Chapter 3 Schematic

This chapter provides an overview of the SacWAM schematic and describes its construction using WEAP's water resources objects. The resulting schematic provides a physically-based, high-resolution representation of water supplies in the mountain and foothill watersheds, and water demands and water use on the valley floor and Delta.

3.1 Overview

The development of all WEAP applications follows a standard approach. The first step in this approach is the Study Definition, wherein the spatial extent and system components of the area of interest are defined and the time horizon of the analysis is set. The user subsequently defines System Components (e.g., rivers, agricultural and urban demands) and the network configuration connecting these components. Following the study definition, the "Current Accounts" are defined, which represents the system under existing conditions – including operating rules to manage both water supplies and water demands. The Current Accounts serve as the point of departure for developing scenarios, which characterize alternative sets of assumptions pertaining to policies, regulatory requirements, and water infrastructure. The properties of the schematic elements, as defined in the Current Accounts, are discussed in detail in Chapter 4, Chapter 5, and Chapter 6

3.1.1 Study Definition

The SacWAM domain, described in Section 1.1 and presented in Figure 1-1, includes the Sacramento River Hydrologic Region and northern part of the San Joaquin River Hydrologic Region. Within this domain, SacWAM considers two types of watersheds. The first type, known as "upper" watersheds, includes the foothill and mountain watersheds of the Trinity/Cascade, Sierra Nevada, and Coast Range. These watersheds are characterized by complex topography, steep slopes, shallow soils, and limited aquifer systems. Upper watersheds are relatively undeveloped and are primarily a mix of forest, pasture, and small scattered communities. The second type of watershed, known as "valley floor" watersheds, covers the floor of the Central Valley. These watersheds are located between the upper watersheds and the Delta. In contrast to the upper watersheds, the valley floor watersheds have been extensively developed over time, are highly managed, and are composed of rich agricultural lands, refuges, and major towns and cities. Valley watersheds overlay the deep alluvial Sacramento Groundwater Basin and parts of the San Joaquin Groundwater Basin.

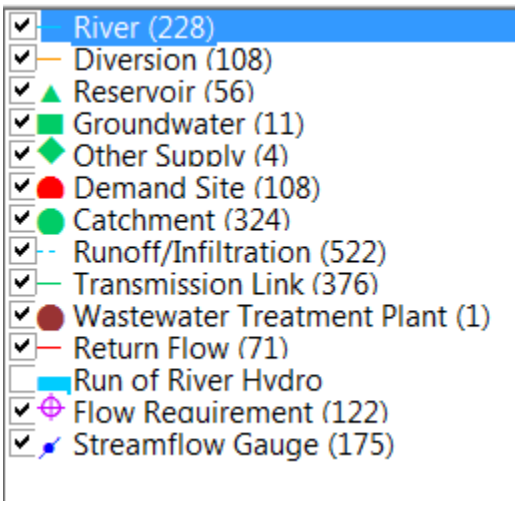
No single source of data has been used to construct the divide between upper and valley floor watersheds. Elevation is an imprecise indicator because of valley grades and the presence of terraces and side valleys. In general, the borders of the valley floor are defined where alluvial soils merge with bedrock features. SacWAM defines the boundary of the valley watersheds according to stream gauge locations and foothill dams, where historical streamflows are known. This flow-based boundary is typically located slightly upslope from the Sacramento and San Joaquin groundwater basin boundaries.

Shapefiles used in the construction of the model are stored within the model, and can be displayed in the model's schematic view to orient the user. File location information for these shapefiles and other files mentioned in this section is presented in Table 3-13. The GIS shape files provide visual cues in

understanding and interpreting the SacWAM schematic. An example of these shape files is presented in Figure 3-1.

3.1.2 System Components

The SacWAM schematic is built using WEAP's system components that define the water supply system and the water demands. The WEAP palette of components is shown below. The following sections describe each component as it is used in SacWAM.



3.1 Rivers and Diversions

Schematic construction began with defining river, canals, and other waterways. Shapefiles were used to identify and trace hydrologic features that were added to the schematic. Shapefiles of **river miles** (RMs) and **canal miles** (CMs), developed using aerial imagery, were subsequently used to identify points of diversion, as well as other water control infrastructure.

3.1.1 River Arcs

River arcs represent rivers, streams, and other natural channels. They are represented by blue arcs in the SacWAM schematic and are listed in Table 3-1. SacWAM represents the Trinity River upstream from Lewiston, the entire Sacramento River, Feather River, and American River, and the San Joaquin River downstream from Vernalis. Additionally, the model represents streams identified by the State Water Board that will form part of Phase IV of the Bay-Delta Plan update.

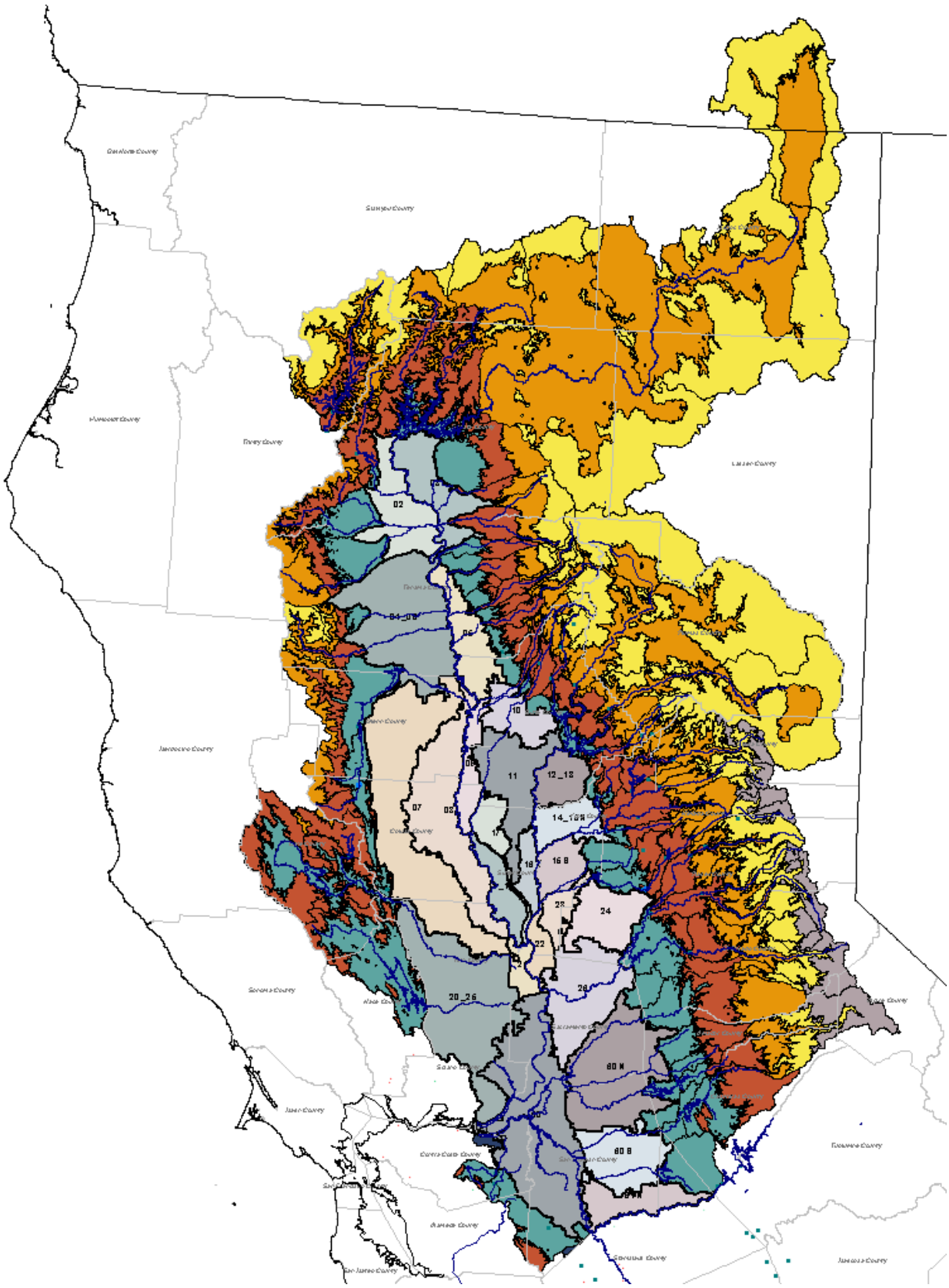


Figure 3-1. SacWAM GIS Layers

Table 3-1. Natural Waterways Represented in SacWAM

Name	Name
Antelope Creek	McCloud River
Auburn Ravine	McClure Creek
Battle Creek	Middle Fork American River
Bear River	Middle Fork Cosumnes River
Big Chico Creek	Middle Fork Feather River
Butte Creek	Middle Fork Mokelumne
Butte Slough	Middle Yuba River
Cache Creek	Mill Creek
Cache Slough	Mokelumne River
Calaveras River	North Fork American River
Camp Creek	North Fork Calaveras River
Canyon Creek	North Fork Cosumnes River
Caples Creek	North Fork Feather River
Clear Creek	North Fork Mokelumne
Cosumnes River	North Yuba River
Cottonwood Creek	Old and Middle River
Cow Creek	Oregon Creek
Deer Creek (Sacramento River tributary)	Paynes Creek
Deer Creek (Yuba River tributary)	Pit River
Dry and Hutchinson Creek	Putah Creek
Dry Creek	Rock Slough
Dry Creek (Mokelumne River tributary)	Rubicon River
Dry Creek (Yuba River tributary)	Sacramento River below Shasta
Duncan Creek	San Joaquin River below Vernalis
Echo Creek	Secret Ravine
Elder Creek	Silver Creek
Fall River	Slate Creek
Feather River below Oroville	Sly Creek
Fordyce Creek	Sly Park Creek
Georgiana Slough	South Fork American River
Gerle Creek	South Fork Calaveras River
Honcut Creek	South Fork Cosumnes River
Indian Slough	South Fork Cottonwood Creek
Jackson Creek	South Fork Feather River
Kellogg Creek	South Fork Mokelumne
Little Dry Creek	South Fork Silver Creek
Little Stony Creek	South Yuba River
Littlejohns Creek	Stony Creek
Lost Creek	Thomes Creek
Lower American River below Folsom Dam	Trinity River above Lewiston
Lower Yuba River below Englebright Dam	West Branch Feather River
Marsh Creek	Wolf Creek

WEAP places restrictions on river arcs that in certain instances prevents the arcs from being used to represent natural channels. First, flow in a river arc must be unidirectional, from upstream to downstream. Second, river arcs may flow into other river arcs as tributaries, but may not divide into two or more river arcs as distributaries. Therefore, the following diversion arcs are used to represent natural flows in SacWAM.

- **Head of Old River** diversion arc: Represents flow from the San Joaquin River to Old River.

- **Indian Slough** diversion arc: A Delta channel that links the San Joaquin River and Old River. It is important in representing regulatory flow requirements for the Old and Middle rivers. Flows through the slough bypass the Old River flow compliance location, thus south Delta water diversions have a less than 1-to-1 effect on gauged Old and Middle River reverse flows.

- **Georgiana Slough** diversion arc: A Delta channel linking the Sacramento and Mokelumne rivers. The Delta Cross Channel is also represented by a diversion arc, but is regarded as a man-made channel.

- **Qwest** diversion arc: Defined as the net westward flow of the San Joaquin River at Jersey Point averaged over a tidal cycle. In SacWAM, it represents reverse flows, which may occur when Delta diversions and agricultural demands in the south and central Delta exceed the inflow into the central Delta. It is further decribed in Section 8.7.2

- **OMR Reverse Flow** diversion arc: Represents flows from north to south in the Old and Middle rivers. Reverse flows may occur when CVP/SWP export pumping exceed flows at the Head of the Old River.

The Old and Middle rivers (OMR) between the intake to Jones Pumping Plant and the confluence with the San Joaquin River are represented by two parallel river arcs. Flow is north to south in one arc (reverse flow) and south to north in the other arc (positive flow).

Similarly, the San Joaquin River downstream from the mouth of the Mokelumne River are represented by two parallel river arcs. Flow is west to east in one arc (reverse flow) and east to west in the other arc (positive flow).

