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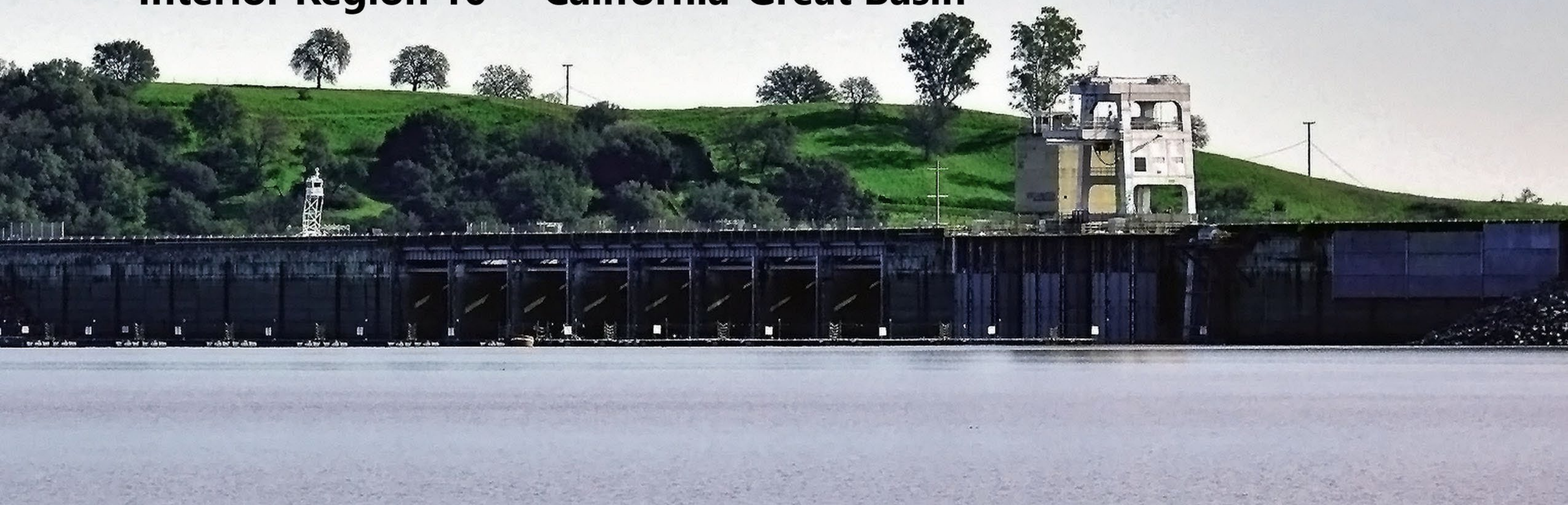
Appendix C

CalSim 3 Upper American River Module Documentation

American River Basin Study
Interior Region 10 – California-Great Basin



Note: This appendix is a record of analysis for the ongoing study (2018 - 2022).
The main report may have updated information that is not reflected in this appendix.

City of Folsom · City of Roseville · City of Sacramento · El Dorado Water Agency · PCWA · RWA Regional Water Authority · SAFCA Sacramento Area Flood Control Agency

U.S. Department of the Interior **March 2022**

BUREAU OF RECLAMATION

American River Basin Study: CalSim 3 Upper American River Module Documentation

Interior Region 10 - California Great Basin

U.S. Department of the Interior **July 2020**

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

American River Basin Study: CalSim 3 Upper American River Module Documentation

Interior Region 10 - California Great Basin

prepared by: *Stantec*

Cover Photo: Folsom Reservoir reached a record low of 135,000 acre-feet on December 5, 2015 (Stantec/ Yung-Hsin Sun)

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Abbreviations and Acronyms

AF	acre-feet
cfs	cubic feet per second
CPUC	California Public Utilities Commission
CVP	Central Valley Project
D-XXX	State Water Board Decision XXX
Delta	Sacramento – San Joaquin Delta
DSOD	California Division of Safety and Dams
DWR	California Department of Water Resources
EID	El Dorado Irrigation District
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
FCRS	flood control reservation space
FERC	Federal Energy Regulatory Commission
FPUD	Foresthill Public Utility District
GIS	geographic information system
GDPUD	Georgetown Divide Public Utilities District
ID	Irrigation District
M&I	municipal and industrial
MFP	Middle Fork Project
mgd	million gallons per day
MOU	Memorandum of Understanding
msl	above mean sea level
MW	megawatt
NF	North Fork
NGVD	National Geodetic Vertical Datum
NSA	North Service Area
PCWA	Placer County Water Agency
PG&E	Pacific Gas and Electric Company
PSA	Purveyor Specific Agreement
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
SCWC	Southern California Water Company
SF	South Fork
SMUD	Sacramento Municipal Utility District
SSA	South Service Area
SWP	State Water Project
TAF	thousand acre-feet
UARP	Upper American River Project
UIFR	Unimpaired inflow to Folsom Lake
USGS	U.S. Geological Survey

WA	Water Agency
WBA	Water Budget Area
WC	Water Company
WD	Water District
WRESL	Water Resources Simulation Language
WRIMS	Water Resources Integrated Modeling System
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
WY	water year

Conversion Factors

1 million gallons per day (mgd) = 1.547 cubic feet per second (cfs)

1 million gallons per day (mgd) = 3.068 acre-feet per day

1 million gallons per day (mgd) = 1.12 acre-feet per year (AF/year)

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Chapter 1 Introduction

This document describes the development of a monthly time-step reservoir operations model of the upper American River watershed. This new model application allows a planning level simulation of the upper watershed to be integrated with the existing CalSim 3 model representation of Folsom Lake and the lower American River. The CalSim 3 model was developed jointly by the U.S. Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR).

Model development includes assembly of historical unimpaired monthly inflows that are computed using historical streamflow records, reservoir storage data, and evaporation estimates from the U.S. Geological Survey (USGS) and from water agencies managing facilities in the watershed. These data are integrated over time at various locations within the watershed using mass balance equations where possible and using statistical methods where historical data are not available. A 94-year monthly hydrologic data set has been developed for the period from October 1921 through September 2015.

There are more than 20 reservoirs in the upper American River watershed, ranging in size from about 400 acre-feet (AF) to about 277,000 AF. The upper American River Model includes simulation of 12 reservoirs located on the Rubicon River, Caples Creek, Echo Creek, Gerle Creek, Pilot Creek, Pyramid Creek, Silver Creek, and the North, Middle, Silver, and South Forks of the American River. Several smaller creeks and diversions are also simulated.

Simulation rules are developed to characterize operations of water control facilities within the watershed. Model calibration and validation was performed by comparing simulated results with recent historical data for water years (WY) 1996-2015. Finally, simulations using current physical facilities, regulatory requirements, and operational criteria were developed to characterize operations under existing level of development conditions.

Background

In 2000, DWR created a general-purpose simulation environment for analyzing management options for reservoirs and river systems. This environment, called the Water Resources Integrated Modeling System (WRIMS), uses a mixed integer linear programming solver to determine the timing and volumes of reservoir releases and water deliveries. The application of WRIMS to the Central Valley Project (CVP) and State Water Project (SWP) is known as CalSim. Geographically, CalSim represents the portion of California's Central Valley that drains to the Sacramento - San Joaquin Delta (Delta), and CVP and SWP exports to the San Francisco Bay area, and central and southern California.

CalSim typically simulates system operations for a multi-year period using a monthly time step. The model assumes that facilities, land use, water supply contracts, and regulatory requirements are constant over this period, representing a fixed level of development (e.g., 2015, 2050). The historical streamflow record, adjusted for the influence of land-use change and upstream flow regulation, is used to represent the possible range of water supply conditions for the Central Valley. Rim watershed inflows, stream accretions and depletions, water diversion requirements (demands), and return flows are the primary components of the input hydrology. The CalSim model is described in detail by DWR and Reclamation (2002), Draper et al. (2004), and DWR (2017).

The primary purpose of CalSim is to evaluate CVP and SWP operations at current or future levels of development, with and without various assumed future facilities, various regulatory requirements, and with different facility management options. One of the principal outputs of the model is the estimate of CVP and SWP exports at project facilities in the south Delta and corresponding delivery reliability of the two projects. However, CalSim has also become a widely accepted modeling tool for Central Valley water resources planning.

DWR and Reclamation are jointly developing a new version of CalSim known as CalSim 3. CalSim 3 will replace its predecessor, CalSim II, for conducting planning studies relating to operations of these two projects. DWR has taken the lead in developing the Sacramento Valley portion of CalSim 3. Reclamation is leading the development of the San Joaquin portion of CalSim 3.

The upper American River model is built on the WRIMS platform and consists of both: a) a stand-alone version that simulates water operations within the watershed; and b) an upper American River module fully integrated with CalSim 3.

Purpose

The upper American River model was developed for two purposes: (1) refine and extend DWR and Reclamation's CalSim 3 planning model; (2) to develop projections of future water supply and demand in the basin, including an assessment of risk to the water supply relating to climate change as part of Reclamation's American River Basin Study. One of the primary outputs of the model are monthly simulated inflows to Folsom Lake for 94 years of inflow hydrology based on the historical record. These objectives determined the level of spatial and temporal detail, operational criteria, model structure, and data management requirements included in the model.

Model Development Summary

The WRIMS-based upper American River model is the product of an extensive work effort spanning more than two years. The following summarizes the work undertaken:

- **Data Collection**: An extensive data collection effort was conducted to gather historical data from USGS, DWR, Reclamation, and local water agencies; documents on water rights, contracts, and regulatory requirements; and previously developed simulation models of the upper American River watershed.

- **Geographic Representations of Model Domain**: A model schematic was developed to represent operations of water development projects in the upper American River watershed and depict both water control facilities and gage locations. In addition, geographic information system (GIS) layers were developed to generate reference maps of the watershed. The GIS representation was also used to delineate subwatersheds associated with each model inflow location.

- **Agency Interaction**: Stantec conducted meetings with staff of water agencies operating in the watershed. At these meetings, additional data and information were acquired regarding the specific operating rules of each agency.

- **Hydrology Development**: A monthly hydrology of the entire watershed was developed using the accumulated historical operations data and the geographic representations of the watershed. The hydrology development process involved the development of a monthly hydrology that is designed to match the unimpaired flow of the American River at Fair Oak, as well as at intermediate points upstream of Folsom Lake.

- **Development of Operational Criteria**: Operational criteria were developed for each water development project in the watershed based on a review of existing documents, assessment of operations data, review of previously developed models and assumptions, and interviews with operating agency staff.

- **Model Development**: A monthly time-step model was developed using the WRIMS software that incorporates the model schematic, hydrology, and operational criteria described above.

- **Calibration of Hydrology**: A hydrology calibration simulation was developed to test the historical hydrology by constraining reservoir and powerplant operations to historical values and comparing modeled river flows with historical values. The results of the hydrology calibration process were used to refine the hydrology computations to better match historical operations.

- **Validation of Operations**: An operations validation simulation was developed to evaluate the reasonableness of the model operating rules. The results of the hydrology calibration process were compared to historical operations and were used to refine the operational criteria to better match historical operations.

- **Projected Level Analyses**: An existing level simulation was developed to represent the 2015 level of development.

Organization of this Report

The contents of each chapter are briefly summarized below.

Chapter 1 Introduction provides an overview of the upper American River model.

Chapter 2 Model Domain describes the geography of the upper American River watershed, the major water agencies located within the watershed, and operations of control facilities.

Chapter 3 Model Schematic presents the arc-node network for the upper American River model.

Chapter 4 Water Supplies summarizes development of unimpaired surface water inflows to the stream network. The chapter also describes the development of reservoir evaporation rates.

Chapter 5 Reservoir Evaporation summarizes development of reservoir evaporation rates.

Chapter 6 Water Rights and Agreements summarizes water rights and water right decisions associated with stream diversions within the upper American River watershed.

Chapter 7 Project Operations describes legal requirements for the operation of water control facilities including flood control, Federal Energy Regulatory Commission (FERC) license requirements, and contract agreements. The chapter also discusses reservoir operations to meet water supply, hydropower, and other discretionary objectives.

Chapter 8 Model Simulation describes model input files.

Chapter 9 Model Results and Validation compares simulated reservoir storage, streamflows, and stream diversions to recent historical gauge data. The chapter also summarizes major model results including water supply reliability over the 94-year period of simulation.

Chapter 10 References presents sources cited in this report.

Chapter 2 Model Domain

The upper American River watershed comprises three subwatersheds formed by the North Fork American River, Middle Fork American River, and South Fork American River. The Middle Fork American River joins the North Fork from the east near the City of Auburn. The North and South Fork American River converge at Folsom Lake. The lower American River watershed stretches from Folsom Lake and Folsom Dam to the American River's confluence with the lower Sacramento River.

Water development projects located in the Upper American River watershed influence the quantity and timing of American River flows entering Folsom Lake, which is one of the primary storage facilities of the CVP. This chapter briefly describes each of these water development projects.

Water Development Projects

The upper American River watershed includes eight major water development projects that are operated for a mix of water supply, hydropower, fishery enhancement, and recreational purposes. These projects are listed in **Table 2-1** and briefly described in the following sections.

Table 2-1. Water Management Facilities in the Upper American River Watershed

Project	Storage Facilities	Conveyance Facilities
Chili Bar Project	Chili Bar Reservoir	None
Drum-Spaulding Project	Lake Valley Reservoir	Lake Valley Canal
Stumpy Meadows Project	Stumpy Meadows Reservoir	Georgetown Diversion
Middle Fork Project	Duncan Creek Reservoir French Meadows Reservoir Hell Hole Reservoir Middle Fork Interbay Oxbow Reservoir	French Meadows Tunnel Duncan Creek Tunnel Hell Hole Middle Fork Tunnel Shaft to Hell Hole-Middle Fork Tunnel (North Fork) Shaft to Hell Hole-Middle Fork Tunnel (South Fork) Middle Fork-Ralston Tunnel Ralston Penstock and Powerplant Oxbow Tunnel Oxbow Penstock and Powerplant Auburn Ravine Diversion
Upper American River Project	Rubicon Reservoir Buck Island Reservoir Loon Lake Reservoir Gerle Creek Reservoir Robbs Peak Reservoir Ice House Reservoir Union Valley Reservoir Junction Reservoir Camino Reservoir Brush Creek Reservoir Slab Creek Reservoir	Rubicon-Rockbound Tunnel Buck Island-Loon Lake Tunnel Gerle Creek Canal Robbs Peak Tunnel Robbs Peak Penstock Jones Fork Tunnel Jones Fork Penstock Union Valley Tunnel Union Valley Penstock Jaybird Tunnel Jaybird Penstock Camino Tunnel Brush Creek Tunnel Camino Penstock Slab Creek Penstock White Rock Tunnel White Rock Penstock
El Dorado Hydroelectric Project (Project 184)	Echo Lake Lake Aloha Caples Lake Silver Lake El Dorado Forebay	El Dorado Diversion/Canal
Central Valley Project	Folsom Lake Natoma Lake	Folsom Pumps Folsom South Canal

Chili Bar Hydroelectric Project (FERC Project No. 2155)

The Chili Bar Project is owned by Pacific Gas and Electric Company (PG&E). It is located in El Dorado County on the South Fork American River immediately downstream from the White Rock Powerhouse, which is owned by Sacramento Municipal Utility District (SMUD). Project facilities, which are shown in **Figure 2-1**, consist of a dam, intake, penstock, and powerhouse. Chili Bar Dam is 126 feet high and 380 feet long with a 170-foot-long spillway having a crest elevation of 997.5 feet national geodetic vertical datum (NGVD). The dam impounds Chili Bar Reservoir, which has a surface area of 110 acres and a useable storage capacity of 1,339 acre-feet (AF) (FERC, 2014c). A 14-foot diameter penstock embedded in the dam conveys water from the intake to a powerhouse located at the foot of the dam. The powerhouse contains a single 7-megawatt (MW) turbine unit. Water is discharged through the penstock at a normal maximum flow of 1,659 cubic feet per second (cfs). Tailrace water enters directly into the river downstream. The maximum normal gross head at the facility is 60 feet (FERC, 2008 and 2014c).

Chili Bar Dam, Photo Credit: PG&E

Figure 2-1. Chili Bar Dam and Powerhouse.

The Chili Bar Powerhouse is a run-of-the-river facility being dependent on releases from storage facilities owned and operated by SMUD. PG&E and SMUD coordinate operations of Chili Bar and White Rock powerhouses to meet regulatory flow requirements for fisheries and summertime whitewater recreational needs below the powerhouses. In August 2019, the SMUD Board of Directors voted to approve a resolution signaling intent by SMUD to purchase PG&E's Chili Bar Project. The two agencies have subsequently signed an agreement for purchase of the project, which must be approved both by FERC and the California Public Utilities Commission (CPUC).

Drum-Spaulding Project (FERC Project No. 2310)

The Drum-Spaulding Project is owned and operated by PG&E. The project is located predominantly in Nevada and Placer counties in the watersheds of the Middle and South Yuba River, Bear River, and North Fork American River. It consists of 10 separate developments encompassing 29 reservoirs, 6 major water conduits, and 12 powerhouses (FERC, 2013). Project facilities located in the North Fork American River watershed include Lake Valley Reservoir and Dam (Drum No. 1 and No. 2 Development), Kelly Lake Reservoir and Dam (Drum No. 1 and No. 2 Development), Lake Valley Diversion Dam and Canal (Drum No. 1 and No. 2 Development), and Towle Diversion Dam and Canal (Alta Development).

PG&E's Drum-Spaulding Project is operated in coordination with Nevada Irrigation District's (ID) Yuba-Bear Project (FERC Project No. 2266), which is located in the watersheds of the Middle Yuba River, South Yuba River, and Bear River.

Photo Credit: PG&E

Figure 2-2. Lake Valley Diversion Dam and Canal.

The following description of the Drum No. 1 and No. 2 Development is from the Environmental Impact Statement (EIS) completed as part of the FERC relicensing (FERC, 2014a).

- **Lake Valley Reservoir Dam** is a 75-foot-high, 1,035-foot-long earth- and rock-fill dam that impounds the North Fork of the North Fork American River to form Lake Valley Reservoir. The dam has a crest elevation of 5,789.9 feet above mean sea level (msl). The reservoir has a usable storage capacity of 7,902 AF and a surface area of 304 acres. Normal maximum water surface elevation within the reservoir is 5,784.9 feet msl. The dam has a 525-foot-long overflow spillway controlled with manually hoisted flashboards from April to September. A 30-inch pipe serves as the low-level outlet and has a maximum flow capacity of 50 cfs. Releases from Lake Valley Dam flow into the North Fork of the North Fork American River.

- **Kelly Lake Dam** is a 10.5- to 23.5-foot-high, 448-foot-long earth and rock-fill dam that impounds Sixmile Creek to form Kelly Lake. The dam has a crest elevation of 5,911.3 feet msl. The reservoir has a usable storage capacity of 352 AF and a surface area of 28 acres. Normal maximum water surface elevation within the reservoir is 5,908.8 feet msl. The dam has an 18-foot-long overflow spillway controlled with manually hoisted flashboards and a maximum discharge of 490 cfs. A 20-inch-diameter pipe with a flow capacity of 25 cfs serves as the low-level outlet. Releases from Kelly Lake Dam flow into the North Fork of the North Fork American River via Sixmile Creek.

- **Lake Valley Canal Diversion Dam**, located on the North Fork of the North Fork American River, diverts water released upstream from Lake Valley reservoir and Kelly Lake to Lake Valley Canal, which delivers up to 36 cfs of water to PG&E's Drum Canal in the Bear River watershed.

- **Towle Canal Diversion Dam**, located on Canyon Creek, is a 5.5-foot-high wooden diversion dam with steel vertical slide gates. The Towle Canal diverts up to 42 cfs of water from Canyon Creek (primarily consisting of deliveries from the Drum Forebay into Canyon Creek) to Alta Forebay. The Towle Canal consists of open ditch and flume sections and has a total length of 3.9 miles.

Lake Valley Reservoir is operated in tandem with Kelly Lake, filling with spring runoff that accumulates during the snowmelt season, and drawndown over the summer and fall. The reservoir provides water for consumptive demands, hydropower, fisheries, and recreational benefits. Located approximately 4 miles downstream from Lake Valley Reservoir, Lake Valley Canal Diversion Dam diverts water releases from the upstream reservoirs through the Lake Valley Canal to the Bear River watershed.

The average annual inflow to Lake Valley Reservoir is 6,400 AF/year, ranging from approximately 1,700 in 1977 to 12,400 AF/year in 1983. River accretions between Lake Valley Dam and the downstream diversion dam average 6,600 AF/year.[1]

Beginning October 1964, flows through Lake Valley Canal have been recorded by USGS gauge 11426190 (Lake Valley Canal near Emigrant Gap). Average annual flows are approximately 11,000 AF/year, with a high of 23,300 AF in 1983 and a low of 1,900 AF in 2014.

Stumpy Meadows Project

Formed in 1946, Georgetown Divide Public Utility District (GDPUD) is located on the western slopes of the Sierra Nevada foothills, approximately 45 miles northeast of the City of Sacramento. The district's service area straddles a ridge separating the drainage basins of the Middle Fork American River and the Rubicon River to the north from the South Fork American River to the south. The district's sphere of influence covers approximately 173,000 acres, equivalent to 270 square miles (GDPUD, 2016).

GDPUD provides raw water for irrigation and treated water for domestic purposes in the Georgetown Divide area of El Dorado County, including the communities of Cool, Pilot Hill,

[1] Flow estimates are approximate and are based on both historical gauged data and synthetic data extension.

Greenwood, Georgetown, Garden Valley, and Kelsey. The district derives its water from Stumpy Meadows Reservoir and Dam located on Pilot Creek, a tributary of the Rubicon River. The reservoir has a gross capacity of 20,000 AF and a usable capacity of approximately 18,800 AF. Water released from the reservoir is diverted 2.8 miles downstream into the Georgetown Divide Ditch and conveyed to the Walton Lake and Auburn Lake Trails water treatment plants. The Walton Lake plant serves the communities of Georgetown, Garden Valley, Kelsey, and Greenwood. The Auburn Lake Trails plant serves Auburn Lake Trails, Cool and Pilot Hill. Additionally, raw water deliveries are made directly from the ditch for agricultural purposes.

The average annual inflow to Stumpy Meadows Reservoir is 22,300 AF/year, ranging from approximately 1,800 in 1924 to 63,500 AF/year in 1983. Diversions into the Georgetown Divide Ditch are approximately 10,000 AF/year. The district estimates that operational water requirements and losses total about 3,600 AF/year.

Middle Fork Project (FERC Project No. 2079)

PCWA's Middle Fork Project (MFP) is a multi-purpose project designed to conserve and control waters of the Middle Fork of the American River, the Rubicon River and certain tributaries for power generation and consumptive water supply. The project's two major reservoirs store up to 343,000 AF. The project includes four additional diversion dams and a powerhouse afterbay. A pumping station on the North Fork American River upstream from Folsom Lake directly diverts water from the river and rediverts storage releases from the MFP. MFP water also is diverted at Folsom Lake.

The MFP includes five developments: French Meadows, Hell Hole, Middle Fork, Ralston, and Oxbow. The following description of project facilities is from the Final EIS completed for FERC relicensing (FERC, 2013).

French Meadows Development

The French Meadows Development includes facilities on Duncan Creek and Middle Fork American River.

- **Duncan Creek Diversion Dam** is a 32-foot-high, 165-foot-long, concrete gravity structure with a 100-foot-wide uncontrolled ogee spillway. Impounded water covers two acres at elevation 5,265 feet with 20 AF of gross storage and negligible active storage. A 10-inch-diameter instream flow maintenance pipe conveys water through the dam to the downstream creek, with a maximum discharge capacity of 8 cfs. Additionally, a 60-inch-diameter low level outlet pipe bypasses water to Duncan Creek with a maximum discharge of 310 cfs.

- **Duncan Creek-Middle Fork Tunnel** is 1.5-mile-long, 9-foot-wide by 10-foot-high and connects Duncan Creek pool to French Meadows Reservoir. The maximum capacity is 400 cfs.

- **French Meadows Dam** is a 231-foot-high, 0.5-mile-long rock- and gravel-filled structure with a crest at elevation 5,273 feet and a 40-foot wide spillway (extending to the Middle Fork American River about 1,000 feet downstream from the dam) that includes two 20-foot-wide radial gates. French Meadows Reservoir has a gross storage of 134,993 AF at elevation 5,262 feet and a corresponding 1,408-acre water surface. The reservoir has an active storage of 127,358 AF. An

8-inch-diameter instream flow maintenance pipe conveys flows from French Meadows Reservoir to the Middle Fork with a maximum discharge capacity of 8 cfs. Additionally, a 72-inch-diameter low level outlet pipe conveys water from French Meadows Reservoir to the Middle Fork with a maximum discharge capacity of 1,430 cfs.

- **French Meadows-Hell Hole Tunnel and Penstock** is a 2.6-mile-long, 12.3-foot-wide tunnel that routes water from the French Meadows Reservoir to French Meadows Penstock. Subsequently, the 6.25-foot-diameter, 691-foot-long penstock conveys water from the French Meadows-Hell Hole Tunnel to the French Meadows Powerhouse.

- **French Meadows Powerhouse** houses a Francis-type unit with an authorized installed capacity of 15.3 MW discharging a maximum of 800 cfs to Hell Hole Reservoir on the Rubicon River.

The diversion of water at the French Meadows Development results in an 8.6-mile-long bypassed reach in Duncan Creek and an 11.6-mile-long bypassed reach in the Middle Fork American River.

Hell Hole Development

The Hell Hole Development, located on the Rubicon River, includes Hell Hole Dam, Penstock, and Powerhouse.

- **Hell Hole Dam**, shown in **Figure 2-3,** is a 410-foot-high, 1,570-foot-long rockfill structure with a crest at elevation 4,650 feet and a 350-foot-wide uncontrolled spillway. The reservoir has 207,590 AF of gross storage at elevation 4,630 feet, 1,253 acre surface area and 205,057 AF of active storage. A tunnel and 16-inch-diameter maintenance pipe conveys flows to the Rubicon River with a maximum discharge capacity of 20 cfs. Additionally, a 48-inch-diameter low level outlet pipe conveys flows to the Rubicon River or to the powerhouse penstock with a maximum discharge capacity of 852 cfs.

- **Hell Hole Penstock** is 100-foot-long, 48-inch to 20-inch in diameter and conveys water from the low level outlet pipe to the Hell Hole Powerhouse.

    - **Hell Hole Powerhouse** located at Hell Hole Dam houses a Francis-type unit with an authorized installed capacity of 0.7 MW discharging tailrace water to the Rubicon River.

The diversion of water at the Hell Hole Development into the Middle Fork Tunnel results in a 30.5-mile-long bypassed reach in the Rubicon River.

Photo Credit: PCWA

Figure 2-3. Hell Hole Reservoir and Dam.

Middle Fork Development

The Middle Fork Development, located on the Middle Fork American River and the North Fork and South Fork of Long Canyon Creek (a tributary of the Rubicon River) includes two diversion dams and associated facilities, the Middle Fork Tunnel and Penstock, and the Middle Fork Powerhouse.

- **North Fork (NF) Long Canyon Diversion Dam** is a 10-foot-high, 120-foot-long diversion structure with a crest at elevation 4,720 feet. A 12-inch-diameter instream flow maintenance pipe conveys water from the diversion dam to the North Fork with a maximum discharge capacity of 2 cfs. Additionally, a 36-inch-diameter low level outlet pipe conveys water through the diversion dam with a maximum discharge capacity of 100 cfs.

- **NF Long Canyon Conveyance Structure** routes water from the diversion dam to the Hell Hole-Middle Fork Tunnel. It consists of a 36-inch diameter, 0.7-mile-long buried pipe, a 403-foot-long, 6-foot-diameter vertical shaft, and a 54-foot-long tunnel with a maximum capacity of 100 cfs.

- **South Fork (SF) Long Canyon Creek Diversion Dam** consists of a 27-foot-high, 145-foot-long diversion structure with a crest at elevation 4,650 feet and a 60-foot-long uncontrolled ogee spillway. A 12-inch-diameter instream flow maintenance pipe conveys water from the diversion dam to the South Fork with a maximum discharge capacity of 5 cfs. Additionally, a 36-inch-diameter low level outlet pipe conveys water through the diversion dam with a maximum discharge capacity of 140 cfs.

- **SF Long Canyon Conveyance Structure** routes water from the diversion dam to the Hell Hole-Middle Fork Tunnel. It consists of a 42-inch-diameter, 50-foot-long buried pipe, a 387-

foot-long, 6-foot-diameter vertical shaft, and a 27-foot-long tunnel with a maximum capacity of 200 cfs.

- **Hell Hole-Middle Fork Tunnel and Penstock** convey water from the Hell Hole Reservoir to the Middle Fork Powerhouse. The tunnel is 13.4-foot-wide, 10.4-mile-long, horseshoe-shaped, with a maximum capacity of 920 cfs. A 0.7-mile-long penstock links the tunnel to the powerhouse, varying in diameter from 5.5 to 9 feet.

- **Middle Fork Powerhouse**, located 11 miles downstream from French Meadows Dam and shown in **Figure 2-4**, houses two Pelton-type units each having an authorized installed capacity of 61.2 MW. These units discharge water into the Middle Fork Interbay pool.

The diversion of water at the Middle Fork Development results in a 3.1-mile-long bypassed reach in the NF Long Canyon Creek, a 3.3-mile-long bypassed reach in the SF Long Canyon Creek, and an 11.4-mile-long bypassed reach on Long Canyon Creek from the confluence of the North and South Forks to the creek's confluence with the Rubicon River.

Photo Credit: PCWA

Figure 2-4. Middle Fork Powerhouse.

Ralston Development

The Ralston development includes the Middle Fork Interbay Dam, Middle Fork-Ralston Tunnel and Penstock, and Ralston Powerhouse.

- **Middle Fork Interbay Dam** is located approximately 0.5 mile downstream from the Middle Fork Powerhouse. It is a 70.5-foot-high, 233-foot-long structure with a crest at elevation 2,536 feet. The upstream pool covers less than 7 acres with 175 AF of gross storage and 173 AF of active storage. A 23-inch-diameter instream flow maintenance pipe conveying water from the Interbay pool to the Middle Fork River with a maximum discharge capacity of 23 cfs.

Additionally, a 60-inch-diameter low level outlet pipe conveys water from the pool to the river with a maximum discharge capacity of 890 cfs.

- **Middle Fork-Ralston Tunnel and Penstock** connect the Middle Fork Interbay Pool to the Ralston Powerhouse. The 13.4-foot-wide, 6.7-mile-long horseshoe-shaped tunnel has a maximum capacity of 836 cfs. A 1,670-foot-long, 8- to 9.5-foot-diameter penstock connects the tunnel to the Ralston Powerhouse.

- **Ralston Powerhouse** is located at the confluence of the Rubicon and Middle Fork American rivers. It houses a Pelton-type unit with an authorized installed capacity of 79.2 MW and discharges water to the Ralston Afterbay on the Middle Fork American and Rubicon rivers.

The diversion of water at the Ralston development results in a 10.8-mile-long bypassed reach in the Middle Fork River.

Oxbow Development

The Oxbow development includes the Ralston Afterbay Dam, Tunnel and Penstock, and the Oxbow Powerhouse.

- **Ralston Afterbay Dam**, shown in **Figure 2-5**, is located 9.5 miles downstream from the Middle Fork Interbay Dam. It is an 89-foot-high, 560-foot-long structure with a crest at elevation 1,189 feet and a 232-foot-wide gated ogee spillway containing five 40-foot-wide radial spillway gates. The 83-acre Ralston Afterbay impoundment at elevation 1,177 feet has a gross storage of 2,782 AF and 1,804 AF of active storage. A 30-inch-diameter instream flow maintenance pipe conveys water through the dam to the Middle Fork American River with a maximum discharge capacity of 155 cfs. Additionally, a 72-inch-diameter low level outlet pipe through the dam has a maximum discharge capacity of 1,132 cfs.

- **Ralston-Oxbow Tunnel and Penstock** connects the Ralston Afterbay to the Oxbow Powerhouse and consists of a 13.25-foot-wide, 403-foot-long horseshoe-shaped tunnel with a maximum capacity of 1,088 cfs and a 5-foot-long, 9-foot-diameter penstock leading from the end of the Ralston-Oxbow Tunnel to the Oxbow Powerhouse.

- **Oxbow Powerhouse** houses a Francis-type unit with an authorized installed capacity of 6.1 MW discharging water into the Middle Fork American River.

The diversion of water at the Oxbow Development results in a 0.48- mile-long bypassed reach of the Middle Fork American River.

Photo Credit: PCWA

Figure 2-5. Ralston Afterbay Dam.

Upper American River Pump Station

The initial construction of the MFP included a pump station on the North Fork American River near Auburn and a three-mile tunnel to deliver project water to Western Placer County. In July 1972 Reclamation and PCWA signed an agreement to allow the removal of the pump station as part of the construction of Auburn Dam. The 1972 Agreement also provided that if PCWA required access to its MFP water to meet the needs of its customers before completion of an Auburn Dam, Reclamation would provide a temporary substitute pumping facility. Following the suspension of construction on Auburn Dam in the mid-1970's, Reclamation seasonally installed a temporary pump station to enable PCWA to access its American River water rights in the summer and fall, and then remove the pump station to prevent damage from winter runoff which frequently exceeded the capacity of the Auburn Dam diversion tunnel. Eventually PCWA and Reclamation cooperatively funded a permanent replacement of PCWA's original pump station (PCWA, 2016a). The new pump station, completed in 2007, has an installed capacity of 100 cfs but is designed to be expanded to 200 cfs to meet future agriculture and municipal and industrial (M&I) demands within PCWA's Zone 1 and Zone 5 service areas. The Environmental Impact Report (EIR) for construction of the pump station analyzed diversion of 35,500 AF/year of water right water. Future diversion amounts greater than 35,500 AF/year would require additional environmental review. However, the EIR anticipated that PCWA may need to divert up to a total of 70,500 AF/year to meet future demand (PCWA, 2016a). In 2015, PCWA diverted 24,000 AF of water from the American River Pump Station.

Photo Credit: PCWA

Figure 2-6. American River Pump Station.

Upper American River Project (FERC Project No. 2101)

The Upper American River Project (UARP), owned and operated by SMUD, stretches across three subwatersheds (Silver Creek, Rubicon River, and South Fork American River) in El Dorado County. The project comprises seven separate developments with a total of 11 reservoirs that can store up to 425,000 AF of water and eight powerhouses. The project is operated for hydropower and has an authorized installed capacity of 637 MW (FERC, 2008 and 2014b). The major elements of the project were constructed in the late 1950s and early 1960s and were operational by 1971. The Jones Fork development was completed and became operational in 1985. The following description of project facilities is from the Facilities Management Plan (SMUD, 2015).

Loon Lake Development

The Loon Lake Development, the highest elevation project facilities, began operations in August 1971. It diverts water from the Rubicon River, Highland Creek, Little Rubicon River, and Ellis Creek. The development includes the following:

- **Rubicon Dam** consists of a concrete, gravity, main diversion dam located on the Rubicon River that is 36-feet-high by 644-feet-long, and a concrete, gravity auxiliary dam that is 29-feet-high by 553-feet-long. These structures create the Rubicon Reservoir, which has a storage capacity of 1,450 AF at a maximum water surface elevation of 6,545 feet.

- **Rockbound Tunnel** is a 0.2-mile-long, 13-foot-diameter, unlined, horseshoe tunnel that conveys water from Rubicon Reservoir to Buck Island Reservoir via Rockbound Lake (a non-UARP facility) located on Highland Creek.

- **Buck Island Dam** consists of a concrete, gravity, diversion dam located on the Rockbound Creek that is 23-feet-high by 293-feet-long, and a 15-foot-high by 244-foot-long concrete gravity auxiliary dam. These structures create Buck Island Reservoir, which has a storage capacity of 1,070 AF at a maximum water surface elevation of 6,436 feet.

- **Buck-Loon Tunnel** is a 1.6-mile-long, 13-foot-diameter unlined modified horseshoe tunnel that conveys water from Buck Island Reservoir to Loon Lake Reservoir.

- **Loon Lake Dam** consists of a rockfill dam on Gerle Creek that is 0.4 mile long by 108 feet high, with a 250-foot-long side channel spillway on the right bank, and a 910-foot-long by 95 foot-high rockfill auxiliary dam, and an earthfill dike. These structures create Loon Lake Reservoir, which has a storage capacity of 76,200 AF at a maximum water surface elevation of 6,410 feet.

- **Loon Lake Penstock** comprises a 0.3-mile-long, 14-foot-diameter concrete-lined horseshoe tunnel; 10-foot-diameter concrete lined vertical shaft; and 8.5-foot-diameter steel lined tunnel extending from Loon Lake Reservoir to Loon Lake Powerhouse.

- **Loon Lake Powerhouse**, located over 1,100 feet below the surface of the Loon Lake Reservoir consists of one turbine with a rated capacity of 70.5 MW.

- **Loon Lake Tailrace Tunnel** is a 3.8-mile-long, 18-foot-diameter unlined horseshoe tunnel extending from Loon Lake Powerhouse to discharge into Gerle Creek Reservoir.

Robbs Peak Development

The Robbs Peak Development began operations in October 1965. The development primarily uses water released from the Loon Lake Development supplemented by inflows from Gerle Creek, Angel Creek, and the South Fork Rubicon River. The development includes:

- **Gerle Creek Dam** is a 58-foot-high, 444-foot-long, concrete, gravity overflow structure located on Gerle Creek, upstream of its confluence with South Fork Rubicon River, incorporating the intake of Gerle Creek Canal in its left abutment, creating Gerle Creek Reservoir having 1,260 AF of storage at maximum water surface elevation of 5,231 feet.

- **Gerle Canal** extends 1.9 mile from Gerle Creek Reservoir to Robbs Peak Reservoir.

- **Robbs Peak Dam** is a 44-foot-high, 320-foot-long, concrete, gravity overflow structure, with 12 steel bulkhead gates, all 6.2 feet high, on the spillway crest, located on the South Fork Rubicon River upstream from its confluence with Gerle Creek. The dam impounds 30 AF of water at maximum water surface elevation of 5,231 feet.

- **Robbs Peak Tunnel** is a 3.2-mile-long, 13-foot-diameter, unlined, horseshoe and 11-foot diameter, lined diversion tunnel that conveys water from Robbs Peak Reservoir to Robbs Peak Penstock.

- **Robbs Peak Penstock** is a 9.75- to 8.5-foot-diameter, 0.4-mile-long steel penstock that leads from Robbs Peak Tunnel to Robbs Peak Powerhouse.

- **Robbs Peak Powerhouse**, located on the northeast shore of Union Valley Reservoir, is equipped with one turbine with a rated capacity of 28.1 MW.

Jones Fork Development

The Jones Fork Development began operations in June 1985. The development diverts, stores, and uses water from the South Fork Silver Creek for non-consumptive purposes. It includes the following facilities:

- **Ice House Dam**, located on the South Fork Silver Creek, is 0.3 mile-long and 150 feet high, incorporating a concrete ogee spillway with radial gates, and two auxiliary earthfill dikes. These structures impound Ice House Reservoir, which has a storage capacity of 45,960 AF at a maximum water surface elevation of 5,450 feet.

- **Jones Fork Tunnel** is a 0.3-mile-long, 8-foot-diameter, horseshoe, concrete- and steel-lined tunnel that conveys water from Ice House Reservoir to the Jones Fork Penstock.

- **Jones Fork Penstock** is a 1.6-mile-long, 6-foot-diameter penstock linking the Jones Fork Tunnel to the Jones Fork Powerhouse.

- **Jones Fork Powerhouse**, located on the southeast shore of Union Valley Reservoir, contains a single Francis-type turbine with a rated capacity of 10.4 MW.

Union Valley Development

The Union Valley Development began operations in June 1963. The development primarily uses water from Big Silver Creek, Jones Fork Silver Creek, Tells Creek, and Wench Creek and releases from Robbs Peak and Jones Fork Powerhouses. The development includes:

- **Union Valley Dam**, located on Silver Creek, is a 0.3 mile-long and 453-feet high earth-fill dam. It incorporates a concrete ogee spillway with radial gates. It impounds Union Valley Reservoir with a storage capacity of 277,290 AF at maximum water surface elevation of 4,870 feet.

- **Union Valley Tunnel** is a 268-foot-long, 11-foot-diameter concrete-lined tunnel with an approximately 10-foot diameter steel penstock in part of the tunnel that connects Union Valley Reservoir with Union Valley Powerhouse.

- **Union Valley Penstock** is a 0.3-mile-long, 10-foot-diameter steel penstock that conveys water from the outlet of the Union Valley Tunnel to the Union Valley Powerhouse.

- **Union Valley Powerhouse**, located at the base of Union Valley Dam, is equipped with one turbine with a rated capacity of 40.1 MW.

Jaybird Development

The Jaybird Development began operations in 1961. It uses water released from Junction Reservoir and flows from South Fork Silver Creek and Little Silver Creek. The development includes the following facilities:

- **Junction Dam** is a double curvature, concrete overflow arch dam located on Silver Creek that is 525 feet long and 168 feet high, creating Junction Reservoir, which has a storage capacity of 3,250 AF at maximum surface water elevation of 4,450 feet.

- **Jaybird Tunnel** is a 11- to 14-foot-diameter modified horseshoe tunnel, 4.4-mile-long, that connects Junction Reservoir and the Jaybird Penstock.

- **Jaybird Penstock** is a 6- to 10-foot-diameter steel penstock that is 0.5 mile-long and connects Jaybird Tunnel and Jaybird Powerhouse.

- **Jaybird Powerhouse** is equipped with two Pelton turbines, with a combined rated capacity of 123.2 MW.

Camino Development

The Camino Development began operations in November 1963. It uses water released from Camino Reservoir and Brush Creek Reservoir. The development includes the following facilities:

- **Camino Dam** is a concrete, double curvature, arch dam located on Silver Creek that is 470-feet long and 133-feet high and has three integral bulkhead gates. These structures create Camino Reservoir, which has a capacity of 825 AF at maximum water surface elevation of 2,915 feet.

- **Camino Tunnel** is a power tunnel 5 miles long, with a diameter ranging from 13 feet to 14 feet, that connects Camino Reservoir with the Camino Penstock.

- **Brush Creek Dam** is a double curvature arch dam located on Brush Creek, 213 feet high and 780 feet long, creating Brush Creek Reservoir, which has a storage capacity of 1,530 AF at maximum water surface elevation of 2,915 feet.

- **Brush Creek Tunnel** is approximately 14-foot-diameter modified horseshoe tunnel extending 0.8 mile from Brush Creek Reservoir to the lower end of Camino Tunnel.

- **Camino Penstock** is a 5-foot to 12-foot-diameter, 0.3-mile-long above-ground steel penstock connecting Camino Tunnel and Camino Powerhouse.

- **Camino Powerhouse** – The powerhouse is located on the South Fork American River and is equipped with two turbines: one with a combined rated capacity of 144.6 MW.

Slab Creek/White Rock Development

The Slab Creek/White Rock Development began commercial operation in 1983 and 1968, respectively. They are the most downstream project facilities and discharge into the Chili Bar Reservoir, which is part of PG&E's Chili Bar Project (FERC No. 2155). The Slab Creek/White Rock Development uses water released from Camino Powerhouse and inflow from the South Fork American River and Slab Creek. The development includes the following facilities:

- **Slab Creek Dam** is a double curvature, variable radius, concrete arch dam that stretches across the South Fork American River. It is 250-feet-high and 817-feet-long, with a central uncontrolled overflow spillway. The structures create Slab Creek Reservoir, which has a capacity of 16,600 AF at normal maximum water surface elevation of 1,850 feet.

- **Slab Creek Penstock** is a 40-foot-long, 36-inch-diameter steel penstock that passes through the dam and connects Slab Creek Reservoir with Slab Creek Powerhouse.

- **Slab Creek Powerhouse**, located at the base of Slab Creek Dam, uses minimum stream flow releases, with one turbine with a rated capacity of 0.45 MW.

- **White Rock Tunnel** is an approximately 20- to 24-foot-diameter modified horseshoe tunnel, 4.9 miles long, that connects Slab Creek Reservoir with White Rock Penstock.

- **White Rock Penstock** is a 9- to 15-foot-diameter, 0.3-mile-long aboveground steel penstock that connects White Rock Tunnel to White Rock Powerhouse.

- **White Rock Powerhouse** is equipped with two turbines, with a combined rated capacity of 224.0 MW.

Photo Credit: SMUD

Figure 2-7. Slab Creek Dam.

El Dorado Hydroelectric Project (FERC Project No. 184)

El Dorado Irrigation District (EID) owns and operates the El Dorado Hydroelectric Project (aka Project 184). The project is mostly located in the South Fork American River watershed but includes Echo Lake in the Tahoe Lake/Truckee River Basin. Portions of the El Dorado Project were built from 1860 to 1876 for gold mining operations. After 1884, water from project was used for industrial, irrigation, and domestic purposes in the Placerville area. Following construction of hydroelectric facilities by then owner Western States Gas and Electric Company, hydroelectric operations began in 1924. Western States Gas and Electric Company merged with PG&E in 1927. EID purchased the project from PG&E on April 2, 1999.

Project 184 stores water in Lake Aloha (aka Medley Lakes), Echo Lake, Caples Lake (aka Twin Lakes), and Silver Lake for release after the spring runoff. Echo Lake is located on a tributary to the Upper Truckee River, from where water is exported from the Truckee Basin into the headwaters of the South Fork American River. Lake Aloha, Caples Lake, and Silver Lake are located on tributaries to the South Fork American River. Water released from these reservoirs flows into the South Fork American River and is subsequently rediverted at the El Dorado Diversion Dam near Kyburz into the El Dorado Canal. Canal flows are supplemented along its 22-mile-long length by inflow from five small creeks (Alder, Bull, Ogilby, Esmeralda, and No Name Creek). The canal provides water to the El Dorado Forebay where flows are divided between the El Dorado Powerhouse and the intake to EID's irrigation canal. The canal and forebay are shown in **Figure 2.8**. Flows that enter the powerhouse pass through two single impulse turbines that are directly connected to two 11.5 MW generators. Upon exiting the powerhouse, water is discharged back into the South Fork American River.

The following description of project facilities is from the Final EIS (FERC, 2003) and FERC P-184 license (FERC, 2006).

- **Lake Aloha Dam** includes a 113-foot-long, 20-foot-high rubble and masonry main structure with 11 auxiliary structures. Auxiliary Dam No. 6 functions as the spillway together with the main dam. The reservoir covers 679 acres at full pond elevation of 8,114.07 feet NGVD with a usable storage of 5,179 AF. Water is released from Lake Aloha Main Dam into Pyramid Creek, a tributary to the South Fork, through a 32-inch gated pipe.

- **Echo Lake Dam**, located in the Lake Tahoe Basin, is a 320-feet-long, 14-feet-high concrete structure that includes a 30-foot-long spillway. At a crest elevation of 7,411.5 feet NGVD, Echo Lake covers 370 acres and has a usable storage of 1,943 AF.

- **Echo Lake Conduit** conveys water a distance of 1.2 miles from Echo Lake to the South Fork American River watershed. It consists of a 0.46 mile 36-inch diameter pipe and 0.21-mile-long tunnel.

- **Caples Lake Dam** consists of a main and an auxiliary structure. The main dam is 1,200 feet long and 84.5 feet high and covers 738 acres at full pond elevation 7,797.7 feet NGVD with a usable storage of 20,338 AF (FERC, 2006). The auxiliary dam is a 164-foot-long concrete structure with a crest elevation of 7,800.9 feet NGVD and 1-foot-high wooden flashboards, a 131.5-foot-long concrete arch spillway with a fixed crest elevation of 7,797.9 feet NGVD and 3-foot-high wooden flashboards, and an earthfill section with a concrete core that is 291.5 feet long with a crest elevation of 7,803.9 feet NGVD.

- **Silver Lake Dam** is a 280-foot-long, 30-foot-high rock and earthfill dam with a crest elevation of 7,261.07 feet NGVD. At this elevation Silver Lake covers 692 acres and has a usable storage of 8,640 AF. The dam includes a 55-foot-wide gated spillway comprising two radial gates. A 26-inch gated pipeline conveys water through the dam to Silver Creek.

- **El Dorado Diversion Dam** is located on the South Fork American River downstream from the Silver Fork American River confluence. The 165-foot-long, 9.5-foot-high structure consists of steel bins filled with rock and gravel. At a crest elevation of 3,910.58 feet, it provides 200 AF of storage.

- **El Dorado Canal** is 22.3 miles long flume structure, running parallel to the South Fork American River.

- **Hazel Creek Tunnel** extends 2,200 feet from the El Dorado Canal to Jenkinson Reservoir. The 8-foot horseshoe-shaped tunnel has a design flow capacity of 160 cfs, however, flows are limited to 30 cfs to prevent streambed scour in Hazel Creek (HDR, 2013).

- **El Dorado Forebay** created by the El Dorado Forebay Dam is located at the end of the El Dorado Canal. The forebay serves as a regulating reservoir for the El Dorado Powerhouse. It covers 23 acres at an elevation of 3,792.23 feet and has a useable storage of 356 AF. A 36-inch outlet pipe through the El Dorado Forebay Dam provides water to the EID irrigation canal, which leads to EID's Reservoir 1 Water Treatment Plant.

- **El Dorado Powerhouse** is connected to the El Dorado Forebay by a 2.8-mile-long pipeline and penstock. The powerhouse contains two single impulse turbines and generators with an authorized capacity of 21 MW. Water discharges back to the South Fork American River at the Slab Creek Reservoir.

The El Dorado Dam diversion results in a bypassed reach of the South Fork American River approximately 22 miles in length.

From 2001 through 2019, the district diverted an average of 8,300 AF/year from the El Dorado Forebay to its Reservoir 1 Water Treatment Plant. Over this period, annual diversions varied from a minimum of 4,500 AF/year to a maximum of 12,400 AF/year. EID also diverts Project 184 water from Folsom Lake to supply its El Dorado Hills service area. The EID Folsom are pumps are shown in **Figure 2-9**. From 2001 through 2019 total diversions at this location (including CVP water and other water right water) averaged 6,900 AF/year, varying from 5,200 AF/year to 9,200 AF/year.

Photo Credit: EID

Figure 2-8. El Dorado Canal and Forebay.

Photo Credit: EID

Figure 2-9. El Dorado Irrigation District Folsom Lake Pumps.

Jenkinson Reservoir, Former Sly Park Unit of the CVP

Jenkinson Reservoir and Sly Park Dam were constructed between 1953 and 1955 as the Sly Park Unit of the CVP. In addition to the reservoir and dam, the CVP Unit included the Camp Creek Diversion Dam and Tunnel and the Camino Conduit and Tunnel. EID has operated and maintained the project since its completion in 1955. Ownership of the Sly Park Unit was transferred from Reclamation to EID in 2003. Jenkinson Reservoir is the district's largest reservoir with a maximum capacity of 41,033 AF.

Camp Creek Diversion Dam diverts a portion of Camp Creek flow to Jenkinson Reservoir through the Camp Creek Tunnel. Camino Tunnel and Conduit delivers water from Jenkinson Reservoir to EID's service area for irrigation and municipal use. Additionally, the Hazel Creek Tunnel allows water to be diverted from EID's El Dorado Canal to Jenkinson Reservoir.

Combined, the annual unimpaired flow at the Camp Creek Diversion Dam and Sly Park Dam is 47,800 AF/year, ranging from approximately 3,700 in 1977 to 148,700 AF/year in 1983.[2] The district's annual water right is 33,400 AF, although the average annual yield of the reservoir is approximately 23,000 AF (EID, 2016). From 2001 through 2019, the district imported an average of 21,500 AF/year from Jenkinson Reservoir to its 'Reservoir A' Water Treatment Plant. Over this period, annual imports varied from a minimum of 15,900 AF to a maximum of 25,700 AF.

Foresthill Public Utility District Sugar Pine Reservoir

Foresthill Public Utility District (FPUD) serves unincorporated communities of Foresthill in Placer County within a service area of approximately 13,000 acres. The district's main water source is Sugar Pine Reservoir located on Shirttail Creek, a tributary to the North Fork American River. The

[2] Flow estimates are approximate and are based on both historical gauged data and synthetic data extension.

reservoir has a storage capacity of 6,922 AF. Water right Permit 015375 (A21945) held by FPUD allows for direct diversion from North Shirttail Creek of up to 18 cfs between November 1 and July 1, and a diversion to storage of up to 15,400 AF/year. Water is diverted directly from the reservoir into a nearby water treatment plant that serves the town of Foresthill. Recent diversions reported to the State Water Board vary between 800 and 1,100 AF/year. FPUD's build-out demands are projected to be 3,069 AF/year (FPUD, 2008).

Sugar Pine Reservoir and FPUD water diversions are currently not represented in the CalSim 3 upper American River model and are not discussed further in this document.

Central Valley Project

Folsom Lake and Dam, located approximately 30 miles east of the City of Sacramento, are a critical component of the CVP. Originally authorized by Congress in 1944 as a flood control unit, Folsom Dam was reauthorized in 1949 as a multipurpose facility to also store water for irrigation, domestic, municipal and industrial use, hydropower generation, recreation, water quality and maintenance of flows stipulated to protect fish. Folsom Lake has a capacity of 967 thousand acre-feet (TAF) and covers roughly 10,000 acres when full. CVP water is delivered from Folsom Lake to the City of Folsom, City of Roseville, San Juan Water District (WD), and EID. Non-project water is also delivered from Folsom Lake under Warren Act contracts to the City of Roseville, San Juan WD, EID, and Sacramento Suburban WD.

Lake Natoma and Nimbus Dam, located 7 miles downstream from Folsom Dam, re-regulate power releases from Folsom Dam to provide a steady flow in the lower American River. Releases from Nimbus Dam to the lower American River pass through the Nimbus Powerplant when releases are less than 5,000 cfs or through the spillway gates for higher flows. Water is also diverted from Lake Natoma into the Folsom South Canal for delivery to M&I CVP contractors.

Water is releases from Folsom Lake to the lower American River to meet minimum instream flow requirements below Nimbus Dam. Additional releases are made considering flow fluctuation and stability requirements and to manage water temperatures in the lower American River to meet the needs of salmon and steelhead. Folsom Lake is also operated by Reclamation to help meet Delta salinity and flow objectives established to improve fisheries conditions and to support CVP south-of-Delta exports.

Chapter 3 Model Schematic

This chapter presents an overview of the XML-based schematic that is the foundation of the upper American River model. The schematic is a node-arc network. Nodes represent specific locations or features, such as water control facilities, stream junctions, points of diversions, and return flows. Arcs represent flows between nodes. Mass balance must be observed at each node (i.e., flows in the incoming arcs equal flows in the outgoing arcs except at nodes representing reservoirs where a change in storage may occur). The schematic is available in a rectilinear 'circuit board' form and georeferenced form.

Schematic Components

The schematic defines the level of geographical detail that is represented in the upper American River model. **Figure 3-1** through **Figure 3-11** illustrate the key features of the upper American River model. Specific aspects of the model schematic are described below:

Chili Bar Project

The Chili Bar Project is represented by a single conveyance node (SFA032) on the South Fork American River. FERC flow requirements for the project are imposed at the downstream node (SFA030) corresponding to the Placerville gauge (USGS 11444500).

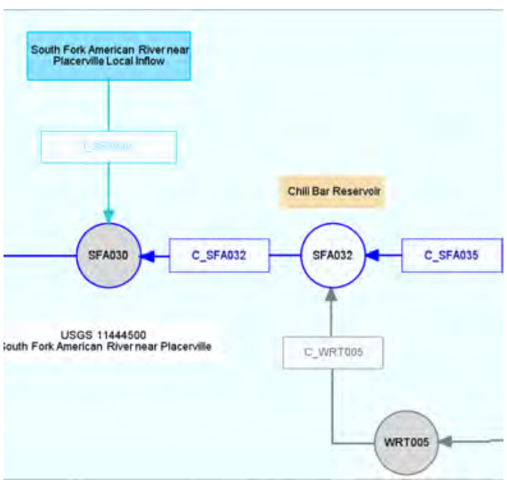

Figure 3-1. Model Representation of Chili Bar Project.

Drum-Spaulding Project

Drum-Spaulding Project facilities included in the upper American River model include Lake Valley Reservoir (storage node LKVLY) and Lake Valley Diversion Dam (node NNA013) on the North Fork of the North Fork American River, and Lake Valley Canal (arc D_NNA013_LVC001). Unimpaired inflow to Lake Valley Reservoir is represented by arc I_LKVLY. River accretions between Lake Valley Dam and Lake Valley Diversion Dam are represented by arc I_NNA013. The model does not represent Kelly Lake.

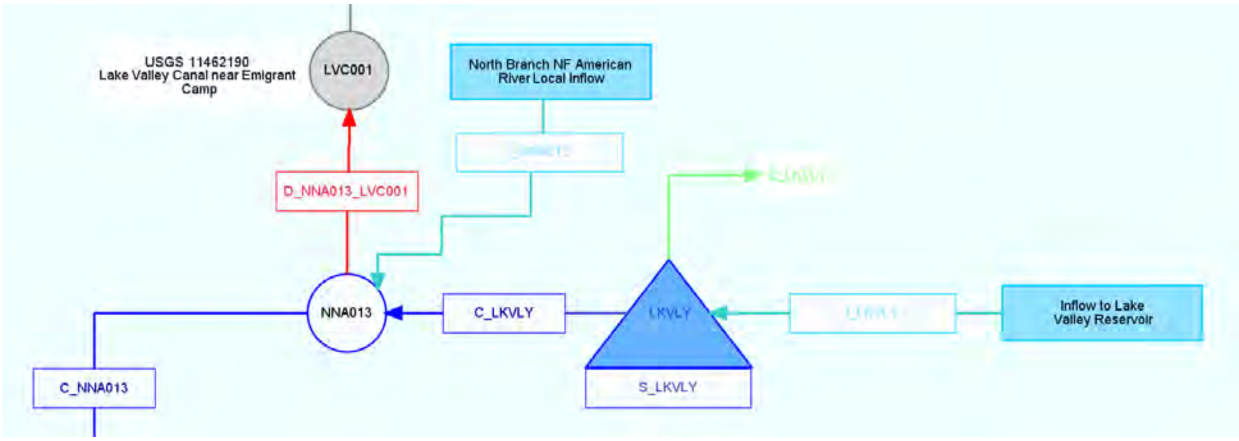

Figure 3-2. Model Representation of Drum-Spaulding Project.

Stumpy Meadows Project

The Stumpy Meadows Project on Pilot Creek is represented by a storage node (STMPY) and associated inflow arc (I_STMPY), the downstream diversion dam (node PLC007), accretions between Stumpy Meadows Dam and the diversion dam (I_PLC007), the Georgetown Divide Ditch (node GDD010) and associated canal losses (D_GDD010_GDDLOS), the Walton Lake Water Treatment Plant (node WTPWAL), and raw and treated water deliveries to the district's service area (arcs D_GDD010_GDPUD_NA, D_WTPWAL_GDPUD_NU). The model also represents the discontinued gauge below Stumpy Meadows Dam (USGS 11432500, Pilot Creek below Georgetown) and the active gauge below the diversion dam (USGS 11433040, Pilot Creek below Mutton Canyon).

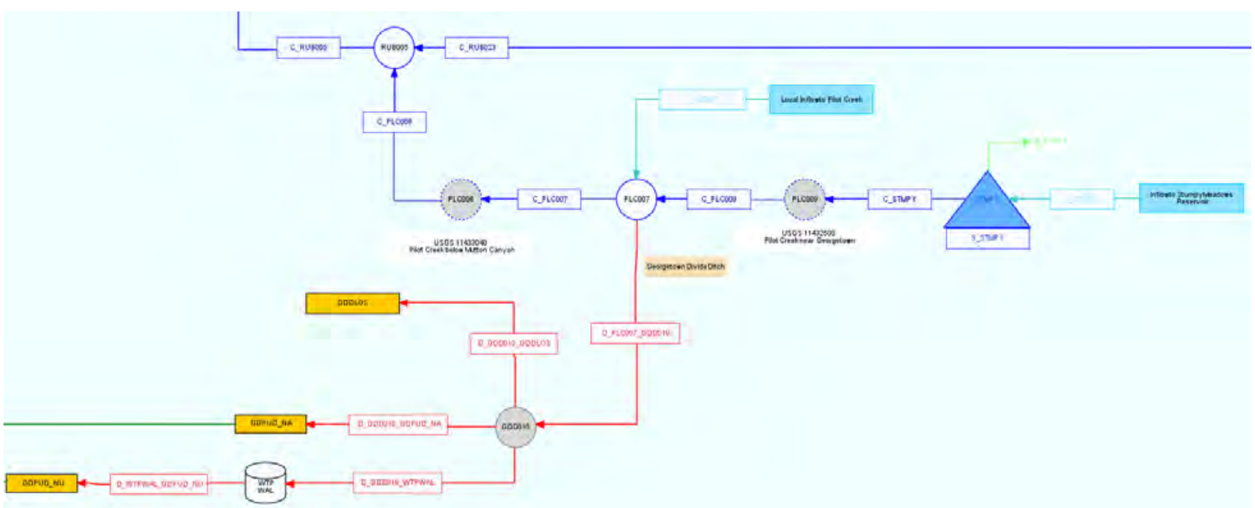

Figure 3-3. Model Representation of Stumpy Meadows Project.

Middle Fork Project

MFP facilities included in the upper American River model comprise French Meadows and Hell Hole reservoirs (storage nodes FRMDW and HHOLE), Duncan Creek Diversion Dam (node DCC009), North Fork and South Fork Long Canyon Creek diversion dams (nodes NLC03 and SLC003), Interbay Dam (node MFA036), and Ralston Afterbay Dam (node MFA026). The model also represents Duncan Creek Tunnel, French Meadows Tunnel and Powerhouse, Hell Hole Tunnel and the Middle Fork Powerhouse, North and South Canyon Creek diversion tunnels, Ralston Tunnel and Powerhouse, and the Oxbow Powerhouse. Unimpaired inflow to French Meadows Reservoir is represented by inflow arc I_FRMDW. Unimpaired inflow to Hell Hole Reservoir is represented by the aggregation of inflow arcs I_RUB047 on the Rubicon River, I_LRB004 on the Little Rubicon River, and I_HHOLE, which represents local inflow to the reservoir. Inflow arc I_DCC010 represents the flow at the Duncan Creek Diversion Dam. Inflow arcs I_NLC003 and I_SLC003 represent flows at North and South Canyon Creek diversion tunnels.

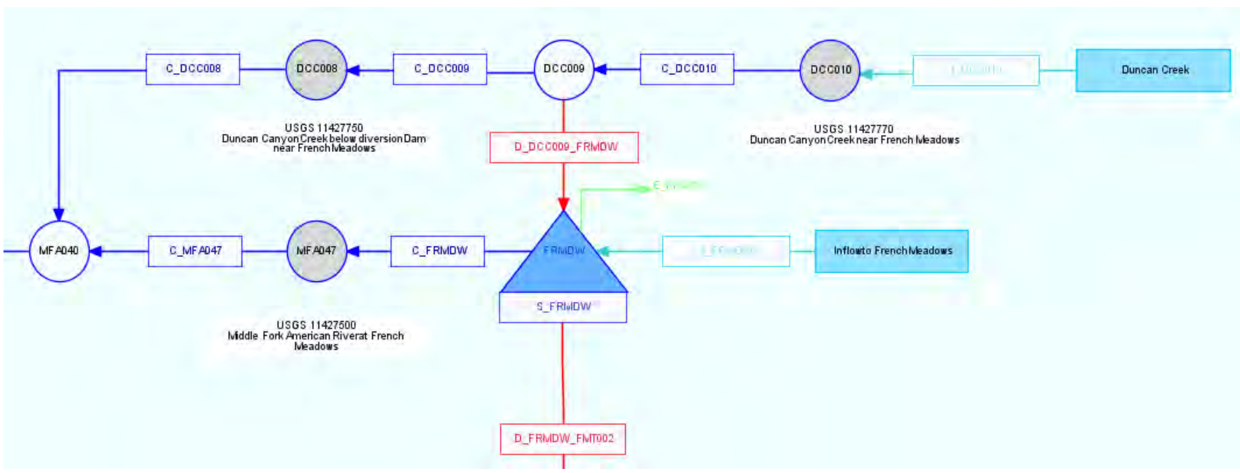

Figure 3-4. Model Representation of Middle Fork Project – Part 1.

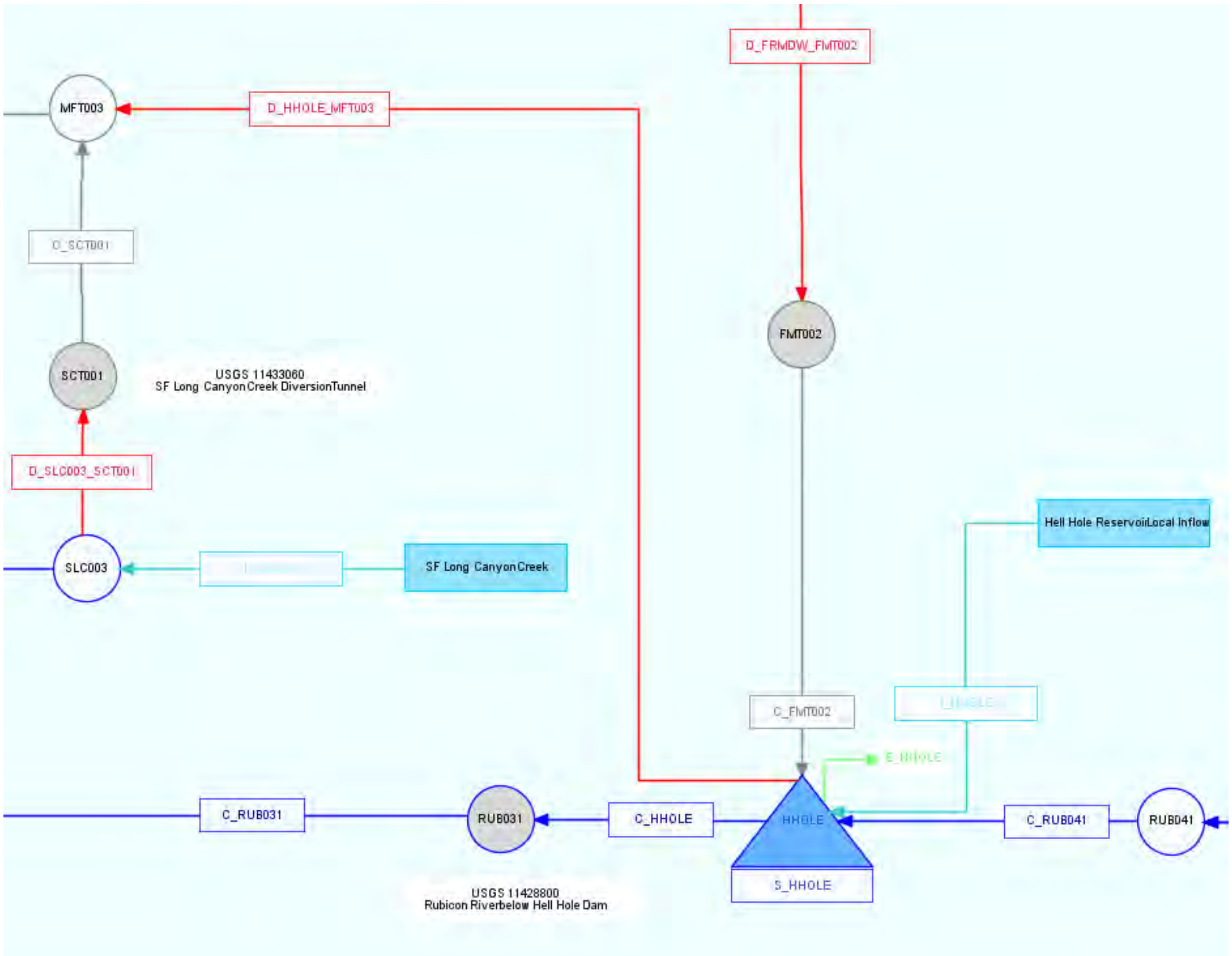

Figure 3-5. Model Representation of Middle Fork Project – Part 2.

Upper American River Project

SMUD's UARP spans the Middle Fork and South Fork American River watersheds. Within the Middle Fork watershed, storage facilities represented in the model include Rubicon Lake (node RUB047), Rockbound Lake (node LRB005), Loon Lake (storage node S_LOONL), and Gerle Reservoir (storage node S_GERLE). The Rubicon-Rockbound Tunnel is represented by node RRT000. The Buck-Loon Tunnel is represented by node BLT000. Loon Lake Powerhouse is represented by node LLT000. The Gerle Canal is represented by diversion arc D_GERLE_SFR006. Water supplies available to the project from the Middle Fork watershed include unimpaired inflows to Rubicon Lake (arc I_RUB047), to Buck Island Lake (arc I_LRB004), to Loon Lake (arc I_LOONL), to Gerle Reservoir (arc I_GERLE), and flow in the South Fork Rubicon River above Robbs Peak Diversion Dam (arc I_SFR006). Robbs Peak Tunnel and Powerhouse that link project facilities in the Middle Fork watershed to those in the South Fork watershed are represented by diversion arc D_SFR006_RPT004 and node RPT004.

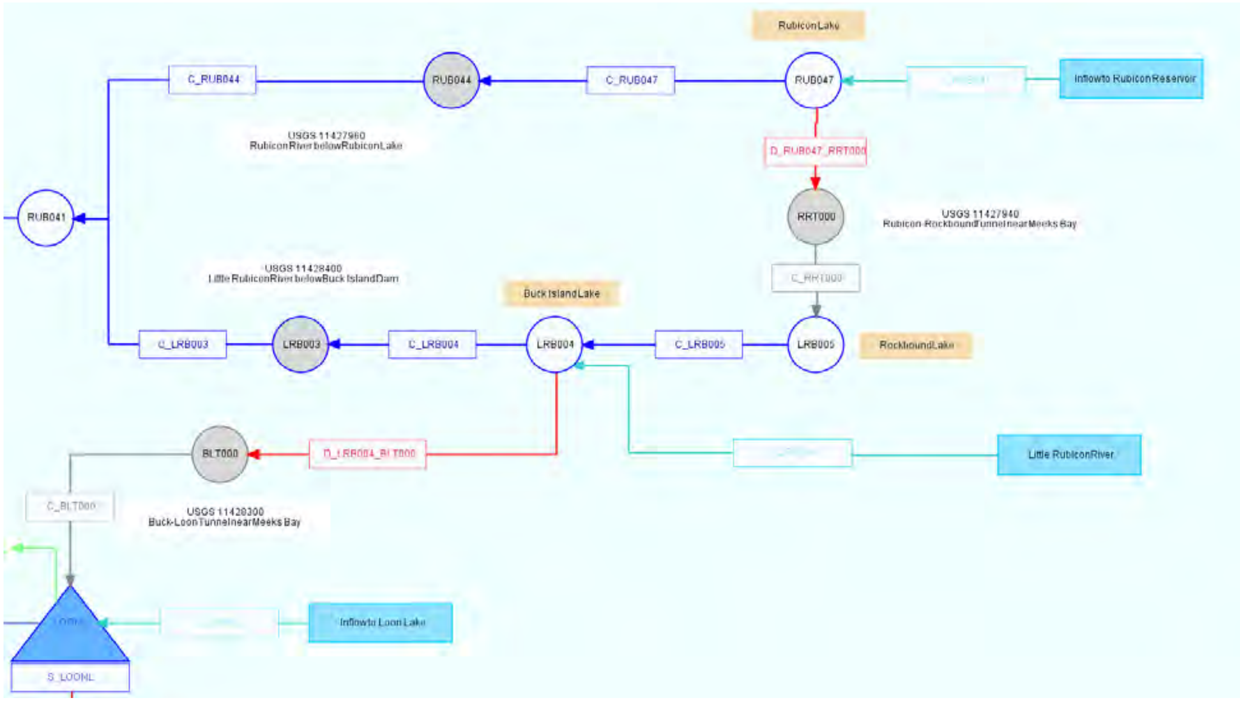

Figure 3-6. Model Representation of Upper American River Project – Part 1.

