at Rio Vista by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	7,797	8,854	20,470	40,713	54,324	44,833	33,925	24,465	14,920	12,459	11,090	10,256	17,119
Wet	8,823	10,774	32,191	73,740	104,708	79,546	69,207	41,787	20,719	13,610	11,591	11,062	28,739
Above Normal	8,052	8,695	17,577	33,140	40,132	41,233	24,789	28,974	17,115	13,081	11,795	10,968	15,432
Below Normal	7,912	7,602	16,626	28,917	39,981	34,479	17,774	12,568	13,470	12,813	11,991	10,870	12,963
Dry	6,589	7,995	12,877	16,400	16,855	17,750	11,122	9,891	8,712	11,488	10,433	9,200	8,426
Critical	7,797	8,854	20,470	40,713	54,324	44,833	33,925	24,465	14,920	12,459	11,090	10,256	17,119

Source: USGS Gaging Station 11455420

Notes:
Period of record WY 1995 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

Delta The hydraulics of the Delta are complicated by tidal influences, a multitude of agricultural and M&I diversions for use within the Delta itself, and by CVP and SWP exports. The principal factors affecting Delta hydrodynamics are (1) river inflow and outflow from the Sacramento River and San Joaquin River systems, (2) daily tidal inflow and outflow through San Francisco Bay, and (3) export pumping from the south Delta, primarily through the Harvey O. Banks (Banks) and C.W. “Bill” Jones (Jones) pumping plants.

Delta Inflow Inflow to the Delta comes from the Sacramento, San Joaquin, Mokelumne, and Cosumnes rivers, and many smaller east side tributaries. Historical monthly average total Delta inflow is shown in Table 1-18 by year type.

Table 1-18. Total Historical Delta Inflow by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	14,175	14,393	27,607	58,848	65,903	59,310	41,364	34,635	27,197	23,377	20,039	18,417	24,456
Wet	17,008	17,478	44,745	115,602	121,007	106,529	80,054	60,166	42,826	31,164	24,795	23,444	41,303
Above Normal	12,464	13,032	21,753	49,529	58,561	58,862	36,989	39,892	30,631	24,398	22,061	19,005	23,377
Below Normal	13,054	12,937	22,028	37,391	55,617	46,451	26,900	20,893	22,358	21,709	19,333	17,725	19,075
Dry	12,772	13,959	19,683	24,207	24,168	25,838	16,975	16,017	15,091	19,875	17,436	14,929	13,369
Critical	13,411	11,589	15,418	18,260	27,989	18,667	11,977	10,553	10,729	12,223	11,771	12,695	10,573

Source: Interagency Ecological Program Dayflow Calculation (2011)

Notes:
Period of record WY 1992 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
WY = water year

Delta Exports The Jones Pumping Plant consists of six pumps, with a maximum export capacity of 4,600 cfs during the irrigation season, and 4,200 cfs during the winter nonirrigation season. Limitations at the Jones Pumping Plant are the result of a Delta-Mendota Canal freeboard constriction near O'Neill Forebay and current water demand in the upper sections of the Delta-Mendota Canal. The Jones Pumping Plant is at the end of an earth-lined intake channel about 2.5 miles long. Table 1-19 shows the respective historical average monthly pumping volumes for the Jones Pumping Plant by year type.

Table 1-19. Historical Exports from the C.W. "Bill" Jones Pumping Plant by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	3,774	3,539	3,202	3,505	3,512	3,176	2,014	1,409	2,893	3,967	4,010	4,083	2,364
Wet	3,965	3,575	3,377	3,545	3,325	2,797	2,067	2,104	3,746	4,365	4,391	4,335	2,517
Above Normal	3,413	3,357	2,721	3,921	4,072	3,796	2,276	1,330	3,402	4,297	4,364	4,313	2,494
Below Normal	4,296	4,316	4,142	4,350	3,961	4,133	1,952	960	3,625	4,367	4,422	4,385	2,717
Dry	3,914	3,906	3,790	3,438	3,558	3,029	2,159	856	2,764	4,241	4,230	4,176	2,423
Critical	3,023	3,124	2,999	2,736	3,166	3,180	1,638	984	1,059	1,705	1,714	2,567	1,686

Source: USGS Gaging Station 11313000

Notes:
Period of record WY 1992 – 2009
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

The SWP Banks Pumping Plant supplies water for the South Bay Aqueduct (SBA) and the California Aqueduct, with an installed capacity of 10,300 cfs. Under current operational constraints, exports from Banks Pumping Plant are generally limited to a daily average of 6,680 cfs, except between December 15 and March 15, when exports can be increased by 33 percent of San Joaquin River flow. The Banks Pumping Plant exports water from Clifton Court Forebay, a 31,000 acre-foot reservoir that provides storage for off-peak pumping, and moderates the effect of the pumps on the fluctuation of flow and stage in adjacent Delta channels. Table 1-20 shows the historical monthly average exports for the Banks Pumping Plant by year type.

Table 1-20. Historical Exports from the Harvey O. Banks Pumping Plant by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	3,781	3,699	4,164	4,395	3,731	3,353	1,816	1,098	2,485	5,309	5,501	4,975	3,699
Wet	4,586	3,975	3,827	3,535	2,620	1,991	1,595	1,481	2,929	5,554	5,568	5,423	3,975
Above Normal	3,147	4,069	4,038	6,650	6,269	5,151	3,179	1,335	5,201	6,535	6,675	6,799	4,069
Below Normal	2,500	2,612	3,775	5,425	4,696	5,275	1,451	819	2,450	5,717	6,632	5,694	2,612
Dry	3,158	4,025	4,651	4,090	3,533	3,887	1,828	666	775	5,539	5,403	3,880	4,025
Critical	4,845	2,747	4,779	3,176	2,692	1,755	772	736	533	1,868	2,603	2,366	2,747

Source: DWR CDEC Gage HRO (2011)

Notes:
Period of record WY 1994 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
CDEC = California Data Exchange Center
TAF = thousand acre-feet
WY = water year

Contra Costa Water District (CCWD) supplies CVP water to its users via a pumping plant at the end of Rock Slough. At Rock Slough, the water is lifted 127 feet into the Contra Costa Canal by a series of four pumping plants. The 47.5-mile-long canal terminates in Martinez Reservoir. The Rock Slough diversion capacity of 350 cfs gradually decreases to 22 cfs at the terminus. CCWD also constructed and operates the 100,000 acre-foot Los Vaqueros Reservoir, which has an intake and pumping plant on the Old River for diverting surplus Delta flows to reservoir storage or contract water to CCWD users. Los Vaqueros is refilled by diversions only when source water chloride concentration is relatively low. Los Vaqueros water is used for water quality blending and delivery during low Delta outflow periods, when the chloride concentration at Rock Slough and Old River is greater than 65 milligrams per liter (mg/L). The Old River facility allows CCWD to divert up to 250 cfs to a blending facility with the Contra Costa Canal, and to divert up to 200 cfs of

CVP and Los Vaqueros water rights water for storage in Los Vaqueros Reservoir. CCWD also has a third diversion facility in the Delta at the southern end of a 3,000-foot-long channel running due south of Suisun Bay, near Mallard Slough, with a capacity of 39.3 cfs, but the Mallard Slough facility is only used during periods of very high Delta outflow. Table 1-21 shows the historical monthly average exports for the CCWD Rock Slough Pumping Plant by year type.

Table 1-21. Historical Exports from the Contra Costa Water District Rock Slough Pumping Plant by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	198	165	126	110	108	104	114	149	140	210	205	205	111
Wet	223	186	117	104	76	72	80	122	137	190	222	226	106
Above Normal	115	152	145	123	186	175	186	229	152	281	240	228	134
Below Normal	**No Below Normal Years in Period of Record**												
Dry	218	54	35	13	16	16	31	69	47	168	29	32	44
Critical	211	179	173	159	155	155	168	176	181	208	213	214	133

Source: USGS Gaging Station 11337000

Notes:
Period of record WY 1992 – 2001
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
USGS = U.S. Geological Survey
WY = water year

Delta Outflow Because tidal inflows are approximately equivalent to tidal outflows during each daily tidal cycle, tributary inflows and export pumping are the principal variables that define the range of hydrodynamic conditions in the Delta. Excess outflow occurs almost entirely during the winter and spring months. Average winter outflow is about 32,000 cfs, while the average summer outflow is 6,000 cfs. Due to tidal factors and changing channel geometry, Delta outflow is typically a calculated value rather than a directly measured one. Table 1-22 shows the historical average calculated Delta outflow by year type.

Table 1-22. Calculated Historical Delta Outflow by Year Type

Year Type	Average Monthly Release (cfs)												Annual Total (TAF)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
All Years	5,424	14,518	30,768	52,981	62,052	53,002	37,108	26,492	15,823	8,322	6,569	9,171	19,662
Wet	6,867	9,969	38,735	111,298	117,230	103,527	75,658	54,680	32,121	16,432	10,641	10,715	35,427
Above Normal	5,325	6,242	15,851	41,114	50,914	51,526	30,858	35,013	18,864	9,395	6,977	5,068	16,718
Below Normal	5,462	5,913	15,347	29,704	49,137	36,968	23,579	16,652	11,085	7,009	4,603	5,280	12,672
Dry	4,241	5,916	11,722	17,074	18,830	18,455	11,807	12,051	7,644	5,203	3,714	4,175	7,296
Critical	4,225	5,193	8,854	13,916	24,473	12,020	7,963	6,450	4,821	3,697	3,063	4,300	5,945

Source: Interagency Ecological Program Dayflow Calculation (2011)

Notes:
Period of record WY 1992 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
cfs = cubic feet per second
TAF = thousand acre-feet
WY = water year

CVP/SWP Service Areas

This section describes the hydrology and hydraulics of the CVP/SWP service areas south of the primary study area.

CVP Service Areas Downstream from the Jones Pumping Plant, CVP water flows in the Delta-Mendota Canal and can be either diverted by the O'Neill Pumping-Generating Plant into the O'Neill Forebay, or can continue down the Delta-Mendota Canal for delivery to CVP contractors. The O'Neill Pumping-Generating Plant releases flows from the O'Neill Forebay back to the Delta-Mendota Canal. The O'Neill Pumping-Generating Plant consists of six pump-generating units, with a capacity of 700 cfs each.

The O'Neill Forebay is a joint CVP/SWP facility, with a storage capacity of about 56,000 acre-feet. In addition to its interactions with the Delta-Mendota Canal via the O'Neill Pumping-Generating Plant, it is a part of the SWP California Aqueduct. The O'Neill Forebay serves as a regulatory body for San Luis Reservoir; the William R. Gianelli (Gianelli) Pumping-Generating Plant, also a joint CVP/SWP facility, can pump flows from the O'Neill Forebay into San Luis Reservoir, and also make releases from San Luis Reservoir to the O'Neill Forebay for diversion to either the Delta-Mendota Canal or the California Aqueduct. Also, several water districts receive diversions directly from the O'Neill Forebay. The Gianelli Pumping-Generating Plant consists of eight units, with 1,375 cfs of capacity each.

San Luis Reservoir lies at the base of foothills on the west side of the San Joaquin Valley. The reservoir provides offstream storage for excess winter and spring flows diverted from the Delta. It is sized to provide seasonal carryover storage, with a total capacity of 2,027,840 acre-feet. The CVP share of the storage is 965,660 acre-feet; the remaining 1,062,180 acre-feet are the SWP share. During spring and summer, water demands and schedules are greater than the capability of Reclamation and the California Department of Water Resources (DWR) to pump water from the Jones and Banks pumping plants; water stored in San Luis Reservoir is used to make up the difference. Since San Luis Reservoir receives very little natural inflow, water must be stored during the fall and winter when the two Delta pumping plants can pump more water from the Delta than is needed to meet water demands. The CVP share of San Luis Reservoir is typically at its lowest in August and September, and at its maximum in April. Table 1-23 shows historical monthly average storage in the CVP share of San Luis Reservoir by year type.

The San Felipe Division of the CVP supplies water to customers in Santa Clara and San Benito counties from San Luis Reservoir. The operation of San Luis Reservoir has the potential to affect the water quality and reliability of these supplies if reservoir storage drops below 300 TAF.

Table 1-23. Historical End-of-Month CVP San Luis Storage by Year Type

Year Type	Average End-of-Month Storage (TAF)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	372	509	633	767	836	892	846	679	493	297	209	270
Wet	442	573	703	827	900	942	915	798	635	419	295	329
Above Normal	241	374	478	662	796	932	917	767	690	420	312	376
Below Normal	355	509	701	855	907	951	830	540	285	123	90	157
Dry	492	652	793	904	896	899	828	587	317	204	172	268
Critical	404	549	662	770	829	926	879	742	461	178	31	94

Source: DWR CDEC Gage SLF (2011)

Notes:
Period of record WY 1992 – 2009
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CDEC = California Data Exchange Center
TAF = thousand acre-feet
WY = water year

South of the O'Neill Forebay, the Delta-Mendota Canal terminates in the Mendota Pool, about 30 miles west of Fresno. From the Delta-Mendota Canal, the CVP makes diversions to multiple water users and refuges. Delta-Mendota Canal capacity at the terminus is 3,211 cfs. Parallel to the Delta-Mendota Canal, the San Luis Canal-California Aqueduct is a joint-use facility for the CVP and SWP. It begins on the southeast edge of the O'Neill Forebay and extends about 101.5 miles southeasterly to a point near Kettlemen City. Water from the canal serves the San Luis Federal service area, mostly for agricultural purposes and for some M&I uses. The canal has a capacity ranging from 8,350 cfs to 13,100 cfs.

SWP Service Areas South of Banks Pumping Plant, the California Aqueduct flows into Bethany Reservoir, a 5,000 acre-foot forebay for the South Bay Pumping Plant. Exiting the Bethany Forebay, the California Aqueduct flows through a series of checks to the aforementioned O'Neill Forebay, and is either pumped into San Luis Reservoir or released to the San Luis Canal, the CVP/SWP joint-use portion of the California Aqueduct. Table 1-24 shows the historical monthly average storage in the SWP share of San Luis Reservoir by year type. Deliveries are made from the California Aqueduct to agricultural and M&I contractors.

