CALFED

TECHNICAL REPORT
AFFECTED ENVIRONMENT

SURFACE WATER RESOURCES

Including Surface Water Hydrology, Surface Water Supply and Management, and Bay-Delta Hydrodynamics and Riverine Hydraulics

DRAFT

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CALFED
BAY-DELTA
PROGRAM

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LIST OF ACRONYMS

AFRP	Anadromous Fish Restoration Program
CALFED	CALFED Bay-Delta Program
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
D-1485	Decision 1485
DCC	Delta Cross Channel
Delta	Sacramento-San Joaquin River Delta
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utilities District
FERC	Federal Energy Regulatory Commission
fps	feet per second
GCID	Glenn-Colusa Irrigation District
ISDP	Interim South Delta Program
km	kilometer
MAF	million acre-feet
mg/L	milligram per liter
MandI	municipal and industrial
MSL	mean sea level
NCP	navigation control point
NGVD	National Geodetic Vertical Datum
PGandE	Pacific Gas and Electric Company
ppm	parts per million
RBDD	Red Bluff Diversion Dam
Reclamation	U.S. Bureau of Reclamation
SSID	South Sutter Irrigation District
SSJID	South San Joaquin Irrigation District
SWP	State Water Project
SWRCB	State Water Resources Control Board
SSWD	South Sutter Water District
TAF	thousand acre-feet
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WQCP	Water Quality Control Plan
YCWA	Yuba County Water Agency

SURFACE WATER RESOURCES

INTRODUCTION

This technical report discusses characteristics of surface water hydrology, surface water supply and management, and Bay-Delta hydrodynamics and riverine hydraulics that could be affected by implementation of the CALFED Bay-Delta Program (CALFED).

Information is provided for the following rivers:

- Sacramento River,
- Feather River,
- Yuba River,
- Bear River,
- American River,
- Trinity River,
- San Joaquin River,
- Stanislaus River,
- Tuolumne River, and
- Merced River.

For each tributary, the following factors are described:

- Watershed runoff characteristics,
- Water management facilities,
- Reservoir storage operation,
- Regulated flows and diversions (exports), and
- Water allocation management.

Because of the complexity of the subject matter and the large volume of data contained in this report, data for each river and Sacramento-San Joaquin River Delta (Delta) (including tables and figures) are contained in a separate section at the end of the main technical report.

Surface Water Supply and Water Management

The available water in each tributary or in the Delta is allocated for instream flows or for diversions. If storage capacity is available, some inflow may be temporarily stored for later diversion or instream use. Some the inflow may be in excess of that which can be used or stored and is considered unallocated (excess or surplus). Flows in excess of the specified instream flow requirements most likely will provide additional ecological benefits.

Table 1 gives the basic hydrological properties for each tributary basin. The watershed size and average annual runoff indicate the available water supply. The ratio of the existing reservoir volume to average annual runoff (storage ratio) indicates the ability to manage the runoff for seasonal or carryover purposes. Some tributaries have a relatively small storage ratio, indicating that the ability to manage water using storage is low. For example, Folsom Reservoir has a volume of 977 thousand acre-feet (TAF) with an average runoff of 2,675 TAF; therefore, the storage ratio is about 35%. All runoff from these tributaries is included in the DWRSIM model as calculated inflows; however, some reservoirs are not simulated directly in DWRSIM.

General water supply conditions can be summarized using annual average rainfall and snowpack measurements, measured streamflow, or unimpaired runoff for each major tributary. The difference between annual average precipitation and unimpaired runoff represents water that is stored in soil moisture, evaporated from the soil or water surface, transpired by vegetation and trees, or infiltrated into the

Tributary Basin	Watershed Area (square miles)	Unimpaired Runoff (TAF)	Reservoir Name	Reservoir Volume (TAF)	Included in DWRSIM
Trinity	692	1,254	Clair Engle	2,448	Yes
Sacramento	14,050	10,936	Shasta	4,552	Yes
Clear Creek	240	350	Whiskeytown	241	Yes
Stony Creek	775	470	Black Butte	144	No
Feather	5,921	6,845	Oroville	3,538	Yes
Yuba	1,350	2,259	New Bullards Bar	966	No
			Englebright	70	No
Bear	300	312	Camp Far West	104	No
American	1,900	2,675	Folsom	977	Yes
Cache Creek	1,300	560	Clear Lake	313	No
			Indian Valley	300	No
Putah Creek	710	415	Berryessa	1,600	No
Mokelumne	675	700	Pardee	210	No
			Camanche	417	No
Calaveras	375	175	New Hogan	317	No
Stanislaus	1,100	1,239	New Melones	2,420	Yes
			Tulloch	68	No
Tuolumne	1,900	1,542	New Don Pedro	2,030	Yes
Merced	1,275	914	McClure	1,024	Yes
Chowchilla			Eastman	150	Yes
Fresno			Hensley		Yes
San Joaquin	1,650	1,672	Millerton	520	Yes
Kings			Pine Flat	1,000	No
Kern			Isabella	568	No
Delta		21,843	San Luis	2,040	Yes

NOTE:
TAF = thousand acre-feet.

SOURCE:
U.S. Geological Survey. 1994a, 1994b, 1994c, 1994d.

Table 1. Tributary Streams and Reservoirs Potentially Affected by CALFED

groundwater. Unimpaired runoff is considered as the basis for the water management assessment of the CALFED alternatives. A water budget approach, like that used in California Department of Water Resources' (DWR's) Bulletin 160-93 (California Water Plan Update) is used to summarize the available water supply for each tributary basin. (A water budget is an accounting of all of the inflow and outflow to and from a basin, watershed, or water body, and is typically used to quantify an unknown component where all of the other components are known.)

UNIMPAIRED RUNOFF AND DELTA INFLOW

Unimpaired flow estimates consist of all rainfall and snowmelt runoff minus the water losses to evapotranspiration from natural soils and native vegetation, and the net losses to groundwater storage. Because it is difficult to correct for the differences between past and present vegetation, unimpaired flow estimates are calculated from historical flow measurements and adjusted for upstream changes in reservoir storage and upstream diversions.

The water supply conditions in the Central Valley are commonly summarized with the unimpaired runoff estimates of four Sacramento River tributaries and four San Joaquin River tributaries. These summaries are referred to as the Sacramento River index and the San Joaquin River index. When combined, the eight-river Central Valley index can be used to summarize available water supply conditions. The 1995 Water Quality Control Plan (WQCP) objectives for X2 location are partially governed by this eight-river index. (X2 location is an in-channel point of measured salinity that determines the amount of estuarine habitat available within San Francisco Bay. Refer to the discussion under "Delta Region" in this report for additional information on X2.) The four-river unimpaired runoff values have been used to develop runoff indices for classifying water-years (the Sacramento 40-30-30 index).

Several tributaries in the San Joaquin and Sacramento River basins are not included in the eight-river index. Unimpaired estimates for Sacramento River at Freeport; plus Yolo Bypass, Cache Creek, and Putah Creek flows; plus San Joaquin River at Vernalis; plus east side San Joaquin streams (the Cosumnes, Mokelumne, and Calaveras rivers) also are used to estimate the total unimpaired inflow to the Delta.

The range of annual Delta unimpaired inflow is quite large because of the extreme hydrologic variability that characterizes the Central Valley. The average annual unimpaired Delta inflow is about 28.5 million acre-feet (MAF) but ranges from less than 7 MAF (1977) to greater than 70 MAF (1983). This 10-fold variation in unimpaired runoff indicates the need for substantial year-to-year water supply storage capacity.

The Sacramento River Basin contributes the majority of Delta inflow. The Sacramento four-river unimpaired index averages about 17 MAF and ranges from about 5 to 38 MAF. The San Joaquin four-river unimpaired index averages about 5.5 MAF and ranges from 1.1 to 15 MAF. The Trinity River unimpaired runoff at Lewiston averages about 1.2 MAF and ranges from 200 TAF to 3 MAF. The Tulare Lake Basin unimpaired runoff averages about 2.9 MAF and ranges from 700 TAF to 8.6 MAF.

CENTRAL VALLEY WATER MANAGEMENT

Central Valley water management consists generally of allocating the available runoff for:

- Maintaining sufficient water in tributary streams for ecological purposes,
- Making direct diversions for export or in-basin water supply needs, or
- Storing excess runoff in reservoirs and later releasing water for maintaining instream flows and making water supply diversions.

Multipurpose reservoirs have been constructed to provide flood control, hydropower, recreation, and water supply benefits. Water management operations must balance the allocation of water and available reservoir storage among these multiple purposes. Because runoff, instream flow requirements, and diversion demands have substantial seasonal fluctuations, monthly as well as year-to-year variations in water supply conditions are important aspects of the CALFED water supply affected environment and impact assessment.

Figure 1 shows the general seasonal pattern of water management. Reservoirs are generally multipurpose facilities and must remain partially empty during the flood control season; therefore, storage capacity often is limited in months with the largest runoff potential. Additional storage capacity generally will allow more seasonal or year-to-year storage of excess runoff during wet periods (high-flow months). Diversions normally are made to satisfy water demands that peak during summer; therefore, only a portion of water demands can be supplied with direct diversion of runoff. A substantial portion of water demands must be supplied from reservoir storage releases. If instream flow requirements are greater than the natural runoff, water to maintain these required flows must be supplied from upstream reservoir storage.

Several tributaries with reservoir storage and diversions are not specifically included in the DWRSIM model (Table 1). The water management operations on the Yuba and Bear rivers are not simulated, but the net outflows from these basins have been simulated as part of the hydrology inputs (inflows and diversions) for the DWRSIM model. These tributaries are discussed briefly in the Feather River water management assessment.

Cache Creek (Clear Lake) and Putah Creek (Lake Berryessa) are not simulated, but the net flows from these tributaries are included in the DWRSIM model as part of the Yolo Basin hydrology.

The Cosumnes, Mokelumne, and Calaveras rivers are tributaries of the San Joaquin River that are not specifically simulated in the DWRSIM model. These streams are referred to as the "east side streams" in Delta inflow evaluations. The Cosumnes River does not have a major storage facility, although several agricultural diversions are located along the lower river. The Mokelumne River is highly regulated by two major reservoirs operated by East Bay Municipal Utilities District (EBMUD). Pardee Reservoir supplies the Mokelumne Aqueduct, and Camanche Reservoir provides flood control and water supply benefits for downstream users. The reservoir for the Calaveras River almost totally regulates flows for downstream irrigation diversions.

WATER MANAGEMENT ALLOCATION

The annual (water-year) water allocation can be summarized using the totals of:

- Monthly inflows or available water supply,
- Monthly required instream flows,
- Monthly diversions,
- All monthly storage increases (diversions to storage),
- All monthly storage decreases (releases from storage), and
- All excess flows (excess runoff and spills).

These six water allocation totals can be compared to summarize water management conditions. The ratio of storage increases to total inflow indicates the fraction of runoff that was stored that year for later beneficial use. The remainder of the runoff was used directly for instream flow and diversion purposes or was excess water that could not be used in the tributary basin because of storage limitations. Some water uses were satisfied by direct runoff. The remainder of the uses depended on the water storage facility. The percentage of total uses supplied from reservoir storage releases is an important water allocation indicator. The ratio of total uses (instream flows and diversions) to runoff indicates the fraction of runoff that was allocated for beneficial uses. This ratio may be greater than 1.0 in some dry years when carryover storage is used.

The monthly water allocation values and annual indices are only an approximation of the actual day-to-day reservoir operation and water use patterns. Flood control operations involve large variations in reservoir storage and releases in any particular month. The monthly average inflows, releases, and end-of-month storage values provide only a rough description of actual operations. Nevertheless, these monthly water allocation values and annual indices provide a general description of water management conditions that can be used for assessment of CALFED alternatives.

Bay-Delta Hydrodynamics and Riverine Hydraulics

Before flow from the Sacramento River and San Joaquin River discharges to the San Francisco Bay, it passes through the Delta. Channel hydraulic processes in the region upstream of the Delta are dominated by flows toward the Delta. Tidal effects are generally small upstream of the Delta. In the Delta, tidal flows into and out of San Francisco Bay strongly influence the magnitude and direction of flow in Delta channels. Analysis of the combined effects of tidal flows and nontidal flows in the Delta and San Francisco Bay requires different analytical tools from those used to analyze the river flows upstream of the Delta. For this reason, Delta and Bay hydrodynamics are discussed separately from river hydraulics in this report.

The hydrodynamics of the Delta include the complex interaction of tides, river inflows, and Delta geometry that influence the movement of water in Delta channels. Delta hydrodynamics also depend on diversions and exports from the Delta. Delta hydrodynamics govern channel flows and Delta outflow. Channel flows influence water quality, such as salinity and dissolved organic carbon, and the movement of fish and entrainment of vulnerable organisms such as larval fish and the organisms on which they feed. Delta outflow has important effects on salinity intrusion and estuarine habitat and conditions.

The discussion of river hydraulics addresses the movement of water within the principal stream channels of the Sacramento River and San Joaquin River regions that are influenced by operation of the Central Valley Project (CVP) and the State Water Project (SWP). The focus of the discussion is on stream flow (discharge) and its relation to stream velocity, width and depth of the stream, and sediment-carrying capacity. Each of these variables has in common a dependence on discharge; that is, if other factors remain the same, a change in discharge will result in a change in velocity, width, depth, and sediment movement. Temperature and salinity, two additional parameters that relate to river hydraulics, also are discussed. Changes in these water quality parameters depend not only on changes in magnitude of discharge but on differences in the quality of discharges from different sources.

Representative study locations were selected throughout the Delta and river systems to assess potential changes to surface water conditions associated with implementation and operation of CALFED program alternatives.

Hydrodynamic/hydraulic factors include stream channel discharge, flow velocity, flow depth, and top width of channels at various points throughout the study area.

SOURCES OF INFORMATION

Water Supply and Management

Among the sources used in compiling this report are the draft 1998 California Water Plan update (DWR 1998) and the 1993 California Water Plan update (DWR 1994); DWRSIM and DWRDSM1 Model Studies performed by DWR (these studies have been published in a variety of formats, including presentation in public meetings, on the internet, and in the Phase 2 report); and various DWR publications. Some of the information presented in this report has previously been presented in the CVPIA EIS (Bureau of Reclamation 1998).

Bay-Delta Hydrodynamics and Riverine Hydraulics

Sources of information for the historical perspective on the San Francisco Bay-Delta include the California Water Plan Update, Bulletin 160-93 (DWR 1994a) and the *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* (SWRCB 1995).

Current resource conditions for flows, velocities, stages, mass fate, central Delta outflow, and salinity in the Delta Region were estimated based on hydrodynamic modeling of the Delta Region using the Delta simulation computer model (DWRDSM1). Table 2 shows key locations in the Delta and their surface area, volume, and mean depth used in the hydrodynamic modeling effort. Representative peak tidal discharges also are provided for reference.

The primary sources of historical information on rivers in the Sacramento River and San Joaquin River regions are water resource data reports published by the U.S. Geological Survey (USGS) (1994a, 1994b), and the California Water Plan Update (DWR 1994a). Historical daily stream flow records for selected USGS stream gaging stations were obtained from the USGS's "California Surface-Water Data Retrieval" page on the Internet at http://h2o.usgs.gov/nwis-w/CA/.

Current resources for river flows were estimated based on computer modeling by DWR, using the statewide water operations planning model DWRSIM. Model output reflecting a 1995 level of statewide water demands was obtained from study 1995C06F-SWRCB-469, which was completed by DWR for the State Water Resources Control Board (SWRCB). The data used in this report were obtained from DWR's Internet site at http://wwwhydro.water.ca.gov/swrcb.html. Additional information concerning the assumptions used in the model were obtained from the Internet web site referenced above. Additional information about DWRSIM and DWRDSM1 can be found in the Supplement to this report.

Equations relating discharge to average stream velocity, average stream width and stream depth, and sediment loading were developed using data for selected stations from 1967 to the present, obtained from the USGS Water Resources Division.

ENVIRONMENTAL SETTING

Regulatory Context

Very little of the water that falls as rain or snow within the region flows unregulated out of the Sacramento River and San Joaquin River regions. Instead, this water is intensely managed to extract from it the maximum benefit. The water is managed through a system of storage facilities and conveyances that enable water managers to deliver water at the time and places where it provides the greatest benefits. In the past, these beneficial uses were broadly classified as municipal and industrial (MandI), agricultural, and fish and wildlife. The SWRCB now lists 17 specific beneficial uses of water in the Bay-Delta estuary, each of which is protected. Since stream channels are used as water conveyances, the rules governing the timing and magnitude of storage and release of water resources determine to a great extent the timing and magnitude of in-stream flows.