Within the South Fork American River watershed, storage facilities represented in the model include Union Valley Reservoir (storage node S_UNVLY), Ice House Reservoir (storage node S_ICEHS), and Bush Creek Reservoir (node BSH003).

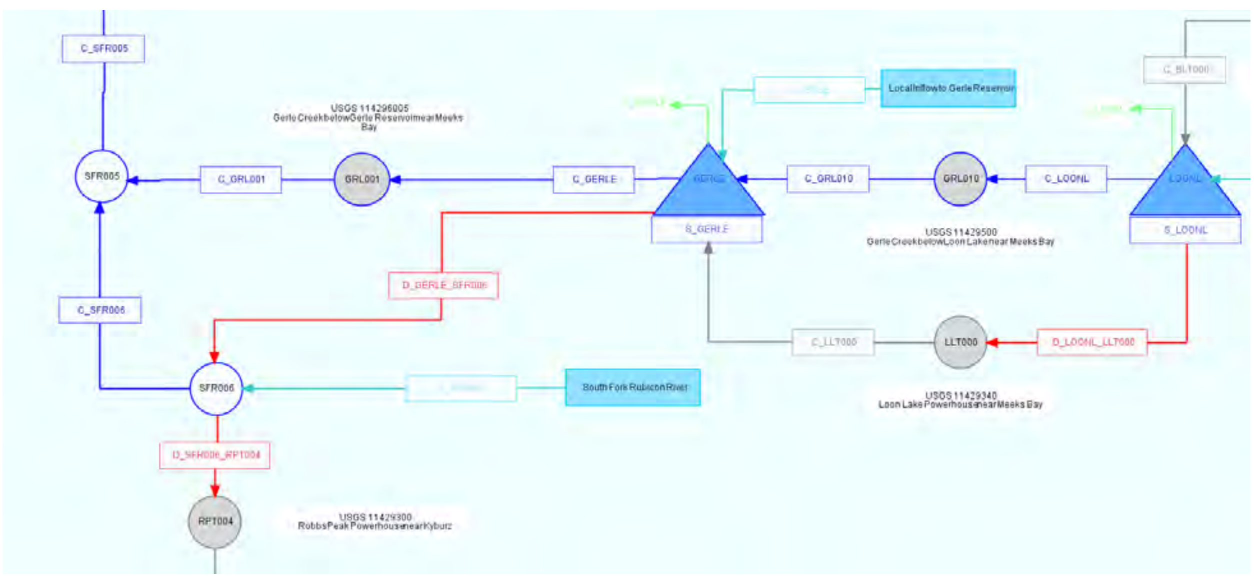

Figure 3-7. Model Representation of Upper American River Project – Part 2.

The Ice House Tunnel and Jones Fork Powerhouse are represented by diversion arc D_ICEHS_IHT002 and node IHT002. The Jaybird Powerhouse is represented by diversion arc

D_SLV015_JBT004 and node JBT004. The Camino Powerhouse is represented by diversion arc D_SLV006_CMN005 and node CMN006. Water that is diverted from Brush Creek to supplement flows through the Camino Powerhouse is represented by diversion arc D_BSH003_CMN005. Water supplies available to the Camino Powerhouse include diversions through Robbs Peak Tunnel, unimpaired inflows to Union Valley and Ice House reservoirs (arcs I_UNVLY and I_ICEHS), unimpaired inflow to Brush Creek Reservoir (arc I_BSH003) and accretions to Silver Creek (arcs I_SLV015, I_SLV006).

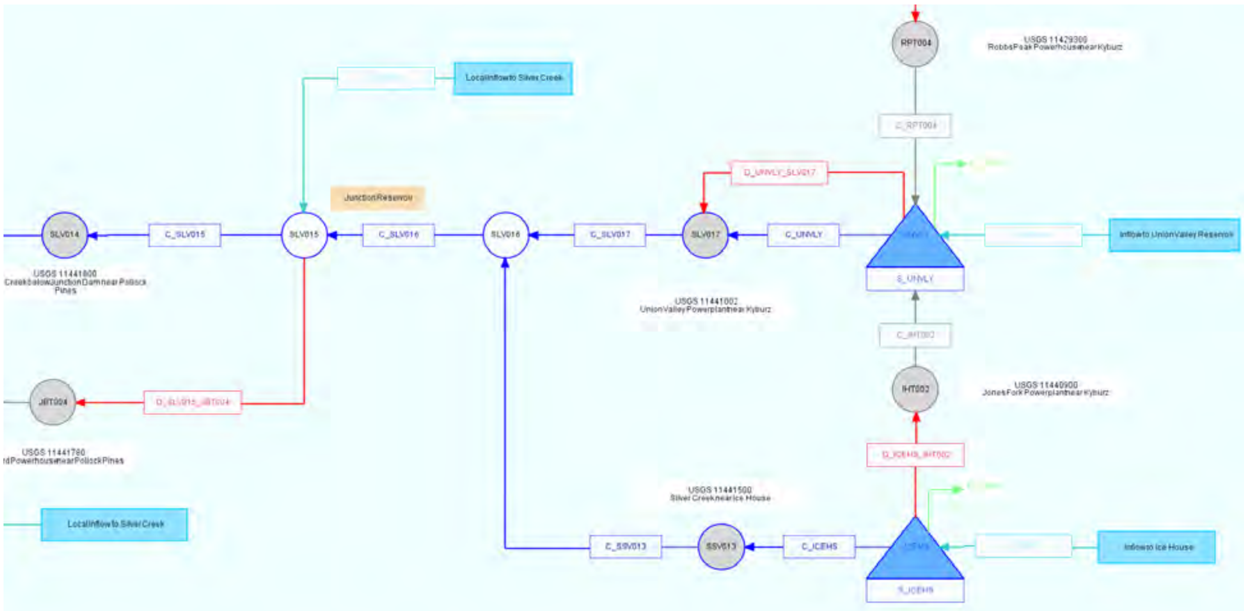

Figure 3-8. Model Representation of Upper American River Project – Part 3.

On the mainstem of the South Fork American River, the simulation model includes Slab Creek Reservoir (node SFA040), White Rock Tunnel (diversion arc D_SFA040_WRT000), and White Rock Powerplant (node WRT000). The model represents river accretions at Slab Creek Reservoir (I_SFA040) and inflows from minor tributaries (I_ALD004, I_ALD002, I_PLM001, I_BSH003, I_RCK001). Flows in Alder Creek may be diverted by EID as part of Project 184 in to the El Dorado Canal.

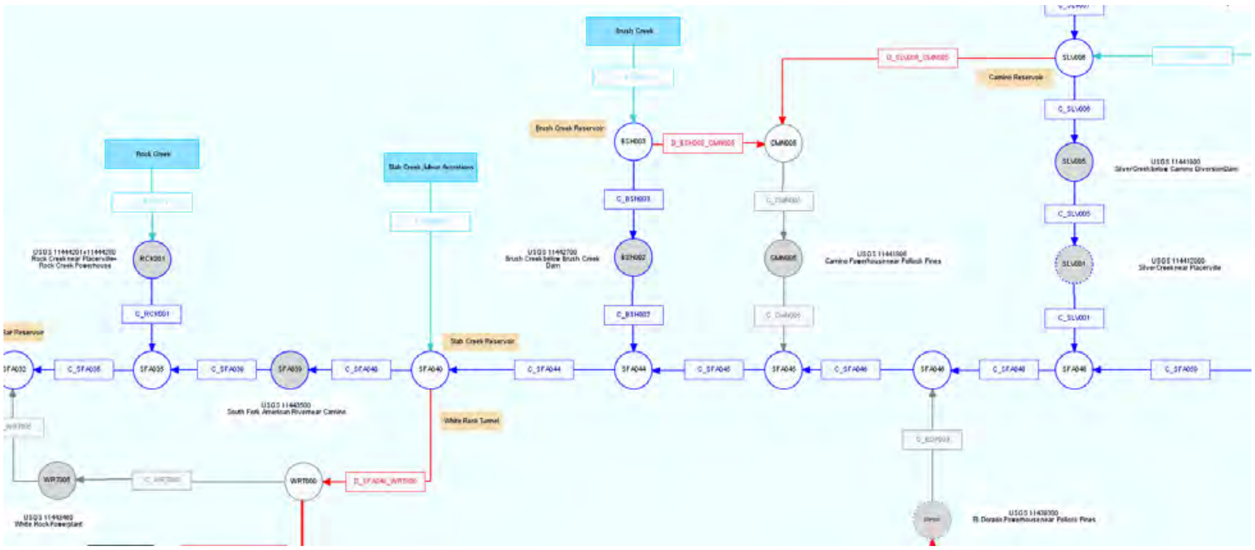

Figure 3-9. Model Representation of Upper American River Project – Part 4.

El Dorado Project

EID facilities included in the upper American River model comprise four reservoirs: Lake Aloha (storage node S_ALOHA), Caples Lake (storage node S_CAPLS), Silver Lake (storage node S_SILVR), and Echo Lake in the Tahoe Basin (storage node ECHOL). The El Dorado Canal is represented by a series of nodes (EDC000 through EDC014). The El Dorado Forebay is represented by node EDC021. The El Dorado Powerhouse is represented by node EDP003. A diversion arc (D_ECHOL_ELC001) represents the Echo Lake Conduit. Water available to the project includes unimpaired inflows to the four reservoirs (arcs I_ALOHA, I_CAPLS, I_SILVR, and I_ECHOL), accretions to the Silver Fork American River (I_SLF009), accretions to Pyramid Creek (I_PYR001), and accretions to the mainstem of the South Fork American River (I_SFA076, I_SFA066).

EID's service area is external to the CalSim 3 Water Budget Area (WBA)[3] domain but is represented in the model by three external demand units: ELDID_NU1, ELDID_NU2, and ELDID_NU3.

[3] CalSim 3 represents the floor of the Sacramento Valley and San Joaquin Valley using demand units and Water Budget Areas (WBA). Demand units represent single of groups of water users. WBAs are more regional in nature, and are the aggregate of a number of demand units.

Model Schematic

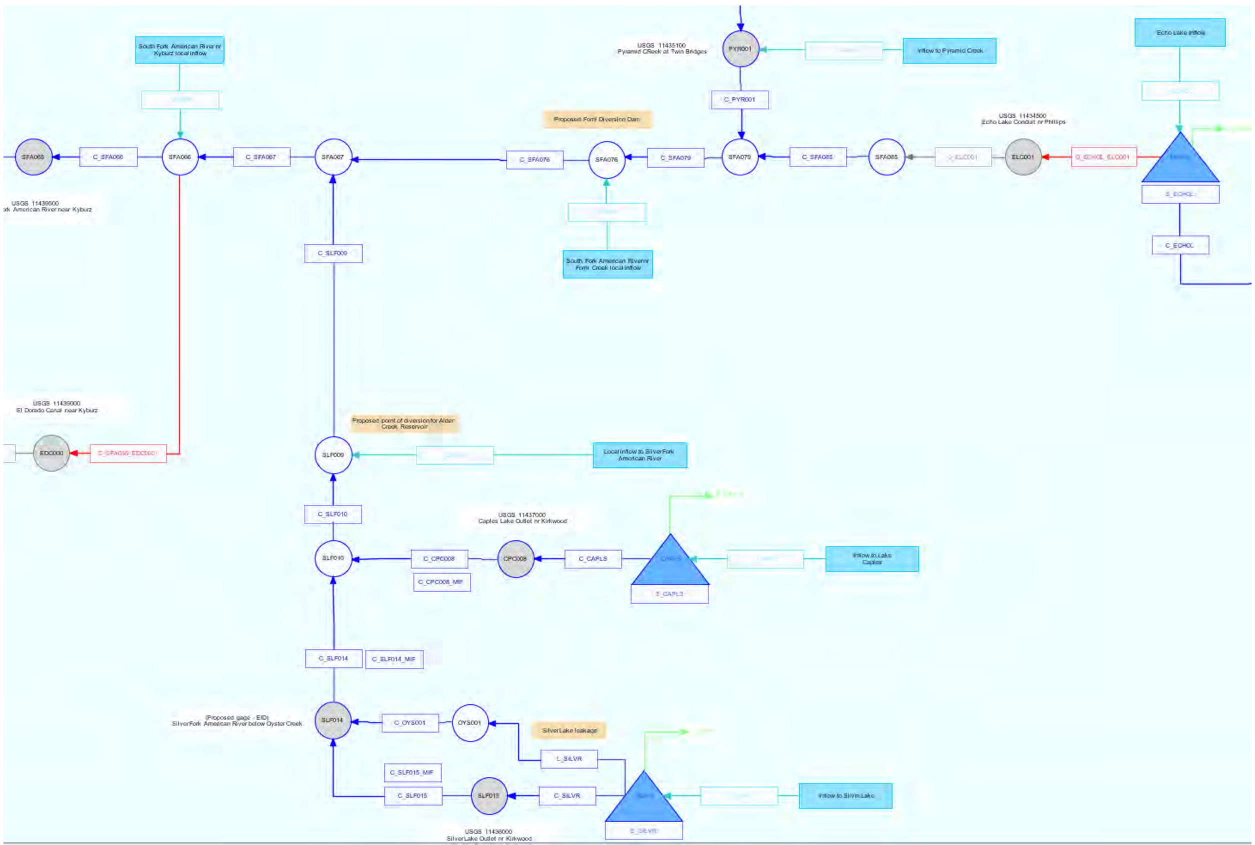

Figure 3-10. Model Representation of Project 184.

Sly Park Unit

EID facilities located in the North Fork Cosumnes River watershed include Jenkinson Reservoir (storage node JNKSN) and Camp Creek Diversion Dam (node CMP014). Deliveries from Jenkinson Reservoir to EID's service area are represented by diversion arc D_JNKSN_WTPRSA. Deliveries to Jenkinson Reservoir from the El Dorado Canal through the Hazel Creek Tunnel are represented by diversion arc D_EDC014_JNKSN. Water supplies available to Jenkinson Reservoir include the unimpaired inflow to Camp Creek (arc I_CMP014) and inflow to Sly Park and Hazel creeks (I_JNKSN).

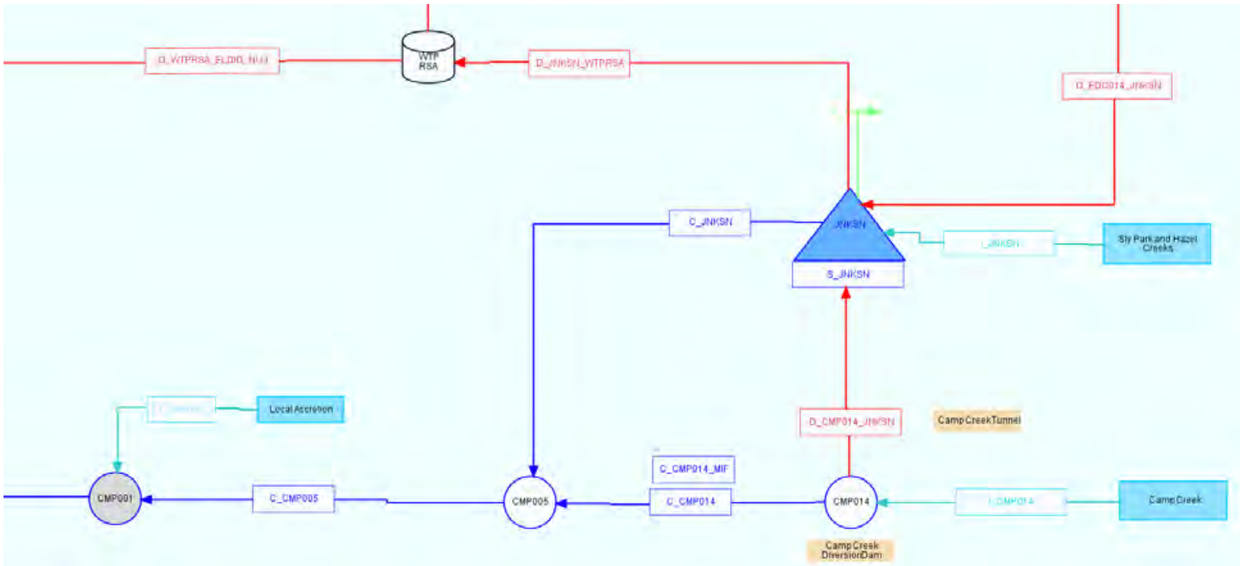

Figure 3-11. Model Representation of Former Sly Creek Unit.

Central Valley Project

The upper American River model includes Folsom Lake and Dam (storage node FOLSM), Lake Natoma and Nimbus Dam (storage node NTOMA), and the Folsom South Canal (nodes FSC003 to FSC027).

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Chapter 4 Water Supplies

The hydrology of the upper American River watershed is represented by preprocessed timeseries of boundary inflows derived from observed streamflow records. The location of these inflows is typically associated with major water control facilities (surface storage reservoirs, diversion dams) or streamflow gauges. Each inflow represents the contributing runoff from a defined subwatershed. Monthly inflows have been developed for October 1921 through September 2015 to represent the flows that would occur under a repeat of historical weather conditions. It is assumed that a repeat of these conditions would result in identical surface runoff and streamflows as historically observed. In many cases streamflow records have been extended using statistical techniques assuming stationarity over the historical period and that statistical relationships between unimpaired streamflows in adjacent watersheds are constant.[4]

This chapter provides an overview of the inflow hydrology development and results. The Hydrology Development Appendix provides additional details of how the individual hydrology computations were performed.

Approach

Beginning with the historical flow, all known impairments are identified and removed so that a natural flow is computed, which represents the runoff that would have occurred in the absence of anthropogenic effects (apart from land use change). Six different types of impairments are considered: imports, exports, storage regulation, reservoir evaporation, stream diversions, and return flows. The unimpairment calculation does not account for the effects of land use change on surface runoff caused by loss of native vegetation and its replacement by irrigated and non-irrigated cropland or urban development.

Historical operations data used to develop the Upper American River hydrology were collected from USGS and California Data Exchange, as well as from agencies operating facilities within the watershed. Historical unimpaired flows at the outflow from each subwatershed were calculated using one of four methods, as follows:

- **Direct gage measurement** – Stream gage data exist at the watershed outflow point for water years 1922 through 2015.
- **Streamflow correlation** – Stream gage data exist at the watershed outflow point for only a limited period between water years 1922 and 2015. These gage data are extended through linear correlation with streamflow records from adjacent watersheds. Double mass plots of

[4] The assumption of stationarity is not appropriate when there has been significant land use change in the rim watersheds or when climate change has significantly affected the timing and amount of runoff.

monthly flows are used to check that a constant (and linear) relationship exists between the dependent and independent variables.

- **Proportionality** – No gage data exist for the watershed. It is assumed that runoff is proportional to the product of drainage area and average annual precipitation depth over the watershed. Outflow is determined through association of the watershed with a similar, but gaged watershed and the use of multiplicative factors representing the ratio of watershed areas and ratio of precipitation depths. Similar to streamflow correlation, it is assumed that no significant land use change has occurred during the historical period. This method is not appropriate where there is significant upstream flow regulation or diversion.

- **Mass balance** – Typically, this method is used when watersheds have significant storage regulation. Reservoir operating records of dam releases and reservoir storage, together with estimated reservoir evaporation, are used to estimate inflows to the reservoir.

Gauge data have been extended through linear correlation of annual flow volumes. Generally, annual volumes are less influenced by watershed characteristics affecting the timing of snowmelt, and retention of precipitation in the upper soil layers or in shallow aquifers. Synthetic or derived annual timeseries data are subsequently disaggregated using one of three methods: (1) disaggregation based on the monthly flow pattern of the independent variable (direct or linear method); (2) disaggregation based on the monthly flow pattern of the independent variable and the average monthly hydrograph of the dependent and independent variables (S-curve method or percent deviation method); and (3) disaggregation based on observed monthly precipitation. The coefficient of determination (r^2) of the observed and derived monthly flows for the common period of record is used to select the appropriate disaggregation method for a particular watershed.

Results

Figure 4-1 shows the Upper American River watershed disaggregated into the model subwatersheds. **Table 4-1** lists each of these subwatersheds, the name of the associated CalSim 3 inflow arc, and provides a short inflow description. **Table 4-2** summarizes the following watershed characteristics:

- Watershed area (acres).
- Estimated annual precipitation (TAF/year) based on 30-year annual average precipitation data from the PRISM Climate Group at Oregon State University for 1981 to 2012.
- Long-term average annual inflows to the downstream watershed (TAF/year).
- Range of annual inflows over the 94-year period of simulation (TAF/year).
- Long-term average annual surface water runoff, or yield, (AF/acre).
- Average flow contribution of the subwatershed compared to total inflows from all subwatersheds in the upper American River watershed (%).

Table 4-3 provides the same information as **Table 4-2**, except inflows are ordered according to long-term average annual inflow, greatest to least. **Table 4-4** presents the average monthly flows.

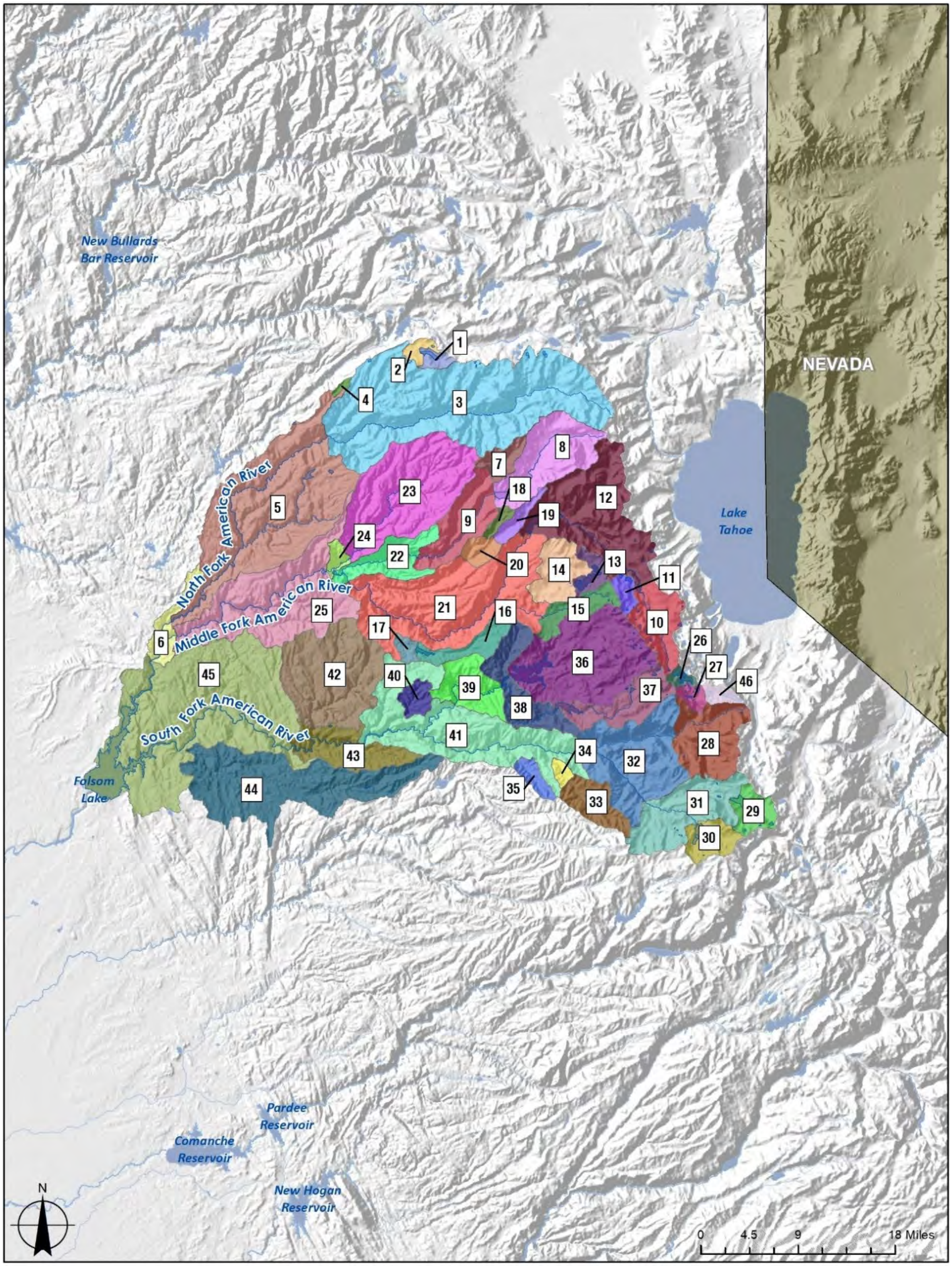

Figure 4-1. Upper American River Subwatersheds.

Table 4-1. Subwatershed Notation and Description

ID	Inflow Arc	Description
North Fork American River Watershed		
1	I_LKVLY	Inflow to Lake Valley Reservoir
2	I_NNA013	Accretion between Lake Valley Dam and downstream diversion dam
3	I_NFA054	North Fork American River at Confluence with North Fork of North Fork
4	I_CYN009	Canyon Creek at Towle Canal Diversion Dam
5	I_NFA022	North Fork American River at North Fork Dam Local Inflows
6	I_NFA016	Local Inflows to North Fork American above Pump Station
Middle Fork American River Watershed		
7	I_DCC010	Duncan Canyon Creek Inflow
8	I_FRMDW	Inflow to French Meadows Reservoir
9	I_MFA036	Local Inflows to Middle Fork American River at the Interbay Diversion Dam
10	I_RUB047	Inflow to Rubicon Lake
11	I_LRB004	Little Rubicon River Inflow to Bucks Island Lake
12	I_HHOLE	Local Inflows to Hell Hole Reservoir
13	I_LOONL	Gerle Creek Inflow to Loon Lake
14	I_GERLE	Local Inflows to Gerle Creek above Gerle Reservoir
15	I_SFR006	South Fork Rubicon River Inflow
16	I_STMPY	Pilot Creek Inflow to Stumpy Meadows Reservoir
17	I_PLC007	Pilot Creek at Diversion Dam
18	I_NLC003	North Fork Long Canyon Creek at Diversion Tunnel
19	I_SLC003	South Fork Long Canyon Creek at Diversion Tunnel
20	I_LNG012	Long Canyon Creek
21	I_RUB002	Local Inflows to Rubicon River
22	I_MFA025	Local Inflows to Middle Fork American at Ralston Afterbay
23	I_NMA003	North Fork of Middle Fork American River Inflow
24	I_MFA023	Local Inflows to Middle Fork American near Foresthill
25	I_MFA001	Local Inflows to Middle Fork American near Auburn
South Fork American River Watershed and Echo Lake		
26	I_ALOHA	Inflow to Lake Aloha
27	I_PYR001	Pyramid Creek - accretion between Lake Aloha and USGS gauge at Twin Bridges
28	I_SFA076	Local Inflows for South Fork American at Forni Creek
29	I_CAPLS	Inflow to Caples Lake
30	I_SILVR	Inflow to Silver Lake
31	I_SLF009	Local Inflows to Silver Fork American River
32	I_SFA066	South Fork American River near Kyburz
33	I_ALD004	Alder Creek
34	I_ALD002	Alder Creek Inflow
35	I_PLM001	Plum Creek Inflow
36	I_UNVLY	Inflow to Union Valley Reservoir
37	I_ICEHS	Inflow to Ice House Reservoir
38	I_SLV015	Local Inflow to Junction Dam
39	I_SLV006	Local Inflow to Camino Dam
40	I_BSH003	Brush Creek
41	I_SFA040	Local Inflows to South Fork American River near Camino, below Slab Creek Reservoir
42	I_RCK001	Rock Creek Inflow
43	I_SFA030	Local Inflows to South Fork American River near Placerville
44	I_WBR001	Weber Creek Inflow
45	I_FOLSM	Local inflow to Folsom Lake
46	I_ECHOL	Inflow to Echo Lake

Table 4-2. Subwatershed Inflow Characteristics

ID	Inflow Arc	Watershed Area (acres)	Average Annual Precipitation[1] (TAF/year)	Average Annual Flow (TAF/year)	Range of Annual Inflows (TAF/year)		Average Unit Yield (feet)	Average Flow Contribution (percent)
					Min	Max		
1	I_LKVLY	4.4	17.8	6.4	1.7	12.4	2.3	0.25%
2	I_NNA013	4.4	18.3	6.6	1.8	12.8	2.3	0.25%
3	I_NFA054	185.4	673.7	346.6	39.9	818.5	2.9	13.31%
4	I_CYN009	1.3	4.6	2.4	0.3	5.6	2.9	0.09%
5	I_NFA022	145.1	402.9	212.9	22.5	508.9	2.3	8.17%
6	I_NFA016	14.5	28.5	15.1	1.6	36.0	1.6	0.58%
7	I_DCC010	9.7	35.6	27.3	3.1	62.9	4.4	1.05%
8	I_FRMDW	47.0	166.7	113.1	17.7	257.8	3.8	4.34%
9	I_MFA036	32.1	109.2	50.2	6.2	121.4	2.4	1.93%
10	I_RUB047	26.5	82.9	74.3	21.7	166.4	4.4	2.85%
11	I_LRB004	5.9	16.4	19.2	8.5	37.5	5.1	0.74%
12	I_HHOLE	81.0	260.6	206.2	39.4	417.9	4.0	7.92%
13	I_LOONL	8.0	23.2	23.7	8.1	51.1	4.6	0.91%
14	I_GERLE	22.7	74.7	47.3	6.4	104.4	3.3	1.82%
15	I_SFR006	15.2	45.6	31.7	4.3	69.9	3.3	1.22%
16	I_STMPY	14.9	46.6	22.3	1.8	63.5	2.3	0.85%
17	I_PLC007	4.0	11.8	8.8	0.7	25.2	3.4	0.34%
18	I_NLC003	3.6	12.3	4.7	0.3	11.8	2.1	0.18%
19	I_SLC003	7.1	24.2	8.5	0.6	20.6	1.9	0.33%
20	I_LNG012	7.4	24.9	13.9	0.6	45.1	2.9	0.53%
21	I_RUB002	107.1	327.9	128.1	8.3	369.9	1.9	4.92%
22	I_MFA025	23.8	68.6	42.9	0.0	170.5	3.2	1.65%
23	I_NMA003	88.7	299.6	175.2	18.1	440.9	2.4	6.73%
24	I_MFA023	4.6	11.8	7.4	0.0	29.4	2.9	0.28%
25	I_MFA001	93.5	228.3	46.5	0.0	204.5	0.8	1.79%
26	I_ALOHA	3.4	10.6	11.2	4.0	19.7	7.3	0.43%
27	I_PYR001	5.3	16.3	18.1	6.4	31.6	7.6	0.69%
28	I_SFA076	39.5	104.2	55.5	10.4	139.6	2.2	2.13%
29	I_CAPLS	13.6	38.2	28.8	9.5	56.0	3.3	1.10%
30	I_SILVR	15.0	48.5	29.1	6.6	64.0	3.0	1.12%
31	I_SLF009	18.6	53.3	63.5	11.8	159.6	5.3	2.44%
32	I_SFA066	67.4	167.4	94.8	17.7	238.3	2.2	3.64%
33	I_ALD004	18.7	47.7	23.6	2.0	63.0	2.0	0.91%
34	I_ALD002	3.3	9.1	4.2	0.4	11.3	2.0	0.16%
35	I_PLM001	7.0	21.2	7.2	0.2	19.3	1.6	0.28%
36	I_UNVLY	83.8	237.9	157.9	41.7	357.0	2.9	6.06%
37	I_ICEHS	27.3	73.4	56.1	16.1	125.4	3.2	2.15%
38	I_SLV015	31.4	96.5	46.4	11.4	104.3	2.2	1.78%
39	I_SLV006	24.5	70.9	26.2	0.0	109.5	3.3	1.01%
40	I_BSH003	8.0	21.7	8.5	0.0	34.6	3.2	0.33%
41	I_SFA040	99.3	267.6	94.2	0.0	351.6	1.0	3.62%
42	I_RCK001	72.9	186.1	47.8	0.0	129.5	1.0	1.84%
43	I_SFA030	31.5	67.4	68.3	0.0	316.4	3.2	2.62%
44	I_WBR001	98.9	194.3	56.9	0.0	172.7	0.9	2.19%
45	I_FOLSM	194.0	346.5	108.2	1.9	370.2	1.3	4.16%
46	I_ECHOL	4.8	14.5	14.8	7.4	25.3	4.9	0.57%
	CT_FAIROAKS_SV			-59.0	-144.0	-1.5		-2.27%
Total				**2,705.67**				**100.0%**

Note:
1. Period 1981-2000. Precipitation data from PRISM Climate Group at Oregon State University.

Key:
TAF = thousand acre-feet

Table 4-3. Subwatershed Inflow Characteristics Sorted by Flow Contribution

ID	Inflow Arc	Watershed Area (acres)	Average Annual Precipitation[1] (TAF/year)	Average Annual Flow (TAF/year)	Range of Annual Inflows (TAF/year)		Average Unit Yield (feet)	Average Flow Contribution (percent)
					Min	Max		
3	I_NFA054	185.4	673.7	346.6	39.9	818.5	2.9	13.31%
5	I_NFA022	145.1	402.9	212.9	22.5	508.9	2.3	8.17%
12	I_HHOLE	81	260.6	206.2	39.4	417.9	4	7.92%
23	I_NMA003	88.7	299.6	175.2	18.1	440.9	2.4	6.73%
36	I_UNVLY	83.8	237.9	157.9	41.7	357	2.9	6.06%
21	I_RUB002	107.1	327.9	128.1	8.3	369.9	1.9	4.92%
8	I_FRMDW	47	166.7	113.1	17.7	257.8	3.8	4.34%
45	I_FOLSM	194	346.5	108.2	1.9	370.2	1.3	4.16%
32	I_SFA066	67.4	167.4	94.8	17.7	238.3	2.2	3.64%
41	I_SFA040	99.3	267.6	94.2	0	351.6	1	3.62%
10	I_RUB047	26.5	82.9	74.3	21.7	166.4	4.4	2.85%
43	I_SFA030	31.5	67.4	68.3	0	316.4	3.2	2.62%
31	I_SLF009	18.6	53.3	63.5	11.8	159.6	5.3	2.44%
44	I_WBR001	98.9	194.3	56.9	0	172.7	0.9	2.19%
37	I_ICEHS	27.3	73.4	56.1	16.1	125.4	3.2	2.15%
28	I_SFA076	39.5	104.2	55.5	10.4	139.6	2.2	2.13%
9	I_MFA036	32.1	109.2	50.2	6.2	121.4	2.4	1.93%
42	I_RCK001	72.9	186.1	47.8	0	129.5	1	1.84%
14	I_GERLE	22.7	74.7	47.3	6.4	104.4	3.3	1.82%
25	I_MFA001	93.5	228.3	46.5	0	204.5	0.8	1.79%
38	I_SLV015	31.4	96.5	46.4	11.4	104.3	2.2	1.78%
22	I_MFA025	23.8	68.6	42.9	0	170.5	3.2	1.65%
15	I_SFR006	15.2	45.6	31.7	4.3	69.9	3.3	1.22%
30	I_SILVR	15	48.5	29.1	6.6	64	3	1.12%
29	I_CAPLS	13.6	38.2	28.8	9.5	56	3.3	1.10%
7	I_DCC010	9.7	35.6	27.3	3.1	62.9	4.4	1.05%
39	I_SLV006	24.5	70.9	26.2	0	109.5	3.3	1.01%
13	I_LOONL	8	23.2	23.7	8.1	51.1	4.6	0.91%
33	I_ALD004	18.7	47.7	23.6	2	63	2	0.91%
16	I_STMPY	14.9	46.6	22.3	1.8	63.5	2.3	0.85%
11	I_LRB004	5.9	16.4	19.2	8.5	37.5	5.1	0.74%
27	I_PYR001	5.3	16.3	18.1	6.4	31.6	7.6	0.69%
6	I_NFA016	14.5	28.5	15.1	1.6	36	1.6	0.58%
46	I_ECHOL	4.8	14.5	14.8	7.4	25.3	4.9	0.57%
20	I_LNG012	7.4	24.9	13.9	0.6	45.1	2.9	0.53%
26	I_ALOHA	3.4	10.6	11.2	4	19.7	7.3	0.43%
17	I_PLC007	4	11.8	8.8	0.7	25.2	3.4	0.34%
19	I_SLC003	7.1	24.2	8.5	0.6	20.6	1.9	0.33%
40	I_BSH003	8	21.7	8.5	0	34.6	3.2	0.33%
24	I_MFA023	4.6	11.8	7.4	0	29.4	2.9	0.28%
35	I_PLM001	7	21.2	7.2	0.2	19.3	1.6	0.28%
2	I_NNA013	4.4	18.3	6.6	1.8	12.8	2.3	0.25%
1	I_LKVLY	4.4	17.8	6.4	1.7	12.4	2.3	0.25%
18	I_NLC003	3.6	12.3	4.7	0.3	11.8	2.1	0.18%
34	I_ALD002	3.3	9.1	4.2	0.4	11.3	2	0.16%
4	I_CYN009	1.3	4.6	2.4	0.3	5.6	2.9	0.09%
	CT_FAIROAKS_SV			-59.0	-144.0	-1.5		-2.27%
Total				**2,705.67**				**100.0%**

Note:
[1] Period 1981-2000. Precipitation data from PRISM Climate Group at Oregon State University.
Key:
TAF = thousand acre-feet

Table 4-4. Subwatershed Average Monthly Flows

Inflow Arc	Average Monthly and Average Annual Flows Water Years 1922 – 2015 (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
I_ALD002	0	0	0	0	0	1	1	1	0	0	0	0	4
I_ALD004	0	1	2	2	3	4	5	5	2	0	0	0	24
I_ALOHA	0	0	0	0	0	1	1	3	3	1	0	0	11
I_BSH003	0	1	1	1	1	1	1	1	1	0	0	0	9
I_CAPLS	0	1	1	1	1	1	3	9	9	3	1	0	29
I_CYN009	0	0	0	0	0	0	0	0	0	0	0	0	2
I_DCC010	0	1	2	2	2	3	5	8	4	1	0	0	27
I_ECHOL	0	1	1	1	1	1	1	4	4	2	1	0	15
I_FOLSM	1	3	12	25	27	27	12	1	1	1	0	0	108
I_FRMDW	1	3	7	8	8	13	21	30	16	4	1	1	113
I_GERLE	0	1	3	4	4	7	11	12	4	1	0	0	47
I_HHOLE	2	7	14	15	15	22	35	54	33	8	2	1	206
I_ICEHS	1	2	3	3	3	4	9	17	11	3	1	0	56
I_LKVLY	0	0	0	0	1	1	1	1	1	0	0	0	6
I_LNG012	0	1	1	2	2	2	3	2	1	0	0	0	14
I_LOONL	0	1	2	2	2	3	5	6	2	1	0	0	24
I_LRB004	0	1	1	1	1	1	3	6	4	1	0	0	19
I_MFA001	1	1	4	7	8	10	8	6	2	0	0	0	47
I_MFA023	0	0	1	1	2	1	1	0	0	0	0	0	7
I_MFA025	1	2	5	7	9	7	5	3	2	1	1	1	43
I_MFA036	0	2	4	5	6	9	11	8	3	1	1	0	50
I_NFA016	0	0	1	2	2	2	3	3	1	0	0	0	15
I_NFA022	2	7	19	26	29	35	36	37	17	4	1	1	213
I_NFA054	3	11	30	41	46	56	59	61	28	7	2	2	347
I_NLC003	0	0	0	0	1	1	1	1	0	0	0	0	5
I_NMA003	2	7	16	20	22	32	37	26	8	3	2	1	175
I_NNA013	0	0	0	0	1	1	1	1	1	0	0	0	7
I_PLC007	0	0	1	1	1	1	2	1	0	0	0	0	9
I_PLM001	0	0	1	1	1	1	1	1	0	0	0	0	7
I_PYR001	0	1	1	1	1	1	2	5	4	2	0	0	18
I_RCK001	1	2	5	7	8	8	7	5	2	1	1	1	48
I_RUB002	1	3	13	21	25	24	18	14	6	2	1	1	128
I_RUB047	1	3	4	3	3	4	10	22	18	6	1	0	74
I_SFA030	2	3	5	7	10	10	9	7	7	4	2	2	68
I_SFA040	1	2	8	14	16	18	14	10	5	2	1	1	94
I_SFA066	1	2	4	5	5	9	17	28	18	5	1	1	95
I_SFA076	0	1	2	3	3	5	10	17	11	3	1	0	56
I_SFR006	0	1	2	3	3	5	7	8	3	0	0	0	32
I_SILVR	0	1	1	1	1	2	5	10	7	1	0	0	29
I_SLC003	0	0	1	1	1	1	2	2	1	0	0	0	9
I_SLF009	1	1	3	3	4	6	11	19	12	3	1	0	63
I_SLV006	1	2	3	4	3	3	4	2	2	1	1	0	26
I_SLV015	1	2	4	5	6	8	11	6	1	1	1	1	46
I_STMPY	0	1	2	3	3	4	4	3	1	1	0	0	22
I_UNVLY	1	5	9	11	12	19	30	43	23	5	1	1	158
I_WBR001	0	2	7	12	12	13	7	2	1	0	0	0	57
CT_FAIROAKS_SV	-4	-2	-3	-2	-1	-2	-7	-12	-9	-6	-6	-6	-59
Total	**27**	**82**	**202**	**282**	**312**	**386**	**440**	**498**	**268**	**73**	**20**	**14**	**2,604**

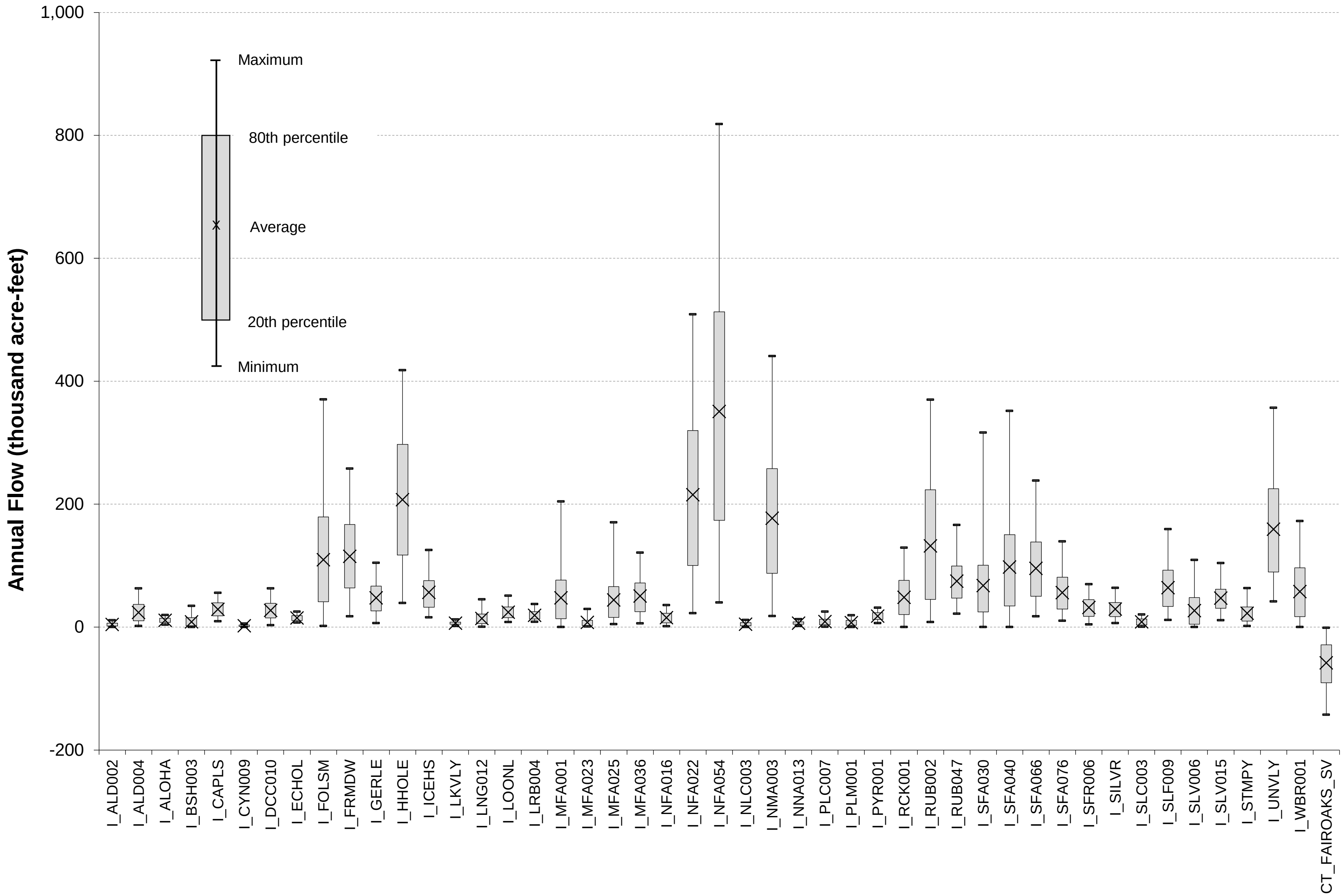

Figure 4-2. Annual Unimpaired Inflows, Upper American River Watershed.

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Chapter 5 Reservoir Evaporation

Reservoir evaporation serves two purposes in the upper American River model. First, estimates of historical evaporation, coupled with reservoir storage and reservoir release data, are used to develop unimpaired inflow data. This is discussed in Chapter 4. Second, reservoir evaporation rates, in inches per month, are used to dynamically compute reservoir evaporative losses at model run time. Reservoir evaporation is calculated as the product of a monthly evaporation rate and reservoir surface area. In model simulation, the area-capacity curve is linearized centered on the beginning-of-month storage so that evaporation becomes a linear function of reservoir storage.

This chapter provides an overview of the development of reservoir evaporation rates and presents summary results.

Approach

Historical daily pan evaporation records exist for many larger reservoirs in California, particularly for reservoirs operated by Reclamation, DWR, or U.S. Army Corps of Engineers. Pan data collected by DWR is published in Bulletin 73-79 (DWR, 1979). Because evaporation data are incomplete, it is necessary to develop a standard method of estimating reservoir evaporation rates beginning October 1921. The upper American River model uses an empirical equation (Samani, 2000) to determine open water evaporation as a function of monthly average maximum and average minimum temperatures and extraterrestrial solar radiation.

$$E_o = \left[0.0023.a.(T_{max} - T_{min})^{0.5}.\ (T_m + 17.8) + b\right].n_d / 25.4 \qquad \text{Eqn. 5-1}$$

where:

E_o = open water evaporation (mm/day)

R_a = extraterrestrial radiation (mm/day)

T_{max} = daily maximum air temperature (°C)

T_{min} = daily minimum air temperature (°C)

T_m = mean daily air temperature (°C)

n_d = the number of days of the month

a, b = calibration coefficients

The mean air temperature is computed as the average of T_{max} and T_{min}. Extraterrestrial radiation is computed based on latitude and Julian day. The constant 1/25.4 is the conversion factor from millimeters to inches.

Temperature Data

Historical temperature data were obtained from the PRISM Climate Group at Oregon State University.[5] PRISM data include estimates of historical maximum and minimum monthly temperatures and dew point available on a 30-arcsecond grid beginning January 1890. Grids of 30-year average (January 1971 – December 2000) monthly maximum and minimum temperatures are also available. These grids are referred to as climate "normals."

Extraterrestrial Radiation

Monthly estimates of extraterrestrial radiation (R_a) as a function of latitude were determined using equations published by Allen et al. (1998). Values are also given by Samani (2000).

Pan Data

Daily pan data were obtained from Reclamation for Folsom Lake beginning March 1955. For Folsom Lake, Reclamation uses a constant value of 0.77 to convert pan evaporation rate to lake evaporation rate. Reclamation assumes that the evaporation rate for Lake Natoma is the same as Folsom Lake. Monthly pan data for Jenkinson Reservoir for water WY 1955-1979 were obtained from Bulletin 73-79. Similarly, pan data for Lake Spaulding for water WY 1950-1978 were obtained from Bulletin 73-79.

Calibration

For each reservoir, the calibration coefficients in Equation 5-1 were determined by the least squares estimator line between observed pan evaporation data and empirical evaporation rate. For each reservoir 12 pairs of coefficients were determined, one pair for each month.

Figure 5-1 presents a scatter plot of observed (x-axis) and derived (y-axis) open water evaporation for Folsom Lake. **Figure 5-2** compares monthly timeseries of observed and derived evaporation rates for Folsom Lake for WY 1976 through 2015.

[5] The Parameter-Elevation Regressions on Independent Slopes Model (PRISM) climate mapping system uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, annual, or event-based climatic parameters. PRISM incorporates point data, a digital elevation model, and information on climatic variation, including rain shadows, coastal effects, and temperature inversions. PRISM data are the official climate data for the U.S. Department of Agriculture (USDA).

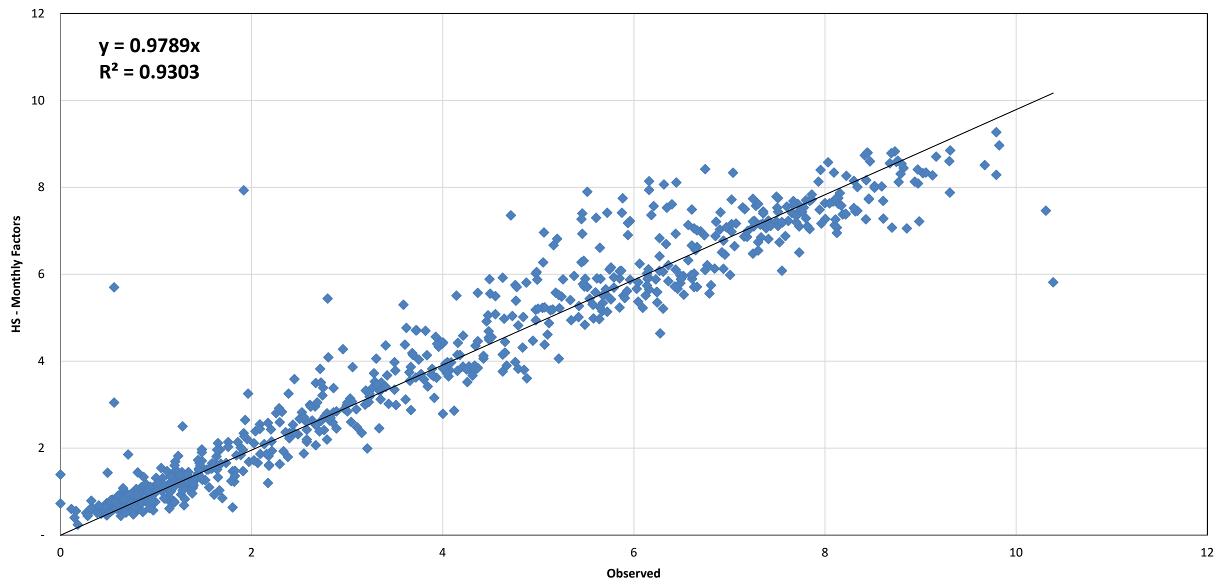

Figure 5-1. Observed and Derived Folsom Lake Evaporation Rate, Scatter Plot.

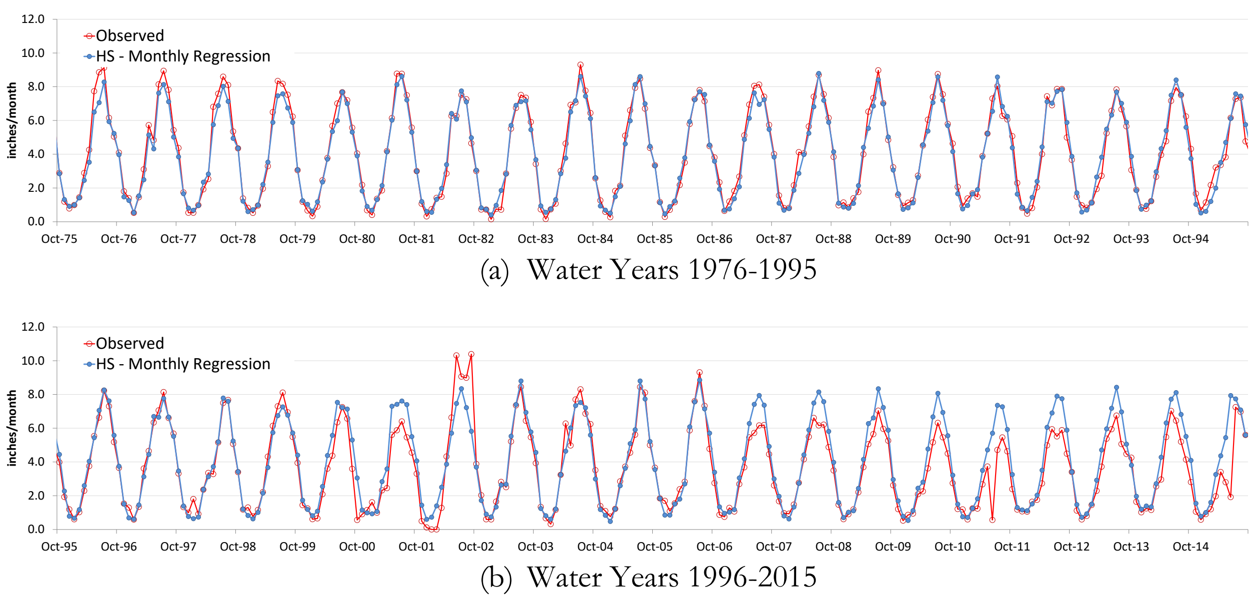

Figure 5-2. Observed and Derived Folsom Lake Evaporation Rate, Timeseries Plots.

Reservoir Evaporation

Where historical evaporation data were not available for a particular reservoir, calibration coefficients from a reservoir most similar in characteristics (latitude, altitude, size) were used, as follows:

Reservoir	Associated Reservoir
Aloha, Caples, Echo, French Meadows, Gerle, Hell Hole, Ice House, Lake Valley, Loon, Silver, Union Valley	Lake Spaulding
Stumpy	Jenkinson Reservoir
Natoma	Folsom Lake

Results

Average monthly evaporation rates resulting from this process are presented in **Table 5-1**.

Table 5-1. Average Monthly Reservoir Evaporation

Month	Evaporation (inches/month)													
	Aloha	Caples	Echo	Folsom	French Meadows	Gerle	Hell Hole	Ice House	Jenkinson	Lake Valley	Loon	Silver	Stumpy Meadows	Union Valley
Oct	4.2	3.9	4.2	3.7	4.2	4.3	4.3	4.4	2.6	4.2	4.1	4.1	2.4	4.4
Nov	1.0	0.8	0.9	1.6	0.9	1.1	1.0	1.1	1	0.9	0.9	0.9	0.9	1.1
Dec	0.5	0.4	0.5	0.8	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Jan	0.4	0.3	0.4	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Feb	0.7	0.8	0.7	1.2	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Mar	1.3	1.1	1.3	2.5	1.4	1.5	1.5	1.6	1.5	1.3	1.4	1.2	1.4	1.6
Apr	2.5	2.2	2.4	3.9	2.5	2.6	2.5	2.7	2.7	2.5	2.4	2.4	2.6	2.7
May	6.0	6.0	6.0	5.8	6.0	6.0	6.0	6.0	4.2	6.0	6.0	6.0	3.7	6.0
Jun	7.6	7.6	7.6	7.1	7.6	7.6	7.6	7.6	6	7.6	7.6	7.6	5.5	7.6
Jul	9.7	10.3	9.7	8.4	9.8	9.6	9.6	9.4	7.5	9.8	10.1	10.0	6.8	9.3
Aug	8.7	9.0	8.7	7.4	8.7	8.6	8.6	8.5	7	8.8	8.8	8.8	6.6	8.5
Sep	6.4	6.8	6.4	5.6	6.4	6.3	6.3	6.2	4.7	6.4	6.5	6.6	4.3	6.2
Total	49.0	49.2	48.9	48.6	49.0	49.2	49.2	49.3	38.8	49.1	49.3	49.1	35.7	49.1

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Chapter 6 Water Rights and Agreements

This chapter briefly describes water rights, water right decisions, court orders, and contractual agreements relating to the upper American River watershed. Its purpose is solely to inform model development and is not a comprehensive assessment and analysis of water rights within these watersheds. Water rights and water contract information is also presented for Folsom Lake and lower American River diversions. This includes a discussion of the Water Forum Agreement (WFA, 2015).

Chili Bar Project

PG&E relies upon a claim of riparian water rights to operate the Chili Bar Powerhouse. PG&E also shares several licensed water rights with SMUD for power generation at the Chili Bar and SMUD powerhouses.

No water rights related code for simulation of the Chili Bar Project were developed for the upper American River model.

Drum-Spaulding Project

As part of the Drum-Spaulding Project, PG&E stores water in Lake Valley Reservoir for subsequent release for power generation at powerhouses located on the Drum Canal, Bear River, Bear River Canal, Wise Canal and South Canal. The company also sells water to Nevada ID and PCWA for agricultural and M&I purposes.

Pre-1914 Appropriative Water Rights

PG&E holds two pre-1914 water rights on the North Fork of the North Fork American River. The first (priority 1853; Statement of Diversion and Use No. 955) is for diversion of up to 40 cfs from the river into the Lake Valley Canal for power generation and domestic use. The second pre-1914 water right (priority 1887; Statement of Diversion and Use No. 952) is for diversion of water from Lake Valley Creek to storage in Lake Valley Reservoir for subsequent power generation at PG&E's Drum-Spaulding Project powerhouses, as well as for irrigation and domestic use. This water right is for diversion of up to 7,964 AF/year of water, which is equivalent to Lake Valley Reservoir's capacity.

Post-1914 Appropriative Water Rights

PG&E holds water right Permit 20253 (A026517) for direct diversion of up to 42 cfs from the North Fork of the North Fork American River to the Lake Valley Canal for hydropower generation and for rediversion at Drum Afterbay, Bear River Canal Diversion Dam, and Halsey Afterbay. The permit allows for direct diversion from November 1 to June 1. The priority date is 1980. The permit requires that PG&E make a fish water release from Lake Valley Diversion Dam of 3 cfs from June 1 to September 30 and 1 cfs for the remaining months of the year. During the period of diversion (November 1 – June 1), the permit restricts the combined rate of diversion under this permit and under claimed pre-1914 water rights to a total of 42 cfs.

Stumpy Meadows Project

GDPUD was formed in 1946 as the successor of the older Georgetown Water Company. This company, as well as its antecedents, held certain rights to both the South Fork Rubicon River and Pilot Creek. Diversions from these sources had been established as early as 1852. The supply from Pilot Creek was supplemented by storage in Loon Lake. The original Loon Lake Dam was constructed in 1884 with a capacity of 8,000 AF, together with a conveyance system to carry water from Loon Lake in to the Pilot Creek drainage and subsequent diversion in to the Georgetown Divide Ditch. The water was primarily used for mining and agriculture along the Georgetown Divide although some water was also used for domestic purposes.

By 1952, GDPUD had purchased all the Georgetown Water Company facilities. In 1957, GDPUD sold the facilities and water rights in the Upper Rubicon River watershed to SMUD to finance the Stumpy Meadows Project. In exchange for these water rights, SMUD agreed to provide GDPUD with financial assistance to construct the Stumpy Meadows Project.

Pre-1914 Appropriative Water Rights

GDPUD claims a pre-1914 water right dating back to about 1863 for an undetermined amount. This water right is described in Application 5644A. The right was originally initiated by the California Water and Mining Company for mining and water supply purposes. The use was gradually changed to power, domestic, and irrigation purposes. The claimed rights include 10,000 AF of storage in Loon Lake and direct diversion from Gerle Creek, Pilot Creek, and all intervening streams up to the capacities of the ditch system at the time the application was filed.

GDPUD pre-1914 statements of water diversion and use for watering 15,000 acres of irrigated agriculture are as follows: S014600 diversion from Deep Canyon; S014601 diversion from Pilot Creek; S014598 diversion from Bacon Canyon; S014597 diversion from Mutton Canyon; and S014599 diversion from an unnamed tributary to Pilot Creek.

Post-1914 Appropriative Water Rights

GDPUD filed water right Application 12421 in 1948 to formalize rights that the district inherited from Georgetown Water Company and to provide for and protect a future potential water supply for Georgetown Divide. Application 12421 also requested a diversion right of 50 cfs and storage rights for 20,000 AF/year in the Pilot Creek watershed, as well as other storage sites in the service area.

GDPUD holds permits granted pursuant to water right applications 5644A, 12421, 16212, 16688, and 27174. These are described in the following sections.

Permit 12827 (A5644A)
Permit 12827 was issued in 1961 pursuant to application 5644A based on a partial assignment of State Filing 5644 with a priority date of July 30, 1927. The permit allows GDPUD the right to directly divert 100 cfs from Pilot Creek and store up to 20,000 AF/year in Stumpy Meadow Reservoir for irrigation, domestic purposes, and stock watering. The seasons for direct diversion and diversion to storage are both from November 1 to August 1 of the following year.

Permit 11305 (A12421)
Permit 11305 for diversion from Pilot Creek has been revoked. GDPUD withdrew its applications for rights in the Upper Rubicon watersheds under A12421 in favor of SMUD but kept that portion of the application related to Stumpy Meadow Reservoir and diversions on Pilot Creek.

Permit 11304 (A16212)
Permit 11304 was issued in 1958 pursuant to application 16212 for a direct diversion from Pilot Creek (50 cfs), Bacon Creek (5 cfs), Deep Canyon (3 cfs), Unnamed Canyon (5 cfs), and Otter Creek (12 cfs) from November 1 through August 1.

Permit 11306 (A16688)
Permit 11306 was issued in 1958 pursuant to application 16688 for a direct diversion from Onion Creek, tributary to Silver Creek, up to 30 cfs from November 1 through August 1, and a diversion to storage of up to 4,000 AF for irrigation, domestic, and stock watering purposes.[6]

Permit 18593 (A27174)
A permit granted pursuant to application 27174 was issued in 1982 for a direct diversion from Pilot Creek, up to 50 cfs from November 1 through August 1 for power generation as part of a planned hydroelectric facility at the base of Stumpy Meadows Dam. The maximum amount that may be diverted is 27,174 AF/year. The maximum combined diversion under Application 27174 and 12421 may not exceed 50 cfs. As of 2018, the hydroelectric plant has not been constructed.

Middle Fork Project

PCWA was established by an Act of the California State Legislature in 1957 to secure and develop water rights in Placer County to provide an adequate water supply for the county's future economic development. To this end, the agency has obtained various water rights, entered into water supply contracts, and purchased and constructed significant water storage, treatment, and delivery infrastructure in Placer County, including the MFP. Existing water right permits allow for the diversion, storage, and rediversion of water from the North Fork American River, Middle Fork American River, and select tributaries. Uses include irrigation, domestic, recreational, municipal, and industrial use in western Placer County and northern Sacramento County. The permits authorize two points of rediversion for consumptive uses: the American River Pump Station at Auburn and Folsom Dam.

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[6] GDPUD has used diversions from Onion Creek as part of the Stumpy Meadows Project. Logging operations have destroyed the conveyance from Onion Creek to Pilot Creek. The District plans to rehabilitate this system in the near future.

Post-1914 Appropriative Water Rights

The water rights for PCWA's MFP are specified in State Water Board Water Rights Decision 1104 (D-1104) approving applications A018084, A018085, A018086, and A018087, and water right permits 18380 and 20754. The permits associated with the applications limit the quantity and timing of both direct diversions and diversions to storage. Water right permits 13855 (A018084) and 13857 (A018086) are for power and recreational purposes and for amounts presented in **Table 6-1**. Water right permits 13856 (A018085) and 13858 (A018087) are for irrigation and incidental domestic, recreational, and M&I purposes and for amounts presented in **Table 6-2**. **Figure 6-1** shows the Place of Use for MFP water.

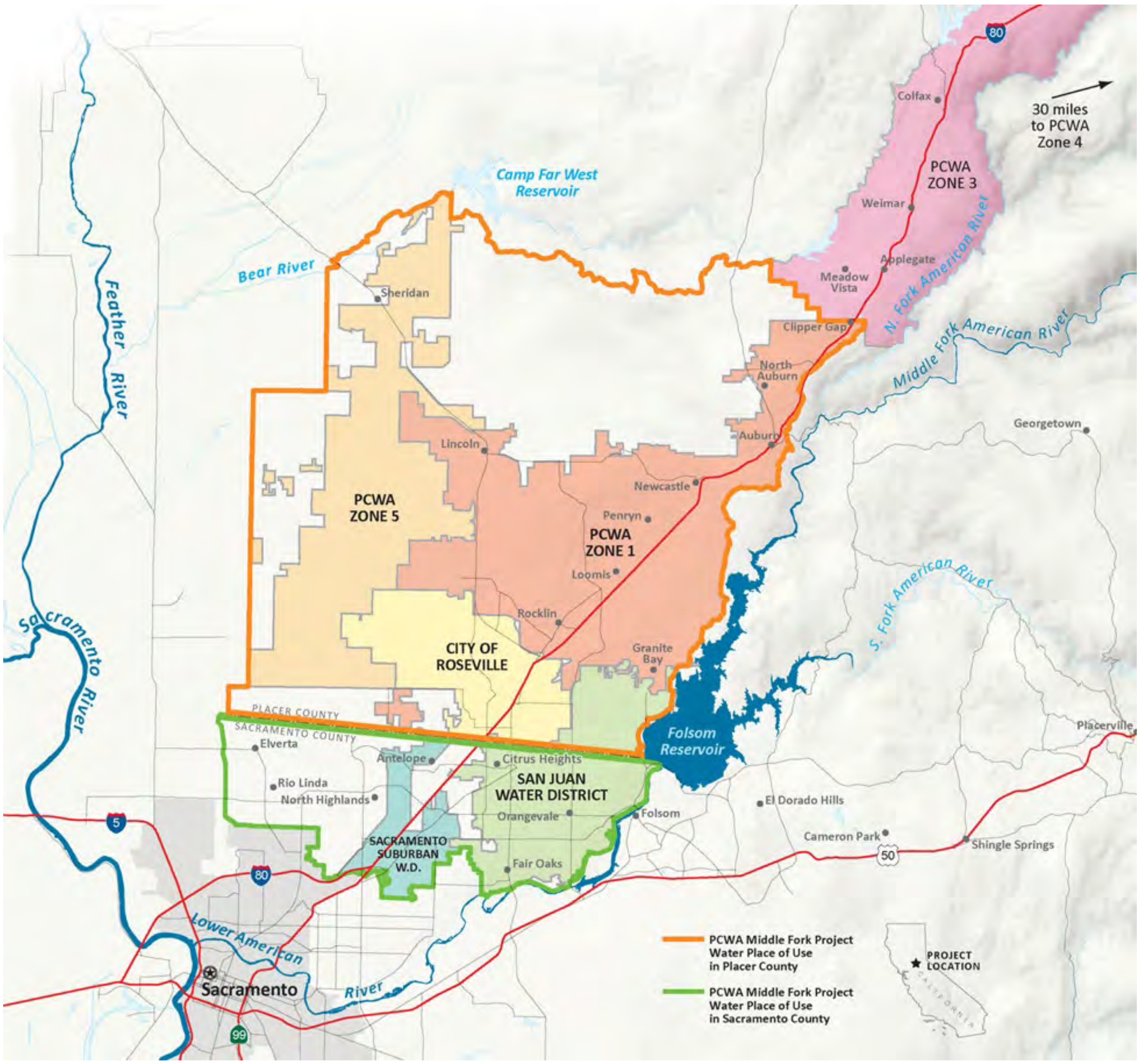

Figure 6-1. Middle Fork Project Place of Use.

Table 6-1. Middle Fork Project Water Rights for Power and Recreational Purposes

Source	Direct Diversion (cfs) Year-Round				Diversion to Storage (acre-feet) Nov 1 – Jul 1		
	P13855 A018084	P13857 A018086	L12644 A26637	P20754 A29721	P13855 A018084	P13857 A018086	Dam
Duncan Creek	150	50			25,000	N/A	French Meadows
MF American River	290	110			95,000	10,000	French Meadows
Rubicon River	675	155	10 - 20	20 - 30	129,000	36,000	Hell Hole
NF Long Canyon Ck	100	N/A			N/A	7,000	Hell Hole
SF Long Canyon Ck	400	N/A			N/A	13,000	Hell Hole
MF American River	1,000	N/A			N/A	N/A	Ralston Interbay
MF American River	1,225	705			N/A	N/A	Ralston Afterbay
Total			11,500	17,640	249,000	66,000	

Key:
cfs = cubic feet per second
MF = Middle Fork
N/A = not applicable
NF = North Fork
SF = South Fork

Table 6-2. Middle Fork Project Water Rights for Consumptive Purposes

Source	Direct Diversion (cfs) Nov 1 – Jul 1		Diversion to Storage (acre-feet) Nov 1 – Jul 1		
	P13856 A018085	P13858 A018087	P13856 A018085	P13858 A018087	Dam
NF American River	1,225	800	N/A	N/A	Auburn Dam site
Duncan Creek			25,000	N/A	French Meadows
MF American River			95,000	10,000	French Meadows
Rubicon River			129,000	36,000	Hell Hole
NF Long Canyon Creek			N/A	7,000	Hell Hole
SF Long Canyon Creek			N/A	13,000	Hell Hole
Total			249,000	66,000	

Note:
The maximum amount of water to be diverted to storage under permits issued pursuant to A18084, 18085, 18086, and 18087 during any one season shall not exceed 133,700 AF at French Meadows Reservoir and 208,400 AF at Hell Hole Reservoir.