Table 1-24. Historical End-of-Month SWP San Luis Storage by Year Type

Year Type	Average End-of-Month Storage (TAF)											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
All Years	595	639	725	876	968	1,008	943	797	643	567	534	583
Wet	822	907	988	1,097	1,110	1,084	1,023	926	824	770	700	781
Above Normal	410	451	523	824	996	1,021	966	797	672	605	611	727
Below Normal	607	613	616	809	972	1,069	939	674	435	370	409	514
Dry	600	653	800	878	977	1,034	945	719	489	426	455	452
Critical	763	679	736	799	883	1,023	944	829	608	404	325	390

Source: DWR CDEC Gage LUS (2011)

Notes:
Period of record WY 1992 – 2010
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CDEC = California Data Exchange Center
TAF = thousand acre-feet
WY = water year

1.1.3 Surface Water Supply

While water supply reliability is one of the two primary planning objectives of the SLWRI, operations for Shasta Reservoir are primarily focused on delivering water supply to CVP contractors. However, because of the interconnectivity of the CVP and SWP, water supply operations of the SWP could be affected by changes in operations of the CVP associated with the SLWRI.

CVP/SWP Service Areas

This section describes surface water supply to CVP and SWP contractors.

CVP Contractors At certain times of the year, operations of Shasta Reservoir are driven by water supply needs of the CVP Contractors. The CVP has 273 water service contractors. The CVP provides water to settlement contractors in the Sacramento Valley, exchange contractors in the San Joaquin Valley, agricultural and M&I water service contractors in both the Sacramento and San Joaquin valleys, and wildlife refuges both north and south of the Delta. At the beginning of each year, Reclamation evaluates hydrologic conditions throughout California and uses this information to forecast CVP operations, and to estimate the amount of water to be made available to the Federal water service contractors for the year (allocations to settlement and exchange contractors are fixed according to unimpaired inflow to Shasta Reservoir).

The majority of the Federal water service contractors have service areas located south of the Delta. Most of their supplies must be conveyed through the Delta before delivery. Allocations vary considerably from year to year. In general, allocations to CVP water service contractors south of the Delta are lower than allocations to service contractors in the Sacramento Valley. A detailed summary of CVP annual contract amounts for service areas supplied from the Delta is presented in Table 1-25.

Table 1-25. Summary of CVP Contract Amounts for Service Areas South of the Delta

Contractors	CVP Long-Term Contracts				Water Right, Annual Amount (acre-feet)
	Contract Number	Current Effective Periods	Annual Entitlements (acre-feet)	Types (acre-feet)	
DELTA-MENDOTA CANAL					
Exchange Contractors	I1r-1144	-	**840,000**		
Central California Irrigation District, Columbia Canal Co., Firebaugh Canal Water District, San Luis Canal Co.				Exchange	
Refuges			**177,297**		
Grassland Water District	01-WC-20-1754	03/01/2001 – 02/28/2026	125,000 [1]	Refuge	-
California Department of Fish and Game (total)	01-WC-20-1756	03/01/2001 – 02/28/2026	37,007 [1]	Refuge	-
Volta Wildlife Management Area	01-WC-20-1756	03/01/2001 – 02/28/2026	13,000 [1]	Refuge	-
Los Banos Wildlife Management Area	01-WC-20-1756	03/01/2001 – 02/28/2026	10,470 [1]	Refuge	-
Salt Slough	01-WC-20-1756	03/01/2001 – 02/28/2026	6,680 [1]	Refuge	-
China Island	01-WC-20-1756	03/01/2001 – 02/28/2026	6,857 [1]	Refuge	-
National Wildlife Refuge in San Joaquin Valley	01-WC-20-1758	03/01/2001 – 02/28/2026	15,290 [1]	Refuge	-
Kesterson National Wildlife Refuge	01-WC-20-1758	03/01/2001 – 02/28/2026	10,000 [1]	Refuge	-
Freitas	01-WC-20-1758	03/01/2001 – 02/28/2026	5,290 [1]	Refuge	-
Irrigation and M&I			**378,872**		
City of Tracy	Being Negotiated	-	10,000	Irrigation and M&I	-
Banta-Carbona Irrigation District	14-06-200-4305A-LTR1	03/01/2005 – 02/28/2030	20,000	Irrigation and M&I	-
West Side Irrigation District	7-07-20-W0045-LTR1	03/01/2005 – 02/28/2030	5,000	Irrigation and M&I	-
Del Puerto Water District	14-06-200-922-LTR1	03/01/2005 – 02/28/2030	140,210 [5]	Irrigation and M&I	-
West Stanislaus Water District	14-06-200-1072-LTR1	03/01/2005 – 02/28/2030	50,000	Irrigation and M&I	-
Patterson Water District	14-06-200-3598A-LTR1	03/01/2005 – 02/28/2030	16,500	Irrigation and M&I	6,000
Centinella Water District	7-07-20-W0055-LTR1	03/01/2005 – 02/28/2030	2,500	Irrigation and M&I	-
Broadview Water District	14-06-200-8092-LTR1	03/01/2005 – 02/28/2030	27,000	Irrigation and M&I	-
Byron Bethany Irrigation District	NA	NA	20,600	NA	NA
Eagle Field Water District	14-06-200-7754-LTR1	03/01/2005 – 02/28/2030	4,550	Irrigation and M&I	-
Mercy Springs Water District	14-06-200-3365A-LTR1	03/01/2005 – 02/28/2030	2,842	Irrigation and M&I	-
Oro Loma Water District	14-06-200-7823-LTR1	03/01/2005 – 02/28/2030	4,600	Irrigation and M&I	-
DWR Intertie @MP7.70-R	NA	NA	NA	Irrigation and M&I	-
Newman Wasteway Recirculation	NA	NA	NA	Irrigation and M&I	-
Panoche Water District	NA	NA	27,000	Irrigation and M&I	-
San Luis Water District	14-06-200-7773A-LTR1	03/01/2005 – 02/28/2030	45,080	Irrigation and M&I	-
Widren Water District	14-06-200-8018-LTR1	03/01/2005 – 02/28/2030	2,990	Irrigation and M&I	-
Total for Delta-Mendota Canal			**1,396,169**		6,000

Table 1-25. Summary of CVP Contract Amounts for Service Areas South of the Delta (contd.)

Contractors	CVP Long-Term Contracts				Water Right, Annual Amount (acre-feet)
	Contract Number	Current Effective Periods	Annual Entitlements (acre-feet)	Types	
SAN JOAQUIN AND MENDOTA POOL					
Exchange Contractors	I1r-1144		**840,000**	Exchange	-
Central California Irrigation District, Columbia Canal Co., Firebaugh Canal Water District, San Luis Canal Co.				Exchange	
Refuges			**218,098**		
Grassland Water District	01-WC-20-1754	03/01/2001 – 02/28/2026	125,000 [1]	Refuge	-
California Department of Fish and Game	01-WC-20-1756	03/01/2001 – 02/28/2026	51,601 [1]	Refuge	-
Los Banos Wildlife Management Area	01-WC-20-1756	03/01/2001 – 02/28/2026	10,470 [1]	Refuge	-
Salt Slough	01-WC-20-1756	03/01/2001 – 02/28/2026	6,680 [1]	Refuge	-
China Island	01-WC-20-1756	03/01/2001 – 02/28/2026	6,857 [1]	Refuge	-
Mendota Wildlife Management Area	01-WC-20-1756	03/01/2001 – 02/28/2026	27,594 [1]	Refuge	-
National Wildlife Refuge in San Joaquin Valley	01-WC-20-1758	03/01/2001 – 02/28/2026	41,497 [1]	Refuge	-
San Luis National Wildlife Refuge	01-WC-20-1758	03/01/2001 – 02/28/2026	19,000 [1]	Refuge	-
Kesterson National Wildlife Refuge	01-WC-20-1758	03/01/2001 – 02/28/2026	10,000 [1]	Refuge	-
West Bear Creek	01-WC-20-1758	03/01/2001 – 02/28/2026	7,207 [1]	Refuge	-
Freitas	01-WC-20-1758	03/01/2001 – 02/28/2026	5,290 [1]	Refuge	-
Irrigation and M&I			**106,348**		
Fresno Slough Water District	14-06-200-4019A-LTR1	03/01/2005 – 02/28/2030	4,000	Irrigation and M&I	866
James Irrigation District	14-06-200-700-A-LTR1	03/01/2005 – 02/28/2030	35,300	Irrigation and M&I	9,700
Tranquility Irrigation District	14-06-200-701-A-LTR1	03/01/2005 – 02/28/2030	13,800	Irrigation and M&I	20,200
Hughes	14-06-200-3537A-LTR1	03/01/2005 – 02/28/2030	70 [3]	Irrigation and M&I	93
Reclamation District 1606	14-06-200-3802A-LTR1	03/01/2005 – 02/28/2030	228	Irrigation and M&I	342
Dudley and Indart[4]	NA	NA	NA	Irrigation and M&I	2,280
Meyers, Marvin, Patricia [4]	NA	NA	NA	Irrigation and M&I	210
Laguna Water District	2-07-20-W0266-LTR1	03/01/2005 – 02/28/2030	800	Irrigation and M&I	-
Tranquility Public Utilities	NA	NA	70	Irrigation and M&I	-
Mid-Valley Water District (no contract)	NA	NA	NA	Irrigation and M&I	-
Terra Linda Farms (Coelho Family Trust)	NA	NA	2,080	Irrigation and M&I	-
Westlands Water District	NA	NA	50,000	Irrigation	-
Wilson, JW (no contract)	NA	NA	NA	Irrigation and M&I	-
Total San Joaquin and Mendota Pool			**1,164,446**		33,691

Table 1-25. Summary of CVP Contract Amounts for Service Areas South of the Delta (contd.)

Contractors	CVP Long-Term Contracts: Contract Number	Current Effective Periods	Annual Entitlements (acre-feet)	Types	Water Right, Annual Amount (acre-feet)
SAN LUIS CANAL / CROSS VALLEY CANAL					
Refuges			**64,601**		
California Department of Fish and Game	01-WC-20-1756	03/01/2001 – 02/28/2026	64,601 [1]	Refuge	-
O'Neill Forebay Wildlife Refuge	NA	NA	NA	Refuge	-
Irrigation and M&I			**1,703,030**		
Broadview Water District	14-06-200-8092-LTR1	03/01/2005 – 02/28/2030	27,000	Irrigation and M&I	-
San Luis Water District	14-06-200-7773A-LTR1	03/01/2005 – 02/28/2030	80,000	Irrigation and M&I	-
Veterans Administration Cemetery	3-07-20-W1124-LTR1	03/01/2005 – 02/28/2045	850	Irrigation	-
Panoche Water District	14-06-200-7864A-LTR1	03/01/2005 – 02/28/2030	94,000	Irrigation and M&I	-
Pacheco Water District	6-07-20-W0469-LTR1	03/01/2005 – 02/28/2030	10,080	Irrigation and M&I	6,000
City of Avenal	14-06-200-4619-LTR1	03/01/2005 – 02/28/2045	3,500	M&I	-
City of Coalinga	14-06-200-4173A-LTR1	03/01/2005 – 02/28/2045	10,000	M&I	-
City of Huron	14-06-200-7081A-LTR1	03/01/2005 – 02/28/2045	3,000	M&I	-
Westlands Water District	14-06-200-495A-LTR1	03/01/2005 – 02/28/2030	1,150,000	Irrigation and M&I	-
County of Fresno	14-06-200-8292A-LTR1	03/01/2005 – 02/28/2030	3,000	Irrigation and M&I	-
Hills Valley Irrigation District	14-06-200-8466A-LTR1	03/01/2005 – 02/28/2030	3,346	Irrigation and M&I	-
Kern-Tulare Irrigation District	14-06-200-8601A-LTR1	03/01/2005 – 02/28/2030	40,000	Irrigation and M&I	-
Lower Tule River Irrigation District	14-06-200-8237A-LTR1	03/01/2005 – 02/28/2030	31,102	Irrigation and M&I	-
Pixley Irrigation District	14-06-200-8238A-LTR1	03/01/2005 – 02/28/2030	31,102	Irrigation and M&I	-
Rag Gulch Water District	14-06-200-8367A-LTR1	03/01/2005 – 02/28/2030	13,300	Irrigation and M&I	-
Tri-Valley Water District	14-06-200-8565A-LTR1	03/01/2005 – 02/28/2030	1,142	Irrigation and M&I	-
County of Tulare	14-06-200-8293A-LTR1	03/01/2005 – 02/28/2030	5,308	Irrigation and M&I	-
San Benito Country Water District	8-07-20-W0130-LTR1 (interim)	03/01/2001 – 02/28/2002	35,550 [4]	Irrigation	-
			8,250 [4]	M&I	-
Santa Clara Valley Water District	7-07-20-W0023-LTR1 (interim)	03/01/2001 – 02/28/2002	33,100 [4]	Irrigation	-
			119,400 [4]	M&I	-
Total for San Luis and Cross Valley Canals			**1,767,631**		6,000
Totals for CVP South of Delta			**3,488,246**		45,691

Data Source: CVPIA long-term water service contract Web site (Reclamation 2005)

Notes:
[1] Level 2 contract amount.
[2] Conveyance not available.
[3] CVPIA long-term contract information is not available. Present in historical delivery record.
[4] Interim contract is based on the latest information available from the CVPIA.
[5] Del Puerto contract includes Davis, Hospital, Kern Canon, Salado, Sunflower, Mustang, Orestimba, Foothill, Quinto, and Romero water districts.