Location	Channel Number	Surface Area of Channel Segment (acres)	Volume of Channel Segment (acre-ft)	Depth Below MSL (ft)	Peak Tidal Flow (cfs)
San Joaquin River at Fourteen Mile Slough	22	77.4	2,406	31.1	7,109,000
San Joaquin River at Antioch	51	876.1	21,989	25.1	22,251,000
Old River at Mossdale	54	12.6	102	8.1	206,000
Old River at Fabian Tract	76	28.0	143	5.1	143,000
Old River at Woodward Island	95	56.7	912	16.1	4,233,000
Old River at Franks Tract	121	57.9	585	10.1	873,000
Middle River at Woodward Island	143	30.8	527	17.1	2,975,000
Grant Line Canal	209	21.8	285	13.1	750,000
Victoria Canal	228	34.4	347	10.1	870,000
Delta Cross Channel	365	29.2	470	16.1	1,666,000
Georgiana Slough	366	24.7	348	14.1	586,000
Diversion to Sutter/Steamboat Sloughs	379	10.8	196	18.1	673,000
Miner Slough	388	54.1	762	14.1	761,000
Sacramento River at Rio Vista	430	758.2	19,030	25.1	35,734,000
Mokelumne River, North Fork	362	49.4	993	20.1	1,809,000
Mokelumne River, South Fork	343	51.5	881	17.1	1,808,000

NOTES:

cfs = cubic feet per second.
ft = feet.
MSL = Mean Sea Level relative to the National Geodetic Vertical Datum (NGVD) at the Golden Gate.

SOURCE:
CALFED. 1997

Table 2. Delta Channel Geometry Used in Hydrodynamic and Water Quality Modeling

WATER SUPPLY AND MANAGEMENT

The Bay-Delta receives runoff from the entire Sacramento and San Joaquin River basins. In addition, the Tulare Lake basin tributaries (for example, Kern, Tule, Keswick, and Kings Rivers) historically drained into the San Joaquin River during high-flow periods when Buena vista and Tulare Lakes overflowed. Presently, only a portion of Kings River flows are diverted to the San Joaquin River during major runoff events. A large fraction of San Joaquin River water (from Friant Dam diversions) and Delta exports is delivered to the Tulare Lake Basin. The Trinity Division of the Central Valley Project (CVP) includes a diversion from the Trinity River at Lewiston Lake to the Sacramento River at Keswick lake.

General water supply conditions can be summarized using annual average rainfall and snow pack measurements or using measured streamflow ("unimpaired runoff") for each major tributary. Some of the precipitation is stored in soil moisture, evaporated, transferred by vegetation, or infiltrates to ground water. Ground water condition are discussed separately in another Supporting Technical Report. Unimpaired runoff within the drainage basin of the Central Valley, Supplemented by some ground water that discharges to surface water bodies (streams, lakes, or wetlands), therefore represents most of the surface water supply available for management within the CALFED Bay-Delta Program. Some of the unimpaired runoff is captured and managed by water projects other than the CVP and SWP (for example, EBMUD, Hetch-Hetchy). A portion of this runoff is subsequently released and eventually flows into the Bay-Delta. This water also contributes to the water supply available for management within the CALFED Bay-Delta Program.

Management of the water supply involves: accounting for the available water supplies through measuring precipitation, snowpack, stream flows, lake and reservoir storage, and increasingly ground water storage for conjunctive management); allocating the available water among various water users, storing some of the water for power production or future uses, and releasing water from storage for various in-stream uses or to make room for flood control. These management decisions are governed by water contracts, regulatory requirements, and reservoir operating rules designed to maximize the beneficial use of the available water supply overtime.

The amount of unimpaired runoff fluctuates widely between wet and dry years. Demand is fairly constant from year to year, but varies seasonally, so that demand exceeds runoff during dry years and during the dry season. Reservoir storage (both in surface water and ground water reservoirs) helps to overcome this temporal mismatch between supply and demand.

Nor does the spatial distribution of the water correspond to the spatial distribution of demand. Most of the runoff occurs in the northern and northeastern portion of the Central Valley Watershed, while much of the demand occurs in the San Joaquin Valley or in urban areas outside the Central Valley. The spatial mismatch between supply and demand is addressed by transferring water through a network of conveyances.

During any particular period of time, lack of runoff, lack of storage capacity, or lack of conveyance capacity can be constraints that limit the ability of the water supply system to meet the demand for water.

BAY-DELTA HYDRODYNAMICS AND RIVERINE HYDRAULICS

The quantity, quality, and timing of flows in river and Delta channels, particularly during below-normal runoff years, increasingly depends on the complex body of laws, regulations, plans, and policies that have evolved to set priorities for allocating the resource among users. These regulations include the Central Valley Project Improvement Act (CVPIA), the Porter-Cologne Water Quality Control Act, and Decision 1485 (D-1485) of the SWRCB. Other laws and regulations may indirectly affect Delta hydrodynamics and river hydraulics. These include laws and regulations on the following:

- Water use efficiency,
- Water transfers,
- Releases of water for fish,
- Fish protection,
- Endangered species, and
- Suisun Marsh.

Additional information on laws and regulations and on flow requirements under the CVPIA is included in the Supplement to this report.

Environmental Setting - Delta and Bay Regions

HISTORICAL PERSPECTIVE

Before the arrival of the Spanish, several Native American tribes lived in the Bay-Delta area. With the discovery of gold in the Sierra Nevada, early settlements in the area expanded rapidly (DWR 1991).

During the mid-1800s, the Delta, an area of nearly 750,000 acres, was mostly undeveloped tidal marsh. The Delta was inundated each year by winter and spring runoff. During this early period prior to development, Delta channel geometry changed in response to the forces of floods and tides.

The rapid influx of new settlers during the mid-1800s resulted in almost immediate changes to the Bay and Delta. Shores of the Bay were expanded with fill material to provide more land for homes and industry. Levees were constructed to convert formerly flooded marshlands in the Delta to arable islands. Valley lands were drained for farming, and Central Valley streams were dammed for water supply. Hydraulic mining for gold in the watershed washed huge amounts of sediment into stream channels. All these activities caused changes in the quantity and quality of water reaching the estuary.

In 1940, water exports from the Delta began after the Contra Costa Canal, a unit of the CVP, was completed. Water was exported at the CVP's Tracy Pumping Plant, supplying the Delta-Mendota Canal in 1951. The Contra Costa Canal originates at Rock Slough, which connects with Old River, approximately 4 miles southeast of Oakley. Diversions historically have ranged from 50 to 250 cubic feet per second (cfs) at the unscreened Rock Slough facility (Contra Costa Canal Pumping Plant Number 1). Although the canal and its associated facilities are part of CVP, they are operated and maintained by the Contra Costa Water District (CCWD). The SWP began exporting water through the South Bay Aqueduct in 1962. Because of increased water demand, the SWP began pumping from the south Delta in 1967, supplying the California Aqueduct, and from the north Delta in late 1987, supplying the North Bay Aqueduct.

To facilitate movement of Sacramento River water to pumping facilities in the south Delta, U.S. Bureau of Reclamation (Reclamation) completed the Delta Cross Channel (DCC) in 1951. This channel connects the Sacramento River to Snodgrass Slough and the Mokelumne River system. The flow from the Sacramento River is controlled by two 60-foot gates at the Sacramento River near Walnut Grove. Downstream of the DCC, Georgiana Slough also connects the Sacramento River to the Mokelumne River system, moving Sacramento River water into the central Delta.

Historically, during summers when mountain runoff was small, ocean water intruded into the Delta as far as Sacramento. During winter and spring, freshwater from heavy rains pushed the saltwater back, sometimes past the mouth of San Francisco Bay. Reservoir releases have resulted in dampened peak winter and spring flows and increased summer and fall flows. In very wet years, such as 1969, 1982, 1983, and 1986, reservoirs were unable to control runoff so that during winter and spring the upper bays became fresh; even at the Golden Gate, the upper several feet of water column consisted of freshwater.

The San Francisco Bay system includes the Suisun, San Pablo, and South bays. The Golden Gate, the outlet of San Francisco Bay, is located 85 miles from Chipps Island, the outlet of the Delta to Suisun Bay. To the north of Suisun Bay and east of Carquinez Strait lies the Suisun Marsh, an extensive mosaic of variably-controlled tidal marshlands. Tributaries to San Pablo Bay include the Napa, Sonoma, and Petaluma rivers. The principal tributary to the South Bay is Coyote Creek. There are numerous lesser streams that collectively drain the Bay Region.

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CURRENT RESOURCE CONDITIONS

WATER SUPPLY AND MANAGEMENT

Water management in the Delta is similar to water management in the tributary basins. The available monthly inflows from the tributary basins are allocated to (1) supply in-Delta diversions for agricultural and municipal water supply demands, (2) provide minimum Delta outflow required to satisfy 1995 WQCP objectives, and (3) allow Delta exports within the 1995 WQCP export/inflow ratio and the permitted pumping capacity. Some of the exports are used for direct deliveries to satisfy water supply demands and some of the exports are stored in San Luis Reservoir (or other local water storage facilities) for later delivery. Any water that cannot be used for one of these beneficial uses is considered to be surplus (unallocated) Delta outflow, although there may be increased ecological values associated with these higher Delta outflows.

The Delta receives runoff from a watershed that includes more than 40% of the state's land area (DWR 1991).

The Delta inflows originate from the Sacramento River (including the Yolo Bypass), the San Joaquin River at Vernalis, the east side streams, and local runoff from precipitation. The average annual unimpaired Delta inflow is about 27.8 MAF but ranges from less than 7 MAF to greater than 70 MAF. Average annual Delta inflow for 1967 to 1991 was about 25 MAF. The difference between unimpaired and historical inflow represents the upstream water management activities in the tributary basins. Monthly Delta inflows vary substantially from periods of relatively low flow (10,000 cfs), to periods of extremely high inflow (greater than 100,000 cfs). Monthly Delta inflows are slightly higher than unimpaired inflows during some dry periods.

The highest Delta inflows occur from January through April, corresponding to the rainfall and flood control season when reservoir storage diversions are limited. Delta inflows are generally higher than the unimpaired inflows from July through October because reservoir releases are being made to supply Delta outflow requirements and export demands.

The Sacramento River maximum channel flow capacity is approximately 80,000 cfs. Sacramento River flows greater than this capacity are diverted into the Yolo Bypass upstream of Sacramento. During late summer of most years, the minimum Sacramento River flows at Freeport are approximately 10,000 cfs. Maintaining salinity control with Delta outflow is most critical during these low-flow periods. During periods of high runoff, a large proportion of Sacramento River and Yolo Bypass flows cannot be controlled by upstream reservoirs. Regardless of SWP and CVP reservoir operations, the high runoff flows enter the Delta in response to natural hydrologic conditions.

San Joaquin River flows frequently have been less than 1,000 cfs. In recent years, releases from New Melones Reservoir have been used to maintain San Joaquin River flows for salinity control. Most runoff occurs during winter storms, when maximum flows on the San Joaquin River can exceed 20,000 cfs and flows of the combined east side streams can exceed 10,000 cfs. High flows in the other east side streams and the Sacramento River generally correspond to periods of high flow in the San Joaquin River.

Based on DWRSIM modeling of existing conditions, average flows in the Delta are about 22 MAF, with a range of less than 8 MAF to more than 68 MAF (in very dry and very wet years, respectively). The required Delta outflows under the 1995 WQCP objectives average 5.5 MAF, with a range of less than 4 MAF to about 8 MAF. The simulated in-Delta net channel depletions are about 1.2 MAF. Total exports average 6.4 MAF, with a range of from less than 3 MAF to about 8 MAF. Average annual deliveries to the SWP-CVP Service areas are about 5.5 MAF. For critically dry hydrologic conditions, the period from May 1928 through October 1934, average annual deliveries have been estimated to be about 4 MAF.

The average annual inflow from the Sacramento River (including Yolo Bypass) for 1967 to 1991 was about 20.5 MAF. The average annual flow in the San Joaquin River for 1967 to 1991 was about 3.5 MAF. The combined average flow in the east side streams (Mokelumne, Cosumnes, and Calaveras rivers) for the same period was approximately 1.1 MAF. Rainfall in the Delta is not considered as Delta inflow because a large fraction is assumed to be stored in the Delta soils.

Several important water management facilities are located in the Delta. These include the Contra Costa Pumping Plants at Rock Slough and Old River, CVP Pumping Plant at Tracy, DCC at Walnut Grove, SWP Clifton Court Forebay and Banks Pumping Plant, North Bay Aqueduct Pumping Plant, and Suisun Marsh Salinity Control Structure on Montezuma Slough.

The CVP Tracy Pumping Plant has a maximum pumping capacity of approximately 4,600 cfs, the nominal capacity of the Delta-Mendota Canal at the pumping plant. Although seasonal fluctuations occur in CVP water demands, additional export pumping is used to fill the CVP portion of San Luis Reservoir.

CCWD presently is constructing a second pumping plant on Old River and the new Los Vaqueros Reservoir that will allow emergency storage and water quality storage. Los Vaqueros will be refilled by diversions only when chloride concentration is less than 65 milligram per liter (mg/L). Los Vaqueros water will be used for delivery during low Delta outflow periods, when chloride concentration at Rock Slough and Old River is greater than 65 mg/L.

The SWP Banks Pumping Plant supplies water for the South Bay Aqueduct and the California Aqueduct, with an installed pumping capacity of 10,300 cfs. The Banks Pumping Plant presently is limited by a U.S. Army Corps of Engineers (Corps) permit with a maximum permitted capacity of 6,680 cfs plus 33% of the San Joaquin River flow (if greater than 1,000 cfs) between December 15 and March 15. An additional four pumps became operational in 1992, increasing the maximum Banks Pumping Plant capacity to approximately 10,300 cfs. The Interim South Delta Program (ISDP) would improve south Delta channels to allow use of the full Banks Pumping Plant capacity whenever Delta inflows are sufficient to satisfy the 1995 WQCP objectives for outflow and maximum% of inflow that can be exported, which is 35% of inflow during February to June and 65% of inflow in remaining months.

Other DWR facilities around the Delta include the North Bay Aqueduct, the Suisun Marsh Salinity Control Structure, and several temporary barriers in the south Delta. The SWP pumps water from Barker Slough into the North Bay Aqueduct for use in Napa and Solano counties. Maximum pumping capacity at Barker Slough is 175 cfs (pipeline capacity); the average annual pumping rate is approximately 35 cfs.

The Suisun Marsh Salinity Control Structure spans Montezuma Slough near Collinsville. The structure's primary objective is to meet the water quality criteria in Suisun Marsh that were developed to offset the effects of upstream diversions by SWP, CVP, and other water diversions. When operating, the salinity control tidal gate structure is opened to allow full tidal flow from the Sacramento River near Collinsville into Suisun Marsh channels during ebb tides. Floodtide flow from Suisun Marsh is blocked by the gates. This tidal gate operation scheme produces a net flow of approximately 2,000 cfs into Montezuma Slough from the Sacramento River at Collinsville.

Regulated Flows and Diversions

In-Delta diversions are estimated in the DWR water budget for the Delta, the DAYFLOW database. CCWD pumping, North Bay Aqueduct pumping, and Vallejo pumping are considered to be in-Delta diversions. The estimated in-Delta diversions have increased with higher demands in the service areas and changing Delta agricultural land use; however, the estimated current level of demands is approximately 1.75 MAF.

Simulated unallocated annual Delta outflow (to the Bay) ranges from less than 0.1 MAF to more than 50 MAF, with an average of 8.7 MAF. Delivery deficits can occur during dry years due to lack of available water. Exports also can be limited by pump capacity, permitted pumping limits, lack of aqueduct demands, and lack of off-aqueduct reservoir storage.
Delta outflow requirements (minimum Delta outflow) are sometimes difficult to estimate because of changing regulatory requirements. The estimates, assuming D-1485 requirements (as simulated by DWRSIM) are therefore only approximate. The annual outflow requirements range from 3 MAF to over 6 MAF, with an average of about 5 MAF.

The annual exports (combined CVP Tracy and SWP Banks) increased during the 1967 to 1991 period and reached an approximate maximum of 6 MAF in the late 1980s. The average annual SWP and CVP exports during 1967 to 1991 were about 4 MAF. The SWP Banks Pumping Plant began operating in 1968, but San Luis Reservoir was first filled in 1969 and the Edmonton Pumping Plant (delivering water to southern California) was not completed until 1973.

The reduced pumping in May and June reflects the D-1485 export limits during these months. Some exports were delivered directly, and some exports were stored in San Luis Reservoir or local water storage facilities for later delivery. The estimated maximum monthly demand pattern for Delta exports is shown for comparison (assumed a 7-MAF total demand).

The maximum physical pumping capacity for combined SWP and CVP is approximately 15,000 cfs.

Figure D-4 shows the monthly ratio of exports to inflow for 1972 to 1992. This ratio is used as one of the 1995 WQCP objectives and may be a general indicator of entrainment effects. The maximum export/inflow ratio has been about 70%, and the ratio has been less than 50% for about 80% of the months (20% exceedance).