3.1.2 Diversion Arcs

Diversion arcs typically represent man-made conveyance facilities, including canals, pipelines, and hydropower penstocks. They are represented by orange arcs in the SacWAM schematic and are listed in Table 3-2.

Table 3-2. Man-Made Conveyance Facilities Represented in SacWAM

Facility	Facility	Facility
Auburn Tunnel	EBMUD Intertie	Old River and Victoria Canal Intake
BDCP Tunnels	El Dorado Canal	Palermo Canal
Bear River Canal	El Dorado Powerhouse	Pardee to Amador Link
Bella Vista Pipeline	Folsom South Canal	Power Canal
Bowman Spaulding Conduit	Freeport Intertie	Putah South Canal
Buck Loon Tunnel	Fremont Weir	Ragsdale Random
Butte Slough	French Meadows Hell Hole Tunnel	Richvale Canal
Butte Slough Outfall Gates	Glenn-Colusa Canal	Robbs Peak Tunnel
San Luis Canal	Hell Hole Tunnel	Rock Slough Intake
California Aqueduct	Joint Board Canal	Sacramento Weir
CA East and West Branches	Jones Fork Tunnel	Slate Creek Tunnel
Camino Conduit	Kelly Ridge Powerhouse	South Bay Aqueduct
Camp Creek Diversion Tunnel	Knights Landing Ridge Cut	South Canal
Camptonville Tunnel	Lohman Ridge Tunnel	South Fork Tunnel
Clear Creek Tunnel	Los Vaqueros Pipeline	South Yuba Canal
Colusa Basin Drain	Lower Boardman Canal	Spring Creek Conduit
Colusa Weir	M and T 3Bs Goose Lake	Sutter Bypass
Constant Head Orifice	Milton Bowman Tunnel	TCC to GCC Intertie
Contra Costa Canal	Miners Ranch Canal	Tehama-Colusa Canal
Cox Spill	Mokelumne Aqueduct	Tisdale Weir
Delta Cross Channel	Mokelumne Los Vaqueros Intertie	Toadtown Canal
Delta-Mendota Canal	Moulton Weir	Transfer to Contra Costa Canal
DMC-CA Intertie	Natomas Cross Canal	Western Canal
Drum Canal	Natomas East Main Drain	Wise Canal
Duncan Creek Tunnel	North Bay Aqueduct	Yolo Bypass

Additional to diversions listed in Table 3-2, the SacWAM schematic includes diversion arcs to represent other aspects of the Sacramento Valley and Delta water system. These diversion arcs include:

- **Canal Losses**: represent seepage from canals to groundwater or loss by evaporation. Canal loss arcs include those for Putah South Canal, South Yuba Canal, and Tehama-Colusa Canal.
- **Water Treatment Plant Intakes**: these diversion arcs are described in Section 3.9
- **Bias Corrections**: Outflows from the river system to correct for bias in the SacWAM hydrology. These include: Bend Bridge Outflow, Butte City Outflow, and Freeport Outflow
- **Delta Depletions**: SacWAM includes the option of using preprocessed timeseries data to represent net channel depletion within the Delta. As part of this option, the model includes seven accretion arcs (represented using river objects) and seven depletion arcs (represented using diversion objects).

The California Aqueduct, the Delta-Mendota Canal, and associated contractor water demands play a key role in SacWAM, determining the volume of exports from the south Delta. To simplify simulation of CVP and SWP joint-use facilities south of the Delta, the CVP and SWP conveyance infrastructure has

been separated. The capacity of the California Aqueduct–Delta-Mendota Canal Intertie is set to zero and the capacity of the Delta-Mendota Canal is modeled as 4,600 cfs along its entire reach.[3]

3.1.2.1 *California Aqueduct*

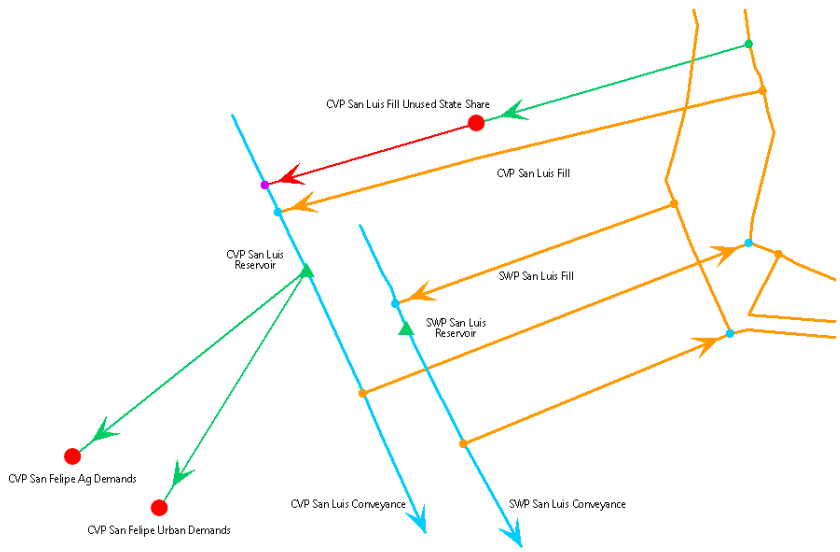
SacWAM represents the California Aqeduct, stretching from Clifton Court Forebay to the division in to the West and East Branches. The SWP share of the joint-reach (known as the San Luis Canal) is treated as an integral part of the aqueduct. The CVP share of the joint-reach is modeled as a separate canal diverting from the Delta-Mendota Canal downstream from O'Neill Pumping Plant and San Luis Reservoir.

3.1.2.1 *Delta-Mendota Canal*

SacWAM represents the 117-mile long Delta-Mendota Canal from the Jones Pumping Plant to the Mendota Pool. To represent diversions from the Mendota Pool, the SacWAM schematic includes the reach of the San Joaquin River from Mendota Dam to Sack Dam and inflows from the James Bypass and the San Joaquin River below the Chowchilla Bifurcation Structure.

3.1.2.2 *O'Neill and Gianelli Pumping Generating Plants*

The CVP and SWP share of San Luis Reservoir are represented as distinct reservoirs. WEAP contains no objects for offstream reservoirs; reservoir objects must be located on a river arc. Therefore, SacWAM uses two artificial river to locate the CVP and SWP shares of San Luis Reservoir.



[3] The purpose of the Intertie is to improve Delta-Mendota Canal conveyance limitations that restrict the Jones Pumping Plant to less than its design capacity of 4,600 cfs and to improve operational flexibility for operations, maintenance, and emergency activities. The Delta-Mendota Canal capacity upstream from the O'Neill Forebay and the pumping capacity at O'Neill Pumping Plant is about 4,200 cfs Therefore, before the Intertie was built, pumping at Jones Pumping Plant could only exceed 4,200 cfs if deliveries were made to contractors located upstream from the O'Neill Pumping Plant.

The O`Neill Pump-Generating Plant consists of an intake channel leading off the Delta-Mendota Canal and six pump-generating units. Normally these units operate to lift water into the O`Neill Forebay. From there CVP water flows through the joint-reach or is lifted into San Luis Reservoir by the Gianelli Pump-Generating Plant. Water released from the reservoir generates power as it passes back through the Gianelli Pump-Generating Plant. CVP water may subsequently flow back to the Delta-Mendota Canal through the O`Neill Pump-Generating Plant.

Simulation of the CVP and SWP shares of San Luis Reservoir requires multiple arcs linking the California Aqueduct and Delta-Mendota Canal to the two simulated reservoir. One set of arcs represents flow of CVP water from the O'Neill Pumping Plant and the Gianelli Pumping Plant to fill the reservoir and the release of CVP water back to the Joint-Reach or Delta-Mendota Canal. A similar pair of arcs represents the flow of SWP water through the Gianelli Pump-Generating Plant either to fill or drain the reservoir.

3.2 Reservoirs

SacWAM represents all major water supply reservoirs within the model domain having a storage capacity in excess of 50,000 acre-feet. SacWAM also represents reservoirs used for hydropower, in cases where there storage regulation significantly affects seasonal river flows downstream. Additionally, smaller reservoirs are included in the schematic to help orientate the model user or to define points of diversion, for example, Lewiston Reservoir on the Trinity River provides a forebay for diversions to the Sacramento Valley through the Clear Creek Tunnel. Table 3-3 lists the reservoirs contained in SacWAM, the owner/operator, and storage capacity.

Table 3-3. Reservoirs Represented in SacWAM

Reservoir	SacWAM River	Owner/Operator	Capacity (TAF)
Black Butte Reservoir	Stony Creek	Reclamation/CVP	144
Bowman Lake	Canyon Creek	Nevada Irrigation District	64
Bucks Lake	North Fork Feather River	PG&E	103
Butt Valley	North Fork Feather River	PG&E	50
Camanche Reservoir	Mokelumne River	EBMUD	417
Camino Reservoir	Silver Creek	Sacramento Municipal Utility District	<1
Camp Far West	Bear River	South Sutter WD	105
Caples Lake	Caples Creek	PG&E	22
Chili Bar Reservoir	South Fork American River	PG&E	4
Clear Lake	Cache Creek	Yolo County FC&WCD	1,155
Clifton Court Forebay	Old and Middle River	DWR/SWP	29
CVP San Luis Reservoir	Offstream	Reclamation/CVP	973
East Park Reservoir	Little Stony Creek	Reclamation/Orland WUA	51
EBMUD Terminal Reservoirs	Mokelumne Aqueduct	EBMUD	155
Englebright Reservoir	Yuba River	USACE	70
Farmington Reservoir	Littlejohns Creek	USACE	52
Folsom Lake	American River	Reclamation/CVP	977
French Meadows	Middle Fork American River	Placer County Water Agency	136
Frenchman Lake	Middle Fork Feather River	DWR/SWP	55
Hell Hole	Rubicon River	Sacramento Municipal Utility District	208
Ice House	South Fork Silver Creek	Sacramento Municipal Utility District	44
Indian Valley Reservoir	North Fork Cache Creek	Yolo County FC&WCD	300
Jackson Meadows Reservoir	Middle Fork Yuba River	Nevada Irrigation District	69
Jenkinson Lake	Sly Park Creek	El Dorado Irrigation District	41
Keswick Reservoir	Sacramento River	Reclamation/CVP	24
Lake Almanor	North Fork Feather River	PG&E	1,308
Lake Amador	Jackson Creek	Jackson Valley Irrigation District	22
Lake Berryessa	Putah Creek	Reclamation/Solano Project	1,602
Lake Combie	Bear River	Nevada Irrigation District	6
Lake Davis	Middle Fork Feather River	DWR/SWP	83
Lake Fordyce	Fordyce Creek	PG&E	48
Lake Natoma	American River	Reclamation/CVP	9
Lake Spaulding	South Fork Yuba River	PG&E	75
Lewiston Lake	Trinity River	Reclamation/CVP	15
Little Grass Valley Reservoir	South Fork Feather River	South Feather Water and Power Agency	93
Loon Lake	Gerle Creek	Sacramento Municipal Utility District	77
Los Vaqueros Reservoir	Kellogg Creek	Contra Costa Water District	160
Merle Collins Reservoir	French Dry Creek	Browns Valley Irrigation District	57
New Bullards Bar Reservoir	Yuba River	Yuba County Water Agency	970
New Hogan Reservoir	Calaveras River	Reclamation/Stockton East WD	317
Oroville Reservoir	Feather River	DWR/SWP	3,538
Pardee Reservoir	Mokelumne River	EBMUD	210
PG&E Upper Watershed Reservoirs	North Fork Mokelumne River	PG&E	194
Rollins Reservoir	Bear River	Nevada Irrigation District	66
Scotts Flat Reservoir	Deer Creek – Yuba River tributary	Nevada Irrigation District	49
Shasta Lake	Sacramento River	Reclamation/CVP	4,552
Silver Lake	Silver Fork American	PG&E	4
Slab Creek Reservoir	South Fork American River	Sacramento Municipal Utility District	17
Sly Creek Reservoir	Lost Creek	South Feather Water and Power Agency	65
Stony Gorge Reservoir	Stony Creek	Reclamation/Orland WUA	50
SWP San Luis Reservoir	Offstream	DWR/SWP	1,067
Thermalito Afterbay	Power Canal	DWR/SWP	57
Trinity Reservoir	Trinity River	Reclamation/CVP	2,448
Union Valley Reservoir	Silver Creek	Sacramento Municipal Utility District	266
Whiskeytown Reservoir	Clear Creek	Reclamation/CVP	241

Key: CVP=Central Valley Project; DWR=Department of Water Resources; SWP = State Water Project; TAF=thousand acre-feet

3.3 Groundwater

Ten groundwater basins are simulated in SacWAM using the WEAP groundwater objects. The horizontal extents of the basins are shown in Figure 3-2. The basins are aggregated from Bulletin 118 Groundwater Basins (DWR, 2014a) as shown in Table 3-4. The **Bulletin 118 GW basins** shapefile was used to create the SacWAM **groundwater basins** shapefile.