Key:
- = 0
CVP = Central Valley Project
CVPIA = Central Valley Project Improvement Act
DWR = California Department of Water Resources
M&I = municipal & industrial
NA = Not Available

The CVP water service contracts have varying water shortage provisions. Since 1991, Reclamation has been developing an M&I Water Shortage Policy applicable to all CVP M&I contractors. This policy provides M&I water supplies with a 75 percent water supply reliability based on a contractor's historical use, as defined by the last 3 years of water deliveries unconstrained by the availability of CVP water. Before M&I supplies are reduced, irrigation water supplies would be reduced below 75 percent of contract entitlement. The proposed policy also provides that when the allocation of irrigation water is reduced below 25 percent of contract entitlement, Reclamation will reassess the availability of CVP water and CVP water demand and, because of limited water supplies, M&I water supplies may be reduced below 75 percent of adjusted historical use. Because of water rights secured before construction of the CVP, Sacramento Valley settlement contractors and San Joaquin Valley exchange contractors have a higher level of reliability for their supplies; except in extremely dry years, when the water year type, as defined by the Shasta Hydrologic Index, is classified as critical, settlement and exchange contractors receive 100 percent of their contract amounts. In Shasta critical years, settlement and exchange contractors receive 75 percent of their contract amounts. A Shasta critical year is defined as a year when the total inflow to Shasta Reservoir is below 3.2 MAF, or the average inflow for a 2-year period is below 4.0 MAF and the total 2-year deficiency for deliveries is higher than 0.8. Table 1-26 shows historical CVP allocations since 1997.

Table 1-26. Historical CVP Annual Allocations

Year	Year Type	CVP Contract Allocation (%)						
		Agricultural		Urban		Wildlife Refuges		Settlement/ Exchange
		North of Delta	South of Delta	North of Delta	South of Delta	North of Delta	South of Delta	
1997	Wet	90	90	90 - 100	90 - 100	As scheduled	As scheduled	100
1998	Wet	100	100	100	100	100	100	100
1999	Wet	100	70	95	95	100	100	100
2000	Above Normal	100	65	100	90	100	100	100
2001	Dry	60	49	85	77	100	100	100
2002	Dry	100	70	100	95	100	100	100
2003	Above Normal	100	75	100	100	100	100	100
2004	Below Normal	100	70	100	95	100	100	100
2005	Above Normal	100	85	100	100	100	100	100
2006	Wet	100	100	100	100	100	100	100
2007	Dry	100	50	100	75	100	100	100
2008	Critical	40	40	75	75	100	100	100
2009	Dry	40	10	75	60	100	100	100

Source: Central Valley Project Operations Web site (Reclamation 2011)

Notes
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Key:
CVP = Central Valley Project
TAF = thousand acre-feet

SWP Contractors The CVP and SWP are intrinsically linked through the Delta; shared responsibilities under their respective water rights and coordinated operations agreements mean that a change in flow from one project could result in a flow change from the other. Accordingly, SWP water supply operations are discussed below.

The SWP operates under long-term contracts with public water agencies throughout California. These agencies, in turn, deliver water to wholesalers or retailers, or deliver it directly to agricultural and M&I water users (DWR 1999). The SWP contracts between DWR and individual State water contractors define several classifications of water available for delivery under specific circumstances. All classifications are considered “project water.” Table A is an exhibit to the SWP long-term water supply contracts. Table A amounts are used to define each contractor’s proportion of the available water supply that DWR will allocate and deliver to that contractor. Each year, each contractor may request an amount not to exceed its Table A amount. The Table A amounts are used as a basis for allocations to contractors, but the actual annual supply to contractors is variable and depends on the amount of water that is available. Water delivery capabilities are frequently lower than Table A amounts. Table

A water is water delivered according to this apportionment methodology and is given first priority for delivery (DWR 2005). The total Table A amount has increased since inception of the SWP, and is projected to reach a maximum amount of about 4.2 MAF per year by 2021. The current Table A amount provided each year is about 4.15 MAF (DWR 2006). Maximum annual Table A amounts allocated to the 29 SWP contractors are presented in Table 1-27.

Table 1-27. Maximum Annual SWP Table A Amounts

Contractors	Maximum Table A	
	(acre-feet)	Percent of Total
FEATHER RIVER		
County of Butte	27,500	0.66
Plumas County FC&WCD	2,700	0.06
City of Yuba City	9,600	0.23
Total for Feather River	**39,800**	**0.95**
NORTH BAY		
Napa County FC&WCD	29,025	0.70
Solano County WA	47,756	1.14
Total for North Bay	**76,781**	**1.84**
SOUTH BAY		
Alameda County FC&WCD, Zone 7	80,619	1.93
Alameda County WD	42,000	1.01
Santa Clara Valley WD	100,000	2.40
Total for South Bay Aqueduct	**222,619**	**5.34**
SAN JOAQUIN VALLEY		
Oak Flat WD	5,700	0.14
County of Kings	9,305	0.22
Dudley Ridge WD	57,343	1.37
Empire West Side ID	3,000	0.07
Kern County WA	998,730	23.93
Tulare Lake Basin WSD	95,922	2.30
Total for San Joaquin Valley	**1,170,000**	**28.04**
CENTRAL COAST		
San Luis Obispo County FC&WCD	25,000	0.60
Santa Barbara County FC&WCD	45,486	1.09
Total for Central Coast	**70,486**	**1.69**
SOUTHERN CALIFORNIA		
Antelope Valley-East Kern WA	141,400	3.39
Castaic Lake WA	95,200	2.28
Coachella Valley WD	121,100	2.90
Crestline-Lake Arrowhead WA	5,800	0.14
Desert WA	50,000	1.20
Littlerock Creek ID	2,300	0.06
Mojave WA	75,800	1.82
MWDSC	1,911,500	45.81
Palmdale WD	21,300	0.51
San Bernardino Valley MWD	102,600	2.46
San Gabriel Valley MWD	28,800	0.69
San Gorgonio Pass WA	17,300	0.41
Ventura County FCD	20,000	0.48
Total for Southern California	**2,593,100**	**62.14**
Table A Total	***4,172,786***	***100.0***

Source: DWR 2006

Key:
FC&WCD = Flood Control and Water Conservation District
FCD = Flood Control District
ID = Irrigation District
MWD = Municipal Water District
MWDSC = Metropolitan Water District of Southern California
SWP = State Water Project
WA = Water Agency
WD = Water District
WSD = Water Storage District

The Monterey Agreement (DWR 2003a), signed by 27 of the 29 SWP water contractors in 1995, restructured the SWP contracts to allocate water based on contractual Table A amounts instead of the amount of water requested for a given year. In times of shortages, the water supply to SWP agricultural and M&I contractors will be reduced equally.

Many contractors also make frequent use of additional contract water types to increase or decrease the amount of water available to the contractors under Table A. Other contract types of water include Article 21 Water, turnback pool water, and carryover water.

The SWP allocation (proportion of Table A to be delivered) for any specific year is made based on a number of factors, including existing storage, current regulatory constraints, projected hydrologic conditions, and desired carryover storage. Since 1995, annual delivery of Table A water has varied between 1.374 MAF (in 2001) and 2.965 MAF (in 2003). Article 21 deliveries have varied between approximately 20 TAF (in 1998) to 309 TAF (in 2000) (DWR 2006). Table 1-28 shows historical SWP deliveries since 1997 by year.

Table 1-28. Historical Annual SWP Deliveries

Year	Year Type	Table A		Article 21 (TAF)	Fish and Wildlife (TAF)	Water Rights and Other Contractors (TAF)
		Allocation (%)	Delivery (TAF)			
1997	Wet	-	2,324	21	1315	4.15
1998	Wet	100	1,726	20	2187	2.11
1999	Wet	100	2,379	158	7794	4.32
2000	Above Normal	90	3,201	309	1419	4.03
2001	Dry	39	1,547	43	1614	2.93
2002	Dry	70	2,573	43	1442	3.69
2003	Above Normal	90	2,901	60	1260	2.85
2004	Below Normal	65	2,600	218	1533	2.87
2005	Above Normal	90	-	-	-	-
2006	Wet	100	-	-	-	-
2007	Dry	60	-	-	-	-

Source: DWR Bulletin 132 1997 through 2006 (DWR 2006)

Notes:
Year types as defined in the Sacramento Valley Water Year Hydrologic Classification Index
Delivery information for 2005-2007 not available at time of publication
Key:
- = No data available
TAF = thousand acre-feet

1.1.4 Groundwater Resources

The use and sustainable management of groundwater resources is an important component in meeting water demands in California. This section describes groundwater resources within the boundaries of the primary and extended study areas. Information specific to groundwater resources includes groundwater levels and budget and groundwater quality.

The primary study area includes Shasta Lake and vicinity, and the upper Sacramento River to Red Bluff. The area of analysis for groundwater resources in the primary study area primarily includes the following groundwater basins:

- Redding groundwater basin
- Sacramento groundwater basin

The Redding groundwater basin and Sacramento groundwater basin can be further divided into 6 and 18 subbasins, respectively, as delineated in DWR Bulletin 118 (DWR 2003b). Groundwater subbasins in the primary study area are listed in Table A-1, along with a general description of the location and area of each subbasin, historical groundwater level trends, and groundwater budget, if available. Groundwater quality conditions in the subbasins are summarized in Table 1-29.

The extended study area includes the Sacramento River from Red Bluff to the Delta, as well as CVP/SWP service areas. Groundwater in the extended study area includes supply from the Sacramento Valley groundwater basin, San Joaquin Valley, Santa Clara Valley, Antelope Valley, Fremont Valley, Coastal Plain of Los Angeles, and Coastal Plain of Orange County groundwater basins, and multiple other smaller groundwater basins underlying areas that receive water from the CVP/SWP system. These groundwater basins and subbasins are listed and briefly described in Table A-2.

Shasta Lake and Vicinity

Shasta Lake and vicinity are located in the foothill area northwest of the Redding groundwater basin.

Groundwater Levels and Budget Small groundwater basins underlying Shasta Lake and vicinity do not have significant groundwater availability for use as a source of supply (Shasta County Water Agency 1998). Groundwater basins underlying Shasta County include the Fall River Valley groundwater basin, Lake Britton groundwater basin, and North Fork Battle Creek (Table A-1). Of these three groundwater basins, the Fall River Valley groundwater basin covers the largest area (54,800 acres) and groundwater extraction for agricultural use in this basin is the highest (approximately 19,000 acre-feet). Estimated groundwater extraction for M&I use in these subbasins ranges from 5 acre-feet to 240 acre-feet. Deep percolation from applied water is minor, ranging from 10 acre-feet to 4,800 acre-feet (Table A-1).

Groundwater Quality. Groundwater quality in Shasta Lake and vicinity is typically good. Total dissolved solids (TDS) concentrations in the Fall River Valley groundwater basin are low, ranging from 115 to 232 mg/L, as presented in Table 1-29.

Table 1-29. Groundwater Quality Data for the Various Groundwater Basins Throughout California

DWR Groundwater Basin/Subbasin Name (number)	TDS (mg/L)	
	Average	Range
Merced Subbasin (5-22.04)	200-400	100-3,600
Delta-Mendota Subbasin (5-22.07)	770	210-86,000
Kings Subbasin (5-22.08)	200-700	40-2,000
Kaweah Subbasin (5-22.11)	189	35-580
Tulare Lake Subbasin (5-22.12)	200-600	200-40,000
Tule Subbasin (5-22.13)	256	200-30,000
Tracy Subbasin (5-22.15)	1,190	210-7,800
Turlock Subbasin (5-22-03)	200-500	100-8,300
Modesto Subbasin (5-22-02)	60-500	200-8,300
Eastern San Joaquin Subbasin (5-22-01)	310	30-1,632
Chowchilla Subbasin (5-22.05)	200-500	120-6,400
Madera Subbasin (5-22.06)	200-400	100-6,400
Westside Subbasin (5-22.09)	520	220-35,000
Kern County Subbasin (5-22.14)	400-450	150-5,000
Pleasant Valley Subbasin (5-22.10)	1,500	1,000-3,000
Antelope Valley Subbasin (6-44)	-	-
Fremont Valley Subbasin (6-46)		
Santa Clara Subbasin (2-9.02)		
Central Subbasin (4-11.04)		
Coastal Plain of Orange County (8-1)		
Fall River Valley Groundwater Basin (5-5)	174	115-23
Lake Britton Area Groundwater Basin (5-46)	-	-
North Fork Battle Creek Groundwater Subbasin (5-50)		
Enterprise Subbasin (5-6.04)	-	160-210
Millville Subbasin (5-6.05)	140	-
Bowman Subbasin (5-6.01)	-	70-247
Rosewood Subbasin (5-6.02)	-	118-218
South Battle Creek Subbasin (5-6.06)	360	-
Red Bluff Subbasin (5-21.50)	207	120-500
Corning Subbasin (5-21.51)	286	130-490
Colusa Subbasin (5-21.52)	391	120-1,220
Bend Subbasin (5-21.53)	-	334-360
Antelope Subbasin (5-21.54)	296	-
Dye Creek Subbasin (5-21.55)	240	159-396
Los Molinos Subbasin (5-21.56)	217	-
Vina Subbasin (5-21.57)	285	48-543
West Butte Subbasin (5-21.58)	293	130-676
North Yuba Subbasin (5-21.60)	-	-

Table 1-29. Groundwater Quality Data for the Various Groundwater Basins Throughout California (contd.)

DWR Groundwater Basin/Subbasin Name (number)	TDS (mg/L)	
	Average	Range
South Yuba Subbasin (5-21.61)	-	-
Sutter Subbasin (5-21.62)	-	-
North American Subbasin (5-21.64)	-	-
Solano Subbasin (5-21.66)	427	150-880
Yolo Subbasin (5-21.)	880	480-2,060
Capay Valley Subbasin (5-21.68)	-	-
Cosumnes Subbasin (5-22.16)	218	140-438
South American Subbasin (5-21.65)	221	24-581

Source: California's Groundwater Bulletin 118 Update (DWR 2003b)
Key:
- = no data available
mg/L = milligrams per liter
TDS = total dissolved solids

Upper Sacramento River (Shasta Dam to Red Bluff)

The upper Sacramento River study area extends from Redding to Red Bluff, and includes the Redding groundwater basin and the northern portion of the Sacramento groundwater basin.

The Redding groundwater basin underlies most of the upper Sacramento River area between Shasta Dam and Red Bluff. The basin is bordered on the north, east, and west by foothills, and on the south by the Sacramento Valley groundwater basin (Tehama GMP 1996). The foothill areas that constitute the eastern and western portions of Shasta and Tehama counties, adjacent to the Redding groundwater basin, are designated as "highland" areas, noted for their relative scarcity of groundwater resources. DWR Bulletin 118 (2003b) subdivides the Redding groundwater basin into six subbasins: Anderson, Enterprise, Millville, Rosewood, Bowman, and South Battle Creek (see Table A-1).