The San Luis Reservoir provides an opportunity for storage of exports that are not immediately needed for water supply deliveries. Although the reservoir is operated as a joint-use facility by SWP and CVP, with each using approximately half of the 2 MAF storage capacity, the combined storage in San Luis is used in this report to illustrate the basic water management of Delta exports.

San Luis Reservoir has been almost fully utilized for seasonal storage and release in many years. When San Luis is full, no excess Delta exports beyond monthly demands can be made, regardless of the Delta inflow available for pumping.

The winter outflows are somewhat reduced from unimpaired values because of upstream reservoir storage diversions and Delta exports. The summer and fall outflows are often higher than unimpaired flows because of the specified minimum Delta outflow requirements.

WATER MANAGEMENT ALLOCATION

At the 1995 level of demand, approximately 46% of water use during average water years in California goes to environmental purposes. This percentage is expected to remain constant through the year 2020. The distribution of the remaining water between urban and agricultural uses is expected to shift, however, toward urban uses, with urban use increasing from about 11 to 15% during the 25-year period and agricultural use decreasing from about 43 to 39% (DWR 1997). This change is primarily a result of a predicted decline in irrigated acreage. More detailed information about the distribution of water demand is included in other sections of this report.

The water management allocation for the Delta can be calculated and described in much the same way as is done for each tributary basin. The available inflow is compared with the specified minimum Delta outflow, in-Delta diversions, and Delta exports. Some Delta inflow depends on upstream reservoir storage releases. Some inflow already has provided instream flow benefits along the tributary streams.

The average annual inflow was 25 MAF, and the average exports were 4 MAF. In-Delta depletions were about 1.7 MAF. The annual average Delta outflow was about 20 MAF, and the required Delta outflow was about 5 MAF (for D-1485 outflow requirements). The surplus (unallocated) Delta outflow during this period therefore averaged about 15 MAF.

Delta average annual exports were about 4 MAF. In 1967, the exports directly supplied the deliveries of 1.25 MAF. San Luis Reservoir allowed some exports to be stored and used during the irrigation season. The average diversion to San Luis Reservoir storage for the 1967 to 1991 period was about 870 TAF, supplying about 20% of the annual average deliveries of 4 MAF. San Luis Reservoir storage capacity therefore has allowed total deliveries to be increased by an average of about 25% (maximum 1.5 MAF storage release with a maximum total delivery of 6 MAF).

For several months, Delta inflow is more than required to satisfy the estimated minimum Delta outflow, supply the in-Delta diversions, and provide all needed export pumping (up to the permitted capacity). In these months, there is surplus Delta outflow.

BAY-DELTA HYDRODYNAMICS

Today the Delta consists of about 740,000 acres, including approximately 500,000 acres of rich farmland, interlaced with hundreds of miles of waterways that divide the Delta into islands. Some of the island interiors are as much as 25 feet below sea level. Therefore, the Delta relies on about 1,100 miles of levees for flood protection.

Tidal influence is important throughout the Delta. Twice a day, Pacific Ocean tides move through San Francisco Bay and into and out of the Delta. The average incoming and outgoing Delta tidal flow is about 170,000 cfs, much larger than the currently permitted combined SWP and CVP export capability of about 11,000 cfs.

Water that flows through the Delta past Chipps Island to San Francisco Bay is called Delta outflow. The average Delta outflow is about 30,000 cfs or about 21 MAF per year. Delta inflow, export, and depletions of channel water within the Delta determine the magnitude of this flow. Seasonally, average natural flow to the Delta varies by a factor of more than 10 between the highest month in winter or spring and the lowest month in fall. During the summer months of critically dry years, Delta outflow can be as low as 3,000 cfs.

The three major sources of freshwater to the Delta are the Sacramento River, the San Joaquin River, and east side streams. The Sacramento River (including the Yolo Bypass) contributes about 77 to 85% of the freshwater flows, the San Joaquin River contributes about 10 to 15%, and streams on the east side and the Mokelumne River provide the remainder. In the west, salty water moves into the Delta with the tides, from Suisun and Honker bays. Water is directly exported from the Delta by the SWP, the CVP, and the City of Vallejo. Delta channels are depleted due to crop irrigation, evaporation, and channel seepage. During normal water years, about 10% of the water reaching the Delta is withdrawn for local use, 30% is withdrawn for export by the SWP and CVP, 20% is needed for salinity control, and the remaining 40% is Delta outflow in excess of minimum requirements. The excess outflow would occur almost entirely during the season of high inflow. Delta surplus is negligible during most dry seasons.

Releases from the upstream storage reservoirs of the SWP and CVP maintain the minimum freshwater Delta outflow. This outflow establishes a hydraulic barrier to prevent ocean water from intruding deep into the Delta and affecting MandI and agricultural water supplies. The hydraulic barrier, where freshwater gradually mixes with ocean water, is generally maintained near Chipps Island. During flood flows, the hydraulic barrier moves out into the Bay.

San Francisco Bay has a surface area of about 400 square miles at mean tide. This is about a 40% reduction from its original size due to fill. Most of the Bay's shoreline has a flat slope, which causes a relatively large intertidal zone. The volume of water in the Bay changes by about 21% from mean higher-high tide to mean lower-low tide. The overall average depth of the Bay is 20 feet, with the Central Bay averaging 43 feet and the South Bay averaging 15 feet (DWR 1986). San Francisco Bay is surrounded by about 130 square miles of tidal flats and marshes.

Delta outflow is the principal source of freshwater in San Francisco Bay. Delta outflows vary greatly according to month and hydrologic year type. From 1967 through 1991, the average annual Delta outflow to the Bay was about 20 MAF. During critically dry periods, such as 1928 and 1934, historical Delta outflows have dropped to zero. Present summer outflows are maintained by upstream reservoir releases.

San Francisco Bay receives freshwater inflow from the following other significant sources: the Napa, Petaluma, and Guadalupe rivers; and Alameda, Coyote, Walnut, and Sonoma creeks. The total average inflow of these tributaries is about 350 TAF. Stream flow is highly seasonal, with more than 90% of the annual runoff occurring during November through April. Many streams often have very little flow during mid- or late summer.

Below the Delta, the first embayment is Suisun Bay. This bay, which includes Grizzly and Honker bays, is the area where the effects of mixing seaward-flowing freshwater and landward-flowing saltwater (driven by tides) are most pronounced. Although saltwater tends to move landward under river water because it is slightly heavier than freshwater, this effect is seen only slightly in the upper Bay and Delta.

Adjacent to Suisun Bay is the Suisun Marsh—about 80,000 acres of brackish water, containing a significant percentage of the remaining contiguous wetlands in California. Below the Carquinez Strait are the San Pablo and Central San Francisco bays. Carquinez Strait isolates these bays from the Suisun Bay and the Delta, and allows such oceanic conditions as tides to play a leading role in their salinity and circulation. These embayments can become quite fresh, especially at the surface, during extremely high freshwater flows (such as during February 1986). During these high flows, the entrapment zone, or mixing zone of seawater from the bay and fresh water from the streams, temporarily can be relocated in San Pablo Bay. At low freshwater flows and high tides, these embayments are quite saline.

South San Francisco Bay is different from the other parts of the system. This bay is out of the main path of Delta outflows and receives significant flows only from the Sacramento and San Joaquin rivers during high outflow or floods. The South Bay is often saltier than the ocean outside the Golden Gate because of low freshwater flows during most of the year and losses of water through evaporation.

Tides move water from the ocean into the Bay-Delta system through the narrow and deep Golden Gate. Although accurate estimates are difficult to obtain, one estimate is that about one-fourth of the Bay water is replaced with new ocean water during each complete tidal cycle. Physical processes that affect the Bay-Delta ecosystem in the ocean include tides; horizontal currents along the coast, which cause up welling of deep oceanic water; temporary and long-term rises in sea level; and changes in ocean temperature.

Flows, Velocities, and Stages

Average flows, velocities, and stages for high inflow, low inflow/high pumping, and low inflow/low pumping conditions for several locations in the Delta provided the input hydrology from DWRSIM, which provides monthly average river inflows and projected exports under predicted 2020 demands. This demand is higher than the current demand; thus, pumping rates and, therefore, flows toward the pumping plants, may be less for existing conditions.

During periods of high inflow, the DCC is closed for Delta flood protection. Higher flows are observed in locations along the Sacramento River and in the north Delta, while flows in the south Delta are generally lower. Average flow rates along the Sacramento River and in the north Delta range from 0 to 185,000 cfs for high inflow conditions, 30 to 6,200 cfs in low inflow/high pumping conditions and 30 to 2,900 cfs for low inflow/low pumping conditions.

Velocities in the Delta are generally well below the nominal scour velocity of approximately 3 feet per second (fps) except at a few locations in high inflow conditions— Old River at Mossdale, Grant Line Canal, the diversion to Sutter and Steamboat sloughs, and the Sacramento River at Rio Vista.

Transport and Fate of Tracer Mass

The fate of mass released into the Delta at various locations after 30 and 60 days was evaluated for a number of flow conditions: low inflow/high pumping, low inflow/low pumping, high inflow/high pumping, and medium inflow/low pumping. These flow conditions were chosen based on fisheries and wildlife issues.

Net Delta Outflow

The Delta is a tidal region with tides causing a 0- to 8-mile back-and-forth movement of water in the Delta twice each day. The net movement of fresh water through the Delta can be thought of as being superimposed on the tidal flows. The tidal flows into and out of the Delta essentially cancel each other out; thus, an equal amount of water flows into the Delta and then flows back out with no net movement of water through the system. Although the fresh water river flows are small in comparison to the tidal flows, they are the source of "net" movement in and through the Delta.

Generally, the average tidal flow (ebb or flood) at Chipps Island is about 170,000 cfs. The peak tidal ebb and flood flows are about 320,000 cfs and 310,000 cfs, respectively, the difference accounting for net Delta outflow. In comparison, average winter net Delta outflow is about 32,000 cfs, with summer flows averaging 6,000 cfs (DWR 1993). Net Delta outflow is the difference between the tidal inflows and tidal plus river outflows (exports and channel depletions).

From 1923 through 1994, average annual Delta outflow was 20,700 cfs and ranged from 5,500 cfs to 94,300 cfs. Monthly average flows are frequently as low as 3,000 cfs in summer and as high as 148,000 cfs in winter (5th and 95th percentiles, respectively) (Table 3).

February typically has the greatest variation of net Delta outflow, ranging from 11,000 cfs to 148,000 cfs for the 5th and 95th percentiles, respectively, in addition to the largest median flow of 31,000 cfs. August has the least variation of net Delta outflow, ranging from 3,000 cfs to 5,000 cfs for the 5th and 95th percentiles, respectively. The low flows are commonly a function of the minimum Delta outflow requirements.

Central Delta Outflow

Central Delta outflow is either downstream in a typical flow pattern or drawn upstream toward the export pumping plants. Reverse flows are a result of high export pumping in the southern Delta compared to the low inflows of the San Joaquin River and southern channel capacities. The difference between the exports and the southern Delta inflows are made up from the Sacramento River and east side streams, drawing water across the Delta from the north and west to the south.

Reverse flows appear to occur in every year between 1976 and 1991, except in 1983, which experienced the highest Delta flows on record (66,000 TAF). During the 1976 to 1977 drought and the 1987 to 1991 drought, flows were almost always upstream. Frequency analysis of central Delta outflows indicates that approximately 60% of the monthly averaged flows are in the upstream direction.

	90%	80%	70%	60%	50%	40%	30%	20%	10%
January	101,435	73,361	33,145	26,682	18,508	12,959	10,880	6,779	6,001
February	129,528	73,542	57,506	49,020	29,712	24,425	19,874	12,533	11,405
March	94,956	62,068	41,309	34,371	27,209	21,760	16,234	12,442	10,363
April	70,993	48,266	26,153	21,316	18,705	14,436	11,340	10,033	8,541
May	45,099	26,581	21,081	15,951	12,360	11,193	9,680	7,416	6,333
June	19,074	12,476	10,688	10,339	9,596	9,078	8,430	7,993	6,890
July	8,002	8,002	8,002	8,002	6,505	6,505	4,993	4,993	4,001
August	5,188	4,850	4,577	4,079	4,001	4,001	3,497	3,497	2,992
September	10,961	5,885	3,576	3,008	3,008	3,008	3,008	3,008	3,008
October	14,585	9,673	5,656	5,465	4,716	4,001	4,001	4,001	4,001
November	16,043	11,102	8,934	7,156	4,672	4,504	4,504	4,504	3,496
December	66,313	38,268	15,847	9,758	7,888	6,609	5,058	4,505	4,505

NOTE:

Averages are in cubic feet per seconds (cfs)

Table 3. Monthly Average Net Delta Outflow (in cfs)

Central Delta outflows show typical winter and spring characteristic flows, and summer and fall characteristic flows. Median flows in mid-winter through spring are downstream, while median flows in summer through fall are upstream. Approximately 70% of the central Delta outflows in late winter through spring are downstream. Flows in April are always downstream. Approximately 70% of the central Delta outflows in summer and fall are in the upstream direction (Table 4).

X2 Position

The location of the mixing zone between fresh water from the Delta and saline water from the Bay varies with the amount of Delta outflow, as well as tides. It is pushed bayward during periods of high Delta outflow and can move up into the Delta if Delta outflow is low or during spring neap tides. In order to track and regulate this movement, a standard has been developed, called X2, which represents the mean distance in kilometers from the Golden Gate Bridge, where the salinity concentration is two parts per thousand and the electrical conductivity is 2,640 micro siemens per centimeter (μs/cm). The X2 position approximates the location of the entrapment zone, an area of high biological productivity.

The entrapment zone is an important biological habitat for specific aquatic species because it creates a region where suspended nutrients tend to accumulate, as do phytoplankton, zooplankton, and the eggs and larvae of many fish. When the entrapment zone is located in the warm, shallow waters of Suisun Bay, it appears that food chain dynamics are most favorable. When the entrapment zone is located inland in the narrow river channels with colder water and decreased residence time, ecosystem productivity is diminished (California State Lands Commission 1991).

During high Delta outflows, X2 can be located near Suisun Bay; with low Delta outflows, X2 can be located in the western Delta, sometimes as far upstream as Jersey Point. The tide can move the position of X2 from 3 to 10 kilometers each day (California State Lands Commission 1991).

	95%	90%	75%	50%	25%	10%	5%
January	21,452	17,906	4,301	-985	-2,844	-4,783	-4,904
February	40,171	35,186	12,292	2,180	-472	-3,287	-3,634
March	36,355	25,580	12,621	564	-1,256	-2,533	-2,872
April	26,262	17,280	2,912	1,000	415	265	106
May	13,403	6,895	2,069	908	-242	-503	-591
June	11,968	4,191	2,342	153	-844	-984	-1,070
July	3,421	1,346	-502	-2,213	-4,770	-5,017	-5,129
August	40	-298	-607	-2,272	-3,717	-4,540	-4,654
September	171	-140	-199	-1,588	-2,692	-3,038	-3,141
October	4,371	3,170	1,318	-454	-2,073	-2,185	-2,263
November	7,858	2,552	-197	-1,727	-3,229	-3,737	-3,898
December	22,300	10,488	-821	-3,141	-4,417	-4,547	-4,630
Overall	22,090	11,156	1,566	-416	-2,350	-3,996	-4,656

NOTE:

Averages are in cubic feet per second (cfs).

Table 4. Monthly Average Central Delta Outflow (in cfs)

The Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta defines requirements for maintaining X2 at Chipps Island and at Port Chicago.

Table 5 shows the distribution of computed X2 positions obtained from DWRSIM simulation for existing conditions. On a percentile basis, X2 varied from 50 kilometers (km) in February and March to 90 km in September, for the 5th and 95th percentiles, respectively. A minimum X2 of 42 km occurs in March 1983. Maximum X2 of 90 km occurs in August, September, and October in 1929, 1931, and 1933.

Salinity

A key factor in the health of the Delta is the relationship between salinity and the ecology of the estuary. During the dry season, saltwater from the Pacific Ocean moves landward within the Bay to the Delta; during the wet winter season, saltwater moves seaward, driven by the increased discharge of fresh water. Salinity also varies from year to year. A heavy winter will push salinity farther out to the Bay than a dry winter.

The distribution of salinity on the San Joaquin River at Jersey Point, on the Sacramento River at Emmaton, on Old River at Rock Slough, and at Clifton Court Forebay numbers are based on modeling of the Delta with existing Delta geometry, predicted 2020 demands, and an improved SWP and CVP pumping capacity of 10,300 cfs. Under existing conditions, the upper percentile range for Jersey Point, Rock Slough, and Clifton Court may be slightly lower.