Key:
cfs = cubic feet per second
MF = Middle Fork
N/A = not applicable
NF = North Fork
SF = South Fork

Under D-1104, the maximum annual diversion to storage under all permits is 133,700 AF at French Meadows Reservoir (combined Middle Fork American River and Duncan Creek rights) and 208,400 AF at Hell Hole Reservoir. The maximum annual allowable diversion to storage at French Meadows and Hell Hole reservoirs under the individual water rights aggregates to 130,000 AF and 165,000 AF, respectively. Because these latter values are less than the total under D-1104, they are used in the upper American River model. The maximum amount of water that can be diverted and put to beneficial consumptive use under these permits is 120,000 AF/year. In addition to rights on the Middle Fork, PCWA holds consumptive use diversion rights on the North Fork of the American River at Auburn.

PCWA's rights for its Middle Fork American River Project under the foregoing permits and license are subject to the agency's obligations respecting minimum stream flow bypass pursuant to agreements between the California Department of Fish and Wildlife, and provisions under the agency's FERC license for Project No. 2079, whichever is more stringent.

Decision 1400 issued in 1972, while not directly impacting the MFP, established a minimum flow requirement of 75 cfs at the Auburn Dam site for maintenance of fishery resources at not less than pre-Folsom project conditions.

Permit 13855 (A18084)

PCWA was granted a permit pursuant to Application 18084 with priority date of April 7, 1958 for both direct diversion and diversion to storage for power purposes. The maximum diversion to storage is 249,000 AF to be collected between November 1 and July 1, including 25,000 AF from Duncan Creek, 95,000 AF from the Middle Fork American River at French Meadows Dam, and 129,000 AF from the Rubicon River at Hell Hole Dam. The direct diversion is year round and includes: Duncan Creek (150 cfs); Middle Fork American River at French Meadows Dam (290 cfs); Rubicon River at Hell Hole Dam (675 cfs); North Fork Long Canyon Creek (100 cfs); South Fork Long Canyon Creek (400 cfs); Middle Fork American River at Ralston Interbay (1,000 cfs); and Middle Fork American River at Ralston Afterbay (1,225 cfs).

Permit 13856 (A18085)

PCWA was granted a permit pursuant to Application 18085 with a priority date of April 7, 1958 to directly divert a total of 1,225 cfs from the North Fork American River at the Auburn Diversion, and store 249,000 AF of water from Duncan Creek, Rubicon River, and Middle Fork American River primarily for municipal, domestic and irrigation purposes. The water is to be stored in French Meadows Reservoir on the Middle Fork American River and Hell Hole Reservoir on the Rubicon River. Water is diverted from Duncan Creek to offstream storage in French Meadows Reservoir at a maximum rate of 400 cfs. The season for direct diversion and storage is from November 1 to July 1 of the succeeding year. Water stored in the reservoirs is released to supplement low flows during the dry season.

Permit 13857 (A18086)

PCWA was granted a permit pursuant to Application 18086 with a priority date of April 8, 1958 to appropriate the amounts of water presented in **Table 6-1** for power and incidental recreational purposes.

Permit 13858 (A18087)

The permit granted pursuant to Application 18087 is a companion filing to Application 18086, except for the diversion season and the water is for municipal, domestic and irrigation purposes. The season for direct diversion and storage is from November 1 to July 1. Water is diverted from North Fork and South Fork Long Canyon Creeks to offstream storage at a maximum allowable rate of 830 cfs in Hell Hole Reservoirs. Water is also diverted from French Meadows Reservoir, passed through the French Meadows Powerhouse, and stored in Hell Hole Reservoir. Water stored in the reservoirs is to supplement low flows during the dry season.

Permit 18380 (License 12644, A26637)

PCWA was granted a license pursuant to Application 26637 with a priority date of December 1, 1980 to directly divert 20 cfs from May 16 to December 14 annually, and 10 cfs from December 15 to May 15 annually for power purposes from the Rubicon River at Lower Hell Hole Dam. The place of use is at the Hell Hole Powerhouse and the maximum amount of water that can be diverted shall not exceed 11,500 AF/year. The water is for non-consumptive use and is returned to the Rubicon River below Hell Hole Powerhouse. This license uses the required release for fishery maintenance from Hell Hole Reservoir to generate power.

Permit 20754 (A29721)

PCWA was granted a permit pursuant to Application 29721 with a priority date of April 18, 1990 to directly divert 20 cfs from May 16 to December 14 and 30 cfs from December 15 to May 15 annually for power purposes from the Rubicon River at Lower Hell Hole Dam. The maximum simultaneous rate of diversion under this permit, together with that diverted under the license issued pursuant to Application 26637, shall not exceed 40 cfs. The place of use is at the Hell Hole Powerhouse and the maximum amount of water that can be diverted under this permit shall not exceed 17,640 AF/year. The water is for non-consumptive use and is returned to the Rubicon River below Hell Hole Powerhouse. This permit uses the required release for fishery maintenance from Hell Hole Reservoir to generate power.

PCWA – PG&E Agreement

PCWA has an agreement with PG&E for operation of the MFP. Under this agreement, consumptive use operations have priority over hydropower operations. PG&E's hydropower operations are otherwise discretionary.

PCWA – Reclamation Agreement

PCWA has entered into an agreement with Reclamation regarding storage and release of American River water by the MFP (Reclamation, 1962). The February 1962 Agreement provided that PCWA, in the operation of the MFP, could divert up to 120,000 AF/year from the American River. PCWA also has an agreement with Reclamation that the end-of-September total MFP storage cannot exceed the previous year's storage if the April 1 through September 30 estimated unimpaired inflow to Folsom Reservoir is less than 600,000 AF. In addition, Reclamation may require storage at the end of July, August, September, October, November, and December to be no greater than the storage at the beginning of the month if the unimpaired flow to Folsom reservoir is less than 600,000 AF, with the following exception: *If the total inflow to French Meadows Reservoir, including Duncan Creek diversions, exceeds*

19,000 AF in November or December, and the inflow to Hell Hole Reservoir exceeds 45,000 AF in November or December, then the storage may be increased during each month this occurs (Reclamation, 1963).

Upper American River Project

Post-1914 Appropriative Water Rights

SMUD holds water right permits and licenses associated with UARP facilities on the Rubicon, South Fork Rubicon, Silver Creek, and South Fork American rivers. These water rights licenses are briefly described below.

License 11073 (A012323)

License 11073 is for both direct diversion and diversion to storage for hydropower purposes:

- 400 cfs direct diversion of Silver Creek at Union Valley and diversion of Silver Creek water to storage in Union Valley Reservoir up to 195,000 AF/year.
- Diversion of South Fork Silver Creek to storage in Ice House Reservoir up to 49,700 AF/year.

The license limits diversion to storage season as October 1 through July 31 and limits the total diversion to storage to 238,000 AF. The license also limits the total diversion (direct diversion plus diversion to storage) to 459,300 AF/year and sets the total of diversions under license 11703 plus license 10495 to 528,400 AF/year.

License 11074 (A012324)

License 11074 allows year-round direct diversion for 500 cfs of direct diversion of Rubicon River at Rubicon Reservoir, 200 cfs of direct diversion of Little Rubicon River at Buck Island and Rockbound Reservoirs, 325 cfs of direct diversion from Gerle Creek at Gerle Reservoir, and 175 cfs of direct diversion from the South Fork Rubicon River at Robbs Peak Reservoir. The License also allows for diversion to storage between October 1 and July 31 from all the direct diversion sources of 92,000 AF at Loon Lake and 141,500 AF at Union Valley. The total amount diverted to storage each year is limited to 226,000 AF, and the total amount diverted (direct diversion plus diversion to storage) is limited to 281,100 AF/year, and the total use (at Robbs Peak Powerhouse) is limited to 250,000 AF/year. In 1998, the State Water Board modified the license to move 450 AF of storage from Union Valley to Rubicon Reservoir, and 440 AF of storage from Union Valley to Buck Island.

License 10495 (A014963)

License 10495 is for 800 cfs direct diversion of South Fork American River at Slab Creek Dam and a 400 cfs direct diversion of Silver Creek at Union Valley Reservoir.

License 10496 (A020522)

License 10496 is for 1,900 cfs direct diversion of up to from the combined sources of Brush Creek and the South Fork American River.

License 10513 (A022110)
License 10513 is for 800 cfs direct diversion of South Fork American River at Slab Creek Dam for hydropower purposes.

Permit 19025 (A026768)
Permit 19025 is for a 270 cfs direct diversion of South Fork Silver Creek at Ice House Reservoir, diversion of South Fork Silver Creek to storage at Ice House, and diversion of South Fork Silver Creek to storage in Union Valley. Diversions to storage is limited to 60,000 AF/year to be collected from October to July.

Permit 21261 (A031595)
Permit 21261 is for storage in SMUD's Rubicon River reservoirs and direct diversion from the Upper Rubicon River.

Permit 21262 (A0331596)
Permit 21262 is for storage in SMUD's regulating reservoirs located on the South Fork American River up to a total combined 27,500 AF/year.

El Dorado Project

EID uses its water right to supply customers at high elevation in the eastern part of its service area and uses a mix of CVP water and its own water rights to supply two residential areas known as the Lake Hills Estates and El Dorado Hills in the western part of its service area. Water is diverted at the El Dorado Forebay, Jenkinson Reservoir, and Folsom Lake. District diversions from its Folsom Lake raw water pumping plant are limited by the 26 million gallons per day (mgd) capacity of the El Dorado Hills Water Treatment Plant (WTP) (approximately equivalent to 29,000 AF/year).

Pre-1914 Appropriative Water Rights – American River Watershed
EID holds two pre-1914 water rights associated with Project 184. The first water right (Statement S009034) is for a 70 cfs year-round diversion for both power and consumptive use with a priority date of 1856. The second water right (Statement S004708) is for the first 5,400 AF of storage release from Caples, Silver, and Echo lakes. Additional releases are made pursuant to License 2541 and/or Permit 21112.

The district has a pre-1914 consumptive water entitlement of 15,080 AF/year at the El Dorado Forebay (EID, 2016).

The district also holds pre-1914 water rights for diversions from Weber Creek (Statement S014968), Slab Creek (Statement S014968), and Hangtown Creek (Statement S014967) that provide approximately 4,560 AF of water in a normal year. EID holds water right License 2184, which grants the district the right to store water in Weber Reservoir. Since 2003, the district has rediverted this water at Folsom Lake under a series of temporary Warren Act contracts with Reclamation. In 2011, the district recently signed a permanent Warren Act Contract (06-WC-20-3315) with Reclamation for diversion of this water at its Folsom Lake raw water pumping plant. The Warren Act contract limits annual diversions under the combined pre-1914 and appropriative rights to 4,560 AF/year during the CVP contract year.

The upper American River model does not explicitly represent the water available at the former Weber Creek, Slab Creek, and Hangtown diversions. This water is part of a general accretion to the South Fork American River and Folsom Lake. The model assumes that 4,560 AF of water are available each year.

Pre-1914 Appropriative Water Rights – North Fork Cosumnes River Watershed

EID holds pre-1914 water rights on Camp Creek (Statement S022682) to divert 12.5 cfs for consumptive use from May through October. This water is diverted in to Jenkinson Reservoir and constitutes the first 12.5 cfs of flow through the Camp Creek diversion tunnel during the diversion season.

EID also holds pre-1914 water rights on Clear Creek (Statement S013502) and North Fork Cosumnes River (Statement S013501) to divert up to 15 cfs and 5,000 AF/year into Crawford Ditch and the North Fork Cosumnes Extension. These ditches provide raw water to rural properties in Pleasant Valley and Diamond Springs. These water supplies are demands are not currently represented in the upper American River model nor in CalSim 3.

Post-1914 Appropriative Water Rights – American River Watershed

EID holds a mix of post-1914 water right permits and licenses for diversion of American River water for both hydropower and consumptive uses. However, it does not hold a post-1914 water right for consumptive use diversion at the El Dorado Forebay.

License 438 (A00654)

License 438 grants storage operation of Caples and Aloha lakes for power production. The license allows for 8,000 AF/year of storage at Caples Lake and 5,000 AF/year of storage at Lake Aloha and rediversion into the El Dorado Powerhouse. The priority date is 1917.

License 2540 (A01440)

License 2540 is for an 86 cfs year-round direct diversion for power generation for use at the El Dorado Power Plant with a priority date of 1919. The point of diversion is the Kyburz Diversion Dam.

License 2541 (A01441)

License 2541 grants storage operation of Aloha, Caples, and Silver Lakes for power production. The license allows for 17,000 AF/year of storage at Caples Lake, 5,000 AF/year of storage at Silver Lake, and 500 AF/year of storage at Lake Aloha and rediversion into the El Dorado Powerhouse. The priority date is 1919.

Permit 21112 (A5645B)

The district also holds water rights associated with Project 184, under which water is diverted from the South Fork of the American River near Kyburz. Historically, Project 184 water was used for power generation and other nonconsumptive uses. However, in 2001, the State Water Board issued

Water Right Order 2001-22, granting EID and El Dorado County Water Agency (WA) consumptive water rights to 17,000 AF/year (Permit 21112). The district is negotiating a Warren Act Contract with Reclamation for use of unused storage in Folsom Lake and diversion of up to 17,000 AF at its Folsom Lake raw water pumping plant.

Permit 21112 is for a diversion to storage of at Aloha (5,350 AF/year), Silver (6,000 AF/year), and Caples Lake (21,581 AF/year) from November 1 through July 31. It also grants direct diversion and rediversion of 17,000 AF/year at Folsom Lake. The priority date is 1927. Direct diversion is limited to 15,000 AF/year from November 1 to July 31 at a maximum diversion rate of 156 cfs. Water must originate from the South Fork American River watershed upstream from Kyburz Diversion Dam.

Post-1914 Appropriative Water Rights – North Fork Cosumnes River Watershed

EID holds two licenses associated with Jenkinson Reservoir operations. Combined, the licenses grant up to 36,700 AF/year collection to storage and a total withdrawal from Camp Creek and Sly Creek of up to 40,300 AF/year. The maximum amount that can be put to beneficial use is 33,400 AF/year.

License 11835 (A002270)

Licenses 11835 and 11836 (see below) allow for 33,400 acre-feet of diversion from the Cosumnes River watershed. These diversions are stored in Jenkinson Reservoir, the largest storage EID, or are directly delivered to the district. License 11835 grants: (a) 27.1 cfs by direct diversion from Sly Park Creek; (b) 43.8 cfs by direct diversion from Camp Creek; (c) 7,000 AF/year diversion to storage from Sly Park Creek; and (d) 15,000 AF/year diversion to storage from Camp Creek. The period of direct diversion is April 15 to June 15. The period of diversion to storage is November 15 to June 1 of the following year. The maximum combined direct diversion is 63.8 cfs.

License 11836 (A005645A)

License 11835 grants: (a) 30.7 cfs by direct diversion from Sly Park Creek; (b) 24.2 cfs by direct diversion from Camp Creek; (c) 5,400 AF/year diversion to storage from Sly Park Creek; and (d) 9,400 AF/year diversion to storage from Camp Creek. The period of direct diversion is November 1 to April 14 and from June 16 to June 30. The period of diversion to storage is November 1 to June 30 of the following year. The maximum combined direct diversion is 32.5 cfs.

Central Valley Project Water

In 1958 and in 1964, EID signed contracts with Reclamation (14-06-200-7312A and 14-06-200-1357A) to obtain CVP water from Folsom Lake. These contracts are for a supply to the Lake Hills Estates for up to 50 AF/year and to El Dorado Hills for up to 7,500 AF/year, both for M&I purposes.[7] In 2006, the two contracts were consolidated into a single contract (14-06-200-1357A) and renewed for the period of 2006 through 2045.

[7] In 1964, Reclamation entered into a contract with El Dorado Hills County WD for a maximum amount of 37,600 acre-feet per year. This contract was assigned to EID in 1973, and subsequently reduced to a fixed amount of 6,500 acre-feet per year in 1979. In 1983, the contract amount was increased to its present amount of 7,500 acre-feet.

Fazio Water

Section 206 of Public Law 101-514, passed by Congress in 1990, directed Reclamation to provide up to 50,000 AF/year of water in the American River Division of the CVP for use by Sacramento County WA, San Juan WD, and El Dorado County WA. This water is commonly referred to as Fazio water. In October 2019, El Dorado County WA signed an agreement with Reclamation giving it access to the 15,000 AF of Fazio water. This water may be diverted at Folsom Lake under a subcontract with EID for use in EID's service area, or alternatively may be made available to GDPUD through an exchange agreement with an upstream water purveyor. For example, PCWA's American River Pump Station could serve as the new point of diversion. Georgetown Divide PUD would receive MFP water in return for relinquishing its CVP water at Folsom Lake. Delivery to GDPUD would require construction of additional infrastructure.

Recycled Water

EID began producing recycled water for landscape irrigation purposes in 1979. Tertiary treated water from Deer Creek and El Dorado Hills wastewater treatment plants supplies western portions of the service area that are plumbed for recycled water. Currently, the peak seasonal demand for recycled water exceeds the quantity produced. The two wastewater treatment facilities are currently able to produce approximately 2,400 AF/year of recycled water and are projected to expand to 3,500 AF annually by 2040 (EID, 2016).

Water Forum Agreement

The American River Water Forum is a diverse group of water managers, local governments, business and agricultural leaders, environmentalists, and citizen groups that, in 1995, joined efforts to devise a plan for water supply in Sacramento County. The Water Forum established two coequal goals: to provide a reliable and safe water supply for the region's economic health and planned development to the year 2030; and to preserve the fishery, wildlife, recreational, and aesthetic values of the Lower American River.[8]

Most of the public water purveyors within Sacramento County are signatories of the Water Forum Agreement Memorandum of Understanding (MOU) of 2000. This agreement includes Purveyor Specific Agreements (PSA) that detail each purveyor's Water Forum commitments. To enable the region to achieve its goals, the Water Forum Agreement describes how the region will address groundwater management, surface water diversions, dry and critical year water supplies, and water conservation goals. All of these activities are balanced with the need to protect the lower American River.

The Water Forum PSAs establish actions to be taken during dry and critical (or driest) years, limiting diversions from the American River to help preserve the ecosystem of the river. The definition of Water Forum water year type is based on the unimpaired inflow to Folsom Lake (UIFR) from March through November, as follows:

[8] Water Forum Agreement, January 2000

- **Wet year** – March to November unimpaired inflow to Folsom is greater than 1,600,000 AF.
- **Average year** – March to November unimpaired inflow is between 950,000 and 1,600,000 AF.
- **Dry year** – March to November unimpaired inflow is between 400,000 and 950,000 AF.
- **Driest (conference) year** – March to November unimpaired inflow is less than 400,000 AF.

Table 6-3 summarizes maximum annual diversion amounts for water purveyors who are signatory to the agreement. The table is based on the Water Forum Agreement signed in 2000 and updated in October 2015. Reclamation is not a signatory to the Water Forum. For planning purposes, the agency typically assumes water diversions at Folsom Lake and the lower American River are equal to full contract and water right entitlement.

Placer County Water Agency

Central Valley Project Water

In September 1970, during the ongoing construction of Auburn Dam, PCWA executed a 40-year water service contract with Reclamation (No. 14-06-200-5028A). This contract allowed PCWA to take up to 117,000 AF/year of CVP water. In 2002, PCWA amended its CVP water service contract with Reclamation, reducing the contract amount from 117,000 AFY to 35,000 AF/year. The contract expired in 2010 and was replaced by a series of interim contracts, although no deliveries have been made to date. In 2020, PCWA and Reclamation signed a permanent contract for 35,000 AF/year replacing the original contract signed by both parties in 1970. The point of diversion is Folsom Lake. The CVP water will be used after PCWA demand for their water rights water develops and additional delivery infrastructure is constructed.

Water Forum Agreement

PCWA is a signatory to the Water Forum Agreement. The agreement requires PCWA to release up to 47,000 AF of additional water in drier years through reoperation of MFP reservoirs (27,000 AF for PCWA and 20,000 AF for the City of Roseville) to replace water diverted above the 1995 baseline amounts. When projected March through November UIFR is between 950,000 AF and 400,000 AF, the amount of these additional water releases is linearly interpolated between 0 AF and 47,000 AF. When projected March through November UIFR is less than 400,000 AF, it is considered a conference year where Water Forum participants meet to determine how best to manage the available water, recognizing that there may not be sufficient water to meet both deliveries and environmental release requirements specified in the agreement.

Table 6-3. Water Forum Purveyor Specific Agreements

Water Supplier or Organization	Allowable Diversions (acre-feet, unless indicated otherwise)			
	1995 Baseline[1]	2030 Diversion Wet and Average Years	2030 Diversions Drier Years	2030 Diversion Driest Years[2]
American River Diversions				
City of Folsom	20,000[19]	34,000[3]	34,000 – 22,000[4]	20,000[5]
Sacramento Suburban WD (formerly Northridge WD)[17]	0	29,000[9]	0[10]	0
Sacramento Suburban WD (Arcade Service Area)[23]	3,500	11,200	11,200	3,500
Placer County WA[6,7]	8,500	35,500[3]	35,500[4,20]	35,500[20]
City of Roseville[7]	19,800	54,900	54,900 – 39,800[4,22]	39,800[20,22]
Golden State Water Company	5,000	5,000	5,000	5,000
San Juan WD and Citrus Heights WD, Fair Oaks WD, Orange Vale WC in Sacramento County	44,200[8]	57,200[3]	57,200 – 44,200[4]	44,200
San Juan WD in Placer County	10,000	25,000[3]	25,000 – 10,000[4]	10,000
South Sacramento County Agriculture	0	35,000[9]	0[10]	0
Sacramento Municipal Utility District	15,000[11]	30,000[3]	30,000 – 15,000[4]	15,000
Carmichael WD[18]	12,000	12,000	12,000	12,000
City of Sacramento	50,000	310 cfs [12,13]	90,000[15]	50,000
Sacramento River Diversions[14]				
City of Sacramento	45,000	290 cfs[13]	290 cfs[13]	290 cfs[13]
County of Sacramento	0	<78,000[16]	< 78,000[16]	< 78,000[16]
Placer County WA[6]	0	35,000	35,000	35,000
Natomas Central MWC in Sacramento County	53,000	45,600	45,600	45,600

Notes:

1 Baseline: Baseline means the historical maximum amount of water that suppliers diverted from the American River in any one year through 1995 or, in certain appropriate instances, other amounts specified in purveyor's specific agreement. Clarifications pertaining to the San Juan WD, SMUD, and the City of Folsom are noted in footnotes 8, 11, and 19.

2 Driest Years (i.e., Conference Years): Years when the projected March through November unimpaired inflow to Folsom Reservoir is less than 400,000 acre-feet. Conference years are those years that require diverters and others to meet and confer on how best to meet demands and protect the American River.

3 Wet and Average Years: As it applies to these diverters, years when the projected March through November unimpaired inflow to Folsom Reservoir is greater than 950,000 acre-feet.

4 Drier Years: As it applies to these diverters, years when the projected March through November unimpaired inflow to Folsom Reservoir is less than 950,000 acre-feet.

5 In Conference Years, the City of Folsom would reduce diversions by an additional 2,000 acre-feet below its baseline to 18,000 acre-feet through additional conservation to achieve recreational benefits to Folsom reservoir and fishery benefits to the lower American River.

6 Placer County WA would receive support for an American River diversion of 35,500 acre-feet (8,500 acre-feet existing and 27,000 acre-feet additional) in wetter and average years and a new Sacramento/Feather Diversion of 35,000 acre-feet. Placer County WA is willing to exchange 35,000 acre-feet of its American River water for Sacramento River and/or Feather River water provided the terms of such exchange do not result in any diminution of Placer County WA's water supply or an increased cost to Placer County WA.

7 For these suppliers, some or all of their water supply diverted from the American River or Folsom Reservoir in drier and driest years could be replaced with water released from the Middle Fork Project Reservoirs by reoperating those reservoirs. Reoperation of the MFP reservoirs causes the reservoirs to be drawn down below historical operational minimum pool volumes.

[8] The baseline for San Joaquin WD and its wholesale service area within Sacramento County is the full amount of its entitlements (CVP contract and water rights), which they exercised in 1995.

[9] Wet/Ave Years: As it applies to these diverters, years when the projected March through November unimpaired inflow to Folsom Reservoir is greater than 1,600,000 acre-feet.

[10] Drier Years: As it applies to these diverters, years when the projected March through November unimpaired inflow to Folsom Reservoir is less than 1,600,000 acre-feet.

[11] The baseline for SMUD is the 1995 diversion amount, which reflects the shutdown of Rancho Seco Power Plant.

[12] Wet and Average Years: As it applies to the City of Sacramento, time periods when the flows bypassing the E. A. Fairbairn Water Treatment Plant diversion exceed the "Hodge flows."

[13] For modeling purposes, it is assumed that the City of Sacramento's total annual diversions from the American and Sacramento rivers in 2030 would be 130,600 acre-feet for use within the city limits.

[14] As it applies to these diverters, there is no Water Forum limitation to diversions from the Sacramento River.

[15] Drier Years: As it applies to the City of Sacramento, time periods when flows bypassing the city's E. A. Fairbairn Water Treatment Plant diversion do not exceed the "Hodge flows." Within its existing capacity, the city can divert from the American River 155 cfs in June, July, and August; 120 cfs in January through May and September; and 100 cfs in October through December.

[16] The total for the County of Sacramento (78,000 acre-feet) represents 45,000 acre-feet of firm entitlement and 33,000 acre-feet of intermittent water. The intermittent supply is subject to reduction in the drier and driest years. To reduce reliance on intermittent surface water, Sacramento County intends to pursue additional firm supplies.

[17] Northridge WD and other signatories have agreed that for an interim 10-year period, Northridge WD would be able to divert Placer County WA water in years when the projected March through November unimpaired inflow to Folsom Reservoir is greater than 950,000 acre-feet. After the 10-year period, unless State Water Board issues a subsequent order, Northridge WD will divert up to 29,000 acre-feet of water from Folsom Reservoir under the Northridge WD - Placer County WA contract only in years when the projected March through November unimpaired inflow into Folsom Reservoir is greater than 1,600,000 acre-feet.

[18] Carmichael WD will divert and use up to its license amount of 14,000 acre-feet. By 2030, it is most likely that water demand for the district will be reduced to its historical baseline level of 12,000 acre-feet by implementation of Urban Water Conservation Best Management Practices. Signatories to the Water Forum Agreement acknowledge and agree that Carmichael WD shall not relinquish control of or otherwise abandon the right to any quantity it has foregone delivery and/or diversion of under this agreement, and shall retain the right (if any) to transfer that water for other beneficial uses, after that water has served its purpose of assisting in implementing the Improved Pattern of Fishery Flow Releases, for diversion or rediversion at, near, or downstream from the confluence of the lower American River and Sacramento River. The signatories also recognize that any such transfer of water by Carmichael WD must be in accordance with applicable provisions of Federal and State law.

[19] This is an agreed-upon amount that is within the historical diversion data and is equivalent to Folsom's treatment capacity, as of 1999.

[20] This requires 27,000 acre-feet of replacement water to the river as part of a dry year action, as provided in Placer County WA's specific agreement. In drier years this requires up to 27,000 acre-feet, the drier the year, the more water would be required. This is contingent on Placer County WA's ability to sell this water to the Department of the Interior to meet Anadromous Fishery Restoration Program goals for the lower American River or to other parties for their use after it flows down the lower American River.

[21] Remaining issues that are being negotiated are (1) environmentalists' support for Placer County WA pumps at Auburn, (2) how water conservation Best Management Practice 5 (Large Landscape Water Audits and Incentives for Commercial, Industrial, Institutional and Irrigation Accounts) will be implemented, and (3) environmentalists' support for conditions related to release of replacement water in drier and driest years.

[22] This requires 20,000 acre-feet of replacement water to the river as part of a dry year action, as provided in Placer County WA's specific agreement. In drier years, this requires up to 20,000 acre-feet, the drier the year, the more water would be required. This is contingent on Placer County WA's ability to sell this water to the Department of the Interior to meet Anadromous Fishery Restoration Program goals for the lower American River or to other parties for their use after it flows down the lower American River.

[23] The former Arcade WD had an agreement with the City of Sacramento for diversion of up to 26,064 AF/year of raw water under the city's American River water rights. This agreement provides for a floating point of diversion from the American River from below Nimbus Dam to the confluence of the American River with the Sacramento River. The nominal capacity of the diversion is about 10 mgd or 15.5 cfs, which is equivalent to 11,200 AF/year.

Key:

CVP = Central Valley Project

MWC = Mutual Water Company

SMUD = Sacramento Municipal Utilities District

WA = Water Agency

WD = Water District

City of Folsom and Folsom Prison

The City of Folsom lies adjacent to Lake Natoma, on both north and south side of the American River. The city's boundaries are not coterminous with the city's water service areas. San Juan WD provides wholesale water to the Ashland area, north of the river. San Juan WD also provides wholesale and retail water services to the American River Canyon area, which also lies north of the river. This water is diverted from Folsom Lake under San Juan WD's water rights and treated at the Sydney N. Peterson WTP (Folsom, 2016a).

The City of Folsom receives surface water diverted through Reclamation facilities at Folsom Lake into the Natoma Pipeline for water service areas south of the American River. The Natoma Pipeline splits into two separate lines: one line serves the Folsom Prison WTP, and one line serves the City of Folsom WTP. Raw water is also delivered to Aerojet for non-potable use.

Pre-1914 Appropriative Water Rights

The City of Folsom holds pre-1914 water rights for diversions from the South Fork American River with a priority date of 1851. The water was originally diverted by the city's predecessor, Natoma Water Company. In 1952, Natoma Water Company signed a settlement agreement with Reclamation in which Reclamation recognized the 1851 right and undertook to deliver up to 32,000 AF/year, as requested, at a rate not to exceed 60 cfs. The agreement contains no shortage provisions.

In 1964, Southern California Water Company (SCWC) acquired the Natomas Water Company and the rights under the 1951 contract. The City of Folsom acquired water rights previously owned by Natomas Water Company through a December 1967 Co-Tenants Agreement with SCWC. Under the Co-Tenants Agreement, the City of Folsom acquired the right to 22,000 AF/year, and SCWC retained a right to 10,000 AF/year. In 1994, the City of Folsom and SCWC signed an agreement under which the city was assigned 5,000 AF/year of the 10,000 AF/year that SCWC had retained under the 1967 Co-Tenancy Agreement (Folsom, 2016b).

The water right of 27,000 AF/year is delivered by Reclamation under contract 14-06-200-4816A and 14-06-200-5515A without reduction on a permanent basis (Folsom, 2016a).[9] This delivery is reported to the State Water Board under Statement of Water Use No. S017326. The remaining 5,000 AF/year is delivered to Golden State WC, the successor to SCWC,[10] from Lake Natoma and the Folsom South Canal.

Folsom State Prison has a water right for 4,000 AF/year for diversion from on the American River. This water is diverted from Folsom Lake (Reclamation, 2005).

[9] Pre-1914 deliveries are included in S017323 & S017326 (both for Contract No. 14-06-200-551A with Reclamation for 22,000 AF/year and S017490 and S017491 (both for Contract No. 14-06-200-4816A with Reclamation) for 5,000 AF/year.

[10] In 2005, American States Water Company announced that its three California divisions, Southern California Water Company, Arden-Cordova Water Service, and California Cities Water Company, would be collectively known as Golden State Water Company. Golden State Water Company remains a wholly-owned subsidiary of American States Water Company.

Central Valley Project Water

In 1999, Reclamation signed a contract (6-07-20-W1372) with Sacramento County WA for the provision of CVP water as part of Section 206 of Public Law 101- 514. The contract dedicated 22,000 AF of Fazio water to the agency. The City of Folsom was specifically named in the Reclamation contract as a subcontractor to gain benefit of a portion of the Fazio water supply. In 2000, Sacramento County WA entered into a separate contract with the city to provide 7,000 AF of the 22,000 AF of Fazio water. This water is subject to CVP allocation deficiencies (Folsom, 2016).

Groundwater

Historically, the City of Folsom has relied on groundwater to serve the area south of U.S. Highway 50. However, the city does not currently use groundwater because of concerns about groundwater contamination, and the city has not pumped groundwater in the past 5 years. In 2007, the city signed an agreement with Aerojet for rights to treated groundwater produced by Aerojet's groundwater extraction and treatment facilities. This supply is not represented in CalSim 3.

Water Forum Agreement

The City of Folsom baseline surface water supply under the Water Forum Agreement MOU is 20,000 AF. The surface water supply would increase to 34,000 AF/year to reflect expected growth in demand. Under the city's PSA, the city would reduce its diversions from Folsom Lake in a three-stage stepped reduction known as the Water Forum Wedge. Water deliveries in dry years would be reduced to 22,000 AF. In the driest years (conference years) the city would reduce diversions to a maximum of 20,000 AF. Further reductions of diversions would be made in the driest years to curtail diversions to 18,000 AF by imposing extraordinary conservation measures throughout the city's service area.

City of Roseville

The City of Roseville is located in Placer County, west of the Cities of Rocklin and Granite Bay and north of Citrus Heights. The city is the retail supplier of water to most of its residents. However, a few small areas of the city bordering the service areas of PCWA, San Juan WD, and Citrus Heights WD are served by each respective water agency (Roseville, 2016). In CalSim 3, the City of Roseville service area is represented by demand unit 26N_PU1.

Surface water is delivered from Folsom Lake to the city's water treatment plant on Barton Road. Historically, groundwater has been used as a backup supply or during drought years when surface water supplies are scarce. However, the city has started to use its wells for aquifer storage and recovery (ASR) in a conjunctive use management strategy. Recycled water, which is available from Roseville's two wastewater treatment plants, Dry Creek Wastewater Treatment Plant (WWTP) and Pleasant Grove WWTP, is used for landscape irrigation.

Roseville does not wholesale water to other agencies but does maintain 13 interties with 5 neighboring water utilities to provide, or receive, water for emergencies or special operating conditions (the agencies are PCWA, San Juan WD, California American WC, Citrus Heights WD, and Sacramento Suburban WD). The City of Roseville does not hold any water rights but has signed water contracts with Reclamation, PCWA, and San Juan WD for the delivery of surface water through the Folsom Lake M&I intake to its water treatment plant. The city's three surface water contract entitlements for American River water total 66,000 AF/year.

Central Valley Project Water

In Water Right Decision 893 (D-893), the State Water Board ruled on competing applications for diversion and storage of American River water. The Board determined that the City of Roseville being within the area "naturally dependent" on the American River would be better served by a contract with the United States and inserted terms in Reclamation's water right permits requiring fulfillment of local water supply needs prior to any exports.

In 1967, the City of Roseville signed a contract (14-06-200-3474A) with Reclamation for up to 32,000 AF/year of CVP water. The contract expired in 2010 but has been renewed on an interim basis. This contract is subject to shortage provisions under Reclamation's CVP M&I Water Shortage Policy finalized in November 2015. Generally, the city has taken delivery of its CVP contract water before using other contracted sources (Roseville, 2016b).

Middle Fork Project Water

The City of Roseville originally signed a contract with PCWA for a supply of MFP water in 1989. The contract was updated and consolidated in 2010. The maximum entitlement of water available under this contract is 30,000 AF/year. The city must pay for the water from PCWA whether or not it takes delivery of the water (Roseville, 2016b). The contract includes a schedule for the build-up of available water from 10,000 AF/year in 2015 to 30,000 AF/year after 2024. The city currently pays for 20,000 AF/year. The city has a long-term Warren Act contract (02-WC-20-2217) with Reclamation for the delivery of this PCWA water.

The City of Roseville has used the PCWA contract water as a source of secondary supply, with the CVP contract water serving as the city's primary water source (Roseville, 2016b). The city used significant amounts of PCWA contract water in 2008, 2014 and 2015 because of low CVP M&I allocations in these years.

San Juan Water District Water

The City of Roseville holds two wholesale contracts with San Juan WD for 4,000 AF/year. This water is derived from part of San Juan WD's contract with PCWA for 25,000 AF/year of MFP water. The first contract, signed in 2001, provides for 800 AF/year. The second contract, signed in 2003, provides an additional 3,200 AF/year. Water is delivered under San Juan WD's Warren Act contract (6-07-20-W1315). However, water from San Juan WD is not available in drier years[11] when the district reduces its take of American River water pursuant to the Water Forum Agreement.

Water Forum Agreement

Under the Water Forum Agreement, the City of Roseville has agreed to limit surface water diversions from Folsom Lake to 58,900 AF/year,[12] which is less than its full contract entitlement of

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[11] Under the Water Forum Agreement drier years are defined as years when the March-November forecast of unimpaired inflow to Folsom Lake is less than 950,000 AF.

[12] This includes the 4,000 AF/year of San Juan WD water.

66,000 AF. In drier years, the city has agreed to reduce its diversion in proportion to the unimpaired inflow to Folsom Lake to a minimum of 39,800 AF/year.[13] In the driest years, when supplies are limited, the city has agreed to work cooperatively with PCWA to provide up to 20,000 AF of additional water (equal to the difference between 39,800 AF and the 1995 baseline demand of 19,800 AF) through storage releases from MFP reservoirs to flow down the lower American River to mitigate environmental impacts resulting from increased diversions above 1995 baseline levels (WFA, 2015).

San Juan Water District

San Juan WD is both a wholesale and retail water agency, providing water to urban areas north of the American River in northeastern Sacramento and southern Placer counties. Wholesale services are provided to a group of retail water agencies, which include Citrus Heights WD, Fair Oaks WD, Orange Vale WC, and part of the City of Folsom lying north of the river (Ashland service area). The San Juan WD retail service area is located adjacent and west of Folsom Lake. This retail service area and the Ashland wholesale area do not have groundwater supplies and rely solely on surface water. The remaining wholesale customers use both surface water from the district and groundwater from their respective well systems as their supply sources (SJWD, 2016a). San Juan WD receives water from Folsom Lake, which is treated at its Sidney N. Peterson WTP. CalSim 3 represents the retail service area by demand unit 26N_PU2 and the wholesale area by demand unit 26N_PU3.

Pre-1914 Appropriative Water Rights

San Juan WD holds pre-1914 water rights based on diversions by the North Fork Ditch Company dating back to 1853. Under this right, the district is entitled to divert from the North Fork American River at a rate of up to 60 cfs (SJWD, 2016b).

In planning for the construction of Folsom Dam, the United States entered into a series of agreements with senior water rights holders to resolve water diversion issues. Under an April 1954 settlement agreement (Contract No. DA 04 167 eng 610) between Reclamation and the North Fork Ditch Company, company diversions are limited to 33,000 AF/year at a maximum diversion rate of about 75 cfs. The 1954 Settlement Agreement contains no shortage provision and does not reduce the water supply available to San Juan WD under its senior water rights in dry years (SJWD, 2016b).

Post-1914 Appropriative Water Right

In 1932, the North Fork Ditch Company was issued water right Permit 4009 (A05830) to divert 35 cfs from the North Fork American River for irrigation and domestic use with a priority date of 1928. In 1961, the State Water Rights Board issued San Juan WD, the successor to the North Fork Ditch Company, water right License 06324 on Permit 4009 authorizing the district to divert 15 cfs from June 1 through November 1 for irrigation and domestic uses within the district's boundaries (SJWD, 2016b).

[13] In drier years, the city has agreed to reduce diversions from 54,900 AF/year to 39,800 AF/year in proportion to the March-November forecast of unimpaired inflow to Folsom Lake dropping from 950,000 AF to 39,800 AF.

Central Valley Project Water

In 1962, San Juan WD acquired up to 40,000 AF/year of CVP water to meet its future projected demands. Reclamation later reduced the contract amount from 40,000 AF/year to 11,200 AF/year based on Reclamation's demand projections for the district. San Juan WD unsuccessfully pursued Reclamation to reinstate the original 40,000 AF amount. In 1999, as part of Public Law 101-514, San Juan WD signed an additional contract with Reclamation for up to 13,000 AF/year. This water is commonly referred to as Fazio water. In 2006, Reclamation combined the two CVP contracts into a single contract (6-07-20-W1373) for delivery of up to 24,200 AF/year through 2045.

Wholesale Agreements

In 1972, San Juan WD negotiated a contract with PCWA for an additional water supply from the agency's MFP. This contract extends through 2021 and is renewable in 20-year periods. It provides for delivery of up to 25,000 AF/year. Water is wheeled through Reclamation facilities under a Warren Act contract. The PCWA contract places a first priority on use in Placer County but allows for surplus water to be used in Sacramento County. The district has an agreement with the City of Roseville to sell up to 4,000 AF of this water during normal years if required by the City of Roseville.

Water Forum Agreement

As a signatory of the Water Forum Agreement MOU, San Juan WD intends to implement the supply restrictions designated in the agreement. Under the agreement, in normal years the district can divert its full 82,200 AF/year (including 4,000 AF for the City of Roseville). During drier years, the district must decrease diversion amounts from 82,200 AF/year down to 54,200 AF/year in proportion to the decreasing unimpaired inflow to Folsom Lake (the Water Forum wedge). In the driest years (conference years), the district has agreed to meet and confer with other signatories to develop a plan for water use. CalSim 3 does not currently represent these restrictions.

Sacramento Suburban Water District

Sacramento Suburban WD provides retail water services to four service areas within Sacramento County: the North Service Area (NSA), Arbors at Antelope Service Area, McClellan Business Park Service Area, and South Service Area (SSA). For CalSim 3 these services areas are aggregated into an NSA and SSA, represented by demand units 26N_NU1 and 26N_NU4. The NSA includes the service area of the former Northridge WD. The SSA includes the Town and Country service area of the former Arcade WD.

Sacramento Suburban WD uses both surface water and groundwater as its supply sources. The district does not hold any water rights, nor does it hold contracts with Reclamation for the delivery of CVP water. Entitlements for surface water are through water sales contracts with other agencies. The NSA has been supplied limited surface water starting in 1991. Surface water use significantly expanded in 1998 with completion of the San Juan Cooperative Transmission Pipeline. Surface water supplies to the SSA began in 2007, following the expansion of the City of Sacramento's Fairbairn WTP.

Placer County WA Wholesale Agreement

In 2000, the former Northridge WD and PCWA signed an agreement for delivery of up to 29,000 AF/year of the agency's MFP water. The conditions of the contract were amended in 2008 to an annual entitlement of 12,000 AF/year, and an additional 17,000 AF supplemental amount, delivered with the approval of PCWA, for a maximum total of 29,000 AF/year. PCWA has projected that its supply to the district would be reduced to 12,000 AF/year in an average year type at buildout of the agency's service area, which is anticipated to occur after 2024 (PCWA, 2016b). Starting in 2010, the supply became available only during Water Forum wet years, when the March-through-November unimpaired inflow into Folsom Lake is greater than 1,600,000 AF. Delivery of this water also may be limited by available capacity at San Juan WD's Sidney N. Peterson WTP. Sacramento Suburban WD holds a Warren Act contract for wheeling MFP water to the district.

City of Sacramento Wholesale Agreement

In January 2004, Sacramento Suburban WD signed an agreement with the City of Sacramento for up to 20 mgd (22,400 AF) of surface water supply. Since 2007, the district has been receiving treated surface water from the City of Sacramento for use within the SSA (SSWD, 2016). American River water is treated at the city's Fairbairn WTP and delivered through the Howe Avenue transmission main. The district supply from the city is constrained by the Water Forum Agreement as well as Hodge flow criteria for the lower American River. Supplies from the city are reduced to zero when the unimpaired March-through-November inflow to Folsom Lake is below 950,000 AF (i.e., Water Forum drier and driest years).

Water Forum Agreement

Under the Water Forum Agreement, surface water deliveries from PCWA and the City of Sacramento to the district will be reduced to zero in dry years.

Golden State Water Company - Cordova

Golden State WC's Cordova service area is located adjacent to the American River and Folsom South Canal and serves the City of Rancho Cordova and the unincorporated community of Gold River.[14] In CalSim 3, the service area is represented by demand unit 26S_PU2. Golden State WC conjunctively uses surface water and groundwater. American River water diverted from the Folsom South Canal is treated at the company's Coloma and Pyrites WTPs, which have a combined treatment capacity of approximately 14.4 mgd (16,100 AF/year). Surface water supplies are supplemented by groundwater pumped at seven production wells with a combined capacity of approximately 18.5 mgd (20,700 AF/year) (GSWC, 2016).

Pre-1914 Appropriative Water Right

Golden State WC has a pre-1914 appropriative water right to divert up to 10,000 AF/year from the American River. The maximum diversion rate is 20 cfs. The point of diversion has been amended to allow diversion from the Folsom South Canal. In 1994, Golden State WC entered into an *Agreement for Reallocation of Water under Co-Tenancy Agreement* with the City of Folsom to lease 5,000 AF/year of

[14] Water services for this area were formerly provided by American States Water Company.

water rights in perpetuity. The water company retained 5,000 AF of its water right for use within the Cordova System (GSWC, 2016).

SMUD Transfer

Golden State WC signed a temporary water transfer agreement with SMUD to divert up to 6,000 AF/year from the Folsom South Canal. The contract term is for 5 years, from 2008 through 2012. The water was provided from SMUD's CVP contract entitlement (14-06-200-5198A). This contract was not extended.

Aerojet Replacement Water

Gencorp/Aerojet Corporation (Aerojet) past manufacturing, testing, and disposal methods have resulted in groundwater contamination in the Rancho Cordova area. Following litigation over the loss of high quality groundwater, Aerojet signed a 2004 settlement agreement to supply Golden State WC with 5,000 AF of replacement water to offset contaminated groundwater and to supply an additional 10,200 AF/year of contingent replacement water, if necessary, to satisfy system demands. The Aerojet replacement water source is currently under negotiation and relies on wheeling discharged remediated groundwater through existing or proposed facilities (GSWC, 2016). This water source is currently not represented in CalSim 3.

Water Forum Agreement

The 1995 baseline diversion for Golden State WC is 5,000 AF. Under the PSA, there are no reduction in diversion from this baseline.

Sacramento Municipal Utility District

SMUD started operating the Rancho Seco nuclear power station in southeastern Sacramento County in 1975. The initial water demand was estimated to be up to 75,000 AF/year for cooling water, power plant operations, and landscape irrigation. Following the closure of the plant in 1989, up to 30,000 AF/year continued to be delivered for plant maintenance, makeup water for on-site lakes, and landscape irrigation. IN 2006, SMUD put into operation a new natural-gas-fired power station at the Rancho Seco site that also uses cooling water diverted from the Folsom South Canal. In CalSim 3, SMUD's Rancho Seco facilities are represented by demand unit 60N_PU.[15]

Water Rights

SMUD has a water right for 15,000 AF/year with a maximum diversion rate of 20 cfs. Both water right water and CVP water (described below) are diverted from the American River at Nimbus Dam and conveyed through the Folsom South Canal to the Rancho Seco site. For accounting purposes, the first 40 acre-feet/day or 15,000 AF/year, not to exceed 20 cfs is water rights water (Reclamation, 2005).

[15] In the past, SMUD has provided their non-project water rights water to Galt ID. However, the agreement between Galt ID and SMUD has expired and has not been renewed. Simulated demands for SMUD may be high as it is based on delivery data provided by Reclamation that includes sales to Galt ID.

Central Valley Project Water

In 1970, SMUD was one of two CVP contractors to sign contracts with Reclamation to take delivery of water from the proposed Folsom South Canal. The contract (14-06-200-5198A) was for delivery by Reclamation of up to 60,000 AF/year of CVP water for M&I use and for delivery of an additional 15,000 AF of SMUD water rights water associated with the UARP. Both CVP water and the water right water are diverted from the American River at Nimbus Dam and conveyed through the Folsom South Canal to the Rancho Seco site. The first 15,000 AF of water delivered each year are designated water right water. The CVP contract expired on December 31, 2012.

Under the terms of a three party agreement (SMUD, Sacramento County WA, and the City of Sacramento), the City of Sacramento provides surface water to SMUD for use at two of its cogeneration facilities located within the city's American River place of use. SMUD, in turn, has assigned 15,000 AF/year of its Reclamation CVP contract water to Sacramento County WA for M&I use ("SMUD 1" assignment).

SMUD has made a second assignment of 15,000 AF/year of CVP water to Sacramento County WA for M&I use ("SMUD 2" assignment). In return, Sacramento County WA is obligated to provide up to 15,000 AF/year of groundwater to SMUD for use at its Rancho Seco facilities. The amount of water required by SMUD varies according to hydrologic conditions and the amount of cut-back imposed on its remaining CVP contract amount. Delivery of Sacramento County WA water will not be through the Folsom South Canal, although the agency has agreed to pay a portion of the canal costs as part of the financial arrangement for the assignment.

Water Forum Agreement

Under the Water Forum Agreement, SMUD's 1995 baseline diversion from the American River is 15,000 AF, which reflects the shutdown of the Rancho Seco Power Plant. In most years, SMUD will divert and use 30,000 AF from the Folsom South Canal. In drier years, SMUD will divert and use a decreasing amount of surface water from 30,000 to 15,000 AF in proportion to the decrease in unimpaired inflow to Folsom Reservoir from 950,000 AF to 400,000 AF.

SMUD, as part of its Water Forum PSA, also supports a third assignment of 13,500 AF/year of CVP contract water to south Sacramento agricultural interests. This assignment is pending the formation of a groundwater management entity that can represent the interests of surface water and groundwater users south of the Cosumnes River. An additional 1,500 AF could be assigned to Rancho Murieta Community Service District (CSD, although no agreement has been made on an acceptable point of diversion. These assignments are not modeled in CalSim 3.

City of Sacramento

The City of Sacramento provides both retail and wholesale water services. The city's retail water service area, which covers approximately 63,000 acres, is largely contiguous with the city limits but includes a small area outside the City limits in the Fruitridge area. Sacramento Suburban WD serves a small area within the city boundary. CalSim 3 represents the City of Sacramento by demand units

26N_NU3 (service area north of the American River) and 26S_NU1 (service area south of the American River).

The City of Sacramento's surface water diversions from the American River and Sacramento River are authorized under a pre-1914 water right and five appropriative water right permits, combined with a water rights settlement contract.[16] The city's authorized Place of Use for the Sacramento River includes all the land within the city limits. The Place of Use for the American River supply includes the city limits and also defined areas adjacent to the City that includes portions of service areas of other water purveyors.

Pre-1914 Appropriative Water Rights

The City of Sacramento holds a pre-1914 water right (Statement S014834) to divert Sacramento River water at a rate up to 75 cfs, based on Sacramento River diversions that began when the city's first pumping plant was constructed in the early 1850s.

Post-1914 Appropriative Water Rights

The City of Sacramento holds three post-1914 water rights. These are described in the following sections.

Permit No. 992 (A001743)

Permit 992 authorizes the City of Sacramento to divert Sacramento River water at a rate up to 225 cfs, in an amount up to 81,800 AF/year. The permit has a priority date of 1920. Water diverted under this permit can be delivered within the city limits. The current points of diversion are located at the Sacramento River Water Treatment Plant and at the Pioneer Reservoir, which is a component of Sacramento's combined sewer system.[17]

Permit Nos. 11358 (A012140) and 11361 (A016060)

Permits 11358 and 11361 authorize the city to divert water from the American River at the city's Fairbairn WTP. The combined maximum allowable rate of diversion is 675 cfs. Permit 11358 has a priority date of October 29, 1947 and Permit 11361 has a priority date of September 22, 1954.

Permit Nos. 11359 (A012321) and 11360 (A012622)

Permits 11359 and 11360 are based on water right applications filed by SMUD and subsequently assigned to the city of Sacramento. In the 1957 *Agreement of Assignment* between SMUD and the City, the assignment was declared to be for the benefit of the city's 'Potential Water Service Area,' which includes the city and designated areas adjacent to the city, some of which are supplied retail water service by other water purveyors. These permits authorize the City to redivert American River water previously utilized for non-consumptive purposes by SMUD's UARP. These re-diversions of American River water can be made at both the Sacramento River and Fairbairn WTPs. The combined maximum allowable diversion under these two permits includes rediversion of up to 1,510 cfs of water diverted, but not stored, by the UARP, and up to 589,000 AF/year of stored

[16] The following description is based on Exhibit Sac-1 (Testimony of James Peifer) submitted to the State Water Board by the City of Sacramento as part of the Water Fix Hearings.

[17] This latter point of diversion is not represented in CalSim 3.

water. The Permit 11359 priority date is February 13, 1948, and the Permit 11360 priority date is July 29, 1948.

Water diverted under Sacramento's four American River permits can be used within the City of Sacramento boundary and within specified areas adjacent to Sacramento, collectively referred to as Sacramento's American River Place of Use. Pursuant to the Water Forum Agreement, the City of Sacramento agreed to add conditions to its four American River water right permits that became effective after the expansion of the Fairbairn WTP, limiting diversions to when American River flows at the treatment plant intake fall below the Hodge Flow Conditions. In addition, the State Water Board's Decision 893 (D-893), which issued the City's four American River water right permits, requires that the City bypass flows (i.e., not divert) on the American River when the flow rate of the American River is less than 250 cfs from January 1 through September 14, and less than 500 cfs from September 15 to December 31 (with relaxation of these thresholds during specified dry periods).

Settlement Contract

In June 1957, the City of Sacramento entered into a permanent water rights settlement contract with Reclamation.[18] The State Water Rights Board was at the time deciding how to allocate water rights on the American River among numerous competing applicants, including the city and Reclamation. The contract settled the protests filed by the city and Reclamation, and as part of the settlement, the city abandoned its plans to construct a reservoir on the upper American River near Coloma, in favor of Reclamation's plan to construct Folsom Dam. The city also agreed to limit its total diversions of American River water under its American River water right permits to a maximum of 675 cfs, up to a maximum amount of 245,000 AF/year in the year 2030 (i.e., less than the total face value of the city's American River water right permits). The city also agreed to limit its diversions of Sacramento River water under Permit 992 to a maximum of 225 cfs and a maximum amount of 81,800 AF/year. The contract's total annual diversion limit from both rivers in the year 2030 is 326,800 AF. In return, Reclamation agreed to operate its facilities so as to make available in the lower American River sufficient water for the City's diversions up to the amounts specified in the settlement contract, and to operate its CVP Sacramento River storage facilities so as not to interfere with the city's diversions up to the amounts specified in the settlement contract. The contract requires an annual payment to Reclamation for Folsom Reservoir storage capacity used to meet Reclamation's obligations under the contract. Water made available for diversion under the water rights settlement contract can be diverted at either the Sacramento River WTP or the Fairbairn WTP under Permit 11359 and 11360.

Water Forum Agreement

Under the Water Forum Agreement, the City of Sacramento's 1995 baseline diversion from the American River is 50,000 AF/year. In all years, the city agreed to limit diversions to a maximum of 310 cfs from the American River so long as the bypassed flow at the Fairbairn intake is greater than the Hodge flow criteria. When bypassed flows are less than the Hodge flow criteria the city agreed to limit diversions at its Fairbairn WTP as follows:

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[18] *Operating Contract Relating to Folsom and Nimbus Dams and their Related Works and to Diversion of Water by the City of Sacramento*, Contract Number 14-06-200-6497.

- January through May maximum of 120 cfs
- June through August maximum of 155 cfs
- September maximum of 120 cfs
- October through December maximum of 100 cfs

In extremely dry years, when the March-November unimpaired inflow is less than 400,000 AF, the city agreed to limit diversions at its Fairbairn intake to a maximum of 155 cfs and not greater than 50,000 AF/year.

Carmichael WD

Carmichael WD is located in unincorporated Sacramento County and serves residential and commercial customers in the community of Carmichael, which is located about 10 miles east of downtown Sacrament along the north side of the American River. Carmichael WD's water supply consists of a direct water diversion from the lower American River, approximately 6 miles below Nimbus Dam. Diverted water is conveyed to the district's Bajamont WTP. The district maintains five groundwater wells to supplement surface water supplies. Groundwater is used to make-up any shortage in surface water supplies and to meet system peaking needs. However, groundwater contamination in and around the district's service area originating from the Aerojet/Rocketdyne Superfund Site has threatened the use of groundwater supplies and groundwater use has been trending downwards since 2006 (CWD, 2016a). Carmichael WD also uses reclaimed water developed from Aerojet's Groundwater Extraction and Treatment facilities for irrigation of Ancil Hoffman Golf Course.

In CalSim 3, Carmichael WD is represented by demand unit 26N_NU2.

Post-1914 Appropriative Water Rights

The district holds three post-1914 appropriative water rights to divert American River water. These are described in the following sections.

License 1387 (Application 138)

License 1387 authorizes the district to divert up to 15 cfs year-round from the natural flow of the American River for domestic and irrigation uses within the boundaries of the Carmichael ID (now Carmichael WD). The license has a September 18, 1915 priority date. The total annual diversion allowed under the license is approximately 10,859 AF/year.

The 1915 priority date makes water diversions under License 1387 highly reliable. However, diversions were curtailed by the State Water Board between May 1, 2015 through October 26, 2015. This marked the first curtailment in the 100-year history of district diversions (CWD, 2016b).

License 8731 (Application 4743)

License 8731 authorizes the district to divert up to 10 cfs from May 1 through November 1 from the natural flow of the American River for domestic and irrigation uses. The water right license has a priority date of August 22, 1925. The total annual diversion allowed under the license is approximately 3,669 AF/year.

License 8731 typically provides the district with a reliable supply in non-critical dry years. However, diversions were curtailed by the State Water Board between May 1, 2015 through October 26, 2015 (CWD, 2016b).

Permit 7536 (Application 12367)

Permit 7536 authorizes the district to divert up to 25 cfs from March 15 through October 15 for irrigation purposes and year-round for domestic purposes from the natural flow of the American River. The water right permit has a priority date of March 1, 1948.

In 2005, the State Water Board denied the district's request for a permit extension to demonstrate that the district could beneficially use the full permit amount. Any future license issued by the State Water Board for use of this water may incorporate Term 91 and may further limit diversions.

Water Forum Agreement

Under the Water Forum Agreement, Carmichael WD's 1995 baseline diversion is 12,000 AF/year. In wetter years, Carmichael WD may divert and use up to its license amount of 14,000 AF. However, by the year 2030, it is likely that the district water demand will be reduced to its historic baseline level of 12,000 AF by implementing urban water conservation measures. Therefore, there will be no reduction of diversions in drier years because the 12,000 AF of demand is less than the district's baseline diversion.

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Chapter 7 Project Operations

Water development projects in the upper American River watershed are operated for a mix of water supply, hydropower, fishery, and recreational purposes. This chapter briefly describes both discretionary and non-discretionary operations of each project.

Drum-Spaulding Project

PG&E owns and operates two storage reservoirs and a diversion dam on the North Fork of the North Fork American River. These facilities are operated as part of the company's Drum-Spaulding Project (FERC No. 2310). Operation of this project is coordinated with Nevada ID's Yuba-Bear Project (FERC No. 2266).

The 1963 FERC license for the Drum-Spaulding Project expired on April 30, 2013. PG&E filed a final application for a new license in April 2011 and subsequently filed license application amendments in June 2012, August 2012, and May 2013.[19]

Water-Year Classifications

Water Year classifications are not defined under the project's 1963 FERC license. Minimum flows below Lake Valley Dam and Lake Valley Diversion Dam are 3 cfs from June through September and 1 cfs at other times of the year.

Lake Valley Reservoir Operations

Lake Valley Reservoir stores winter runoff that is subsequently released in the summer and fall. Reservoir flashboards are in place between April 1 and August 31, increasing the reservoir capacity from 7,156 AF to 7,902 AF. Typically, the reservoir is drawn down at a rate of 30 cfs between October 1 and November 30 then is filled according to winter rule curve formulated to minimize spills from snowmelt in the late spring and early summer. Between December 1 and June 30, when the storage is above rule curve, discretionary releases of up to 36 cfs are made to draw down storage to the rule curve. The Lake Valley Diversion Dam has a maximum diversion capacity of 36 cfs. It is typically shut down each year from July 1 through September 30. When the diversion is not shut down, the diversion dam bypasses minimum instream flows and diverts additional inflow, up to 36 cfs, to the Bear River watershed. Any additional inflow to the diversion dam above these amounts is spilled to the North Fork of the North Fork American River.

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[19] As part of the 2013 amendment, PG&E proposed to split the currently licensed Drum-Spaulding Project into three new licensed projects: (1) the Lower Drum Project, (2) the Deer Creek Project, and (3) the remaining Drum-Spaulding Project (referred to by FERC and in this document as the Upper Drum-Spaulding Project). The proposed Upper Drum-Spaulding Project (FERC Project No. 2310-193) would encompass the Spaulding No. 3, Spaulding No. 1 and No. 2, Alta, Drum No. 1 and No. 2, and Dutch Flat No. 1 Developments. The proposed Lower Drum Project (FERC Project No. 14531) would encompass the Halsey, Wise, Wise No. 2, and Newcastle Developments. The proposed Deer Creek Project (FERC Project No. 14350) would include only the Deer Creek Development. The three PG&E projects are currently in the process of attaining Clean Water Act Section 401 water quality certifications in support of their FERC license applications.

Water diverted at Lake Valley Diversion Dam consists of both direct diversions and rediverted storage releases from Lake Valley Reservoir and Kelly Lake. Flows of up to 36 cfs are diverted through the Lake Valley Canal to the Bear River watershed for power generation and water supply. Historically, approximately 11,000 AF/year have been exported from the North Fork American River watershed, ranging from a low of 1,900 AF/year (WY 2014) to a high of 23,300 AF/year (WY 1983).

Proposed License Requirements

Proposed new FERC license conditions for the Drum-Spaulding Project are contained in the 2014 Final EIS for the relicensing (FERC, 2014a). These include new water year classifications based on the forecasted annual unimpaired runoff for the Yuba River at Smartville and new flow requirements below Lake Valley Dam and Lake Valley Diversion Dam. A minimum pool elevation of 5763.7 feet (equivalent to 2,590 AF of storage) is proposed for Lake Valley Reservoir as part of the new license requirements.

Chili Bar Project

The Chili Bar Powerhouse is a run-of-the-river facility being dependent on releases from storage facilities owned and operated by SMUD. PG&E and SMUD coordinate operations of Chili Bar and White Rock powerhouses to meet regulatory flow requirements for fisheries and summertime whitewater recreational needs below the powerhouses. The original FERC license for the project was issued by FERC in August 1962 and expired in July 2007. The 1962 license specified a minimum release requirement at Chili Bar Dam of 100 cfs, measured at South Fork American River near Placerville gauge (USGS 11444500). However, project operations typically resulted in minimum flows of 200 cfs (FERC, 2008). In February 2007, SMUD and PG&E filed a comprehensive settlement agreement related to relicensing both the UARP and Chili Bar projects.[20] In August 2014, FERC issued a new 50-year license to PG&E for continued operation of the Chili Bar Project. The Water Quality Certificate Conditions for the Chili Bar Project issued by the State Water Board specify minimum instream flows to protect aquatic life beneficial uses, and recreational flows to protect recreational use.

Water-Year Classifications

Water Year classifications are defined in PG&E's Chile Bar FERC license based on the forecast of annual unimpaired runoff for the American River below Folsom Lake that is published near the beginning of each month from February through May in DWR's Bulletin 120 "*Report of Water Conditions in California*." Six water year types are defined as follows:

[20] PG&E utilized a modified Traditional Licensing Process for the relicensing proceeding that involved public input and collaboration. Due to the existence of many overlapping issues that were common to the Chili Bar Project and the UARP proceedings, many studies and technical reports were developed and coordinated through PG&E's participation in the UARP's Alternative Licensing Process.

Water Year Classification	Folsom Lake Forecasted Unimpaired Inflow (acre-feet/year)
Wet	> 3,500,000
Above Normal	2,600,000 – 3,500,000
Below Normal	1,700,000 – 2,600,000
Dry	900,000 – 1,700,000
Critically Dry	< 900,000
Super Dry	Any Critically Dry year that is immediately preceded by a Dry or Critically Dry year or any Dry year that is immediately preceded by any combination of two Dry or Critically Dry years

Minimum Instream Flows to Protect Aquatic Life Beneficial Uses

FERC-mandated minimum flows for the South Fork American River below Chili Bar Dam are listed in **Table 7-1**. These flows are contingent on sufficient inflows to Chili Bar Reservoir, as well as sufficient Chili Bar Reservoir elevations to maintain these flows. The compliance point for the measurement of the required minimum streamflows is the USGS gauge near Placerville (USGS 11444500).

Table 7-1. FERC Flow Requirement for South Fork American River below Chili Bar Dam

Month	Flow Requirement (cfs)					
	Super Dry	Critically Dry	Dry	Below Normal	Above Normal	Wet
October	150	185	200	250	250	250
November	150	185	200	200	200	250
December	150	185	200	200	200	250
January	150	185	200	200	200	250
February	150	185	200	200	200	250
March	150	185	200	200	200	250
April	150	200	250	250	300	350
May	150	200	250	250	350	500
June	200	200	250	250	350	500
July	150	185	200	250	300	350
August	150	185	200	250	300	300
September	150	185	200	250	250	250

Key:
cfs = cubic feet per second
FERC = Federal Energy Regulatory Commission

Recreational Streamflows to Protect Recreational Use

FERC recreational streamflow requirements for the South Fork American River below Chili Bar Dam are listed in **Table 7-2**. The compliance point for the measurement of the required minimum flows is the same as that for the FERC minimum streamflows.

The recreational flow schedule presented in **Table 7-2** specifies minimum recreational streamflows by day of the week, as well as by holidays that occur on different days each year. Because CalSim 3 runs on a monthly time step, an average monthly recreational requirement is required for the model. Monthly requirements were developed assuming that:

- Recreational flow requirements are met for the specified number of hours (with respect to day of year, day of week, and water year type).
- Instream requirements are met for the remaining hours of the day (i.e., 24 less the required hours of recreational flow).

These assumptions were applied and calculated for every day from October 1921 through September 2015 for each year type. The resulting number for each day represents the average hourly flow that would have to be released from Chili Bar Reservoir on that day to match the volume of water that would result from the required combination of FERC instream/recreational hourly releases. Monthly averages were calculated for each year from 1922 through 2015 (94 years). Finally, an average of those 94 values was calculated for each month, providing a <u>total</u> monthly requirement for each year type. **Table 7-3** lists these total requirements.

Table 7-2. FERC Minimum Recreational Flow for South Fork American River Below Chili Bar Dam

Water Year	Period	Duration (hours) and Flow Rate (cubic feet per second)						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
Super Dry	April 1 - Friday before Memorial Day	3 hours at 1,300	---	---	---	---	3 hours at 1,300	3 hours at 1,300
	Memorial Day - Labor Day1	3 hours at 1,300	---	---	3 hours at 1,300	3 hours at 1,300	5 hours at 1,300	5 hours at 1,300
	Tuesday after Labor Day - September 30	---	---	---	---	---	3 hours at 1,300	3 hours at 1,300
	October 1 - March 31	---	---	---	---	---	3 hours at 1,300	---
Critically Dry	March 1 - Friday before Memorial Day	3 hours at 1,300	---	---	---	---	3 hours at 1,300	3 hours at 1,300
	Memorial Day - Labor Day1	3 hours at 1,300	---	---	3 hours at 1,300	3 hours at 1,300	5 hours at 1,500	5 hours at 1,500
	Tuesday after Labor Day - September 30	---	---	---	---	3 hours at 1,300	3 hours at 1,300	3 hours at 1,300
	October 1 - February 28/29	---	---	---	---	---	3 hours at 1,300	---
Dry	March 1 - Friday before Memorial Day	3 hours at 1,300	3 hours at 1,300	---	---	3 hours at 1,300	3 hours at 1,500	3 hours at 1,500
	Memorial Day - Labor Day1	3 hours at 1,300	3 hours at 1,300	---	3 hours at 1,300	3 hours at 1,300	5 hours at 1,500	5 hours at 1,500
	Tuesday after Labor Day - September 30	---	---	---	---	3 hours at 1,300	3 hours at 1,300	3 hours at 1,300
	October 1 - February 28/29	---	---	---	---	---	3 hours at 1,300	3 hours at 1,300

Table 7-2. FERC Minimum Recreational Flow for South Fork American River Below Chili Bar Dam (contd.)

Water Year	Period	Duration (hours) and Flow Rate (cubic feet per second)						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
Below Normal	March 1 - Friday before Memorial Day	3 hours at 1,300	3 hours at 1,300	---	3 hours at 1,300	3 hours at 1,300	3 hours at 1,500	3 hours at 1,500
	Memorial Day - Labor Day1	3 hours at 1,300	3 hours at 1,300	---	3 hours at 1,300	3 hours at 1,300	6 hours at 1,500	6 hours at 1,500
	Tuesday after Labor Day - September 30	---	---	---	3 hours at 1,300	3 hours at 1,300	3 hours at 1,500	3 hours at 1,500
	October 1 - 31	3 hours at 1,300	---	---	---	3 hours at 1,300	3 hours at 1,500	3 hours at 1,500
	November 1 - February 28/29	---	---	---	---	---	3 hours at 1,300	3 hours at 1,300
Above Normal	March 1 - Friday before Memorial Day	3 hours at 1,300	3 hours at 1,300	3 hours at 1,300	3 hours at 1,300	3 hours at 1,300	4 hours at 1750	4 hours at 1,750
	Memorial Day - Labor Day1	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500	6 hours at 1,750	6 hours at 1,750
	Tuesday after Labor Day - September 30	---	---	---	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500
	October 1 - 31	3 hours at 1,300	---	---	---	3 hours at 1,300	3 hours at 1,500	3 hours at 1,500
	November 1 - February 28/29	---	---	---	---	---	3 hours at 1,500	3 hours at 1,500
Wet	March 1 - Friday before Memorial Day	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500	6 hours at 1,750	6 hours at 1,750
	Memorial Day - Labor Day1	4 hours at 1,500	4 hours at 1,500	4 hours at 1,500	4 hours at 1,500	4 hours at 1,500	6 hours at 1,750	6 hours at 1,750
	Tuesday after Labor Day - September 30	---	---	---	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500	3 hours at 1,500
	October 1 - 31	3 hours at 1,300	---	---	---	3 hours at 1,300	3 hours at 1,500	3 hours at 1,500
	November 1 - February 28/29	---	---	---	---	---	3 hours at 1,500	3 hours at 1,500

Table 7-3. Total FERC Flow Requirements for South Fork American River below Chili Bar Dam

Month	Flow Requirement (cubic feet per second)					
	Super Dry	Critically Dry	Dry	Below Normal	Above Normal	Wet
October	171	205	239	332	332	332
November	171	205	239	239	247	288
December	171	205	239	239	246	287
January	171	205	239	240	247	288
February	171	205	239	240	247	288
March	171	245	305	325	372	469
April	212	259	351	370	458	553
May	224	274	362	382	514	683
June	324	336	399	414	553	708
July	280	323	356	414	511	587
August	280	323	356	414	511	547
September	206	258	273	345	355	362

Stumpy Meadows Project

GDPUD operates Stumpy Meadows Reservoir to meet agricultural and urban demands within the district service area and to meet minimum flow requirements on Pilot Creek that are specified in its water right permit. For modeling purposes, agricultural demands are assumed to be 7,120 AF/year and urban water demands 3,000 AF/year. Canal conveyance losses are assumed to be 20 percent.