The Sacramento groundwater basin extends from the Redding groundwater basin to the San Joaquin Valley, and includes Tehama, Glenn, Butte, Yuba, Colusa, Placer, and Yolo counties. The Sacramento groundwater basin is divided into the subbasins that are listed, and briefly described, in Table A-1.

Groundwater Levels and Budget In general, groundwater flows southeasterly on the west side of the Redding groundwater basin and southwesterly on the east side, towards the Sacramento River (Reclamation and DWR 2003). Historically, groundwater levels in the Redding groundwater basin have remained relatively stable, with no apparent long-term trend of declining or increasing levels. A slight decline in groundwater levels associated with the 1976 through 1977 and 1987 through 1994 droughts was followed by a recovery to predrought conditions of the early 1970s and 1980s. Generally, groundwater levels have a seasonal fluctuation of approximately 2 to 15 feet

(DWR 2003b). DWR has estimated the total quantity of groundwater storage in the Redding groundwater basin at approximately 6.9 MAF (Reclamation and DWR 2003). As of 1995, approximately 12.5 percent of all water used in the Redding groundwater basin was derived from groundwater, the vast majority of which was used to meet M&I demands (Shasta County Water Agency 1998). Total annual groundwater pumping for the Redding groundwater basin is approximately 37,000 acre-feet (DWR 1998). This is a minor amount compared to the basin's groundwater discharge to surface water of 266,000 acre-feet (Shasta County Water Agency 1998).

In the northern portion of the Sacramento groundwater basin, the following three subbasins are included in upper Sacramento River study area: Red Bluff, Antelope, and Bend subbasins (Table A-1). Groundwater extraction in the Red Bluff subbasin is nearly 90,000 acre-feet. This is much larger than the estimated groundwater pumping of approximately 19,000 acre-feet in the Antelope subbasin and 340 acre-feet in the Bend subbasin (A-1).

Groundwater Quality Groundwater in the Redding area is of good quality, as shown by low TDS concentrations, ranging from 70 to 360 mg/L (Table 1-29). This range is below the California Environmental Protection Agency (Cal/EPA) and U.S. Environmental Protection Agency (EPA) secondary drinking water standard of 500 mg/L and also below the agricultural water quality goal of 450 mg/L. Areas of high salinity and poor quality are generally found on the basin margins where groundwater is derived from marine sedimentary rock (Reclamation and DWR 2003).

Groundwater quality in the Sacramento groundwater basin is generally good, and sufficient for agricultural and M&I uses, with TDS levels ranging from 200 to 500 mg/L (DWR 2003b) (Table 1-29). Localized groundwater quality issues occur as a result of natural water quality impairments at the north end of the Sacramento Valley, where marine sedimentary rocks containing brackish to saline water are near the surface (DWR 2003b).

Lower Sacramento River and Delta

The groundwater basins underlying the lower Sacramento River and Delta areas include the Sacramento Valley groundwater basin, and North and South San Joaquin Valley groundwater basins.

Groundwater Levels and Budget In the Sacramento groundwater basin, groundwater flows inward from the edges of the basin and south parallel to the Sacramento River. Groundwater extraction in some local areas resulted in groundwater depressions and local groundwater gradients (Reclamation and DWR 2003). Before the completion of CVP facilities (1964 through 1971), pumping along the west side of the basin caused groundwater levels to decline. In the Sacramento groundwater basin, a slight decline of 2 to 12 feet was experienced in groundwater levels as a result of the 1976 through 1977 and 1987 through 1994 droughts. This was followed by a recovery to predrought conditions of the early 1970s and 1980s. Generally, groundwater level data show an average seasonal fluctuation ranging from 2 to 15 feet. Groundwater production in the basin increased from 500,000 acre-feet in the 1940s to 2 MAF annually in the mid-1990s.

Groundwater Quality As mentioned, groundwater quality in the Sacramento groundwater basin is generally good, and sufficient for agricultural and M&I uses, with TDS levels ranging from 200 to 500 mg/L (DWR 2003b) (Table 1-29).

CVP/SWP Service Areas

The groundwater basins underlying the CVP/SWP service areas include the San Joaquin Valley, Santa Clara Valley, Antelope Valley, Fremont Valley, Coastal Plain of Los Angeles, and Coastal Plain of Orange County groundwater basins, and multiple other smaller groundwater basins underlying areas that receive water from the CVP/SWP system.

Groundwater Levels and Budget The San Joaquin groundwater basin is a regional basin and is the largest in California, extending approximately from the Delta to Bakersfield. The San Joaquin Valley is divided into nine subbasins, listed in Table A-2 in Exhibit A. Areas within the San Joaquin groundwater basin are heavily groundwater-reliant. Groundwater accounts for about 30 percent of the annual supply used for agricultural and urban purposes (DWR 2003b). Groundwater production in the North San Joaquin groundwater basin alone increased from 1.5 MAF annually in the 1920s to more than 3.5 MAF annually in 1990 (Reclamation and DWR 2003). In the South San Joaquin groundwater basin, groundwater production for agriculture rose from approximately 3.0 MAF per year in the 1920s to more than 5.0 MAF per year 1980s (Reclamation and DWR 2003). Much of the San Joaquin groundwater basin is in overdraft conditions due to extensive groundwater pumping and irrigation, although the extent of overdraft varies widely from region to region.

Groundwater Quality Groundwater quality throughout the San Joaquin Valley is in general suitable for most urban and agricultural uses. Average TDS concentrations range from 218 to 1,190 mg/L, as listed in Table 1-29. Areas of high TDS concentration, primarily along the west side of the San Joaquin Valley, are the result of streamflow recharge that originates from marine sediments. High TDS concentrations are also seen in the trough of the Sacramento Valley due to concentration of salts resulting from evaporation and poor drainage (DWR 2003b). Agricultural pesticides and herbicides have been detected in groundwater throughout the region, but primarily along the east side of the San Joaquin Valley, where soil permeability is higher and depth to groundwater is shallower. From 1994 to 2000, 523 public wells out of 689 wells sampled met the State primary maximum contamination levels (MCL) for drinking water. The remaining wells have constituents that exceed one or more MCLs (DWR 2003b).

1.1.5 Flood Management

This section describes major features of the flood management system in the primary and extended study areas, including reservoirs, levees, weirs, and bypasses, shown in Figure 1-6. Historical operation of these facilities is also described.

Shasta Lake and Vicinity

Releases from Shasta Dam are often made for flood management. Table 1-30 shows the historical annual inflow, storage, and outflow for Shasta Reservoir from 1945 through 2006. Releases for flood management either occur in the fall, beginning in early October, to reach the prescribed vacant flood space, or to evacuate space during or after a storm event to maintain the prescribed vacant flood space in the reservoir. During a storm event, releases for flood management occur either over the spillway during large events or through river outlets for smaller events. As shown in Table 1-30, between 1950 and 2006, flows over the spillway occurred in 12 years, or in 21 percent of years. During the same time interval, releases for flood management (either for seasonal space evacuation or during a flood event, and including spills over the spillway) occurred in about 37 years, or nearly 70 percent of the years.

Upper Sacramento River

Historically, the largest flood events along the upper Sacramento River have been from heavy rainfall, with a relatively smaller component of the flows coming from snowmelt in the upper basin. Flood management operations at Shasta Dam include forecasting runoff into Shasta Lake as well as runoff of unregulated creek systems downstream from Keswick Dam. A critical component of upper Sacramento River flood operations is the forecast of local runoff entering the Sacramento River between Keswick Dam and Bend Bridge near Red Bluff.

The unregulated creeks (major tributaries include Cottonwood, Cow, and Battle creeks) discharging into the Sacramento River between Keswick Dam and Bend Bridge can produce high runoff rates into the Sacramento River in short periods of time. During large flood events, the local runoff between Keswick Dam and Bend Bridge can exceed 100,000 cfs.

Regulated peak flood flow frequency curves have been developed at several selected locations within the Sacramento River basin. The curves were developed to establish the relative frequency of annual peak flows at each location. Earlier curves developed at or near these locations were reevaluated and updated to incorporate recent floods, including floods in 1983, 1986, 1995, and 1997.

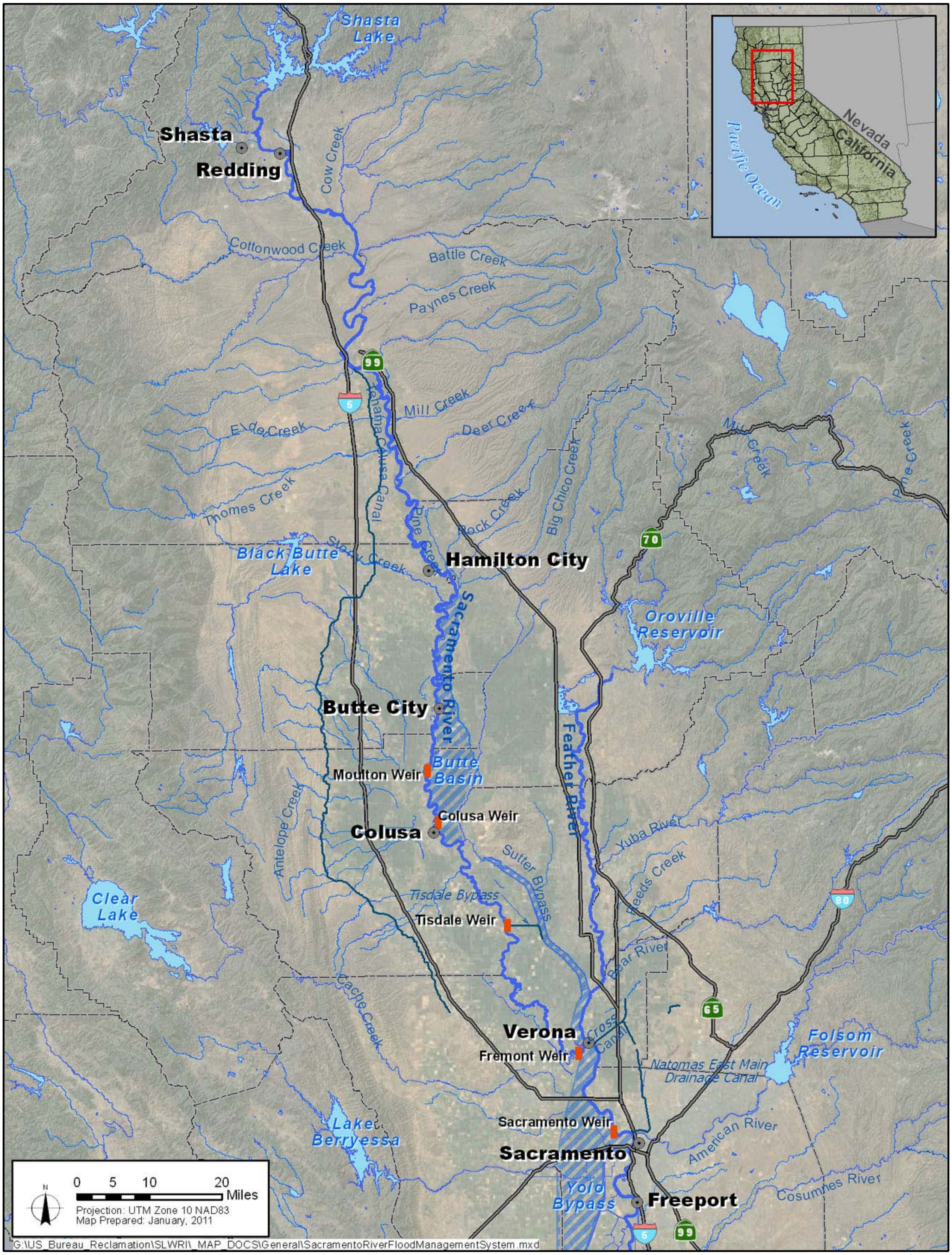

Figure 1-6. Sacramento Valley Flood Management Facilities

Table 1-30. Historical Shasta Dam and Reservoir Flood Management Operations

Water Year	Annual Inflow	End of Sept. Storage	Annual Outflow				Water Year	Annual Inflow	End of Sept. Storage	Annual Outflows			
			Total	Power-plant	Spill-way	Outlets				Total	Power-plant	Spill-way	Outlets
	(TAF)							(TAF)					
1945	4,858	-	3,462	2,624	-	839	1978	7,837	3,428	4,944	4,538	-	407
1946	5,906	-	5,599	3,898	-	1,700	1979	4,022	3,141	4,203	4,203	-	-
1947	3,908	-	3,964	3,571	-	393	1980	6,415	3,321	6,139	4,773	-	1,366
1948	5,416	-	4,958	4,244	-	714	1981	4,103	2,480	4,845	4,845	-	-
1949	4,318	-	4,303	4,303	-	-	1982	9,013	3,486	7,910	6,464	253	1,193
1950	4,133	-	3,784	3,781	1	2	1983	10,794	3,617	10,576	7,123	1	3,452
1951	6,316	-	6,486	5,696	-	790	1984	6,667	3,240	6,944	6,514	-	429
1952	7,785	-	6,800	5,625	9	1,166	1985	3,971	1,978	5,154	5,152	2	-
1953	6,540	3,300	6,408	5,067	-	1,341	1986	7,546	3,211	6,225	4,383	-	1,842
1954	6,541	3,059	6,826	5,941	-	885	1987	3,944	2,108	4,957	4,800	-	157
1955	4,112	2,455	4,612	4,612	-	-	1988	3,931	1,586	4,368	3,973	-	395
1956	8,834	3,569	7,606	4,926	12	2,668	1989	4,745	2,096	4,154	3,951	-	203
1957	5,368	3,485	5,341	4,841	17	483	1990	3,616	1,637	3,999	3,707	-	292
1958	9,698	3,473	9,610	6,672	13	2,924	1991	3,051	1,340	3,286	2,666	-	620
1959	5,086	2,504	5,952	5,631	-	321	1992	3,622	1,683	3,204	1,755	-	1,449
1960	4,733	2,756	4,380	4,380	-	-	1993	6,825	3,102	5,316	3,728	-	1,588
1961	5,071	2,333	5,402	5,402	-	-	1994	3,087	2,102	4,002	3,252	-	750
1962	5,262	2,908	4,582	4,582	-	-	1995	9,638	3,136	8,511	5,187	-	3,324
1963	7,003	3,242	6,575	6,077	13	485	1996	6,846	3,089	6,781	3,703	-	3,078
1964	3,905	2,202	4,849	4,849	-	-	1997	7,424	2,308	8,106	5,808	-	2,298
1965	6,983	3,612	5,475	4,581	-	894	1998	10,294	3,441	9,072	6,698	2	2,372
1966	5,299	3,263	5,544	5,544	-	-	1999	7,196	3,328	7,202	6,379	-	824
1967	7,404	3,506	7,066	6,131	-	935	2000	6,839	2,985	7,074	5,573	-	1,501
1968	4,772	2,670	5,515	5,138	-	377	2001	4,141	2,200	4,824	4,823	-	1
1969	7,668	3,528	6,714	5,421	-	1,293	2002	5,052	2,558	4,590	4,590	-	-
1970	7,902	3,440	7,885	5,477	4	2,404	2003	6,363	3,159	5,659	5,409	-	250
1971	7,328	3,275	7,402	6,824	1	578	2004	5,738	2,183	6,615	5,617	-	998
1972	5,078	3,267	5,000	5,000	-	-	2005	5,639	3,035	4,692	4,475	-	217
1973	6,167	3,317	6,026	5,583	-	443	2006	9,241	3,205	8,964	6,608	-	2,356
1974	10,796	3,658	10,364	6,796	-	3,568	2007	3,957	1,879	5,173	5,166	-	6
1975	6,405	3,570	6,384	6,153	-	231	2008	3,984	1,385	4,362	4,362	-	-
1976	3,611	1,295	5,813	5,813	-	-	2009	4,533	1,774	4,056	4,049	-	7
1977	2,628	631	3,247	3,247	-	-	2010	5,646	3,319	3,903	3,899	-	4
							Average	5,948	2,773	5,814	4,949	27	1,114