Between winter and summer, salinity can vary by as much as 1,900 parts per million (ppm) at Jersey Point. Higher variation exists further downstream and closer to the Bay. For example, salinity at Benicia can range from 20,000 ppm in fall to 150 ppm in winter (1983). Upstream at Clifton Court, salinity varies by about 600 ppm, depending on year and month.

	95%	90%	75%	50%	25%	10%	5%
January	85.1	83.6	80.0	74.1	62.0	55.2	51.7
February	78.5	78.1	73.7	66.5	58.6	51.5	50.5
March	77.6	75.5	72.3	66.2	58.4	53.1	50.1
April	79.7	77.5	74.1	68.4	61.5	54.6	51.8
May	81.0	81.0	77.3	72.5	65.4	57.8	55.0
June	81.0	81.0	78.0	75.5	72.3	65.1	60.0
July	85.2	85.2	82.4	79.4	77.3	74.6	73.0
August	88.7	88.7	86.7	84.7	82.0	81.8	81.7
September	89.9	89.9	89.2	88.6	84.3	77.7	74.9
October	87.9	87.9	87.7	86.4	81.6	73.8	72.4
November	87.7	87.7	86.5	85.0	77.7	74.2	70.2
December	87.6	86.1	85.8	79.8	70.9	63.5	59.0

NOTE:

Averages are in Kilometers

Table 5. Average X2 Position

There is a much wider range of salinity at the San Joaquin River and Sacramento River locations. These two sites are closest to the seaward side of the Delta. Rock Slough and Clifton Court Forebay are further upstream from the Bay and are less affected by seawater intrusion.

Salinity varies much less in late winter and spring, when high runoff generated by precipitation and snowmelt pushes salinity seaward. Winter and spring salinity concentrations vary from around 90 to 400 ppm, depending on location and time of year.

Sacramento River Region

The Sacramento River Region contains the entire drainage area of the Sacramento River and its tributaries and extends almost 300 miles from Collinsville in the Sacramento-San Joaquin Delta north to the Oregon border. The total land area within the region is 26,960 square miles. Average annual precipitation is 36 inches, and average annual runoff is approximately 22.4 million acre-feet.

For the Sacramento River Region, the Sacramento, American, Feather, and Trinity rivers are described below. River sections most likely to be affected by the CALFED program include the Sacramento River below Lake Shasta, the Feather River below Oroville Lake, and the American River below Folsom Lake.

The discussion is further divided into the Sacramento River above Keswick, the Sacramento River from Keswick to the Feather River, and the Sacramento River from the Feather River to the Sacramento Delta.

HISTORICAL PERSPECTIVE

For more than 100 years the flows in the Sacramento River have been subject to some regulation as the result of construction and operation of storage facilities. By 1900, storage capacity on the Yuba River, a tributary of the Sacramento River, already exceeded 30,000 acre-feet.

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The Sacramento River region contributes the majority of Delta inflows. Combined historic, unimpaired flows from the major rivers of the Sacramento system (Sacramento, Feather, Yuba, and American rivers) averaged about 17 MAF and ranged from 5 MAF to 38 MAF during the 1969-1991 period. Of this, the Sacramento River (at Red Bluff) averaged 8 MAF (including Trinity River imports, described below), the Feather River averaged 4.3 MAF, the Yuba River averaged 2.3 MAF, and the American River averaged 2.6 MAF. Overall "excess" (unallocated) flows from the Sacramento River (including Trinity River diversions) at the Delta have averaged 5.4 MAF, and ranged from about 0.64 MAF to nearly 20 MAF.

Since 1900, numerous reservoirs have been constructed in or have affected this region. These include Shasta Lake, Lake Oroville, Clair Engle Lake, and Folsom Reservoir, as well as numerous smaller reservoirs. Total reservoir capacity in or affecting the Sacramento Region is approximately 15.25 MAF, or nearly one year of average system discharge. Historically, these reservoirs have been operated to provide agricultural and domestic water supplies, flood control capacity and, more recently, recreation and ecological flows.

Historic instream flow requirements for the Sacramento River below Shasta Dam have been about 2.9 MAF, and average pre-1980 diversions (these diversions were halted in 1980) have been about 1 MAF. Average Shasta Lake storage was about 2.8 MAF. Historic Feather River allocations have been about 0.87 MAF for instream flows and 0.79 MAF for diversions. Average annual carryover storage in Oroville Reservoir has been about 2.2 MAF. Historic Feather River allocations have been 0.23 MAF of instream flows, with direct water uses of about 0.43 MAF. Folsom Lake had an average annual carryover storage of 0.56 MAF. In 1962, Clair Engle Lake was constructed on the Trinity River, allowing water from that river to be diverted to the Sacramento River system via the Clear Creek Tunnel Diversion. An average of about 1.3 MAF of runoff occurs in the Trinity River watershed, with a range of 0.2 to 3 MAF. An average of about 1 MAF has been diverted annually from Trinity River to the Sacramento River (1962 through 1991).

The population of Sierra foothill upper watershed areas boomed in the mid-late 1800s, then declined but over the past 20 years has once again increased dramatically, increasing water demand for municipal use. Dams have been constructed on nearly every tributary to increase storage and operational flexibility. Many upper watershed streams contain multiple reservoirs that control flows, store water, produce power, and provide recreation.

CURRENT RESOURCES

The two major tributaries to the Sacramento River along its lower reach are the Feather River (which also includes flows from the Yuba River) and the American River. The combined flows of the Feather River and Sutter Bypass enter the river near Verona. The American River joins the Sacramento River north of downtown Sacramento. Smaller contributions are made by the Natomas Cross Canal, draining the area between the Bear River and American River drainages, and the Colusa Basin Drain, which drains the west side of the Sacramento Valley from about Willows south to Knights Landing.

Table 6 shows the volume of water contributed to the Sacramento River system by the Feather, American, and Sacramento rivers.

SACRAMENTO RIVER

The Sacramento River watershed upstream of Shasta Reservoir has an area of about 6,420 square miles. The Sacramento River watershed upstream of the Feather River is about 14,050 square miles. The average annual inflow to Shasta Reservoir is about 5.9 MAF, and the total runoff upstream of the Feather River is about 11 MAF; therefore, about half of the runoff is potentially controllable in Shasta Reservoir and the other half is runoff from the tributary streams. The tributary streams have very limited reservoir storage; therefore, the

Stream or River	USGS Station	USGS Station Location	Average Annual Volume (af)[a]	Water Years of Record
American River	11446500	Fair Oaks, CA	2,645,000	1905-1992
Sacramento River	11425500	Verona, CA	13,459,000	1930-1992
Sacramento River	11447650	Freeport, CA	16,677,000	1949-1992
Feather River	11425000	Nicholas, CA	5,844,000	1944-1983

NOTES:

[a] Volumes compiled from USGS data.

af = acre-feet.
USGS = U.S. Geological Survey.

Table 6. Volume of Water Contributed to the Sacramento River System by the Feather, American, and Sacramento Rivers

runoff follows the natural (unimpaired) pattern with some local diversions for irrigation in the downstream sections of the tributaries.

The monthly flows generally increase from November through March, with peak flows generally occurring in March. Snowmelt is not a dominant component of Shasta Lake inflow. Monthly flows decrease in April and May, and are less than 5,000 cfs from June through October. The flows in these summer and fall months are relatively constant (between 3,000 and 4,000 cfs) because the volcanic geology of the watershed provides a large groundwater component that sustains the streamflow.

Shasta Lake stores and releases flows of the Sacramento, Pit, and McCloud rivers. Shasta Dam is a 602-foot-high concrete gravity structure providing a storage capacity of approximately 4.5 MAF. Water can be released from Shasta Lake through the powerhouse, the low-level or high-level river outlet, or the spillway.

Keswick Reservoir, a 159-foot-high concrete gravity structure, is located 8 miles downstream of Shasta Lake. With a storage capacity of approximately 25 TAF, Keswick is a regulating reservoir for releases from the Spring Creek and Shasta Powerhouses. The storage and elevation in Keswick Reservoir are maintained by concurrent operation of the powerhouses. The Keswick Powerhouse has a capacity of approximately 16,000 cfs.

Whiskeytown Lake, located on Clear Creek, has a storage capacity of approximately 240 TAF. Although Whiskeytown Lake collects some natural inflow from Clear Creek (about 350 TAF), most of its inflow comes from Trinity River exports. Whiskeytown is operated with only limited seasonal storage fluctuations. Releases to Clear Creek of about 100 TAF per year provide instream flows and some downstream diversions. Some water supply diversions are made directly from Whiskeytown Lake. Most Trinity River exports and Clear Creek inflows are diverted through the Spring Creek tunnel and Powerhouse to Keswick Lake.

The Red Bluff Diversion Dam (RBDD) is located on the Sacramento River just downstream of Red Bluff. Diversions are made to the Tehama-Colusa Canal and Corning Canal, with a maximum annual diversion of about 600 TAF. Several smaller diversions occur between Keswick and Red Bluff. The RBDD gates are allowed to be closed only from May 15 through September 15 because of concerns for winter-run chinook salmon passage; therefore, the diversions are limited to the pumping capacity of about 150 cfs at the beginning and end of the irrigation season. Some water for the Tehama-Colusa Canal is obtained from Stony Creek

(Black Butte Reservoir) when excess water is available.

The major diversion downstream of Red Bluff is the Glenn-Colusa Irrigation District (GCID), located downstream of Hamilton City, with an annual diversion of about 800 TAF. Several additional diversions along the Sacramento River result in a combined annual diversion of about 1.85 MAF, and the estimated annual diversions for the entire Sacramento River basin above the Feather River mouth is estimated at about 3.25 MAF. The water allocation estimates for 1945 to 1991 are considerably lower (maximum of about 2 MAF).

Maximum storage each year occurs in April or May, following the months with highest runoff. The maximum flood control storage level is reduced in wet years to provide greater flood control storage space. Shasta Lake monthly storage usually decreases from May through September, and usually increases from January through April. Because Shasta Lake has a relatively small maximum storage capacity during the winter flood control season, much of the winter storm runoff cannot be captured in Shasta Lake.

The Sacramento River early spring runoff must be stored for summer irrigation diversions and releases for Delta outflow and exports. The seasonal storage and subsequent releases from Shasta Lake average about 1.5 MAF. The average annual inflow for 1967 to 1991 was 6 MAF. Shasta Reservoir also provides some year-to-year carryover storage in drought periods. The lowest carryover storage of 630 TAF occurred in 1977.

Regulated Flows and Diversions

Minimum stream flows for the Sacramento River below Keswick Dam are assumed, based on the 1993 Biological Opinion for winter-run chinook salmon, at 3,250 cfs. Sacramento River navigation control point (NCP) flows are a maximum of 5,000 cfs.

Releases from Keswick Lake originate from Shasta Lake releases and Spring Creek releases from Whiskeytown. Keswick releases are made for downstream uses, including diversions along the Sacramento River; minimum required flows at the NCP; and Delta uses for outflow, diversions, and exports. Some Keswick releases result from flood control operations when the monthly maximum Shasta and Clair Engle Reservoir storage capacities are exceeded.

Although instream flow requirements exist at Keswick, they are generally less than 5,000 cfs (monthly volume of about 300 TAF) and do not often control releases from Keswick. Additional releases for temperature control in the Sacramento River between Keswick and Red Bluff have been made since 1991 in summer and fall months. The regulated Keswick releases are much higher than unimpaired flows during the summer irrigation season.

The seasonal water management operations for downstream diversions and Delta requirements are clearly evident in the monthly release patterns (May through September).

Water Management Allocation

The average Shasta inflow for 1945 to 1991 was about 5.9 MAF. The average Shasta carryover storage was 2.8 MAF. The average annual storage diversion was 1.4 MAF (about 25% of the Shasta inflow). The average annual storage release was also about 1.4 MAF, of which an average of about 350 TAF were carryover storage releases and the remaining 1 MAF were seasonal storage releases.

The water allocation for the Sacramento River Basin upstream of the Feather River has satisfied instream flow requirements at Keswick and the NCP, as well as supplied diversions for water supply along the Sacramento River. Additional releases from Shasta have been made to satisfy Delta outflow requirements and provide water for CVP exports at the Tracy Pumping Plant.

Diversions along the Sacramento River are somewhat difficult to estimate because direct measurements of all diversions are not available. A combination of streamflow measurements and diversion measurements have been used. The current annual estimate, used in DWRSIM for the No-Action Alternative, is about 3.25 MAF. The flow requirements at the NCP can be approximated as 5,000 cfs in most years, with 4,000 cfs required in dry years and 3,500 cfs required in critical years; therefore, the allocation of Sacramento River runoff and Trinity River exports for instream uses and for water supply diversion uses can be calculated and summarized.

When monthly runoff exceeds the monthly requirements for instream flow and export, the excess inflow is stored in the reservoir (if storage space is available) for subsequent use. When the runoff is less than the monthly requirements for instream flow and export, the Shasta or Clair Engle Reservoir storage is reduced to supply the necessary water. This is the essence of water management on the Sacramento River and is the general water allocation procedure used for all tributary basins.

The maximum monthly storage for flood control purposes is shown to indicate the available storage space in Shasta Reservoir. Excess runoff occurs frequently because the available storage in Shasta is relatively small relative to the runoff. Storage releases often are made during summer to supply downstream diversions, Delta outflow, or Delta exports.

Hydraulic Conditions

Sacramento River above Keswick

The drainage area of the watershed above Keswick, excluding the Goose Lake Basin, includes the basins of the upper Sacramento, over the McCloud, and over the Pit River, as well as two smaller tributaries, Squaw Creek and Backbone Creek. Average annual precipitation varies from 60 to 70 inches over most of the watershed.

Most flow in the Sacramento River at Keswick is from Shasta Dam, which began operations in December 1943 (USGS 1994a, 1994b). Shasta Dam was retrofitted with a temperature control device in 1997. The retrofit was installed by the Reclamation in response to the CVPIA and is designed to correct a design flaw in the dam that prevented release of deep, cold water from Shasta Lake. The temperature control device allows the temperature of water in the Sacramento River to be regulated for the benefit of migrating fish.

Keswick Reservoir is used to regulate flows into the Sacramento River. About 1.3 MAF of water are diverted annually from Whiskeytown Lake to Keswick Reservoir, which represents about 17% of the flows measured in the Sacramento River at Keswick. The Spring Creek flow to Keswick Reservoir contains heavy metal contamination from mine drainage, and releases from Spring Creek Debris Dam are metered to achieve water quality objectives in the Sacramento River below Keswick Dam by dilution.

Sacramento River: Keswick to the Feather River at Verona

Average annual precipitation in the central Sacramento basin ranges from 15 to 20 inches per year; average annual precipitation ranges up to 60 inches per year in the northern portion of the basin. Between Keswick Reservoir and the confluence with the Feather River at Verona, the Sacramento River receives inflows from more than 31 tributary streams, with more than 50 established diversions. As a result, there are many opportunities for flows in the river to be modified by local inflows and outflows. The character of the river also changes as the valley floor flattens. The gauge elevation below Keswick Dam is about 480 feet above mean sea level (MSL). At the Bend Bridge gauge near Red Bluff, the gauge elevation is about 286 feet above MSL, a drop of nearly 200 feet in about 40 miles. Between Bend Bridge and the gaging station at Butte City, the elevation drops another 200 feet in about 80 miles. Within this reach, the river increasingly meanders. Between Butte City and the confluence with the Feather River, the elevation drops about 60 feet over about 55 miles.

Historical topographic maps show that the river has frequently changed its course within a roughly mile-wide meander zone, cutting across old meanders and creating new ones. Below Chico Landing (at Big Chico Creek) the floodplain of the Sacramento River is increasingly constrained by levees. Below Colusa, levees constrain the river to a channel that is typically less than 500 feet wide.

Starting near Butte City, flood flows are diverted to flood bypasses outside the main channel by means of weirs. The flood bypasses allow extreme flows to be diverted and temporarily stored in portions of the floodplain set aside for this purpose. The USGS identifies four flood flow control points between Stony Creek and the Feather River. These control points are an unnamed weir upstream of Butte City, Moulton Weir, Colusa Weir, and Tisdale Weir. The unnamed weir overflows when flow in the Sacramento River exceeds 90,000 cfs; 30,000 cfs. The overflow is directed into Butte Sink and Sutter Bypass. The Tisdale Weir discharges to Sutter Bypass through the Tisdale Bypass when flows in the Sacramento River exceed 23,000 cfs. Butte Creek discharges to the Sacramento River between Colusa Weir and Tisdale Bypass. During periods of high flow in the Sacramento River, water from Butte Creek may go to Butte Slough, instead of to the river, ultimately reaching the Sutter Bypass. These controls place an upper limit on the flows in the main channel.

Sacramento River from the Feather River Confluence to the Sacramento Delta

The drainage area of the Sacramento River above Sacramento, 11 miles to the north, is 23,502 square miles. Average annual precipitation over this reach of the Sacramento River ranges from 8 to 19 inches.