Water-Year Classifications

Water Year classifications are defined in water right Permit 12827 based on the forecast of the annual unimpaired runoff for the American River at Fair Oaks. The classifications are as follows:

Water Year Classification	Unimpaired American River at Fair Oaks (acre-feet/year)
Wet	> 1,5000,000
Dry	< 1,5000,000

Stumpy Meadows Reservoir Operations

GDPUD has a staged response to water shortage that triggers on mid-April Stumpy Meadows Reservoir storage (GDPUD, 2016). Agricultural and urban water users are subject to the same deficiency, as presented below. For modeling purposes, these reductions are imposed beginning May 1st, and are relaxed once Stumpy Meadows Reservoir storage rises above the listed threshold.

Stumpy Meadows April Storage (acre-feet)	Deficiency (%)
>17,000	0%
<17,000	15%
<15,000	25%
<13,000	35%
<10,000	50%

Upper American River Project

SMUD's UARP consists of three major storage reservoirs and eight powerhouses. In addition to power generation, the project is operated to meet minimum flows, pool elevations, and recreational flow requirements specified in its FERC license. Reservoirs fill in the spring and early summer from rainfall-runoff and snowmelt. In model simulation, discretionary power releases are made during the refill season to avoid subsequent spilling in May when peak inflows typically occur. Powerhouses are operated so that flows do not create or exacerbate downstream spilling unless inflows are so high that spill is unavoidable. Loon Lake, Union Valley and White Rock Powerhouses often operate at less than their maximum penstock flow to avoid downstream spill. To increase the likelihood of meeting the Ice House Reservoir FERC license requirements, SMUD aims to fill and maintain Ice House Reservoir storage at its maximum level prior to the spillway gates lowering in April.

Reservoir storage is drawn down in the late summer and fall to meet a total carryover storage target of between 200,000 – 220,000 AF by the end of September (SMUD, 2020), while maintaining minimum pool elevations from July to September as specified in the FERC license. For modeling purposes, a target end-of-September carryover storage of 200,000 AF is adopted, disaggregated as follows: Loon Lake 40,000 AF, Ice House 30,000 AF, and Union Valley 140,000 AF. From October through December the model attempts to maintain these storage levels.

Requirements of the Chili Bar Project FERC license dictate many of the releases from storage, especially during the winter in drier years, when water is released for boating flows that would otherwise be saved for summer releases.

Annual maintenance of powerhouses impacts operations. Historically, the timing of maintenance has varied from year to year, but for modeling purposes a 'standard' outage schedule has been adopted beginning in October, as follows:

- Loon Lake Powerhouse, Robbs Peak Powerhouse: October 1st – 15th
- Jones Fork Powerhouse, Union Valley Powerhouse: October 16th – 31st
- Jaybird Powerhouse Unit 1, Camino Powerhouse Unit 1: November 1st – 15th
- Jaybird Powerhouse Unit 2, Camino Powerhouse Unit 2: 16th – 30th
- Whitehouse Powerhouse Unit 1: December 1st – 15th

- Whitehouse Powerhouse Unit 2: December 16th – 31st

Water-Year Classifications

Water Year classifications are defined in SMUD's UARP FERC license based on the forecast of annual unimpaired inflow to Folsom Lake. The classifications are as follows:

Water Year Classification	Unimpaired American River at Fair Oaks (acre-feet/year)
Wet	> 3,5000,000
Above Normal	2,600,000 – 3,500,000
Below Normal	1,700,000 – 2,600,000
Dry	900,000 – 1,700,000
Critical Dry	<900,000

The UARP is operated for hydropower purposes within the requirements of the FERC license. There are currently no consumptive use demands.[21] SMUD has discretion in the scheduling of storage releases from UARP reservoirs to optimize hydropower generation. These generation decisions are heavily influenced by the price of electricity.

Rubicon Reservoir Operations

Rubicon Reservoir located on the Rubicon River is typically operated as a passive system; hydrologic conditions and reservoir elevation dictating tunnel flows. The Rubicon-Rockbound Tunnel, which connects Rubicon Reservoir to Buck Island Reservoir is a gated structure. The tunnel gates are closed in the summer, usually between mid-June and August once Rubicon River inflows drop below 20 cfs. The gates are reopened in October when inflows reach 40 cfs. This operation allows summer reservoir storage to meet minimum streamflows throughout the summer.

Rubicon Reservoir spills at elevation 6,545 feet, corresponding to storage of 1,435 AF. Flows through the diversion tunnel are head-dependent, with a different head-capacity relationship when the gates are closed than when open. This head-dependent relationship is not simulated in the upper American River model, neither is storage regulation modeled. In model simulation, releases to the Rubicon River are made to meet FERC license requirements. Any additional river flow, up to the diversion tunnel capacity, is diverted through the Rubicon-Rockbound Tunnel to Buck Island Reservoir. On a monthly time-step, the physical capacity of the tunnel does not constrain river diversions.

Buck Island Reservoir Operations

Similar to the Rubicon Reservoir diversion, Buck Island located on the Little Rubicon River is operated as a passive system. Flows through the Buck-Loon Tunnel that connects the reservoir to Loon Lake are determined by hydrologic conditions and reservoir elevations. The gated tunnel is closed in the summer, usually between mid-June and August when flows in the Little Rubicon River

[21] Under the 2005 El Dorado – SMUD Agreement, SMUD undertakes to directly deliver to El Dorado County or deliver to El Dorado County carryover storage up to 30,000 AF through 2025 and thereafter 40,000 AF for the remaining term of the Agreement. It is anticipated that water deliveries would be made at the White Rock Penstock. These provisions are not included in upper American River model but were added in scenario planning for the American River Basin Study.

fall below 8 cfs. The gates are reopened in October when inflows climb above 10 cfs. Buck Island Reservoir spills at elevation 6,436 feet, corresponding to storage of 1,077 AF.

Flows through the diversion tunnel are head-dependent, with a different head-capacity relationship when the gates are closed than when open. This head-dependent relationship is not modeled in the upper American River model. Neither is storage regulation modeled. In model simulation, releases t the Little Rubicon River are made to meet FERC license requirements. Any additional river flow, up to the diversion tunnel capacity, is diverted to Loon Lake. On a monthly time-step, the physical capacity of the tunnel does not constrain river diversions.

Loon Lake Operations

SMUD operates Loon Lake: to meet downstream flow requirements on Gerle Creek, including spring pulse flows; to meet FERC minimum pool in the late summer; and to maximize power generation. At the start of the refill season, discretionary power releases drawdown reservoir storage to avoid reservoir spills in April-May. Loon Lake spills at elevation 6,410 ft, corresponding to storage of 69,309 AF. From July to September, SMUD maintains reservoir levels to meet FERC minimum pool levels. After September, the reservoir is drawdown to meet an end-of-December carryover storage target of 40,000 AF (Warady, 2020). In January and February, the reservoir may be drawdown to lower elevations. The reservoir is then allowed to fill throughout the spring.

For modeling purposes, Loon Lake Powerhouse has a capacity of 1,000 cfs at all reservoir elevations. The model assumes a fixed 2-week maintenance period for the powerhouse at the beginning of October.

Gerle Reservoir and Robbs Peak Reservoir Operations

Minimum flows are released to Gerle Creek, all additional flow is diverted into the Gerle Canal up to the 1,025 cfs canal capacity. Similarly, minimum flows are released at Robbs Peak Reservoir to the South Fork Rubicon and all additional flow is diverted into the Robbs Peak Powerhouse penstock, up to its 1,250 cfs capacity. The model assumes a fixed 2-week maintenance period for Robbs Peak Powerhouse beginning at the start of October.

The upper American River model does not simulate storage regulation in Gerle Reservoir and Robbs Peak Reservoir. Gerle Reservoir is represented as a storage node. Robbs Peak Reservoir is represented as a junction node. On a monthly time-step, the physical capacity of Robbs Peak Tunnel does not constrain river diversions.

Ice House Reservoir Operations

Ice House Reservoir, located on South Fork Silver Creek, is the smallest of SMUD's major reservoirs. SMUD operates the reservoir to meet flow requirements and pulse flow requirements for the South Fork Silver Creek below Ice House Dam and for power generation at Jones Fork Powerhouse. Reservoir operations follow an annual cycle. The reservoir refills in the spring and summer from snowmelt. During this refill period, SMUD makes discretionary power releases, as needed, to avoid spilling or making controlled releases to the river over and above the FERC license requirements. From July to September, SMUD maintains reservoir levels to meet FERC minimum pool levels and there is little flexibility in operations. After September, releases are made in the fall for power generation to meet an end-of-December carryover storage target of approximately 30,000 AF.[22]

The Ice House Dam gated spillway is closed from April 1 through November 1. For the rest of the year, in accordance with DSOD regulations, the gates must remain open; the reservoir spills at elevation 5436.5 ft, corresponding to 34,855 AF of storage. When the gates are closed, spills occur at elevation 5,450 feet corresponding to a storage of 43,496 AF. The maximum normal storage is assumed to be 42,200 AF, which provides 2 feet of freeboard.

For modeling purposes, Jones Fork Powerhouse has a capacity of 319 cfs at all reservoir elevations. The model assumes a fixed 2-week maintenance period for the powerhouse during the latter part of October.

Union Valley Reservoir Operations

Union Valley Reservoir, located on Silver Creek, is the most downstream of SMUD's major storage reservoirs. Union Valley Reservoir is operated to meet minimum flows in its FERC license on Silver Creek, on South Fork American River below Slab Creek Diversion Dam, and to meet PG&E's FERC responsibilities for minimum flows below Chili Bar Dam and Powerhouse.

Reservoir operations follow an annual cycle. The reservoir refills in the spring and summer from snowmelt and inflows from Ice House Reservoir and from Robbs Peak Tunnel. During the refill period, SMUD makes discretionary power releases, as needed, to avoid spilling or controlled releases to the river over and above the FERC license requirements. From July to September, SMUD maintains reservoir levels to meet FERC minimum pool levels and there is little flexibility in operations. After September, releases are made in the fall for power generation to meet an end-of-December carryover storage target of approximately 140,000 AF (Warady, 2020).

Union Valley Dam has a gated spillway. The spillway gates are open from November 1 to March 31; during this time spills occurs at elevation 4,855 feet, which is equivalent to 225,046 acre-feet. The spillway gates are closed from April 1 to October 31. During this time spills occur at elevation 4,870 feet corresponding to a storage of 266,369 AF. The maximum normal storage is assumed to be 260,581 AF, which provides 2 feet of freeboard.

For modeling purposes, Union Valley Powerhouse has a capacity of 1,500 cfs at all reservoir elevations. The model assumes a fixed 2-week maintenance period for the powerhouse during the latter part of October.

Junction and Camino Reservoir Operations

Minimum flows specified in the FERC license are released to Gerle Creek and all additional flow is diverted into the Gerle Canal up to the 1025 cfs capacity. Similarly, minimum flows are released at Robbs Peak Reservoir to the South Fork Rubicon, and all additional flow is diverted into the powerhouse penstock, up to the capacity of the 1,250 cfs penstock.

[22] For planning purposes, SMUD aims for a total storage between 200,000 AF – 2220,000 AF by December 31 (Warady,2020).

In the upper American River model, storage regulation is not simulated at Gerle Reservoir and Robbs Peak Reservoir. Gerle Reservoir is represented as a storage node. Robbs Peak Reservoir is represented as a junction node. On a monthly time-step, the physical capacity of Robbs Peak Tunnel does not constrain river diversions.

Brush Creek Reservoir and Diversion Dam

Brush Creek Reservoir is not modeled as a storage facility. All flow above the minimum flow requirements are diverted to the Camino Penstock. Flows below Brush Creek Diversion Dam must be the maintained at the lesser of the FERC flow schedule and the natural flow.

Slab Creek Reservoir Operations

Historically, SMUD has operated Slab Creek Reservoir with no seasonal storage regulation, storage being regulated at daily and sub-daily timescales. In the upper American River model, Slab Creek Reservoir is represented as a simple junction node with no available storage. First, minimum flows are released to the river, these include instream flow requirements, pulse flows, and recreational flows. Second, flow is diverted into the White Rock Powerhouse penstock, up to its 4,000 cfs capacity. Lastly, any remaining inflow to Slab Creek Reservoir is released to the river to supplement the downstream flow requirement.

El Dorado Project 184

EID reservoirs are all located at high elevation in snow-dominated watersheds. In general, EID fills Project 184 reservoirs in the spring, while diverting natural flow at the Kyburz Diversion Dam into the El Dorado Canal. Releases from storage are made in the summer and fall. Typically, the reservoirs are drawn down in sequence.

EID operates Project 184 to meet the requirements of its FERC license and water right permit (P21112). The Project 184 license, issued on 18th October 1986, species minimum and maximum pool levels for reservoirs, instream flow requirements, and other restrictions on project operations.

Water-Year Classifications

Project 184 water year classifications are defined in the Project 184 FERC license and are based on the April - July full natural inflow to Folsom Lake as a percent of average.[23] The water year classifications are as follows:

[23] DWR forecasts published in Bulletin 120 use 1966-2015 to define the 50-yar average.

Water Year Type	Folsom Lake April-July Unimpaired Inflow (Percent of Average)	Folsom Lake April-July Unimpaired Inflow (acre-feet)
Wet	> 125%	> 3,370,000
Above Normal	100% - 125%	2,700,000 – 3,370,000
Below Normal	75% - 100%	2,020,000 – 2,700,000
Dry	50% - 75%	1,350,000 – 2,020,000
Critical Dry	< 50%	< 1,350,000

Silver Lake Operations

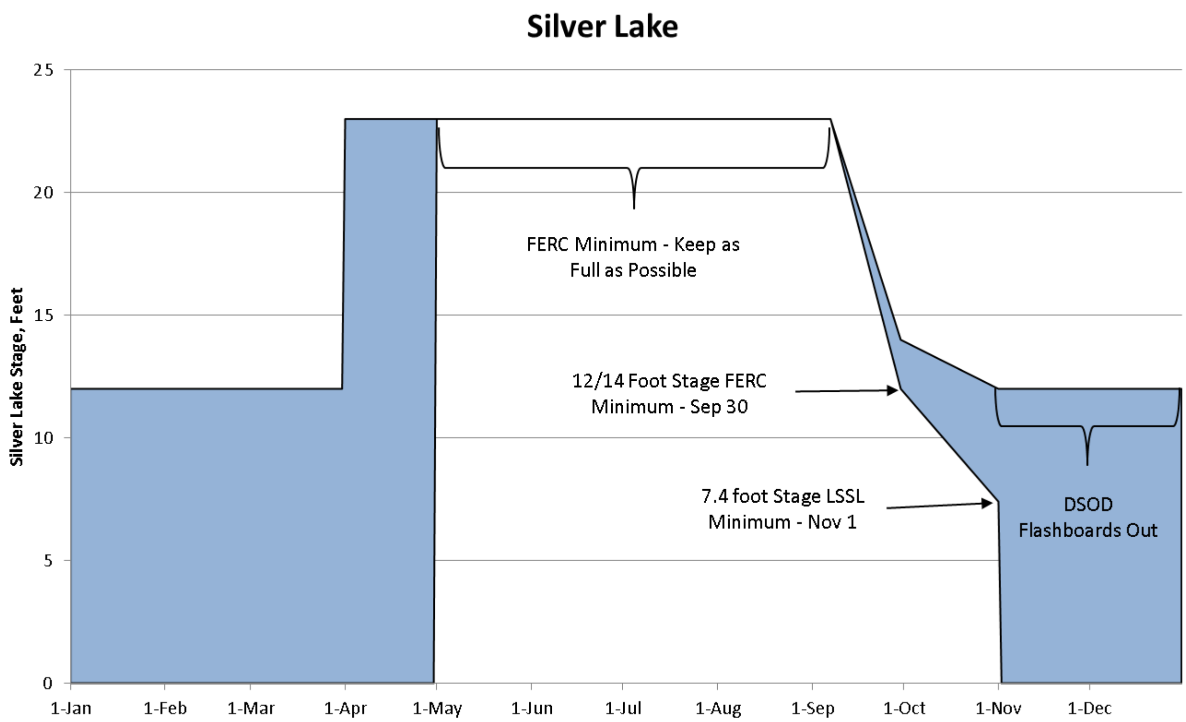
Silver Lake has a maximum capacity of 8,640 AF, which depends on the installation of flashboards at the dam spillway. With flashboards removed, the lake has a maximum capacity of 3,756 AF. Operation of the lake is constrained by requirements specified by the California Division of Safety of Dams (DSOD) and specified in the Project 184 FERC license. DSOD requires that the flashboards be removed from November 1 through March 31. This keeps storage at a 12-foot stage or below and prevents filling until after April 1. There is a FERC requirement to keep the lake as full as possible between May 1 and September 15. In model simulation, no discretionary lake releases are made from April 1 through September 15. During this period lake levels may fall as a result of minimum flow releases, seepage, and evaporation.

Maintenance of the El Dorado Canal is typically scheduled between October 1 through December 15. This further constrains operation of Silver Lake and the timing of discretionary releases for power generation and water supply.

An agreement with the League to Save Sierra Lakes requires a minimum 7.4-foot stage in Silver Lake on November 1. Because of the El Dorado Canal maintenance period, this agreement effectively results in a Silver Lake 7.4-foot stage through December 15. The agreement with League to Save Sierra Lakes also specifies a minimum 12-foot stage on September 30 in normal years, and a minimum 14-foot stage on September 30 in wet years.

Silver Lake has a minimum flow requirement directly below the dam of 4 cfs or natural flow, whichever is less. Silver Lake also has a minimum flow requirement on Silver Fork American River below the confluence with Oyster Creek.

Water seeps from Silver Lake through rock fissures to Oyster Creek, a tributary to the Silver Fork American River. The amount of seepage depends on the lake's water surface elevation and empirical flow-elevation relationships have been derived by EID from field measurements.

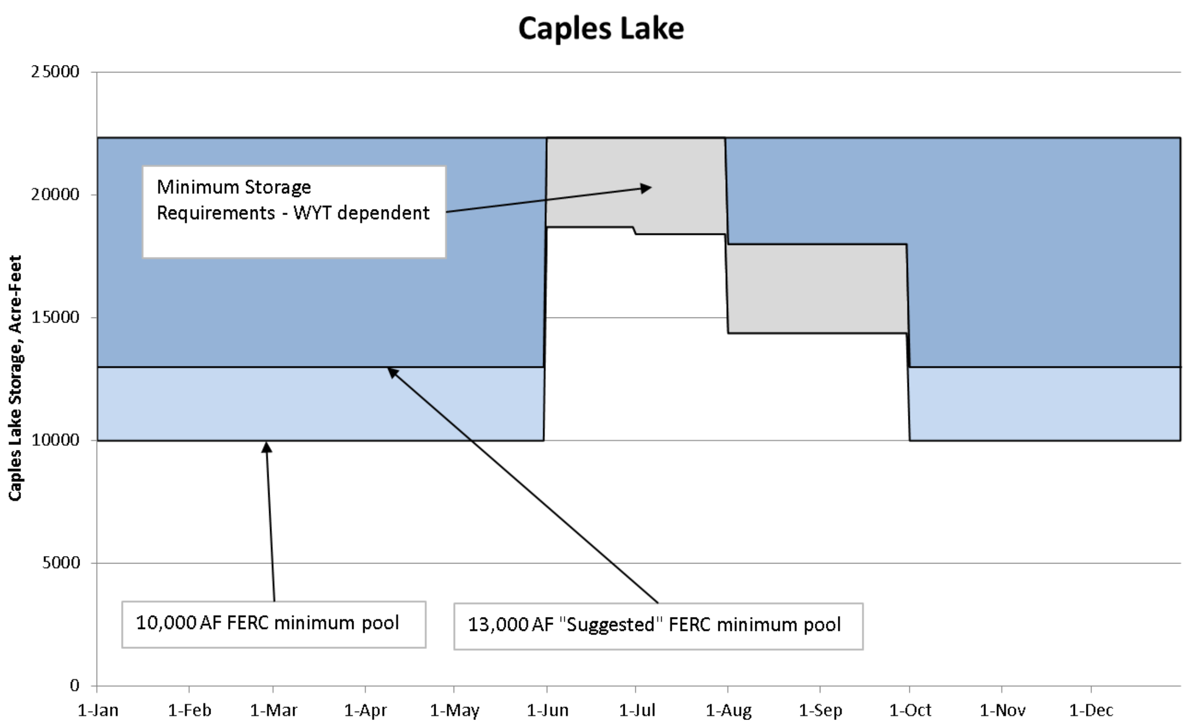


Credit: Western Hydrologics

Figure 7-1. Silver Lake Operations.

Capes Lake Operations

Caples Lake is operated to meet minimum pool elevations specified in EID's water right (Permit 21112) and in the P-184 FERC license. The latter are higher than the water right's minimum storage requirements. Caples Lake has limitations on its outflow during fall hydropower operations. Caples Lake is kept full through the early summer. In model simulation, reservoir releases begin in August, releasing up to 40 cfs in August and 5-10 cfs in September. In the fall and winter Caples Lake releases are constrained by a drawdown curve and the El Dorado Canal capacity. No discretionary releases are made Caples Lake after April 1st to ensure the reservoir fills.



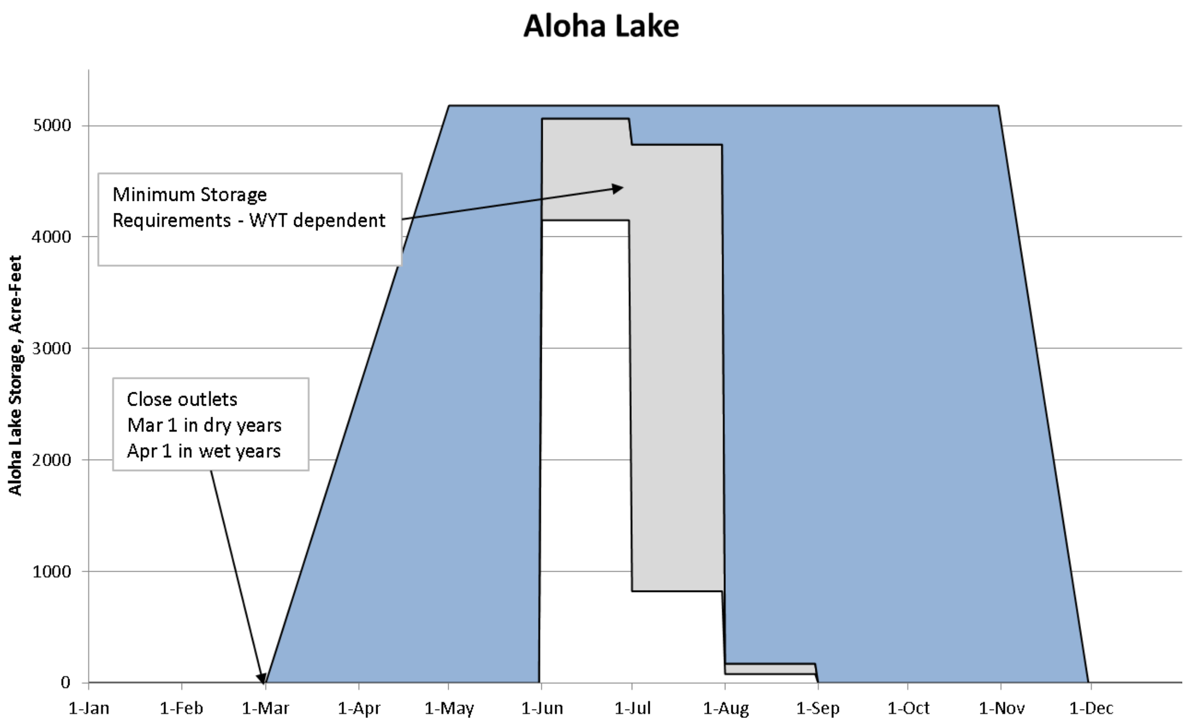
Credit: Western Hydrologics

Figure 7-2. Caples Lake Operations.

Aloha Lake Operations

Aloha Lake is operated to bypass inflow in the winter and subsequently to store snowmelt runoff in the late spring. Stored water is released for rediversion in the late summer. There are no discretionary lake releases prior to June 30th. D-1635 specifies minimum lake elevations to protect recreational uses. EID may not redivert water released for consumptive use, excluding FERC P-184 and DSOD requirements, unless these lake elevations are met. D-1635 requires that Lake Aloha never be drawn below the historical minimum, and not to be drawndown below the historical 5-year average. These storage targets were further codified in water right Permit 21112.

In model simulation, Aloha Lake is drawndown to dead storage by the end of November. The lake outlet is kept open from December through March. On April 1, the outlets are closed, and the lake is allowed to fill. Stored water is released from July through September, while maintaining minimum required pool elevations. The model assumes EID undertakes facility maintenance in October.



Credit: Western Hydrologics

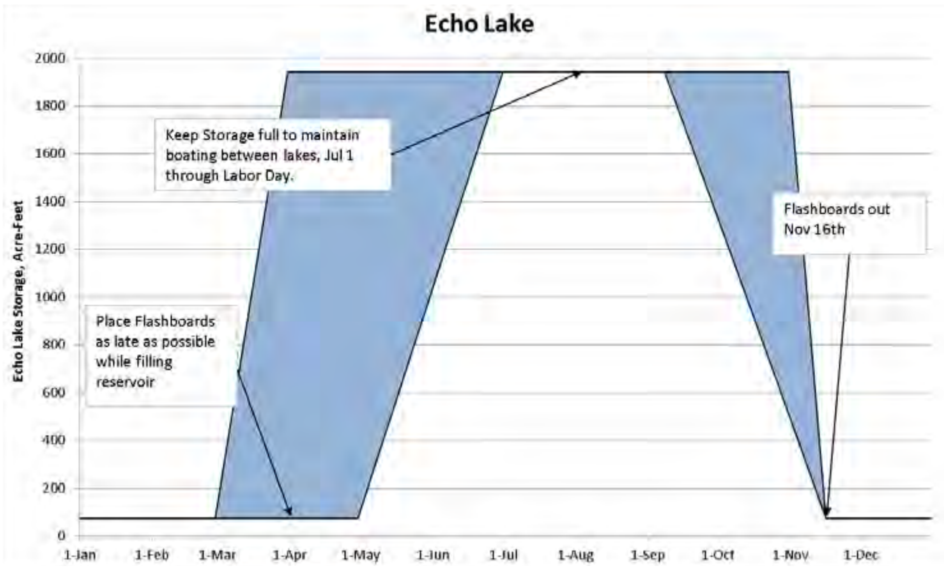
Figure 7-3. Lake Aloha Operations.

Echo Lake Operations

For most of the year, releases from Echo Lake are limited to water required to meet downstream flow requirements on Echo Creek or for spill operations. The FERC license for Project 184 requires that Echo Lake be kept as full as possible between June 1st and Labor Day. After Labor Day the Echo Lake Conduit is opened and water flows at the full capacity of the conduit until the lake surface water elevation falls below the invert of the conduit, or November 16th, whichever occurs first, and the flashboards are removed. In model simulation, the flashboards are reinstalled in the spring allowing the lake to fill. This installation is delayed as late as possible while allowing the reservoir to fill. In model simulation, the installation is linked to the water year type as follows:

Water Year Type	Installation Date
Wet, Above Normal, Below Normal	May 1
Dry	April 1
Critical Dry	March 1

Flow through Echo Lake Conduit is head dependent. For modeling purposes, it is assumed that the conduit flow is 26 cfs for a reservoir storage above 800 AF. Below this storage threshold it is assumed that the conduit flow falls linearly with storage.



Credit: Western Hydrologics

Figure 7-4. Echo Lake Operations.

El Dorado Canal Operations

EID diverts water at the Kyburz Diversion Dam into the El Dorado Canal under a mix of pre- and post-1914 water rights for consumptive use and hydropower purposes. The canal capacity, outside of the maintenance period, is 156 cfs. For model simulation, an annual maintenance period stretches from October 1 through December 15, during when there are no diversions into the canal either at Kyburz or from the creeks that cross the canal. The model diverts as much water as possible, while ignoring inflows from minor creeks along its length. In model simulation only Alder Creek is simulated, Bull, Ogilby, Esmeralda, and No Name creeks are not represented. It is assumed that inflows from these canals are approximately offset by canal seepage losses.

El Dorado Forebay Diversions

The district has a pre-1914 consumptive water right of 15,080 AF/year at the El Dorado Forebay. The full entitlement can be provided in all years including the historical critically dry years of 1977 and 2015. Therefore, this source of water is considered assured, and not subject to shortage during droughts (EID, 2016). Water is diverted from the El Dorado Forebay to the district's Reservoir A WTP for subsequent treatment, transmission, and distribution.

Jenkinson Reservoir Operations

Jenkinson Reservoir is the largest of EIDs reservoirs and is the main source of supply. The reservoir is also used to backfill any shortage in water supplies from the El Dorado Forebay and Folsom Lake. The average annual draft from the reservoir is approximately 23,000 AF, though the district's annual water right is for 33,400 AF of total beneficial use. The reservoir provides a measure of drought protection and EID limits deliveries in dry years to hedge against continued drought. Reservoir water level elevations serve as the primary indicator of water shortage that may trigger voluntary and/or mandatory rationing (EID, 2016).

Folsom Lake Diversions

EID diversions from Folsom Lake include CVP water, ditch water from pre-1914 water rights, and Permit 21112 water. Non-CVP water is diverted under Warren Act contracts with Reclamation.

Middle Fork Project

The MFP includes two major storage reservoirs, five diversion dams and associated conveyance facilities, five powerhouses, and a pump station. Water diverted at the Duncan Creek Diversion Dam is moved to French Meadows Reservoir, and water stored at French Meadows Reservoir is mostly passed through the French Meadows Powerhouse into Hell Hole Reservoir. From Hell Hole Reservoir, water is moved into Middle Fork Powerhouse, then into the Middle Fork Interbay where it is routed into Ralston Powerhouse and emptied into Ralston Afterbay. Water in Ralston Afterbay is released into the Middle Fork American River through Oxbow Powerhouse. Middle Fork Storage is dispatched in a Fill-Carryover cycle. The project carryover date is December 31, and the project estimated fill date is June 15th.

Water-Year Classifications

The MFP water year classifications are defined in the Project 2079 FERC license and are based on the annual unimpaired inflow to Folsom Lake as forecast by DWR in Bulletin 120. These classifications are used to set minimum flow requirements, pulse flow requirements, minimum pool requirements, reservoir objectives, and recreational flow requirements. The water year classifications are as follows:

Water Year Type	Folsom Annual Unimpaired Inflow (acre-feet)
Wet	> 3,400,000
Above Normal	2,400,000 – 3,400,000
Below Normal	1,500,000 – 2,400,000
Dry	1,000,000 – 1,500,000
Critical Dry	600,000 – 1,000,000
Extreme Critical Dry	< 600,000

The model adds an over-release to the flow requirement to mimic actual operations to ensure compliance. The over-release is 1 cfs in Critical and Extreme Critical water year types, and 2 cfs in all other water year types.

Duncan Creek Diversion Dam

Duncan Creek Diversion Dam is operated as a passive system; inflows dictate diversion rates. Once the flow requirement below the diversion dam has been met, all additional flows are diverted through the Duncan Creek Tunnel, up to the tunnel capacity of 400 cfs. However, diversions from Duncan Creek to French Meadows are discontinued when French Meadows Reservoir is spilling.

North Fork and South Fork Long Canyon Diversion Dams

The North Fork and South Fork Long Canyon Diversion Dams are mostly operated as passive systems with hydrology dictating the diversions and outflows. In the fall and early winter, PCWA leaves the diversion intakes closed to prevent debris from entering the Middle Fork Tunnel. In early spring PCWA opens the diversion intakes to capture the snowmelt runoff and re-closes the diversion intake in late summer when inflows have dropped below minimum flow levels. For modeling purposes, the diversion intakes are closed from October – February and open through the remainder of the water year.

The diversion tunnel from North Fork Long Canyon has a capacity of 100 cfs; the diversion tunnel from South Fork Long Canyon has a capacity of 200 cfs. Minimum flows below the diversion dam are specified in the FERC license.

French Meadows Reservoir and French Meadows Powerhouse Operations

Operation of French Meadows Reservoir is typically independently of Hell Hole Reservoir. During the refill period, reservoir levels are drawn down to avoid spilling during the snowmelt. Forecasted operations account for inflows from Duncan Creek, natural inflow from the Middle Fork American River, reservoir evaporative losses, and flow requirements below the dam. There are both minimum flow requirements and pulse flow requirements below the dam. Additionally, the FERC license specifies minimum pool elevations. In dry years, discretionary power releases during the refill period are zero as the reservoir does not fill and power generation is curtailed to attain the highest possible storage level prior to the summer dispatch season.

Beginning in June, French Meadows Reservoir is drawn down to achieve a carryover storage target of 50,000 AF by the end of December. For modeling purposes, power releases are scheduled uniformly across the June – December period.

For modeling purposes, it is assumed that French Meadows Powerhouse is closed for a 3-week maintenance period beginning April 7th.

Hell Hole Reservoir and Middle Fork Powerhouse Operations

Hell Hole Reservoir is operated for water supply, hydropower, to comply with minimum pool elevations specified in the FERC license and to meet downstream flow requirements on the Rubicon, Middle Fork, and North Fork American River. Except for the Rubicon River flow requirement, all controlled releases are dispatched through the Hell Hole Tunnel to the Middle Fork Powerhouse. There are both minimum flow requirements and pulse flow requirements below the dam. Releases to the river are made through a small hydropower unit with a capacity of 80 cfs. The dam also has a Howell-bunger valve for additional releases from the dam.

During the refill period, reservoir levels are drawn down to avoid spilling during the snowmelt. Forecasted operations account for inflows from French Meadows Reservoir, natural inflow from the Rubicon River, reservoir evaporative losses, and downstream flow requirements. The model forecast assumes that there is sufficient accretions downstream from French Meadows and Hell Hole dams to meet all consumptive demands.

Beginning in June, Hell Hole Reservoir is drawn down to meet consumptive use demands. Additional discretionary hydropower releases are made to achieve a carryover storage target of 100,000 AF by the end of December. For modeling purposes, incremental power releases are scheduled uniformly across the June – December period.

Middle Fork Interbay and Ralston Powerhouse Operations

Middle Fork Interbay is a 183-acre-foot regulating reservoir on the Middle Fork American River downstream from the Middle Fork Powerhouse and at the head of the Ralston Tunnel. In the American River module, it is represented as a conveyance node with no storage regulation. Outflow from the Middle Fork Powerhouse combines with flow in the Middle Fork American to either be routed to the Ralston Powerhouse or released into the Middle Fork American River below the Middle Fork Powerhouse to meet minimum instream flow requirements specified in the FERC license. Spills to the river may occur when French Meadows Reservoir is spilling or local accretions to the river are large.

Ralston Afterbay

Ralston Afterbay is a 2,782-acre-foot regulating reservoir that is typically operated on an hourly basis, but with some inter-day variability. In the American River module, it is represented as a conveyance node with no storage regulation. Water at the Afterbay is diverted to the Oxbow Powerhouse, up to the capacity of the powerhouse, so bypassing a short reach of the river. The Ralston Afterbay and Oxbow Powerhouse are operated to meet minimum flow requirements at the Foresthill stream gauge and recreational flow requirements.

American River Pump Station Operations

PCWA operates the MFP to meet a minimum flow requirement of 75 cfs below the American River Pump Station and to meet PCWA's Folsom Lake diversions. Generally, water is pumped from the American River, into the Auburn Tunnel, eventually into the Auburn Ravine for delivery to the growers in PCWA Zone 5. During the annual PG&E outage, usually after October 15th, the outlet valve of the tunnel is closed and water is pumped out of the tunnel at the Auburn Tunnel Pump Station, near the Auburn Waste Water Treatment Plant. The water is pumped into the PG&E South Canal for use at the Foothill Water Treatment Plant (YB 278). Currently there is a maximum pumping flow rate of 50 cfs until the completion of the Auburn Ravine mitigation study. Water deliveries from the American River Pump Station to PCWA lower Zone 1 and Zone 5 supplement water purchased from PG&E's Drum-Spaulding Project. Since the 1990s, diversions from the pumps station have steadily increased. Drought year deliveries in 2014 and 2015 totaled 17,500 AF and 24,200 AF, respectively.

Water Forum Agreement Operations

PCWA's commitments under the American River Water Forum Agreement consist of storage releases to mitigate for diversions above 1995 baseline levels by both PCWA and the City of Roseville. Water Forum mitigation water is calculated using a water index of March-November unimpaired inflow to Folsom Lake. Since October and November inflows are difficult to forecast, this index is calculated as forecasted March through September inflow to Folsom Lake, plus an additional 60,000 AF. Water Forum mitigation is calculated on a sliding scale based on the March-November index as shown below.

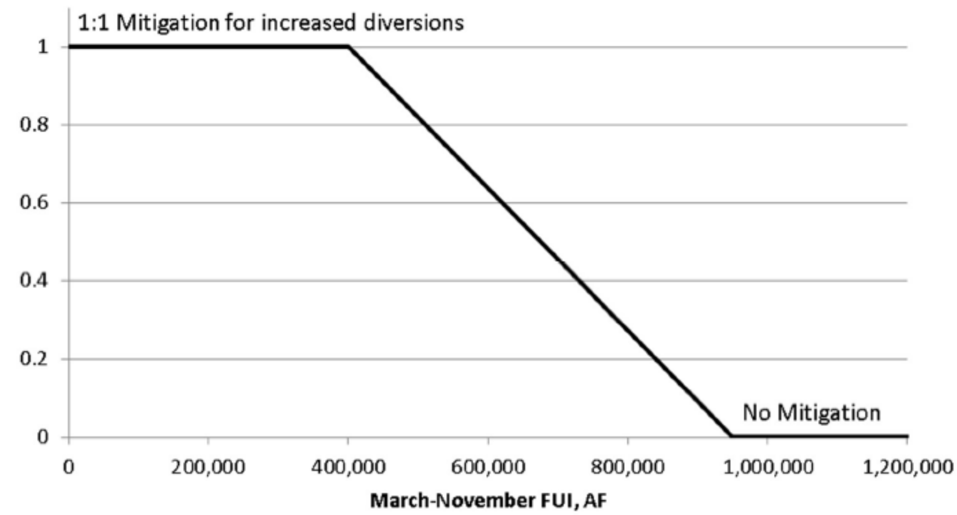


Figure 7-5. Placer County Mitigation Water.

There is no mitigation water for an index value above 950,000 AF. For an index value below 400,000 AF, mitigation water is equal to the incremental diversion above the 1995 baseline. For index values between 400,000 - 950,000 AF, the mitigation ratio linear increases from zero to one.

PCWA's 1995 baseline diversion at the American River Pump Station is 8,500 AF, and annual diversions above this level are mitigated up to 27,000 AF, equal to a total annual diversion of 35,500 AF.

The City of Roseville's 1995 baseline at Folsom Lake is 19,800 AF, and annual diversions above this level are mitigated up to 20,000 AF, qual to a total annual diversion of 39,800 AF. The Water Forum Agreement requires that the City of Roseville meet any additional demand above 39,800 AF with groundwater pumping.

In years when the March-November index is less than 950,000 AF, the model calculates the mitigation volume required associated with PCWA's diversion at the American River Pump Station and the City of Roseville's surface water diversions. In these years, the MFP carryover storage target is reduced by the amount of the calculated mitigation volume. This mitigation water is released from July through December using a fixed pattern as follows:

Month	Fraction of Annual Mitigation
July	0.250
August	0.275
September	0.185
October	0.000
November	0.155
December	0.135

Water Rights Curtailment Operations

PCWA water rights on the Middle Fork American River are junior to many of the downstream water rights holders. Therefore, water rights curtailments imposed by the State Water Board may require PCWA to bypass inflow to its reservoirs and only redivert previously stored water for consumptive purposes. Water right curtailments are currently not simulated in CalSim 3.

Chapter 8 Model Simulation

This chapter briefly describes model operational code as specified in a series of text files known as Water Resources Simulation Language (WRESL). The upper American River model is integrated as an upper watershed module in CalSim 3. It can be run either as a stand-alone model or integrated with the rest of the CalSim 3 model domain.

Model Activation

The upper American River module consists of a single cycle named UPPERAMERICAN, which is activated by setting the state variable *simulateUpperAmerican* to a value of 1 in the *mainCONV_30_SAplus.wresl* file:

```
svar simulateUpperAmerican{value 1.}
SEQUENCE CYCLE04 {
   model   UPPERAMERICAN
   condition simulateUpperAmerican >= 0.5
   order   4}
```

Model Links

Upper Yuba-Bear Module Inputs

The Upper American River module requires four inputs from the Yuba-Bear module, as follows:

- Flow through PG&E's Newcastle Powerhouse (model arc *C_STH007*)
- Newcastle Powerhouse bypass flows to the Mormon Ravine (model arc *C_MRM001*)
- Flow in the North Fork American River below the Canyon Creek confluence (model arc *C_NFA048*)
- Diversions at PCWA's American River Pump Station (model arc *D_NFA016_ABT002*)

These inputs may either be read as timeseries data as specified in the file *arcs-PreOperations.wresl* or read from the *YUBABEAR* cycle that runs before the *UPPERAMERICAN* cycle. The choice is determined by the variable *simulateUpperAmerican,* which is assigned a value of 0 or 1, and conditional code statements contained in *constraints-PreOperations.wresl.*

CalSim 3 Main Module Inputs

The Upper American River module requires two inputs from CalSim 3, as follows:

- Folsom Lake spill flag indicating the reservoir has filled (variable *FOL_Spill*)[24]
    - CVP north-of-Delta M&I allocation (variable *PERDV_CVPMI_SYS_SV*).

These inputs are read as timeseries data.

Upper American River Module Outputs

The lower American River watershed is simulated in the Upper American River module for the purposes of model testing and validation. The lower American River is resimulated as part of the CalSim 3 simulation of the Sacramento Valley floor. This subsequent simulation includes dynamic simulation of stream losses to groundwater, return flows to the lower American River, and Folsom Lake releases to support water demands on the lower Sacramento River and Delta, Delta outflow requirements, and south-of-Delta exports. None of these components are included in the upper American River module. However, output from the upper American River module is used to inform the CalSim 3 simulation of the Sacramento Valley floor. These outputs are as follows:

- North Fork American River inflow to Folsom Lake (model arc *C_NFA016*)
- South Fork American River inflow to Folsom Lake (model arc *C_SFA011*)
- EID's deliveries to El Dorado Hills service area from El Dorado (Canal) Forebay (model arc *D_WTPRS1_ELDID_NU3*) and from Jenkinson Reservoir (model arc *D_WTPRSA_ELDID_NU3*)
- MFP water delivered to Folsom Lake for diversion by Sacramento Suburban WD, San Juan WD, and the City of Roseville.
    - Mitigation water released by PCWA from its MFP reservoirs as part of Water Forum PSA to support flows in the lower American River in Water Forum dry and driest years.
    - Reservoir storage in French Meadows, Hell Hole, and Union Valley reservoirs[25]

The upper American River model simulates Folsom Lake and Lake Natoma operations and downstream diversions from the lower American River. This capability was added primarily for model development and testing. When run in a stand-alone mode, additional American River outflow requirements must be added to the model to represent Delta demands on Folsom Lake. When the upper American River model is run as a module of CalSim 3, final Folsom Lake storage, diversions, and releases and downstream diversions from the lower American River are determined by CalSim 3 in the simulation of the Sacramento Valley floor.

[24] The spill flag is used to control refilling of MFP reservoirs following the release of mitigation water as required under the Water Forum Agreement. It is anticipated that future refinement of the model will allow dynamic calculation of the flag.

[25] Storage values were initially needed to calculate the flood space requirement at Folsom Lake. This is no longer the case as CalSim 3 has adopted a variable 400/600 TAF flood space requirement that is independent of upstream storage.

Input Data

Monthly timeseries input data for the upper American River model are contained in a DSS file in the *common\dss* directory.[26] The file is denoted by the suffix 'SV'. These data include unimpaired inflows, hydrologic indices for water year classification, reservoir evaporation rates, urban and agricultural water demands, and return flows from wastewater treatment plants. Initial timeseries data for reservoir storage are stored in a separate DSS file, which is denoted by the suffix 'init'.

Paired or relational data are stored in a series of 'lookup' tables in the run\lookup directory. Tables relating to the upper American River model are denoted using the 'American' prefix.[27]

System WRESL Files

The file structure for the American River model is shown in **Figure 8-1**.

System files for the American River watershed are divided into: (a) Upper American River watershed above Folsom Lake; (b) Lower American River including and below Folsom Lake. Include statements for the upper and lower watersheds are found in *System_American.wresl*.

System files consist of three types, as follows:

- Files named with the prefix "arcs-" define state and decision variables.
- Files named with the prefix "constraints-" define linear constraints binding decision variables.
- Files named with the prefix "weight-" define the cost coefficients for the LP formulation, which represents a system of relative priorities.

Upper American River Watershed

System_UpperAmerican.wresl consists of 14 include statements that point to the files described below.

Arcs-Channels.wresl

Arcs-Channels.wresl defines variables representing stream and canal reaches. Where applicable, the upper bound defines the physical capacity of the arc, otherwise the upper bound is assigned a value of 99999.

Arcs-Deliveries.wresl

Arcs-Deliveries.wresl defines agricultural and urban water demands for GDPUD and EID. These are defined as timeseries data. Additionally, decision variables are defined for the total surface water diversion to meet demand (prefix DG_), net surface water delivery after losses (prefix DN_), and water shortage (prefix SHRTG).

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[26] Recent reorganization of the CalSim file structure has eliminated the common folder and the DSS folder is directly under the CalSim folder.

[27] This has not been consistently implemented and some lookup files are prefixed with a project acronym e.g., UARP for the Upper American River Project.

GDPUD water demands are 12-month repeating timeseries. The annual irrigation demand is 7,120 AF; the annual domestic water demand is 3,000 AF. Conveyance losses along the Georgetown Divide Ditch are assumed to be 20 percent.

EID urban water demands, divided amongst three service areas, are 12-month repeating timeseries totaling 36,000 AF/year.

Arcs-Diversions.wresl

Arcs-Diversions.wresl defines variables representing diversions from the stream and canal network. Where applicable, the upper bound defines the physical capacity of the diversion, otherwise the upper bound is assigned a value of 99999.

Arcs-Inflows.wresl

Arcs-Inflows.wresl defines 47 state variables as timeseries data that represent unimpaired inflows to the stream network. This includes three inflows to the upper watershed of the Cosumnes River.

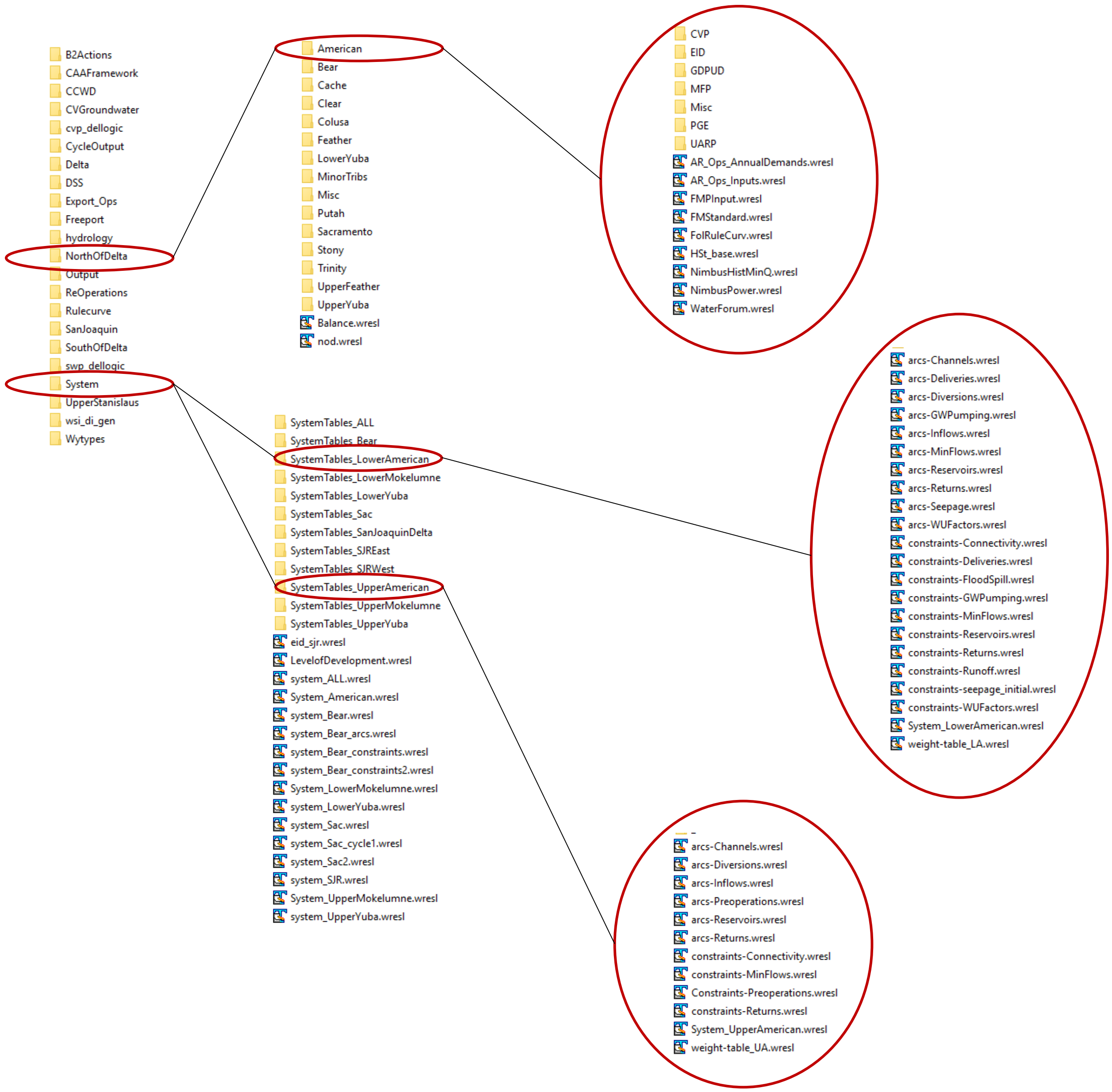

Figure 8-1. Upper American River Model File Structure.

Arcs-PreOperations.wresl

Arcs-PreOperations.wresl defines four state variables as timeseries data that represent boundary conditions to the upper American River module to be used if the Yuba-Bear module is not run dynamically. These boundary conditions include:

- Outflow from PG&E's South Canal into North Fork America River/Folsom Lake (C_STH007_SV)
- Outflow from Mormon Slough into North Fork America River/Folsom Lake (C_MRM001_SV)

- Flow in the North Fork American River below its confluence with Canyon Creek (C_NFA048_SV)
    - Diversion from the American River Pump Station to the Auburn Tunnel (D_NFA016_ABT002_SV)

Arcs-Reservoirs.wresl
Arcs-Reservoirs.wresl typically defines five storage levels and storage zones for the following reservoirs with exceptions given in parenthesis:

- Stumpy Meadows Reservoir
- French Meadows Reservoir (six storage zones, levels 2-6 defined elsewhere)
- Hell Hole Reservoir (six storage zones, levels 2-6 defined elsewhere)
- Loon Lake (levels 2-4 defined elsewhere)
- Gerle Creek Reservoir
- Union Valley Reservoir (levels 2-4 defined elsewhere)
- Ice House Reservoir (levels 2-4 defined elsewhere)
- Echo Lake (levels 2-5 defined elsewhere)
- Lake Aloha (levels 2-5 defined elsewhere)
- Silver Lake (levels 2-4 defined elsewhere)
- Lake Caples (levels 2-4 defined elsewhere)
- Jenkinson Reservoir

Except for Stumpy Meadows Reservoir and Jenkinson Reservoir, the top storage zone represents flood space that must be kept empty. *Arcs-Reservoirs.wresl* also defines reservoir area (acres), evaporation rate (inches/month), and net evaporation (TAF).

Arcs-Returns.wresl
Arcs-Returns.wresl defines decision variables that represent return flows from agricultural and urban demand units.

Arcs-WUFactors.wresl
Arcs-WUFactors.wresl defines decision variables associated with the conveyance loss of surface water from the point of diversion to the point of delivery.

Constraints-Connectivity.wresl
Constraints-Connectivity.wresl defines the connectivity of the arc-node network. It includes the entire American River watershed upstream from Folsom Lake, except for PG&E's Lake Valley Reservoir and downstream diversion facilities on the North Fork of the North Fork American River. It also

includes EID's Jenkinson Reservoir and associated facilities located on Camp and Sly creeks in the Cosumnes River watershed.

Constraints-Deliveries.wresl

Constraints-Delieveries.wresl sets the surface water diversion to a demand unit equal to the sum of stream and canal diversions. It subsequently sets the net surface water delivery equal to the gross diversion less conveyance loss. Water demand less any water shortage is set equal to the net surface water delivery, less conveyance loss, plus groundwater pumping, where applicable.

Constraints-MinFlows.wresl

Constraints-MinFlows.wresl defines 'minimum' and 'additional' flow subarcs for 35 compliance locations. Goal statements set the combined flow in the subarcs to equal the associated channel arc. In model simulation, a small buffer flow is typically added to the FERC minimum instream flow requirement.

Constraints-PreOperations.wresl

Constraints-PreOperations.wresl sets the four boundary flows for the upper American River module to equal predefined timeseries data or values calculated dynamically as part of the Yuba-Bear module.

Constraints-Returns.wresl

Constraints-Returns.wresl sets the return flow from agricultural water use in the GDPUD service area equal to 20 percent of the delivered water. The file defines a state variable for wastewater return flows as timeseries data and sets the return flow from urban water use in the district service area equal to these data.

Constraints-WUFactors.wresl

Constraints-WUFactors.wresl determines the evaporative and seepage losses associated with surface water deliveries to demand units.

Weight-Table_UA.wresl

Weight-Table_UA.wresl contains weights on decision variables whose values are maximized during the LP solution.

Lower American River Watershed

System_LowerAmerican.wresl consists of 18 include statements that point to the files described below.[28]

Arcs-Channels.wresl

Arcs-channels.wresl defines arcs representing the lower American River (10 decision variables) and the Folsom South Canal (4 decision variables).

Arcs-Deliveries.wresl

Arcs-Deliveries.wresl defines 20 state variables as timeseries data that represent urban demands in the lower American River basin. Additionally, decision variables for gross surface water deliveries, net

[28] The file *constraints-reservoirs.wresl* is no longer used because reservoir storage zones are defined as part of each project's operational logic.

deliveries (after conveyance losses), and water shortages are defined. Agricultural demands for PCWA lower Zone 1 and Zone 5 are also defined.

Arcs-Diversions.wresl

Arcs-Diversions.wresl defines arcs representing diversions from Folsom Lake, Lake Natoma, and the lower American River. It also includes diversions from water treatment plants to the urban demand units. Where applicable, a physical capacity is given as the upper bound.

Arcs-GWPumping.wresl

Arcs-GWPumping.wresl defines decision variables for groundwater pumping for each demand unit in the lower American River Basin or that receive American River water, including SMUD's Rancho Seco facility (GP_60N_PU). The file also defines minimum and maximum groundwater pumping expressed as a faction of the applied water demand or urban demand. These limits of pumping are state variables read from the lookup table *UrbanMinMaxgw.table*.

Arcs-Inflows.wresl

Arcs-Inflows.wresl defines 2 state variables as monthly timeseries data that represent the total runoff for WBA 26N and 26S. Subsequently, the file defines 9 decision variables that disaggregate the runoff at WBA level to specific points of the stream network. It also defines timeseries data for the local inflow to Folsom Lake.

Arcs-Inflows.wresl also defines a closure term as timeseries data, which is based on the historical gauged flow at Fair Oaks but applied at Folsom Lake. A decision variable for this inflow/outflow adjustment is set equal to the timeseries data using a soft constraint with an associated large weight.

Arcs-MinFlows.wresl

Arcs-MinFlows.wresl defines subarcs for instream flow compliance locations on the lower American River: below Lake Natoma (node *NTOMA*) and at H-Street (node *AMR006*). The subarcs represent flows to meet the instream flow requirement (suffix _*MIF*) and flows above the flow requirement (suffix _*ADD*).

Arcs-Reservoirs.wresl

Arcs-Reservoirs.wresl defines six storage zones for Folsom Lake. Three storage levels are defined for Folsom Lake, but levels 3, 4, and 5 are defined elsewhere. Five storage zones and corresponding storage levels are defined for Lake Natoma.

Arcs-Returns.wresl

Arcs-Returns.wresl defines return flows to the lower American River associated with the Aerojet Superfund Site and groundwater remediation.

Arcs-Seepage.wresl

Arcs-seepage.wresl defines seven decision variables that represent stream-groundwater interaction for Folsom Lake, Lake Natoma, and the lower American River. These variables may be positive or negative, a positive value indicates an inflow to the stream system. The variable *SG_AMR_Total* represent the total interaction. Positive values represent an inflow to the river.

Arcs-WUFactors.wresl

Arcs-WUFactores.wresl defines decision variables for conveyance losses associated with the delivery of surface water. It also defines associated loss factors. These factors are set to zero except for 26S_PU3, which represents non-potable water use along the Folsom Lake shoreline.

Constraints-Connectivity.wresl

Constraints-Connectivity.wresl defines the connectivity of the arc-node network for Folsom Lake, Lake Natoma, lower American River, and Folsom South Canal (not including its extension as part of the Freeport Project). It also includes the connectivity for the water treatment plants.

Constraints-Deliveries.wresl

Constraints-Deliveries.wresl defines goal statements for the total surface water delivery, these deliveries after conveyance losses, and the requirement that urban demands are met in full. No water shortage is simulated as groundwater pumping to meet demand in unrestricted. The exception is EID service area for which water shortages are permitted. The file also defines and imposes conveyance losses for the Folsom South Canal.

Constraints-GWPumping.wresl

Constraints-GWPumping.wresl contains goal statements that set a minimum level of groundwater pumping to meet urban water demands in the lower American River basin. Constraints for maximum groundwater pumping have been commented out.

Constraints-MinFlows.wresl

Constraints-MinFlows.wresl sets the sum of 'minimum flow' and 'additional flow' subarcs equal to flow in the associated river arc for two compliance locations on the lower American River.

Constraints-Returns.wresl

Constraints-Returns.wresl temporarily sets the return flow from the Areojet Superfund Site to the lower American River equal to a predefined timeseries data.

Constraints-Runoff.wresl

Constraints-Runoff.wresl sets four runoff arcs entering Lake Natoma and the lower American River to equal the runoff for the entire WBA multiplied by a watershed drainage factor, which is read from the lookup table *WatershedAreaPpt.table*.

Constraints-Seepage_Initial.wresl

Constraints-Seepage_Initial.wresl temporarily sets the stream-groundwater interaction for the lower American River to zero. These gains and losses are subsequently dynamically simulated by CalSim 3 as part of the Sacramento Valley floor.

Constraints-WUFactors

Constraints-WUFactors.wresl contains goal statement for evaporative and seepage losses associated with the delivery of surface water.

Weight-Table_LA.wresl

Weight-Table_LA.wresl contains weights on decision variables whose values are maximized during the LP solution. Weights are placed on 6 storage zones in Folsom Lake and 5 storage zones in Lake Natoma, deliveries from water treatment plants to demand units, and flow compliance locations on the lower American River. Additionally, a weight is placed on mitigation water released by PCWA as part of its Water Forum PSA, and that is routed down the lower American River.

UnimpairedFlowCheck.wresl

UnimpairedFlowCheck.wresl was developed during model testing and debugging to calculate the impaired flow at the Fair Oaks gauge based on the simulated flow, upstream storage regulation, reservoir evaporation, imports, exports, and diversions.

Operational WRESL Files

Operational logic for American River watershed is spread across nine 'project' folders under *common\NorthOfDelta\American*, as follows:

- **CVP** contains nine files relating to the operation of Folsom Lake and Lake Natoma.
- **EDC_OCA** contains a single file related to urban and agricultural growth in El Dorado County.
- **EID** contains four files for EID's Project 184 and Sly Park facilities.
- **FMS** contains files relating to the Flow Management Standard.
- **GDPUD** contains three files operation of GDPUD's Stumpy Meadows Reservoir.
- **MFP** contains 11 files for the operation of PCWA's MFP.
- **PGE** contains two files relating to the operation of PG&E's Chili Bar Project and Drum-Spaulding Project.
- **URP** contains three files relating to the operation of SMUD's Upper American River Project.
- **WS** contains a single file relating to water rights, contracts and agreements that limit diversions from Folsom Lake, Lake Natoma, and the lower American River.
- **WYT** contains two files that define water year types.

CVP Folder

CVPAllocationUpperAmericanModule.wresl

The Upper American River module is designed to be run as a stand-alone model or as a prior cycle to the full CalSim 3 valley floor model. In both cases, the CVP North-of-Delta M&I allocation need to be determined. In the stand-alone mode, the allocation is set equal to monthly timeseries data *perdel_cvpmi_sys_sv*. When the Upper American River module is run in conjunction with the full CalSim 3 model, the CVP M&I allocation is taken from the previous timestep. This introduces minor errors in months of March through May, but these errors are subsequently corrected in the CalSim 3 cycles.

FolsomFloodOps_UARM.wresl

FolsomFloodOps_UARM.wresl is read as part of the Upper American River module. It establishes the top of conservation for Folsom Lake given the upstream creditable space in French Meadows, Hell Hole, and Union Valley reservoirs. The flood control space is based on the 400-600 variable requirement. The creditable space is limited to 45 TAF, 80 TAF, and 75 TAF, respectively. From November through February, Folsom Lake flood control reservation space (FCRS) is reduced by the creditable space. In March and April, FCRS is reduced by a fraction of the creditable space. In April, there is no allowance for creditable space.

No flood control space is required from May through September. However, limits to the top of conservation are imposed from July to September to implement drawdown for hydropower purposes and to meet the end of October requirement.

As an approximation, storage in French Meadows, Hell Hole, and Union Valley reservoirs at the end of the previous month is used to determine the upstream creditable space. This introduces minor errors, but these errors are subsequently corrected in the CalSim 3 cycles.

FolsomFloodOps_SAC.wresl

FolsomFloodOps_SAC.wresl is read as part of the main CalSim 3 model. The file is identical to *FolsomFloodOps_UARM.wresl* except that the creditable space in French Meadows, Hell Hole, and Union Valley reservoirs is read from Upper American River module (or predefined timeseries is the module is turned-off) for the current timestep.

FolsomRuleCurve_UARM.wresl

FolsomRuleCurve_UARM.wresl is read as part of the Upper American River module. It defines Folsom Lake levels 2, 3, and 4 and sets four goal statements to define storage zones 2, 3, 4, and 5 (level 5 for Folsom Lake is set in *FolsomFloodOps_UARM.wresl.wresl*). Folsom storage levels are determined as follows:

- *S_FOLSMlevel1,* the top of dead storage, is equal to 90 TAF and is established in *arcs-reservoirs.wresl.*
- *S_FOLSMlevel2* is timeseries data read from the input DSS file and established in *arcs-reservoirs.wresl.* Monthly values vary between 300 – 350 TAF and typically change in January, but with a few exceptions. Only seven months have values other than 300 or 350 TAF. The original source of these data has not been identified. Values for the upper American River model are based on values developed for CalSim II.
- *S_FOLSMlevel3*init, the initial determination of level 3, is set equal to 400 TAF, except from October through March of wet years when it is set equal to 300 TAF.
- *S_FOLSMlevel3*adj, the final determination of level 3, is a function of forecasted inflows to Folsom Lake from the current month through the end of September during the drawdown cycle. From October through April, the adjusted level 3 is equal to the initial level 3 value.
- *S_FOLSMlevel4* is determined based on *S_FOLSMlevel5*. From November through March it is equal to level 5. In April and May it is assigned values of 792 and 967 TAF, respectively. From June through October it is assigned a value of 592 TAF.

- *S_FOLSMlevel5*, the top of conservation storage, is determined in *FolsomFloodOps_UARM.wresl*.
- *S_FOLSMlevel6,* the top of flood control space, is equal to 966,832 AF and is established in *arcs-reservoirs.wresl*. This is based on the 2005 bathymetric survey of the late and corresponds to an elevation of 468.34 (NAD 88).

The adjusted level 3, *S_FOLSMlevel3adj*, for the months of June through September is based on the following parameters:

- *S_FOLSM(-1)*, previous end-of-month storage in Folsom Lake
- *FolsomFNF*, the unimpaired flow at Folsom Dam, calculated as the sum of all upstream unimpaired inflows
- *FolsomFNFSum*, the sum of monthly unimpaired flows at Folsom Dam from the current month through the end of September.
- *UAStorage*, the previous end-of-month storage in reservoirs upstream from Folsom Lake.
- *UAStorageTarget*, the target carryover storage in reservoirs upstream from Folsom Lake. SMUD's total target storage is 200 TAF. PCWA's total target storage is 150 TAF by the end of the calendar year. A value of 190 TAF is assumed for the end of September based on simulated operations. A value of 15 TAF is assumed for Stumpy Meadows Reservoir based on historical operations. For Aloha, Caples, and Silver lakes, target values of 0, 16, and 4 TAF were adopted based on FERC requirements and operational rules.
- *UAEvapEst*, total reservoir evaporation for the current month is estimated as the product of beginning of month surface area and current month reservoir evaporation rate.
- *UAEvapEstSum*, total reservoir evaporation from the current month through the end of September assumed to be equal to the previous year's evaporation as an approximate estimate.
- *UAImportEst, monthly imports to the watershed are assumed equal to the previous year's import for that month.*
- *UAImportEstSum, annual imports to the watershed are assumed equal to the previous year's import.*
- *UAExportSum, monthly exports from the watershed are assumed equal to the previous year's export for that month.*
- *UAExportSum, annual exports from the watershed are assumed equal to the previous year's export.*
- *WFMitigation*, release of mitigation water from PCWA's MFP reservoirs as defined under the Water Forum Agreement.
- *WFMitigationSum*, release of mitigation water from PCWA's MFP reservoirs from the current month through the end of September.
- *FolsomInflowEst*, estimate of current month's inflow to Folsom Lake.
- *FolsomInflowEstSum,* estimate of inflow to Folsom Lake from the current month through the end of September. It is calculated as *FolsomFNFSum + UAStorage - UAStorageTarget + WFMitigationSum - UAEvapSum + UAImportSum – UAExportSum.*
- *FolDivEst,* estimate of the current month's diversions from Folsom and Natoma lakes.

- *FolDivEstSum,* estimate of diversions from Folsom and Natoma lakes from the current month through the end of September.
- *FolSupEst* is the forecast of the volume of water that can be released from Lake Natoma from the current month through the end of September while meeting a Folsom carryover storage target of level 3. It is calculated as *FolsomInflowEstSum - FolDivEstSum + S_FOLSM(-1) - S_FOLSMlevel3init*.
- *FolFlowTarg* is the *FolSupEst* translated into an equivalent constant flow rate in cfs.
- *FolRuleCalc* is the Folsom level 3 that would achieve the desired release of water in the current month. For May through September, it is calculated as *FolsomInflowEst - FolDivEst + S_FOLSM(-1) - FolFlowTarg*cfs_taf*.
- *S_FOLSMlevel3adj* is the final value of Folsom level 3 set equal to *FolRuleCalc* but constrained to lie between level 2 and level 4.

The forecasted end-of-month storage is equal to the previous month storage plus the forecasted inflow, less the forecasted diversion. Forecasted inflows are equal to the unimpaired inflow to Folsom Lake, less forecasted evaporation, plus forecasted releases from upstream storage, plus forecasted imports, less forecasted exports.

FolsomRuleCurve_SAC.wresl

FolsomRuleCurve_SAC.wresl is read as part of the main CalSim 3 model. The file is similar to *FolsomRuleCurve_UARM.wresl* except that it omits the dynamic estimate of Folsom Lake impaired inflow.

HStreetBase.wresl

HSt_Base.wresl establishes the flow requirement at H-Street (*HMin*) on the lower American River (*C_AMR004*) and applies a small penalty of -10 to flows above this requirement when storage in Folsom Lake is below 400 TAF. The purpose of the penalty is to shift storage releases to Lake Shasta, if possible.

NimbusHistMinQ.wresl

NimbusHistMinQ.wresl defines the historical minimum flow requirement at H Street (*HStMin*) and below Nimbus Dam (*nimbus_hist_std*) based on a modified D893 requirement.

NimbusPower.wresl

Nimbus Dam forms Lake Natoma to reregulate the releases for power made through Folsom Powerplant. Nimbus Powerplant is a run-of-the-river plant and provides station service backup for Folsom Powerplant. *Arcs-MinFlows.wresl* disaggregates the release from Nimbus Dam into the component to meet instream flow requirements (*C_NTOMA_MIF*) and any additional release (*C_NTOMA_ADD*). *NimbusPower.wresl* further disaggregates releases into a power release (*C_NTOMA_POW*) and a non-power release. It is assumed that water released to meet instream flow requirements passes through the powerhouse as the plant's capacity exceeds regulatory flow requirements. Flows through the powerhouse are limited to 5,000 cfs and consist of *C_NTOMA_MIF* and *C_NTOMA_ADD1*.

WS_Contracts.wresl

WS_Contracts.wresl contains logic to restrict diversions from Folsom Lake, Lake Natoma, and the lower American River based on: (a) water rights; (b) contract agreements; and (c) Water Forum Agreement. Additionally, it specifies water treatment capacities and maximum groundwater pumping rates for some of the lower American River water purveyors. Blocks of code are written for each water purveyor as follows:

- Establish the monthly pattern of urban demand
- Define water right amounts or flow rates (if any)
- Define CVP contract amounts (if any)
- Define MFP amounts (if any)
- Define Water Forum annual limits
- Translate annual limits to monthly limits based on the urban pattern of demand
- Constrain monthly diversions to sum of water rights, CVP water and MFP water
- Constrain monthly diversions to sum of Water Forum limits

EID Folder

Cosumnes_EID.wresl

The file *Cosumnes_EID.wresl* contains operational logic relating to Jenkinson Reservoir, including: (a) reservoir allocation logic, (b) water right limits, and (c) Hazel Creek Tunnel flows.