Source: U.S. Department of the Interior, Bureau of Reclamation 2011

Key:
- = No data available or no flow
Sept. = September
TAF = thousand acre-feet

The frequency of flood flows of different magnitudes can be significant for different types of analyses. Table 1-31 summarizes the percentage of years in which Sacramento River flow below Bend Bridge exceeded the specified flow rate one or more times during a month over the recorded historical period.

Table 1-31. Percentage of Years with Flows in Excess of Specified Flow Rate for Sacramento River Below Bend Bridge by Month (1939-2010)

Flow (cfs)	Percentage of Years (%)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
>100,000	0	0	3	8	7	7	3	0	0	0	0	0
>80,000	0	0	10	17	13	8	3	0	0	0	0	0
>60,000	0	3	19	31	29	21	10	1	0	0	0	0
>40,000	0	6	28	43	47	32	14	6	0	0	0	0
>20,000	3	19	54	68	78	63	28	21	4	0	0	0

Source: USGS Gaging Station 11377100

Key:
cfs = cubic feet per second
USGS = U.S. Geological Survey

Lower Sacramento River and Delta

Flood management facilities along the lower Sacramento River and in the Delta include the levees, weirs, and bypasses of upper and lower Butte Basin, the Sacramento River between Colusa and Verona, and the Sacramento River between Verona and Collinsville. The levees, weirs, and bypasses are features of the Sacramento River Flood Control Project, which began operation in the 1930s and was significantly expanded in the 1950s.

Butte Basin Butte Basin is the northernmost of the natural overflow basins flanking the Sacramento River. Located east of the Sacramento River, it extends from northwest of Chico to the mouth of Butte Slough, north of Meridian. Its eastern boundary is an indefinite line along the gently sloping lands rising from the basin toward the Sierra Nevada foothills.

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

Butte Basin has a significant attenuation effect on flood flows before they are discharged into the Sutter Bypass downstream from Colusa. Butte Basin holds more than 1 MAF when in full flow, and water has a travel time of about 2 days from its upper end to the Sutter Bypass.

Moulton Weir. In 1932, the U.S. Army Corps of Engineers (USACE) constructed Moulton Weir (RM 158), an ungated weir between the towns of Butte City and Colusa. The weir has a 535-foot crest length and 49-foot crest width. The weir spills water from the Sacramento River into Butte Basin when flows in the Sacramento River at the weir exceed 60,000 cfs.

Colusa Weir. Colusa Weir (RM 146), completed by USACE in 1933, is an ungated weir located between Moulton Weir and the town of Colusa. The weir has a 1,650-foot crest length and 20-foot crest width. The weir starts to discharge excess flows from the Sacramento River into Butte Basin when flows in the river at the weir exceed 30,000 cfs. During a sharp rise on the Sacramento River, Colusa Weir usually begins to pass flows before either the Moulton Weir or Tisdale Weir, approximately 2 hours before the Colusa gage is expected to exceed 59.8 feet (32,000 cfs).

Sacramento River Between Colusa and Verona The Sacramento River meanders through the 64 miles between Colusa (RM 143) and Verona (RM 79). The levee system continues along both sides of this river reach. The levee spacing (or channel width), 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 east side tributary to the Sacramento River, enters the river just above Verona. Flood management diversions occur at two places in this segment of the river: at the Tisdale Weir and the Fremont Weir.

Tisdale Weir In 1932, USACE built the Tisdale Weir, south of Colusa and just downstream from Grimes (RM 119). This ungated weir, with a 1,150-foot crest length and 38-foot crest width, discharges excess flows from the Sacramento River into the Tisdale Bypass, which leads to the Sutter Bypass. The weir starts to discharge excess flow when Sacramento River flows exceed 23,000 cfs. During a slow rise on the river, this weir begins to pass flows before the Moulton and Colusa weirs, 8 to 10 hours after the upstream Colusa gage exceeds 55.0 feet (23,000 cfs). During high flows in the Sutter Bypass, and when the Sacramento River stage is sufficiently lower, flows may leave the bypass and rejoin the river flowing through the Tisdale Bypass over Tisdale Weir.

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

Sutter Bypass The Sutter Bypass, which began operation in the 1930s, is a leveed portion of the natural floodway in the Sutter Basin. The bypass is located south of the Sutter Buttes, and runs approximately between and parallel to the Sacramento and Feather rivers. Flows enter the Sutter Bypass from Butte Basin at its upper end near Colusa at Butte Slough. Other flows enter the bypass from the east via the Wadsworth Canal and DWR's drainage pumping plants (No. 1, 2, and 3). Flows exit the Sutter Bypass and combine with the Sacramento River and Feather River upstream from Fremont Weir near the town of Verona.

Fremont Weir Fremont Weir (RM 83), completed in 1924 by USACE, is an ungated weir with a 9,518-foot crest length and 35-foot crest width. Fremont Weir is located on the west bank of the Sacramento River where the Sutter Bypass, Feather River, and Sacramento River meet near Verona. Excess flows discharge over the weir into the Yolo Bypass when flows in the Sacramento River at Verona exceed 62,000 cfs.

Sacramento River Between Verona and Collinsville Below Verona, the Sacramento River flows 79 miles to Collinsville, at the mouth of the Delta, passing the City of Sacramento along the way. 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 at the City of Sacramento. Flows in the Yolo Bypass reenter the river near Rio Vista (RM 12). As the river enters the Delta, Georgiana Slough branches off from the mainstem Sacramento River, routing flows into the central Delta. The one diversion point for flood management is at Sacramento Weir, where floodwaters are diverted from the Sacramento River through the Sacramento Bypass to the Yolo Bypass under the highest flow conditions. The major features that affect flow in this segment of the river are described below.

Sacramento Weir In 1916, the City of Sacramento began construction of the Sacramento Weir along the Sacramento River (RM 63) upstream from the American River confluence, immediately west of Sacramento. This weir has a variable crest with 48 removable gates, and net crest length of 1,830 feet. High flows from the Sacramento River are diverted at the weir into the Yolo Bypass via the Sacramento Bypass. When flows from the American River are high enough, some of the American River water flows upstream through the Sacramento River channel to the weir.

The Sacramento Weir is the only weir in the Sacramento flood management system with gates for manual operation during a flood. The weir is operated to limit flood stages in the Sacramento River to project design levels, to reduce sediment in the Sacramento River channel downstream from the weir, to prevent flooding of agricultural lands in the Yolo Bypass until after those lands have been inundated by flows over the Fremont Weir, and to make maximum use of the flood-carrying capacity of the Sacramento River channel downstream from the weir.

DWR operates the weir under rules specified by USACE to achieve the objectives described above. The rules have been in effect since 1940, except from 1963 through 1975, when a higher initial opening level was specified. Where USACE's rules allow flexibility, DWR opens the gates at the minimum stage permitted. Weir opening begins when the stage on the Sacramento River at the I Street gage is 27.5 feet. The procedure for continued operation is to open as many gates as necessary to maintain the stage at the I Street gage at or below 27.5 feet, until all gates are open.

Yolo Bypass The Yolo Bypass is a leveed floodway through the natural overflow Yolo Basin on the west side of the Sacramento River between Verona and Rio Vista near Suisun Bay. The bypass flows generally north to south and extends from the Fremont Weir (RM 83) downstream to Liberty Island (RM 14) in the Delta.

During high flows in the Sacramento River, water enters the Yolo Bypass over the Fremont Weir and Sacramento Weir and Bypass and is conveyed south around the City of West Sacramento. During periods of high stage in the Sacramento River, flows from the Colusa Basin are discharged through Knights Landing Ridge Cut to the Yolo Bypass. Additional flows enter the bypass from the west side tributaries, including Cache Creek, Putah Creek, Willow Slough, and the Willow Slough Bypass. Flood waters reenter the Sacramento River upstream from Rio Vista.

The Yolo Bypass floods approximately once every 3 years, generally during the winter months of December, January, and February. However, in 1998, water entered the bypass in June. During the irrigation season, nonflood waters exit the bypass primarily through the east levee toe drain.

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

Table 1-32 shows the recurrence of historical spills over each of the Sacramento Valley weirs. A single day of spill in a given year would constitute a year with a spill. Some weirs, like the Tisdale and Colusa weirs, spill almost every year, whereas the Sacramento Weir rarely spills.

Table 1-32. Number of Years with Spills over Sacramento Valley Weirs

Weir Name	Number of Years with Spill
Moulton Weir	49 (66%)
Colusa Weir	62 (84%)
Tisdale Weir	70 (95%)
Fremont Weir	53 (72%)
Sacramento Weir	21 (28%)

Source: DWR Bulletin 69-95 (DWR 2003c) with additional information from DWR Flood Systems Analysis Office (DWR 2008)

Notes:

Period of record: Water years 1935-2008

(%) indicates percent of years in period of record with spill

CVP/SWP Service Areas

This section describes flood management facilities in the CVP/SWP service areas by river basin, including the Feather River, American River, San Joaquin River, and east side tributaries to the Delta (Littlejohns Creek, Calaveras River, and Mokelumne River).

Feather River The primary flood management feature of the Feather River basin is Oroville Reservoir, with a flood management reservation volume of 750 TAF. Oroville Reservoir releases are used to help meet the objective flow on the Feather River of 150,000 cfs, and in conjunction with New Bullards Bar Reservoir on the Yuba River, to meet an objective flow below the Yuba River confluence of 300,000 cfs. Levees line the Feather River from its confluence with the Sacramento River up to the City of Oroville (RM 63).

American River The lower American River is primarily protected from flooding by Folsom Dam. The Folsom Reservoir flood management reservation volume is variable, ranging from 400 TAF to 670 TAF. The objective release on the American River is 115,000 cfs; however some damage to infrastructure along the American River occurs at flows above 20,000 cfs. The American River is leveed from its confluence with the Sacramento River to near the Carmichael Bluffs on the north bank, and to near the Sunrise Boulevard Bridge on the south bank (RM 19).

San Joaquin River The San Joaquin River basin is protected by an extensive reservoir system, including the following:

- Friant Dam and Millerton Lake (RM 270), with a flood management reservation volume of 170 TAF
- Big Creek Dam, on Big Creek, with a flood management reservation of 30.2 TAF
- Hidden Dam and Hensley Lake on the Fresno River, with a flood management reservation of 65 TAF

- Buchanan Dam and H.V. Eastman Lake on the Chowchilla River, with a flood management reservation of 45 TAF
- Los Banos Detention Dam on Los Banos Creek, with a flood management reservation of 14 TAF
- Merced County Stream Group Project, consisting of five dry dams (Bear, Burns, Owens, Mariposa, and Castle) and two diversion structures, with a total flood storage capacity of 30.5 TAF
- New Exchequer Dam and Lake McClure on the Merced River, with a flood management conservation of 350 TAF
- Don Pedro Dam and Lake on the Tuolumne River, with a flood management conservation of 340 TAF
- New Melones Dam and Lake on the Stanislaus River, with a flood management reservation of 450 TAF

Eastside Tributaries to the Delta The streams in the northern portion of the San Joaquin River basin, between the American and Stanislaus rivers, are commonly referred to as the eastside tributaries to the Delta. These rivers flow into the San Joaquin River within the boundaries of the Delta. Flood management features on the eastside tributaries to the Delta include the following:

- Farmington Dam and Reservoir on Littlejohns Creek, with a flood management reservation of 52 TAF
- New Hogan Dam and Lake on the Calaveras River, with a flood management reservation of 165 TAF
- Camanche Dam and Reservoir on the Mokelumne River, with a flood management reservation of 200 TAF

1.1.6 South Delta Water Levels

This section discusses the variability of water levels in the south Delta, as part of CVP/SWP operations in the extended study area.

Lower Sacramento River and Delta

In the south Delta, decreases in water levels due to CVP and SWP export pumping are a concern for local agricultural diverters, because during periods of low water levels, sufficient pump draft cannot be maintained and irrigation can be interrupted. Historically, the highest minimum stage in the Middle River typically occurs in February and is about 0.1 foot below mean sea level (msl). The lowest minimum stage typically occurs in August and is about 0.8 foot below msl. During dry and critical years, under existing conditions, the highest minimum stage in the Middle River typically occurs in April and is about 0.6 foot below msl. The lowest minimum stage typically occurs in September and is about 0.7 foot below msl (CALFED 2000).