The historical average annual flow is 16.7 MAF at Freeport, which is more than twice the average annual flow measured in the Sacramento River above the confluence with the Feather River. The maximum mean monthly discharge measured for the period of record was 71,340 cfs (March 1986); the minimum mean monthly discharge was 4,494 cfs (October 1977).

The flow data for this station do not account for the upstream flood overflows that bypass the Sacramento River, such as flows into the Colusa Basin, Sutter Basin, Sutter Bypass, and Yolo Bypass. Flood flows from the Sacramento River, Feather River, and Sutter Bypass are directed away from the Sacramento area by spilling over the Fremont Weir at Verona into the Yolo Bypass. Overflows occur at this point when Sacramento River flows, as measured at Verona exceed 55,000 cfs. Sacramento River overflows also may enter the Yolo Bypass just north of Sacramento by spilling over the Sacramento Weir.

The two major tributaries to the lower reach of the Sacramento River are the Feather River (which also includes flows from the Yuba River) and the American River. The combined flows of the Feather River and Sutter Bypass enter the Sacramento River near Verona. The American River joins the Sacramento River north of Sacramento. Smaller contributions are made by the Natomas Cross Canal, draining the area from the Feather River east to Auburn and Roseville, and the Colusa Basin Drain, draining the west side of the Sacramento Valley from about Willows south to Knights Landing.

The greatest ranges in flows occur from November through March and April. The average flows hover within a relatively narrow range over the entire year. However, the height of the bars above the averages from November through March and April reflects the fact that extremely high flows are relatively uncommon. The increase in average flows and narrower range of flows during the summer reflects releases from storage to meet the relatively high and constant demand during this period. Average summer flows are comparable to average winter flows in the upper reaches of the Sacramento River and tributaries.

Although the maximum flows generally increase downstream, the patterns in these two graphs are similar to the pattern for Keswick.

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The minimum and average flows at Bend Bridge are nearly the same as at Keswick, while they increase by 25 to 50% during the wet season between Bend Bridge and Colusa. Average wet season flows begin to exceed average dry season flows in the Sacramento River below Bend Bridge.

Although average flows are significantly higher at Freeport than at Wilkins Slough, reflecting the contributions of the Feather River and American River, maximum (simulated) flows during the peak winter months of January and February are actually higher at Wilkins Slough than at Freeport. This is due to diversion of flood flows into the Yolo Bypass and to operation of Oroville Dam for flood control.

FEATHER RIVER

The Feather River contributes a substantial amount of high-quality water to the Sacramento River. Originating in the volcanic formations of the Sierra Nevada, the Feather River flows southwest to Lake Oroville and is joined by two major tributaries: the Yuba and Bear rivers. The Yuba River joins the Feather River at the City of Marysville; the confluence with the Bear River is approximately 15 miles downstream of Marysville.

The average flow of the Feather River at Oroville is about 5,800 cfs. The monthly flows indicate that both rainfall and snowmelt contribute to the natural runoff that is greater than 2,000 cfs (80% exceedance) from January through June. The summer flows are well sustained at about 1,000 cfs (80% exceedance) because of snowmelt and groundwater (springs) from the high-elevation watersheds. Upstream reservoirs (Lake Almanor) contribute some seasonal storage that reduces runoff in spring and increases flows in summer and fall. The average annual inflow to Oroville is simulated to be about 4.0 MAF, slightly less than the unimpaired inflow of 4.3 MAF because of several small upstream diversions.

The Yuba River drains a watershed of about 1,350 square miles of the western slope of the Sierra Nevada and is the major tributary to the Feather River. The average annual unimpaired flow is about 2.25 MAF. Several reservoirs have been constructed within the watershed. Englebright Dam, the lowermost dam, was completed in 1941. The major storage reservoir is New Bullards Bar on the North Fork, with a storage capacity of about 1 MAF and a watershed area of 490 square miles. More than 15 other reservoirs have a combined storage capacity of 400 TAF. A major portion of the Yuba watershed is unregulated, however, and very high flows are released from Englebright during major storms. The Bear River is almost completely regulated and diverted for uses, except during very wet years. The average annual unimpaired inflow is about 300 TAF.

Lake Oroville has a storage capacity of approximately 3.5 MAF. Completed in 1968, the lake functions as the major storage facility for the SWP. The Hyatt Powerhouse intake is at an elevation of 615 feet; the 13 temperature control panels, or shutters, can raise the sill elevation in 19-foot increments, from a minimum elevation of approximately 615 feet to a maximum elevation of approximately 860 feet. These panels are operated to reserve cool water for later in summer. Panels are raised to lower the effective elevation of the powerhouse outlet and lower the release temperature.

From Lake Oroville, the river flows south to the Thermalito Diversion Pool (16 TAF volume), where it can be pumped back into Lake Oroville, released down the Feather River, or diverted to the Thermalito Forebay (10 TAF volume) and Afterbay (71 TAF volume) reservoirs. A pump-back powerhouse connects these two storage pools. Releases to the Feather River below the diversion pool are regulated by instream flow requirements. The Feather River hatchery is located below the diversion pool. Most of the diverted water is returned to the Feather River downstream through Thermalito Afterbay releases, while some water is diverted from the Thermalito Afterbay to various canals.

Highest storage at Oroville is achieved in the early summer months following spring runoff from snowmelt. The average annual change in storage has been approximately 1 MAF, with an average carryover storage of 2.2 MAF. Carryover storage was less than 1 MAF in 1977 and 1990. Because extremely low reservoir storage in late summer and fall may have a large effect on release temperatures, both California Department of Fish and Game (DFG) and the Anadromous Fish Restoration Program (AFRP) recommend a minimum carryover storage of 1.5 MAF.

Regulated Flows and Diversions

Minimum flows in the lower Feather River are established by a 1983 agreement between the DFG and DWR. The major provisions include minimum flow standards between October and march for preservation of salmon spawning and rearing habitat, as well as stream flow reduction limits to prevent salmon redds from drying out (DWR 1994a).

Current streamflow requirements are 1,700 cfs below Thermalito Afterbay from October to March and 1,000 cfs from April to September (some reductions are allowed in dry years). A maximum of 2,500 cfs are maintained in October and November to prevent spawning in overbank areas that might become dewatered.

Substantial irrigation diversions from Thermalito Afterbay historically were diverted from the Feather River in the vicinity of Oroville. These diversions now occur from the Thermalito complex. The maximum monthly diversions from Thermalito for 1971 to 1991 of about 2,500 cfs (150 TAF) are made in the May to August irrigation season. The total annual Thermalito diversions are slightly less than 1 MAF.

Releases of 600 cfs are made year-round into the "low-flow" section of the Feather River, providing ideal holding, spawning, and rearing habitat for spring-run and fall-run salmon and steelhead. Releases from Thermalito Afterbay to the Feather River are generally much warmer than releases from Oroville directly into the 8-mile-long "low-flow" section. Current streamflow requirements are 1,700 cfs below Thermalito Afterbay from October to March and 1,000 cfs from April to September (some reductions are allowed in dry years). A maximum of 2,500 cfs are maintained in October and November to prevent spawning in overbank areas that might become dewatered.

The average flow near Gridley is about 4,400 cfs, suggesting that an average of about 1,400 cfs are diverted or evaporated upstream of Gridley (compared with unimpaired flow).

Water Management Allocation

The water allocation for the Feather River has satisfied instream flow requirements at Gridley, as well as supplied diversions for water supply at Thermalito and along the Feather River. Additional releases from Oroville have been made to satisfy Delta outflow requirements and provide water for SWP exports at the Banks Pumping Plant.

Diversions from Thermalito have been measured with an average annual diversion of about 800 TAF for 1969 to 1991. Many smaller diversions along the Feather River have not been measured. The flow requirements at Gridley can be approximated as ranging from 600 TAF in dry years to about 1 MAF in wet years; therefore, the allocation of Feather River runoff for instream flow and measured water supply diversion uses can be calculated to range from about 1.1 MAF to about 1.9 MAF.

The maximum monthly Lake Oroville Reservoir storage for flood control purposes is shown to indicate the available storage space in Lake Oroville Reservoir. Excess runoff occurs frequently because the available storage in Lake Oroville is relatively small relative to the runoff. When downstream uses are greater than inflow, Lake Oroville storage releases are used to supply downstream beneficial uses. When Oroville flows are greater than downstream uses, some of the inflow is stored in Lake Oroville (if storage space is available).

The average Oroville inflow was about 4.3 MAF. An additional 2 MAF of runoff originate from the Yuba and Bear Rivers. The average Oroville carryover storage was

2.3 MAF. The average annual storage diversion was 1 MAF (about 25% of the Oroville inflow). The average annual storage release was also about 1 MAF, of which an average of about 250 TAF were carryover storage releases and the remaining 750 TAF were seasonal storage releases. An average of 40% of the Oroville inflow is used for beneficial uses. Additional diversions and Delta outflow requirements are satisfied with Feather River flows downstream of the Yuba River.

Hydraulic Conditions

The Feather River drains a large portion of the east side of the Sacramento Valley and is a major contributor to Sacramento River flows, typically contributing about 25% of Sacramento River flows as measured at Freeport. Its upper watershed consists of the West Branch and the North, Middle, and South forks. Average annual precipitation over the drainage area ranges from 80 inches in the upper watershed to 15 inches near the mouth.

Oroville Dam is operated in part to control downstream flooding. Prior to construction of the dam, the maximum instantaneous flow in the Feather River below the dam was 230,000 cfs (March 19, 1907). From 1969 to the present, following the construction of Oroville, the maximum instantaneous flow was 153,800 cfs (February 18, 1986). The maximum mean monthly flow in the Feather River near Gridley was 37,860 cfs (January 1970). The minimum mean monthly flow was 804 cfs (April 1991).

YUBA RIVER

The Yuba River, with a watershed of 1,339 square miles, is the largest tributary of the Feather River and contributes more than 40% of the flow at Oroville. The median unimpaired runoff was 2.1 MAF, with a range of 0.4 to 4.9 MAF. The unimpaired average monthly flow peaked in May. Under current operations, the peak average monthly flow occurs in February.

The major diversions from the Yuba River are made at or near Daguerre Dam by six water districts from three diversions. Several small unscreened diversions are downstream of Daguerre. Although an average of about 600 cfs is diverted (a maximum of 1,000 cfs during summer months), the summer through fall flows at Marysville (July to October) are generally higher than unimpaired summer flows. The annual average diversions from the Yuba River are about 500 TAF. There are minimum flows below Engelbright Reservoir, but no required flows below Daguerre Dam or at Marysville.

The major impoundment on the river is New Bullards Bar Reservoir (1 MAF), operated by the Yuba County Water Agency (YCWA). Other reservoirs in the watershed include Lake Spaulding, Bowman Lake, Jackson Meadows Reservoir, Englebright Reservoir, Scott's Flat Reservoir, and Lake Fordyce. Total storage capacity in these impoundments is over 475 TAF.

Most of the 70 TAF of water from Englebright Reservoir, the lowermost dam on the river, is released through the Narrows 1 and 2 powerhouses for hydroelectric power generation. The river between the dam and the powerhouses (0.2 mile) is dewatered unless the reservoir is spilling. The major diversion point on the Yuba River is Daguerre Point Dam, 12.5 miles downstream of Narrows Dam.

BEAR RIVER

The Bear River, the second largest tributary to the Feather River, has a median unimpaired runoff of 272 TAF with a range of 20 to 74 TAF. Peak mean monthly unimpaired (from 1922 to 1991) flows occur in February. Current (from 1967 to 1991) actual peak mean monthly flows also peak in February and March.

The largest impoundment in the Bear River watershed is Camp Far West Reservoir, with a storage capacity of 104 TAF and operated by the South Sutter Water District (SSWD). Other small impoundments include Rollins Reservoir and Lake Combie, which store an additional 70 TAF. Approximately 11 Pacific Gas and

Electric Company (PGandE) power plants with their forebays and afterbays also regulate Bear River flows.

As part of the hydroelectric project operations in the Bear River, water is exchanged with the Yuba River and American River basins. Water from the South Fork Yuba River is conveyed by the Drum Canal into the Drum Forebay on the Bear River. The average annual flow through the Drum Canal for the period from 1965 to 1992 was over 367 TAF. Water from the North Fork of the American River, diverted through Lake Valley Canal, also flows into the Drum Forebay. From 1965 to 1992, the average annual flow through the Lake Valley Canal was 11,530 acre-feet.

From the Drum Forebay, water is diverted to two places. The first is Canyon Creek, where the water either supplies the Alta Powerhouse or flows back into the American River. Portions of the Alta Powerhouse discharge may be diverted to the Bear River. The second diversion from the Drum Forebay is to Drum Powerhouses 1 and 2. All discharge from these power plants flows into the Bear River.

Flows in the Bear River watershed are almost totally regulated by several storage and diversion facilities. Required fish releases downstream from Camp Far West storage reservoir and South Sutter Irrigation District (SSID) diversion dam into Bear River are 25 cfs from April to June and 10 cfs the remainder of the year.

Based on 1992 data, it is estimated that more than 90% of the inflow from the Drum and Lake Valley canals is diverted to Drum Powerhouses 1 and 2 and into the Bear River. The remainder is diverted to the American River or Alta Powerhouse.

AMERICAN RIVER

The American River is a major tributary of the Sacramento River, entering just north of Sacramento. The American River drains a watershed of about 1,900 square miles that covers the western Sierra Nevada and foothills with three major branches: the South Fork, Middle Fork, and North Fork. Maximum elevations are about 10,000 feet, and a substantial portion of the runoff results from snowmelt.

During low-runoff years (70% exceedance), the historical inflows are almost uniform, with monthly flows of about 100 to 200 TAF throughout the year.

Development began during the Gold Rush with numerous diversions and small impoundments. Thirteen major reservoirs now have a total storage capacity of about 2 MAF. Folsom Lake was constructed in 1956 and is the largest reservoir on the American River, with a storage capacity of about 1 MAF. Nimbus Dam, a regulating reservoir constructed downstream of Folsom Dam and about 23 miles upstream of the mouth, is the upstream migration barrier for salmon and steelhead, and provides diversions to the Folsom South Canal. The Nimbus hatchery, located just below Nimbus Dam, was constructed as mitigation for the effects of Folsom and Nimbus dams that eliminated upstream salmon and steelhead spawning and rearing habitat.

Diversions are made from Folsom Lake, from the Folsom South Canal, and from the lower American River (Carmichael and Sacramento City water treatment plants). Measurements of these diversions are not available. Based on the No-Action Alternative (with current hydrology and demands), the diversions from Folsom Reservoir are about 210 TAF. Annual diversions from Folsom South Canal are about 70 TAF and lower American River diversions are about 120 TAF. Total American River diversions are therefore about 400 TAF but are expected to increase in the future.

Folsom Lake storage capacity is approximately 975 TAF, and the normal annual drawdown is approximately 500 TAF. The required flood control storage is dependent on upstream storage. Additional flood control space has been provided in recent years to increase flood protection along the American River.

Regulated Flows and Diversions

Because releases from Folsom are made in summer to supply CVP exports from the Delta and maintain sufficient Delta outflow to satisfy water quality objectives, summer and fall streamflows in the Lower American River are much higher inflows than unimpaired flows would have been. Because diversions are primarily located downstream, the Lower American River is used as the natural conveyance for the majority of Folsom releases. The average historical flow is about the same as the average unimpaired flow.

Diversion data could not be found for the American River. The seasonal pattern is governed by the municipal water supply uses along the American River. The two largest diversions are the San Juan Water District located in Folsom Reservoir and the City of Sacramento Fairbairn treatment plant located about 7 miles upstream of the mouth of the American River.

Instream flow requirements were established in the SWRCB D-893: 500 cfs during the fall spawning season (September 15 through December 15), with 250 cfs for the remainder of the year (annual allocation of about 225 TAF). Only during extreme droughts have American River flows been this low. DFG has determined that these flows are insufficient to maintain anadromous fishery resources in good condition. SWRCB D-1400, following hearings from the proposed Auburn Dam, specified higher releases from Nimbus should the Auburn Dam be constructed. D-1400 flows are 1,250 from October 15 to July 15, with 800 cfs for the remainder of the year (annual allocation of about 825 TAF). A 1990 court order (Hodge Decision) specified American River streamflow conditions that must be satisfied before allowing EBMUD to divert any water from the Folsom South Canal, which diverts water from Nimbus Dam. The court-required flows for EBMUD diversions are 2,000 cfs from October 15 through February 28, 3,000 cfs from March 1 through June 30, and 1,750 cfs between July 1 and October 14.