Inflows and outflows to and from the groundwater basins include: (1) deep percolation from demand unit catchment objects, (2) return flows from urban demand sites, (3) seepage losses on surface water distribution systems, (4) interaction with the stream network through the *Groundwater Inflow* and *Groundwater Outflow* parameters on stream reaches, and (5) groundwater pumping to meet catchments and demand site water demands.

In the SacWAM schematic, vertical recharge from catchment objects to the groundwater basins are shown by dashed blue runoff/infiltration arcs, return flows from demand sites are indicated by red arcs, and groundwater pumping is represented by green transmission links. Other groundwater flow components, though simulated, are not represented in the schematic.

Table 3-4. Relationship between SacWAM Groundwater Objects and Bulletin 118 Basins

SacWAM Groundwater Basin	Bulletin 118 Basins
Redding	South Battle Creek, Bowman, Rosewood, Anderson, Enterprise, Millville
Red Bluff Corning	Bend, Antelope, Dye Creek, Corning, Red Bluff, Vina, Los Molinos
Colusa	Colusa
Butte	East Butte, West Butte
Sutter Yuba	North Yuba, South Yuba, Sutter
Yolo Solano[1]	Yolo, Solano
American[1]	North American, South American
Cosumnes	Cosumnes
Eastern San Joaquin[1]	Eastern San Joaquin
Delta[1]	Not represented
Suisun[2]	Suisun-Fairfield

Notes:
[1] Parts of Yolo Solano, American, and Eastern San Joaquin are represented as part of the Delta groundwater object. The boundaries of the Delta groundwater object coincide with the Delta boundaries.
[2] Only a small portion of the Suisun-Fairfield groundwater basin is represented in SacWAM.

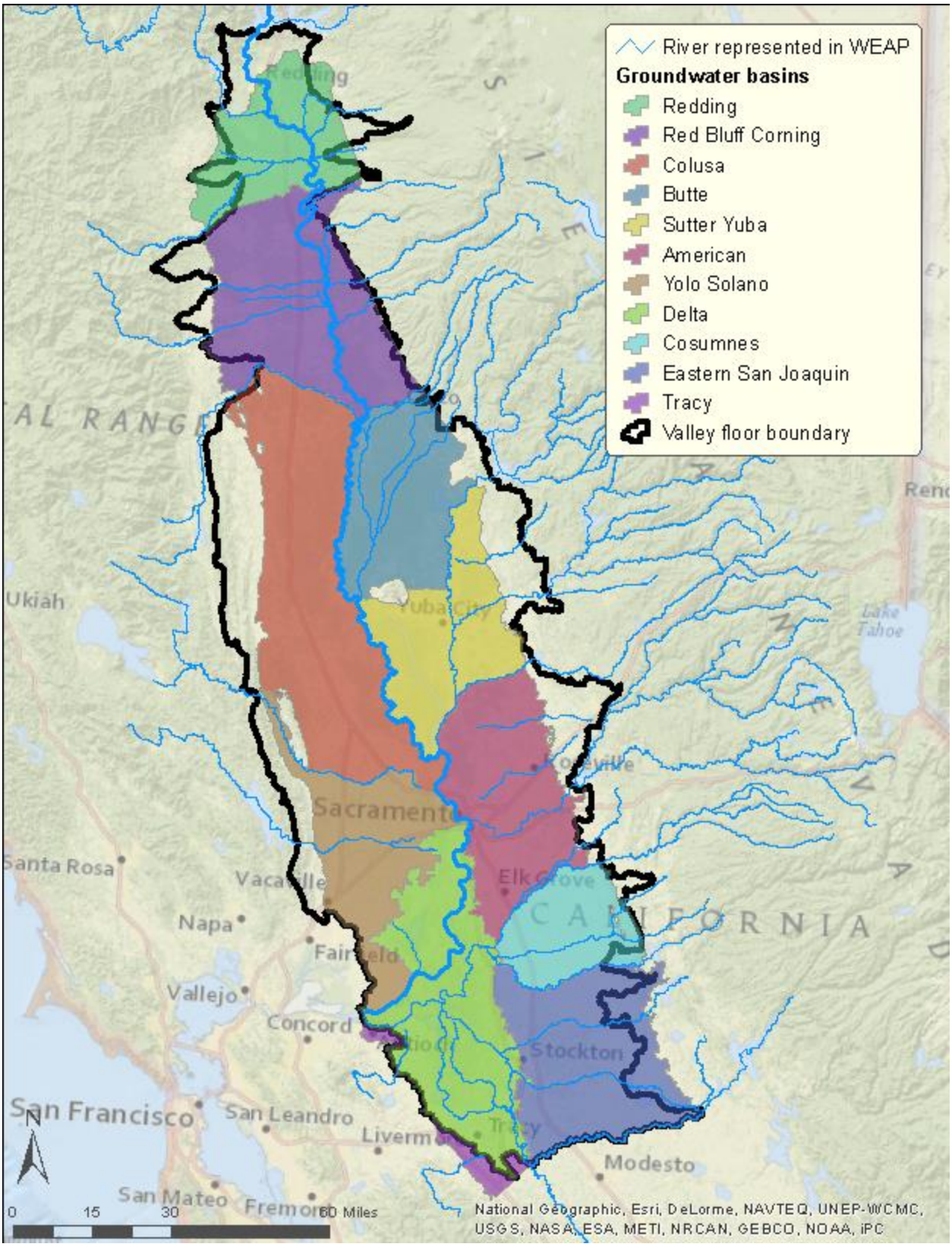


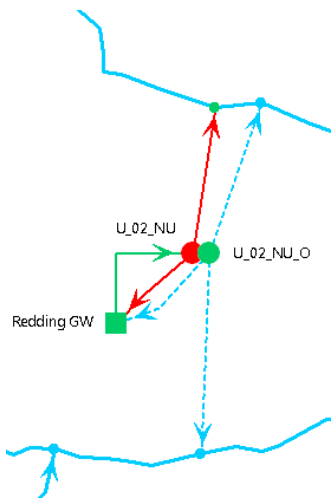
Figure 3-2. Groundwater Basins

3.4 Other Supplies

The use of the 'Other Supply' object in SacWAM is limited to the San Joaquin Valley. It provides water to lands on the southern boundary of the model domain located between the Calaveras and Stanislaus rivers, east of the San Joaquin River. The Other Supply represents: (1) water that is diverted from the Stanislaus River and flows into the Calaveras watershed; and (2) water used by riparian diverters along the San Joaquin River that extract their water upstream from Vernalis. It is assumed that these supplies are sufficient to meet the water demands of the local water users.

3.5 Demand Sites

WEAP's demand sites are used to represent urban water demands and deliveries to water users located outside the model domain (e.g., CVP and SWP south-of-Delta contractors). Rainfall-runoff and deep percolation from urban lands is represented using a WEAP catchment object associated with each urban demand site within the model domain. In the example shown, the demand site is DU U_02_NU and the associated catchment object is U_02_NU_O ("_O" denoting outdoor).



Urban demand sites are discussed in Chapter 4 and are listed in section Table 4-3.

3.6 Catchments

Catchment objects were added to the schematic to represent groups of water users on the valley floor, known as demand units (DUs). These are described in detail in Sections 4.1.1 and 4.1.2.

The spatial extents of **water budget areas** (WBAs) and **demand units** were used to determine catchment placement in the SacWAM model-building process. Because there are multiple, non-contiguous polygons associated with a single DU in SacWAM but there is only a single catchment object used to represent that DU, a DU's catchment placement in the model is only accurate within its WBA boundary.

3.7 Runoff/Infiltration

3.7.1 Surface Runoff and Return Flows

A comprehensive, GIS-based approach was used to determine surface water runoff and return flow locations for SacWAM DUs. This approach ensured the accurate simulation of flows of tributary rivers at their confluences with the Sacramento River, the accurate simulation of flows at USGS gauges on the Sacramento River, and flows into the Delta (Figure 1-2, Figure 1-3).

The contributing watersheds for each of these return points of interest (**valley floor returns**) were delineated through a combination of GIS tools and the use of the Natural Resources Conservation Service (NRCS) **Hydrologic Unit Code (HUC)-12 watersheds** dataset (NRCS, 2013a). In the case where the point of interest fell on a boundary between two NRCS **HUC-12 watersheds**, the HUC-12 boundary was used. In all other cases the watershed tool in ArcGIS was used to delineate the downstream extent of the watershed boundary using the National Hydrography Dataset (NHD) **flow accumulation** grid and the NRCS **HUC-12 watersheds** were used from the point that the GIS-generated watershed boundary intersected the HUC-12 boundary. There are two places where the approach was amended. These include the American River and Rodeo Creek, where relevant flow details are not captured in the NRCS **HUC-12 watersheds**. Rodeo Creek flows into McClure Creek, rather than directly into the Sacramento River as suggested by the HUC-12 boundaries. For this reason, the approximate area of the Rodeo Creek HUC-12 that drains to Rodeo Creek was added to the contributing area for McClure Creek. The American River watershed was divided along a boundary established in DWR models (**American boundaries**). The resulting file is called **watershed boundaries**.

Once SacWAM watershed boundaries were determined, an intersection was performed with the **demand units** and **watershed boundaries** shapefiles. The result of this intersection is the surface **returns intersection** shapefile. This intersection determined the proportion of each DU that lies within each SacWAM watershed. Where the percentage of a DU that lies within each SacWAM watershed is less than or equal to 10%, the return was not represented on the schematic and proportions were recalculated with the watersheds less than or equal to 10% omitted from the total area. The post-intersection processing is documented in the **surface returns** file. Table 3-5 presents surface runoff and return information for each DU, with the percentage of runoff/return flow that contributes to each return location. On the schematic, surface runoff and return locations are referred to with an “SR” preceding location names. For instance, surface runoff to Cottonwood Creek from DU A_02_NA is referred to as “SR Cottonwood Creek” in Table 3-5 and in SacWAM.

Surface runoff is represented in SacWAM with a runoff link to a surface water body (dashed blue line). If a catchment has multiple receiving surface water bodies, the runoff is distributed among the return locations using the surface returns intersection. The corresponding percentage of runoff that contributes to each return location (indicated in Table 3-5 and the **surface returns** file) was entered in the *Supply and Resources\Runoff and Infiltration\Demand Unit\Inflows and Outflows\Surface Runoff Fraction* branch of the data tree.

There are some urban DUs that represent both municipalities and scattered urban communities. For example, U_02_NU represents the City of Anderson, Cottonwood WD, Lake California (Rio Alto WD) and small communities (self-supplied). The municipalities hold permits to discharge wastewater to the Sacramento River at RM 281, but the small communities do not. In SacWAM, these DUs are represented with multiple return flows. One return flow link will flow to the wastewater treatment plant (WWTP) discharge location, and the other link(s) will flow to the groundwater basin(s) which the DU overlies. The rainfall runoff from this DU type will flow to surface water locations as determined by the surface **returns intersection**.

The exceptions to the approach described above were the DUs that encompass the Delta. These are: A_50_NA1, A_50_NA2, A_50_NA3, A_50_NA4, A_50_NA5, A_50_NA6, and A_50_NA7, which have

runoff to specified RMs. Because the HUC-12 watersheds may be an imprecise indicator of flow in the Delta, surface returns from CalSim II were used instead (Reclamation, 2007).

Runoff to surface water bodies from urban catchments was treated in the same way as from agricultural catchments. Surface runoff locations and percentages were determined from the surface **returns intersection** for each DU. In cases where a DU only represents municipalities that hold a permit to discharge to a WWTP, it is assumed that 100% of the runoff from the urban DU's catchment flows to the WWTP discharge location. The parameter values are contained in the surface returns file.