Diversions from Jenkinson Reservoir to EID's Reservoir A for water treatment is divided into a firm allocation (D_JNKSN_WTPRSA_firm) and a variable allocation (D_JNKSN_WTPRSA_alloc) that depends on hydrologic conditions and a target carryover storage of 16 TAF. The firm allocation is set equal to 12 TAF/year on a fixed monthly pattern with a maximum monthly diversion of 125 cfs. The variable allocation is based on recent historical deliveries.

Cosumnes_EID.wresl defines water right limits for direct diversion and diversion to storage from Camp Creek and Sly Creek according to the requirements of its pre-1914 water right (reported under S022682) and water right licenses 11835 and 11836. Subsequently, a goal statement restricts diversions from Jenkinson Reservoir to the sum of direct diversion and rediversion from storage releases. *Cosumnes_EID.wresl* also includes a goal statements that sets flow through the Hazel Creek Tunnel to zero.

EID_Contracts.wresl

The file *EID_Contracts.wresl* implements water right and contract limits for EID diversions at the El Dorado Forebay and Folsom Lake. This includes: (a) district diversion of CVP contract water (14-06-200-1375A-LTR1) at Folsom Lake, (b) district diversion of CVP Fazio water, (c) district diversion of Permit 21112 water at Folsom Lake, (d) district diversion of its pre-1914 ditch water rights at Folsom Lake, (e) district diversion of water right water at El Dorado Forebay.

Min_flows.wresl

The file *Min_Flows.wresl* implements minimum flow requirements as specified in EID's FERC license 184-065. Water year types are based on the April-July unimpaired runoff of the American River at Fair Oaks. Compliance locations include Echo Creek below Echo Lake Dam, Pyramid Creek at Twin Bridges, Caples Creek below Caples Lake Dam, Silver Creek below Silver Lake Dam, and South Fork American River below the Kyburz Diversion Dam. The file also specifies minimum flows for Alder Creek in the upper American River watershed and Sly Creek and Camp Creek in the upper Cosumnes River watershed.

Silver Lake is partly overlying fractured lahar rock containing subterranean channels through which water flows out at certain lake levels. *Min_Flows.wresl* defines elevation-dependent lake leakage that flows through the subterranean channels to discharge in to Oyster Creek, downstream of Oyster Pond.

FERC License No. 184-065 specifies an annual maintenance period for the El Dorado Canal and El Dorado Powerhouse (aka Akin Powerhouse) to begin no later than October 3rd each year (Condition No.52). During this maintenance period, El Dorado Canal is non-operational. *Min_Flows.wresl* specifies a maintenance period from October 1 through December 15 and uses a goal statement to limit canal flows based on a canal capacity of 156 cfs and the period of closure. Similarly, diversions from Alder Creek in to the El Dorado Canal are limited based on a diversion capacity of 15 cfs and the period of closure.

That same time period is specified here for consistency, and for lack of a more specific timeframe provided in the FERC license.

Res_Ops.wresl

Operations for Project 184 reservoirs are primarily driven by requirements specified in FERC license 184-065 Appendix A. These requirements are implemented in the file *Res_Ops.wresl* using storage levels and associated storage zones, which are assigned different weights.

Caples Lake

- Storage Level 1 represents dead storage and is assigned a value of 2.0 TAF in *arcs-reservoirs.wresl.*
- Storage Level 2 is used to represent FERC minimum operating pool.[29]
- Storage Level 3 represents the June – September FERC target storage levels below which no discretionary lake releases are allowed.
- Storage Level 4 is not needed as there is no flood control requirement and is set equal to Level 5.
- Storage Level 5 represents the reservoir capacity and is assigned a value of 22.388 TAF in *arcs-reservoirs.wresl.*

[29] The 2006 FERC license for Project 184-065 states that the licensee shall maintain a minimum pool in Caples Lake of 10,000 AF and also operate the lake during the fall and early winter so that target lake levels are likely to be met in the following summer. Model simulation indicates that a storage of 13,000 AF may be needed on November 30 to ensure that these target levels are met. Therefore, 13,000 AF was chosen for Level 2.

Lake Aloha

- Storage Level 1 represents dead storage and is assigned a value of zero TAF in *arcs-reservoirs.wresl*.
- Storage Level 2 represents minimum pool levels established by the State Water Board in D-1635 and as modified in Water Right Order 2001-22 and adopted by reference in the FERC license.
- Storage Level 3 represents average historical storage conditions. Storage above level 3 is released for power generation at the El Dorado Powerhouse.
- Storage Level 4 is not needed as there is no flood control requirement and is set equal to Level 5.
- Storage Level 5 is the top of conservation storage, which is controlled by the lake outlet valve. The valve is typically closed in April but closed in March in Dry and Critical years to allow the lake to fill.

Echo Lake

- Storage Level 1 represents dead storage and is assigned a value of 0.07 TAF in *arcs-reservoirs.wresl*.
- Storage Level 2 represents the FERC minimum target storage and is also used to provide a smooth drawdown between the lake being kept full until Labor Day and the lake's drawdown over the following 10-week period to dead storage.[30]
- Storage Level 3 is not needed and is set equal to Level 5.
- Storage Level 4 is not needed as there is no flood control requirement and is set equal to Level 5.
- Storage Level 5 represents the top of conservation storage as controlled by placement of flashboards at the lake outlet. The FERC requirement is to keep the waterway between Upper Echo and Lower Echo Lakes navigable between July 1 and Labor Day of each year (i.e., keep lake full). The file *Res_Ops.wresl* installs the flashboards based on water year type. In model simulation, the flashboards are removed in September. Flow through the Echo Lake conduit are simulated as head dependent. It is assumed that the conduit valve is opened on Labor Day and closed when the water surface elevation drops below the conduit invert or November 16th, whichever occurs first.

Silver Lake

- Storage Level 1 represents dead storage and is assigned a value of zero TAF in *arcs-reservoirs.wresl*.
- Storage Level 2 represents the FERC minimum target storage. Minimum targets include: no discretionary releases prior to September 15; a 12-foot minimum stage required on September 30, a 7.4-foot stage required on November 1; and keeping the reservoir as full as possible from May-September 15.

[30] The 2006 FERC license for Project 184-065 states that the licensee shall operate Echo Lakes such that the channel between the Upper and Lower Echo Lakes is navigable by motorized watercraft, between July 1 and Labor Day of each year, while still complying with minimum streamflow or other conditions and requirements.

- Storage Level 3 represents the June – September FERC target storage levels below which no discretionary lake releases are allowed. Storage above level 3 is released for power generation at the El Dorado Powerhouse.
- Storage Level 4 is not needed as there is no flood control requirement and is set equal to Level 5.
- Storage Level 5 represents the top of conservation storage as controlled by placement of flashboards at the lake outlet. In model simulation, the flashboards are installed April 1 through October 31.

FMS Folder

AR_Ops_AnnualDemands.wresl

The file *AR_Ops_AnnualDemands.wresl* calculates the value of state variables required for implementation of the American River Flow Management Standard. For the nine agencies that receive water from the American River Pump Station, Folsom Lake, Folsom South Canal, and the lower American River, the file determines water demands as follows:

- March-April water demand
- March-May water demand
- March-June water demand
- March-July water demand
- March-August water demand
- March-September water demand
- June-September water demand
- Current month-September water demand
    - Annual water demand

Water demands do not include reuse or conveyance losses. Subsequently, the file determines the water demand as a fraction of the annual demand as follows:

- March-April water demand as fraction of annual demand
- March-May water demand as fraction of annual demand
- March-June water demand as fraction of annual demand
- March-July water demand as fraction of annual demand
- March-August water demand as fraction of annual demand
- March-September water demand as fraction of annual demand
- June-September water demand as fraction of annual demand
- Current month-September water demand as fraction of annual demand

- Current month water demand as fraction of annual demand

AR_Ops_Inputs.wresl

The file *AR_Ops_Inputs.wresl* calculates the value of additional state variables required for implementation of the American River Flow Management Standard. These variables include the following inflow forecasted:

- October-March forecasted inflows to Folsom Lake
- March-April forecasted inflows to Folsom Lake
- March-May forecasted inflows to Folsom Lake
- March-June forecasted inflows to Folsom Lake
- March-July forecasted inflows to Folsom Lake
- March-August forecasted inflows to Folsom Lake
- March-September forecasted inflows to Folsom Lake
- June-September forecasted inflows to Folsom Lake

AR_Ops_Inputs.wresl also estimates Folsom Lake and lower American River diversions for the following timeframes:

- October-March estimated diversions
- March-April estimated diversions
- March-May estimated diversions
- March-June estimated diversions
- March-July estimated diversions
- March-August estimated diversions
- March-September estimated diversions
- June-September estimated diversions
- Current month-September estimated diversions

FMStandard.wresl

The file *FMStandard.wresl* implements the 2017 modified Flow Management Standard. It includes a minimum carryover storage target of 275 TAF.

GDPUD Folder: Stumpy Meadows Project

Files relating to the Stumpy Meadows Project are in the folder: *common**NorthOfDelta**American**GDPUD*.

Stumpy_min_flows.wresl

Stumpy_min_flows.wresl specifies flow requirements in accordance with Paragraph 9 of water right Permit 12827 (Application 5644A). Goal statements enforce the requirements using soft constraints and an associated high weight, as follows:

- Pilot Creek flow between Stumpy Meadows Reservoir and the Pilot Creek Diversion Dam (C_PLC009_MIF) is constrained to be less than the required monthly flow requirement.
- Pilot Creek flow downstream of the Pilot Creek Diversion Dam (C_PLC006_MIF) is constrained to be less than the required monthly flow requirement.

Stumpy_res_ops.wresl

Stumpy_res_ops.wresl implements GDPUD water shortage contingency measures in response to dry hydrologic conditions. Water storage at Stumpy Meadows is evaluated each May. If the end-of-April storage in Stumpy Meadows Reservoir meets one of GDPUD's defined shortage stages, delivery of both domestic and irrigation water is reduced by up to 50 percent.

Stumpy_res_ops.wresl defines 5 goal statement as follows:

- The decision variable *StumpyDroughtReduction* is set equal to the state variable *DroughtReduction* for output purposes.
- The Georgetown Divide Ditch conveyance loss (D_GDD010_GDDLOS) is constrained to be less than 20 percent of the upstream delivery arc (D_PLC007_GDD010).
- GDPUD's urban delivery (D_WTPWAL_GDPUD_NU) is constrained to be less than the monthly demand for domestic water multiplied by the *DroughtReduction* factor.
- GDPUD's agricultural delivery (D_GDD010_GDPUD_NA) is constrained to be less than the monthly demand for irrigation water multiplied by the *DroughtReduction* factor.
- The decision variable *GDPUD_NU_dem_rem* is set equal to any municipal water supply shortage after accounting for the drought reduction.[31]

GDPUD_Exchange.wresl

GDPUD_Exchange.wresl simulates future possible supply of CVP water delivered by PCWA from the American River Pump Station to the GDPUD service area.

MFP Folder: Middle Fork Project

The MFP folder contains files relating to simulation of PCWA's MFP.

ARPSdemand.wresl

PCWA's Zone 1 and Zone 5 water demands are primarily met through purchases from PG&E and deliveries from the Bear River via the lower Boardman Canal and South Canal. CalSim 3 simulates these deliveries as part of the Upper Yuba-Bear module. Subsequently, as part of the upper

[31] Decision variables SHRTG_GDPUD_NA and SHRTG_GDPUD_NU measure the water supply shortage relative to full demand.

American River module, any unmet water demands are supplied from PCWA's American River Pump Station on the North Fork American River (node NFA016).

ARPSdemand.wresl calculates the unmet demand based on the Yuba-Bear cycle and assuming groundwater pumping is at its minimum prescribed level. Water demands in Zone 5 are increased by 6.25% to account for losses along the Auburn Ravine. Currently, no allocation logic has been developed for customers in PCWA's service area, and the model will try to meet demands in full.

The wresl file contains one goal statement that limits diversions at the American River Pump Station to the unmet water demands.

Minflows.wresl

MinFlows.wresl determines minimum flow requirements as specified in Condition 22 of FERC MFP No. 2079 License. MFP minimum flows are based on the annual unimpaired flow at the Fair Oaks gauge. Most flow requirements for Project No. 2079 are defined as changing in March (usually approximately halfway through the month). As a result, many flow requirements in the wresl file use the previous water year type for their February and first half of March requirements, then switch to using current water year type in the second half of March. Only Oxbow and Ralston flow requirements are defined as changing in February. The file includes a 2 cfs buffer allowance. Flow requirements are established for the following locations:

- Duncan Creek below Diversion Dam (node DCC008)
- Middle Fork American River below French Meadows Dam (node MFA047)
- Middle Fork American River below Interbay Dam (node MFA035)
- Rubicon River below Hell Hole Dam (node RUB031)
- North Fork Long Canyon Creek Below North Fork Long Canyon Diversion Dam (node NLC002)
- South Fork Long Canyon Creek Below South Fork Long Canyon Diversion Dam (node SLC002)
- Middle Fork American River below Oxbow Powerhouse (node MFA025)

Additionally, there is a 75 cfs flow requirement specified below the American River Pump Station (node NFA016) as per the 1962 agreement between PCWA and CDFW.

For each flow requirement, a goal statements restricts flow through the '_MIF' subarc to be less than the requirement and an associated positive weight forces the flow towards this upper bound. Alias statements are used to write the flow requirements to the output DSS file.

Minflows_Hist.wresl

The file *minflows_hist.wresl* is similar in nature to *minflows.wresl*, except in contains the flow requirements from the original FERC license for the MFP. These requirements are used for the purposes of model validation against recent historical data.

PCWA_EBMUD_Transfer.wresl

PCWA_EBMUD_Transfer.wresl routes mitigation water released by PCWA as part of its Water Forum obligation through Folsom Lake and through the lower American River. The routing is achieved through disaggregation of the channel arc *C_AMR006* in to 6 subarcs as follows:

- *C_AMR006_MIF*, flow requirement at H-Street as part of the Flow Management Standard
- *C_AMR006_ADD*, flow over and above requirement at H-Street with components:
- *C_AMR006_EBMUD*, released mitigation water from Folsom Lake for EBMUD, with an upper bound of 155 cfs
- *C_AMR006_ADD2*, flow over and above the combined flow requirement and controlled release of EBMUD water with components:
- *C_AMR006_EBMUDspill*, EBMUD water spilled from Folsom Lake
- *C_AMR006_ADD3*, CVP water spilled from Folsom Lake or CVP water released for Delta and South of Delta export demands (including outflow requirements)

Mitigation water is reregulated in Folsom Lake. Folsom Lake storage is divided into CVP water (S_FOLSM_CVP) and EBMUD water (S_FOLSM_EBMUD). Stored EBMUD water in Folsom Lake is the sum of the previous month's EBMUD water, plus inflow of mitigation water (less 5% carriage water cost), less EBMUD water released from storage, less EBMUD spilled from storage. EBMUD water is accorded a lower weight than CVP storage so is pilled first. A goal statement limits the controlled release of EBMUD to be less than the previous month's EBMUD storage plus the current month's inflow of mitigation water to Folsom Lake, less 5% carriage water cost.

PowerOps.wresl

The file *PowerOps.wresl* contains code relating to the operation of French Meadows Reservoir for hydropower purposes as part of the MFP. It includes a single goal statements to close French Meadows Tunnel for the month of April for maintenance when the annual unimpaired flow forecast for the American River is less than 3.4 million acre feet; otherwise flows are restricted by the 4,000 cfs tunnel capacity.[32] The main purpose of the file is to determine the flow release through French Meadows Tunnel for power generation (*MFPpow_FRMDW_release*). The value of this state variable is assigned so that the two MFP reservoirs release amounts in equal proportion to the forecasted water supply to each reservoir. The initial logic determines the Hell Hole Reservoir release for hydropower as follows (with the name of state variables given in parenthesis):

- From May through December determine the combined beginning of month storage in the two reservoirs (*MFPpow_storage*).
- From May through December determine the forecasted inflow to French Meadows Reservoir from the current month through the end of the calendar year using perfect foresight (*MFPpow_inflow_FRMDW*).

[32] Additional goal statements included in the file are for writing state variables to DSS and do not influence the LP solution.

- From May through December determine the forecasted local inflow to Hell Hole Reservoir from the current month through the end of the calendar year using perfect foresight (*MFPpow_inflow_HHole*).

- From May through December determine the forecasted inflow to Hell Hole Reservoir from the upper watershed. The calculation assumes that all streamflows in the upper watershed above minimum flow requirements are diverted through the Buck-Loon Tunnel to Loon Lake up to the tunnel's physical capacity (*MFPpow_inflow_LRB003, MFPpow_inflow_RUB044*).

- For the month of May and from October through December determine the forecasted inflow from Duncan Creek to French Meadows Reservoir (*MFPpow_inflow_DCC010*). The model assumes that the Duncan Creek Tunnel is closed June through October.

- From May through December determine the combined forecasted inflow to both reservoirs (MFPpow_inflow).

- From May through December determine the demand at Folsom Lake for MFP Water (*MFPpow_demand_Folsom*). This is the sum of annual contract amounts for the City of Roseville, San Juan WD, and Sacramento Suburban WD decreased in proportion to the May-December water demand divided by the annual demand.

- From May through December determine the total demand at the American River Pump Station (*MFPpow_demand_ARPS*). This is the sum of PCWA's annual water right as limited by the Water Forum Agreement (35.5 TAF) decreased in proportion to the May-December water demand divided by the annual demand for PCWA's Zone 1 urban demand and a 75 cfs instream flow requirement below the pump station. This ignores the contribution from the North Fork American River and unregulated inflow to the Middle Fork American River below the MFP Reservoirs.

- Determine the controlling demand on MFP reservoirs (*MFPpow_demand_max*) as the larger of *MFPpow_demand_Folsom* and *MFPpow_demand_ARPS*.

- From May through December determine the total of the above "controlling" demand (*MFPpow_demand* from the current month through the end of the calendar year.

- From May through December determine the total water supply available for purposes of hydropower (*MFPpow_supply*) as the beginning of month storage less the forecasted inflow less the above controlling demand on the system.

- From May through December, convert the above supply into a uniform release rate in cfs (*MFPpow_release*).

Subsequently, *PowerOps.wresl* contains code for the transfer of water from French Meadows Reservoir to Hell Hole Reservoir as follows:

- From May through December determine the beginning of month storage in French Meadows Reservoir (*MFPpow_FRMWD_storage*).

- From May through December determine the French Meadows Reservoir release to meet downstream regulatory flow requirements (*MFPpow_FRMDW_demand*).

- From May through December calculate the water supply available for power generation (*MFPpow_FRMDW_supply*) based on the beginning of month storage, forecasted inflow, and releases for downstream flow requirements less a December target carryover storage of 50,000 AF. Convert this supply into a uniform rate (*MFPpow_FRMDW_release*) representing the transfer of water from French Meadows to Hell Hole reservoirs.

ResOps.wresl

The file *ResOps.wresl* determines the various storage levels and zones for French Meadows and Hell Hole reservoirs. A total of six storage zones and levels represent the following:

- Zone 1: Dead storage
- Zone 2: Minimum storage as designated by FERC license
- Zone 3: Storage to meet reservoir recreational requirements
- Zone 4: Storage available to meet discretionary water supply demands
- Zone 5: Storage available to support discretionary hydropower releases
- Zone 6: Flood space/storage kept empty to avoid refill impacts after release of mitigation water.

ResOps_Hist.wresl

ResOps_Hist.wresl is similar to *ResOps.wresl* except that is based on operations under the original FERC license issued in 1963.

WaterForum_mitigation.wresl

As part of the Water Forum Agreement, PCWA undertakes to release additional water from its MFP reservoirs in years when the unimpaired flow for the American River at Fair Oaks from March to November is forecast to be less than 950,000 AF. Specifically, PCWA undertakes to replace water to the river diverted at the American River Pump Station over and above the 1995 base amount (8,500 AF). The volume of water to be replaced varies from 0 AF to 27,000 AF in linear proportion as the unimpaired flow forecast drops from 950,000 AF to 400,000 AF. Additionally, the City of Roseville PSA requires replacement of 0 AF to 20,000 AF., which is achieved under an agreement between the City and PCWA. The total amount of reoperation water expected to be released by PCWA in a conference year (unimpaired flow < 4,000,000 AF) is 47,000 AF. This includes the 27,000 AF listed above and the 20,000 AF of reoperation water provided under the City of Roseville PSA.

The source of this replacement water for both agencies is from re-operation of the MFP and is water that would not be released under normal dry year operations. The replacement water is released from the MFP from May 1 through September 30 of each mitigation year by increasing the Middle Fork Powerplant release from Hell Hole Reservoir (*D_HHOLE_MFT003*) by a constant daily amount that produces the total replacement water obligation. However, the MFP is otherwise operated as if the replacement water was still in storage. Modeling of the mitigation water requirements is performed through the use of a “deficit account” in Hell Hole Reservoir. The "deficit account" accounts for water released directly for the Water Forum mitigation water requirements and serves the purpose of being added to the actual storage such that MFP operations are unchanged as compared to the "no mitigation" operation.

The deficit is made up by reducing the Middle Fork Powerplant release from Hell Hole Reservoir by 50 percent below what it would be without the mitigation water operation. These makeup flow reductions are only allowed to occur after the first month in which Folsom Lake spills in each water year. After this month, the makeup operations continue until the deficit is completely eliminated.

An exception to this occurs when replacement flows are required in two consecutive years. In this case, makeup operations are allowed to occur until the end of February, at which point the operation changes to releasing replacement water for the new year. Any deficit that is not made up prior to the end of February is then made up as part of makeup operations in the subsequent year.

WaterForum_mitigation.wresl contains code relating to the following:

- Volume of water to be released based on the forecasted unimpaired flow, which is subsequently translated in to a constant 143-day flow starting May 1.
- Release of mitigation water from Hell Hole Reservoir
- Refill of MFP reservoirs following a mitigation release based on when Folsom starts to spill.

Power releases from Hell Hole Reservoir are adjusted to achieve the correct release of mitigation water, or for reservoir refill following spilling at Folsom Lake.

WaterForum_mitigation.wresl is used in the first cycle of the American River module. It sets the top of Zone 4 (level 4) for Hell Hole Reservoir equal to the top of Zone 5 (level 3). This reduces Zone 4 which may be used to support discretionary releases for hydropower purposes to zero.

WaterRights.wresl

The file *WaterRights.wresl* imposes water right constraints on PCWA direct diversions and diversions to storage. The period of direct diversion and diversion to storage (November 1 – July 1) is represented by the variable *PCWA_DD_Flag*. A goal statement limits the combined diversion of MFP water at the American River Pump Station and at Folsom Lake to be less than the flow in the North Fork American River upstream from the pump station. A second goal statement limits the combined diversion of MFP water outside the period of direct diversion to be less than the storage release from MFP upstream reservoirs. A third goal statement prevents an increase in MFP storage outside the period of diversion to storage.

WaterRights.wresl also enforces PCWA's agreement with Reclamation that limits carryover storage in MFP reservoirs if the April 1 through September 30 estimated unimpaired inflow to Folsom Lake is less than 600,000 AF.

PGE Folder: Chili Bar and Drum-Spaulding Projects

The PGE folder contains files relating to PG&E's Chili Bar Project and Drum-Spaulding Project.

The Lake Valley component of the Drum-Spaulding Project is simulated together with the Bear River watershed, rather than as part of the Upper American River module.

No operational code has been developed specifically for the Chili Bar Project. It is assumed that FERC flow requirements imposed at the downstream Placerville gauge are met by storage withdrawals from SMUD reservoirs, if and when required. The weight on the flow requirement, relative to upstream storage, has been set so that the model will not use EID Project 184 reservoirs to meet the requirement.

ChiliBarOperations.wresl

ChiliBarOperations.wresl relates to PG&E's Chili Bar Project. Chili Bar Reservoir is not operated as a reservoir in this model, but rather as a junction (node SFA032) at which water from White Rock Powerplant is discharged back to the South Fork American River. The downstream node (SFA030) is the compliance location for the flow requirements specified by the California State Water Resources Control Board in Appendix A of FERC License No. 2155-024.

Water year types for the Chili Bar Project are defined by comparing the forecasted' unimpaired flow for the American River at Fair Oaks – determined in *amer_unimp.wresl* via a month-dependent lookup of known and forecasted unimpaired flow at Fair Oaks – to the water year delineations. The total monthly flow requirements are subsequently read from *MIF_PGECh_req.table* based on water year type.

ChiliBar_ops.wresl defines one goal statement that sets the flow downstream from Chili Bar Dam (C_SFA030_MIF) must be less than the appropriate required monthly flow requirement described above. The requirement is met through use of a large positive weight applied to the subarc.

Total required flows include recreational flows (Table 4 of Appendix A), and minimum instream flow requirements (Table 2). Monthly requirements were developed by first calculating the daily flow-weighted flow requirement, assuming that:

- Recreational flow requirements are met for the specified number of hours (with respect to the day of year, day of week, and water year type).
- Instream requirements are met for the remaining hours of the day.

This assumption was applied to every day from 1/1/1922-12/31/2015. Monthly requirements represent the average of the flow-weighted requirements of every day in that month from 1922-2015. Flow requirements include a 2 cfs buffer.

min_flows_LakeValley.wresl

FERC mandated flow requirements for the North Fork of the North Fork of the American River (NF NF American River) (see Section 10.2) are implemented in *min_flows_LakeValley.wresl*. Flow requirements are defined at two compliance locations on the NF NF American River: (a) below Lake Valley Reservoir; and (b) below Lake Valley Canal Diversion Dam.

Although there are no existing FERC requirements at these locations, PG&E and CDFW have an agreement that provides for fish flow release below Lake Valley Canal Diversion Dam (Section 9.2). Proposed flow requirements for both locations are read from *MIF_PGELV.table* based on the water year type. Following this, the appropriate flow requirement for the goal statement is defined based on the user-defined *LODflag*. The simulated requirement includes a 3 cfs buffer for the Lake Valley Dam requirement and a 1 cfs buffer for the Lake Valley Canal Diversion Dam requirement. The flow requirements are implemented as part of the system files for the Bear River (*SystemTables_Bear\constraints-MinFlows.wresl*).

- NF NF American River flow downstream of Lake Valley Reservoir (C_LKVLY_MIF) is constrained to be less than the required monthly flow requirement described above.
- NF NF American River flow downstream of Lake Valley Canal dam (C_NNA013_MIF) is constrained to less than the required monthly flow requirement described above.

UARP Folder: Upper American River Project

MinFlows.wresl

MinFlows.wresl determines minimum flow requirements as specified in Appendix A of FERC UARP No. 2101 License.

PowerOps.wresl

PowerOps.wresl establishes powerhouse capacities and imposes fixed maintenance periods when these capacities are reduced based on the number of days outage during the month.

Flow through the Robbs Peak Powerhouse, Jones Fork Powerhouse, and Union Valley Powerhouse are disaggregated into subarcs with the suffixes '_OPS' and '_EXC'. This was originally implemented to simulate minimum power generation targets. This approach was later abandoned.

ResOps.wresl

The file *ResOps.wresl* defines storage levels for Loon Lake, Ice House, and Union Valley reservoirs.

Loon Lake

- Storage Level 1 represents dead storage and is assigned a value of 3.4 TAF in *arcs-reservoirs.wresl*.
- Storage Level 2 is used to represent the FERC minimum operating pool.
- Storage Level 3 controls discretionary releases for hydropower. Storage above Level 3 is released for power generation up to the capacity at the powerplants
- Storage Level 4 is set equal to 6,410 feet, which is equivalent to 69.309 TAF and Level 5. There is no flood space requirement for the reservoir.
- Storage Level 5 represents the reservoir capacity and is assigned a value of 69.309 TAF in *arcs-reservoirs.wresl*.

Ice House Reservoir

- Storage Level 1 represents dead storage and is assigned a value of 0.20 TAF in *arcs-reservoirs.wresl*.

- Storage Level 2 represents the FERC minimum storage.
- Storage Level 3 controls transfer of storage to Union Valley. Storage above Level 3 is released through the Jones Fork Powerhouse.
- Storage Level 4 is the top of conservation storage as defined by DSOD. DSOD regulations specify that the level of Ice House Reservoir shall be lowered gradually from elevation 5,447 feet to elevation 5436.5 feet over the course of October.
- Storage Level 5 represents the reservoir capacity, which is controlled by a gated spillway. Values are assigned in *arcs-reservoirs.wresl*: with gates open the capacity is 34.903 TAF, with gates closed the capacity increases to 43.496 TAF.

Union Valley Reservoir

- Storage Level 1 represents dead storage and is assigned a value of 7.0 TAF in *arcs-reservoirs.wresl*.
- Storage Level 2 represents the FERC minimum storage.
- Storage Level 3 controls discretionary releases for hydropower. Storage above Level 3 is released for power generation up to the capacity at the powerplants.
- Storage Level 4 is the top of conservation storage as defined by DSOD. DSOD regulations specify that the level of Union Valley Reservoir shall be lowered gradually from elevation 4,867 feet to elevation 4,855 feet over the course of October.
- Storage Level 5 represents the reservoir capacity, which is controlled by a gated spillway. Values are assigned in *arcs-reservoirs.wresl*: with gates open the capacity is 225.325 TAF, with gates closed the capacity increases to 266.369 TAF.

WYT Folder: Water Year Types

Amer_Unimp.wresl

The file Amer_Unimp.wresl creates state variables for:

- Forecasted unimpaired flow at the Fair Oaks gauge from the current month through to the end of the water year (*frcst_amr*)
- Known unimpaired flow at Fair Oaks from October through the previous month (*known_amr*)
- Forecasted annual flow at Fair Oaks for the current water year (*amer_annual*)
- Forecasted April-July forecasted flow at Fair Oaks (*amer_apr_july*) and percent of normal (*amr_aprjul_pct*)
- Forecasted April-September forecasted flow at Fair Oaks (*amer_unimp*) and forecasted March-November flow at Fair Oaks (*FUI_MarNov*).

Forecasted flows are based on perfect foresight and are contained in a series of lookup tables: *american_runoff_forecast_perfectFS.table; known_fairoaks_flow; amr_aprjul_tot.table; amr_aprjul_pct.table*. Combined forecasted inflow for the months of October and November is assumed to be 60 TAF.

WYT_D893.wresl

The aquatic resources protection requirements for the lower American River were adopted in 1958 as part of D-893. This decision established minimum flows in the lower American River at its confluence with the Sacramento River of 250 cfs from January through mid-September, and 500 cfs for the remainder of the year under all hydrologic conditions. These requirements are defined by the file *WYT_D893.wresl*. However, the State Water Board, Reclamation, the Water Forum, and other stakeholders agree that D-893 does not sufficiently protect the aquatic resources of the lower American River and larger minimum flows have been adopted. The definition of D-893 standards in CalSim 3 is a code legacy issue.

Weight Structure

The WRIMS software uses a mixed integer linear programming solver to efficiently route water through the system network given the user-defined priorities or weights. Rather than specify complex operating rules, the user attaches weights to storages, flows and other system variables to define relative priorities. Additionally, constraints may be formulated as soft constraints with associated penalties for deviating from user-specified target values. These constraints are internally reformulated by WRIMS by the introduction of auxiliary slack and surplus variables in the constraint equation and associated penalties on these variables in the objective function. Currently, penalties are not used in the American River Basin model.

Weights in the American River Basin model have been established from the following considerations:

- Weights are relative; the absolute value of a weight is not meaningful.
- Weights describe user-defined relative priorities, but the relative magnitude of the weights may be designed to allow trade-offs between objectives or structured so that prioritized goals are met sequentially with no degradation of previously satisfied goals.
- The range of weights from the largest weight to the smallest weight should not exceed several orders of magnitude to avoid numerical solution difficulties.
- Weights may be additive; for example, a unit release from storage may contribute to meeting multiple downstream flow objectives before being diverted for consumptive use or stored in downstream reservoirs, thus satisfying multiple objectives.
- System continuity isolates part of the American River watershed; for example, weights in this American River watershed cannot affect operations within the related Yuba-Bear watershed.
- Large negative weights are also associated with flood storage, large positive weights are attached to reservoir dead storage.
- Small ‘persuasion’ penalties are used to influence water routing or to obtain a unique solution in cases where the model would otherwise be indifferent.

Upper American River Watershed

Tables 8-1 to 8-5 present the weight structure used in the upper American River model for projects owned by GDPUD, PCWA, SMUD, EID, and Reclamation. The following sections provide a brief explanation of how the relative weights were developed.

Georgetown Divide Public Utility District

The weight structure for GDPUD is comparatively simple. There are 3 objectives: water storage, instream flow requirements, and water deliveries. Weights have been set relatively high so that downstream weights associated with the Middle Fork American River, North Fork American River, and Folsom Lake do not affect operations of the Stumpy Meadows Project. Twelve possible operations were identified. The value of retaining water in storage varies from 75,000 to 20,000 less the opportunity value of releasing that water. The value assigned to dead storage (80,000) is greater than the combined value (70,000) of meeting instream flow requirements below Stumpy Meadows Dam and the Pilot Creek Diversion Dam. Similarly, the value assigned to storage zone 2 (75,000) is sufficiently high to prevent releases for instream flow requirements. The value assigned to storage zone 3 (30,000) allows releases for downstream flow requirements. It also allows releases for water deliveries when the releases meet the flow requirement below Stumpy Meadows Dam and the flow requirement below the diversion dam is met by stream accretions (I_PLC007).

Weights on deliveries (25,000) from the Georgetown Divide Ditch are set high enough to draw water from reservoir zones 4 and 5. The weight on canal conveyance loss (25,005) is set slightly above water deliveries. Using a weight rather than a hard constraint simplifies the setting of relative weights.[33]

Storage levels 1, 2, and 3 are set equal to 1.2 TAF. Therefore, weights on storage zones 2 and 3 have no effect on model simulation. Storage level 4 is set equal to 10 TAF, storage level 5 is set equal to 20 TAF. Currently, there is no differentiation in the model treatment of storage zones 4 and 5.

Table 8-1. Weights for Georgetown Divide Public Utility District Operations

Variable	Weight	Description
S_STMPY_1	80,000	Reservoir dead storage
S_STMPY_2	75,000	No releases for flow requirements nor irrigation and M&I demands
C_PLC009_MIF	35,000	Instream flow requirements on Pilot Creek below dam
C_PLC006_MIF	35,000	Instream flow requirements on Pilot Creek below diversion dam
S_STMPY_3	30,000	Storage zone drawdown for flow requirements only
D_GDD010_GDDLOS	25,005	Canal conveyance loss
D_GDD010_GDPUD_NA	25,000	Deliveries for agricultural purposes
D_WTPWAL_GDPUD_NU	25,000	Deliveries for M&I purposes
S_STMPY_4	21,000	Storage zone drawdown for flow requirements and water supply

[33] The assumed canal conveyance loss is 20 percent. In the absence of a weight on these losses, deliveries from Georgetown Divide Ditch would effectively be devalued and the effective weight equivalent to 80 percent of its numerical value.

S_STMPY_5 [1]	20,000	Storage zone drawdown for flow requirements and water supply

Notes:
[1.] Stumpy Meadows Reservoir has no flood control requirement.
[2.] The model also includes 'flood' arcs with an assigned weight of -10,000 to prevent simulation infeasibility during flood operations if reservoir inflows exceed the reservoir simulated discharge capacity.

Middle Fork Project

The weight structure for PCWA's operations of the MFP are complex because of multiple objectives that may combine. For example, water released from storage may meet flow requirements at multiple locations before being stored in Folsom Lake or diverted to meet water demands. The starting point for the weight structure was to assign a weight of 5,000 for all instream flow requirements and to assign a weight of 240 to deliveries from Folsom Lake.

French Meadows Reservoir

Water released from French Meadows Reservoir may contribute to flow requirements at up to 5 locations, each with an assigned weight of 5,000, before being stored in Folsom Lake, which has weights that range from 50 – 500, or being diverted for water supply, which has assigned weights of 400. The total value of a unit of released water may vary up to a maximum of 25,500. Consequently, a value of 30,000 was assigned to dead storage. Storage zone 2, representing FERC mandated minimum pool elevations, was assigned a weight of 28,000 to be independent of downstream weights.

Storage zone 3 is used to meet FERC mandated flow requirements, including pulse flows and recreation flows. The assigned weight of 4,000 is set below that assigned to instream flow requirements. Releases from zone 3 may be diverted downstream for water demands after meeting upstream flow requirements.

Storage zone 4 is used to supply water deliveries at the American River Pump Station and Folsom Lake for agricultural and M&I purposes.[34] Deliveries of MFP water at Folsom Lake are assigned an additional weight of 2,000 over and above the weight of 400 assigned to all lake diversions. Deliveries of MFP water at the American River Pump Station are assigned a value of 2,400. This is a boundary outflow from the American River module, which is determined in the Yuba-Bear River module.

Storage zone 5 is used for discretionary hydropower generation, over and above that which may opportunistically occur using water released for water supply purposes or using river accretions downstream from MFP reservoirs. The assigned weight is 1,000 compared to a weight of 1,495 assigned to flow through Ralston Powerhouse. Discretionary hydropower releases may subsequently be stored in Folsom Lake, which has weights that range from 50 – 500. To avoid dead storage in Folsom Lake triggering storage releases from zone 4, the Ralston Powerhouse weight was adjusted from its initial value of 1,500 to 1,495.

[34] Diversions at the American River Pump Station are determined in the Yuba-Bear simulation module and enforced as a hard constraint in the Upper American River model.

Persuasion weights and penalties are used to direct operations under flood control or spill operations. River flows below French Meadows Dam are assigned a negative weight of 5 to direct potential spills through the French Meadows – Hell Hole Tunnel, when tunnel capacity is available. Flows through the Duncan Creek Tunnel are assigned a weight of 5. When French Meadows Reservoir is full, Duncan Creek water is directed through Duncan Creek Tunnel and thence French Meadows – Hell Hole Tunnel. If the latter is flowing at capacity, water from Duncan Creek will flow through French Meadows Reservoir and spill to the Middle Fork American River. It is assumed than Duncan Creek Diversion Dam is mostly a passive operation with little day to day management.

Hell Hole Reservoir
Storage zones in French Meadows Reservoir and Hell Hole Reservoir have an identical set of weights. There are no weights assigned to flow through the French Meadows – Hell Hole Tunnel. Transfer of storage will occur when the reservoirs are in different storage zones. However, there are constraints on flow through the tunnel based on reservoir spill avoidance and an end of December French Meadows carryover storage objective of 50 TAF.

Hydropower
Persuasion weights are used to direct river flows through powerhouses, as appropriate. These include weights of 5 assigned to diversion from North Fork and South Fork Long Canyon Creek to Hell Hole Tunnel and Middle Fork Powerhouse, and a weight of 5 assigned to flow through the Oxbow Powerhouse. A weight of 10 is assigned to discretionary hydropower releases through the Hell Hole – French Meadows Tunnel to achieve the correct coloring of water for output purposes.

Table 8-2. Weights for Placer County Water Agency Operations

Variable	Weight	Description
S_FRMDW_1	30,000	Reservoir dead storage
S_HHOLE_1	30,000	Reservoir dead storage
S_FRMDW_2	28,000	FERC minimum pool
S_HHOLE_2	28,000	FERC minimum pool
C_NLC002_MIF	5,000	North Fork Long Canyon Creek below diversion tunnel (USGS 11433085)
C_SLC002_MIF	5,000	South Fork Long Canyon Creek below diversion tunnel (USGS 11433065)
C_RUB031_MIF	5,000	Rubicon River below Hell Hole Dam (USGS 11430000)
C_DCC008_MIF	5,000	Duncan Creek below diversion dam (USGS 11427750)
C_MFA047_MIF	5,000	Middle Fork American River at French Meadows (USGS 11427500)
C_MFA035_MIF	5,000	Middle Fork American River below Interbay Dam (USGS 11277700)
C_MFA025_MIF	5,000	Middle Fork American River below Ralston Afterbay
C_MFA023_MIF	5,000	Middle Fork American River near Forest Hill (USGS 11433300)
C_NFA016_MIF	5,000	North Fork American River at Auburn Dam site
S_FRMDW_3	4,000	Storage zone for FERC mandated recreation, releases for flow requirements
S_HHOLE_3	4,000	Storage zone for FERC mandated recreation, releases for flow requirements
D_NFA016_ABT002	2,400	PCWA delivery to its service area (Zones 1 and 3)
D_FOLSM_WTPSJP_MFP	2,000	PCWA delivery of MFP water to San Juan Water District
D_FOLSM_WTPRSV_MFP	2,000	PCWA delivery of MFP water to City of Roseville
S_FRMDW_4	2,000	Storage zone for discretionary releases for water supply
S_HHOLE_4	2,000	Storage zone for discretionary releases for water supply
D_MFA036_RLT007	1,500	Ralston Powerhouse
S_FRMDW_5	1,000	Storage zone for discretionary releases for hydropower and water supply
S_HHOLE_5	1,000	Storage zone for discretionary releases for hydropower and water supply
D_WTPRSV_26N_PU1	400	Folsom Lake deliveries to the City of Roseville
D_WTPSJP_26N_PU2	400	Folsom Lake deliveries to San Juan WD – retail
D_WTPSJP_26N_PU3	400	Folsom Lake deliveries to San Juan WD – wholesale
D_WTPSJP_26N_NU1	400	Folsom Lake deliveries to Sacramento Suburban WD
D_HHOLE_MFT003_EXC	10	Discretionary hydropower releases through Hell Hole Tunnel
D_NLC003_NCT001	25	North Fork Long Canyon Creek diversion
D_SLC003_SCT001	25	South Fork Long Canyon Creek diversion
D_MFA026_OXB000	5	Oxbow Powerhouse
D_DCC009_FRMDW	10	Duncan Creek – French Meadows Tunnel
C_MFA036 MFA047_ADD	-5	Middle Fork American River below French Meadows Dam
S_FRMDW_6	-10,000	Reservoir flood control space - to be kept evacuated
S_HHOLE_6	-10,000	Reservoir flood control space - to be kept evacuated
S_FOLSM_1 [1]	500	Folsom Lake storage zones
S_FOLSM_2 [1]	150	Folsom Lake storage zones
S_FOLSM_3 [1]	100	Folsom Lake storage zones
S_FOLSM_4 [1]	100	Folsom Lake storage zones
S_FOLSM_5 [1]	50	Folsom Lake storage zones
S_FOLSM_6 [1]	-10,000	Folsom Lake storage zones

Notes:

1. Folsom Lake storage zones are listed here as they have the potential to affect upstream operations.
2. The model also includes 'flood' arcs with an assigned weight of -10,000 to prevent simulation infeasibility during flood operations if reservoir inflows exceed the reservoir simulated discharge capacity.

Key:
FERC = Federal Energy Regulatory Commission
MFP = Middle Fork Project
PCWA = Placer County Water Agency
USGS = U.S. Geological Survey

Upper American River Project

The weight structure for SMUD's operations of the UARP are the most complex in the upper American River module because of storage reservoirs spread across two watersheds, flow requirements, and discretionary power releases through multiple powerhouses. This section also discusses the weight structure for PG&E's Chili Bar Project.

Rubicon Watershed Diversions

After meeting downstream flow requirements, SMUD diverts water from Rubicon Lake and thence Rockbound Lake through the Buck-Loon Tunnel to Loon Lake. Weights on FERC instream flow requirements below the diversion dams are assigned a weight of 60,000. A weight of 30,000 is assigned to flows through the Buck Loon Tunnel. These high weights isolate diversion operations from downstream storage considerations. Weights assigned to Hell Hole Reservoir storage range from 1,000 to 30,000. Weights assigned to Loon Lake storage range from 30 to 30,000.

Loon Lake

Water is released from Loon Lake to meet downstream flow requirements, power generation at Loon Lake Powerhouse, and/or transfer of storage to Union Valley Reservoir.

A weight of 31,000 is assigned to dead storage. This value is higher than dead storage weights on other reservoirs to prevent transfer of storage under low storage conditions. Storage level 2 represents FERC mandated minimum pool elevations that are defined from July-September. At other times of the year, level 2 is set equal to dead storage. Storage zone 2 is assigned a weight of 1,500 giving FERC minimum streamflows priority over minimum pool requirements. Storage zone 4 is used for discretionary hydropower generation, over and above that which may opportunistically occur using water released for water supply purposes or using river accretions downstream from UARP reservoirs. It is assigned a weight of 30. Storage zone 5 corresponds to the flood space requirement and is assigned a weight of -10,000.

Releases from Loon Lake may meet flow requirements below the dam (C_GRL010) and below Gerle Dam (C_GRL001). Water may also be diverted through the Gerle Canal to the South Fork Rubicon River to meet flow requirements below the Robbs Peak Forebay. All flow requirements specified in the UARP FERC license are assigned a weight of 5,000.

Transfer of storage from Loon Lake to Union Valley Reservoir will occur as indicated by the highlighted combinations below.

Storage Zone		S_UNVLY_1	S_UNVLY_2	S_UNVLY_3	S_UNVLY_4	S_UNVLY_5
	Weight	30,000	1,495	1,350	20	-10,000
S_LOONL_1	31,000	-1,000	-29,505	-29,650	-30,980	-41,000
S_LOONL_2	1,500	28,500	-5	-150	-1,480	-11,500
S_LOONL_3	1,460	28,540	35	-110	-1,440	-11,460
S_LOONL_4	30	29,970	1,465	1,320	-10	-10,030
S_LOONL_5	-10,000	40,000	11,495	11,350	10,020	0

A weight of -5,000 is assigned to South Fork Rubicon River flow below its confluence with Gerle Creek above a minimum flow requirement to dissuade outflow to the Rubicon River. This requirement is calculated as the sum of FERC flow requirements below Gerle Dam and below Robbs Peak Forebay Dam.

Ice House Reservoir

Water is released from Ice House Reservoir to meet FERC license requirements on the South Fork Rubicon River (including minimum flows, pulse flows, and recreational flows), power generation at Jones Fork Powerhouse, and/or transfer of storage to Union Valley Reservoir. A weight of 5,000 is assigned to flow requirements below the dam.

A weight of 30,010 is assigned to dead storage. This value is higher than dead storage weight assigned to Union Valley Reservoir to prevent transfer of storage under low storage conditions when Ice Reservoir is at or below dead pool (Level 1).

Storage level 2 represents FERC mandated minimum pool elevations that are defined from July-September. At other times of the year, level 2 is set equal to dead storage. Storage zone 2 is assigned a weight of 1,500 giving FERC minimum flows on the South Fork Rubicon River priority over minimum pool requirements.

Storage level 3 represents SMUD target or preferred storage. It is assigned a weight of 1,500.

Storage zone 4 is used for discretionary hydropower generation, over and above that which may opportunistically occur using river accretions downstream from UARP reservoirs. It is assigned a weight of 25.

Level 5 corresponds to the storage capacity under gated spillway operations. Level 4 corresponds to the maximum DSOD elevation. DSOD requires that the level of Ice House Reservoir be lowered gradually from an elevation of 5,447 feet to an elevation of 5,436.5 feet over the course of October. Spillway gates must be opened on November 1. Storage zone 5 is assigned a weight of -10,000 to ensure the zone remains evacuated in model simulation.

There is a persuasion weight of 5 on flow through the Jones Fork Tunnel and Powerhouse. Transfer of storage from Ice House Reservoir to Union Valley Reservoir will occur as indicated by the highlighted combinations below.

Storage Zone		**S_UNVLY_1**	**S_UNVLY_2**	**S_UNVLY_3**	**S_UNVLY_4**	**S_UNVLY_5**
	Weight	**30,000**	**1,495**	**1,350**	**20**	**-10,000**
S_ICEHS_1	30,010	-5	-28,510	-28,655	-29,985	-40,005
S_ICEHS_2	1,500	28,505	0	-145	-1,475	-11,495
S_ICEHS_3	1,400	28,605	100	-45	-1,375	-11,395
S_ICEHS_4	25	29,980	1,475	1,330	0	-10,020
S_ICEHS_5	-10,000	40,005	11,500	11,355	10,025	5

In model simulation, releases from Ice House Reservoir storage and/or bypassed flows are routed through the Jones Fork Tunnel rather than released to the South Fork Silver Creek once the FERC flow requirements have been met, up to the capacity of the tunnel.

Union Valley Reservoir

Water is released from Union Valley Reservoir to meet FERC license requirements on Silver Creek and the South Fork American River (including minimum flows, pulse flows, and recreational flows), and power generation at Jaybird Powerhouse, Camino Powerhouse, and White Rock Powerhouse. Water also is released to meet the FERC license requirements for PG&E's Chili Bar Project.[35]

A weight of 30,000 is assigned to dead storage.

Storage level 2 represents FERC mandated minimum pool elevations that are defined from July-September. At other times of the year, level 2 is set equal to dead storage. Storage zone 2 is assigned a weight of 1,500 giving FERC minimum flows on the South Fork Rubicon River priority over minimum pool requirements.

Storage level 3 represents SMUD target or preferred storage. It is assigned a weight of 1,500.

Storage zone 4 is used for discretionary hydropower generation, over and above that which may opportunistically occur using river accretions downstream from UARP reservoirs. It is assigned a weight of 25.

Level 5 corresponds to the storage capacity under gated spillway operations. Level 4 corresponds to the maximum DSOD elevation. DSOD requires that the level of Union Valley Reservoir be lowered gradually over the course of October. Spillway gates must be opened on November 1. Storage zone 5 is assigned a weight of -10,000 to ensure the zone remains evacuated in model simulation.

A unit release of water from Union Valley Reservoir may increase the objective function through a combination of weights assigned to instream flow requirements, powerhouse flows, and Folsom Lake storage. These weights are typically additive as released water may meet multiple objectives. The weight structure was developed by considering the effects of storage releases for 600 possible states of the system. The adopted structure results in the following operations for Union Valley Reservoir:

- No water is released from the reservoir if the water level is below dead pool (Storage Zone 1).
- Water is released from Storage Zone 2 to meet one or more instream flow requirements as specified in the FERC license. No water is released from Storage Zone 2 for discretionary hydropower purposes.
- Water is released from Storage Zone 3 to meet one or more instream flow requirements as specified in the FERC license. No water is released from Storage Zone 3 for discretionary hydropower purposes.

[35] SMUD has agreed to purchase the project from PG&E.

- Water is released from Storage Zone 4 to meet one or more instream flow requirements as specified in the FERC license or to make discretionary releases for power generation.
- Storage Zone 5 is always kept evacuated.

Table 8-3. Weights for Sacramento Municipal Utility District Operations

Variable [2]	Weight	Description
S_LOONL_1	31,000	Reservoir dead storage
S_ICEHS_1	30,015	Reservoir dead storage
S_UNVLY_1	30,000	Reservoir dead storage
S_GERLE_1	31,000	Reservoir dead storage
S_GERLE_2	31,000	Storage regulation not simulated – reservoir kept full
S_GERLE_3	31,000	Storage regulation not simulated – reservoir kept full
S_GERLE_4	31,000	Storage regulation not simulated – reservoir kept full
D_LRB004_BLT000	3,100	Higher weight than downstream flow requirement because of weight on Hell Hole Reservoir storage
C_SFA030_MIF	5,000	Chili Bar FERC flow requirements (instream and recreational)
C_RUB031_MIF	5,000	Rubicon River below Hell Hoe Dam (USGS 11430000)
C_RUB044_MIF	60,000	Rubicon River below Rubicon Lake (USGS 11427960)
C_LRB003_MIF	60,000	Little Rubicon River below Buck Island Dam (USGS 11428400)
C_GRL010_MIF	5,000	Gerle Creek below Loon Lake (USGS 11429500)
C_GRL001_MIF	5,000	Gerle Creek below Gerle Reservoir (USGS 114296005)
C_SFR006_MIF	5,000	South Fork Rubicon River below Diversion Dam
C_SSV013_MIF	5,000	South Fork Silver Creek below Ice House (USGS 114415000)
C_SLV014_MIF	5,000	Silver Creek below Junction Dam (USGS 11441800)
C_SLV005_MIF	5,000	Silver Creek below Camino Diversion Dam (USGS 11441900)
C_BSH002_MIF	5,000	Bush Creek below Bush Creek Dam (USGS 11442700)
C_SFA039_MIF	5,000	South Fork American River near Camino (USGS 11443500)
S_LOONL_2	1,500	Storage zone
S_GERLE_2	1,500	Storage zone
S_ICEHS_2	1,500	Storage zone
S_UNVLY_2	1,495	Storage zone
S_LOONL_3	1,460	Storage zone
S_GERLE_3	1,450	Storage zone
S_STMPY_4	1,405	Storage zone
S_ICEHS_3	1,400	Storage zone
S_UNVLY_3	1,350	Storage zone
S_LOONL_4	30	Storage zone
S_GERLE_4	30	Storage zone
S_ICEHS_4	25	Storage zone
S_UNVLY_4	20	Storage zone
D_UNVLY_SLV017	25	Union Valley Powerhouse
D_SLV015_JBT004	25	Jaybird Powerhouse
D_SLV006_CMN005	25	Silver Creek diversion to Camino Powerhouse
D_BSH003_CMN005	25	Brush Creek diversion to Camino Powerhouse
D_SFA040_WRT000	25	White Rock Powerhouse
D_LOONL_LLT000_EXC	5	Loon Lake Powerhouse
D_ICEHS_IHT002_OPS	5	Jones Fork Powerhouse
D_ICEHS_IHT002_EXC	5	Jones Fork Powerhouse
D_SFR006_RPT004_OPS	5	Robbs Peak Tunnel
D_SFR006_RPT004_EXC	5	Robbs Peak Tunnel
D_SFA039_ADD	-150	Isolate power operations from weights on storage in Folsom Lake

Table 8-3. Weights for Sacramento Municipal Water District Operations (contd.)

Variable [2]	Weight	Description
S_GERLE_5	-10,000	Reservoir flood control space - to be kept evacuated
S_ICEHS_5	-10,000	Reservoir flood control space - to be kept evacuated
S_LOONL_5	-10,000	Reservoir flood control space - to be kept evacuated
S_UNVLY_5	-10,000	Reservoir flood control space - to be kept evacuated
C_SFR004_ADD	-30,000	Minimize spills to Rubicon River
S_FOLSM_1 [1]	500	Folsom Lake storage zones
S_FOLSM_2 [1]	150	Folsom Lake storage zones
S_FOLSM_3 [1]	100	Folsom Lake storage zones
S_FOLSM_4 [1]	100	Folsom Lake storage zones
S_FOLSM_5 [1]	50	Folsom Lake storage zones
S_FOLSM_6 [1]	-10,000	Folsom Lake storage zones

Notes:

1. Folsom Lake storage zones are listed here as they have the potential to affect upstream operations.

2. The model also includes 'flood' arcs with an assigned weight of -10,000 to prevent simulation infeasibility during flood operations if reservoir inflows exceed the reservoir simulated discharge capacity.

Key:
FERC = Federal Energy Regulatory Commission
USGS = U.S. Geological Survey

Project 184

The weight structure for EID's operations of Project 184 are complex because of multiple objectives that may combine. For example, water released from storage could meet flow requirements at multiple locations before being stored in Folsom Lake or diverted to meet water demands. The starting point for the weight structure was to assign a weight of 5,000 for all instream flow requirements and to assign a weight of 240 to deliveries from Folsom Lake.

Echo Lake

Simulation of Echo Lake is relatively simple. Lake storage is disaggregated by storage levels into 5 zones. Storage Level 1 is dead storage. Storage Level 5 is the lake capacity, which varies according to whether flashboards are installed. For most of the year, storage Level 2 is set equal to storage Level 5. However, in September and October Level 2 is reduced below level 5 to encourage drawdown. Storage Level 4 is not needed as there is no flood space requirement and is set equal to Level 5. Weights on storage are as follows: 30,000 (dead storage); 4,540 (Zone 2); 4,540 (Zone 3).

In model simulation, water may be imported through the Echo Lake Conduit from September through November. For the rest of the year, the conduit remains closed. Flow requirements below Echo Lake Dam are assigned a weight of 6,000, which is sufficient to draw water from storage from all zones, except dead storage. When Echo Lake Conduit is open, water may be used to meet instream flow requirements, for water supply, for hydropower, or a combination of these objectives. However, constraints prevent imported water being diverted at Folsom Lake for water supply purposes. A weight of 5,000 is assigned to flows through the conduit to drain the lake under conditions when this water is not put to beneficial use in the South Fork American River watershed.

Lake Aloha

Lake Aloha storage is disaggregated by storage levels into 5 zones. Storage Level 1 is dead storage. Storage Level 5 is the lake capacity of 5,063 AF but is set to zero when the lake outlet is open from November through March or April. Storage Level 2 corresponds to minimum pool elevations specified in water right decision 1635. Storage Level 3 corresponds to FERC minimum storage levels. Weights on storage are as follows: 30,000 (dead storage); 4,520 (Zone 2); 820 (Zone 3); 250 (Zone 4). Zone 5 is also zero as there is no flood space requirement and storage Level 4 is set equal to Level 5.

From March/April through October, water may be released from storage or inflow bypassed to meet instream flow requirements, for water supply, for hydropower, or a combination of these objectives. Flow requirements for Pyramid Creek at Twin Bridges are assigned a weight of 5,000, which is sufficient to draw water from storage from all zones, except dead storage. Downstream from Pyramid Creek, water from Lake Aloha may be put to beneficial use as follows:

- Diverted at El Dorado Forebay for water supply, assigned weight =
- Diverted through the El Dorado Powerhouse, assigned weight = 300
- Contribute to flow requirements on the South Fork American River at Kyburz, Camino, and/or Placerville, assigned weight = 5,000

- Contribute to hydropower generation at White Rock Powerplant, assigned weight = 25
- Diverted at Folsom Lake for EID water supply, assigned weight = 450
- Stored in Folsom Lake, assigned weight varies = 50 – 500

A penalty of -150 is assigned to South Fork American River flow below Chili Bar Dam in excess of that project's flow requirement to help isolate EID's operations from CVP storage regulation.

Silver Lake
The weight structure for Silver Lake is similar to Lake Aloha, except storage Zone 2 and Zone 3 have slightly higher weights to encourage first use of Lake Aloha storage.

Caples Lake
The weight structure for Caples Lake is similar to Lake Aloha, except storage Zone 2 and Zone 3 have slightly lower weights to encourage first use of Caples Lake storage.

Jenkinson Reservoir
Jenkinson Reservoir is located within the North Cosumnes River watershed so is isolated from most of the model simulated operations. The reservoir is divided in to 5 storage levels and zones. Storage Zone 1, dead storage, is assigned a weight of 30,000 as for other reservoirs. There is no flood space requirement. Storage Zones 2, 3, 4 and 5 are managed for water supply with assigned weights of 200, 100, 50, and 10, respectively. The flow requirements on Camp Creek and on Sly Creek below Sly Park Dam are assigned a weight of 5,000. Deliveries from the reservoir to EID's RSA water treatment plant are disaggregated into firm deliveries and storage-dependent deliveries. Firm deliveries are assigned a weight of 4,510. Storage-dependent deliveries are assigned a weight of 100.

Table 8-4. Weights for El Dorado Irrigation District Operations

Variable [3]	Weight	Description
S_ALOHA_1	30,000	Dead storage – high weight to prevent release from storage
S_CAPLS_1	30,000	Dead storage – high weight to prevent release from storage
S_ECHOL_1	30,000	Dead storage – high weight to prevent release from storage
S_SILVR_1	30,000	Dead storage – high weight to prevent release from storage
S_JNKSN_1	30,000	Dead storage – high weight to prevent release from storage
L_SILVR	10,000	Head-dependent leakage to Oyster Creek
C_ECHOL_MIF	6,000	Echo Creek below Echo Lake
C_ALD001_MIF	5,000	Alder Creek below Diversion Dam
C_CMP014_MIF	5,000	Camp Creek below diversion dam
C_CPC008_MIF	5,000	Caples Lake outlet near Kirkwood (USGS 11437000)
C_JNKSN_MIF	5,000	Sly Park Creek below Jenkinson Reservoir
C_PYR001_MIF	5,000	Pyramid Creek at Twin Bridges (USGS 11435100)
C_SFA030_MIF [1]	5,000	South Fork American River near Placerville (USGS 11445500)
C_SFA039_MIF [1]	5,000	South Fork American River near Camino (USGS 11443500)
C_SFA065_MIF	5,000	South Fork American River near Kyburz (USGS 11439500)
C_SLF014_MIF	5,000	Silver Fork American River below Oyster Creek
C_SLF015_MIF	5,000	Silver Lake outlet near Kirkwood (USGS 11436000)
D_ECHOL_ELC001	5,000	Drain Echo Lake once conduit is open
S_ECHOL_2	4,540	Storage zone drawdown for flow requirements only
S_ECHOL_3	4,540	Storage zone not used
S_ECHOL_4	4,540	Storage zone not used
S_SILVR_2	4,530	Storage zone drawdown for flow requirements only
S_ALOHA_2	4,520	Storage zone drawdown for flow requirements only
S_CAPLS_2	4,510	Storage zone drawdown for flow requirements only
D_JNKSN_WTPRSA_firm	4,510	District deliveries from Jenkinson Reservoir for M&I purposes
D_EDC021_WTPRS1	4,350	District deliveries from El Dorado Forebay for M&I purposes
S_CAPLS_3	4,510	FERC target storage, no releases except for instream flow requirements
S_SILVR_3	830	Storage zone drawdown for water supply and flow requirements
S_ALOHA_3	820	Storage zone drawdown for water supply and flow requirements
D_FOLSOM_WTPEDH	240	District deliveries from Folsom Lake for M&I purposes
D_FOLSM_WTPEDH_CVP	40	District CVP deliveries from Folsom Lake for M&I purposes
D_FOLSM_WTPEDH_WR	450	District water right deliveries from Folsom Lake for M&I purposes
D_EDC021_EDP003	300	Hydropower generation. Weight set to drawdown district storage to level 3
S_SILVR_4	250	Storage drawdown for hydropower, water supply, and flow requirements
S_CAPLS_4	250	Storage drawdown for hydropower, water supply, and flow requirements
S_ALOHA_4	250	Storage drawdown for hydropower, water supply, and flow requirements
S_JNKSN_2	200	Storage zone
S_JNKSN_3	100	Storage zone
D_JNKSN_WTPRSA_alloc	100	Jenkinson Lake delivery
S_JNKSN_4	50	Storage zone
D_SFA040_WRT000	25	White Rock Powerhouse (SMUD facility)
S_JNKSN_5	10	Storage zone
D_WTPRS1_ELDID_NU1	3	Persuasion penalties to provide unique solution for Forebay M&I deliveries
D_WTPRS1_ELDID_NU2	2	Persuasion penalties to provide unique solution for Forebay M&I deliveries
D_WTPRS1_ELDID_NU3	1	Persuasion penalties to provide unique solution for Forebay M&I deliveries

Table 8-4. Weights for El Dorado Irrigation District Operations (contd.)

Variable [3]	Weight	Description
D_WTPRSA_ELDID_NU2	3	Persuasion penalties to provide unique solution for Jenkinson deliveries
D_WTPRSA_ELDID_NU1	2	Persuasion penalties to provide unique solution for Jenkinson deliveries
D_WTPRSA_ELDID_NU3	1	Persuasion penalties to provide unique solution for Jenkinson deliveries
D_CMP014_JNKSN	-1	Keep Camp Creek water in the creek when Jenkinson Reservoir is spilling
S_ALOHA_5	-10,000	Reservoir flood control space - to be kept evacuated
S_CAPLS_5	-10,000	Reservoir flood control space - to be kept evacuated
S_ECHOL_5	-10,000	Reservoir flood control space - to be kept evacuated
S_SILVR_5	-10,000	Reservoir flood control space - to be kept evacuated
S_FOLSM_1 [2]	500	Folsom Lake storage zones
S_FOLSM_2 [2]	150	Folsom Lake storage zones
S_FOLSM_3 [2]	100	Folsom Lake storage zones
S_FOLSM_4 [2]	100	Folsom Lake storage zones
S_FOLSM_5 [2]	50	Folsom Lake storage zones
S_FOLSM_6 [2]	-10,000	Folsom Lake storage zones

Notes:

1. Except for flow below the Kyburz Diversion Dam, EID is nor responsible for meeting flow requirements on the South Fork American River. Weights are listed here as they have the potential to affect upstream operations. However, weights on SMUD storage facilities are set lower than those for the district.
2. Folsom Lake storage zones are listed here as they have the potential to affect upstream operations.
3. The model also includes 'flood' arcs with an assigned weight of -10,000 to prevent simulation infeasibility during flood operations if reservoir inflows exceed the reservoir simulated discharge capacity.

Key:
CVP = Central Valley Project
FERC = Federal Energy Regulatory Commission
M&I = municipal and industrial
USGS = U.S. Geological Survey

Lower American River Watershed

Much of the code and logic governing Folsom Lake operations (e.g. flood/spill releases, target rule curves; contractual CVP deliveries; Water Forum and mitigation water) was developed as part of the Sacramento Valley portion of CalSim 3.

The weight structure for Folsom Lake and the lower American River, which is presented in **Table 8.5**, is comparatively simple.[36] There are 3 objectives: water storage, instream flow requirements, and water deliveries. Weights are relatively low so that weights associated with lower American River operations do not affect operations upstream from Folsom Lake.

Folsom Lake is divided into 5 storage zones plus an additional storage zone for flood space. A large negative weight on the flood space results in this storage volume remaining empty. All other storage zones are positively weighted. The value of retaining water in Folsom Lake from 50 to 500, less the opportunity value of releasing the water.

Lake Natoma is divided into 4 storage zones plus an additional storage zone for flood space. The value of retaining water in Lake Natoma varies from 200 to 495 less the opportunity value of

[36] The upper American River model includes Folsom Lake and the lower American River but does not simulate the effect of Delta demands, Delta outflow, and CVP exports in the South Delta on Folsom Lake.

releasing that water. There are 30 possible combinations of CVP reservoir storage, as presented below. Transfer of water from Folsom Lake to Lake Natoma will occur in all months except when: (a) storage in Lake Natoma is at top of conservation (level 4); or (b) storage in Folsom Lake is at or below dead storage.

Storage Zone		**S_NTOMA_1**	**S_NTOMA_2**	**S_NTOMA_3**	**S_NTOMA_4**	**S_NTOMA_5**
	Weight	**495**	**230**	**220**	**200**	**-10,000**
S_FOLSM_1	500	-5	-270	-280	-300	-10,500
S_FOLSM_2	150	345	80	70	50	-10,150
S_FOLSM_3	100	395	130	120	100	-10,100
S_FOLSM_4	100	395	130	120	100	-10,100
S_FOLSM_5	50	445	180	170	150	-10,050
S_FOLSM_6	-10,000	10,495	10,230	10,220	10,200	0

Minimum instream flow requirements are imposed immediately below Nimbus Dam for the American River at Fair Oaks and for the American River at H-Street. Assigned weights of 245 are sufficient to trigger releases from Folsom Lake storage except when lake levels are at or below dead pool. The value of water released to meet these flow requirements may be cumulative, i.e., having a marginal value of 490 rather than 245. This cumulative value is slightly less than the weight assigned to reservoir dead storage.

A weight of 240 is assigned to all diversions from Folsom Lake, Folsom South Canal, and the lower American River. This weight is sufficient to pull water from all storage zones, except dead storage. A persuasion penalty of -1 assigned to delivery shortages assures that groundwater, where available, is used to meet water demands in full up to any groundwater pumping constraint.

Table 8-5. Weights for Lower American River Operations

Variable [1]	Weight	Description
S_FOLSM_1	500	Reservoir dead storage
S_NTOMA_1	495	Reservoir dead storage
D_FOLSM_WTPEDH_WR	450	Delivery of water right water to El Dorado ID
C_AMR006_EBMUD	245	Water transfer from PCWA to EBMUD
C_AMR006_MIF	245	Instream flow requirement
C_NTOMA_MIF	245	Instream flow requirement
D_FSC025_60N_PU, D_WTPBJM_26N_NU2, D_WTPCOL_26S_PU2, D_WTPFBN_26N_NU1, D_WTPFBN_26N_NU3, D_WTPFBN_26S_NU1, D_WTPFOL_26S_PU1, D_WTPRSV_26N_PU1, D_WTPSAC_26N_NU3, D_WTPSAC_26S_PU4, D_WTPSRW_26N_PU1, D_WTPSJP_26N_NU1, D_WTPSJP_26N_PU2, D_WTPSJP_26N_PU3, D_WTPSRW_26N_NU1, D_WTPSRW_26N_NU3, D_WTPFBN_26N_NU4, D_WTPFBN_26S_NU2, D_FOLSM_26S_NU4, D_FOLSM_26S_PU3, D_FOLSM_WTPEDH	240	Weight on deliveries from Folsom Lake and the lower American River sufficiently high to pull water from Folsom Lake storage, except dead storage.
S_NTOMA_2	230	Lake Natoma storage zone
S_NTOMA_3	220	Lake Natoma storage zone
S_NTOMA_4	200	Lake Natoma storage zone
S_FOLSM_2	150	Folsom Lake storage zone
S_FOLSM_3	100	Folsom Lake storage zone
S_FOLSM_4	100	Folsom Lake storage zone
S_FOLSM_5	50	Folsom Lake storage zone
D_FOLSM_WTPEDH_CVP	40	Delivery of CVP water to El Dorado ID
S_FOLSM_EBMUD	-1	Small negative weight to ensure EBMUD water stored in Folsom Lake spills before CVP water.
SHRTG_26N_NU1, SHRTG_26N_NU2, SHRTG_26N_NU3, SHRTG_26N_NU4, SHRTG_26N_NU5, SHRTG_26N_PU1, SHRTG_26N_PU2, SHRTG_26N_PU3, SHRTG_26S_NU1, SHRTG_26S_NU2, SHRTG_26S_NU3, SHRTG_26S_NU4, SHRTG_26S_PU1, SHRTG_26S_PU2, SHRTG_26S_PU3, SHRTG_26S_PU4, SHRTG_26S_PU5, SHRTG_26S_PU6, SHRTG_60N_PU	-1	Urban water shortages. Weights are placed on surface water deliveries, but no weights are applied to groundwater pumping to meet water demands. Small persuasion penalties applied to water shortage decision variables result in groundwater pumping to meet any unmet demand.
S_FOLSM_6	-10,000	Reservoir flood control space - to be kept empty
S_NTOMA_5	-10,000	Reservoir flood control space - to be kept empty

Note:

[1.] The model also includes ‘flood’ arcs with an assigned weight of -10,000 to prevent simulation infeasibility during flood operations if reservoir inflows exceed the reservoir simulated discharge capacity.

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Chapter 9 Model Results and Validation

This chapter provides a detailed validation of the upper American River Model by comparing simulated and historical flows, diversions, and storage. Simulated data are for an existing (2015) level of development, i.e., CalSim 3 simulates existing conditions under a repeat of the historical weather sequence WY 1922 – 2015. Historical data are for WY 1996 – 2015, except when data are unavailable. Comparison of simulated to historical data for the last 20 years of simulation provides a check that the model is correctly simulating the complex management of water resources in the upper American River watershed.