Current operations use a relationship between storage and projected inflow to determine instream flow requirements. At relatively high storage and projected inflow values, instream flow requirements are set at the maximum AFRP monthly targets. As storage and projected inflow decreases, the instream flow requirements are reduced. This provides an adaptive balance between available water and instream flow benefits. The maximum specified instream flows are 2,500 cfs for July through February, with 4,500 specified from March through June. The maximum instream flow use is therefore about 2.3 MAF; however, the average instream flow allocation is about 1.5 MAF.

The summer flows downstream of Nimbus are much higher than inflows or unimpaired flows because reservoir releases are being made to supply downstream uses for instream flow and Delta exports, and Delta outflow.

Water Management Allocation

The water allocation for the American River has satisfied instream flow requirements at Nimbus, as well as supplied diversions for water supply from Folsom Reservoir, Folsom South Canal, and along the American River. Additional releases from Folsom have been made to satisfy Delta outflow requirements and provide water for CVP exports at the Tracy Pumping Plant.

The average Folsom inflow was about 2.6 MAF. The average Folsom carryover storage was 560 TAF. The average annual storage increase was 460 TAF (about 18% of the Folsom inflow). The average annual storage release was also about 460 TAF, of which an average of about 80 TAF were carryover storage releases and the remaining 380 TAF were seasonal storage releases. An average of about 20% of the Folsom inflow was used for beneficial uses. Almost all the American River diversions and instream flow requirements have been satisfied without requiring Folsom Reservoir releases. Additional diversions and Delta outflow requirements are satisfied with American River flows and releases from Folsom storage.

Diversions from the American River are assumed to be approximately 400 TAF. The flow requirements at Nimbus have been relatively small, ranging from 225 to 825 TAF; therefore, the allocation of American River runoff for instream flow and estimated water supply diversion uses can be calculated to range from about 625 TAF to about 1.2 MAF.

The maximum monthly Folsom Reservoir storage for flood control purposes is shown to indicate the available storage space in Folsom Reservoir. Excess runoff occurs frequently because the available storage in Folsom is small relative to the runoff. When downstream uses are greater than inflow, Folsom storage releases are made to supply downstream beneficial uses. When Folsom inflows are greater than downstream uses, some inflow is stored in Folsom Lake. Often, however, the inflow cannot be stored because of the limited storage space during the flood control season.

Hydraulic Conditions

The American River drains approximately 1,895 square miles. Average annual precipitation in the American River watershed ranges from 17 inches near its confluence with the Sacramento River to nearly 65 inches in the headwaters. The American River flows have contributed approximately 15% to Sacramento River flows.

Folsom Lake is the primary regulating facility on the American River. The lake has a storage capacity of 1 MAF. Reclamation began operating the dam in February 1955 as an integrated component of the CVP. Just downstream of Folsom Dam is Nimbus Dam, which also began operating in 1955. Lake Natoma (formed by Nimbus Dam) acts as a re-regulating reservoir for diurnal fluctuations from Folsom Power Plant.

More than 19 other major reservoirs are situated within the upper American River watershed, with capacities ranging from approximately 1 to 270 TAF.

TRINITY RIVER

The Sacramento River Region essentially is bounded by the ridge tops of the Sacramento River watershed or hydrologic region. The Goose Lake watershed, in the northeast corner of California, is not included in the CALFED study area because it rarely contributes to the flow of the Pit and Sacramento rivers—apparently Goose Lake last spilled very briefly sometime in the 1950s and only a few times in between 1869 and the present—and no actions are proposed in the watershed. Although the Trinity River is connected by a pipeline to the Sacramento River system, the Trinity River does not flow naturally into the Sacramento River watershed, and no CALFED programs are being proposed for the Trinity River or its watershed.

The Trinity River watershed upstream of Lewiston has a drainage area of about 692 square miles. The average basin runoff of 1.2 MAF is therefore equivalent to about 36 inches per year.

Clair Engle Lake, completed by Reclamation in 1960, has a storage capacity of about 2.5 MAF.

Lewiston Lake creates an afterbay reservoir for the Trinity Powerhouse and serves to regulate releases from Clair Engle Lake.

The maximum storage in Clair Engle Lake currently is limited to 1.85 MAF at the end of October through the end of December, and increases to 1.9 MAF at the end of January, 2 MAF at the end of February, and 2.1 MAF at the end of March as required by the Division of Safety of Dams for maximum spillway capacity (to provide necessary flood regulation volume).

An annual drawdown of approximately 500 to 800 TAF usually occurs during summer and fall. For water-years 1967 to 1991, carryover (end of September) reservoir storage varied from a maximum of 2.16 MAF in 1983 to a minimum of 242 TAF in 1977, with an average carryover storage of 1.69 MAF.

DWRSIM Modeling Results for Existing Conditions

Nine locations were selected as the focal points for analyzing current hydraulic conditions in the Sacramento River Region (Figure 1). The locations were selected based on their proximity to principal hydraulic features in the region and include stations on both the Feather and American rivers.

The DWRSIM model was used to simulate monthly flows. Flow simulations illustrate how the current storage and conveyance facility configurations would respond to the 73-year record of hydrologic input data from water year 1922 through water year 1994. Hydraulic geometry equations were derived from recent USGS gaging station data. These equations were used to estimate the mean velocity, stream width, and mean depth corresponding to the simulated average monthly discharges at each study location.

The results of the flow simulations for existing conditions for February and September are presented in Table 7. The maximum, minimum, and average values of hydraulic parameters for February and September are shown in the table. February was selected to represent wet season flows because average flows are highest in that month. September represents dry season flows because average flows are lowest during that month.

The values shown in the table are estimates for comparison purposes. They depend on local stream channel geometry at the measurement points. It should also be noted that average velocities are calculated from the average monthly discharge divided by the cross-sectional area of the stream channel. Stream velocities at any point are greater in the center of the channel and lower at the margins and near the channel bottom due to friction. In addition, flow conditions may vary considerably over a month, particularly during the wet season.

Figure 2 shows the distribution of the simulated average monthly flows at Freeport using the 73-year hydrologic record. The Freeport station is used to represent the point at which the Sacramento River enters the Delta. In Figure 2, the heights of the bars correspond to the rate of discharge that is exceeded with the frequency shown in the table below. The exceedence frequencies are based on the percentile ranking of the discharge values for the month. The percentile is calculated by ranking the values from smallest to largest. Since DWRSIM calculates the average monthly discharge for each month of the 73-year simulation period, there are 73 discharge values associated with each month.

Water Quality

The discussion of current water quality conditions in the corresponding subsection in the preceding section under Delta Region: Existing Conditions also applies to the Sacramento River Region. Summaries of loadings of the major contaminants of concern are provided in the water quality supporting document.

Water Supply and Water Management

Total flows on the Sacramento River system above the Delta Region average approximately 19.9 MAF annually. Average total diversions are about 6.1 MAF.

Based on historical conditions, total average annual runoff in the Sacramento River Basin upstream of the Feather River is approximately 11 MAF, of which approximately 5.9 MAF per year on average flows into Shasta Reservoir. The average instream flow requirement on the Sacramento River, just upstream of the Feather River, is approximately 3.6 MAF. Average total diversions between Shasta Lake and the Feather River are about 3.2 MAF. The average historic unallocated flow on the Sacramento River above the confluence with the Feather River is about 4.2 MAF.

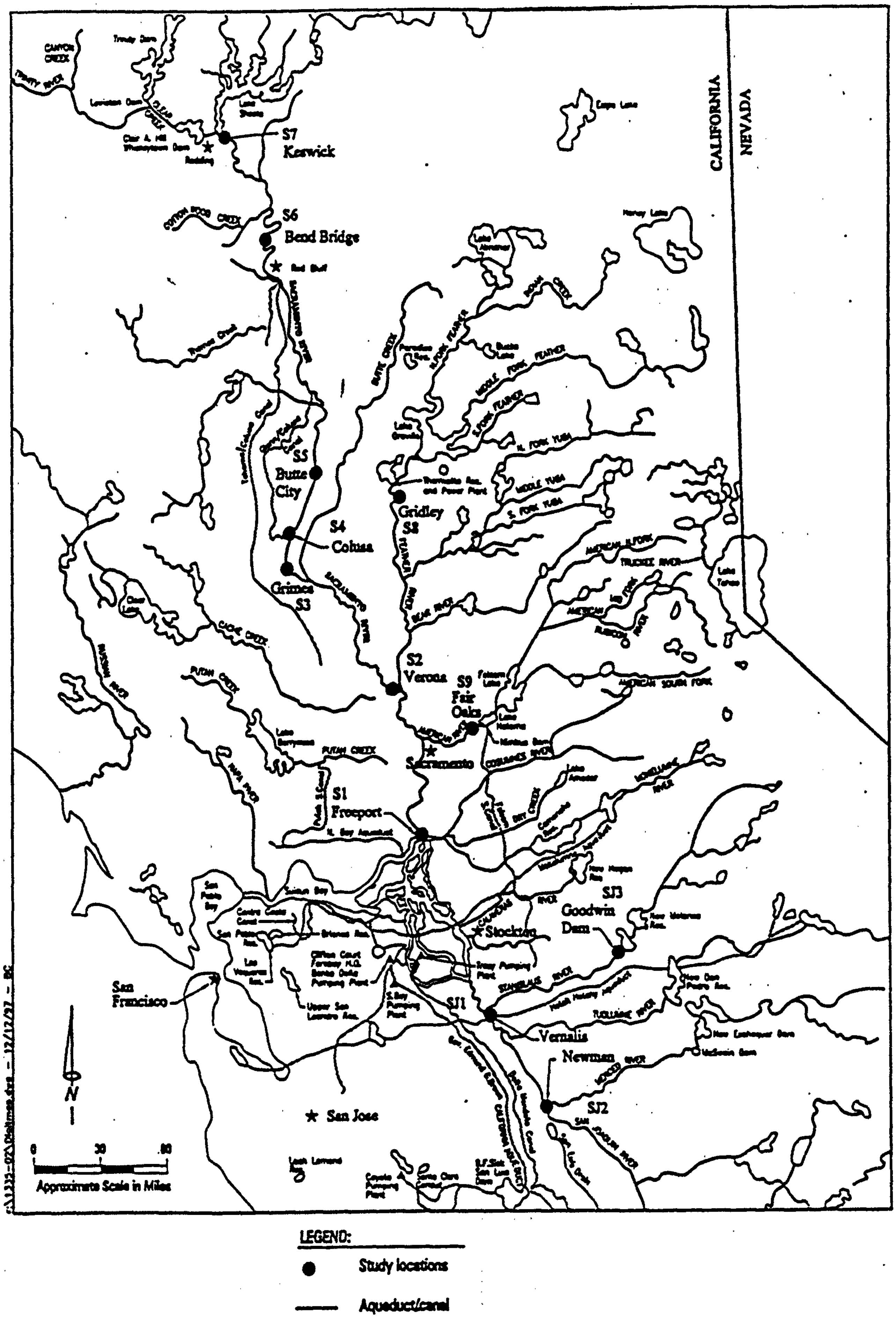
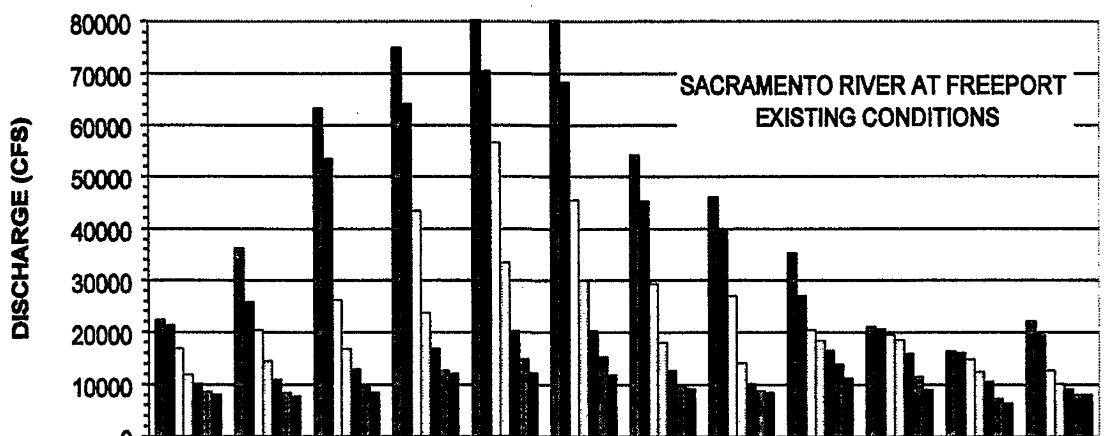


Figure 1. Key Locations Used in the Delta Hydrodynamics Analysis

FLOW CONDITIONS BASED ON 73-YEAR HYDROLOGIC RECORD	CP#137, GS4476.5, SAC. R @ FREEPORT	CP#61, GS4255, SAC. R. @ VERONA	CP#61, GS3905, SAC. R. BLW WILKINS SLOUGH NR. GRIMES	CP#120, GS3890, SAC. R. @ BUTTE CITY	CD#120, SAC. R. @ COLUSA	CD#73, SAC. R. ABV. BEND BRIDGE	CP#62, GS3705, SAC R. @ KESWICK	CP#9, GS 4465, AM. R. @ FAIR OAKS	CP#106, GS4071.5, FEA. R. NR. GRIDLEY
Location Map Station >	S1	S2	S3	S4	S5	S6	S7	S8	S9
FEBRUARY									
Discharge (cfs)									
Maximum	95090	107874	107874	78056	78056	53694	46186	33005	24884
Minimum	11632	3997	3997	4808	4808	3619	3241	504	900
Average	38605	25227	25227	20257	20257	13198	10966	5168	6194
Mean Velocity (fps)									
Maximum	4.26	4.48	5.81	6.13	4.86	6.24	7.25	6.04	4.24
Minimum	1.34	1.67	2.25	1.42	2.26	4.16	1.94	0.70	0.34
Average	2.60	3.02	3.82	3.02	3.35	5.06	3.63	2.32	1.84
Top Width (feet)									
Maximum	621	839	375	509	389	569	629	462	317
Minimum	564	460	213	459	269	335	429	260	275
Average	596	536	292	484	326	382	516	358	299
Mean Depth (feet)									
Maximum	36.2	30.6	49.7	25.5	40.1	14.7	10.1	12.2	9.9
Minimum	16.2	5.2	8.3	7.4	7.9	2.6	3.9	2.7	9.1
Average	25.6	15.5	22.6	14.0	18.5	7.0	5.8	6.3	9.3
SEPTEMBER									
Discharge (cfs)									
Maximum	27494	14638	14638	14621	14621	13327	13041	4790	6420
Minimum	7999	4437	4437	6016	6016	6117	6000	504	756
Average	12722	6689	6689	7630	7630	7159	6974	1865	1613
Mean Velocity (fps)									
Maximum	2.15	2.54	3.27	2.54	3.07	5.06	3.96	2.23	1.90
Minimum	1.09	1.73	2.32	1.59	2.40	4.50	2.66	0.70	0.29
Average	1.41	1.97	2.61	1.81	2.56	4.61	2.87	1.37	0.57
Top Width (feet)									
Maximum	587	512	266	478	312	382	530	354	299
Minimum	555	464	217	463	278	353	471	260	273
Average	567	480	233	467	286	359	482	311	282
Mean Depth (feet)									
Maximum	22.5	11.2	16.8	12.1	15.4	7.0	6.1	6.1	9.3
Minimum	14.0	5.5	8.8	8.2	9.1	3.8	4.7	2.7	9.1
Average	16.8	7.1	11.0	9.1	10.5	4.3	5.0	4.4	9.2

Table 7. Range of Existing Hydraulic Conditions at Selected Stations in the Sacramento River Region



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
5 percent	22200	36000	63200	74800	80000	80000	54000	45900	35000	20900	16200	21900
10 percent	21200	25700	53300	64000	70300	68200	45100	39400	26900	20400	15900	19100
25 percent	16700	20300	26200	43200	56500	45300	29200	26900	20300	19400	14700	12600
50 percent	11800	14400	16600	23500	33300	29800	17900	14100	18200	18300	12300	10100
75 percent	10100	10900	12800	16700	20100	20100	12600	10100	16300	15700	10500	9080
90 percent	8530	8330	9350	12600	14700	15100	9550	8700	13800	11400	7110	7980
95 percent	8010	7610	8380	12000	12100	11700	9070	8380	11100	9000	6310	7960

MONTH

Figure 2. Flow Frequencies, Sacramento River at Freeport, Existing Conditions

Combined Feather/Yuba/Bear River flows are about 6.3 MAF. Of these, about 2.5 MAF are diverted on these rivers. Instream flow requirements are about 0.85 MAF.

Annual inflows on the American River (at Folsom Reservoir) average about 2.6 MAF. Direct uses for instream flow requirements average 1.5 MAF, and diversions average about 0.4 MAF.

The most intensive runoff occurs in the upper watershed of the Sacramento River above Shasta Reservoir and on the rivers originating on the west slope of the Sierra Nevada. These watersheds produce an annual average of 1,000 to more than 2,000 acre-feet of runoff per square mile annually.