Table 3-5. Surface Runoff from Demand Units

Demand Unit	Return Flow Node and Percent of Runoff	Demand Unit	Return Flow Node and Percent of Runoff
A_02_NA	SR Cottonwood Ck (84%)	A_11_SA3	Butte Ck (52%)
	SR Sacramento R ab Keswick Gauge (16%)		Sutter Bypass (48%)
A_02_PA	SR Sacramento R ab Bend Bridge Gauge (62%)	A_11_SA4	Sutter Bypass (100%)
	SR Cottonwood Ck (23%)	A_12_13_NA	SR Feather R (100%)
	SR Clear Ck (15%)	A_12_13_SA	SR Feather R (80%)
A_02_SA	SR Sacramento R ab Bend Bridge Gauge (54%)		SR Feather R ab Gridley Gauge (20%)
	SR Cottonwood Ck (46%)	A_14_15N_NA1	SR Feather R (100%)
A_03_NA	SR Sacramento R ab Bend Bridge Gauge (85%)	A_14_15N_NA2	SR Feather R (100%)
	SR Cow Ck (15%)	A_14_15N_NA3	SR Yuba R ab Marysville Gauge (58%)
A_03_PA	SR Sacramento R ab Bend Bridge Gauge (75%)		SR Feather R (42%)
	SR Cow Ck (25%)	A_14_15N_SA	SR Feather R (100%)
A_03_SA	SR Sacramento R ab Bend Bridge Gauge (100%)	A_15S_NA	SR Bear R (74%)
A_04_06_NA	SR Sacramento R ab Hamilton City Gauge (83%)		SR Feather R (26%)
	SR Thomes Ck (17%)	A_15S_SA	SR Feather R (100%)
A_04_06_PA1	SR Sacramento R ab Hamilton City Gauge (56%)	A_16_NA	Sutter Bypass (100%)
	SR Sacramento R ab Vina Gauge (44%)	A_16_PA	Sutter Bypass (100%)
A_04_06_PA2	SR Sacramento R ab Hamilton City Gauge (100%)	A_16_SA	Sutter Bypass (100%)
A_04_06_PA3	SR Stony Ck (28%)	A_17_NA	Sutter Bypass (100%)
	SR Sacramento R ab Ord Ferry Gauge (28%)	A_17_SA	Sutter Bypass (100%)
	SR Colusa Basin Drain (21%)	A_18_19_NA	Sutter Bypass (100%)
	SR Sacramento R ab Hamilton City Gauge (12%);	A_18_19_SA	Sutter Bypass (100%)
	SR Sacramento R ab Butte City Gauge (11%)	A_20_25_NA1	SR Yolo Bypass (53%)
A_05_NA	SR Sacramento R ab Hamilton City Gauge (100%)		SR Cache Ck (31%)
A_07_NA	SR Colusa Basin Drain (100%)		SR Cache Ck ab Yolo Gauge (16%)
A_07_PA	SR Colusa Basin Drain (100%)	A_20_25_NA2	SR Sacramento R ab Rio Vista Gauge (87%)
A_08_NA	SR Colusa Basin Drain (100%)		SR Sacramento R RM 003 (13%)
A_08_PA	SR Colusa Basin Drain (100%)	A_20_25_PA	SR Sacramento R ab Rio Vista Gauge (100%)
A_08_SA1	SR Colusa Basin Drain (100%)	A_21_NA	SR Yolo Bypass (100%)
A_08_SA2	SR Colusa Basin Drain (100%)	A_21_PA	SR Yolo Bypass (100%)
A_08_SA3	SR Colusa Basin Drain (100%)	A_21_SA	SR Yolo Bypass (100%)
A_09_NA	SR Butte Ck (87%)	A_22_NA	SR Natomas East Main Drain (100%)
	SR Sacramento R ab Butte City Gauge (13%)	A_22_SA1	SR Natomas East Main Drain (77%)
A_09_SA1	SR Butte Ck (88%)		SR Sacramento R ab Verona Gauge (23%)
	SR Sacramento R ab Ord Ferry Gauge (12%)	A_22_SA2	SR Sacramento R above Verona Gauge (100%)
A_09_SA2	SR Butte Ck (100%)	A_23_NA	Auburn Ravine RM 000 (76%)
A_10_NA	SR Butte Ck (100%)		SR Bear R (24%)
A_11_NA	Sutter Bypass (100%)	A_24_NA1	Auburn Ravine RM 000 (84%)
A_11_SA1	SR Butte Ck (100%)		SR Auburn Ravine (16%)
A_11_SA2	Butte Ck (100%)		

Table 3-5. Surface Runoff from Demand Units contd.

Demand Unit	Return Flow Node and Percent of Runoff	Demand Unit	Return Flow Node and Percent of Runoff
A_24_NA2	Auburn Ravine RM 000 (83%)	A_60N_NA1	SR Jackson Ck (87%)
	SR Bear R (17%)		SR Dry Ck (13%)
A_24_NA3	SR Auburn Ravine (29%)	A_60N_NA2	SR Cosumnes R (100%)
	SR Dry Ck (27%)	A_60N_NA3	SR San Joaquin R 57%)
	SR Secret Ravine (22%)		SR Mokelumne R (43%)
	Natomas Cross Canal (22%)	A_60N_NA4	SR Mokelumne R (73%)
A_26_NA	SR Mokelumne R (70%)		SR San Joaquin R (27%)
	SR American R above Fair Oaks Gauge (17%)	A_60N_NA5	SR Cosumnes R (56%)
	SR Natomas East Main Drain (13%)		SR Dry Ck (24%)
A_50_NA1	Sacramento R RM 041 (100%)		SR San Joaquin R (20%)
A_50_NA2	Sacramento R RM 017 (100%)	A_60S_NA	SR San Joaquin R (100%)
A_50_NA3	Sacramento R RM 000 (100%)	A_60S_PA	SR San Joaquin R (76%)
A_50_NA4	Mokelumne R RM 004 (100%)		SR Calaveras R (24%)
A_50_NA5	San Joaquin R RM 026 (100%)	A_61N_PA	SR San Joaquin R (100%)
A_50_NA6	San Joaquin R RM 013 (100%)	A_61N_NA1	SR Stanislaus R (47%)
A_50_NA7	Old R RM 027 (100%)		SR Littlejohns Ck (37%)
A_60N_NA1	SR Jackson Ck (87%)		SR San Joaquin R (16%)
	SR Dry Ck (13%)	A_61N_NA2	SR Stanislaus R (100%)
A_60N_NA2	SR Cosumnes R (100%)	A_61N_NA3	SR San Joaquin R (100%)
A_60N_NA3	SR San Joaquin R 57%)	U_02_NU	SR Cottonwood Ck (53%)
	SR Mokelumne R (43%)		SR Sacramento R above Bend Bridge Gauge (47%)
A_60N_NA4	SR Mokelumne R (73%)	U_02_PU	Sacramento R RM 287 (100%)
	SR San Joaquin R (27%)	U_02_SU	Sacramento R RM 287 (100%)
A_24_NA2	Auburn Ravine RM 000 (83%)	U_03_NU	SR Sacramento R above Vina Gauge (100%)
	SR Bear R (17%)	U_03_PU	Sacramento R RM 281 (100%)
A_24_NA3	SR Auburn Ravine (29%)	U_03_SU	Sacramento R RM 281 (100%)
	SR Dry Ck (27%)	U_04_06_NU	SR Sacramento R above Vina Gauge (87%)
	SR Secret Ravine (22%)		SR Sacramento R above Ord Ferry Gauge (13%)
	Natomas Cross Canal (22%)	U_05_NU	SR Sacramento R above Vina Gauge (69%)
A_26_NA	SR Mokelumne R (70%)		SR Antelope Ck (31%)
	SR American R above Fair Oaks Gauge (17%)	U_07_NU	SR Colusa Basin Drain (100%)
	SR Natomas East Main Drain (13%)	U_08_NU	SR Colusa Basin Drain (100%)
A_50_NA1	Sacramento R RM 041 (100%)	U_09_NU	SR Butte Ck (100%)
A_50_NA2	Sacramento R RM 017 (100%)	U_10_NU1	Sacramento R RM 195 (100%)
A_50_NA3	Sacramento R RM 000 (100%)	U_10_NU2	SR Butte Ck (100%)
A_50_NA4	Mokelumne R RM 004 (100%)	U_11_NU1	Feather R RM 063 (100%)
A_50_NA5	San Joaquin R RM 026 (100%)	U_11_NU2	Sutter Bypass (50%)
A_50_NA6	San Joaquin R RM 013 (100%)		Butte Ck (50%)
A_50_NA7	Old R RM 027 (100%)		

Table 3-5. Surface Runoff from Demand Units contd.

Demand Unit	Return Flow Node and Percent of Runoff	Demand Unit	Return Flow Node and Percent of Runoff
U_12_13_NU1	Feather R RM 063 (100%)	U_26_PU5	American R RM 007 (85%)
U_12_13_NU2	SR Feather R (100%)		Sacramento R RM 048 (15%)
U_14_15N_NU	Feather R RM 028 (100%)	U_60N_NU1	San Joaquin R RM 024 (100%)
U_15S_NU	Feather R RM 025 (100%)	U_60N_NU2	SR Cosumnes R (100%)
U_16_NU	Sutter Bypass (100%)	U_60N_PU	SR Cosumnes R (100%)
U_16_PU	Feather R RM 028 (100%)	U_60S_NU1	San Joaquin R RM 042 (100%)
U_17_NU	Sutter Bypass (100%)	U_60S_NU2	SR Calaveras R (100%)
U_18_19_NU	Sutter Bypass (100%)	U_61N_NU2	SR San Joaquin R (57%)
U_20_25_NU	Yolo Bypass CM 032 (100%)		SR Stanislaus R (43%)
U_20_25_PU	Cache Slough RM 005 (100%)	U_ANTOC	None
U_21_NU	SR Yolo Bypass (100%)	U_CCWD	None
U_21_PU	SR Yolo Bypass (100%)	U_CLLPT	None
U_22_NU	SR Natomas East Main Drain (100%)	U_EBMUD	None
U_23_NU	SR Natomas East Main Drain (100%)	U_ELDID	None
U_24_NU1	Auburn Ravine RM 027 (100%)	U_FVTB	None
U_24_NU2	Natomas Cross Canal CM 002 (50%)	U_JLIND	None
	Natomas East Main Drain CM 007 (50%)	U_NAPA	None
U_26_NU1	SR Natomas East Main Drain (79%)	U_PCWA3	None
	American R RM 007 (21%)	R_08_PR	SR Colusa Basin Drain above HWY 20 Gauge (80%)
U_26_NU2	American R RM 007 (100%)		SR Colusa Basin Drain above Outfall Gates Gauge (20%)
U_26_NU3	Sacramento R RM 048 (100%)	R_09_PR	SR Butte Creek (100%)
U_26_NU4	SR Mokelumne R (56%)	R_11_PR	SR Butte Creek (100%)
	Sacramento R RM 048 (32%); American R RM 007 (12%)	R_17_NR	Butte Creek (100%)
U_26_NU5	American R RM 007 (100%)	R_17_PR1	Butte Creek (100%)
U_26_NU6	SR American R above Fair Oaks Gauge (100%)	R_17_PR2	Sutter Bypass (100%)
U_26_PU1	Dry Creek (100%)		
U_26_PU2	SR Natomas East Main Drain (72%)		
	SR American R above Fair Oaks Gauge (15%)		
	American R RM 007 (13%)		
U_26_PU3	SR American R above Fair Oaks Gauge (73%)		
	American R RM 007 (27%)		
U_26_PU4	Sacramento R RM 048 (100%)		
U_61N_NU1	SR San Joaquin R (100%)		

Key: ab=above; Ck=creek; CM=canal mile; R=River; RM=river mile; SR=surface runoff; WWTP=wastewater treatment plant

For some urban DUs, the surface **returns intersection** was not used to determine return flows and/or surface runoff locations. Treated wastewater from large urban centers, with dedicated or regional WWTPs, may be discharged to surface waters. However, in most rural and smaller towns, wastewater typically is discharged to private systems or evaporation ponds, which recharge the underlying groundwater aquifer. An example of a DU that holds a permit to discharge to a surface water body is U_26_NU1. Wastewater from the municipalities represented by this DU is treated at the Sacramento Regional WWTP and discharged to the Sacramento River at RM 048. For municipalities that hold permits to discharge to surface water, it was assumed in SacWAM that 100% of the return flow and 100% of the surface runoff return to the specified WWTP location.