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Exhibit A
Description of Groundwater Basins and Subbasins

Table A-1. Description of Groundwater Basins and Subbasins in the Primary Study Area

Groundwater Basin/ Subbasin (name/ number)	Information on Groundwater Conditions			
	County	**Acres**	**Groundwater Level Trends**	**Groundwater Budget**
Fall River Valley Groundwater Basin (5-5)	Lassen and Shasta	54,800	Variable water levels commonly dependent on the topographic elevation of a particular area, proximity to the Pit River, and localized pumping effects. The northern portion of the basin consistently showing the shallowest depths to groundwater (10 feet or less). Areas adjacent to the Pit River displaying more variable conditions (DWR 2003b).	Groundwater extraction for agricultural and municipal/industrial uses is 19,000 and 240 acre-feet, respectively. Deep percolation from applied water is estimated to be 4,800 acre-feet. Based on DWR 1995 and 1997 surveys (DWR 2003b).
Lake Britton Area Groundwater Basin (5-46)	Shasta	14,060	Not applicable.	Groundwater extraction for municipal and industrial uses is estimated to be 5 acre-feet. Deep percolation of applied water is estimated to be 10 acre-feet.
North Fork Battle Creek Groundwater Basin (5-50)	Shasta	12,760	A seasonal fluctuation of 1 foot with the lowest elevations occurring during periods of maximum evapotranspiration (DWR 2003b).	Groundwater extraction for municipal and industrial use is estimated to be 190 acre-feet. Deep percolation of applied water is estimated to be 220 acre-feet (DWR 2003b).
Enterprise Subbasin (5-6.04)	Shasta	60,900	A gradual decline of approximately 5 to 10 feet associated with the 1976-77 and 1987-94 droughts, followed by a gradual recovery to predrought conditions of the early 1970s and 1980s. A seasonal fluctuation of approximate 5 to 10 feet and, for the semiconfined wells, between 10 to 15 feet for normal and dry years. There are no apparent increasing or decreasing trends in groundwater levels (DWR 2003b).	Groundwater extraction for agricultural and municipal/industrial uses is 4,449 and 4,127 acre-feet, respectively. Deep percolation from applied water is estimated to be 3,788 acre-feet (DWR 2003b).
Millville Subbasin (5-6.05)	Shasta	67,900	A slight decline of approximately 5 feet associated with the 1976-77 and 1987-94 droughts, followed by a gradual recovery in levels to predrought conditions of the early 1970s and 1980s. Seasonal fluctuations ranging from 2 to 8 feet for normal and dry years. There are no apparent increasing or decreasing trend in groundwater levels (DWR 2003b).	Groundwater extraction for agricultural and municipal/industrial uses is 250 and 1,273 acre-feet, respectively. Deep percolation of applied water is estimated to be 912 acre-feet (DWR 2003b).
Bowman Subbasin (5-6.01)	Tehama	85,330	A slight decline in groundwater levels associated with the 1976-77 and 1987-94 droughts, followed by a recovery to predrought conditions of the early 1970s and 1980s. The seasonal fluctuation of approximately 5 feet for normal and dry years. There are no apparent increasing or decreasing trends in groundwater levels (DWR 2003b).	Groundwater extraction for agricultural and municipal/industrial uses is 350 and 9 acre-feet, respectively. Deep percolation of applied water is estimated to be 1,500 acre-feet (DWR 2003b).

Table A-1. Description of Groundwater Basins and Subbasins in the Primary Study Area (contd.)

Groundwater Basin/ Subbasin (Name/ Number)	Information on Groundwater Conditions			
	County	**Acres**	**Groundwater Level Trends**	**Groundwater Budget**
Rosewood Subbasin (5-6.02)	Tehama	45,230	Review of the hydrographs for long-term comparison of spring-spring groundwater levels indicates a slight decline in groundwater levels associated with the 1976-77 and 1987-94 droughts, followed by a recovery to predrought conditions of the early 1970s and 1980s. Generally, groundwater levels have a seasonal fluctuation of approximately 5 to 10 feet for normal and dry years. Overall, there are no apparent increasing or decreasing trends in the groundwater levels (DWR 2003b).	Estimates of groundwater extraction are based on surveys conducted by the DWR during 1994 and 1995. Surveys included land use and sources of water. Estimates of groundwater extraction for agricultural and municipal/industrial uses are 680 and 990 acre-feet, respectively. Deep percolation of applied water is estimated to be 1,200 acre-feet (DWR 2003b).
South Battle Creek Subbasin (5-6.06)	Tehama	32,300	Not applicable.	Estimates of groundwater extraction are based on surveys conducted by DWR during 1994 and 1995. Surveys included land use and sources of water. Estimates of groundwater extraction for agricultural and municipal/industrial uses are 1,300 and 310 acre-feet, respectively. Deep percolation of applied water is estimated to be 860 acre-feet (DWR 2003b).
Red Bluff Subbasin (5-21.50)	Tehama	266,750	Review of hydrographs for long-term comparison of spring-spring groundwater levels indicates a decline of 3 to 7 feet associated with the 1976-77 and 1987-94 droughts, followed by a recovery to predrought conditions of the early 1970s and 1980s. Generally, groundwater level data show a seasonal fluctuation ranging from 5 to 10 feet for unconfined, semiconfined, and composite wells. Wells constructed in confined aquifers can fluctuate up to 50 feet. Overall, there are no apparent increasing or decreasing trends in the groundwater levels (DWR 2003b).	Estimates of groundwater extraction for the Red Bluff Subbasin are based on a survey conducted by DWR in 1994. The survey included land use and sources of water. The estimate of groundwater extraction for agricultural use is 81,000 acre-feet. Groundwater extraction for municipal and industrial uses is 8,900 acre-feet. Deep percolation from applied water is estimated to be 20,000 acre-feet (DWR 2003b).

Table A-1. Description of Groundwater Basins and Subbasins in the Primary Study Area (contd.)

Groundwater Basin/ Subbasin (Name/ Number)	Information on Groundwater Conditions			
	County	Acres	Groundwater Level Trends	Groundwater Budget
Corning Subbasin (5-21.51)	Tehama, Glenn	205,640	Review of hydrographs for long-term comparison of spring-spring groundwater levels indicates a decline of 5 to 12 feet associated with the 1976-77 and 1987-94 droughts, followed by a recovery to predrought conditions of the early 1970s and 1980s. Groundwater level data show seasonal fluctuations of approximately 3 to 15 feet for unconfined wells (5 feet near the Sacramento River), up to 30 feet for semiconfined wells away from the river, 5 to 20 feet for composite wells, and 10 to 30 feet for confined wells. Overall, there are no apparent increasing or decreasing trends in the groundwater levels (DWR 2003b).	Estimates of groundwater extraction for the Corning Subbasin are based on surveys conducted during 1993, 1994, and 1997. Surveys included land use and sources of water. Groundwater extraction for agricultural use is estimated to be 152,000 acre-feet. Groundwater extraction for municipal and industrial uses is estimated to be 6,600 acre-feet. Deep percolation of applied water is estimated to be 54,000 acre-feet (DWR 2003b).
Colusa Subbasin (5-21.52)	Colusa, Glenn, Tehama, Yolo	918,380	Review of hydrographs for long-term comparison of spring-spring groundwater levels indicates a slight decline in groundwater levels associated with the 1976-77 and 1987-94 droughts, followed by recovery to predrought conditions of the early 1970s and 1980s. Some wells increased in levels beyond the predrought conditions of the 1970s during the wet season of the early 1980s. Generally, groundwater level data show an average seasonal fluctuation of approximate 5 feet for normal and dry years. Overall, there are no apparent increasing or decreasing trends in groundwater levels (DWR 2003b).	Estimates of groundwater extraction for the Colusa Subbasin are based on surveys conducted by DWR during 1993, 1994, and 1999. Surveys included land use and sources of water. Estimates of groundwater extraction for agricultural, municipal and industrial, and environmental wetland uses are 310,000, 14,000 and 22,000 acre-feet, respectively. Deep percolation from applied water is estimated to be 64,000 acre-feet (DWR 2003b).
Bend Subbasin (5-21.53)	Tehama	20,770	Not applicable.	Estimates of groundwater extraction are based on a survey conducted by DWR in 1994. Surveys included land use and sources of water. Estimates of groundwater extraction for agricultural and municipal/industrial uses are 220 and 120 acre-feet, respectively. Deep percolation from applied water is estimated to be 340 acre-feet (DWR 2003b).

Table A-1. Description of Groundwater Basins and Subbasins in the Primary Study Area (contd.)

Groundwater Basin/ Subbasin (Name/ Number)	Information on Groundwater Conditions			
	County	**Acres**	**Groundwater Level Trends**	**Groundwater Budget**
Antelope Subbasin (5-21.54)	Tehama	18,710	Review of hydrographs for long-term comparison of spring-spring groundwater levels indicates a decline of 5 to 10 feet associated with the 1976-77 and 1987-94 droughts, followed by a recovery to predrought conditions of the early 1970s and 1980s. Generally, groundwater level data show a seasonal fluctuation of approximate 2 to 15 feet for normal and dry years. Overall, there are no apparent increasing or decreasing trends in groundwater levels (DWR 2003b).	Estimates of groundwater extraction for the Antelope Subbasin are based on a survey conducted by DWR in 1994. The survey included land use and sources of water. Estimates of groundwater extraction for agricultural and municipal/industrial uses are 17,000 and 2,100 acre-feet, respectively. Deep percolation of applied water is estimated to be 3,800 acre-feet (DWR 2003b).
Dye Creek Subbasin (5-21.55)	Tehama	27,730	Review of hydrographs for long-term comparison of spring-spring groundwater levels indicates a decline of 2 to 5-feet associated with the 1976-77 and 1987-94 droughts, followed by a recovery to predrought conditions of early 1970s and 1980s. Generally, groundwater level data show a seasonal fluctuation ranging from 2 to 10 feet for normal and dry years. Overall, there are no apparent increasing or decreasing trends in the groundwater levels (DWR 2003b).	Estimates of groundwater extraction for the Dye Creek Subbasin are based on a survey conducted by DWR in 1994. The survey included land use and sources of water. Estimates of groundwater extraction for agricultural and municipal/industrial uses are 9,300 and 680 acre-feet, respectively. Deep percolation of applied water is estimated to be 3,200 acre-feet (DWR 2003b).
Los Molinos Subbasin (5-21.56)	Tehama, Butte	33,170	Review of the hydrographs for long-term comparison of spring-spring groundwater levels indicates a slight decline associated with the 1976-77 and 1987-94 droughts, followed by a recovery to predrought conditions of the early 1970s and 1980s. Generally, groundwater level data show an average seasonal fluctuation of approximate 2 feet for normal and dry years. Overall, there are no apparent increasing or decreasing trends in groundwater levels (DWR 2003b).	Estimates of groundwater extraction for the Los Molinos Subbasin are based on a field survey conducted by DWR in 1994. Surveys included land use and sources of water. Estimate of groundwater extraction for agricultural use is 5,900 acre-feet. Municipal and industrial use is estimated to be approximately 1,000 acre-feet. Deep percolation of applied water is estimated to be 3,000 acre-feet (DWR 2003b).
Vina Subbasin (5-21.57)	Tehama, Butte	125,640	As part of a groundwater inventory analysis prepared for Butte County, the portion of the Vina Subbasin located within Butte County was evaluated for seasonal and long-term changes in groundwater levels for unconfined and confined aquifer systems. Long-term comparison of spring-spring groundwater levels in the northern part of the Butte County shows a decline as a result of the 1976-77 and 1987-94 droughts, followed by a recovery of groundwater levels to predrought conditions (DWR 2003b).	Estimates of groundwater extraction for the Vina Subbasin are based on surveys conducted by DWR during 1993, 1994, and 1997. Surveys included land use and sources of water. Estimate of groundwater extraction for agricultural use is 130,000 acre-feet. Municipal and industrial use is estimated to be approximately 20,000 acre-feet. Deep percolation of applied water is estimated to be 30,000 acre-feet (DWR 2003b).

Table A-1. Description of Groundwater Basins and Subbasins in the Primary Study Area (contd.)

Groundwater Basin/ Subbasin (Name/ Number)	Information on Groundwater Conditions			
	County	Acres	Groundwater Level Trends	Groundwater Budget
West Butte Subbasin (5-21.58)	Glenn, Colusa	181,560	Review of the hydrographs for long-term comparison of spring-spring groundwater levels indicates a decline in groundwater levels associated with the 1976-77 and 1987-94 droughts, followed by a recovery in groundwater levels to predrought conditions of the early-1970s and 1980s. Comparison of spring-spring groundwater levels from the 1950s and 1960s versus today's levels indicates about a 10-foot decline in groundwater levels in portions of the West Butte Subbasin (DWR 2003b). Areas unaffected by municipal water use reflect the natural groundwater table distribution and direction of movement. Year-round extraction of groundwater for municipal use in the Chico area causes several small groundwater depressions that tend to alter the natural southwesterly movement of groundwater in the area (DWR 2003b). In the Chico area, groundwater levels in the unconfined portion of the aquifer system is about 5 to 7 feet during normal precipitation and up to approximately 16 feet during periods of drought. Annual fluctuation in the confined or semiconfined portion of the aquifer system is approximately 15 to 25 feet during normal years and up to approximately 30 feet during periods of drought. Long-term comparison of spring-spring groundwater levels indicates a 10- to 15-foot decline in levels since the 1950s (DWR 2003b).	Estimates of groundwater extraction for the West Butte Subbasin are based on surveys conducted by DWR during 1993 and 1997. Surveys included land use and sources of water. Estimates of groundwater extraction for agricultural, municipal/industrial, and environmental wetland uses are 161,000, 10,000 and 4,600 acre-feet, respectively. Deep percolation of applied water is estimated to be 64,000 acre-feet (DWR 2003b).
North Yuba Subbasin (5-21.60)	Yuba	50,000		Previous DWR unpublished studies have estimated natural and applied recharge. DWR has also estimated urban and agricultural extractions and subsurface outflow. Inflows include natural recharge of 51,100 acre-feet and applied recharge of 13,900 acre-feet. Outflows include urban extraction of 9,000 acre-feet, agricultural extraction of 65,800 acre-feet, and subsurface outflow of 21,800 acre-feet (DWR 2003b).