This chapter consists of four sections, as follows:

- Comparison of simulated and historical storage in major reservoirs.
- Comparison of simulated and historical surface water diversions for agricultural and M&I purposes.
- Comparison of simulated and historical streamflows at key gauge locations.
- Comparison of simulated and historical flows through major canals, tunnels, and powerhouses.

For each comparison, a set of four charts is presented, comprising: (1) monthly timeseries; (2) average monthly values; (3) monthly exceedance; and (4) annual flows or annual carryover storage for reservoirs.

Simulated and Historical Reservoir Storage

Comparisons of simulated and historical storage are presented for the following reservoirs:

- Lake Valley Reservoir
- French Meadows Reservoir
- Hell Hole Reservoir
- MFP reservoirs combined
- Stumpy Meadows Reservoir
- Loon Lake
- Ice House Reservoir
- Union Valley Reservoir
- UARP reservoirs combined

- Echo Lake (1999-2015, missing storage data has been estimated from mass balance)
- Aloha Lake (no historical storage data are available)
- Caples Lake
- Silver Lake
- Project 184 reservoirs combined
- Jenkinson Reservoir
- Folsom Lake[37]
- Lake Natoma

In some cases, reservoir operating criteria have changed significantly over the period of comparison (WY 1996 – 2015). In interpreting model results and performance, the following should be noted:

- A new license was issued for EID's Hydroelectric Project FERC Project No. 184 on October 18, 2006 with revised minimum flow and minimum pool requirements for the project.
- A new license was issued for SMUD's Upper American River Project, FERC Project No. 2101, on July 23, 2014 with revised minimum flow and minimum pool requirements for the project.
- A new license was issued for PG&E's Chili Bar Project, FERC Project No. 2155 on August 20, 2014 with revised minimum flow and minimum pool requirements for the project.

A new FERC license was issued for the Middle Fork Project on June 11, 2020. For the purposes of model validation, model results presented in this chapter simulate the original 1963 license conditions.

[37] Simulated storage in Folsom Lake is partly controlled by storage releases to meet Sacramento-San Joaquin Delta requirements, including outflow and south-of-Delta CVP exports.

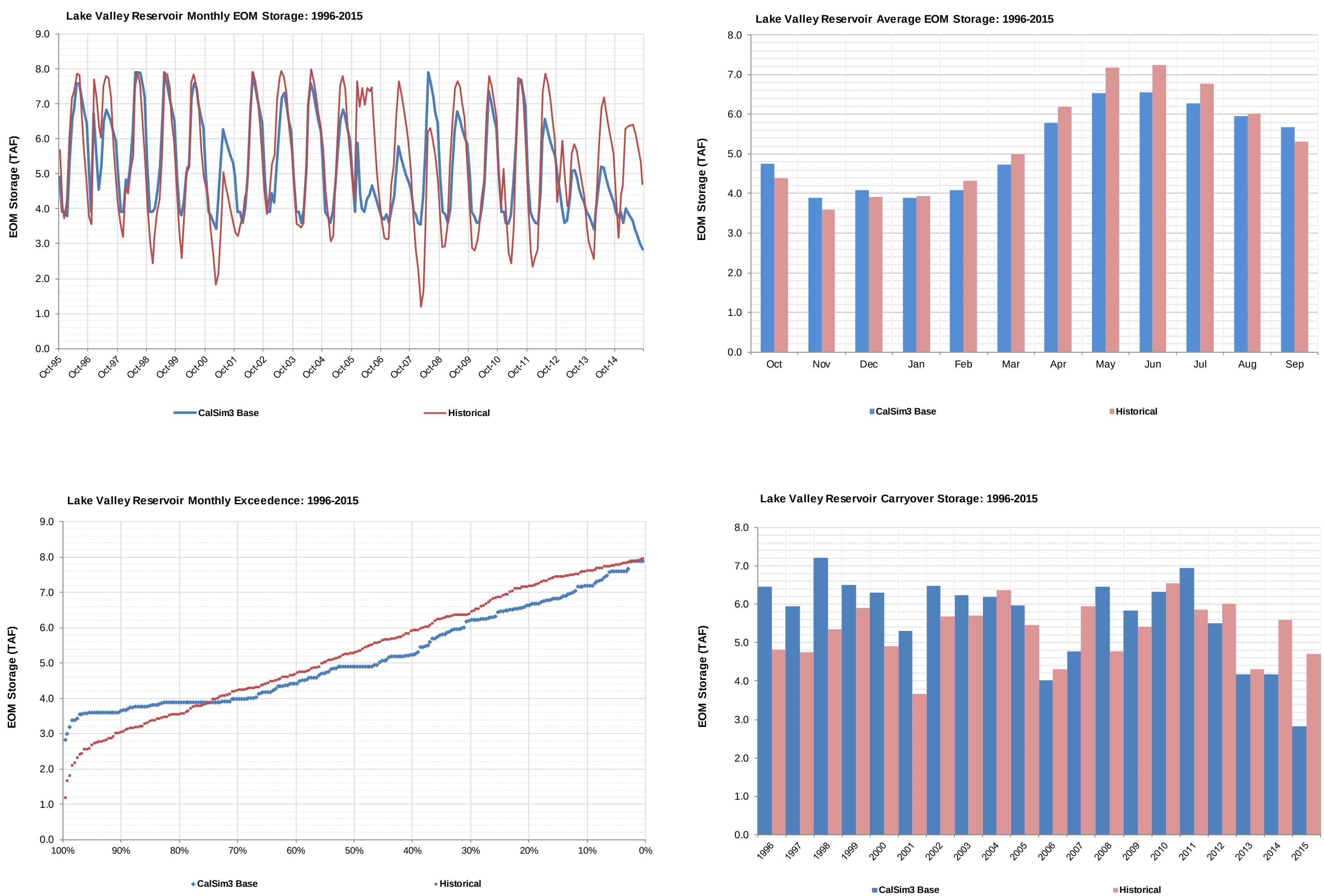
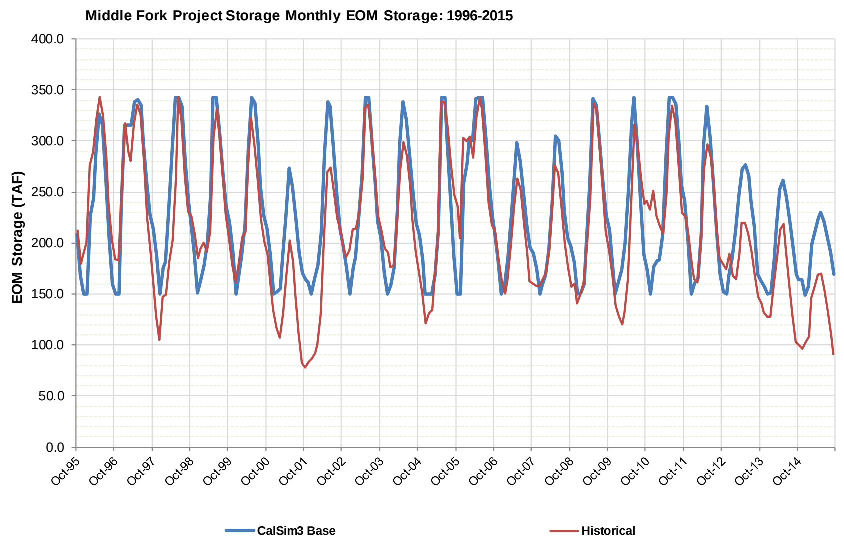
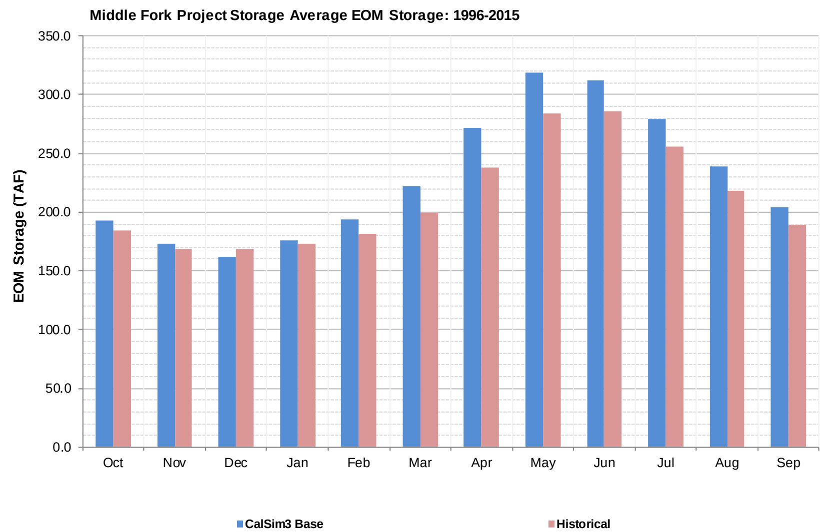


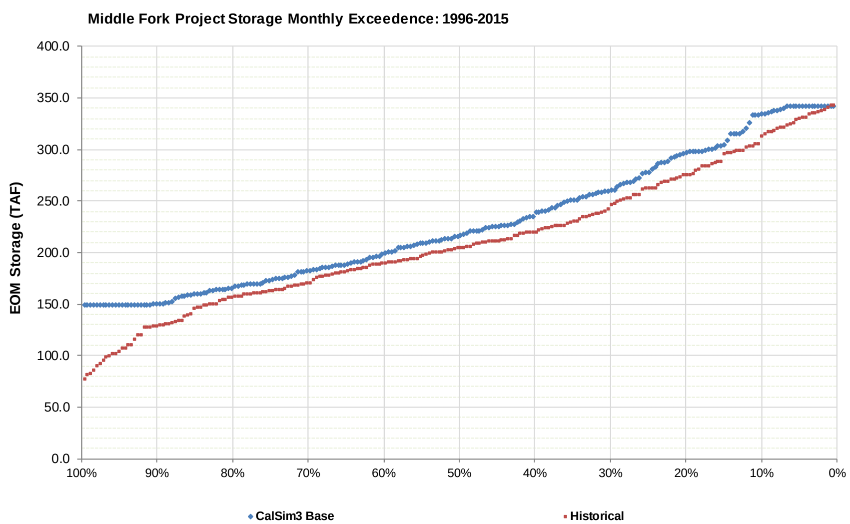
Figure 9-1. Lake Valley Reservoir Storage (S_LKVLY).

Figure 9-2. French Meadows Reservoir Storage (S_FRMDW).

Figure 9-3. Hell Hole Reservoir Storage (S_HHOLE).







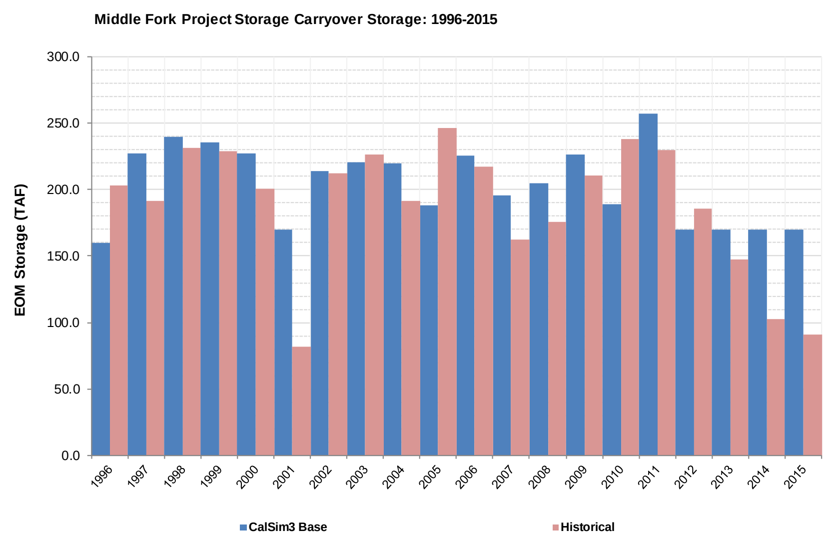


Figure 9-4. Middle Fork Project Reservoir Storage.

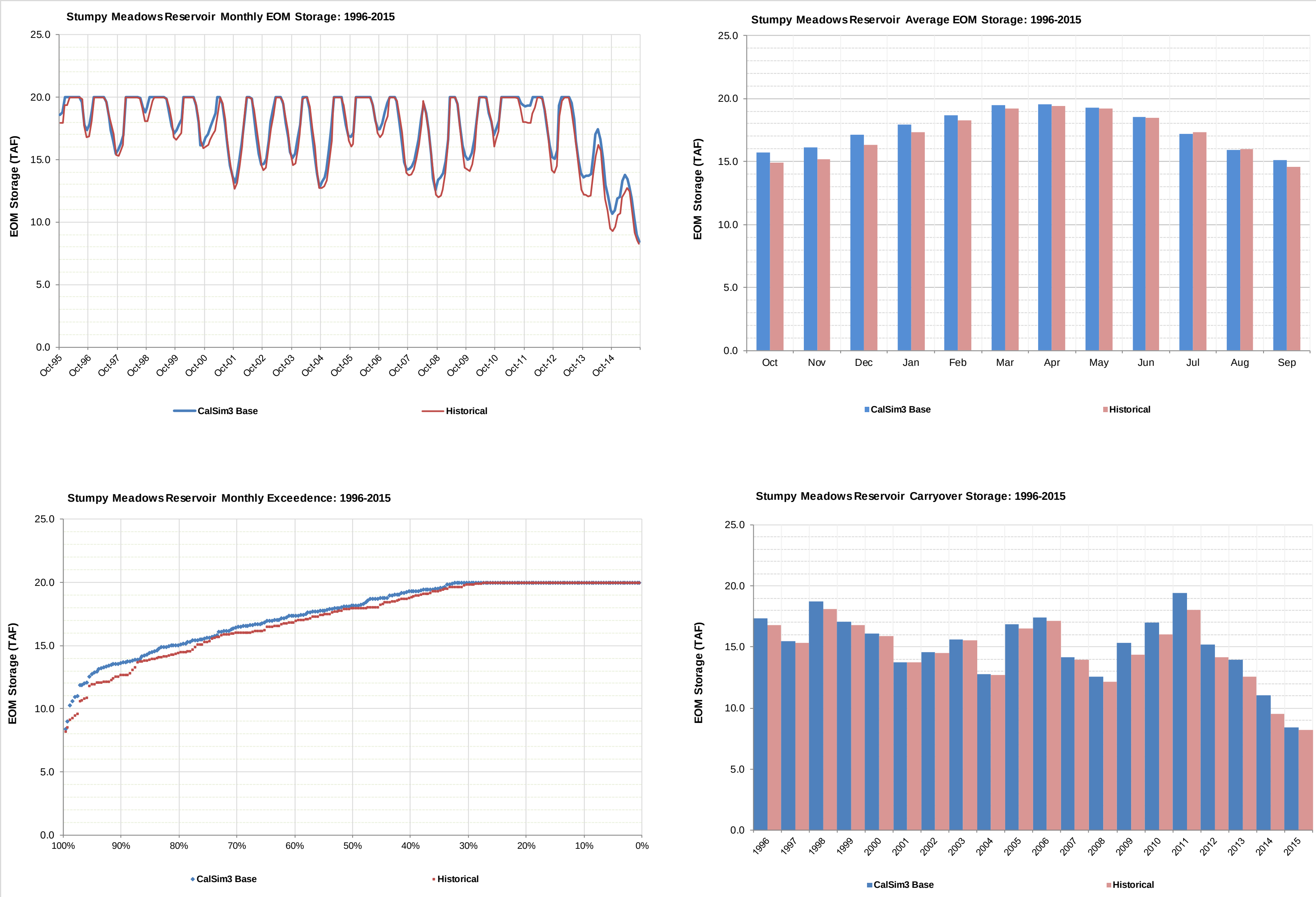


Figure 9-5. Stumpy Meadows Reservoir Storage (S_STMPY).

Figure 9-6. Loon Lake Reservoir Storage (S_LOONL).

Figure 9-7. Ice House Reservoir Storage (S_ICEHS).

Figure 9-8. Union Valley Reservoir Storage (S_UNVLY).

Figure 9-9. Upper American River Project Reservoir Storage.

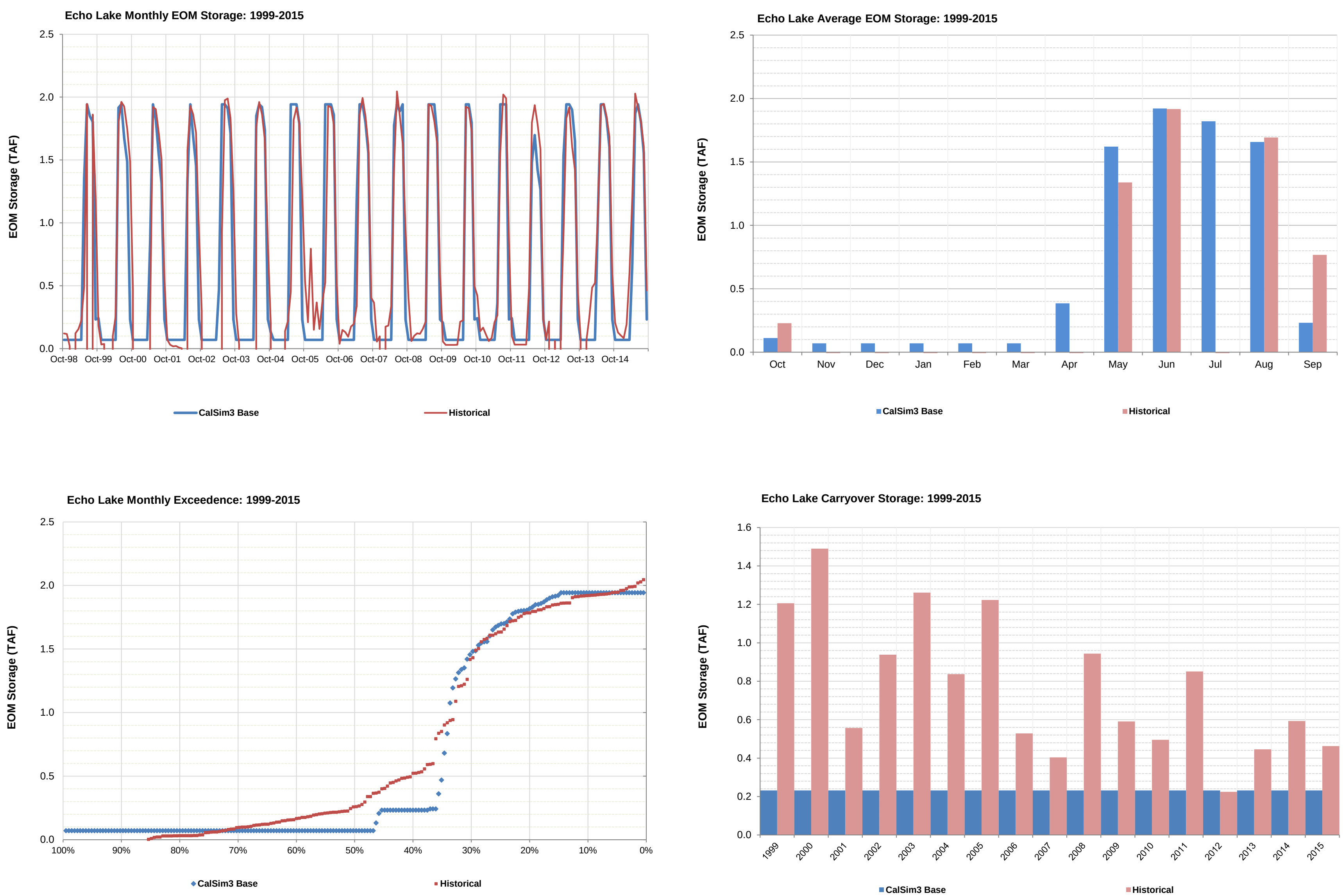


Figure 9-10. Echo Lake Storage (S_ECHOL).

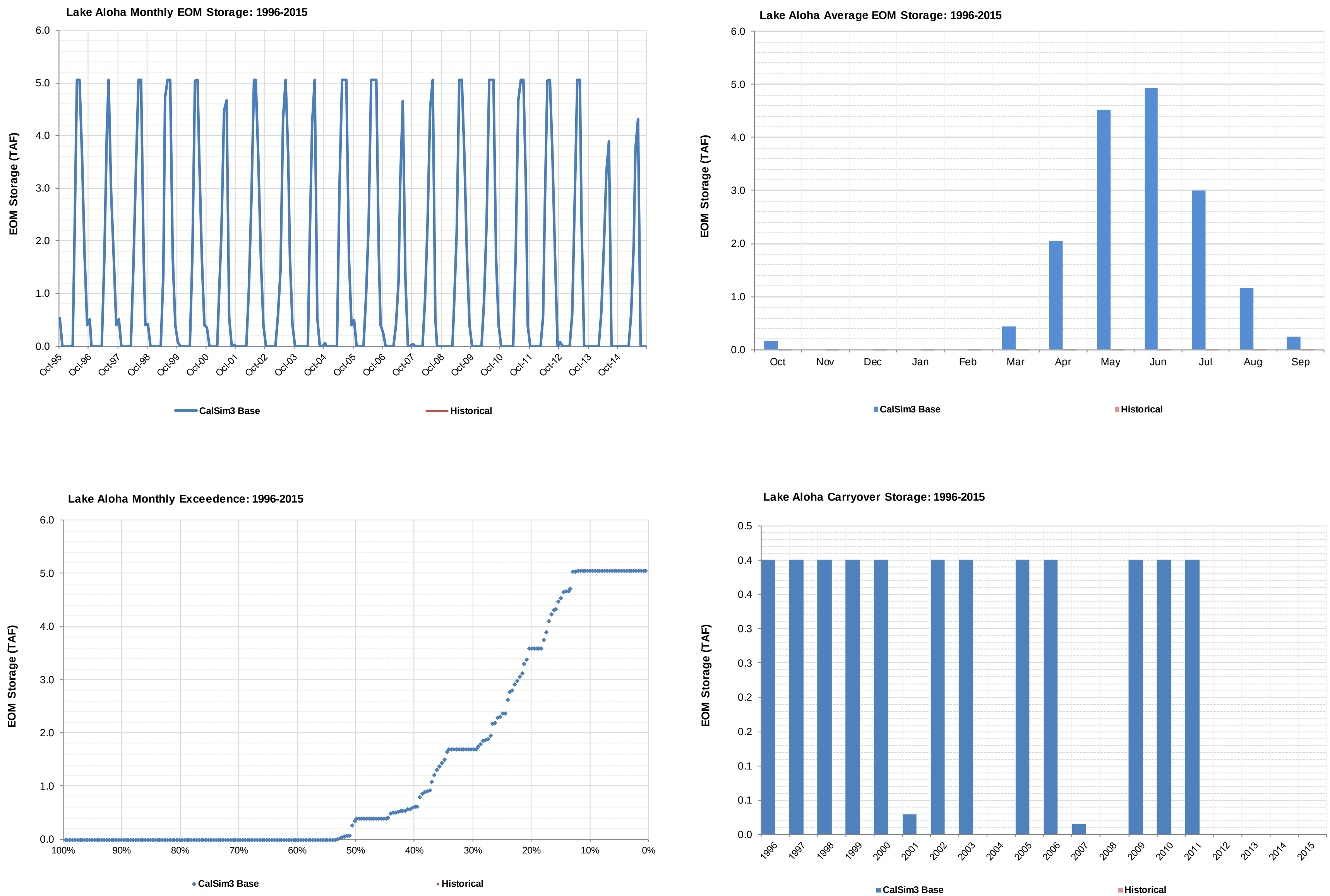


Figure 9-11. Aloha Lake Storage (S_ALOHA).

Figure 9-12. Caples Lake Storage (S_CAPLS).

Figure 9-13. Silver Lake Storage (S_SILVR).

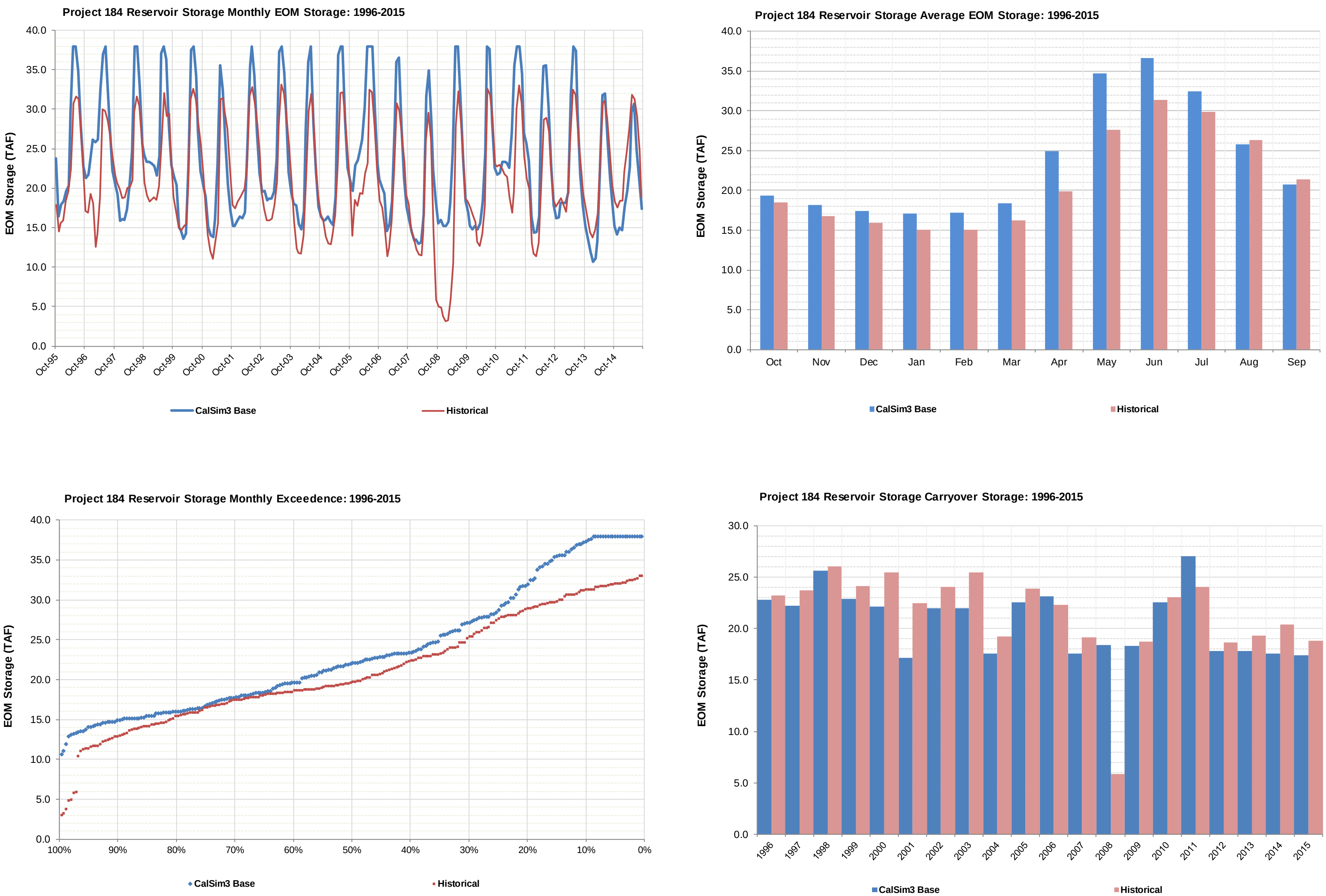


Figure 9-14. Project 184 Reservoir Storage.

Figure 9-15. Jenkinson Reservoir Storage (S_JNKSN).

Figure 9-16. Folsom Lake Reservoir Storage (S_FOLSM).

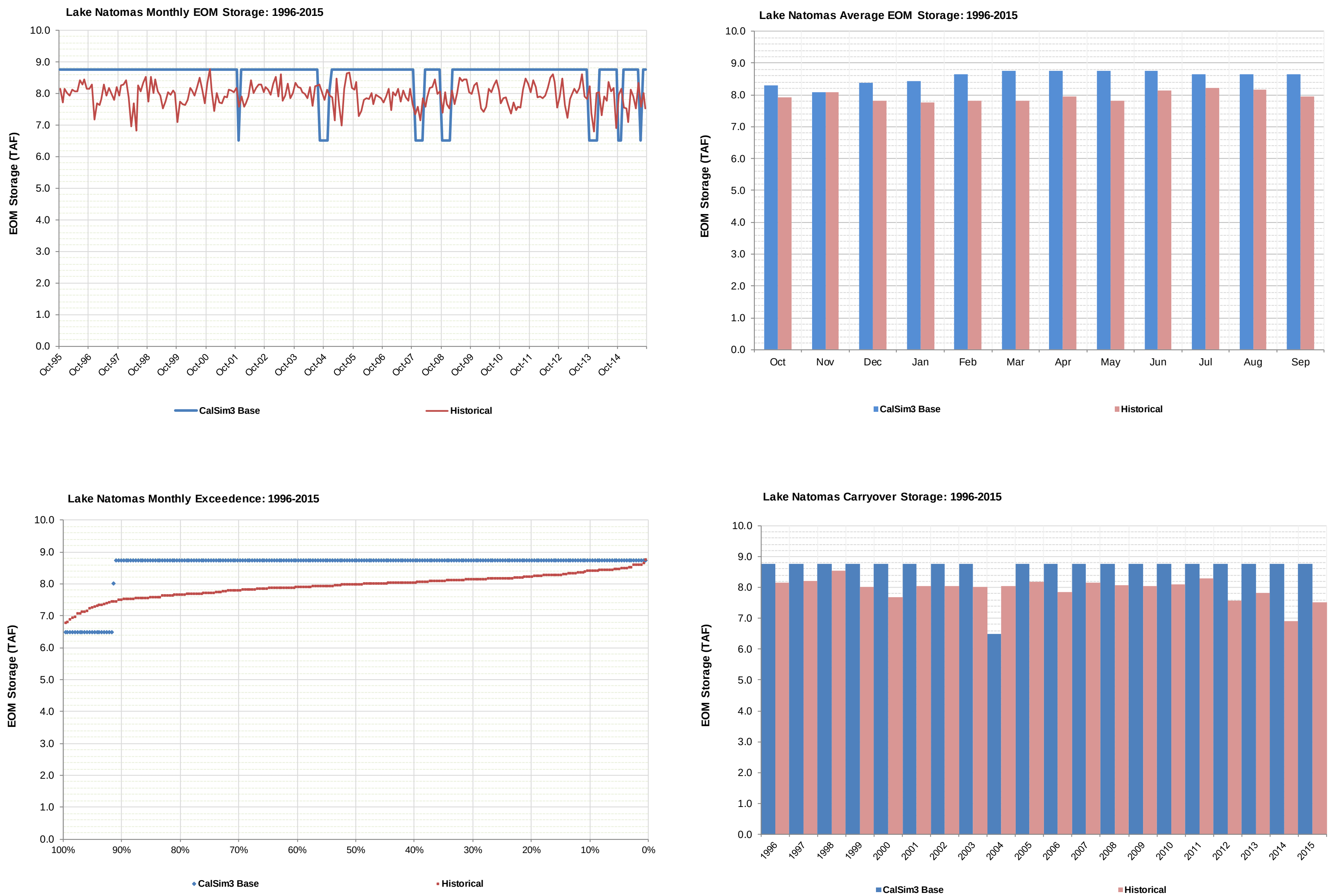


Figure 9-17. Lake Natoma Reservoir Storage (S_NTOMA).

Simulated and Historical Diversions

This section presents model results for stream and canal diversions for agricultural and M&I water use. Simulated diversions are compared to recent historical data for the following locations:

- GDPUD diversion from Pilot Creek to Georgetown Divide Ditch
- PCWA diversion from the American River Pump Station[38]
- EID diversion from El Dorado Forebay to RS1 Water Treatment Plant
- EID diversion from Jenkinson Reservoir to RSA Water Treatment Plant
- EID diversion from Folsom Lake to El Dorado Hills Water Treatment Plant
- City of Roseville diversion from Folsom Lake
- San Juan WD diversion from Folsom Lake (including Sacramento Suburban WD wheeled water)
- City of Folsom diversion from Folsom Lake

[38] Diversions from the American River Pump Station are determined in the upper Yuba-Bear simulation module. It is assumed that PCWA first meets demands within its service area through water supply contracts with PG&E. The American River Pump Station is used to mee any shortfall in demand.

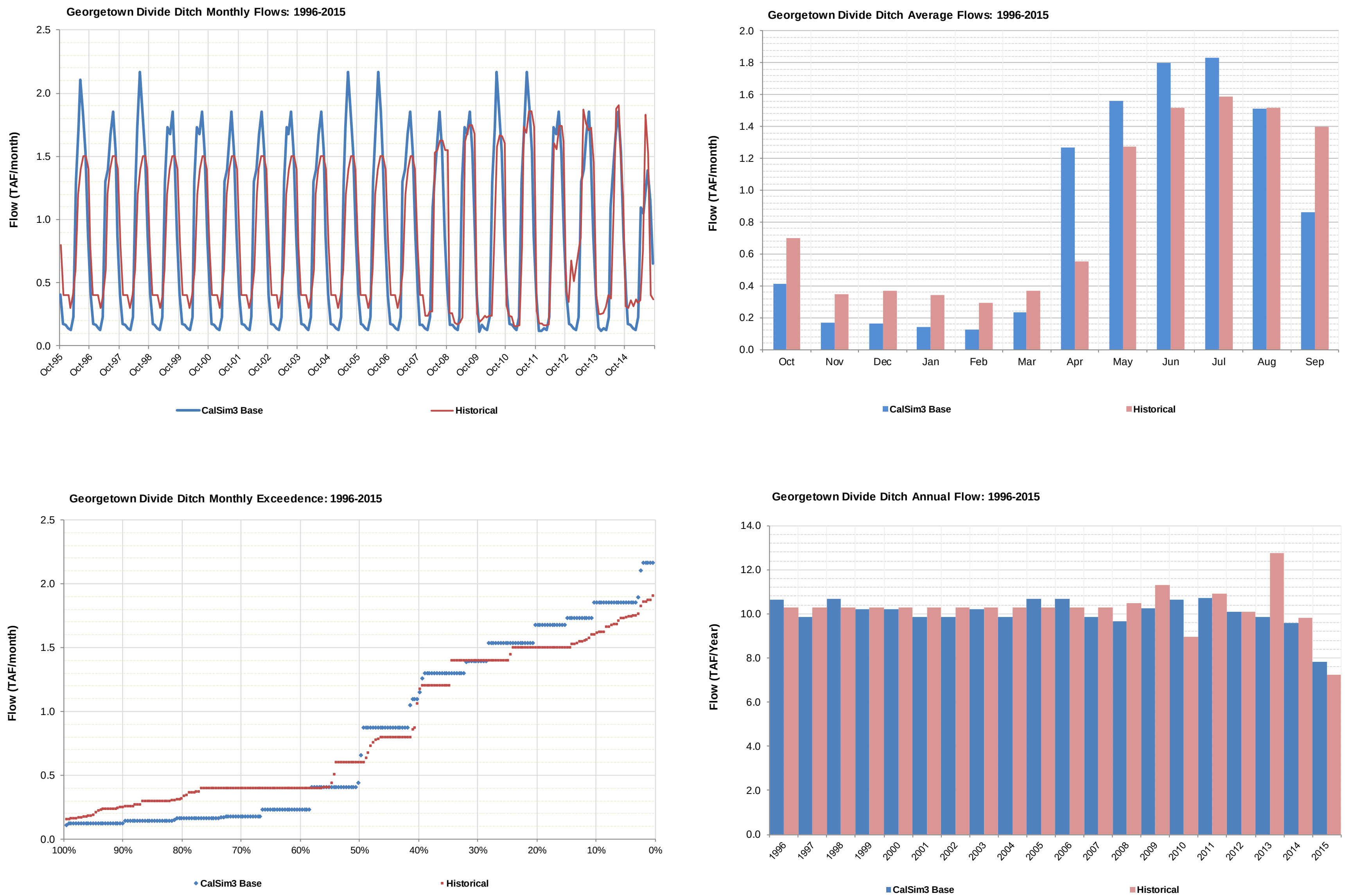


Figure 9-18. Georgetown Divide Ditch (D_PLC007_GDD010).

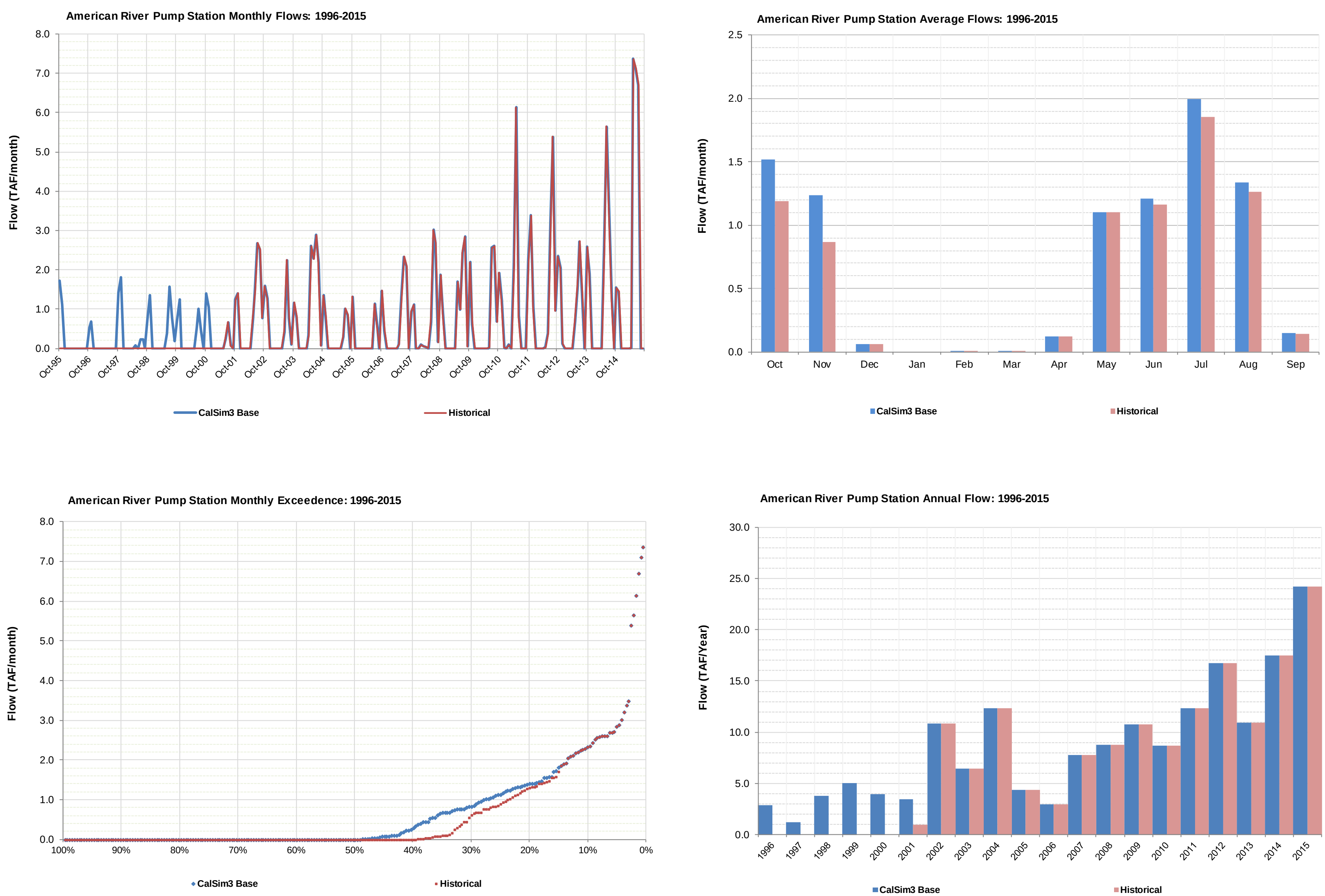


Figure 9-19. American River Pump Station (D_NFA016_ABT002).

Figure 9-20. El Dorado Forebay to RS1 Water Treatment Plant (D_EDC021_WTPRS1).

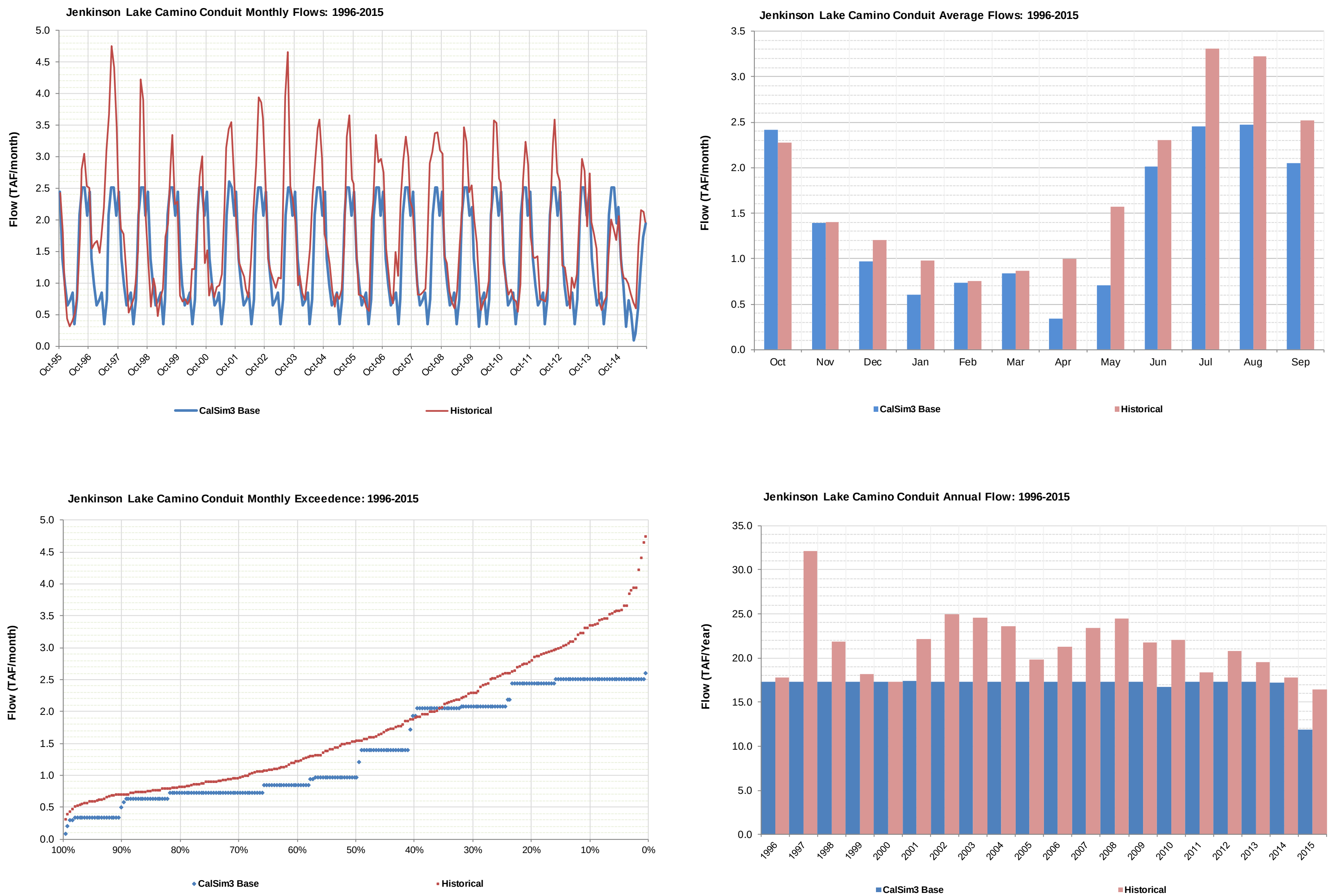


Figure 9-21. Jenkinson Reservoir to RSA Water Treatment Plant (D_JNKSN_WTPRSA).

Figure 9-22. EID Diversion from Folsom Lake (D_FOLSM_WTPEDH).

Figure 9-23. City of Roseville Diversion from Folsom Lake (D_FOLSM_WTPRSV).

Figure 9-24. San Juan Water District Diversion from Folsom Lake (D_FOLSM_WTPSJP).

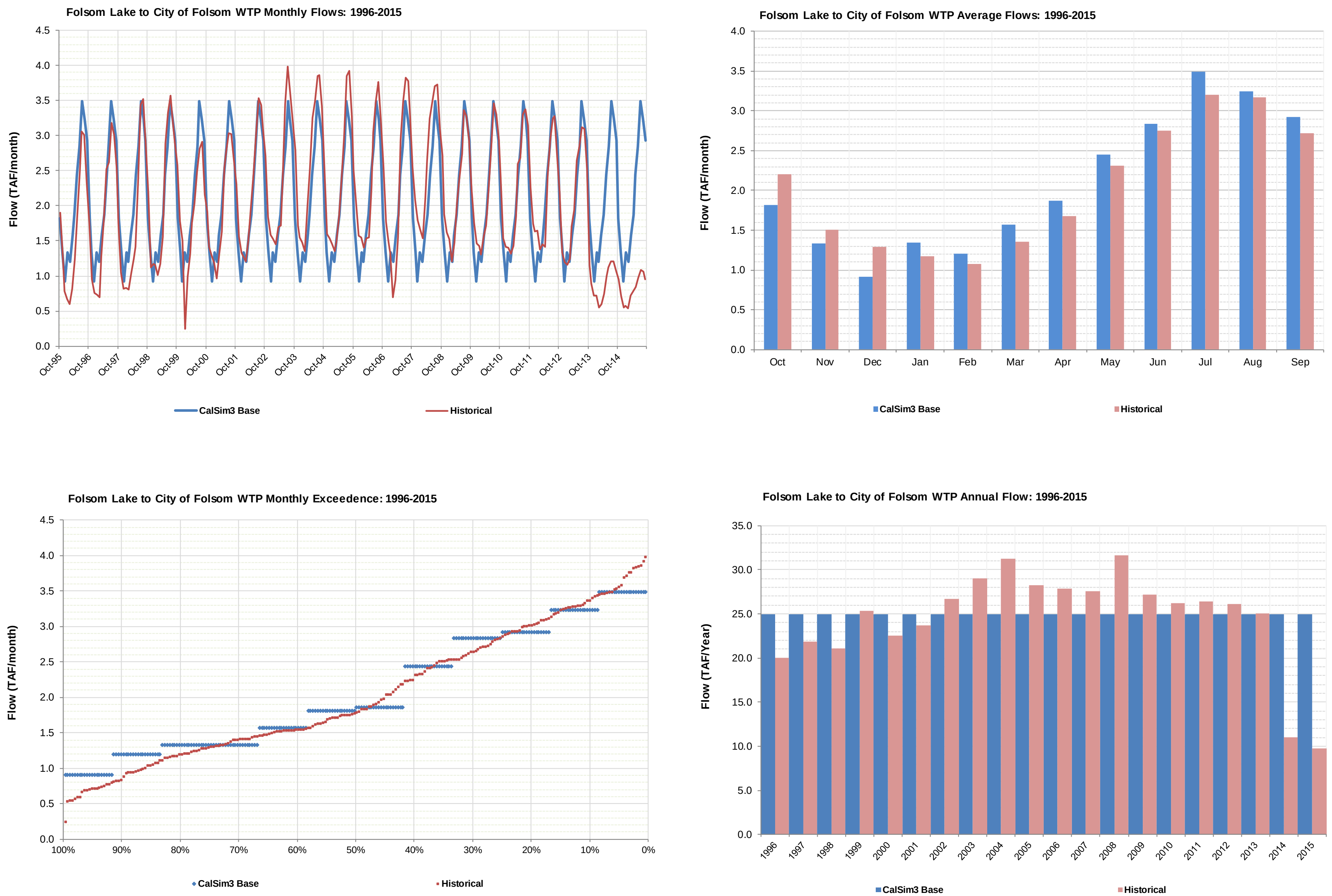


Figure 9-25. City of Folsom Diversion from Folsom Lake (D_FOLSM_WTPFOL).

Simulated and Historical Streamflows

Simulated and historical streamflows are compared at a total of 24 locations. These locations include:

- North Fork American River
  - North Fork American River at North Fork Dam
- Middle Fork American River Watershed (excluding Rubicon River watershed)
  - Duncan Creek below Diversion Dam
  - Middle Fork American River below French Meadows Dam
  - Middle Fork American River below Interbay Dam
  - Middle Fork American River near Foresthill
  - Pilot Creek below Mutton Canyon
- Rubicon River Watershed
  - Rubicon River below Rubicon Lake
  - Little Rubicon River below Buck Island Dam
  - Rubicon River below Hell Hole
  - Gerle Creek below Loon Lake
  - South Fork Rubicon River below Gerle Creek
- Silver Creek and Brush Creek
  - Silver Creek near Ice House
  - Silver Creek below Junction Diversion Dam
  - Silver Creek below Camino Diversion Dam
  - Combined Silver Creek, Camino Powerhouse, and Bush Creek
  - Brush Creek below Brush Creek Dam
- South Fork American River Watershed (excluding Silver and Brush Creek)
  - Pyramid Creek at Twin Bridges
  - Caples Lake Outlet
  - Silver Lake Outlet nr Kirkwood
  - South Fork American River near Kyburz
  - South Fork American River near Camino

  - South Fork American River near Placerville
- American River
  - Inflow to Folsom Lake
  - American River at Fair Oaks

Duncan Creek Below Diversion Dam

The model releases water from the Duncan Creek Diversion Dam to Duncan Creek to meet flow requirements specified in the MFP FERC license. Flow requirements specified in the original 1963 license vary between 4 – 8 cfs depending on the natural flow.[39] The model includes a 2 cfs buffer flow to ensure compliance. From November to June, all inflow to the diversion dam above this flow requirement is diverted through the Duncan Creek Tunnel to French Meadows Reservoir, up to its 400 cfs capacity. In the model, the tunnel is closed July to September. In model simulation for the most recent 20 years, spills over the diversion dam during the diversion season occur only once in October 2010. Spills during the non-diversion season occur twice, in July 1998 and July 2011. Historically, spills over the diversion dam occurred much more frequently.

The disparity between simulated and historical flows below the diversion dam are caused by the model monthly timestep. Inflows to Duncan Creek when averaged over a monthly timestep rarely exceed the 400 cfs tunnel capacity, while instantaneous flow often do so.

Middle Fork American River Below French Meadows Dam

The model releases water from French Meadows Reservoir and Dam to meet flow requirements specified in the MFP FERC license. These flows vary between 6-10 cfs depending on the water year type and include a 2 cfs buffer flow to ensure compliance. In model simulation, major spills from French Meadows Dam occur in June 1998, May 2006, and June 2011, with minor spills in additional 12 moths. Typically, spills occur when flows through the French Meadows – Hell Hole Tunnel are equal to the 400 cfs capacity. Simulated spills may occur in April of drier years when the model assumes the French Meadows Tunnel and Powerhouse are closed for maintenance. Minor spills sometimes occur when the Hell Tunnel and Middle River Powerhouse are at capacity.

Rubicon River Below Rubicon Lake

The model releases water from Rubicon Reservoir and Dam to the downstream channel to meet flow requirements specified in SMUD's UARP FERC license. These requirements vary between 6-35 cfs (or the natural flow, if less) depending on the water year type. At this location, the model does not include a buffer flow to ensure compliance. All inflow to the reservoir above the flow requirement is diverted through the Rubicon-Rockbound Tunnel to Buck Island Lake, up to the tunnel's 1,038 cfs capacity. In model simulation, no spills over the diversion dam occur. However, historically, spills over the diversion dam occurred on six occasions, all in the wetter years. The disparity between simulated and historical flows below the diversion dam are caused by averaging instantaneous flows over the model monthly timestep. Inflows to Rubicon Reservoir when averaged over a monthly timestep rarely exceed the 1,038 cfs tunnel capacity.

[39] A new FERC license for Project 2079 was issued on June 11, 2020.

The new FERC license (P-2101) for the UARP was issued on July 23, 2014. The minimum flow below Rubicon Lake specified in the old 1964 license was the minimum of 6 cfs or the natural flow.

Little Rubicon River Below Buck Island Lake

The model releases water from Buck Island Lake and Dam to the downstream channel to meet flow requirements specified in SMUD's Upper American River Project FERC license. These flows vary between 1-8 cfs (or the natural flow, if less) depending on the water year type. At this location, the model does not include a buffer flow to ensure compliance. All inflow to the reservoir above this flow requirement is diverted through the Buck-Loon Tunnel to Loon Lake, up to the tunnel's 1,199 cfs capacity. In model simulation, no spills over the diversion dam occur. Historically, no spills occurred.

The P-2101 FERC license was issued on July 23, 2014. The minimum flow below Rubicon Lake specified in the old license was the minimum of 1 cfs or the natural flow.

Rubicon River Below Hell Hole Dam

The model releases water from Hell Hole Reservoir and Dam to meet flow requirements on the Rubicon River specified in the MFP FERC license. Under the original 1963 license, these flows vary between 8-22 cfs depending on the water year type. In model simulation, a 2 cfs buffer flow is added to the license requirement to ensure compliance. Model results show that large simulated spills from Hell Hole Dam occur in May 1996, January 2007, June 1998, June 2006, and June 2011, with minor spills in an additional 4 months. Spills occur when simulated flows through the Hell Hole Tunnel are at its 920 cfs capacity. The model assumes no fixed period for powerhouse maintenance. Rather, it is assumed that PCWA schedules maintenance to occur outside periods of discretionary power releases.

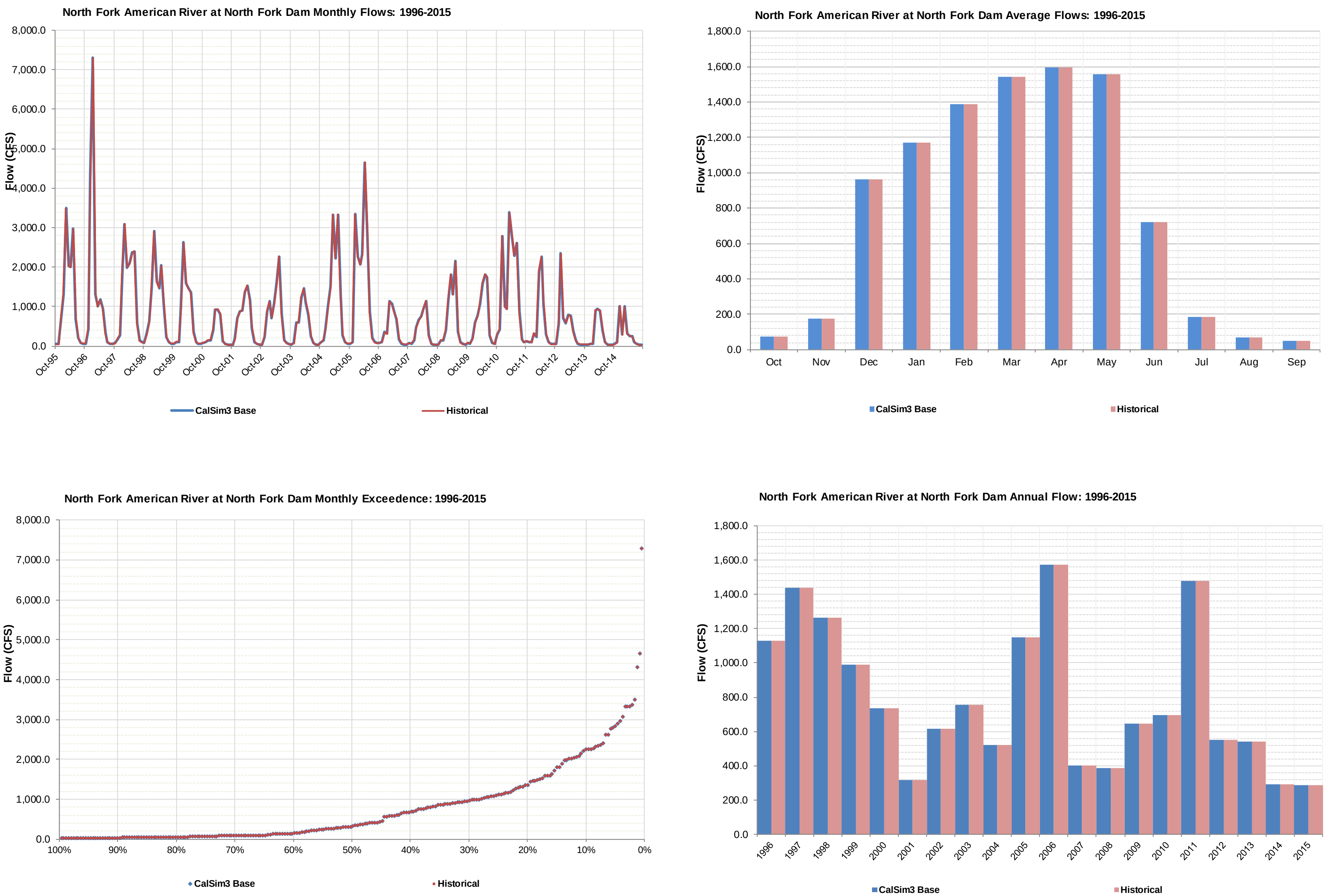


Figure 9-26. North Fork American River at North Fork Dam (C_NFA048).

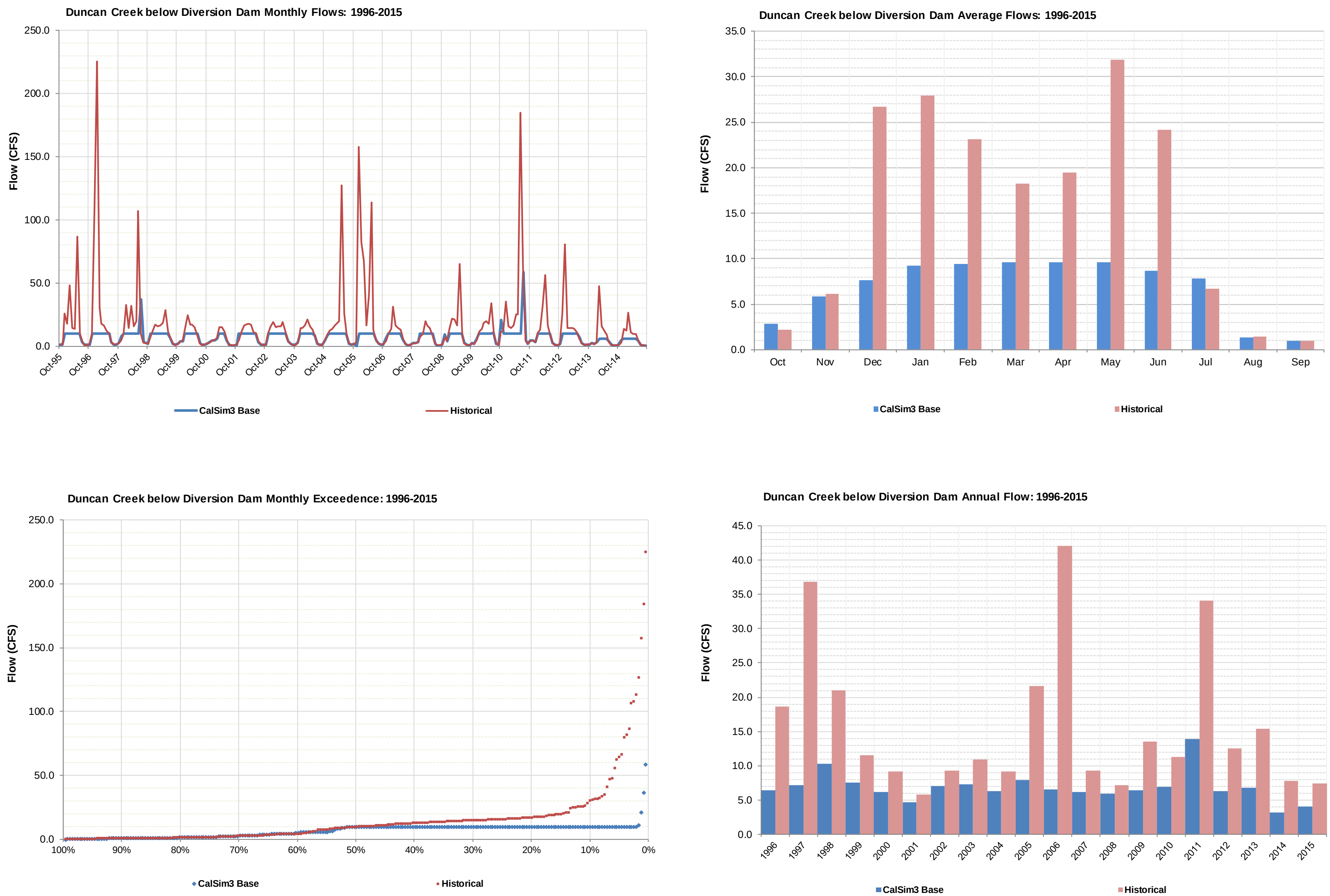


Figure 9-27. Duncan Creek Below Diversion Dam (C_DCC008).

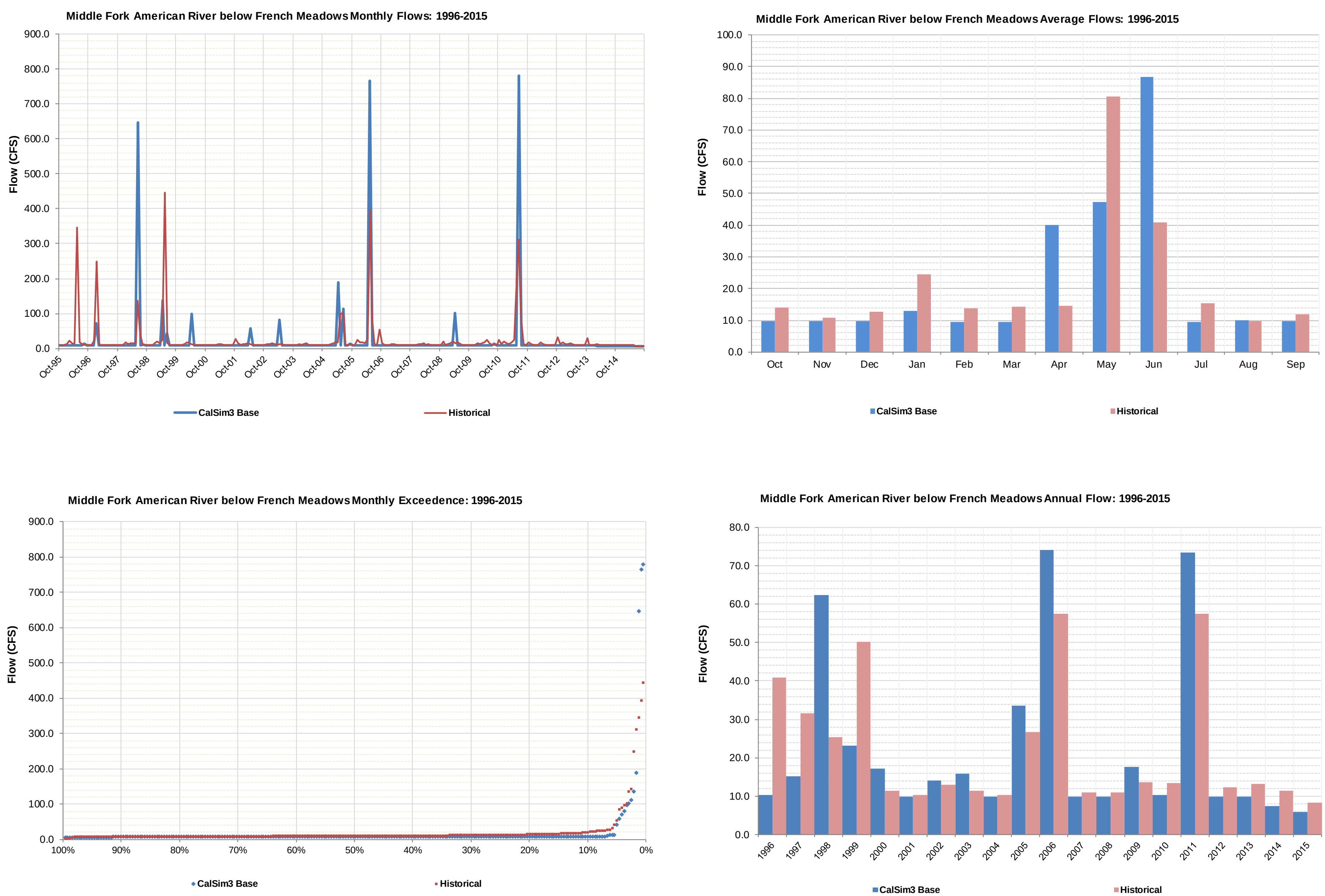


Figure 9-28. Middle Fork American River Below French Meadows Dam (C_MFA047).

Figure 9-29. Middle Fork American River Below Interbay Dam (C_MFA035).

Figure 9-30. Middle Fork American River near Foresthill (C_MFA023).

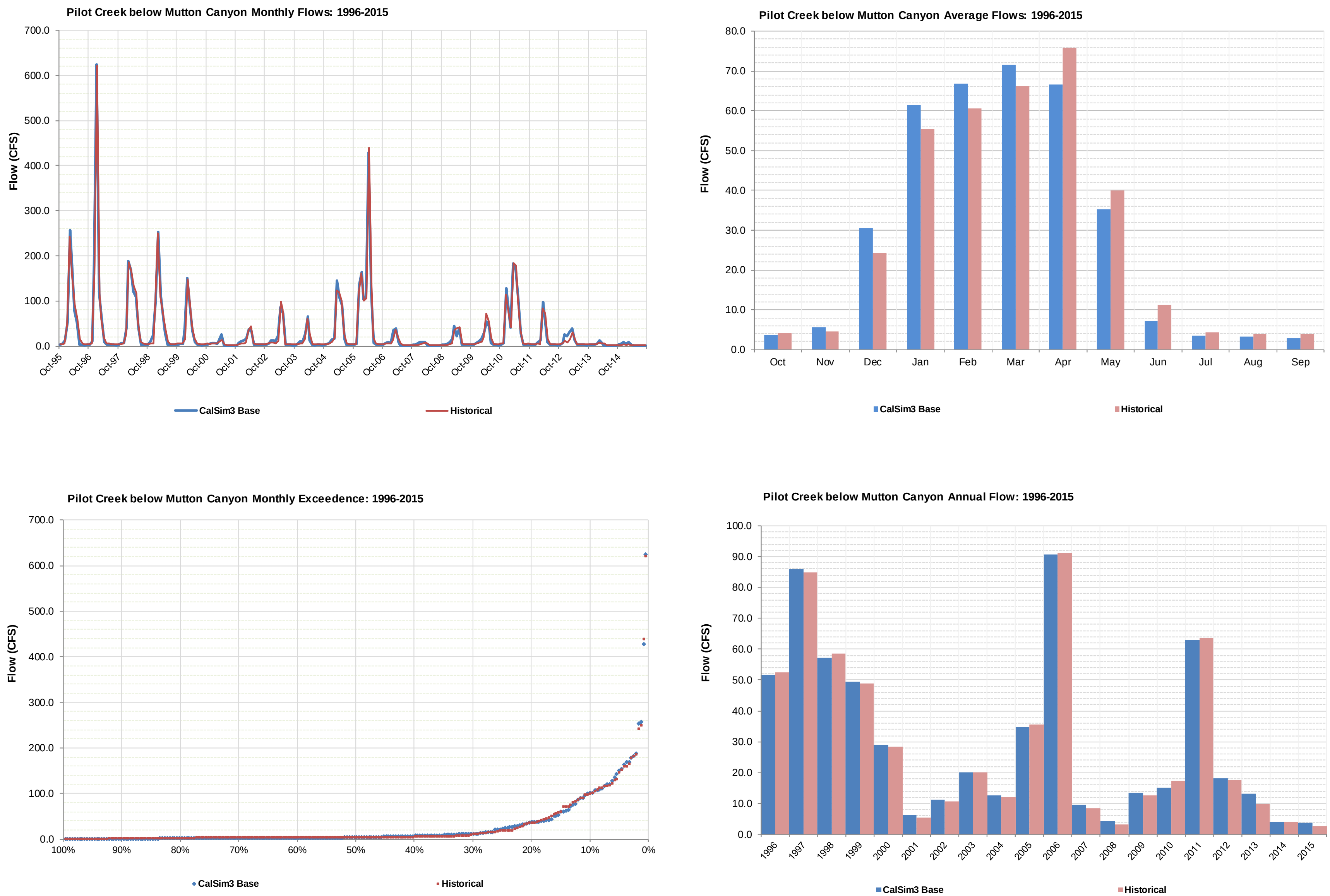
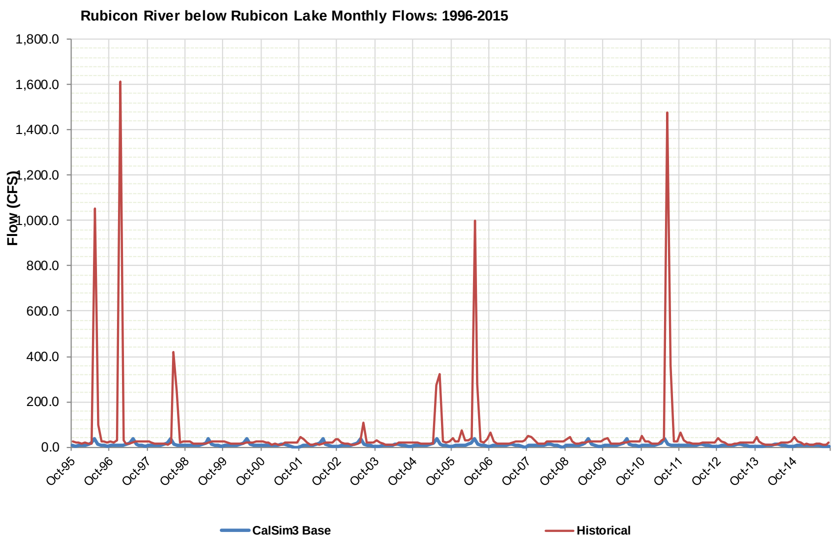
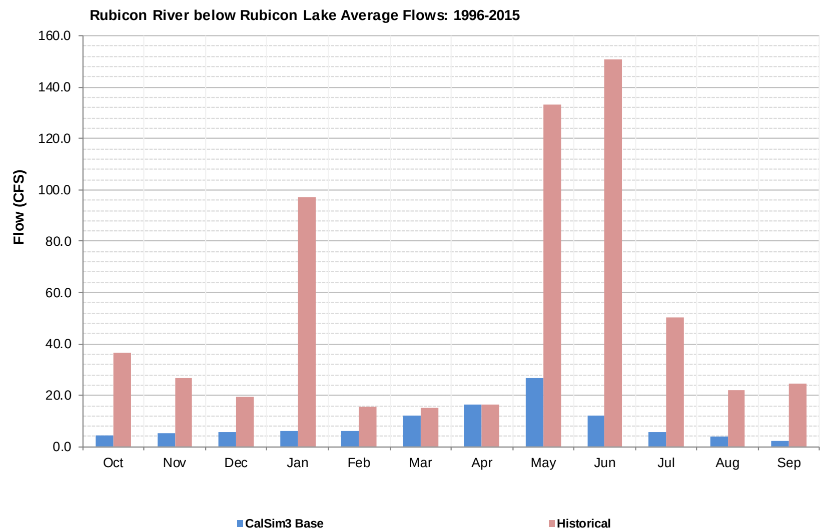
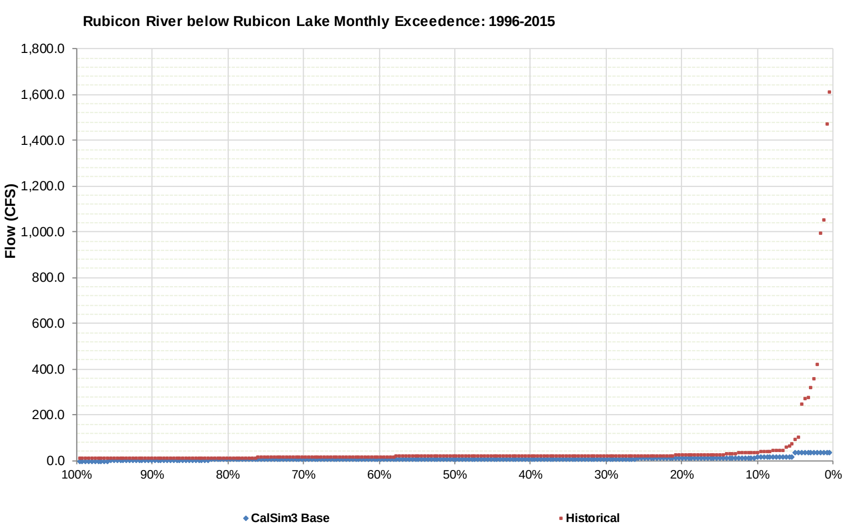


Figure 9-31. Pilot Creek Below Mutton Canyon (C_PLC006).