3.8 Transmission Links

Transmission links connect water supplies to water demands, represented in WEAP by "Demand Site" objects and "Catchment" objects. Points of diversion for CVP/SWP contractors were identified using a variety of sources, including CVP contract documents[4] (Reclamation, 2013a), the SWP Handbook (DWR, 1992), and the Delta-Mendota Canal Structures (Reclamation 1986). Non-Project points of diversion were identified using a combination of SWRCB's Electronic Water Rights Information Management System (eWRIMS) database (SWRCB, 2014), Bulletin 23 (DWR, 1924-1962) and Bulletin 130 (DWR, 1963-1975, 1988) data, and aerial imagery. SacWAM's surface water diversion are summarized in Table 3-6, Table 3-7, and Table 3-8.

3.8.1 Central Valley Project Diversions

Under the terms of its authorization, the CVP provides water to Sacramento River water right settlement contractors (settlement contractors) in the Sacramento Valley; San Joaquin River exchange contractors (exchange contractors) and water right holders in the San Joaquin Valley; agricultural and municipal and industrial (M&I) water service contractors in both the Sacramento and San Joaquin valleys; and wildlife refuges both north and south of the Delta.

Reclamation's long-term water service contracts for CVP diverters give exact locations of surface water diversions by RM for each contractor that diverts from the Sacramento River. SacWAM **river miles** were defined from recent aerial imagery. In contrast, CVP contract miles are based on the historical path of the river. Consequently, CVP contract miles have been adjusted to SacWAM RMs.

Diversion locations that are determined from CVP contracts (Reclamation, 2013a) are indicated in the "Contract Type" column of Table 3-6, Table 3-7 and Table 3-8. Those indicated as "Other" in this column were determined using a combination of sources, including Bulletin 23 and 130 data, the eWRIMS database, CalSim II, and aerial imagery.

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[4] Reclamation's long-term water service contracts for CVP diverters give exact locations of surface water diversions by RM for each contractor that diverts from the Sacramento River. SacWAM river miles were defined from recent aerial imagery. In contrast, CVP contract miles are based on the historical path of the river. Consequently, CVP contract miles have been adjusted to SacWAM RMs.

3.8.2 State Water Project Diversions

The SWP operates under long-term contracts with 29 public water agencies. These agencies deliver water to wholesalers or retailers, or deliver water directly to agricultural and M&I water users. Additionally, DWR has signed "settlement" agreements with senior water right holders on the Feather River to resolve water supply issues associated with the operation of SWP facilities associated with Lake Oroville and Thermalito Forebay and Afterbay.

3.8.2.1 *Feather River Service Area*

Three SWP long-term contractors are located north of the Delta: Plumas County Flood Control and Water Conservation District (FC&WCD), Butte County, and the City of Yuba City. Plumas County FC&WCD is located upstream from Lake Oroville in the upper Feather River basin. The City of Yuba City diverts water from the Feather River immediately upstream from the Yuba River confluence with the Feather River–RM 028. Butte County acts as a wholesaler of SWP water to municipal agencies within the county.

For modeling purposes, Butte County's SWP water is available to Thermalito Irrigation District (ID) (DU U_11_NU1), Cal Water–Oroville (DU U_12_13_NU1), and the City of Yuba City (DU U_16_PU). Cal Water–Oroville purchases water from Pacific Gas and Electric (PG&E), which is delivered from the West Branch of the Feather River via the Miocene Canal, and diverts SWP water, through Butte County, from the Thermalito Power Canal. Thermalito ID holds water rights associated with Concow Reservoir. Under an agreement with the State, the reservoir is kept full during the summer months for fishery purposes. Water released in the fall, winter, and spring is stored in Lake Oroville and re-released in the summer to meet Thermalito ID demands.

DWR has signed contracts/agreements with districts in the Feather River Service Area (FRSA). These districts include Western Canal WD, Joint Board WD, Plumas Mutual Water Company (MWC), Garden Highway MWC, Oswald WD, and Tudor MWC. Western Canal WD and the Joint Board WD divert from the Thermalito Afterbay. Points of diversion from the other WDs are based on SWP settlement contracts (DWR, 1997a). FRSA is represented in SacWAM by portions of WBAs 11, 12, and 16.

In addition to WDs, many individual agricultural water users hold water rights senior to SWP for Feather River water. Data on water entitlements for the Feather River were collected by DWR as part of the Feather River Trial Distribution Program, and published in Bulletin 140 (DWR, 1965). The net irrigable area of lands of riparian and appropriative water rights was estimated to be approximately 30,000 acres. For SacWAM, surface water diversions to these individuals are based on estimates of irrigated riparian lands, beneficial use, and appropriative water rights (Sergent, 2008); and on Bulletin 168 (DWR, 1978).

3.8.2.2 *North Bay Aqueduct*

The North Bay Aqueduct is part of the SWP, delivering water to Solano County Water Agency (WA) and Napa County FC&WCD, which are both long-term water contractors. Under agreements with Solano County WA, water from the North Bay Aqueduct is delivered to the cities of Benicia, Vallejo, Fairfield, and Vacaville. The cities of Suisun, Rio Vista, and Dixon all have contract entitlements to water from the North Bay Aqueduct but currently do not have facilities to receive this supply. Under agreements with Napa County FC&WCD, the cities of Calistoga, Napa, St. Helena, and American Canyon, and the Town of

Yountville receive SWP water from an extension of the North Bay Aqueduct. In addition, SWP delivers water right water through the North Bay Aqueduct.

SacWAM represents the North Bay Aqueduct as a diversion from Cache Slough. Points of diversion are based on data ptresented in the SWP Handbook (DWR, 1997a). Except for the City of Vacaville (DU U_20_25_PU), all deliveries from the North Bay Aqueduct are exports from the model domain. Three demand sites represent the export demands for Solano and Napa. Multiple arcs to each demand site differentiate between types of SWP water (Table A and Article 21) and water right water (Vacaville Permit Water and Settlement Water).

3.8.3 Non-Project Diversions

In the context of SacWAM, non-project diversions include all surface water diversions that are not part of the CVP or SWP. However, non-project diversions include Federal projects other than the CVP.

3.8.3.1 *Diversions from Sacramento River*

Major diverters of non-project water along the Sacramento River include Llano Seco Rancho, and the Cities of Sacramento and West Sacramento. Additionally, Sacramento County WA and East Bay Municipal Utility District (EBMUD) divert non-project water as part of the Freeport Regional Water Project. In the future, the Cities of Davis and Woodland are planning to divert non-project water as part of the Davis-Woodland Project.

Non-project diversions from the Sacramento River other than those described above are not well defined, and records of their historical diversions are incomplete or unavailable. DWR's county land use surveys (DWR, 1994a-b, 1995a-b, 1996, 1997b, 1998a-c, 1999a-b, 2000a) were used to identify land that was contiguous with the Sacramento River, and within three miles of the river centerline. From the county land use survey information, a subset of these lands was identified as cropland that is irrigated by surface water or mixed surface water and groundwater and lies outside any WDs or IDs. Model diversion arcs to these non-project diverters can represent multiple real-world diversion locations.

3.8.3.2 *Diversions from Feather River*

SacWAM represents the major imports and exports of water from the upper Feather River watershed above Lake Oroville. These include the export of water from the West Branch Feather River at the Hendricks Diversion Dam as part of PG&E's DeSabla-Centerville Project (FERC No. 803), and the import of water from Slate Creek as part of South Feather Water and Power Agency's South Feather Hydroelectric Project (FERC No. 2088). Water diversions for use within the Feather watershed include West Branch Feather River diversion in to the Miocene Canal and South Feather Water and Power Agency's diversions in to the Oroville-Wyandotte Canal and in to the Miners Ranch Canal.

Major diversions from the Feather River below Oroville consist of water right holders who have signed settlement agreements with DWR (see section 3.8.2.1). In addition, there are many minor appropriative and riparian water right holders who divert water from both the left and right banks of the river. For SacWAM, these minor diversions were determined using detailed diversion data published in Bulletin 168 (DWR, 1978), estimates of irrigated riparian lands and beneficial use, eWRIMS database of appropriative water rights, and from personal communication with DWR (Sergent, 2008).

3.8.3.3 *Diversions from Yuba River*

The Yuba River has been extensively developed for hydropower generation and water supply. Development in the upper watersheds of the North, Middle and South Yuba rivers and Deer Creek include: parts of South Feather Water and Power Agency's South Feather Hydroelectric Project (FERC 2088), Yuba County WA's Yuba River Development Project (FERC No. 2246), Nevada ID's Yuba-Bear Hydroelectric Project (FERC No. 2266), PG&E's Drum-Spaulding Project (FERC No. 2310), and USACE's Englebright and Daguerre Point dams. SacWAM represents the major diversion and export facilities associated with these projects, including Slate Creek Tunnel, Lohman and Camptonville tunnels, Milton-Bowman Tunnel, Bowman-Spaulding Conduit, and the South Yuba and Drum canals. Demand sites within these upper watersheds are limited to Nevada ID's Deer Creek unit, which includes irrigated agriculture and urban water supplies to Grass Valley and Nevada City.

As part of the Yuba River Development Project, Yuba County WA delivers water to its member units at Daguerre Point Dam located at RM 11. Water is diverted to irrigate lands both north and south of the river. Additionally, Browns Valley ID diverts water at its pumping plant located approximately two miles upstream at RM 13. SacWAM includes three transmission links for these non-project diversions from the lower Yuba River.

Dry Creek joins the Yuba River from the north, approximately two miles upstream from Daguerre Point Dam. Flows in Dry Creek are regulated by Browns Valley ID's operation of Merle Collins Reservoir and Virginia Ranch Dam. The district supplements Yuba River water with diversions below Merle Collins Reservoir. SacWAM aggregates these diversions to a single point of diversion.

3.8.3.4 *Diversions from Bear River*

The Bear River watershed upstream from Camp Far West Reservoir includes storage and diversion facilities owned and operated by Nevada ID, Placer County WA, and PG&E. The SacWAM schematic includes inflows from PG&E's Drum Canal and exports to PG&E's Bear River Canal and Placer County WA's Lower Boardman Canal. SacWAM also represents Nevada ID diversions from Combie Canal.

Water is released from Camp Far West Reservoir for power generation, irrigation, and to meet downstream flow requirements (see section 7.2.3.6). South Sutter WD operates a diversion dam at RM 17, approximately one mile downstream from Camp Far West Dam, to irrigate lands served by Camp Far West ID and South Sutter WD. SacWAM uses two transmission links to represent left bank and right bank diversions at the diversion dam.

3.8.3.5 *Diversions from American River*

SacWAM represents the upper American River watersheds of the North Fork, Middle Fork, and South Fork. The schematic portrays the export of water from the North Fork American River watershed to the Bear River watershed as part of PG&E's Drum-Spaulding Project. The schematic also includes diversions associated with Placer County WA's Middle Fork Project, Sacramento Municipal Utility District's (SMUD) American River Project, and El Dorado ID's South Fork Project. There is a single demand site in the upper watershed representing Georgetown PUD. Additionally, SacWAM represents the Placer County WA diversion upstream from Folsom at the Auburn Dam site and El Dorado ID's diversion from the El Dorado Canal.

There are no significant agricultural diversions from Folsom Lake and the lower American River. There are, however, four municipalities that divert water from Folsom Lake (City of Roseville, San Juan WD, City of Folsom, and El Dorado ID). Additionally, Aerojet, Folsom State Prison, and State Parks receive water from Folsom Lake. As part of the CVP, water is diverted from Lake Natoma into the Folsom South Canal. From the canal, project water is delivered to Golden State WA, and Sacramento Municipal Utility District's Rancho Seco Power Plant. On the lower American River, there are two diversions to the Carmichael WD and the City of Sacramento. In SacWAM these diversions are represented by diversion arcs to water treatment plants and transmission links connecting the diversion arc to individual demand units.