Table A-1. Description of Groundwater Basins and Subbasins in the Primary Study Area (contd.)

Groundwater Basin/ Subbasin (Name/ Number)	Information on Groundwater Conditions			
	County	**Acres**	**Groundwater Level Trends**	**Groundwater Budget**
South Yuba Subbasin (5-21.61)	Yuba	89,000	As early as 1960, groundwater levels showed a well-developed cone of depression beneath the South Yuba Basin. Water levels in the center of the cone of depression were just below sea level. Nearly all water levels were well below adjacent river levels on the Bear, Feather, and Yuba rivers. Groundwater conditions in 1984 reflect a continued reliance on groundwater pumping in the South Yuba Basin. Water levels in the center of the South Yuba cone of depression had fallen to 30 feet below sea level. The water level contours adjacent to the Bear and Yuba rivers indicated a large gradient and seepage from the rivers. By 1990, water levels in the South Yuba Basin cone of depression rose to 10 feet above sea level. The rise in water levels was due to increasing surface water irrigation supplies and reduced groundwater pumping. Current DWR records indicate groundwater levels continue to increase (DWR 2003b).	Previous DWR unpublished studies have estimated natural and applied recharge. DWR has also estimated urban and agricultural extractions and subsurface outflow. Basin inflows include natural recharge of 53,700 acre-feet, and applied water recharge of 26,000 acre-feet. Outflows include urban extraction of 6,000 acre-feet, agricultural extraction of 93,400 acre-feet, and subsurface outflow of 24,900 acre-feet (DWR 2003b).
Sutter Subbasin (5-21.62)	Sutter	234,400	Current DWR records indicate groundwater levels have remained relatively constant. DWR hydrographs indicate a shallow-depth water table. Most groundwater levels in the Sutter Subbasin tend to be within about 10 feet of ground surface (DWR 2003b).	As part of its water planning process, DWR estimated the following components of the groundwater budget for the entire Sutter Subbasin. The calculations are for a 1990 level of development. Estimated inflows include natural recharge at 40,000 acre-feet and applied water recharge at 22,100 acre-feet. There was no artificial recharge. Estimated outflows include urban extraction at 3,900 acre-feet and agricultural extraction at 171,400 acre-feet (DWR 2003b).
North American Subbasin (5-21.64)	Sutter, Placer, Sacramento	351,000	Groundwater levels in southwestern Placer County and northern Sacramento County have generally decreased, with many wells experiencing declines at a rate of about 1.5 feet per year for the last 40 years or more. Some of the largest decreases have occurred in the area of the former McClellan AFB. Groundwater levels in Sutter and northern Placer counties generally have remained stable, although some wells in southern Sutter County have experienced declines (DWR 2003b).	As part of its water planning process, DWR estimated the following components of the groundwater budget. The calculations are for a 1990 level of development. Estimated inflows include natural recharge at 83,800 acre-feet and applied water recharge at 29,800 acre-feet. There was no artificial recharge. Estimated outflows include urban extraction at 109,900 acre-feet and agricultural extraction at 289,100 acre-feet (DWR 2003b).

Table A-1. Description of Groundwater Basins and Subbasins in the Primary Study Area (contd.)

Groundwater Basin/ Subbasin (Name/ Number)	Information on Groundwater Conditions			
	County	Acres	Groundwater Level Trends	Groundwater Budget
Solano Subbasin (5-21.66)	Solano, Sacramento, Yolo	425,000	Groundwater levels were measured at what are now considered to be natural, predevelopment levels in 1912 by USGS. At that time, the general direction of groundwater flow in this subbasin was from northwest to southeast. From 1912 to 1932, below-average precipitation resulted in lower groundwater levels throughout the basin. Because of above-average precipitation from 1932 and 1941, groundwater levels recovered slightly in spite of increased groundwater development. After 1941, groundwater levels continued to decline because of increasing agricultural and urban development, reaching their lowest historical levels in the late 1950s. A large pumping depression between Davis and Dixon was one of the more notable groundwater level depressions in the subbasin. Surface water deliveries from the Solano Project beginning in 1959 caused groundwater levels to rise slightly or slow their descent. Since that time, groundwater level trends within the Solano Subbasin have been impacted by drought periods in the mid-1970s and late-1980s but have recovered quickly in the following “wet” years (DWR 2003b).	Not applicable.
Yolo Subbasin (5-21)	Yolo, Solano	256,000	Groundwater levels are impacted by periods of drought due to increased groundwater pumping and less surface water recharge (e.g., in the late 1970s and early 1990s), but recover quickly in “wet” years. Long-term trends do not indicate any significant decline in water levels, with the exception of localized pumping depressions in the vicinity of the Davis, Woodland, and Dunnigan/Zamora areas. Past studies have concluded that the Sacramento River Hydrologic Region California’s Groundwater Sacramento Valley Groundwater Basin Bulletin 118 Last update 2/27/04 Yolo subbasin is subject to overdraft; however, the completion of Indian Valley Reservoir in 1976 provided significant relief in the form of additional available surface water (DWR 2003b).	Not applicable.

Table A-1. Description of Groundwater Basins and Subbasins in the Primary Study Area (contd.)

Groundwater Basin/ Subbasin (Name/ Number)	Information on Groundwater Conditions			
	County	**Acres**	**Groundwater Level Trends**	**Groundwater Budget**
Capay Valley Subbasin (5-21.68)	Yolo	25,000	Groundwater levels within most the Capay Valley Subbasin vary from approximately 10 to 40 feet below ground surface and remain relatively stable, even through dry years. Wells located in the higher elevations along the edge of the valley show a greater variability, and appear to be more impacted by dry years (DWR 2003b).	It was estimated that the average annual safe yield for the Capay Valley over the 6-year study period was 7,300 acre-feet based on the average annual groundwater draft (DWR 2003b).
South American Subbasin (5-21.65)	Sacramento	248,000	A review of 18 long-term hydrographs from the 1960s shows a consistent pattern of water level trends through much of the basin. Groundwater elevations generally declined consistently, from the mid-1960s to about 1980, on the order of 20 feet. From 1980 through 1983, water levels recovered by about 10 feet and remained stable until the beginning of the 1987 through 1992 drought. From 1987 until 1995, water levels declined by about 15 feet. From 1995 to 2000, most water levels recovered by up to 20 feet, leaving them generally higher than levels before the 1987 through 1992 drought. Exceptions to this trend include (1) wells in the vicinity of the City of Sacramento, which fluctuated generally less than 10 feet overall since the mid-1970s, and (2) wells in the vicinity of Rancho Cordova, which appear to have recovered less than the other wells in the subbasin since 1995 (generally less than 10 feet) (DWR 2003b).	Based on previous modeling results and data updates, basin inflows include natural and applied water recharge, which total 257,168 acre-feet. Subsurface inflow and outflow are not known specifically, but the model indicates that there is a net subsurface outflow of 29,676 acre-feet annually. Other groundwater outflows include annual urban extraction of 68,058 acre-feet and agricultural extraction of 162,954 acre-feet (DWR 2003b).

Source: California Groundwater, Bulletin 118, Update 2003. California Department of Water Resources.
Key:
AFB = Air Force Base
DWR = California Department of Water Resources
USGS = U.S. Geological Survey

Table A-2. Description of Groundwater Basins and Subbasins in the Extended Study Area

DWR Subbasin (name/ (number)	Pertinent Data			
	County	**Acres**	**Groundwater Level Trends**	**Groundwater Budget**
Merced Subbasin (5-22.04)	Merced	491,000	Between 1970 and 2000, average decline of 30.0 feet (DWR 2003b).	Natural recharge estimated to be 47.0 TAF; artificial recharge not determined but 243.0 TAF of surface water applied annually. Annual urban and agricultural extractions are 54.0 and 492.0 TAF, respectively (DWR 2003b).
Delta-Mendota Subbasin (5-22.07)	Stanislaus, Merced, Madera, Fresno	747,000	Between 1970 and 2000, average increase of 2.2 feet (DWR 2003b).	Natural recharge estimated to be 8.0 TAF, artificial recharge not determined but 74.0 TAF of surface water applied annually. Annual urban and agricultural extractions are 17.0 and 491.0 TAF, respectively (DWR 2003b).
Kings Subbasin (5-22-08)	Fresno, Kings, and Tulare	976,000	Variability in groundwater levels in response to the 1976-77 drought ranged from 10 feet to 50 feet, with similar declines in the western subbasin during the 1987-92 drought (DWR 2003b).	Recharge and extraction values are not reported by DWR (DWR 2003b).
Kaweah Subbasin (5-22.11)	Tulare, Kings	446,000	Between 1970 and 2000, average declines of 12 feet (DWR 2003b).	Natural recharge estimated to be 62.4 TAF; artificial recharge not determined but 286.0 TAF of surface water applied annually. Annual urban and agricultural extractions are 58.8 and 699.0 TAF, respectively (DWR 2003b).
Tulare Lake Subbasin (5-22.12)	Kings	524,000	Between 1970 and 2000, average declines of 17 feet (DWR 2003b).	Natural recharge estimated to be 89.2 TAF; artificial recharge not determined but 195.0 TAF of surface water applied annually. Annual urban and agricultural extractions are 24.0 and 648.0 TAF, respectively (DWR 2003b).
Tule Subbasin (5-22.13)	Tulare	467,000	Between 1970 and 2000, water level has increased 4 feet. Variability in groundwater levels has ranged from 34-foot decreases between 1988 and 1995, to 20-foot increases between 1970 and 1988 (DWR 2003b).	Natural recharge estimated to be 34.4 TAF; artificial recharge not determined but 201.0 TAF of surface water applied annually. Annual urban and agricultural extractions are estimated to be 19.3 and 641.0 TAF, respectively (DWR 2003b).
Tracy Subbasin (5-22.15)	San Joaquin, Contra Costa, Alameda	345,000	Except for seasonal variation resulting from recharge and pumping, majority of water levels have remained relatively stable over the majority of at least the last 10 years (1996-2006) (DWR 2003b).	There are insufficient published data available to provide a groundwater budget for this subbasin (DWR 2003b).

Table A-2. Description of Groundwater Basins and Subbasins in the Extended Study Area (contd.)

DWR Subbasin Name and (number)	Pertinent Data			
	County	**Acres**	**Groundwater Level Trends**	**Groundwater Budget**
Turlock Subbasin (5-22.03)	Stanislaus, Merced	347,000	On average, water level has declined nearly 7 feet from 1970 through 2000; 1970 through 1992 showed a generally steep decline totaling about 15 feet. Between 1992 and 1994, water levels stayed near this low level. From 1994 to 2000, the water levels rebounded about 8 feet, to approximately 7 feet below 1970 levels. Water level declines have been more severe in the eastern portion of the subbasin after 1982. From 1970 to 1982, water level declines were more severe in the western portion of the subbasin (DWR 2003b).	Natural recharge of the subbasin was estimated to be 33 TAF. Artificial recharge and subsurface inflow were not determined. Applied water recharge was calculated to be 313 TAF. Annual urban extraction and annual agricultural extraction were calculated at 65 and 387 TAF, respectively. Other extractions and subsurface inflow were not determined (DWR 2003b).
Modesto Subbasin (5-22-02)	Stanislaus	247,000	On average, water level has declined nearly 15 feet from 1970 through 2000; 1970 through 1978 showed steep declines totaling about 12 feet. From 1978 to 1984, levels stabilized and rebounded about 7 feet. From 1984 through 1995, again declined, bottoming out in 1995 at nearly 20 feet below the 1970 level. Water levels then rose about 5 feet from 1996 to 2000. Water level declines have been more severe in the eastern portion of the subbasin, but have risen faster in the eastern subbasin between 1996 and 2000 than in any other portion of the subbasin (DWR 2003b).	Natural recharge into the subbasin estimated to be 86 TAF. Artificial recharge and subsurface inflow values not determined. Approximately 92 TAF of applied water recharge. Annual urban and agricultural extractions are estimated to be 81 and 145 TAF, respectively. There are no other extractions, and values for subsurface outflow not determined (DWR 2003b).
Eastern San Joaquin Subbasin (5-22.01)	San Joaquin, Stanislaus, Calaveras	707,000	Measurements over the past 40 years show a fairly continuous decline in groundwater levels in eastern San Joaquin County. Groundwater levels have declined at an average rate of 1.7 feet per year and have dropped as much as 100 feet in some areas. It is estimated that groundwater overdraft during the past 40 years has reduced storage in the basin by as much as 2 MAF. Due to the continued overdraft of groundwater within the subbasin, significant groundwater depressions are present below the City of Stockton, east of Stockton, and east of Lodi. Several of these groundwater depressions extend to depths of about 100 feet below ground surface (or more than 40 feet below mean sea level) (DWR 2003b).	Inflow estimates: average annual infiltration from applied water and precipitation (593,356 acre-feet); average annual seepage from surface water (141,127 acre-feet) and average annual net subsurface inflow (3,586 acre-feet). Outflow estimates include average annual municipal and industrial pumpage (47,493 acre-feet); and average annual agricultural pumpage (761,828 acre-feet). This balance shows that there has been a total net outflow from the system of about 1.5 MAF over the 20 year study period, which represents an average annual outflow (or overdraft) of about 70 TAF. The 1990 annual groundwater extraction in San Joaquin County was estimated to be about 731 TAF/year, which exceeds the estimated safe yield of 618 TAF/year. This results in an estimated overdraft of 113 TAF/year. It is estimated that 70 TAF/year of overdraft occurs in northeastern San Joaquin County and about 35 TAF/year of overdraft occurs in the Stockton East Water District area (DWR 2003b).

Table A-2. Description of Groundwater Basins and Subbasins in the Extended Study Area (contd.)