San Joaquin River Region

The San Joaquin River Region includes the Central Valley south of the watershed of the American River. It is generally drier than the Sacramento Valley, and flows into the Delta from the San Joaquin River are considerably lower than those into the Delta from the Sacramento River. The region is also subject to extreme variations in flow, as exemplified by flooding that occurred during January 1997.

The drainage area of the San Joaquin River above Vernalis is 13,356 square miles, including 2,100 square miles of drainage contributed by James Bypass. Inflows from the Merced (farthest upstream), Tuolumne, and Stanislaus rivers historically contribute over 60% of the flows in the San Joaquin River, as measured at Vernalis. Average annual precipitation in the lower reach of the river ranges from 10 to 12 inches per year.

HISTORICAL PERSPECTIVE

The USGS has operated a gaging station on the San Joaquin River near Vernalis (Station 11303500) since 1922, although complete records are available only back to 1930. The instantaneous maximum recorded at the station was 79,000 cfs, observed on December 9, 1950. The lowest daily mean flow was 19 cfs, on August 10, 1961. The maximum mean monthly discharge was 40,040 cfs (March), and the minimum mean monthly discharge was 804 cfs (April).

Historically, the major rivers of the San Joaquin system have contributed an average of about 5.5 MAF to Delta flows, with an annual range of from 1.1 to 15 MAF. Historic unimpaired flows on the Stanislaus, Tuolumne, Merced, and San Joaquin rivers averaged a total of 5.6 MAF. Numerous dams and diversions have been constructed on these rivers and other rivers in this system.

On the Stanislaus River, approximately 0.52 MAF have been diverted and 0.2 MAF have been allocated for instream flows. These total 64% of the river's average flows of 1.1 MAF. Prior to construction of the New Melones Reservoir in 1980, an average of 25% of these uses were supplied by reservoir releases. The Tuolumne River has average unimpaired flows of about 1.8 MAF. Over 2.5 MAF of storage capacity has been constructed on this river. Historical water allocations have been approximately 13% for instream flows and 58% for diversions. About 28% of historical water uses were supplied from reservoir releases. The Merced River has average unimpaired flows of about 1 MAF. Over 1 MAF of storage capacity has been constructed on this river. Historical water allocations have been approximately 4% for instream flows and 54% for diversions. About 40% of historical water uses were supplied from reservoir releases. The upper San Joaquin River has average unimpaired flows of about 1.7 MAF. Approximately 0.6 MAF of storage capacity has been constructed on this reach of the river. Historically, approximately 70% of the river's runoff has been diverted to the Friant-Kern and Madera canals, primarily for agricultural uses. About 20% of historical water uses were supplied from reservoir releases.

The upper watershed of the San Joaquin River Region has historically been less developed than that of the Sacramento Region, although the same general process of development has occurred, including mining, logging, housing construction, industrial development, and dam construction. As in the Sacramento River Region the upper watershed contains major parks and wilderness areas. Most development has occurred in the lower foothills, near or below the snow line.

Three locations have been selected to represent the range of hydraulic conditions in the San Joaquin River Region. The most important of these is the San Joaquin River at Vernalis because of its location near the Delta. The San Joaquin River at Newman was chosen to characterize the upstream portion of the river. The Stanislaus River below Goodwin Dam was also selected.

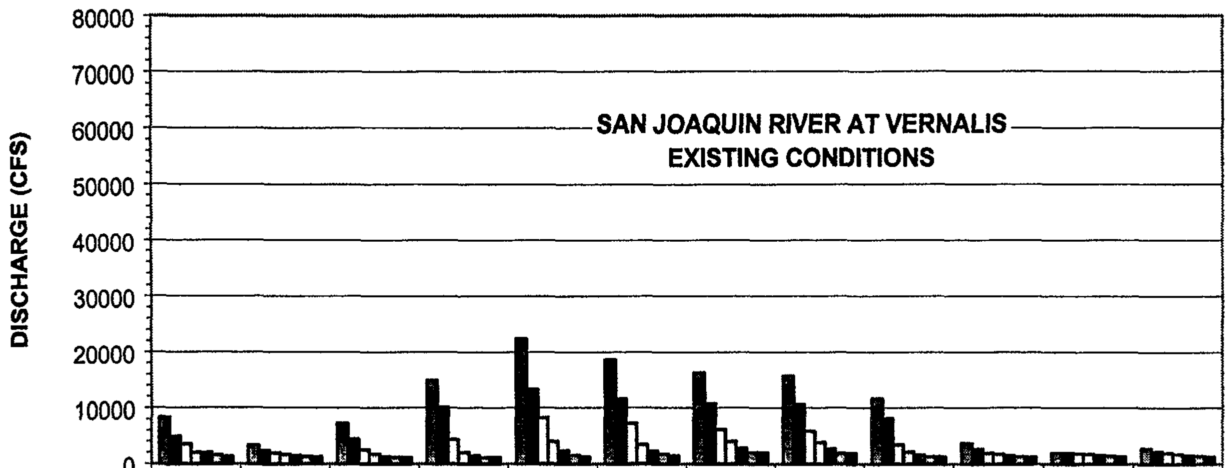
HYDRODYNAMICS AND HYDRAULICS

Table 8 presents the estimated range in discharge, average stream velocities, top width, and mean depth for February (high-flow period) and August (low-flow period).

Figure 3 shows the frequency distribution of flows for the San Joaquin River at Vernalis, the point at which the river flows into the Delta. The data are plotted at the same scale used to plot the data for Sacramento River stations to illustrate the relative contributions in flows to the Delta from each river. As described for Sacramento River stations, the results indicate that the average winter flows are skewed by infrequent elevated flows. The medians in the low flow months of July through November, are nearly the same and stay within a narrow range reflecting the effects of reservoir operations during these months.

FLOW CONDITIONS BASED ON 72-YEAR HYDROLOGIC RECORD	CP#682, GS3035, SAN. JOAQ. R @ VERNALIS	CP#695, GS2740, SAN. JOAQ. R. NR. NEWMAN	CP#675, GS3020, SAN. JOAQ. R. BLW. GOODWIN DAM, NEAR KNIGHTS LANDING
Location Map Station >	**SJ1**	**SJ2**	**SJ3**
FEBRUARY			
Discharge (cfs)			
Maximum	36534	21409	5078
Minimum	972	306	216
Average	6410	2917	738
Mean Velocity (fps)			
Maximum	3.17	3.64	4.27
Minimum	1.42	0.89	1.12
Average	2.15	1.88	2.01
Top Width (feet)			
Maximum	512	261	151
Minimum	247	140	88
Average	294	195	105
Mean Depth (feet)			
Maximum	20.8	25.4	7.9
Minimum	2.8	2.4	2.2
Average	9.7	8.4	3.5
AUGUST			
Discharge (cfs)			
Maximum	1919	683	960
Minimum	1106	342	732
Average	1626	520	878
Mean Velocity (fps)			
Maximum	1.65	1.16	2.27
Minimum	1.46	0.92	2.00
Average	1.59	1.06	2.18
Top Width (feet)			
Maximum	263	157	109
Minimum	250	142	105
Average	259	151	108
Mean Depth (feet)			
Maximum	4.3	3.8	3.9
Minimum	3.0	2.6	3.5
Average	3.9	3.3	3.7

Table 8. Range of Existing Hydraulic Conditions at Selected Stations in the San Joaquin River Region



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
5 percent	8330	3250	7220	14900	22400	18500	16200	15700	11600	3670	1890	2670
10 percent	4900	2330	4350	10100	13300	11500	10700	10600	8150	2650	1870	2200
25 percent	3550	1850	2520	4370	8260	7240	6200	5940	3430	1870	1810	1950
50 percent	2000	1630	1690	2020	4000	3420	3980	3820	2130	1680	1680	1700
75 percent	1920	1410	1320	1350	2290	2280	2810	2680	1560	1450	1500	1480
90 percent	1520	1290	1170	1150	1430	1670	1980	1890	1330	1310	1370	1360
95 percent	1330	1240	1140	1130	1260	1370	1980	1870	1300	1280	1290	1290

MONTH

Figure 3. *Flow Frequencies, San Joaquin River at Vernalis, Existing Conditions*

CURRENT RESOURCE CONDITIONS

Of the 5.5 MAF of unimpaired flows, a total of 3.5 MAF are diverted from the major rivers of the San Joaquin system. An average of about 3 MAF annually reaches Vernalis and contributes to Delta inflows.

Most of the inflow to the San Joaquin River region originates from the upper watershed tributary streams between the Mokelumne River and the San Joaquin River, on the west slope of the Sierra Nevada. Runoff intensity averages less than 1,000 AF/square mile in this region. For a detailed description of the upper watersheds of the San Joaquin River Region, see the supporting document for Surface Water Resources.

SAN JOAQUIN RIVER

The San Joaquin River flow, originating in the Sierra Nevada, is regulated by a series of small hydroelectric projects and Friant Dam which forms Millerton Lake. Millerton Lake was constructed by Reclamation in 1941. From Friant Dam, the Madera Canal conveys water north and the Friant-Kern Canal conveys water south to the Bakersfield area. These two canals divert most of the water entering Millerton Lake.

Friant Dam is the upstream barrier for anadromous fish in the San Joaquin River; however, because salmon migrating upstream past the Merced River are not able to successfully spawn and rear, a temporary fish barrier has been installed by DFG just upstream of the Merced River mouth since 1992.

Annual inflows on the upper San Joaquin River (at Millerton Reservoir) average about 1.67 MAF. An annual average of about 0.234 MAF are not diverted or otherwise allocated.

For 1949 to 1992, the average annual (unimpaired) runoff into Millerton Lake was about 1,730 TAF (2,390 cfs), with a range of 360 TAF (1977) to 4.6 MAF. Upstream reservoirs may affect Millerton Lake inflow; however, total annual inflow to Millerton is very similar to the unimpaired inflow.

Peak runoff caused by snowmelt occurs in May and June. Rainfall storms cause only moderate runoff from December through March. Late-summer and fall inflows are relatively low; the median flow is less than 100 TAF from September through February.

Several reservoirs upstream of Friant Dam have a combined storage capacity of about 600 TAF. Millerton Lake stores runoff from 1,638 square miles of the upper San Joaquin River and has a storage capacity of approximately 520 TAF. Because most of the water entering Millerton Lake is diverted through the Madera Canal and from the Friant-Kern Canals, river releases from Friant Dam are typically less than 150 cfs, although they may be much greater during storm events and when runoff is large enough to require spilling. Because most of the San Joaquin River flow is now diverted at Friant Dam, diversions for previous water users (exchange contractors) along the San Joaquin River are now supplied by water pumped at the Tracy Pumping Plant from the Delta into the Delta-Mendota Canal to the Mendota Pool.

Millerton Lake storage is typically drawn below 200 TAF in fall and median storage reaches a maximum of only about 400 TAF in summer.

The lake is relatively small and provides limited carryover storage benefits. Average carryover storage is 180 TAF. This carryover storage generally provides only small releases the following year. An average of about 25 TAF of carryover storage are used in the subsequent year, so the average use of seasonal storage is about 335 TAF (i.e., 360-25 TAF). Millerton Lake storage is needed to supply an average of about 20% (240 TAF) of the combined diversions from the Friant-Kern and Madera canals, which total about 1,210 TAF.

Maximum diversions generally peak in July with a median diversion of approximately 225 TAF. The Friant-Kern and Madera canals support the largest diversions in the upper San Joaquin River. Some of the water diverted by these canals during wet years is used for groundwater recharge. Annual diversion estimates range from about 200 TAF (in 1949) to more than 2,000 TAF in several years, with an average of about 1,200 TAF. These average diversions represent 70% of the average unimpaired inflow. The maximum diversion of 2,130 TAF represents about 123% of the average unimpaired runoff.

Below Friant Dam, the total downstream flow between 1949 and 1992 has averaged 508 TAF (700 cfs average), with the highest flows tending to occur in the earlier years because the Delta Mendota Canal was not completed until 1952. There are no instream flow requirements for the San Joaquin River between Friant Dam and the Merced River. Downstream riparian diversions at Gravelly Ford are estimated to require about 100 TAF. Since 1958, reservoir releases have been made in less than half of the years for flood control operations.

Average flows below Millerton Lake are skewed by the few years when high flows occurred as a result of reservoir spilling. For most years, release flows are quite low, with 70th percentile flows staying below 450 cfs. During the high-flow years, however, flows are much higher, with 90th percentile flows exceeding 6,900 cfs during the April peak. During the drier years, release flows peak during summer, whereas, during the wetter years, release flows peak in spring with the spring runoff.

Regulated Flows and Diversions

There are no instream flow requirements for the San Joaquin River between Friant Dam and the Merced River.

Water Management Allocation

The inflows are often greater than beneficial uses in winter and spring months, and Millerton Lake storage sometimes increases to the flood control capacity. During summer months, storage releases from Millerton are needed to supply diversions. Occasionally in fall and winter months, the releases are greater than the downstream uses. These releases are made for flood control or may be released downstream as water transfers. Water allocation has been approximately 70% of the runoff for Friant-Kern and Madera Canal diversions. About 20% of the upper San Joaquin River water uses were supplied from reservoir releases.

Hydraulic Conditions

The instantaneous maximum recorded on the San Joaquin River near Vernalis was 79,000 cfs, observed on December 9, 1950; the lowest daily mean flow was 19 cfs, on August 10, 1961. The maximum mean monthly discharge was 40,040 cfs (March), and the minimum mean monthly discharge was 804 cfs (April). Inflows from the Merced (farthest upstream), Tuolumne, and Stanislaus rivers contributed over 60% of the flows in the San Joaquin River, as measured at Vernalis.

The drainage area of the Merced River above Stevenson, near the San Joaquin River, is 1,273 square miles. A gaging station is located on the San Joaquin River near Newman (USGS Station No. 11274000), about 650 feet downstream from the confluence of the Merced River. The maximum mean monthly discharge measured at the Newman station from 1944 to 1994 was 24,170 cfs (March), and the minimum monthly mean was 25.2 cfs. The average monthly flow during the same period ranged from 481 cfs (August) to 2,841 cfs (March).

The drainage area of the Tuolumne River above Modesto is 1,884 square miles. Mean monthly discharge ranges from 331 cfs (August) to 1,852 cfs (March), as recorded at the Modesto gaging station.

The drainage area of the Stanislaus River above Ripon, near the San Joaquin River, is approximately 1,075 square miles. Stanislaus River flows account for approximately 22% of the San Joaquin River flows at Vernalis. Most of the water is from snowmelt, with the highest monthly flows occurring in May and June. The watershed above Goodwin Dam has an area of 986 square miles. The instantaneous maximum flow for the period of record was 40,200 cfs on December 24, 1964; the minimum daily mean flow was 0.12 cfs, recorded on February 8, 1975.

Three locations have been selected to represent the range of hydraulic conditions in the San Joaquin River Region. The most important of these is the San Joaquin River at Vernalis. Vernalis lies just inside the legal boundary of the Delta, but it is widely used as a monitoring point for Delta inflows and standards. The San Joaquin River at Newman was chosen to characterize the upstream portion of the river. The Stanislaus River below Goodwin Dam was selected to represent the basin margin.

Maximum flows remain significantly above the average at all three stations during May, June, and July. In fact, the maximum flows during these months at Vernalis are roughly equivalent to the maximum flows during this time on the Sacramento River at Colusa. August clearly represents the low-flow period at the San Joaquin stations, with flows just maintained above minimum flow requirements at Vernalis. Average April flows are maintained by pulse flow requirements at Vernalis. As in the Sacramento River Region, the highest average flows occur from January through March, but the magnitudes of the flows are roughly the same as the American River at Fair Oaks and the Feather River near Gridley during this period.

February represents the period of highest average flows and relatively high peak flows. August is the lowest flow period. Average stream velocities during February calculated for Vernalis, the lowest point in the San Joaquin River Region, span a range comparable to the stream velocities at the highest stations evaluated in the Sacramento River Region—Keswick, Feather River at Gridley, and American River at Fair Oaks.

As described for Sacramento River stations, the results indicate that the average winter flows are skewed by infrequent elevated flows. The medians are nearly the same in the low-flow months of July, August, September, and November, reflecting the effects of releases to maintain minimum stream flows during these months.

STANISLAUS RIVER

Total flows on the Stanislaus River currently average approximately 1.2 MAF annually. About 0.2 MAF are allocated for instream flows, and about 0.7 MAF are diverted.

The largest reservoir on the Stanislaus River is New Melones, which was completed by the Corps in 1978 and is operated by Reclamation. The reservoir first was filled to capacity in 1993. Reservoir storage was nearly depleted during the 1987 to 1991 drought.