3.8.3.6 *Diversions from Stony Creek*

The Orland Project, centered on Stony Creek, is one of the oldest Federal Reclamation projects in the country. Water was delivered to the first farm units at the beginning of the 1910 growing season. The main elements of the project include East Park Dam, Stony Gorge Dam, Rainbow Diversion Dam and East Park Feeder Canal, South Diversion Intake and South Canal, and Northside Diversion Dam and North Canal. Black Butte Dam, constructed by the U.S. Army Corps of Engineers (USACE), is an authorized facility of CVP. The CVP and the Orland Project are separate projects with separate water rights.

3.8.3.7 *Diversions from Cache Creek*

Clear Lake is the dominant feature within the Cache Creek watershed. Releases from the lake for agricultural water supply are supplemented by releases from Indian Valley Reservoir located on the North Fork Cache Creek. SacWAM represents minor withdrawals from Clear Lake to the surrounding communities (U_CLLPT). SacWAM represents all agricultural water use by a single diversion at the Capay Diversion Dam at RM 30, where water is delivered to the Yolo County FC&WCD service area (A_20_25_NA1).

3.8.3.8 *Diversions from Putah Creek*

The Solano Project was constructed from 1953 to 1959 by Reclamation to provide irrigation water to approximately 96,000 acres of land located in Solano County. The project also furnishes M&I water to the major cities of Solano County. Project facilities include Lake Berryessa and Monticello Dam, Putah Diversion Dam, Putah South Canal and canal distribution system, and a small terminal reservoir (Solano County WA, 2011). Water released from Monticello Dam is diverted at the Putah Diversion Dam located approximately six miles downstream. Water is subsequently conveyed to its end users via the Putah South Canal. In addition to the Solano Project, there are minor diversions in the Putah Creek watershed under both riparian and appropriative water rights. These include diversions by UC Davis from the South Fork of Putah Creek. These minor diversions are not represented in SacWAM.

3.8.3.9 *Diversions from Cosumnes River*

The Cosumnes River watershed remains largely unimpaired by development except for the former Sly Park Unit of the CVP that was transferred to El Dorado ID in 2003. SacWAM represents Jenkinson Lake and associated imports from Camp Creek and exports through the Sly Park-Camino Conduit to the El Dorado ID service area. El Dorado ID diversions into the Crawford Ditch from the North Fork Cosumnes River are not represented. Below the USGS gauge at Michigan Bar, SacWAM represents a single point of diversion - to the community of Rancho Murieta (DU U_60N_NU2) at Granlees Dam. There are many

small diversions along the lower Cosumnes River, typically consisting of small pumps that divert less than 1 cfs. SWRCB records show there are approximately 133 active water rights applicants and licenses, representing an annual entitlement of up to 5,700 acre-ft in the lower Cosumnes River watershed. These diversions are not currently represented in SacWAM.

3.8.3.10 *Diversions from Dry Creek*

Dry Creek, located south of the Cosumnes watershed, joins the Mokelumne River near the confluence with Cosumnes River. Flows in Dry Creek are partially regulated by Lake Amador, located on Jackson Creek. SacWAM represents the lake and the water supply from Pardee Reservoir under an agreement between Jackson Valley ID and EBMUD. SacWAM represents diversions from Lake Amador to supply the irrigation district (A_60N_NA1), but does not represent any other diversions in the Dry Creek watershed.

3.8.3.11 *Diversions from Mokelumne River*

The Mokelumne River watershed can be divided into upper and lower watersheds by the USGS gage at Mokelumne Hill (11319500) located near Highway 49. The upper watershed includes the North Fork, Middle Fork, and South Fork, and 8 miles of the main stem of the Mokelumne River.

North Fork

PG&E owns and operates the Mokelumne Hydroelectric Project (FERC No. 137) on the North Fork Mokelumne River. The project consists of seven storage reservoirs and associated diversions and powerhouses. SacWAM combines the reservoirs, principally Lower Bear and Salt Springs reservoirs, in to a single storage unit. Downstream diversions by Amador Water Agency to serve local communities are aggregated to a single point of diversions in the model (DU AMADR).

Middle and South Forks

SacWAM represents the Middle Fork and South Mokelumne River as two fixed timeseries of inflows. The model aggregates diversions by Calaveras County WD and Calaveras PUD to a single point of diversion downstream from the confluence of the two forks. The diversion supplies Mokelumne Hill and other rural communities (DU CCWD and CPUD).

Main Stem

EBMUD owns and operates Pardee and Camache reservoirs located on the main stem of the Mokelumne River in the lower watershed. From Pardee, the district diverts water in to the Mokelumne Aqueduct to convey water to its service district in the San Francisoo Bay Area. SacWAM simulates diversions to the Mokelumne Aqueduct and also water delivers from Pardee Reservoir to Lake Amador.

Water right holders on the lower Mokelumne River below Camanche Dam include North San Joaquin WCD, Woodbridge ID, and minor riparian and appropriative water right holders. SacWAM represents separate diversions to these entities. Diversions to North San Joaquin WCD (DU A_60N_NA3) are represented as a single diversion at RM 51. Minor diversions to individual water right holders (DU A_60N_NA5) are located at two points, upstream and downstream from the Woodbridge Diversion Dam. Lastly, SacWAM represents diversions to Woodbridge ID (DU A_60N_NA4) and district wholesale agreements with the City of Lodi (U_60N_NU1) and the City of Stockton (U_60S_NU1) using three transmission links located at the diversion dam at RM 37.

3.8.3.12 *Diversions from Calaveras River*

The Calaveras River is divided into upper and lower reaches by New Hogan Reservoir located at RM 45, which was built by USACE for water supply and flood control purposes. There is little development above the dam. Approximately 20 miles below the dam, the river divides at the Bellota Weir in to Mormon Slough and the old Calaveras River channel. There are many irrigation diversions along both of these waterways.

Water stored in New Hogan Reservoir is shared between Stockton East WD and Calaveras County WD. From New Hogan Dam to Bellota Weir at RM 25, SacWAM includes only a single diversion - at RM 43 to the unincorporated area of Jenny Lind (DU U_JLIND). All other diversions are aggregated and represented in the model by two transmission links located at Bellota Weir. The first transmission link supplies irrigation water to Stockton East WD and riparian diverters in Claveras County (DU A_60S_PA). The second represents the raw water supply to the Stockton East WD water treatment plant that supplies the City of Stockton (U_60S_NU1).

3.8.3.13 *Diversions from Minor Streams and Creeks*

Points of diversion for minor tributaries to the Sacramento River were identified from a variety of sources, including SWRCB's eWRIMS database (SWRCB, 2014), annual bulletins published by DWR and its predecessors[5], and aerial imagery. Typically, on minor creeks, diversions for agricultural water supply are aggregated to a single point in SacWAM located at the largest diversion structure, where one exists.

3.8.3.14 *Diversions from the Sacramento-San Joaquin Delta*

SacWAM's representation of agricultural water use in the Delta and associated surface water diversions and return flows is highly conceptual and represents a balance between Delta channel accretions and channel depletions.

Channel accretions result from rainfall-runoff, excess irrigation water, and seepage from Delta islands. Excess water is pumped from the Delta islands back into the Delta. Channel depletions primarily consist of irrigation and leach water. Net channel depletions are the difference between total diversions and total drainage or return flows. In SacWAM, the Delta is divided into seven Delta subregions, each represented by a single diversion and and a single return flow. These subregions are illustrated in Figure 3-3, and are identical to regions identified by DWR for modeling purposes. SacWAM incorporates two options for quantifying the diversions and return flows, as follows:

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[5] Bulletin 23, published continuously between 1930 and 1965 (DWR, 1924-1962), contains data for monthly diversions, streamflows, return flows, water use, and salinity in the Sacramento River and San Joaquin watersheds. The series was discontinued in 1965, following the publication of Bulletin 23-62. Bulletin 130 superseded Bulletin 23 and presented hydrologic data in five appendices covering the entire State. The bulletin was published annually from 1963 through 1975 and was last published in 1988 (DWR, 1963-1975, 1988). Bulletin 130 superseded Bulletin 23, and presents hydrologic data in five appendices covering the entire State. The bulletin was published annually from 1963 through 1975 and was last published in 1988 (DWR, 1963-1975, 1988).

- For consistency with DWR's planning model CalSim II and the agency's Delta hydrodynamic model DSM2, SacWAM Delta channel diversions and return flows may be read from a CSV file containing monthly timeseries developed by DWR for CalSim.
- SacWAM includes 7 watershed objects to represent the Delta subregions with associated transmission links and runoff-infiltration arcs.

Though use of SacWAM watershed objects may provide a better estimate of crop consumptive use, the default option for running SacWAM is to use DWR-based flows to provide consistency with other planning processes.