DWR Subbasin Name and (number)	Pertinent Data			
	County	**Acres**	**Groundwater Level Trends**	**Groundwater Budget**
Chowchilla Subbasin (5-22.05)	Madera, Merced	159,000	On average, the subbasin water level has declined nearly 40 feet from 1970 through 2000; 1970 through 1978 showed steep declines totaling about 30 feet; and 1978 to 1987 showed stabilization and rebound of about 25 feet, close to 1970 level. From 1987 through 1996, steep declines again occurred, bottoming out in 1996 at about 45 feet below 1970 levels. Water levels rose about 8 feet from 1996 to 2000. Water level declines have been more severe in the eastern portion of the subbasin from 1980 to the present, but the western basin showed the strongest declines before 1980 (DWR 2003b).	Natural recharge of the subbasin is estimated to be 87 TAF. Artificial recharge and subsurface inflow are not determined. There is approximately 179 TAF of applied water recharge. Annual urban and agricultural extractions are 6 TAF and 249 TAF, respectively. There are no other extractions, and subsurface outflow has not been determined (DWR 2003b).
Madera Subbasin (5-22.06)	Madera	394,000	On average, the subbasin water level has declined nearly 40 feet from 1970 through 2000; 1970 through 1978 showed steep declines totaling about 30 feet; and 1978 to 1987 showed stabilization and rebound of about 25 feet, taking the water levels close to where they were in 1970. From 1987 through 1996, steep declines again occurred, bottoming out in 1996 at about 45 feet below 1970 levels. Water levels rose about 8 feet from 1996 to 2000. Water levels declines have been more severe in the eastern portion of the subbasin from 1980 to the present, but the western subbasin showed the strongest declines before 1980 (DWR 2003b).	Natural recharge estimated to be 34.4 TAF; artificial recharge not determined but 201.0 TAF of surface water applied annually. Annual urban and agricultural extractions are estimated to be 19.3 and 641.0 TAF, respectively (DWR 2003b).
Westside Subbasin (5-22.09)	Fresno, Kings	640,000	Groundwater levels were generally at their lowest levels in the late 1960s, before importation of surface water. The CVP began delivering surface water to the San Luis Unit in 1967-68. Water levels gradually increased to a maximum in about 1987-88, falling briefly during the 1976-77 drought. Water levels began dropping again during the 1987-92 drought with water levels showing the effects until 1994. Through a series of wet years, after the drought, 1998 water levels recovered nearly to 1987-88 levels (DWR 2003b).	Seepage from west side streams was estimated to be 30-40 TAF per year. For 1951, secondary recharge from the east into the upper aquifer was 20-30 TAF and was 150-200 TAF into the lower aquifer. Average deep percolation between 1978 and 1996 was estimated to be 244 TAF per year. Average applied groundwater between 1978 and 1997 was estimated to be 193 TAF per year (DWR 2003b).

Table A-2. Description of Groundwater Basins and Subbasins in the Extended Study Area (contd.)

DWR Subbasin Name and (number)	Pertinent Data			
	County	**Acres**	**Groundwater Level Trends**	**Groundwater Budget**
Kern County Subbasin (5-22.14)	Kern	1,945,000	The average subbasin water level is essentially unchanged from 1970 to 2000, after experiencing cumulative changes of approximately -15 feet through 1978, a 15-foot increase through 1988, and an 8-foot decrease through 1997. However, net water level changes in different portions of the subbasin were quite variable through the period of 1970-2000. These changes ranged from increases of over 30 feet at the southeast valley margin and in the Lost Hills/Buttonwillow areas to decreases of over 25 and 50 feet in the Bakersfield area and McFarland/Shafter areas, respectively (DWR 2003b).	Inflows to the subbasin include natural recharge of 150 TAF/year, artificial recharge of 308 TAF/year, applied water recharge 843 TAF/year, and a 1958-1966 average estimated subsurface inflow of 233 TAF/year, for a total subbasin inflow of 1,534 TAF/year. Subbasin outflows are urban extraction of 154 TAF/year, agricultural extraction of 1,160 TAF/year, and other extractions (oil industry related) of 86,333, with subsurface outflow considered minimal, for a total subbasin outflow of 1,400,300 acre-feet/year. In addition to the above budget, a detailed long-term water balance from 1970-1998 shows an average change in storage of - 325 TAF/year. This analysis does not consider subsurface inflow (DWR 2003b).
Pleasant Valley Subbasin (5-22-10)	Fresno, Kings	146,000	The rate of water level decline was calculated between the mid-1960s and early 1980s in Pleasant Valley WD as 4.8 feet/year. Estimated annual decline for the previous four decades at approximately 4 feet/yr. The slower decline was attributed to recent reductions in groundwater pumping. In the past decade, water levels have generally continued their long historic decline, with hydrographs on file with DWR indicating water level changes of -5 to -25 feet. Localized areas however have shown some rebound from 1995 to 2001 (DWR 2003b).	No data for subsurface inflow or outflow exist. Applied water recharge is estimated at 4 TAF/year, there is no known artificial recharge, and natural recharge has not been determined. Estimated extractions include urban pumping at 5,700 acre-feet/year, agricultural pumping at 90 TAF/year, and oil industry related extractions at 8,830 acre-feet/year (DWR 2003b).

Table A-2. Description of Groundwater Basins and Subbasins in the Extended Study Area (contd.)

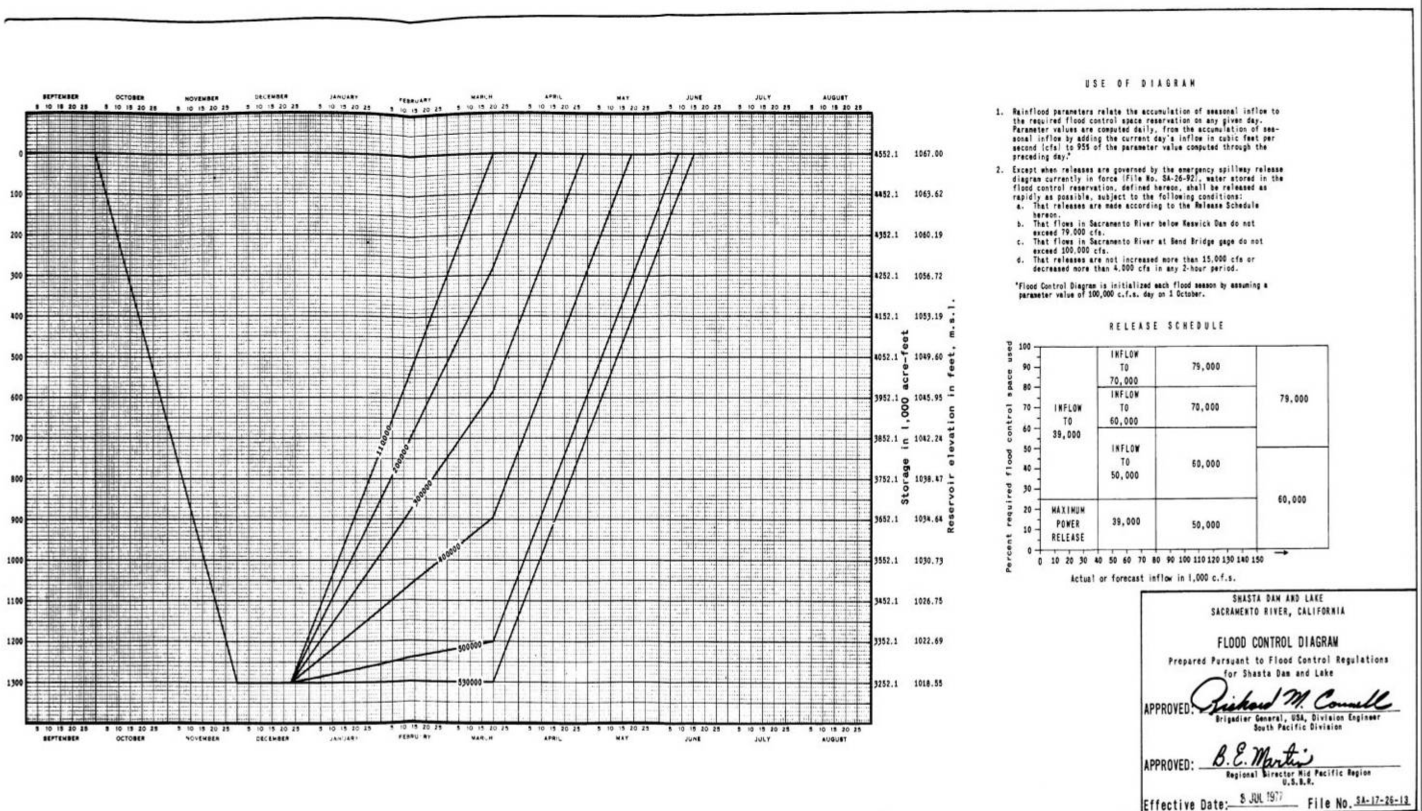
DWR Subbasin Name and (number)	Pertinent Data			
	County	Acres	Groundwater Level Trends	Groundwater Budget
Antelope Valley Subbasin (6-44)	Los Angeles, Kern, San Bernardino	1,010,000	From 1975 through 1998, groundwater level changes ranged from an increase of 84 feet to a decrease of 66 feet. The parts of the basin with declining water levels are along the Highway 14 corridor from Palmdale through Lancaster to Rosamond and surrounding Rogers Lake on Edwards AFB. Historically, groundwater in the basin flowed north from the San Gabriel Mountains and south and east from the Tehachapi Mountains toward Rosamond Lake, Rogers Lake, and Buckhorn Lake. These dry lakes are places where groundwater can discharge by evaporation. Because of recent groundwater pumping, groundwater levels and flow have been altered in urban areas such as Lancaster and Edwards AFB. Groundwater pumping has caused subsidence of the ground surface, and earth fissures to appear in Lancaster and on Edwards AFB. By 1992, 292 square miles of Antelope Valley had subsided more than 1-foot. This subsidence has permanently reduced aquifer-system storage by about 50 TAF (DWR 2003b).	Urban extraction of 25,803 acre-feet and agricultural extraction of 1,006 acre-feet were reported for 1992. Average natural recharge of about 48,000 acre-feet, and a range in annual natural recharge of 31,200 to 59,100 acre-feet /year were reported (DWR 2003b).
Fremont Valley Subbasin (6-46)	Kern, San Bernardino	335,000	A hydrograph for one well west of Koehn Lake indicates a decline in groundwater level of about 92 feet between 1960 and 1980. During 1980 through 1998, the water level stabilized in this well, fluctuating about 4 feet. Hydrographs indicate that groundwater elevations declined in the southwestern part of the basin about 9 feet between 1957 and 1999, in the center of the basin about 5 feet between 1967 and 1998, in the northwest part of the basin about 6 feet between 1979 and 1997, and east of Koehn Lake about 25 feet between 1967 and 1999 (DWR 2003b).	Average annual well pumping was about 32 TAF during the 1950s through early 1960s (DWR 2003b).
Santa Clara Subbasin (2-9.02)	Santa Clara	153,600	Historically, since the early 1900s through the mid-1960s water level declines from groundwater pumpage have induced subsidence in the Santa Clara subbasin and caused degradation of the aquifer adjacent to the bay from saltwater intrusion. Before importation of surface water via the Hetch Hetchy Aqueduct and South Bay Aqueduct, and the introduction of an artificial recharge program, water levels declined more than 200 feet in the Santa Clara Valley. Groundwater levels have generally increased since 1965 as a result of increase in recharge and decrease in pumpage (DWR 2003b).	No information available.

Table A-2. Description of Groundwater Basins and Subbasins in the Extended Study Area (contd.)

DWR Subbasin Name and (number)	Pertinent Data			
	County	Acres	Groundwater Level Trends	Groundwater Budget
Central Subbasin (4-11.04)	Los Angeles	177,000	Water levels varied over a range of about 25 feet between 1961 and 1977 and have varied through a range of about 5 to 10 feet since 1996. Most water wells show levels in 1999 that are in the upper portion of their recent historical range (DWR 2003b).	The Watermaster reported natural recharge for the subbasin to be 31,950 acre-feet and artificial recharge to be 63,688 acre-feet for 1998. Additionally, the subbasin receives 27 TAF/year through the Whittier Narrows from the San Gabriel Valley Basin in the form of subsurface flow. Urban extractions for the subbasin were 204,335 acre-feet in 1998 (DWR 2003b).
Coastal Plain of Orange County (8-1)	Orange	224,000	Groundwater levels are generally lower than the level in 1969, when the basin is considered to have been full. The level in the forebay has generally stabilized, whereas the southern coastal area has declined steadily through time. Since 1990, the magnitude of yearly groundwater level fluctuation has approximately doubled near the coast because of seasonal water demand and short-term storage programs, but has stayed the same in the forebay. Average groundwater levels for the Orange County Basin have risen about 15 feet since 1990, with average levels in the forebay area rising about 30 feet and average levels in the coastal area dropping a few feet (DWR 2003b).	Basin inflow of 258,413 acre-feet and an outflow of 342,823 acre-feet for the 1998-1999 water year. The inflow includes natural recharge (29,434 acre-feet), artificial recharge (222,755 acre-feet), and return of applied water (6,224 acre-feet). The outflow includes nonirrigation extraction (334,136 acre-feet) and irrigation extraction (8,687 acre-feet) (DWR 2003b).

Source: California Groundwater, Bulletin 118, Update 2003. California Department of Water Resources.
Key:
AFB = Air Force Base
CVP = Central Valley Project
DWR = California Department of Water Resources
MAF = million acre-feet
TAF = thousand acre-feet
WD = Water District

Exhibit B
Shasta Dam Flood Management Diagram



Source: U.S. Army Corps of Engineers, Shasta Dam and Lake, Sacramento River, California, Report on Reservoir Regulation for Flood Control, Rev. January 1977

Shasta Lake Water Resources Investigation, California

SHASTA DAM FLOOD CONTROL DIAGRAM

U.S. Bureau of Reclamation, Mid-Pacific Region
December 2006

PLATE 11

Exhibit B-1. Shasta Dam Flood Management Diagram

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Chapter 2
Modeling Results

As described in the SLWRI Preliminary Draft Environmental Impact Statement Chapter 6, extensive modeling was conducted to support technical analysis of the SLWRI alternatives. Modeling of the CVP and SWP systems was conducted using CalSim-II to determine flow and storage changes. Delta Simulation Model 2 (DSM2) was used to determine Delta water level changes. Detailed modeling results are presented in Attachments A and B to this Report.

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3.1.1 Chapter 1 Affected Environment

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