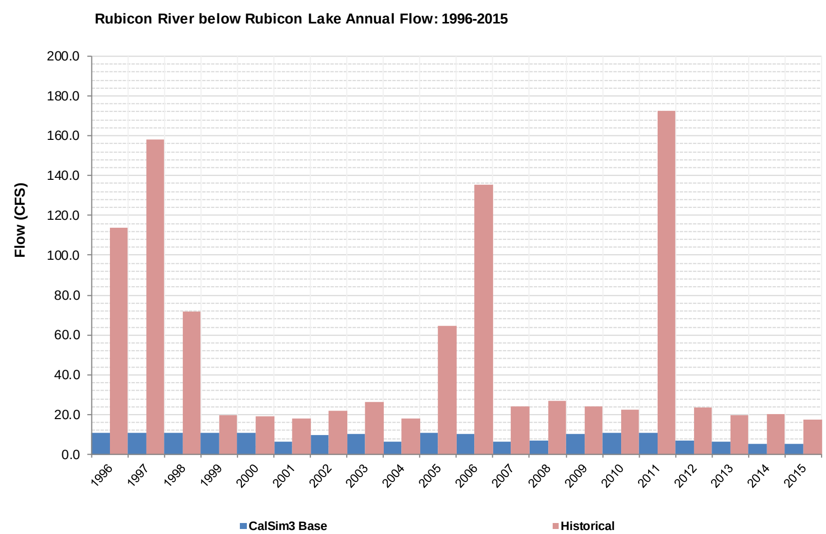


Figure 9-32. Rubicon River Below Rubicon Lake (C_RUB044).

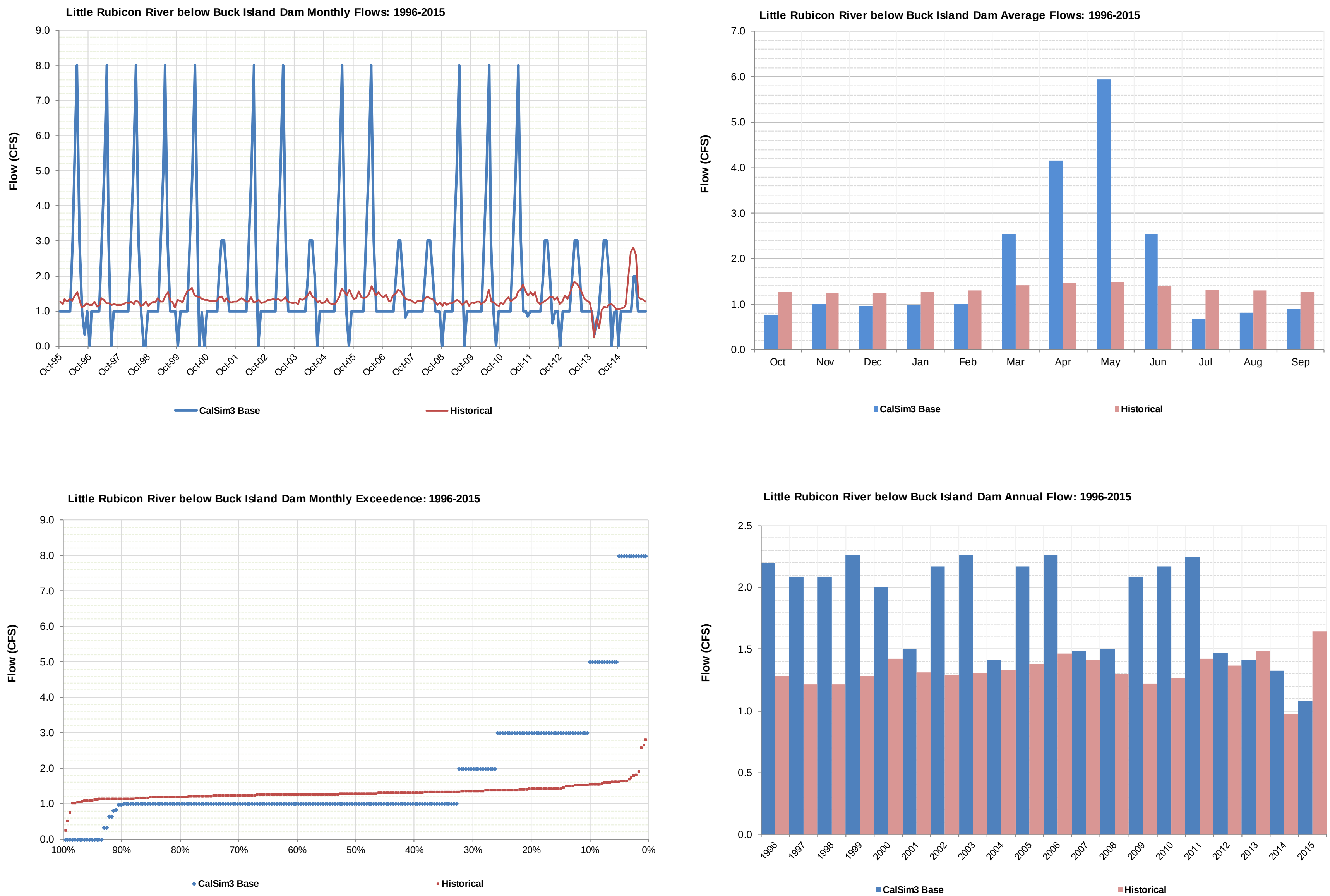


Figure 9-33. Little Rubicon River Below Buck Island Dam (C_LRB003).

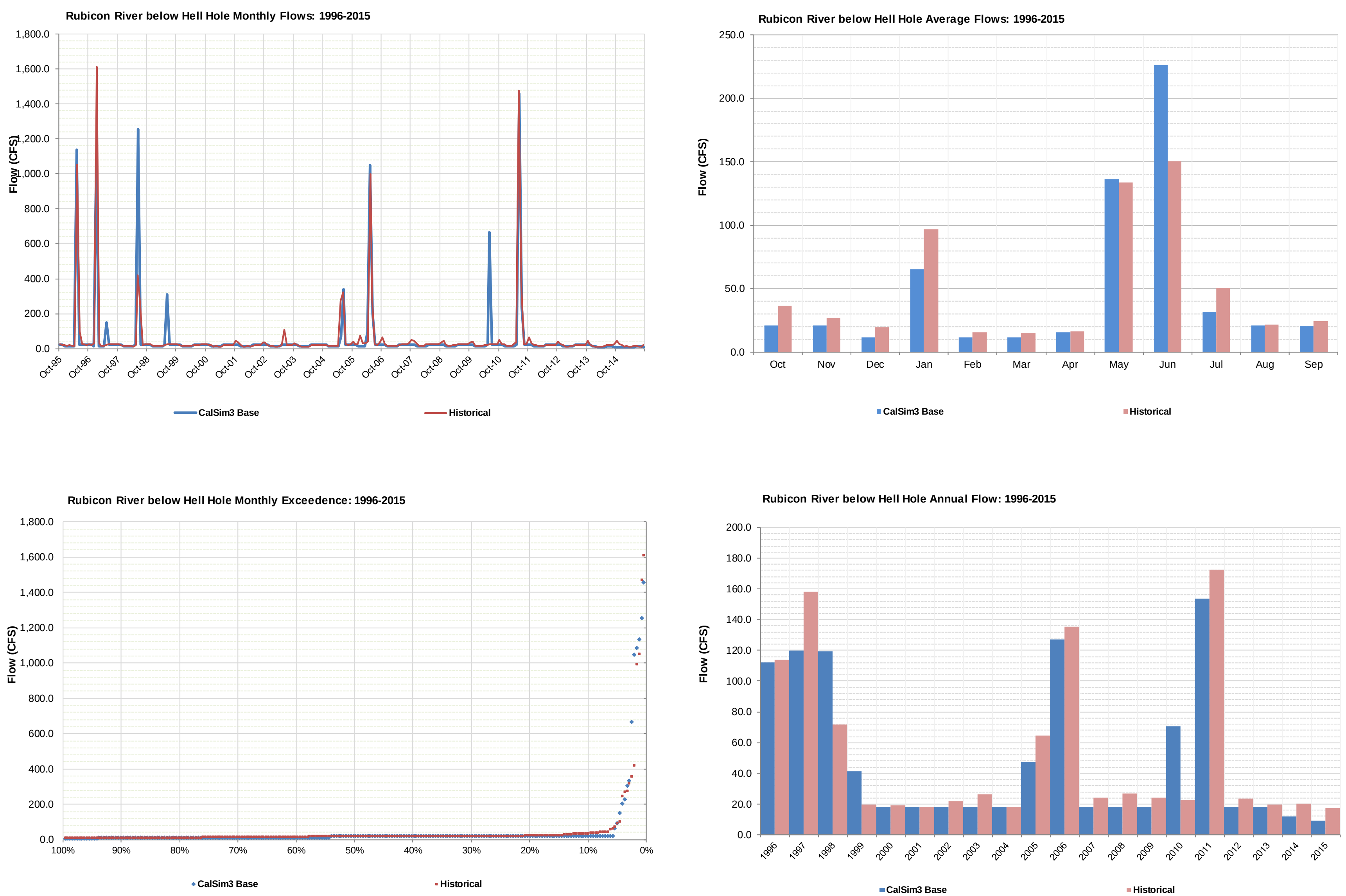


Figure 9-34. Rubicon River Below Hell Hole (C_RUB031).

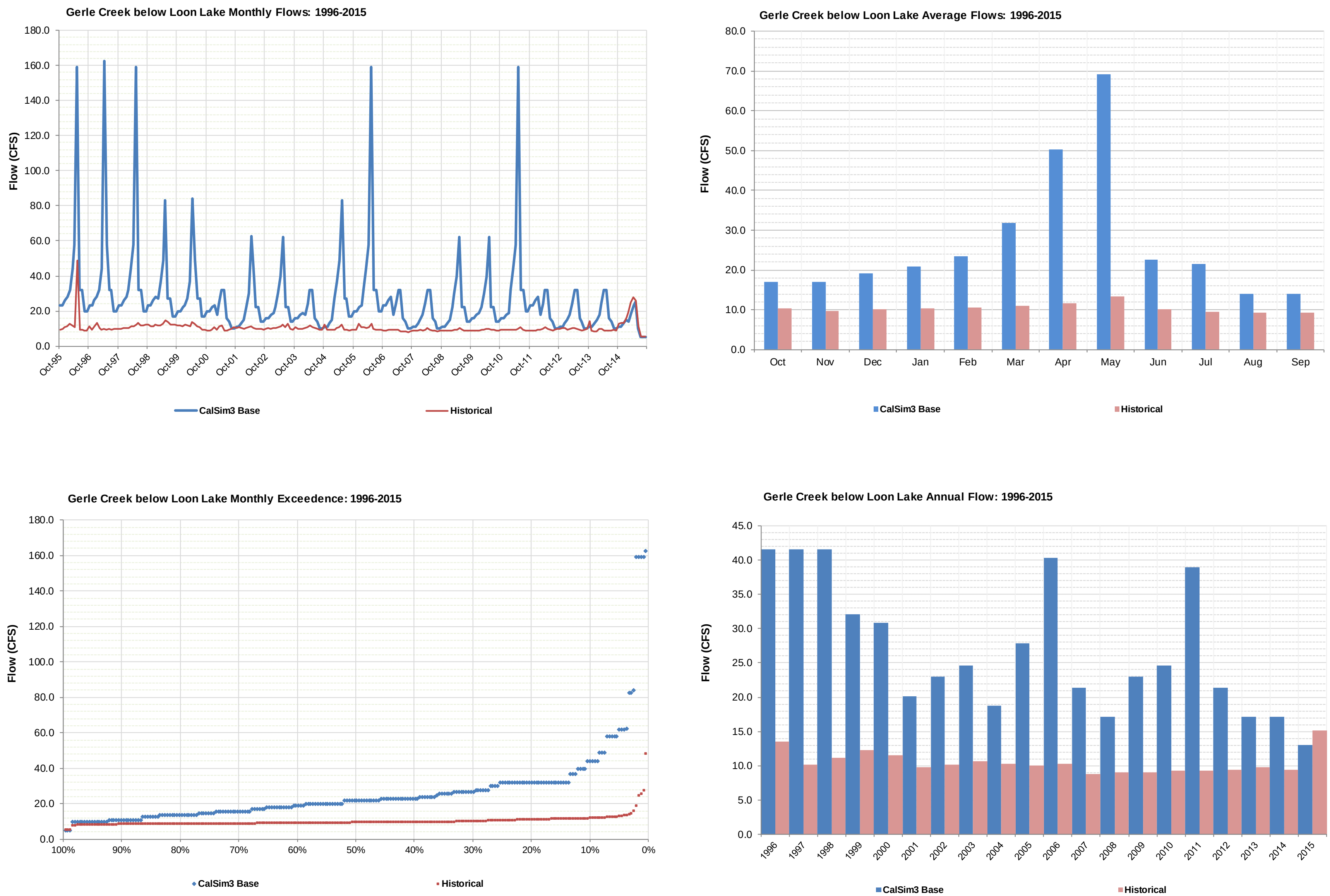


Figure 9-35. Gerle Creek Below Loon Lake (C_GRL010).

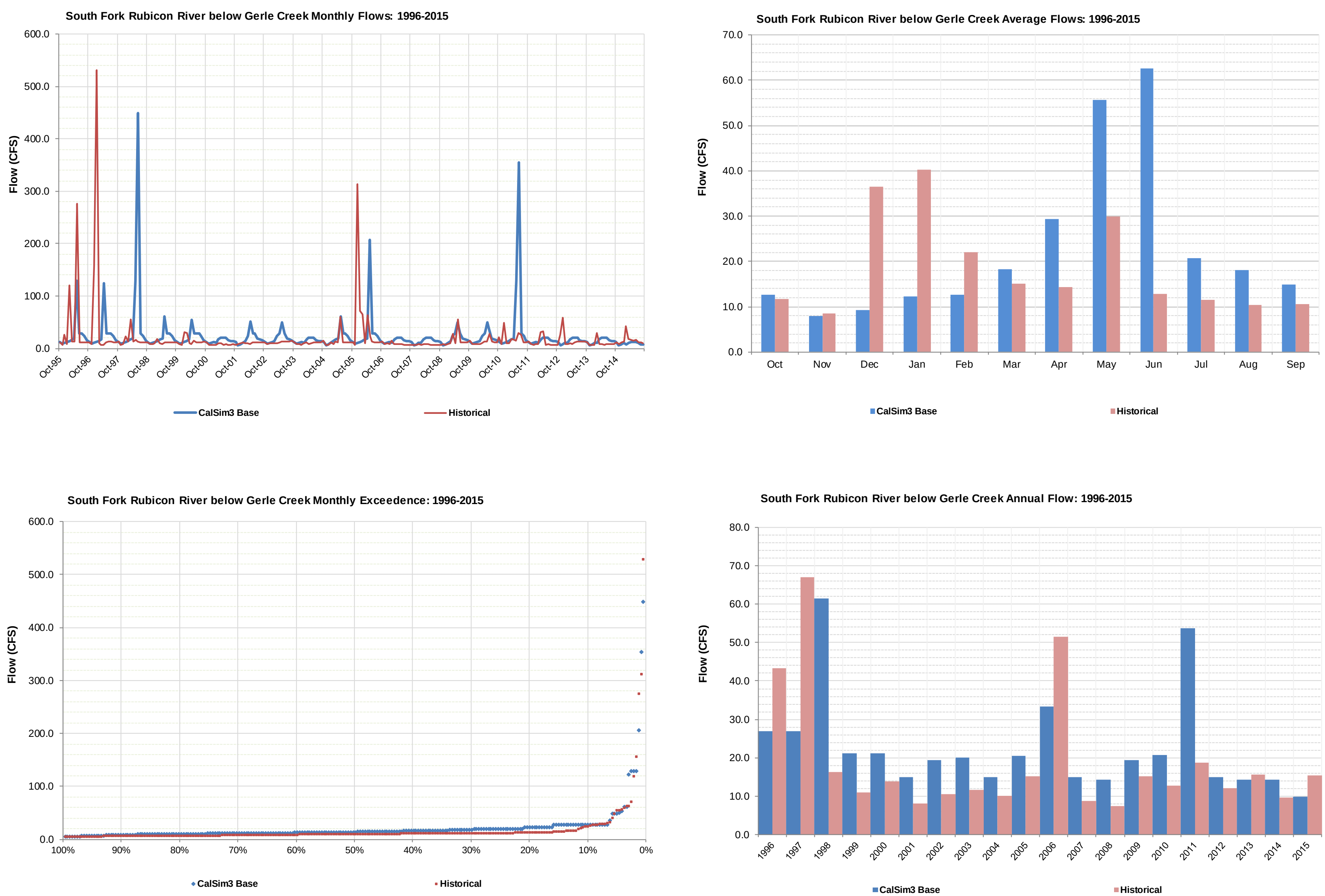


Figure 9-36. South Fork Rubicon River Below Gerle Creek (C_SFR004).

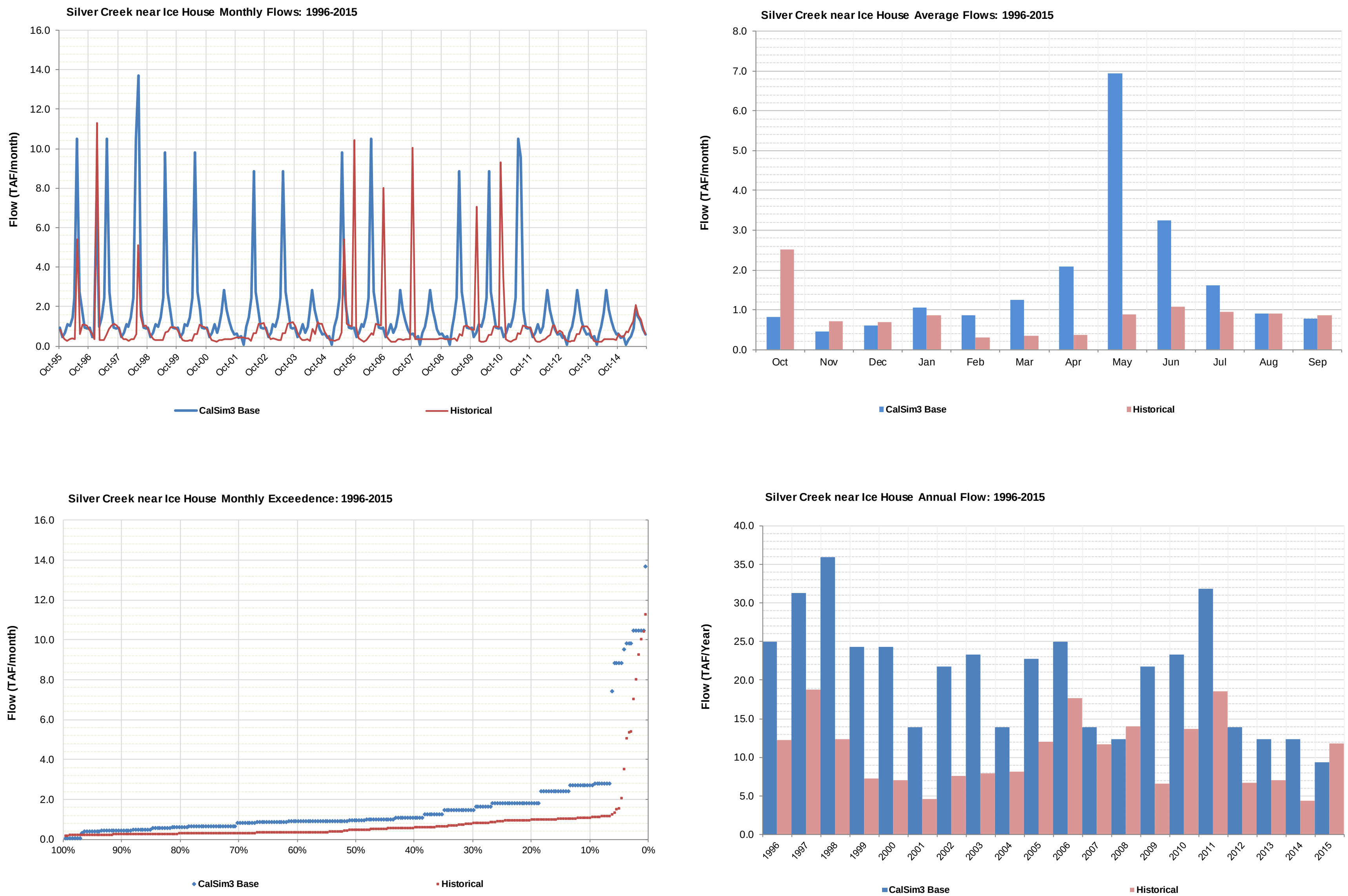
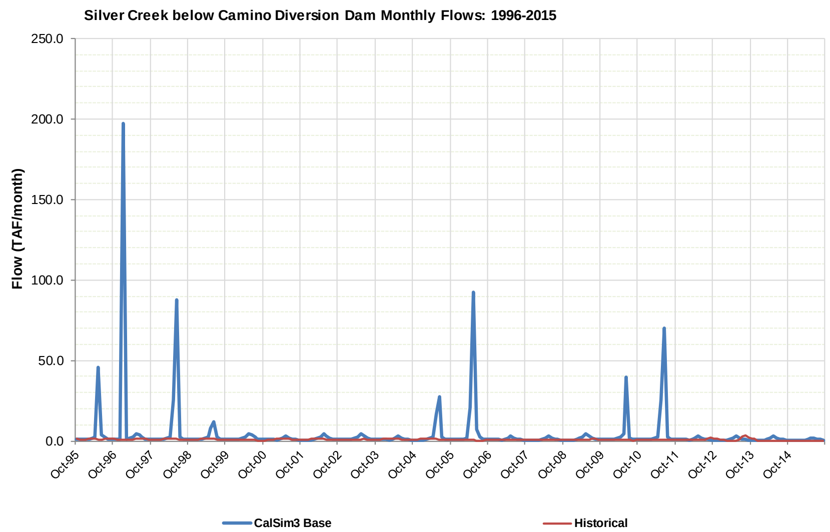
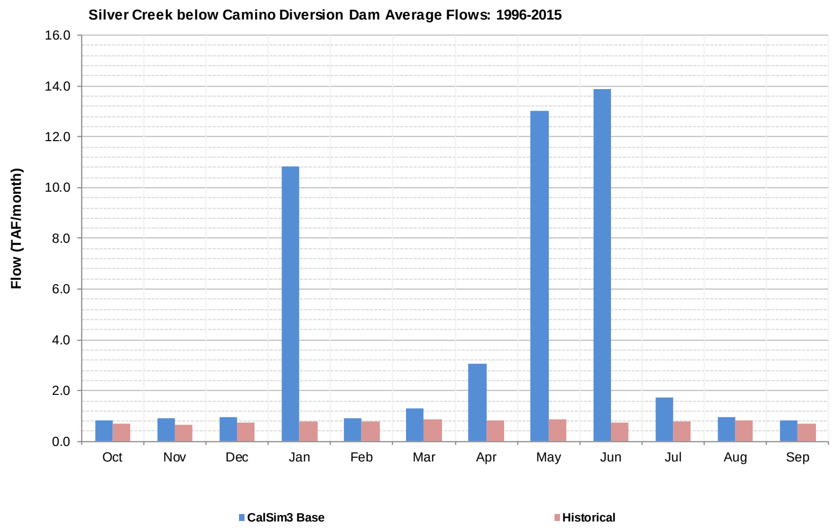
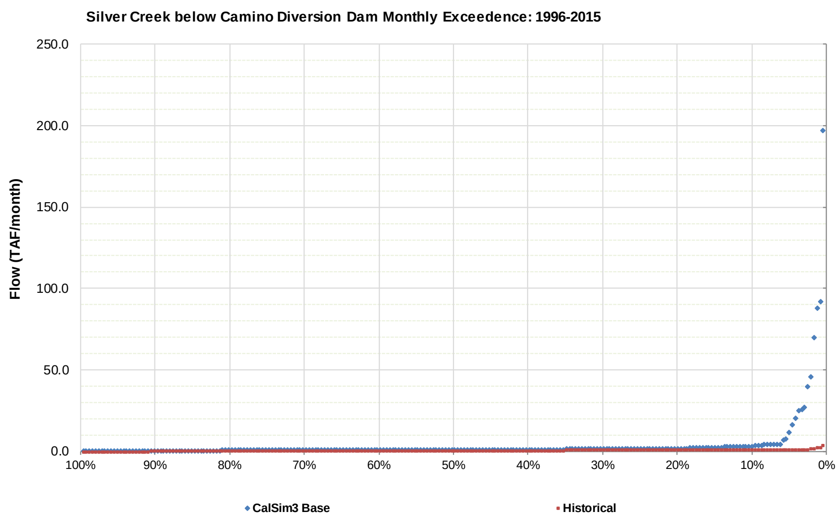


Figure 9-37. Silver Creek near Ice House (C_SSV013).

Figure 9-38. Silver Creek Below Junction Dam (C_SLV014).







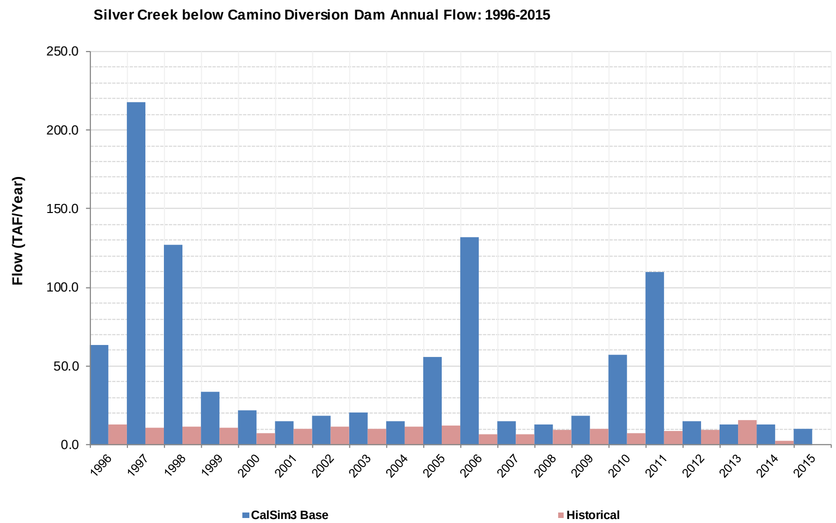


Figure 9-39. Silver Creek Below Camino Diversion Dam (C_SLV005).

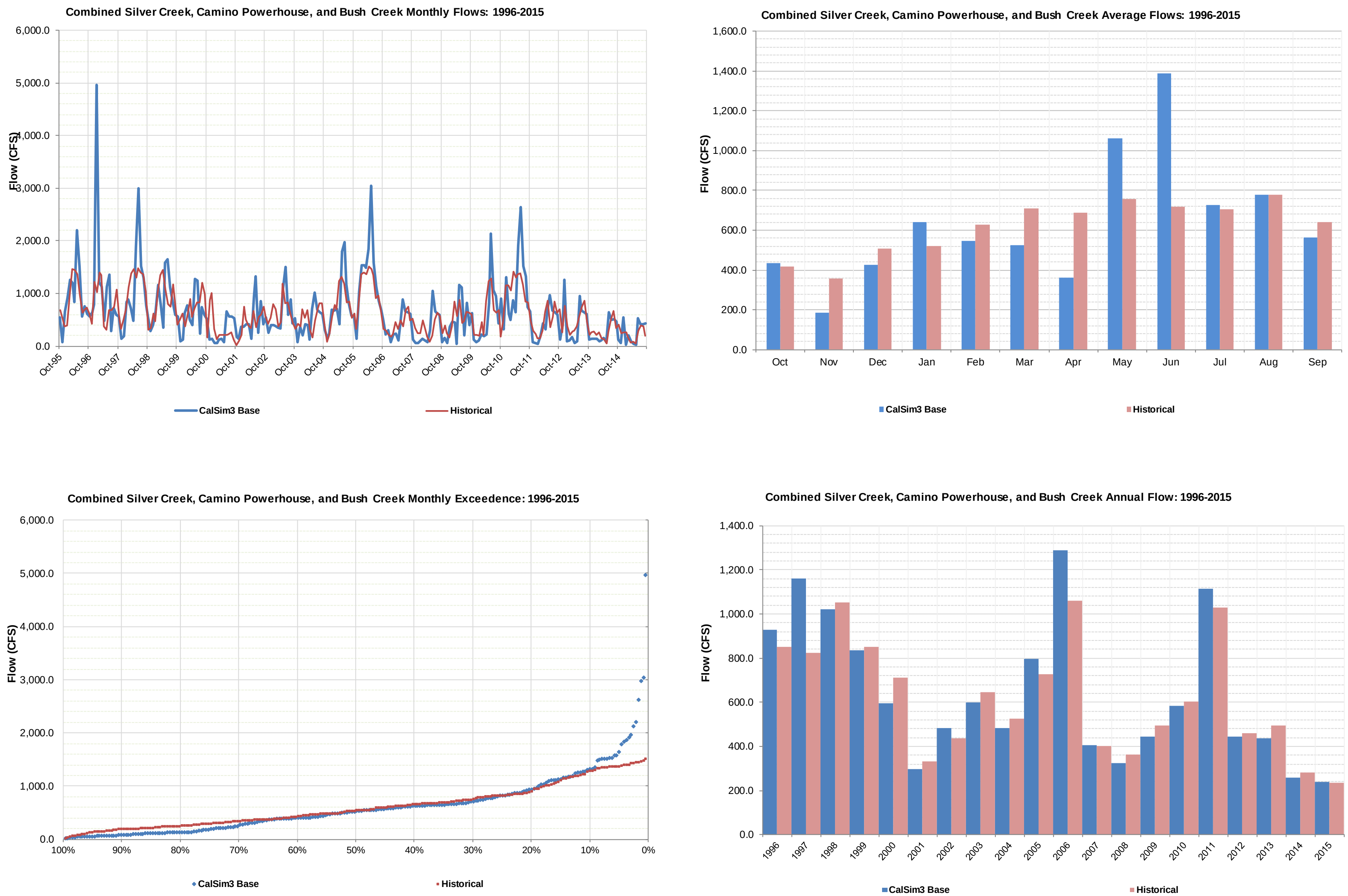
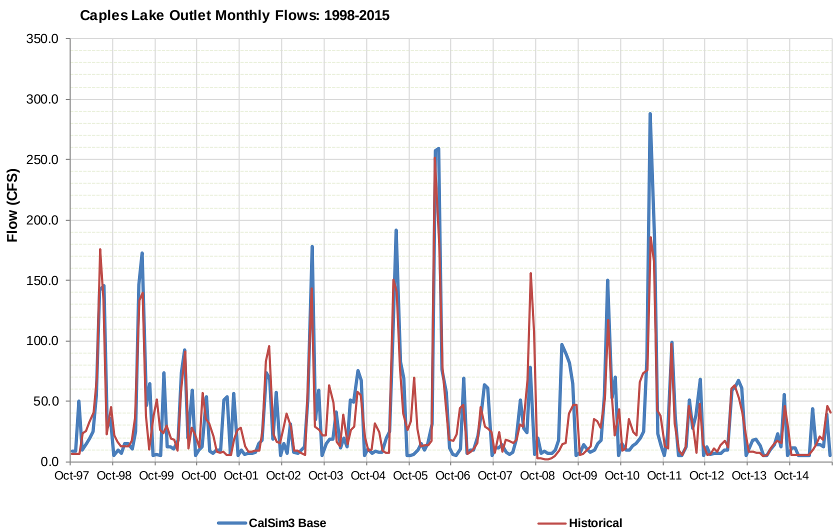
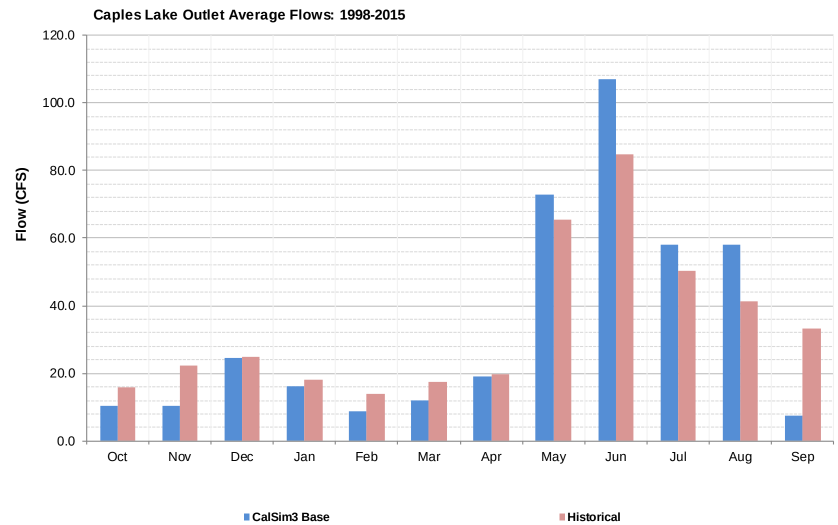


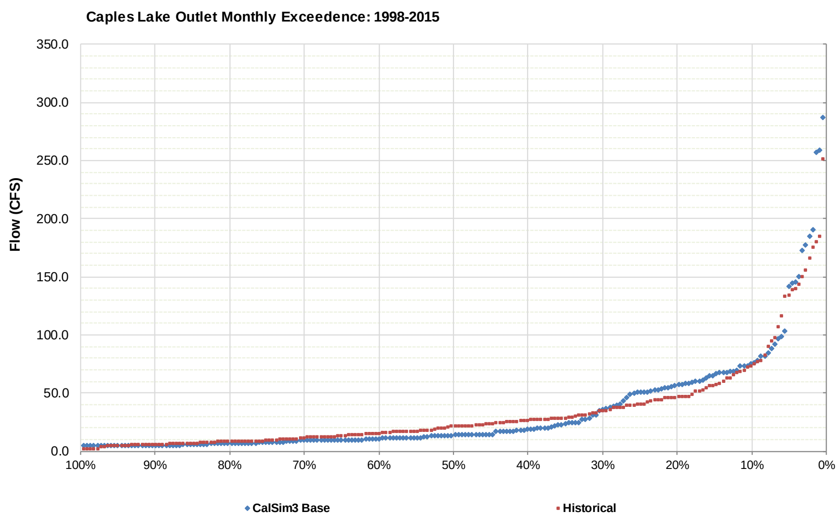
Figure 9-40. Combined Silver Creek, Camino Powerhouse, and Bush Creek.

Figure 9-41. Brush Creek Below Brush Creek Dam (C_BSH002).

Figure 9-42. Pyramid Creek at Twin Bridges (C_PYR001).







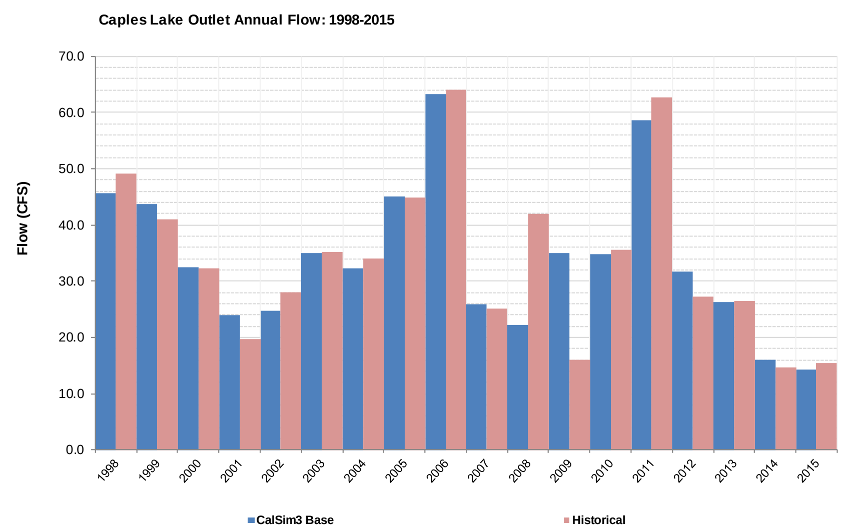


Figure 9-43. Caples Lake Outlet (C_CPC008).

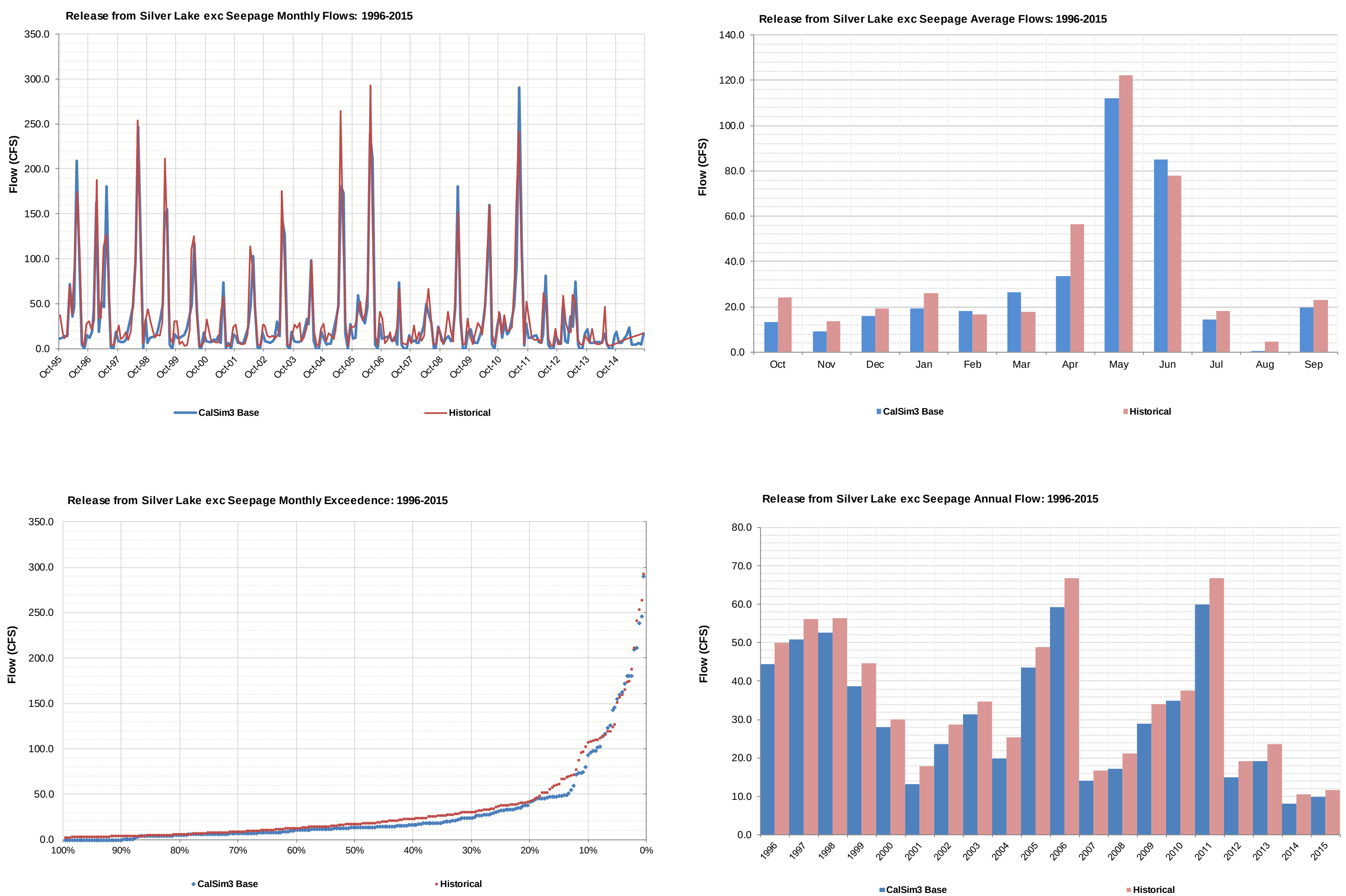


Figure 9-44. Silver Lake Outlet near Kirkwood (C_SLF015).

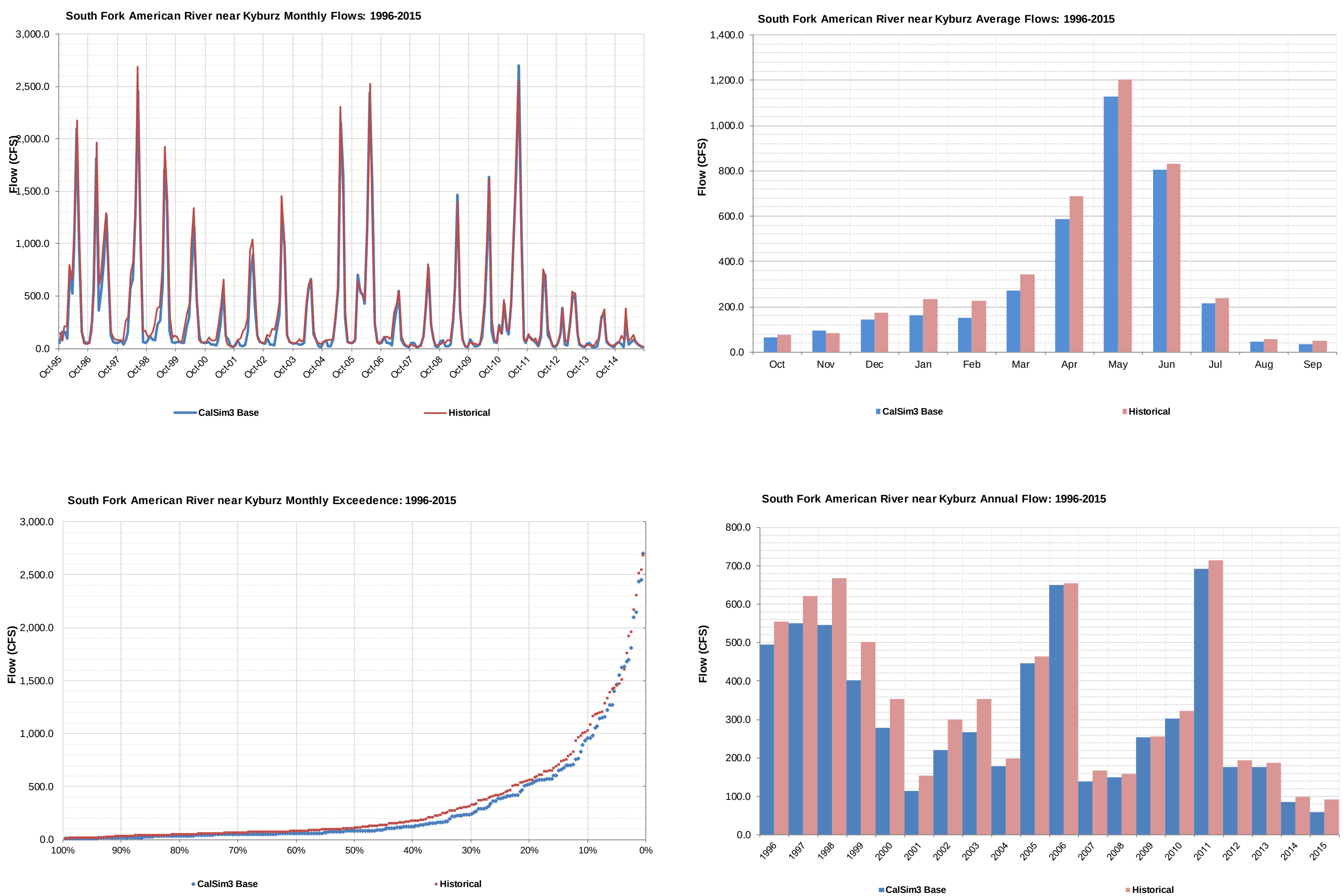
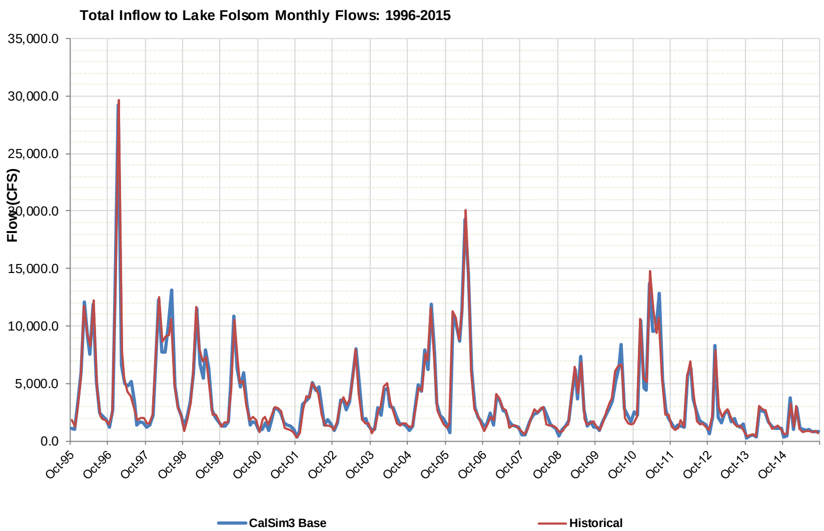
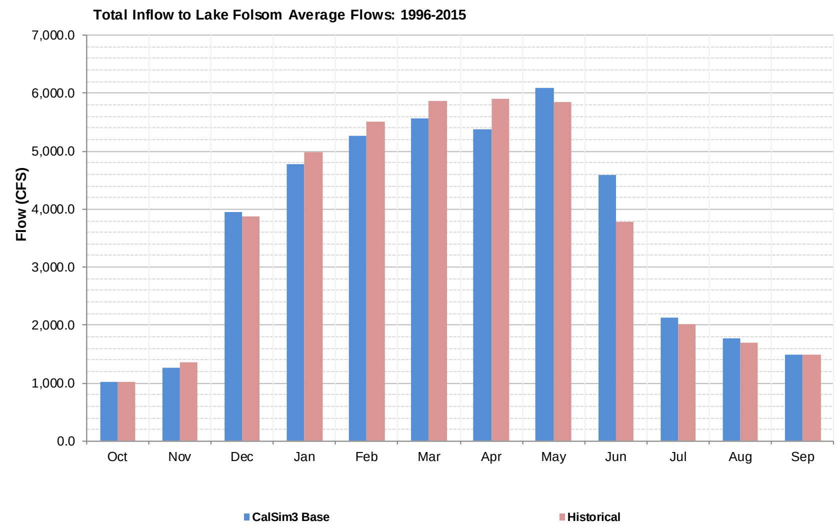


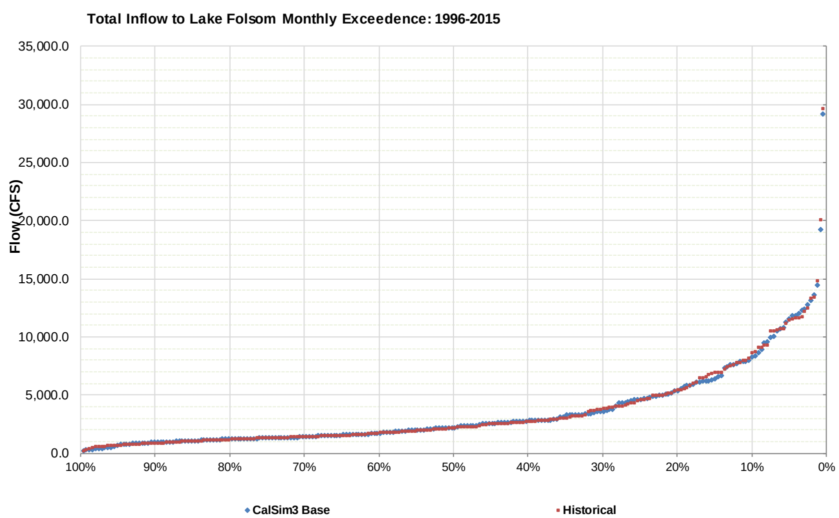
Figure 9-45. South Fork American River near Kyburz (C_SFA065).

Figure 9-46. South Fork American River near Camino (C_SFA039).

Figure 9-47. South Fork American River near Placerville (C_SFA030).







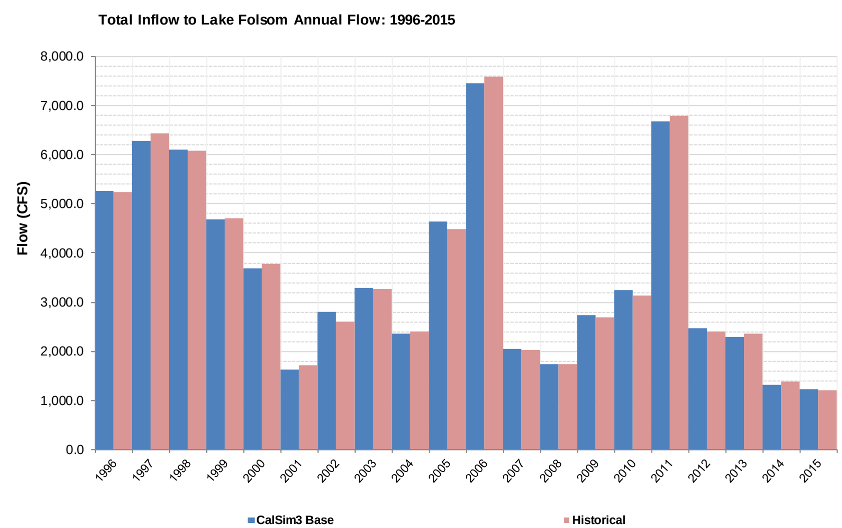


Figure 9-48. Inflow to Folsom Lake.

Figure 9-49. American River at Fair Oaks.

Simulated and Historical Canal, Tunnel, and Penstock Flows

Simulated and historical canal, tunnel, penstock, and powerhouse flows are compared at a total of 19 locations. These locations include:

- Drum-Spaulding Project
  - Lake Valley Canal
- Middle Fork Project
  - Duncan Creek Tunnel[40]
  - French Meadows Tunnel[41]
  - North Fork Long Canyon Creek Diversion
  - South Fork Long Canyon Creek Diversion
  - Middle Fork Powerhouse
  - Ralston Tunnel and Powerhouse
  - Oxbow Powerhouse
- Upper American River Project
  - Rubicon-Rockbound Tunnel
  - Buck-Loon Tunnel
  - Robbs Peak Tunnel and Powerhouse
  - Jones Fork Tunnel and Powerhouse
  - Jaybird Powerhouse
  - Bush Creek Tunnel (no historical data are available)
  - Camino Powerhouse
  - White Rock Tunnel and Powerhouse
- Project 184
  - Echo Lake Conduit
  - El Dorado Canal (period of comparison 2004-2015)
  - El Dorado Powerhouse (period of comparison 2004-2015)

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[40] Historical data are not available and have been estimated from mass balance.
[41] Historical data are not available for WY 2007 and have been estimated from mass balance.

Drum-Spaulding Project

Lake Valley Canal

The Lake Valley Canal diversion is simulated as part of the CalSim 3 Yuba-Bear module. The boundary between this module and the upper American River module is the North Fork American River upstream from the North Fork Dam. In the Yuba-Bear module, flows through Lake Valley Canal are restricted to the October-June period; the diversion dam is assumed to be closed from July through September. Historical data for WY 1996-2015 shows that this is the case for 11 years for July and August and for 16 years for the month of September. In model simulation, spills over the diversion dam may occur when: (a) Lake Valley Canal is at capacity, (b) the diversion dam is closed (July-September), or (c) Lake Valley Reservoir is at capacity.

From October through June, simulated flows through the Lake Valley Canal are dictated by Lake Valley Reservoir storage regulation and river accretions between Lake Valley Dam and Lake Valley Diversion Dam. Storage in Lake Valley Reservoir typically follows a rule curve adopted from the HEC ResSim model developed as part of the Drum-Spaulding FERC relicensing and adjusted to better match observed data. Simulated reservoir storage lies below rule curve only in dry years when winter and spring inflows are insufficient to refill the reservoir. In these circumstances, storage may remain low for the rest of the water year.

Middle Fork Project

Duncan Creek Tunnel

Operation of the Duncan Creek Diversion Dam is discussed in the above section 'Simulated and Historical Streamflows'. Simulated flows through the tunnel match the historical record except during high flow events when the simulation monthly time-step overestimates the ability to divert short duration high intensity runoff. Model simulation could potentially be improved by artificially limiting the capacity of the tunnel.

French Meadows Tunnel

In model simulation, water is transferred from French Meadows to Hell Hole reservoirs to avoid spilling during the refill season and to reach a target end-of-December carryover storage of 50,000 AF. For the June-December drawdown season, simulated flows through the powerhouse average 88 TAF/year compared to a historical flow of 73 TAF/year. This discrepancy is partly cause by:

- Higher (5 TAF) simulated end-of-May storage in French Meadows Reservoir caused by greater imports from Duncan Creek resulting from the model's monthly timestep and the capacity limitation on the Duncan Creek Tunnel.

- Lower (9 TAF) simulated end-of-December storage in French Meadows Reservoir as the model operates to a 50 TAF December target storage.

Simulated end-of-December storage in French Meadows Reservoir is greater than the 50 TAF carryover storage target in wet years with high reservoir inflows and when tunnel flows are at the physical capacity.

For the January-May refill season, simulated flows through the powerhouse average 29 TAF/year compared to a historical flow of 39 TAF/year. This discrepancy is partly cause by the lower (9 TAF) simulated end-of-December storage in French Meadows Reservoir described above.

Hell Hole Tunnel and Middle Fork Powerhouse

In model simulation, flow through the Middle Fork Powerhouse is opportunistic. There is no associated code or logic and powerhouse flows result from storage releases and bypassed flows from Hell Hole Reservoir for power generation at Ralston Powerhouse and/or for meeting downstream water supply obligations. Small persuasion penalties are used to determine routing through Hell Hole Tunnel. The simulated powerhouse/tunnel capacity is 920 cfs.

Both simulated and historical flow data for the powerhouse appear erratic with no easily discernable pattern. Annual simulated flows average 4 TAF/year lower than historical, however, there are significant differences in the monthly flow patterns. Average months simulated flows from October to December are significantly higher than historical. This is caused by simulated drawdown of MFP reservoirs to meet end-of-December carryover storage targets.[42] Average months simulated flows from January to April are significantly lower than historical.

NF Long Canyon Creek Diversion

The North Fork and South Fork Long Canyon Diversion Dams are mostly operated as a passive system with the natural hydrology determining the diversions. In model simulation the diversion intakes are closed from October through February to prevent debris entering the Middle Fork Tunnel. The model diverts all stream flows above the downstream flow requirement into the Hell Hole Tunnel for power generation at the Middle Fork Powerhouse. The capacity of the North Fork Diversion Dam is 100 cfs.

Historical data suggest that at times when Hell Hole Reservoir is spilling, diversions from the North Fork and South Fork Long Canyon Creek take preference over diversions from Hell Hole Reservoir to the Hell Hole Tunnel because the former are passive systems. Small persuasion penalties on diversions were created to implement this preferred operation.

North Fork and South Fork Long Canyon diversions typically drop to zero after May and the end of the snowmelt. However, in wet years such as the El Nino 1998, diversions may continue through June.

The comparison of simulated and historical data suggests that diversions historically occurred in the October through February timeframe. However, no diversions have occurred in this period since 2003. Average annual simulated diversions are approximately equal to historical.

SF Long Canyon Creek Diversion

Similar to the North Fork, the model diverts all stream flows in the South Fork Long Canyon Creek above the downstream flow requirement into the Hell Hole Tunnel for power generation at the

[42] The model assumes an end-of-December carryover storage target of 50 TAF for French Meadows Reservoir and 100 TAF for Hell Hole Reservoir.

Middle Fork Powerhouse. The capacity of the diversion is 200 cfs. Average annual simulated diversions are 1 TAF/year greater than historical.

Ralston Tunnel

In model simulation, weights assigned to flow through the Ralston Powerhouse draw MFP reservoir storage down to a rule curve developed for discretional power releases. Average annual simulated powerhouse flows are 19 TAF/year greater than historical. Historically, the Ralston Powerhouse was shut down for the first 6 months of WY 2008. If this period is excluded from the simulated historical comparison, average annual differences decrease to 15 TAF/year.

Average annual simulated streamflows below the Interbay Dam are 24 TAF/year less than historical. Major differences occur when either French Meadows Reservoir is spilling or there are large river accretions below French Meadows Dam and Interbay Dam from short duration high intensity rainfall events. Differences in simulated and historical flows appear to be driven by the model's monthly timestep and period averaging.

Oxbow Powerhouse

Simulated flow through the Oxbow Powerhouse is opportunistic. There is no associated code or logic and powerhouse flows result from upstream storage releases for other purposes and upstream river accretions. A small persuasion penalty directs river flows at the Ralston Afterbay in excess of the downstream flow requirement through the powerhouse up to its physical capacity of 1,025 cfs. Both simulated and historical flow data for the powerhouse appear erratic with no easily discernable pattern. Annual simulated flows average 44 TAF/year higher than historical, and simulated average months flows from October to December are significantly higher than historical. This is caused by simulated drawdown of MFP reservoirs to meet end-of-December carryover storage targets.

Upper American River Project

Rubicon-Rockbound Tunnel

Rubicon Lake, which has a capacity of 1,439 AF, is not simulated in the upper American River model. In model simulation, water is directly diverted from the Rubicon River in to the 1,038 cfs-capacity Rubicon-Rockbound Tunnel that leads via the Little Rubicon River to Loon Lake. Minimum flows below the diversion dam vary from a maximum of 10 cfs (or the natural flow) in Critically Dry years to a maximum of 35 cfs (or the natural flow) in wet years but never less than 1 cfs.

Simulated flows through the Rubicon-Rockbound Tunnel are in direct response to the inflow hydrology. Tunnel flows average 67 TAF/year (WY 1996-2015) compared to an historical average flow of 70 TAF/year. New FERC license requirements adopted in 2014 and incorporated into the model are the reason for the small discrepancy.

Buck-Loon Tunnel

Buck Island Lake, which has a capacity of 1,070 AF, is not simulated in the upper American River model. In model simulation, inflows from the Rubicon-Rockbound Tunnel are supplemented by direct diversions from the little Rubicon River and flow through the 1,199 cfs-capacity Buck-Loon

Tunnel that leads to Loon Lake. Minimum flows below the diversion dam vary from a maximum of 2 cfs (or the natural flow) in Critically Dry years to a maximum of 8 cfs (or the natural flow) in wet years but never less than 1 cfs.

Simulated flows through the Buck-Loon Tunnel are in direct response to the inflow hydrology. Tunnel flows average 85 TAF/year (WY 1996-2015) compared to an historical average flow of 88 TAF/year. New FERC license requirements adopted in 2014 and incorporated into the model are the reason for the small discrepancy.

Robbs Peak Tunnel and Powerhouse
Water is transferred from the Rubicon and South Fork Rubicon River watershed to the Silver Creek watershed through Robbs Peak Tunnel and Powerhouse to Union Valley Reservoir. The tunnel has a capacity of 1,020 cfs. In model simulation, most natural flow above the FERC license requirements at four locations (Rubicon River below Rubicon Reservoir Dam, Little Rubicon River below Buck Island Reservoir Dam, Gerle Creek below Gerle Creek Reservoir Dam and South Fork Rubicon River below Robbs Peak Reservoir Dam) is exported from the watershed. Some of the exported water is temporarily stored in Loon Lake.

In model simulated, outflow from the South Fork Rubicon River to the Rubicon River exceeds minimum flow requirements only 3 times between 1996-2015: June 1998, June 2010, and June 2011. Only June 1998 and June 2011 have significant excess flows. This occurs when Loon Lake is full and spilling and Robbs Peak Tunnel is flowing at capacity

Simulated Robbs Peak Tunnel flows average 170 TAF/year (WY 1996-2015) compared to an historical average flow of 175 TAF/year. New FERC license requirements for instream flows adopted in 2014 and incorporated into the model are one reason for the minor discrepancy. Simulated flows through the tunnel peak in June. In contrast. Historical flows typically peak in May. This is caused by the forecasting routine used in the upper American River model that makes discretionary releases for hydropower with the objective of filling Loon Lake in May. Subsequently, snowmelt inflow in June is often spilled. A modification to the hydropower routine to fill the reservoir by June rather than May could potentially improve the simulated historical match.

Jones Fork Tunnel and Powerhouse
Simulated flows through the Jones Fork Tunnel and Powerhouse are dictated by Ice House Reservoir operations, including flood control, FERC minimum pool elevations, downstream flow requirements on the South Fork Silver Creek and an end-of-September carryover storage target (23,045 AF). The Jones Fork Powerhouse has a simulated capacity of 291 cfs but with no capacity when the reservoir elevation is below 5330.5 ft, equivalent to 87,400 AF of storage. It is assumed that the powerhouse is closed for maintenance for 10 days in October of each year.

Both simulated and historical flow data for the powerhouse appear erratic with no easily discernable pattern. Tunnel flows average 34 TAF/year (WY 1996-2015) compared to an historical average flow of 44 TAF/year. New FERC license requirements for the South Fork Silver Creek below Ice House Dam adopted in 2014 and incorporated into the model are one reason for the discrepancies. These requirements include minimum flows for fisheries, pulse flows, and recreational flows.

Jaybird Powerhouse

Simulated flow through the Jaybird Powerhouse is opportunistic. There is no associated code or logic and powerhouse flows result from upstream storage releases from Union Valley Reservoir for other purposes and river accretions between upstream dams and the Junction Diversion Dam. A small persuasion penalty directs river flows at the diversion dam in excess of the downstream flow requirement through the powerhouse up to its physical capacity of 1,232 cfs. Both simulated and historical flow data for the powerhouse appear erratic with no easily discernable pattern. Annual simulated flows average 365 TAF/year compared to a historical value of 398 TAF/year. New FERC license requirements adopted in 2014 and incorporated into the model are one reason for the discrepancy. Simulated inflows to Junction Diversion Dam are only 9 TAF/year greater than historical.

Brush Creek Tunnel

Brush Creek Reservoir, which has a capacity of 1,350 AF, is not simulated in the upper American River model. In model simulation, water is directly diverted from Brush Creek in to the 710 cfs-capacity Brush Creek Tunnel that leads to SMUD's Camino Powerhouse. Minimum flows below the diversion dam vary from a maximum of 6 cfs (or the natural flow) in Critically Dry years to a maximum of 10 cfs (or the natural flow) in wet years but never less than 1 cfs. The model uses a small persuasion weight on diversions to Camino Powerhouse from Brush Creek and Silver Creek to route through the powerhouse. The model preferentially diverts Brush Creek water for the Camino Powerhouse compared to storage releases from UARP reservoirs. In model simulation, flows below the diversion dam never exceed the minimum flow requirement.

Simulated flows through the Brush Creek Tunnel are in direct response to the inflow hydrology. They average 7 TAF/year (WY 1996-2015). No historical data are available for a comparison.

Camino Powerhouse

Simulated flow through the Camino Powerhouse is opportunistic. There is no associated code or logic and powerhouse flows result from upstream storage releases from Union Valley Reservoir for other purposes and river accretions between upstream dams and the Camino Diversion Dam. A small persuasion penalty directs river flows at the diversion dam in excess of the downstream flow requirement through the powerhouse up to the physical capacity of the upper Camino Tunnel of 1,458 cfs. Flows through the powerhouse are supplemented by inflows from Brush Creek Both simulated and historical flow data for the powerhouse appear erratic with no easily discernable pattern. Annual simulated flows average 409 TAF/year compared to a historical value of 435 TAF/year. New FERC license requirements adopted in 2014 and incorporated into the model are one reason for the discrepancy.

White Rock Tunnel and Powerhouse

The upper American River model uses power generation objectives at the White Rock Powerhouse to drawdown the upstream reservoirs to rule curve. The simulated capacity of the powerhouse is 4,000 cfs. Simulated and historical flows through the White Rock Powerhouse match well. Annual simulated flows average 763 TAF/year compared to a historical value of 782 TAF/year. New FERC license requirements adopted in 2014 and incorporated into the model are one reason for the discrepancy. Simulated and historical average annual flows for the South Fork American River near Placerville are within 1 TAF.

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Echo Lake Conduit

The model assumes that the conduit valve is opened on Labor Day and closed when the water surface elevation drops below the conduit invert or November 16th, whichever occurs first. The largest flow through the conduit occurs in September, with minor flows in October and November. The accuracy of the simulation is limited by approximating a head-dependent discharge using a monthly timestep. The conduit has a capacity of 30 cfs, but the discharge capacity starts to fall for lake elevations below 7,410 feet, equivalent to AF. The simulated monthly discharge as a function of beginning-of-month storage was calibrated to observed data. With the exception of WY 2005, for which no conduit flows occurred, simulated and historical conduit flows match reasonably well and are approximately 1 TAF/year.

El Dorado Canal

EID diverts water from the South Fork American River near Kyburz in to the El Dorado Canal. The simulated capacity is 156 cfs. Simulated diversions are driven by consumptive demands at the El Dorado Forebay and the capacity of the El Dorado Powerhouse. The model assumes a 10-week shutdown for maintenance from October 1 to December 15. The period of comparison between simulated and historical flows is WY 2004-2015. Before 2004, historical canal flows were severely limited by lack of maintenance and repair needs.

Average annual simulated flows are 10 TAF/year higher than historical (70 TAF/year compared to 60 TAF/year). Simulated and historical diversions at the El Dorado Forebay match well, both average 9 TAF/year. Average annual simulated flows through the powerhouse are 15 TAF/year higher than historical, and average monthly simulated flows in the winter and spring are significantly higher than historical.

Discrepancies between simulated and historical canal flows may partly be caused by no simulation of canal seepage and no simulated inflow from minor streams, other than Alder Creek.[43] The actual volume of flow being diverted from the South Fork of the American River at the El Dorado diversion dam is dependent on the volume of flow entering the canal from the seven diverted tributaries. Flows up to 15 cfs are diverted from Alder Creek and flows up to 10 cfs are diverted from the remaining six creeks (FERC, 2003).

El Dorado Powerhouse

All flows in the El Dorado Canal not diverted for consumptive use at the El Dorado Forebay are routed to the El Dorado Powerhouse, which discharges water back to the SF American River. The simulated canal capacity is 156 cfs but the canal is assumed to be closed for maintenance October 1st – December 15th. This results in potential maximum diversion of 89,420 AF. Diversion from Alder Creek into the canal is limited to a maximum of 15 cfs or the natural flow less the instream flow

[43] The model assumes that on average canal seepage and local inflows are approximately in balance over the long-term.

requirement of 5-95 cfs. Consumptive water demands at the El Dorado Forebay are assumed to equal 9,000 AF/year distributed on a fixed monthly pattern.

Initially, the capacity of the El Dorado Powerhouse was set at 163 cfs. This was later reduced to135 cfs to better match model simulations conducted by EID.