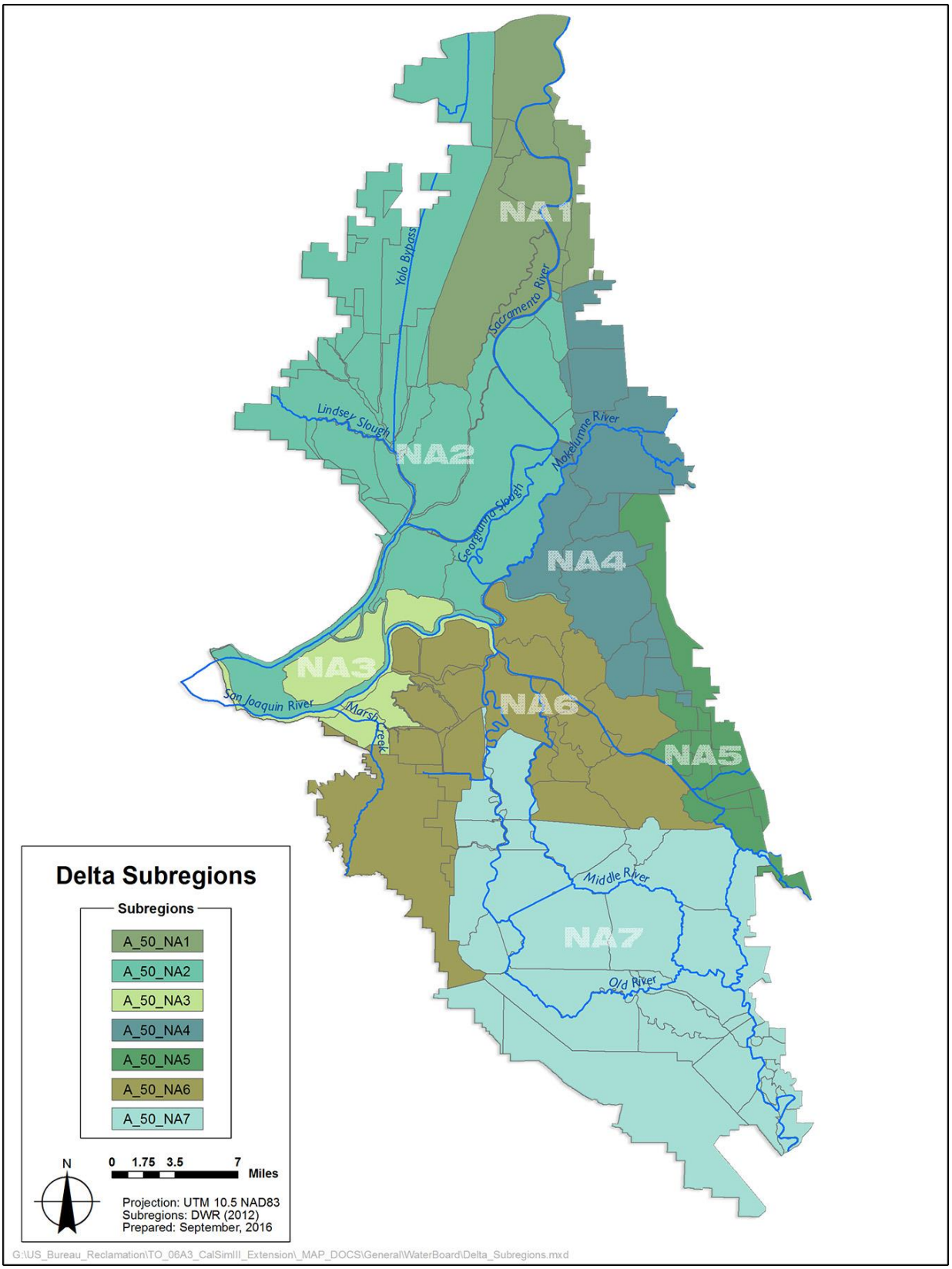


Figure 3-3. Delta Subregions

Table 3-6. Surface Water Diversions by Agricultural Demand Unit

Demand Unit	Surface Diversion(s)
CVP North of Delta Water Service Contracts	
A_02_PA	Whiskeytown Reservoir
A_03_PA	Sacramento River RM 294
A_04_06_PA1	Tehama-Colusa Canal CM 001
A_04_06_PA2	Tehama-Colusa Canal CM 022
A_07_PA	Tehama-Colusa Canal CM 036 & CM 081
A_08_PA	Colusa Basin Drain CM 028; Glenn-Colusa Canal CM 065
A_16_PA	Feather River RM 021
A_21_PA	Knights Landing Ridge Cut CM 005
CVP Sacramento River Settlement Contracts	
A_02_SA	Sacramento River RM 296
A_03_SA	Sacramento River RM 289
A_08_SA2	Colusa Basin Drain CM 041; Glenn-Colusa Canal CM 027
A_09_SA1	Sacramento River RM 196; Butte Creek RM 045
A_08_SA1	Sacramento River RM 159 & RM 178; Colusa Basin Drain CM 049
A_08_SA3	Sacramento River RM 109 & RM 121; Colusa Basin Drain CM 028
A_09_SA2	Sacramento River RM 162; Butte Creek RM 012
A_21_SA	Sacramento River RMs 074 & 083; Yolo Bypass CM 023
A_22_SA1	Sacramento River RMs 078 082; Auburn Ravine RM 000
Other Federal Project Diverters	
A_04_06_PA3	Stony Creek RM 021 & RM 026 (Orland Project)
A_20_25_PA	Putah South Canal CM 003 (Solano Project)
SWP Feather River Service Area	
A_11_SA1	Thermalito Reservoir Afterbay
A_11_SA2	Thermalito Reservoir Afterbay; Joint Board Canal CM 000
A_11_SA3	Joint Board Canal CM 000
A_11_SA4	Feather River RM 039; Joint Board Canal CM 000
A_12_13_SA	Feather River RM 059
A_14_15N_SA	Feather River RM 059
A_15S_SA	Feather River RM 028
A_16_SA	Feather River RM 014
A_17_SA	Feather River RM 014
A_22_SA2	Feather River RM 012
In-Delta Diverters	
A_50_NA1	Sacramento River RM 041
A_50_NA2	Sacramento River RM 017
A_50_NA3	Sacramento River RM 000
A_50_NA4	Mokelumne River RM 004
A_50_NA5	San Joaquin River RM 026
A_50_NA6	San Joaquin River RM 013
A_50_NA7	Old River RM 027
Non-Project Diverters	
A_24_NA2	Auburn Ravine RM 010
A_24_NA1	Auburn Ravine RM 024; Rock Creek Reservoir; Lake Combie
A_23_NA	Bear River RM 017; Auburn Ravine RM 006
A_10_NA	Butte Creek RM 036; West Branch Feather RM 015
A_20_25_NA1	Cache Creek RM 030
A_20_25_NA2	Cache Slough RM 005
A_60S_PA	Calaveras River RM 026; Farmington Reservoir
A_60N_NA2	Folsom South Canal CM 015

Table 3-6. Surface Water Diversions by Agricultural Demand Unit contd.

Demand Unit	Surface Diversion(s)
A_14_15N_NA3	French Dry Creek RM 006; Yuba River RM 013
A_60N_NA1	Lake Amador
A_24_NA3	Lower Boardman Canal CM 049
A_60N_NA4	Mokelumne River RM 035
A_60N_NA3	Mokelumne River RM 050
A_60N_NA5	Mokelumne River RM 050
A_12_13_NA	Oroville Wyandotte Canal CM 000; Miners Ranch Reservoir
A_02_NA	Sacramento River RM 281; Cottonwood Creek RM 009
A_03_NA	Sacramento River RM 273; Battle Creek RM 006; Cow Creek RM 014
A_04_06_NA	Sacramento River RM 224; Thomes Creek RM 012
A_05_NA	Sacramento River RM 240; Antelope Creek RM 010; Mill Creek RM 006; Deer Creek RM 005 & RM 010
A_08_NA	Sacramento River RM 146
A_09_NA	Sacramento River RM 185 & RM 196; Butte Creek RM 045
A_18_19_NA	Sacramento River RM 136; Sutter Bypass CM 034
A_18_19_SA	Sacramento River RMs 115, 121, & 136
A_21_NA	Sacramento River RM 081
A_22_NA	Sacramento River RM 075
A_61N_NA3	San Joaquin River RM 070
A_61N_NA2	Stanislaus River RM 030
A_61N_PA	Stanislaus River RM 059
A_17_NA	Sutter Bypass CM 014
A_11_NA	Sutter Bypass CM 028
A_16_NA	Sutter Bypass CM 028
A_14_15N_NA2	Yuba River RM 011
A_15S_NA	Yuba River RM 011

Notes:
[1] A_04_06_NA includes some minor CVP settlement contractors.
Key: CM=Canal Mile; CVP=Central Valley Project; RM=River Mile; SWP=State Water Project.

Table 3-7. Surface Water Diversions by Urban Demand Unit

Demand Unit	Surface Diversion(s)
CVP North of Delta Water Service Contracts	
U_02_PU	Whiskeytown Reservoir (Centerville CSD, Clear Creek CSD,Keswick CSA, Shasta CSD)
U_03_PU	Shasta Lake; Sacramento River RM 294; Whiskeytown Reservoir (City of Redding, Bella Vista WD, others)
U_21_PU	Sacramento River RM 065 (West Sacramento)
U_26_PU1	Folsom Lake (City of Roseville)
U_26_PU2	Folsom Lake (San Juan WD)
U_26_PU3	Folsom Lake (City of Folsom/Folsom Prison)
U_26_PU4	Sacramento River RM 054, RM 062 (Sacramento County WA)
U_26_PU5	Folsom South Canal CM 003 (Golden State WC)
U_60N_PU	Folsom South Canal CM 025 (SMUD)
U_CCWD	Sacramento River RM 000; Contra Costa Canal CM 019 (Contra Costa WD)
U_EBMUD	Sacramento River RM 050 (EBMUD)
U_ELDID	Folsom Lake (El Dorado ID)
CVP Sacramento River Settlement Contracts	
U_02_SU	Sacramento River RM 296 (City of Redding)
U_03_SU	Sacramento River RM 296 (City of Redding)
Other Federal Projects	
U_20_25_PU	Putah South Canal CM 013 (Solano Project - City of Vacaville)
U_FVTB	Putah South Canal CMs 013 & 017 (Cities of Benicia, Fairfield, Suisun, Vacaville, and Vallejo)
SWP Settlement and Long-Term Table A Contractors	
U_11_NU1	Thermalito Power Canal (Thermalito ID)
U_12_13_NU1	West Branch Feather RM 015; Thermalito Power Canal (CalWater-Oroville); Palermo Canal
U_16_PU	Feather River RM 031 (Yuba City)
U_FVTB	North Bay Aqueduct CM 009 (Cities of Benicia, Fairfield, Vacaville, and Vallejo)
U_20_25_PU	North Bay Aqueduct CM 011 (City of Vacaville)
U_NAPA	North Bay Aqueduct RM 027 (Napa County FC&WCD)
Non-Project Diverters	
U_12_13_NU2	Miners Ranch Reservoir (South Feather Water and Power Agency)
U_14_15N_NU	Yuba River RM 003 (City of Marysville)
U_20_25_NU	Sacramento River RM 074 (Cities of Davis and Woodland)
U_24_NU1	Wise Canal CM 004; Lower Boardman Canal CM 038 (Placer County WA - Zone 1, Nevada ID)
U_24_NU2	South Canal CM 004; Auburn Tunnel CM 002 (Placer County WA - Zone 1)
U_26_NU1	American River RM 007 (City of Sacramento wholesale agreements)
U_26_NU2	American River RM 017 (Carmichael WD)
U_26_NU3	Sacramento River RM 062; American River RM 007 (City of Sacramento)
U_26_NU4	American River RM 007 (City of Sacramento)
U_26_NU5	Folsom Reservoir (Aerojet)
U_26_NU6	Folsom Reservoir (Parks and Recreation)
U_60N_NU2	Cosumnes River RM 033 (Rancho Murieta)
U_60S_NU1	Calaveras River RM 026; Mokelumne River RM 035; San Joaquin River RM 028; Farmington Reservoir (City of Stockton)
U_ANTOC	Contra Costa Canal CM 007; San Joaquin River RM 006 (City of Antioch)
U_CLLPT	Clear Lake (lakeshore communities)
U_EBMUD	Mokelumne Aqueduct CM 057 (East Bay MUD)
U_JLIND	Calaveras River RM 043 (Jenny Lind)
U_PCWA3	Lower Boardman Canal CM 010 (Placer County WA - Zone 3)

Key: CM=Canal Mile; CSA=County Service Area; CSD=Community Service District; CVP=Central Valley Project; EBMUD=East Bay Municipal Utility District; FC&WCD=Flood Control and Water Conservation District; ID=Irrigation District; RM=River Mile; SMUD = Sacramento Municipal Utility District; SWP=State Water Project; WA=Water Agency; WC=Water Company; WD=Water District.

Table 3-8. Surface Water Diversions by Refuge Demand Unit

Demand Unit	Surface Diversion(s)
R_08_PR	Glenn-Colusa Canal CMs 027 & 056
R_09_PR	Sacramento River RM 196
R_11_PR	Thermalito Reservoir
R_17_NR	Butte Creek RM 012
R_17_PR1	Thermalito Reservoir
R_17_PR2	Feather River RM 039

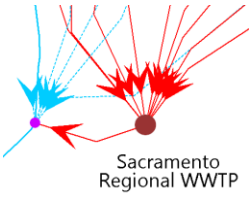
Key: CM=Canal Mile; RM=River Mile.

3.9 Water Treatment Plants

The WEAP software does not have an object for representing water treatment plants. However, SacWAM does represent several water treatment plants indirectly using a combination of diversion arcs and transmission links. The diversion arc represents the river intake to the water treatment plant; the transmission links connect the diversion to the urban demand unit and represent the distribution system downstream from the water treatment plant. Water treatment plants are represented in this manner where they serve more than one demand unit. Examples include the City of Redding's Foothill WTP, City of Sacramento's Sacramento WTP and Fairbairn WTP, Sacramento County WA's Vineyard WTP, El Dorado ID's El Dorado Hills WTP, City of Roseville's WTP, San Juan WD Petersen WTP, and Carmichael WD's Bajamont WTP.

3.10 Wastewater Treatment Plants

SacWAM defines wastewater return flows for each urban demand unit. Treated wastewater from large urban centers, with dedicated or regional wastewater treatment plants, may be discharged to surface waters. However, in most rural areas and smaller communities, wastewater typically is discharged to private septic systems or evaporation ponds, which recharge the underlying groundwater aquifer. Wastewater treatment plants are explicitly represented in SacWAM in cases where they have a capacity greater than 5 million gallons per day (mgd) and discharge treated water to a surface water body. WEAP "Wastewater Treatment Plant" objects are represented by a brown circle.



Wastewater treatment plants that discharge to surface waters were identified from the NPDES permits database (EPA, 2014). Those represented in SacWAM are listed in Table 3-9, together with their discharge permit capacity and average dry weather discharge rate, where available.