Tulloch Reservoir has a storage capacity of about 70 TAF. Releases from Tulloch Powerhouse flow downstream to Goodwin Dam, where diversions are made into the Oakdale and South San Joaquin canals. More than 40 small pump diversions along the Stanislaus River supply irrigation water during spring and summer.

The average annual unimpaired runoff for 1957 to 1993 was about 1,113 TAF, with a range of 155 TAF (in 1977) to more than 2 MAF (in 1969, 1982, and 1983).

Peak runoff caused by snowmelt occurs from April through June. Rainfall can cause substantial runoff from November through March. Late summer and fall unimpaired flows are relatively low; the median flow is less than 200 cfs from July through October.

The wide range of monthly storage reflects the large component of carryover storage; the reservoir storage remains relatively high in wet years but can be relatively low in dry years.

Regulated Flows and Diversions

Maximum monthly diversions are about 100 TAF during the irrigation season from May through August. The New Melones Reservoir allows the reliability of these diversions to be increased.

Salmon spawn in the 23-mile reach between Goodwin Dam and Riverbank, and rear in the entire lower Stanislaus River. Current instream flow requirements vary from about 135 cfs (average in dry years) to about 415 cfs (average in wet years). The monthly flow schedule, specified by DFG, emphasizes fall and winter conditions for fall-run salmon. A minimum of 70 TAF is also allocated for water quality benefits (salinity control) at Vernalis. This increases the releases during the irrigation months by an average of 200 cfs. DFG and AFRP recommend that spring releases for outmigration are the greatest additional flow needs for the Stanislaus River. An adaptive management framework, with releases that depend on available water supply, has been suggested by AFRP. Because of the water rights and contract obligations, additional instream flow requirements may be difficult to achieve in some years.

Several riparian diversions occur below the major diversions at Goodwin Dam, but the streamflow near the mouth of the Stanislaus River between 1981 and 1991 has averaged about 680 TAF (938 cfs average).

The highest flows occur during winter from rainfall storms. The snowmelt and rainfall runoff from the upper watershed generally are captured and released for irrigation diversions. Summer flows at Ripon generally have been greater than 200 cfs, which is much higher than unimpaired flows, because of the reservoir releases for water quality control.

Water Management Allocation

The reservoir was first filled in 1983 and remained at fairly high storage levels through 1986. The reservoir storage then declined from 1987 through 1991 during the drought. In wet years, when the inflows are greater than beneficial uses, New Melones Reservoir storage increases to the flood control capacity. During summer months, storage releases from New Melones are needed to supply beneficial uses along the Stanislaus River.

The Old Melones Reservoir provided some seasonal storage capacity prior to the completion of New Melones Reservoir. Water allocation has been approximately 194 TAF for estimated instream flow use (17% of the runoff) and about 522 TAF (47% of the runoff) for diversions. An additional release for downstream water quality control has been made since 1982. Releases were made prior to 1982 for flood control purposes. An average of 67% of Stanislaus runoff is allocated for beneficial uses, and an average of about 25% of water uses were supplied from reservoir releases.

TUOLUMNE RIVER

The Tuolumne River has a watershed of about 1,900 square miles that drains the Sierra Nevada Mountains and foothills, including the north half of Yosemite National Park. Water is impounded and regulated by several dams in the high Sierra for municipal water supply and power generation, most notably Hetch-Hetchy Reservoir, operated by the City and County of San Francisco. Downstream of the San Francisco facilities, Tuolumne River water is impounded and regulated by New Don Pedro Reservoir. Water released from New Don Pedro Reservoir is diverted at La Grange Reservoir into the Turlock and Modesto Canals by the Turlock and Modesto Irrigation Districts.

La Grange Dam is the upstream limit for anadromous fish on the Tuolumne River. Salmon spawn in the 25-mile reach between La Grange Dam and the town of Waterford, and rear in the entire lower Tuolumne River.

Tuolumne River flows are simulated to be about 1.55 MAF at New Don Pedro Reservoir. Of this, about 0.9 MAF (58%) are used for average annual diversions and 0.2 MAF (13%) are for instream flows.

The average annual unimpaired runoff for this period was about 1,800 TAF (2,500 cfs), with a range of 383 TAF (1977) to about 4.6 MAF (1983). The inflow to New Don Pedro Reservoir is affected by San Francisco's upstream reservoirs and diversions. Total annual inflow to New Don Pedro Reservoir, as estimated for the No-Action Alternative or as estimated from reservoir outflow and change in storage, indicate that estimated inflow is about 275 TAF less than the unimpaired inflow.

Peak runoff caused by snowmelt occurs in April and June. Rainfall can cause substantial runoff from December through March. Late summer and fall inflows are relatively low; the median inflow is less than 50 TAF (800 cfs) from July through December.

The Hetch-Hetchy Reservoir (located in Yosemite National Park) was constructed by the City and County of San Francisco in 1923 for drinking water supply with a capacity of about 360 TAF. Cherry Lake (260-TAF capacity) was completed in 1953 to increase the aqueduct yield. New Don Pedro Reservoir was completed in 1971 by the Turlock and Modesto Irrigation districts to increase the reliability of water supply diversions. A smaller reservoir with a storage capacity of 290 TAF was operated beginning in 1923. New Don Pedro Reservoir has a capacity of about 2 MAF and allows the diversion of about 900 TAF each year from La Grange Dam, located downstream of New Don Pedro Reservoir.

New Don Pedro Reservoir storage capacity (2 MAF) is moderate compared with average reservoir inflow (1.5 MAF) so that the reservoir stays well below capacity during dry years but cannot hold all inflow during the wetter years.

Total storage release, which is water from current seasonal runoff plus water saved from the previous year, ranges from 93 to 910 TAF, with an average of 420 TAF. The reservoir is large enough to provide moderate carryover storage benefits. Average carryover storage (end-of-September storage) is 1,184 TAF. This carryover storage sometimes is used to provide releases the following year. An average of about 166 TAF of carryover storage is used in the subsequent year, so the average use of seasonal storage is 254 TAF (420 to 166 TAF). New Don Pedro Reservoir storage is needed to supply an average of about 30% (310 TAF) of the combined diversion and instream flow uses, which total about 1,100 TAF.

Regulated Flows and Diversions

Almost all diversions from the Tuolumne River below New Don Pedro Reservoir are made by the Modesto and Turlock Irrigation Districts. Maximum diversions generally peak in July with a median diversion of approximately 175 TAF. The combined annual diversions made by these two irrigation districts range from 437 TAF (in 1977) to about 1,100 TAF in several years, with an average of about 900 TAF. These average diversions represent 58% of the average estimated inflow. The maximum diversion of 1,194 TAF represents about 77% of the average estimated inflow.

Instream flow requirements for the New Don Pedro hydropower Federal Energy Regulatory Commission (FERC) license were quite low (170 cfs average in normal years and 90 cfs average in dry years); however, following studies by DFG, U.S. Fish and Wildlife Service (USFWS), the City and County of San Francisco, and the irrigation districts, a new adaptive management approach to instream flows, that involves several year-type schedules with temperature-management goals and fish-count monitoring, has been adopted in a revised 1997 FERC license. The flows are specified for the October-to-March salmon spawning and rearing season, the April and May outmigration pulse, and the summer steelhead rearing season. The salmon rearing flows vary from 80 to 300 cfs, with pulse flows of 500 to 3,000 cfs. The summertime steelhead rearing flows vary from 50 to 200 cfs.

The monthly flows below La Grange Dam from 1972 to 1992 indicate the efficiency of the water storage and delivery systems on the Tuolumne River. The average flow is about 880 cfs, with most of this flow occurring during winter when rainfall storms cause reservoir flood control releases. Summer flows (80% exceedance) are only about 20 cfs. Local inflows below La Grange cause the flows at Modesto to be greater than those at La Grange by an average of about 200 TAF per year.

Water Management Allocation

The inflows often are greater than beneficial uses in winter and spring months, and New Don Pedro Reservoir storage sometimes increases to the flood control capacity. During summer, storage releases from New Don Pedro Reservoir are needed to supply beneficial uses along the Tuolumne River. Occasionally in fall and winter, the releases are greater than the downstream uses. These releases are made for flood control and hydropower benefits or may be released downstream as water transfers. Water allocation has been approximately 13% of the runoff for instream flow requirements (as estimated by the No-Action Alternative) and about 58% of the runoff for diversions. About 28% of the Tuolumne River historical water uses were supplied from reservoir releases.

MERCED RIVER

The Merced River has a watershed of about 1,275 square miles and drains the Sierra Nevada Mountains and foothills, including the southern half of Yosemite National Park (Yosemite Valley).

Merced River flows are simulated to be about 0.9 MAF at McClure Reservoir. Of this, about 0.525 MAF are used for diversions and 0.043 MAF are for instream flows.

The average annual unimpaired runoff for this period was about 1,020 TAF (average flow of

1,410 cfs), with a range of 150 TAF (in 1977) to more than 2 MAF (in 1969 and 1983).

Peak runoff caused by snowmelt occurs from April through July. Rainfall storms can cause substantial runoff from December through March. Late-summer and fall unimpaired flows are relatively low; the median flow is less than 100 cfs from August through October.

Lake McClure is formed by New Exchequer Dam, which was completed by the Merced Irrigation District in 1967 to increase the reliability of water supply diversions. The storage capacity of Lake McClure is approximately 1 MAF. Annual diversions of about 600 TAF are made into the North Canal at the Merced Falls Dam and into the Main Canal at the Crocker-Huffman Dam. The Crocker-Huffman Dam near the town of Snelling is the upstream limit for anadromous fish on the Merced River. The Merced River Hatchery is located immediately below the Crocker-Huffman Dam.

The available storage is utilized in the majority of years, with maximum storage levels achieved in May and June following the spring snowmelt season. The reservoir is large enough to provide substantial carryover storage benefits. Average carryover storage (end-of-September storage) is 485 TAF. This carryover storage is sometimes used to provide releases the following year. Annual storage release, which is water from current season runoff plus water saved from the previous year, ranges from about 150 to 550 TAF, with an average of 350 TAF. An average of about 125 TAF of carryover storage are used in the subsequent year, so the average use of seasonal storage is about 225 TAF (350 to 125 TAF).

Lake McClure storage is needed to supply an average of about 40% (230 TAF) of the combined diversion and instream flow uses, which total about 600 TAF.

Regulated Flows and Diversions

Several diversions are located downstream of Crocker-Huffman Dam. Annual diversion estimates range from about 200 TAF (in 1977) to more than 650 TAF in several years, with an average of about 550 TAF. These average diversions represent 54% of the average unimpaired inflow. The maximum diversion of 650 TAF represents about 65% of runoff. Maximum diversions occur in July and August, the peak irrigation months.

Instream flow requirements for the New Exchequer and McSwain hydropower FERC license are relatively low. The instream flow requirements are estimated to range from 35 TAF in dry years to about 50 TAF in wet years, with an average estimated requirement of 42 TAF (58 cfs). The Davis-Grunsky contract between DFG and Merced Irrigation District includes flow requirements of 200 cfs from November through March. Because these flow requirements are not included in the No-Action DWRSIM simulations, actual instream flow requirements may be somewhat higher than those simulated by DWRSIM.

DFG and AFRP have suggested instream flows that depend on available runoff. DFG and AFRP flows are specified for the October-to-March salmon spawning and rearing season, the April and May outmigration pulse period, and the summer steelhead rearing season. DFG-recommended salmon rearing flows vary from 200 to 300 cfs, with pulse flows of 300 to 500 cfs, and summer flows of 200 to 300 cfs. Additional flow for temperature control may be required in April and May. AFRP recommended considerably greater releases during years with higher runoff.

Below the major Merced River diversions, the total downstream flow between 1967 (when McClure was completed) and 1991 has averaged 428 TAF (590 cfs average). Downstream riparian diversions are estimated to require about 30 TAF; therefore, an average of about 350 TAF were released from the reservoir for hydropower or flood control operations in excess of requirements for diversions or instream flows. At the mouth (near Stevinson), average flow was higher, about 502 TAF (695 cfs average) for 1967 to 1991, indicating that some of this flow is contributed by irrigation return flows along the lower Merced River.

The highest flows occur during winter, when rainfall storms require reservoir flood control releases. The unimpaired flows generally are captured and released for irrigation diversions. Summer flows at Stevinson are generally less than 50 cfs, and median flows during the October-to-March salmon spawning and rearing season are between 250 and 500 cfs.

Water Management Allocation

The inflows are often greater than beneficial uses in winter and spring, and Lake McClure storage often increases to the flood control capacity. During summer, storage releases from Lake McClure are needed to supply beneficial uses along the Merced River. Sometimes in fall, the releases are greater than the downstream uses. These releases are made for flood control and hydropower benefits or may be released downstream as water transfers. Water allocation has been approximately 4% of the runoff for instream flows and about 54% of the runoff for diversions. About 40% of the Merced River historical water uses were supplied from reservoir releases.

DWRSIM Modeling Results for Existing Conditions

The USGS has operated a gaging station on the San Joaquin River near Vernalis (USGS Station No. 11303500) since 1922, although complete records are available only back to 1930. The instantaneous maximum recorded at the station was 79,000 cfs, observed on December 9, 1950. The lowest daily mean flow was 19 cfs, on August 10, 1961. The maximum mean monthly discharge was 40,040 cfs (March), and the minimum mean monthly discharge was 804 cfs (April).

Historically, the major rivers of the San Joaquin system have contributed an average of about 5.5 MAF to Delta flows, with an annual range of from 1.1 to 15 MAF. Historic unimpaired flows on the Stanislaus, Tuolumne, Merced, and San Joaquin rivers averaged a total of 5.6 MAF. Numerous dams and diversions have been constructed on these rivers and other rivers in this system.

On the Stanislaus River, approximately 0.52 MAF have been diverted and 0.2 MAF have been allocated for instream flows. These total 64% of the river's average flows of 1.1 MAF. Prior to construction of the New Melones Reservoir in 1980, an average of 25% of these uses were supplied by reservoir releases. The Tuolumne River has average unimpaired flows of about 1.8 MAF. Over 2.5 MAF of storage capacity has been constructed on this river. Historical water allocations have been approximately 13% for instream flows and 58% for diversions. About 28% of historical water uses were supplied from reservoir releases. The Merced River has average unimpaired flows of about 1 MAF. Over 1 MAF of storage capacity has been constructed on this river. Historical water allocations have been approximately 4% for instream flows and 54% for diversions. About 40% of historical water uses were supplied from reservoir releases. The upper San Joaquin River has average unimpaired flows of about 1.7 MAF. Approximately 0.6 MAF of storage capacity has been constructed on this reach of the river. Historically, approximately 70% of the river's runoff has been diverted to the Friant-Kern and Madera canals, primarily for agricultural uses. About 20% of historical water uses were supplied from reservoir releases.

The upper watershed of the San Joaquin River Region has historically been less developed than that of the Sacramento Region, although the same general process of development has occurred, including mining, logging, housing construction, industrial development, and dam construction. As in the Sacramento River Region the upper watershed contains major parks and wilderness areas. Most development has occurred in the lower foothills, near or below the snow line.

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SWP and CVP Service Areas Outside the Central Valley

HYDRODYNAMICS AND HYDRAULICS

Surface water flows in SWP and CVP service areas outside the Central Valley are not directly affected by the CALFED project.

The SWP includes 20 dams and 662 miles of aqueduct. Conveyance facilities serving the area outside the Central Valley include the North Bay Aqueduct (serving parts of Napa and Solano Counties), the South Bay Aqueduct (serving Santa Clara County), the Coastal Branch Aqueduct (serving San Luis Obispo and Santa Barbara counties), and the California Aqueduct (which serves the South Coast Region). The capacity of the California Aqueduct at the Delta is 10,300 cfs. South of the Tehachapi Mountains at the southern end of the Central Valley, the capacity of the aqueduct is 4,480 cfs. The major SWP reservoirs outside the Central Valley include Pyramid Lake and Castaic Lake, which receive water via the west Branch of the California Aqueduct, and Silverwood Lake and Lake Perris, which receive water via the East Branch of the California Aqueduct. Of the initial project contracts for annual delivery of 4.2 MAF, about 2.5 MAF was allotted to southern California, about 1.3 MAF to the San Joaquin Valley, and about 0.4 MAF was allotted to San Francisco Bay, Central Coast, and Feather River areas. Since about 1980, the southern California area has received about 60% of its full entitlement, while the San Joaquin valley has received nearly all of its entitlement. It has been estimated that SWP facilities have about a 65% chance of making full deliveries at the existing (1995) level of demand.

The U.S. Bureau of Reclamation's Central Valley Project supplies water to more than 250 long-term water contractors in its service area. Most of the service area is inside the Central Valley. Outside the Central Valley the service area includes part of Santa Clara County, northwest San Benito County, a small region along both sides of the Santa Cruz/Monterey County line, and northeastern Contra Costa County. About 90% of the south-of-Delta contractual delivery is for agricultural users.

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