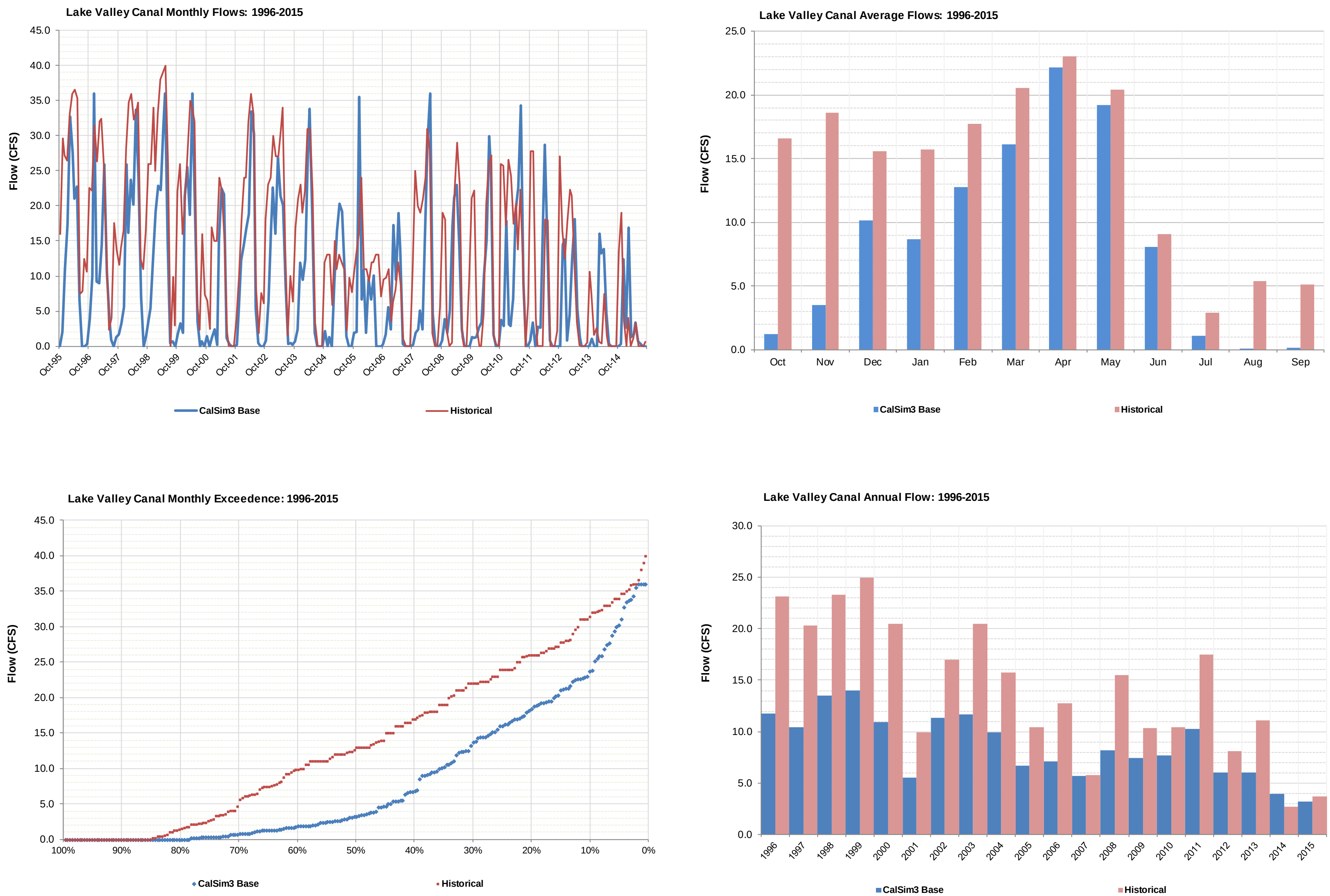


Figure 9-50. Lake Valley Canal (C_LVC001).

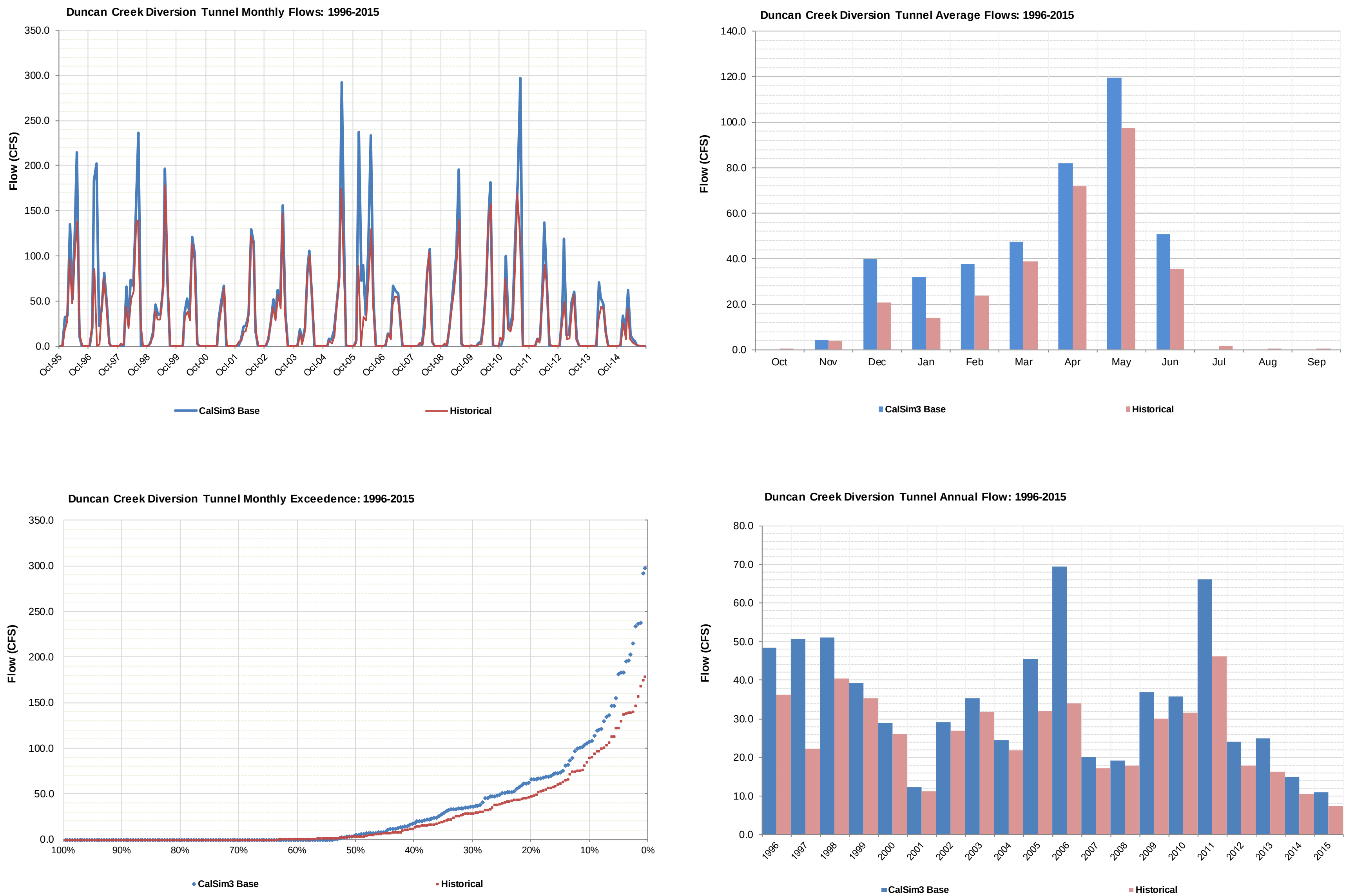


Figure 9-51. Duncan Creek Tunnel (D_DCC009_FRMDW).

Figure 9-52. French Meadows Tunnel (D_FRMDW_FMT002).

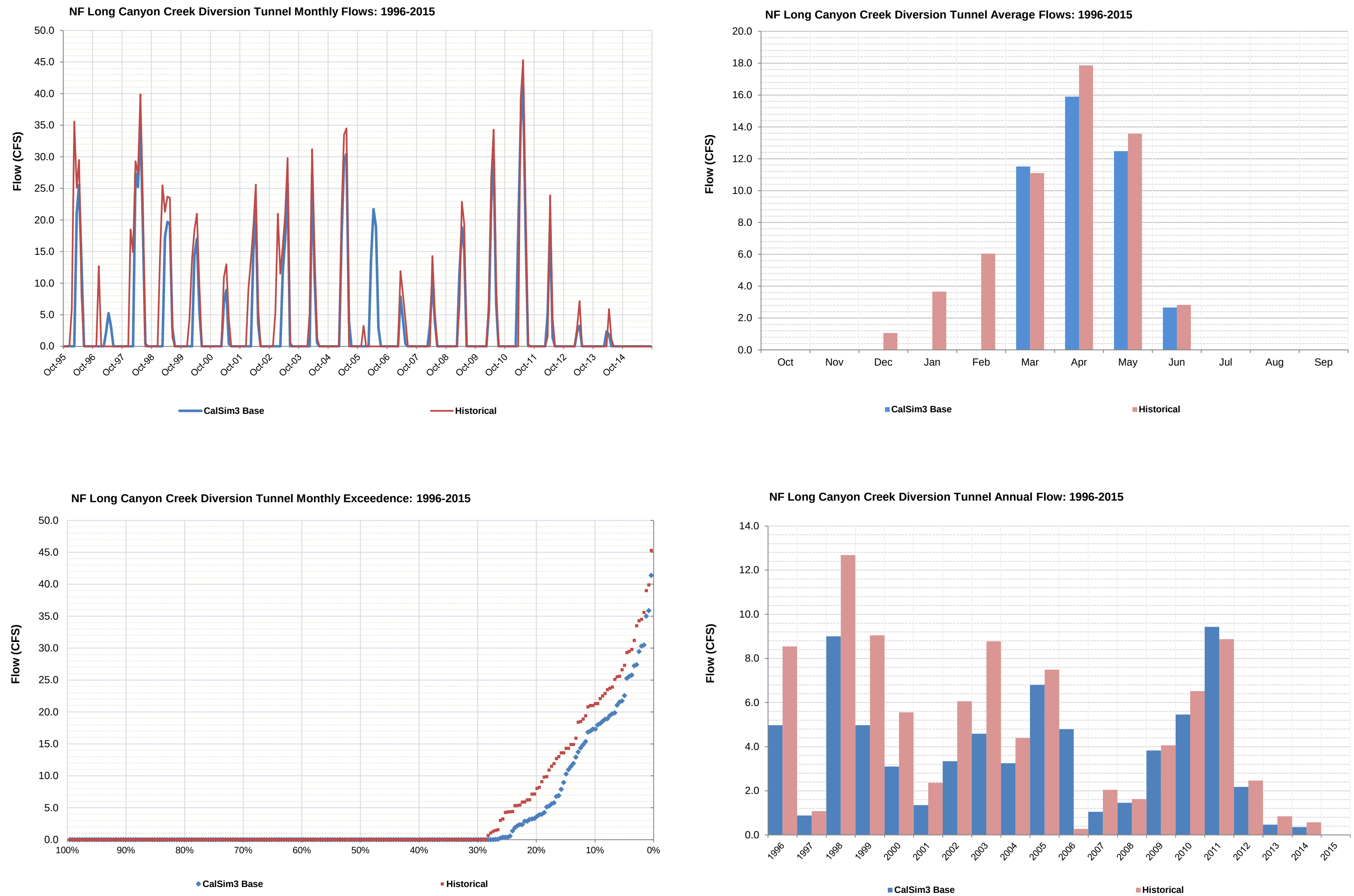


Figure 9-53. North Fork Long Canyon Creek Diversion (D_NLC003_NCT001).

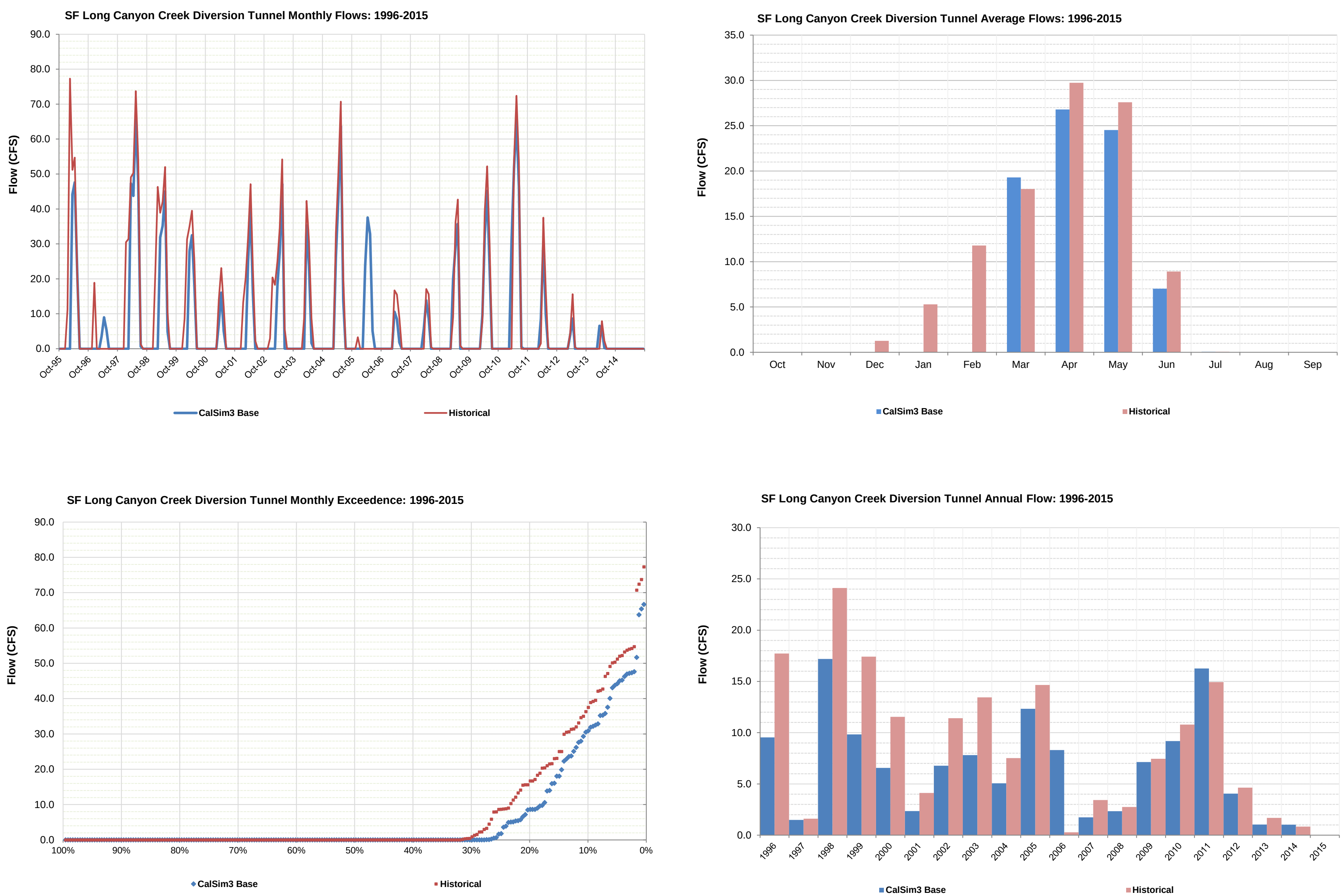
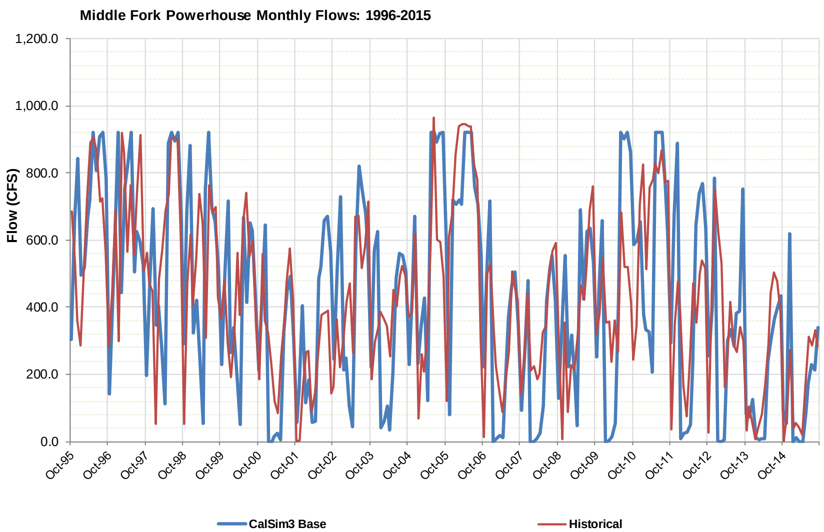
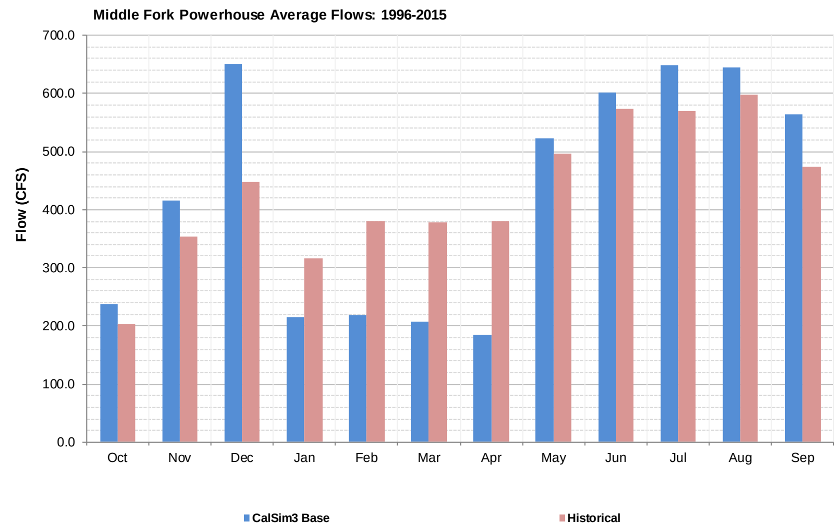
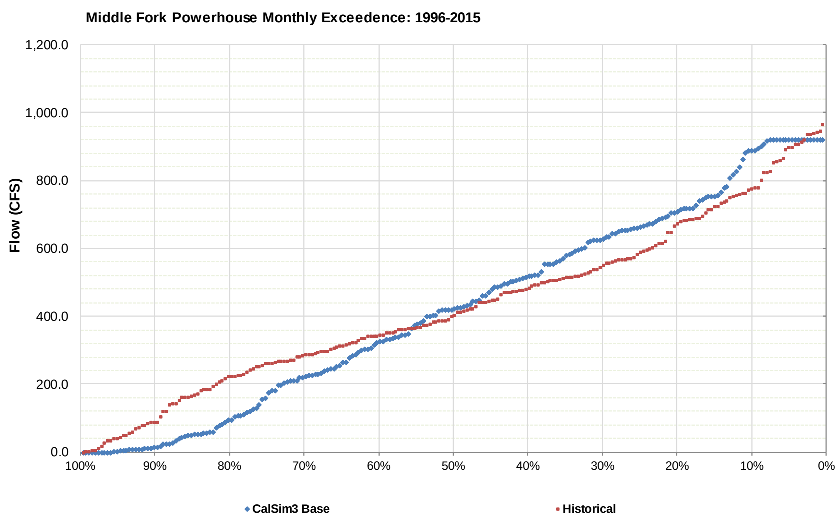


Figure 9-54. South Fork Long Canyon Creek Diversion (D_SLC003_SCT001).







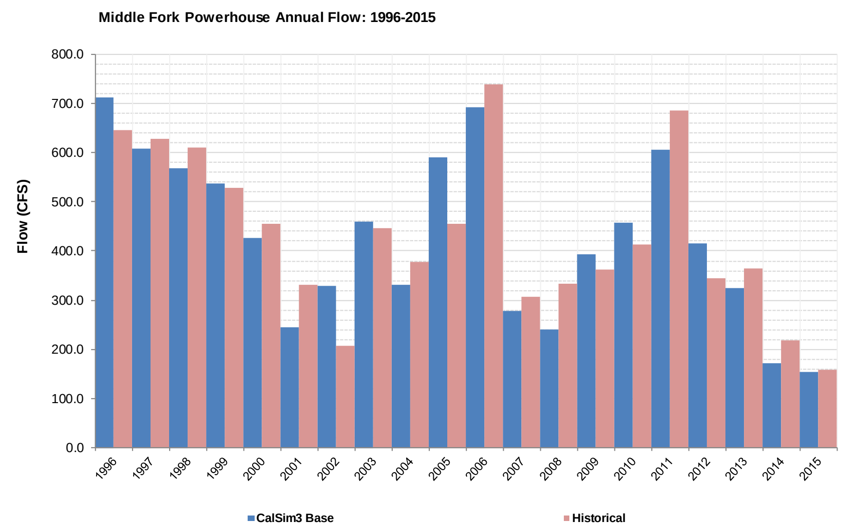
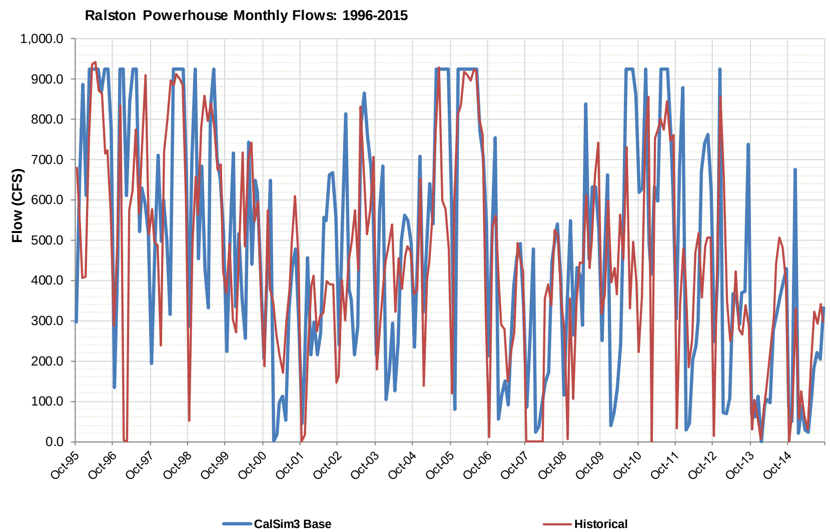
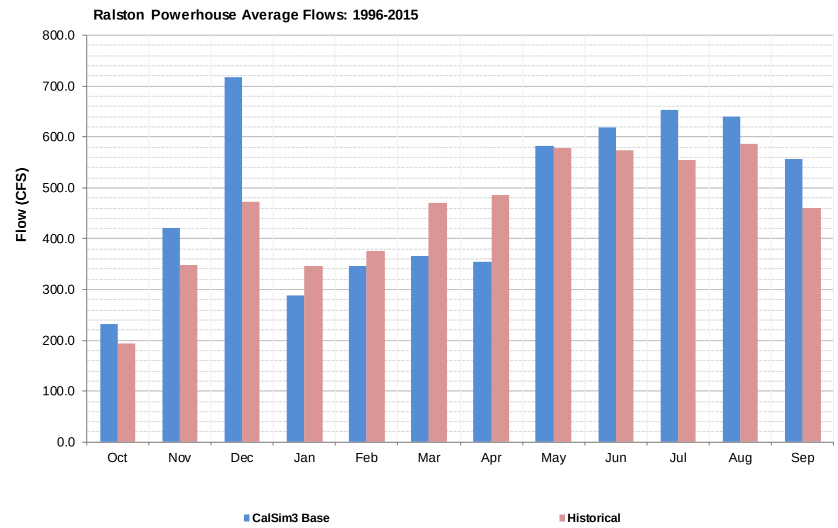
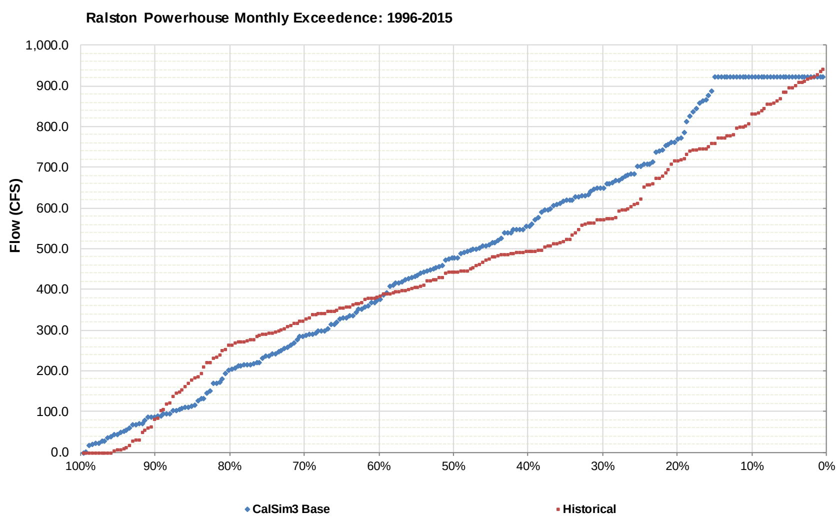


Figure 9-55. Hell-Hole Tunnel and Middle Fork Powerhouse (C_MFT011).







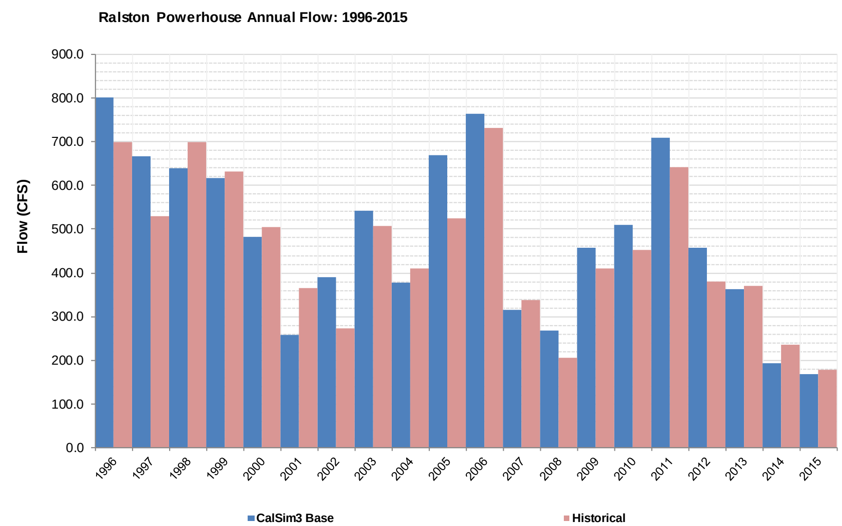


Figure 9-56. Ralston Tunnel and Powerhouse (D_MFA036_RTL007).

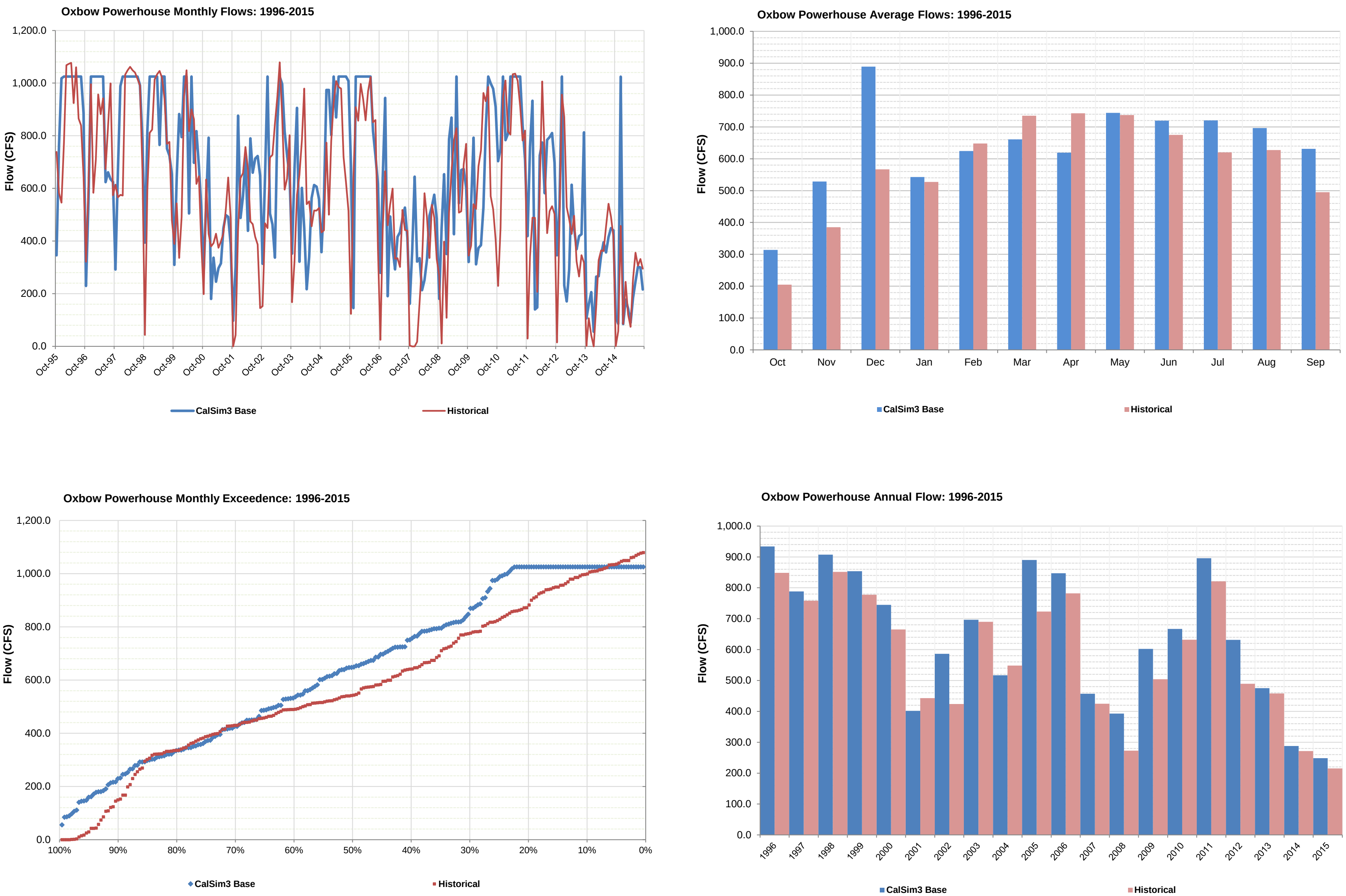
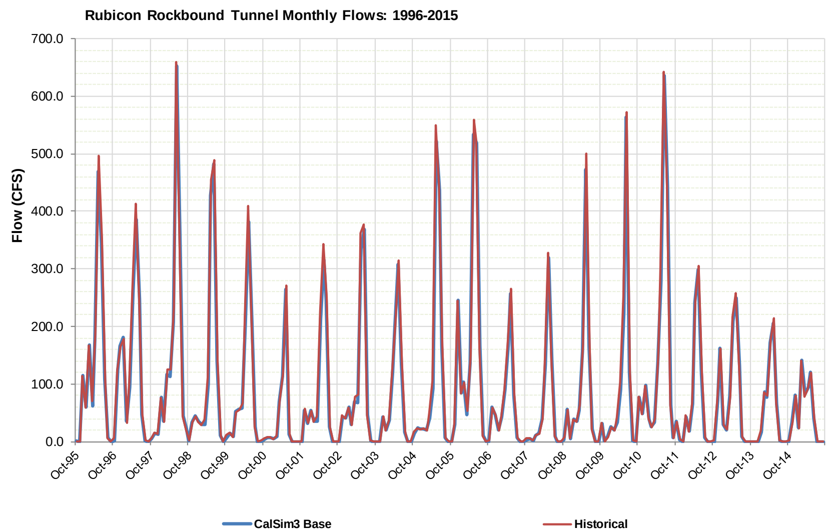
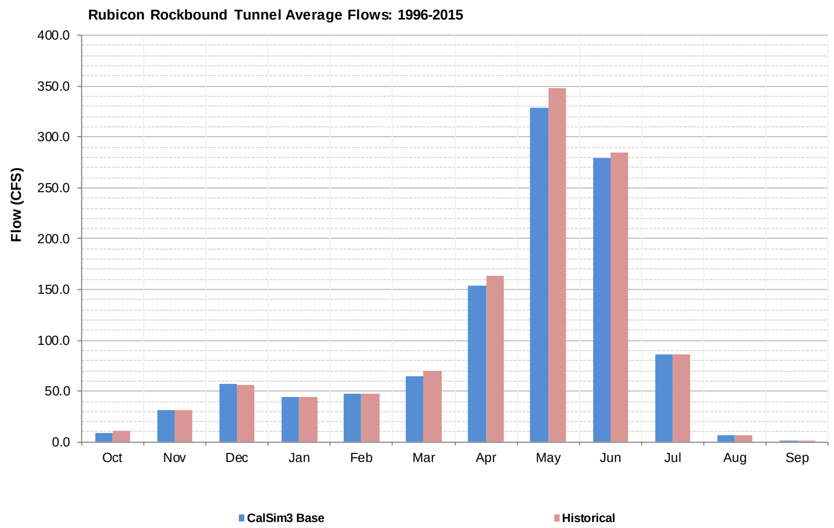
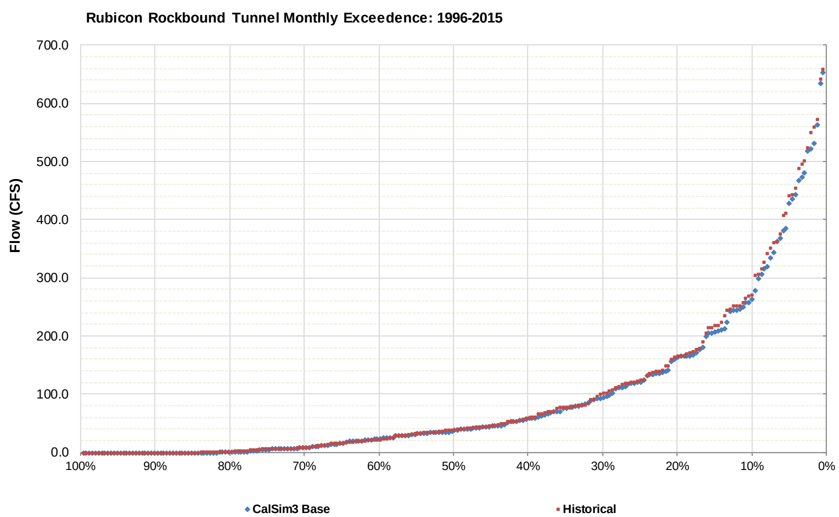


Figure 9-57. Oxbow Powerhouse (D_MFA026_OXB000).







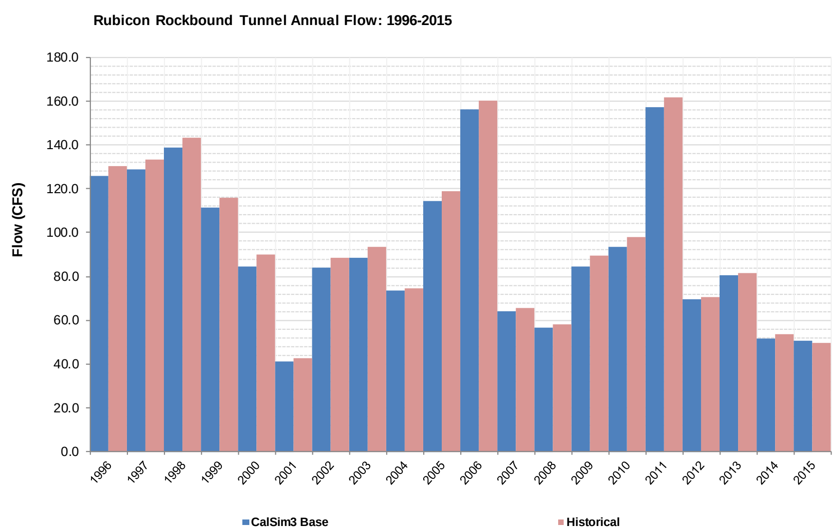


Figure 9-58. Rubicon-Rockbound Tunnel (D_RUB047_RRT000).

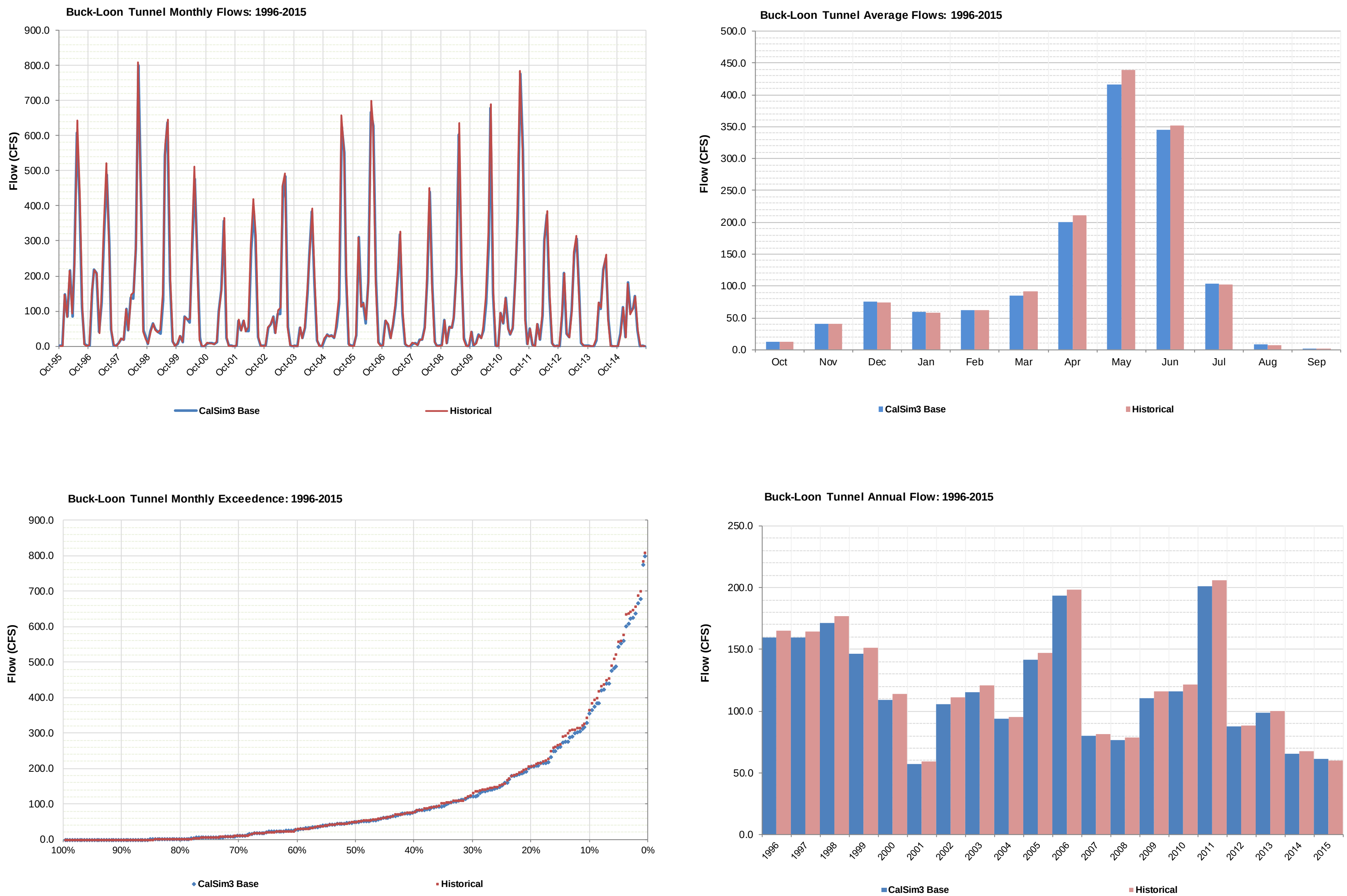
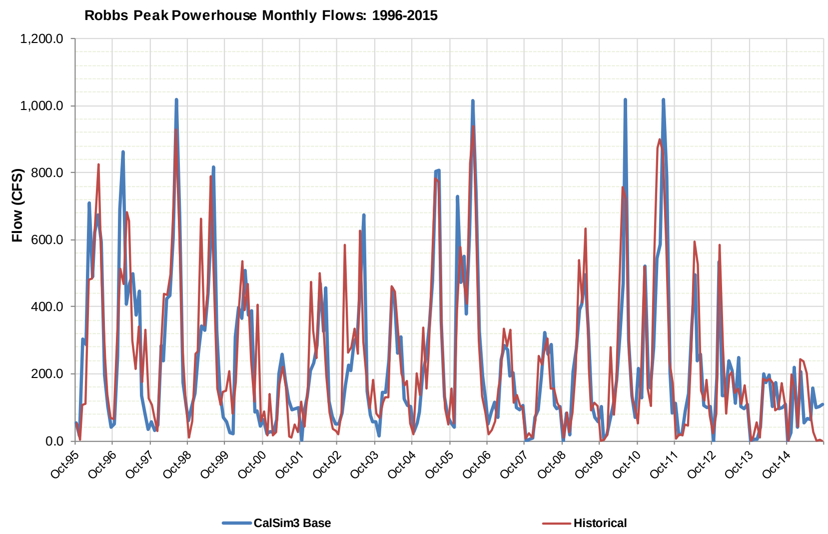
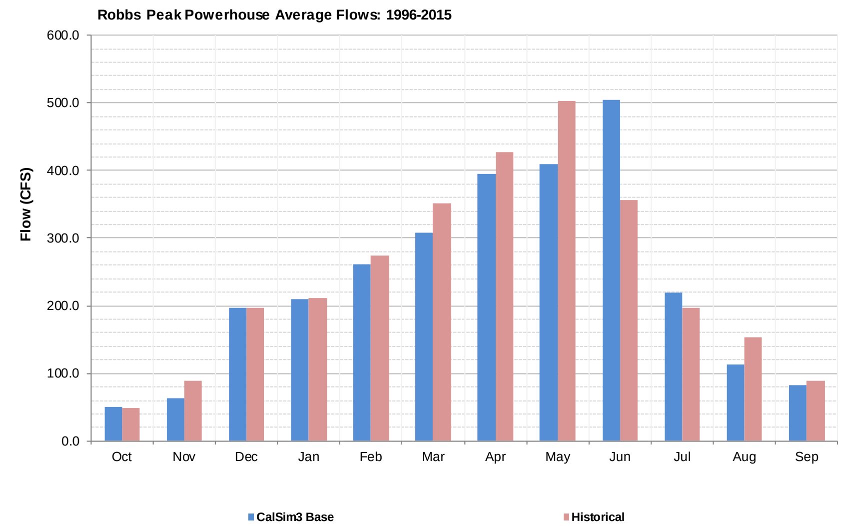
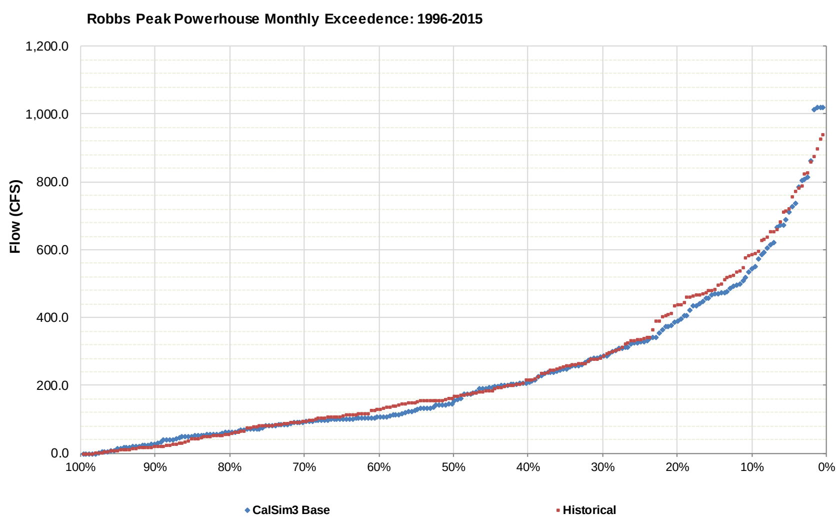


Figure 9-59. Buck-Loon Tunnel (D_LRB004_BLT000).







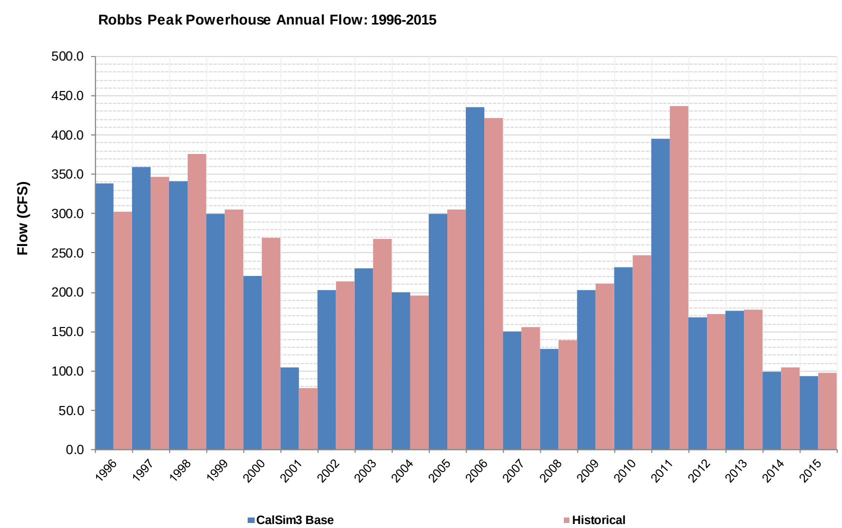


Figure 9-60. Robbs Peak Tunnel and Powerhouse (D_SFR006_RPT004).

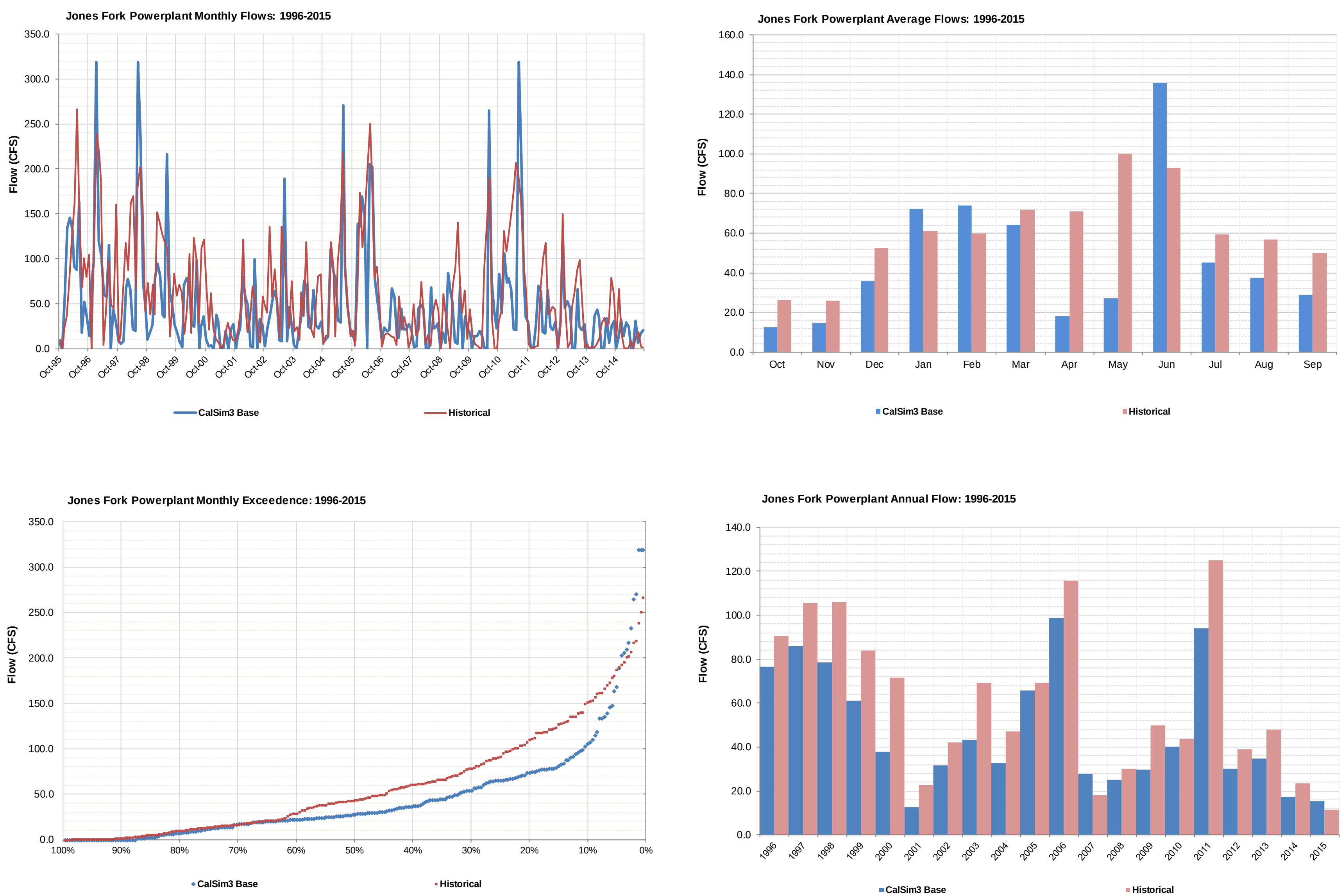
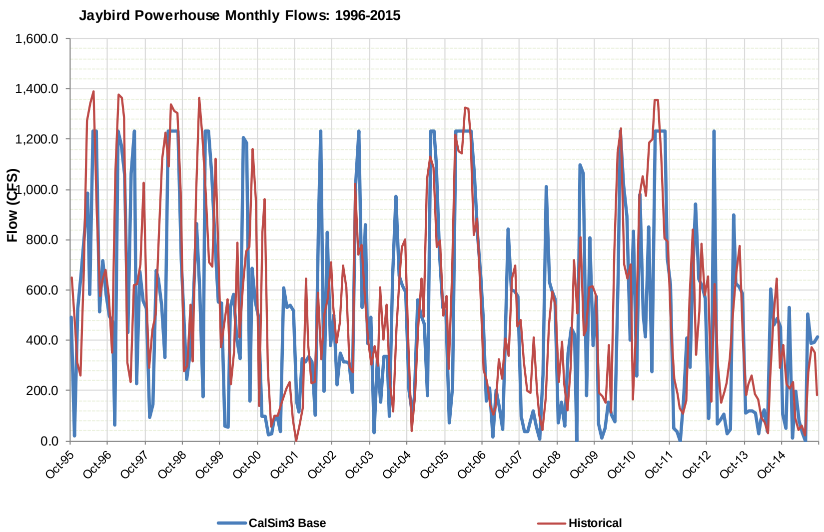
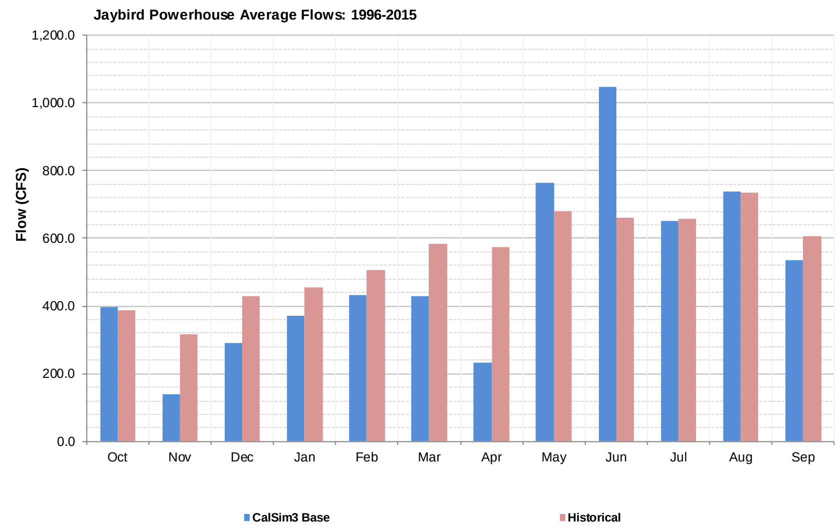
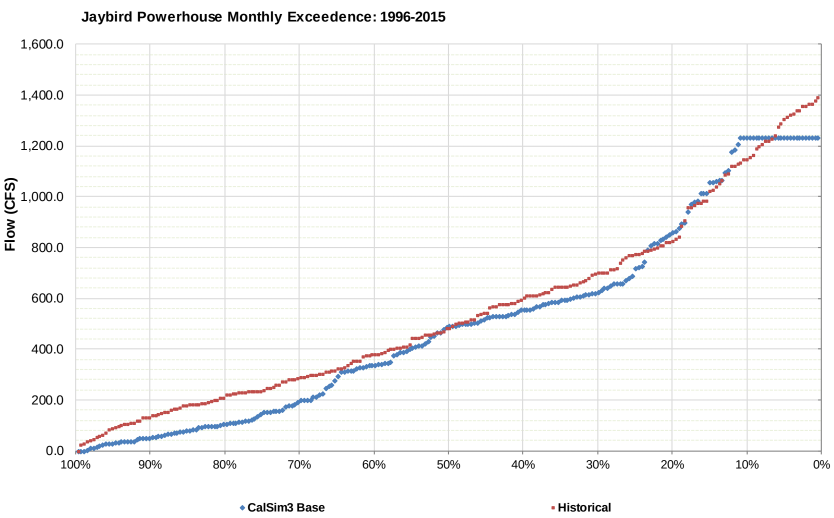


Figure 9-61. Jones Fork Tunnel and Powerhouse (D_ICEHS_IHT002).







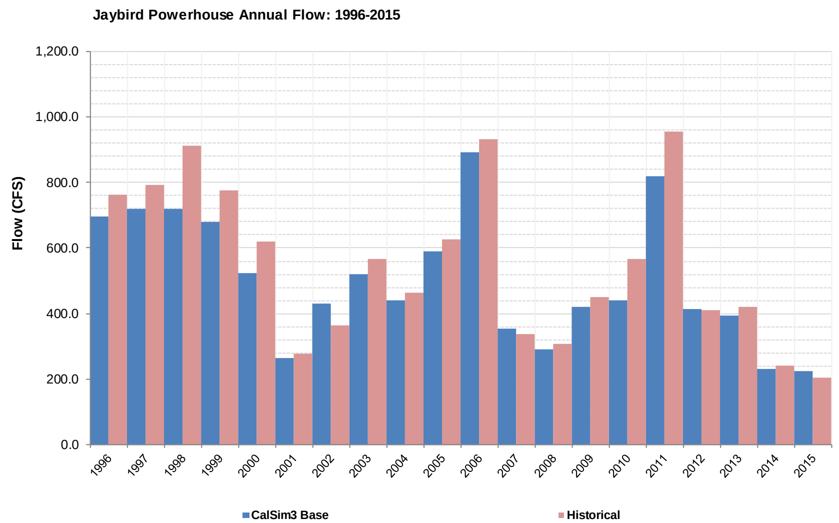


Figure 9-62. Jaybird Powerhouse (D_SLV015_JBT004).

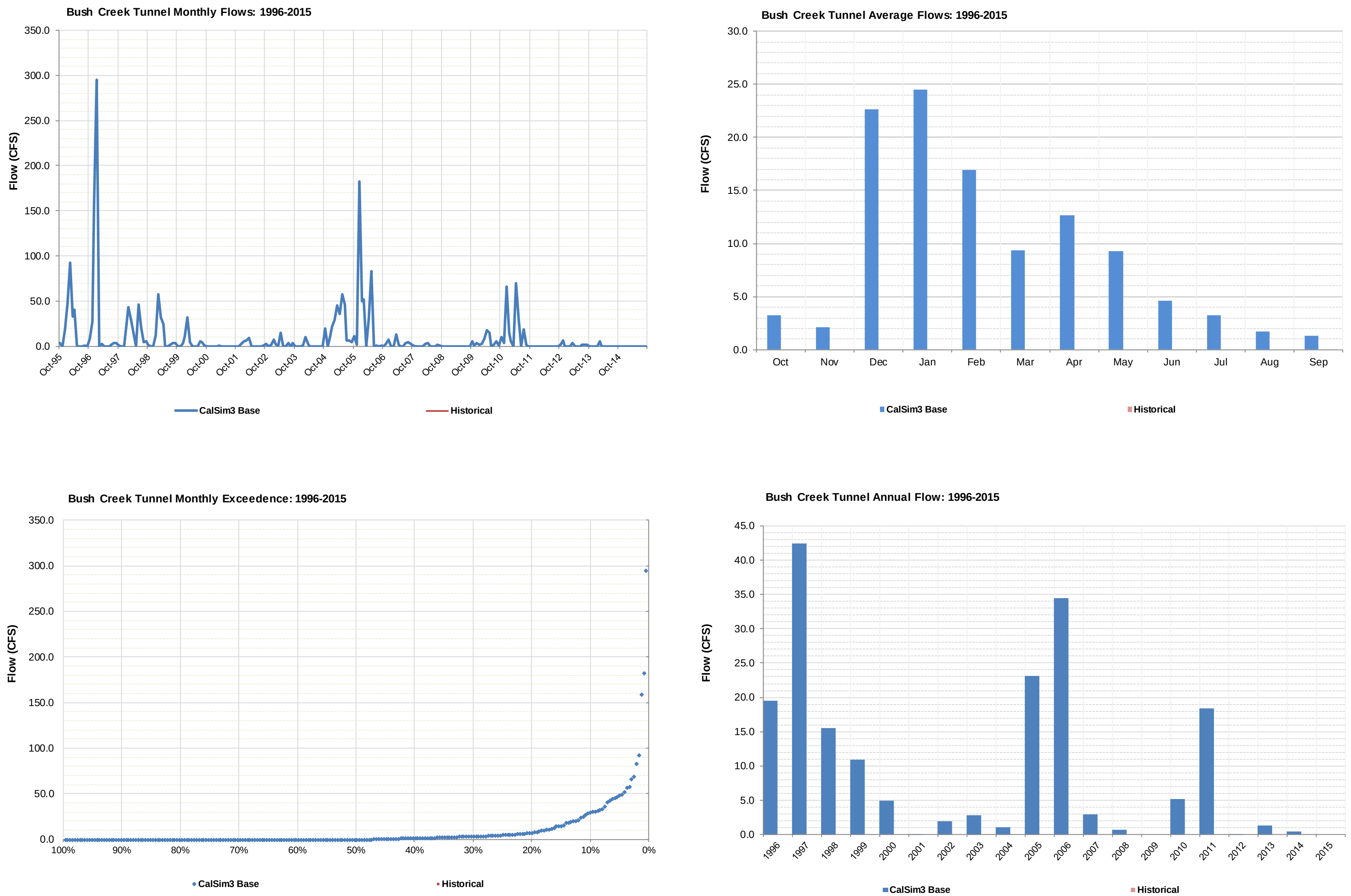
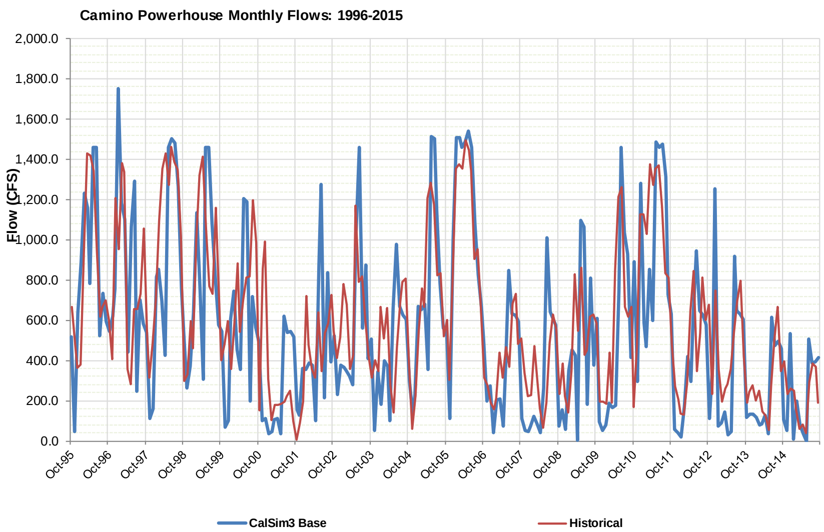
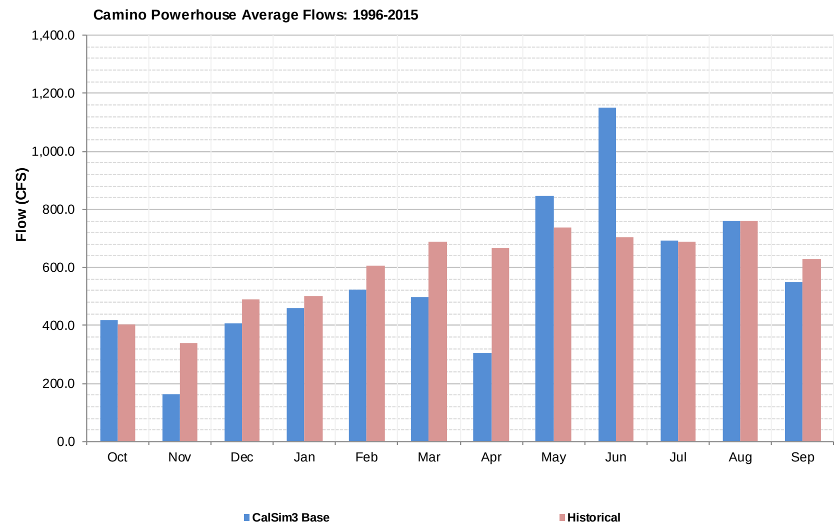
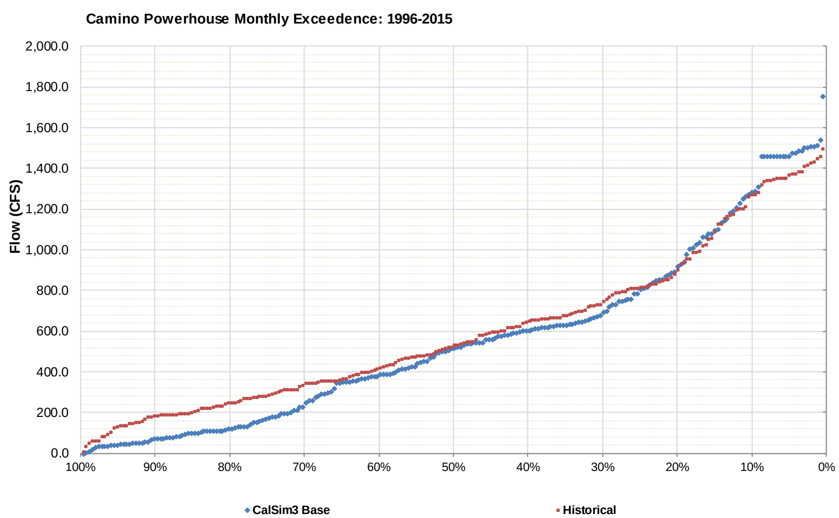


Figure 9-63. Brush Creek Tunnel (D_BSH003_CMN005).







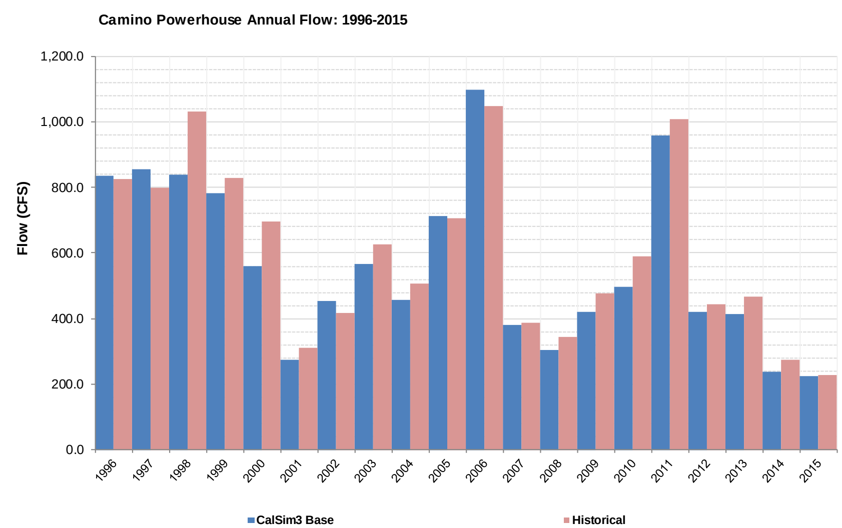


Figure 9-64. Camino Powerhouse (C_CMN006).

Figure 9-65. White Rock Tunnel and Powerhouse (D_SFA040_WRT000).

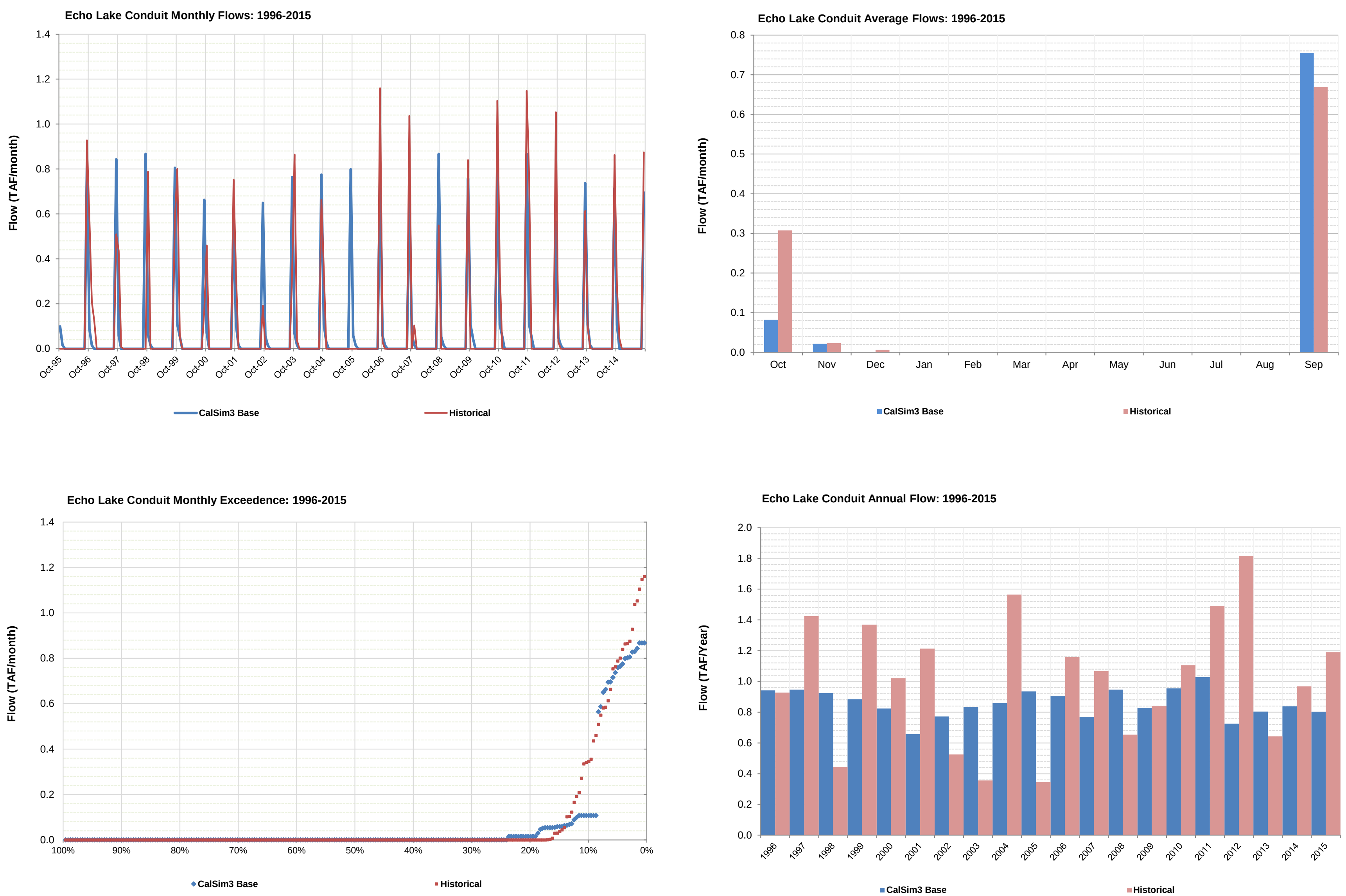


Figure 9-66. Echo Lake Conduit (D_ECHOL_ELC001).

Figure 9-67. El Dorado Canal (D_SFA066_EDC000).

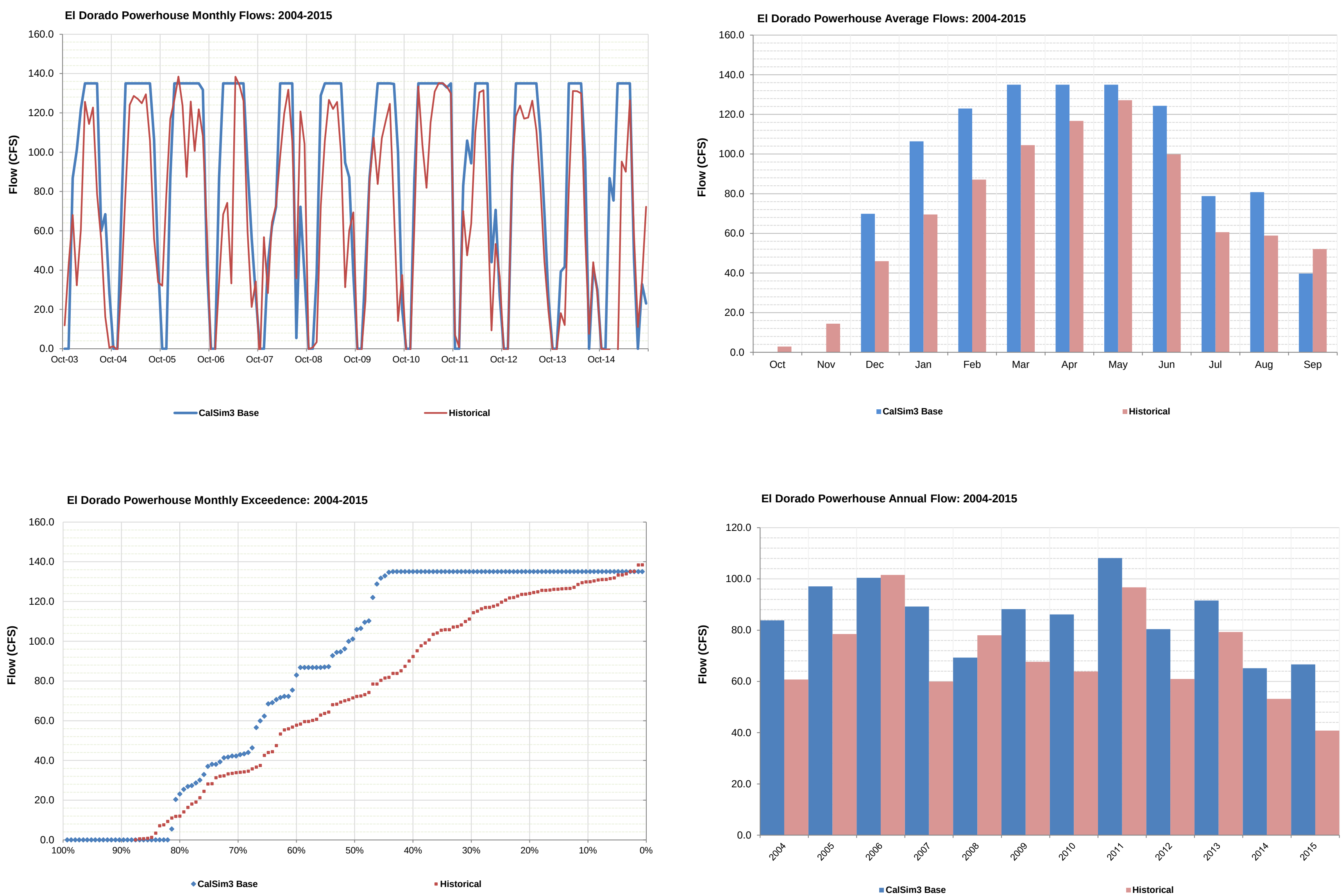


Figure 9-68. El Dorado Powerhouse (D_EDC021_EDP003).

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