Table 3-9. Wastewater Treatment Plants Represented in SacWAM

	Facility Data		Surface Water Discharge			
Facility	**Operator**	**Treated Wastewater[1] (mgd)**	**Receiving Waters**	**SacWAM River Mile**	**Permit Capacity[2] (mgd)**	**Fraction of Wastewater Discharged[3]**
Anderson WPCP	City of Anderson	1.4	Sacramento River	281	2.0	100%
Auburn WWTP	City of Auburn	–	Auburn Ravine	027	1.7	100%
Chico WPCP	City of Chico	7.0	Sacramento River	195	9.0	100%
Clear Creek WWTP	City of Redding	9.6	Sacramento River	287	8.8	100%
Cottonwood WWTP	Shasta CSA #17	0.3	Cottonwood Creek	281	0.4	100%
Dry Creek WWTP	City of Roseville	10.0	Dry Creek	012	18.0	100%
Easterly WWTP	City of Vacaville	14.9	Alamo Creek	005 (Cache Slough)	6.9	100%
Lake California WWTP	Rio Alto WD	0.2	Sacramento River	281	0.6	100%
Lincoln WWTP	City of Lincoln	2.8	Auburn Ravine	002 (Natomas Cross Canal)	1.4	100%
Linda WWTP	Linda WD	1.3	Feather River	025	6.7	100%
Oroville WWTP	Sewage Commission Oroville Region	3.0	Feather River	063	6.5	100%
Red Bluff WWTP	City of Red Bluff	1.4	Sacramento River	240	2.5	100%
Sacramento Regional WWTP	Sacramento Regional County Sanitation District	142.2	Sacramento River	048	181.0	100%
Stillwater Regional WWTP	City of Redding	4.0	Sacramento River	281	4.0	100%
Stockton Regional Wastewater Control Facility	City of Stockton	28.0	San Joaquin River	042	55.0	100%
White Slough WPCF	City of Lodi	6.3	White Slough	028 (San Joaquin River)	8.5	100%
Willows WWTP	City of Willows	–	Drain Ditch	049 (Colusa Basin Drain)	1.1	100%
Woodland WPCF	City of Woodland	5.6	Tule Canal	032 (Yolo Bypass)	7.8	100%
Yuba City WWTP	City of Yuba City	8.9	Feather River	028	10.5	75%

Notes:

[1] Estimated dry weather flow for 2010. Values were obtained from 2010 urban water management plans, wastewater system master plans, and other sources. The symbol "–" indicates that no historical data were collected as part of the CalSim Hydrology Development Project. One mgd is equivalent to 1,120 acre-feet per year.

[2] Source: Permit Compliance System (PCS) database (Environmental Protection Agency, 2014), a computerized management system which contains data on National Pollutant Discharge Elimination System (NPDES) permit holding facilities. http://oaspub.epa.gov/enviro/ef_home2.water.

[3] The fraction of treated water that is discharged to surface water is assumed equal to 100 percent unless specific information (including reuse) is published in 2010 urban water management plans. For modeling purposes, treated wastewater not discharged to surface waters is assumed to percolate to groundwater.

Key: CSA=community service area; mgd=million gallons per day; WD=water district; WPCF=water pollution control facility; WPCP=water pollution control plant; WWTP=wastewater treatment plant.

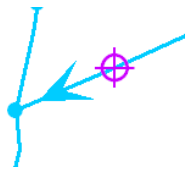
3.11 Return Flows

In SacWAM, WEAP's return flow arcs are associated with urban demand units and represent discharge of treated wastewater to either a surface body or the underlying groundwater aquifer. Table 3-9 lists the major wastewater return flows to surface water. Twenty-two urban demand units discharge all treated water to groundwater; in some instances to two or more groundwater basins. Three demand units

discharge treated water to a mix of surface water and groundwater. Thirty-four demand units discharge all treated wastewater water to a surface water body. In the Sacramento metropolitan area, return flows from nine demand units are aggregated at the the Sacramento Regional WWTP and subsequently discharge to the Sacarmento River below the Freeport gauge.

Demand unit NIDDC_NA is an exception in the SacWAM schematic, being an agricultural demand represented by a WEAP demand site object. Irrigation return flows are represented using a Return Flow arc, rather than a Runoff/Infiltration arc.

3.12 Flow Requirements



WEAP "Instream Flow Requirement" objects are represented by a purple circle and cross. Three types of flow requirements are represented in the SacWAM schematic. They are distinguished by their prefix as follows:

- REG: Flow requirements that are regulatory in nature.
- OPS: Flow requirements that are used to drive upstreamstorage regulation or diversions through canals and tunnels.
- SWRCB: Potential new regulatory flow requirements where the flow requirement is specified as a fraction of the unimpaired flow.

Flow requirements are discussed in greater details in Sections 6.1.3 and 7.2.3. Table 3-11 lists the regulatory instream flow requirements included in the schematic. Table 3-10 lists potential instream flow requirements that may be implemented as part of the revised Bay-Delta Plan.

3.13 Run of River Hydro Plants

WEAP includes "Run of River Hydro" objects to simulate hydropower generation. However, these objects are not used in SacWAM.

Table 3-10. Instream Flow Requirements Represented in SacWAM

Name	River	Description
REG American IFR	American River	Lower American River Flow Management Standard
REG D893 H St	American River	1958 WRD-893
REG Bear R blw CFW	Bear River	1994 Settlement Agreement between DWR, South Sutter WD, and Camp Far West ID.
REG CA Health and Safety	California Aqueduct	Minimum export at Banks Pumping Plant to meet Health and Safety flow requirements
REG Clear Ck IFR	Clear Creek	Combination fo 1960 MOA between DWR and CDFG, (b)2 actions, and 2009 NMFS BiOp
REG DMC Health and Safety	Delta-Mendota Canal	Minimum export at Jones Pumping Plant to meet Heath and Safety flow requirements
REG HighFlow Channel	Feather River	1986 MOU between CDFG and DWR
REG LowFlowChannel	Feather River	1986 MOU between CDFG and DWR
REG Verona	Feather River	1986 MOU between CDFG and DWR
REG Kellog Creek IFR	Kellogg Creek	SWRCB D-1629: Los Vaqueros Project
REG blw Camanche	Mokelumne River	1998 Joint Settlement Agreement and FERC license for the Lower Mokelumne Hydroelectric Project (FERC No. 2916).
REG Below Woodbridge Diversion Dam	Mokelumne River	1998 Joint Settlement Agreement and FERC license for the Lower Mokelumne Hydroelectric Project (FERC No. 2916).
REG X2	Net Delta Outflow	Outflow to meet D-1641 X2 requirements and USFWS 2009 BO Fall X2 requirement
REG MRDO	Net Delta Outflow	Outflow to meet D-1641 flow requirements
REG Below PG&E Dams	NF Mokelumne River	2001 FERC license for the North Fork Mokelumne Project (FERC No. 137)
REG Below Electra Powerhouse	NF Mokelumne River	2001 FERC license for the North Fork Mokelumne Project (FERC No. 137)
REG Below Electra Dam	NF Mokelumne River	2001 FERC license for the North Fork Mokelumne Project (FERC No. 137)
REG Lower Putah Diversion Dam	Putah Creek	2000 Putah Creek Accord/Settlement Agreement flow requirements below Putah Diversion Dam.
REG Lower Putah I80 Bridge	Putah Creek	2000 Putah Creek Accord/Settlement Agreement flow requirements at I-80 road bridge
REG Delta Salinity GModel	Sacramento River	Outflow to meet D-1641 flow requirements using G-model. Not active.
REG Sac at Rio Vista	Sacramento River	D-1641 flow requirement
REG Sac bw Keswick	Sacramento River	Combination of CVPIA (b)2 actions, WR90-5, and 2009 NMFS BiOp.
REG Vernalis	San Joaquin River	Not active
REG Trinity IFR	Trinity River	2001 Trinity River Record of Decision
REG Yuba River nr Marysville	Yuba River	Lower Yuba River Accord/SWRCB Revised WRD-1644.
REG Yuba River nr Smartville	Yuba River	Lower Yuba River Accord/SWRCB Revised WRD-1644.

Key: BiOp=Biological Opinion; CVPIA=Central Valley Improvement Act; DWR=Department of Water Resources; FERC=Federal Energy Regulatory Commision; ID=Irrigation District; MOU=Memorandum of Understanding; NF=North Fork; WD=Water District; WRD=Water Right Decision; SWRCB=State Water Resources Control Board;

Table 3-11. State Water Board Potential Instream Flow Requirements Represented in SacWAM

Name	River	Location
SWRCB American River	American River	Confluence with Sacramento River
SWRCB Antelope Creek	Antelope Creek	Confluence with Sacramento River
SWRCB Battle Creek	Battle Creek	Confluence with Sacramento River
SWRCB Bear River	Bear River	Confluence with Sacramento River
SWRCB Big Chico	Big Chico Creek	Confluence with Sacramento River
SWRCB Black Butte	Stony Creek	Confluence with Sacramento River
SWRCB Butte Creek	Butte Creek	Confluence with Butte Slough
SWRCB Cache Creek	Cache Creek	Confluence with Yolo Bypass
SWRCB Calaveras River	Calaveras River	Confluence with San Joaquin River
SWRCB Camanche	Mokelumne River	Below Camanche Dam
SWRCB Camp Far West	Bear River	Below Camp Far West Dam
SWRCB Clear Creek	Clear Creek	Confluence with Sacramento River
SWRCB Clear Lake	Cache Creek	Below Cache Creek Dam
SWRCB Cosumnes River	Cosumnes River	Confluence with Mokelumne River
SWRCB Cottonwood Creek	Cottonwood Creek	Confluence with Sacramento River
SWRCB Cow Creek	Cow Creek	Confluence with Sacramento River
SWRCB Deer Creek	Deer Creek	Confluence with Sacramento River
SWRCB Delta	Sacramento River	Net Delta outflow
SWRCB Englebright	Yuba River	Below Englebright Dam
SWRCB Feather River	Feather River	Confluence
SWRCB Folsom	American River	Confluence
SWRCB Lake Berryessa	Putah Creek	Below Monticello Dam
SWRCB Mill Creek	Mill Creek	Confluence
SWRCB Mokelumne River	Mokelumne River	Upstream from confluence with Cosumnes River
SWRCB New Hogan	Calaveras River	Below New Hogan Dam
SWRCB Oroville	Feather River	Below Oroville Dam
SWRCB Putah Creek	Putah Creek	South Fork Putah Creek near Davis
SWRCB Sac ab Bend Bridge	Sacramento River	USGS Bend Bridge Gauge
SWRCB Sac at Butte City	Sacramento River	DWR Butte City Gauge
SWRCB Sac at Colusa	Sacramento River	Below Colusa Weir
SWRCB Sac at Freeport	Sacramento River	USGS Freeport gauge
SWRCB Sac at Hamilton	Sacramento River	DWR Hamilton Gauge
SWRCB Sac at Knights Landing	Sacramento River	Below Colusa Basin Drain outfall
SWRCB Sac at Ord Ferry	Sacramento River	DWR Ord Ferry Gauge
SWRCB Sac at Rio Vista	Sacramento River	Rio Vista Gauge
SWRCB Sac at Verona	Sacramento River	USGS Verona Gauge
SWRCB Sac at Vina	Sacramento River	DWR Vina Bridge Gauge
SWRCB Sac bw Wilkins Slough	Sacramento River	BUSGS Wilkins Slough Gauge
SWRCB Shasta	Sacramento River	Below Shasta Dam
SWRCB Stony Creek	Stony Creek	Confluence with Sacramento River
SWRCB Thomes Creek	Thomes Creek	Confluence with Sacramento River
SWRCB Trinity	Trinity River	Below Trinity Dam
SWRCB Yuba River	Yuba River	Confluence with Sacramento River

3.14 Streamflow Gauges

WEAP streamflow gauge objects allow rapid comparison of simulated flows to historical observed data using the WEAP results view. Gauge objects have also been included in SacWAM to help orientate the model user. They are represented by a blue circle with an associated diagonal arrow. SacWAM gauge names are prefixed with "HIS" to indicate associated data are historical observed mean monthly flows. The designation "FNF" indicates that full natural flow data[6] are available for the gauge.

Table 3-12 lists the gauges included in the model.

[6] For the purposes of this report "Full Natural Flow" indicates that observed gauge flows have been unimpaired for: (a) upstream storage regulation, (b) upstream reservoir evaporation, and (c) upstream imports and exports.

Table 3-12. Streamflow Gauges Represented in SacWAM

River/Channel	Gauge[1]	Gauge ID
Antelope Creek	HIS Antelope Ck nr Red Bluff	11379000
American River	HIS at Fair Oaks	11446500
Battle Creek	HIS Battle Ck nr Cottonwood	11376550
Bear River	HIS Bear bw Drum Afterbay	11421750_60_70
Bear River	HIS Bear bw Dutch Flat Afterbay	11421780_90
Bear River	HIS Bear bw Rollins Dam	11422500
Bear Creek	HIS Bear Ck nr Millville	11374100
Bear River	HIS Bear nr Wheatland	11424000
Bear River Canal	HIS Bear River Canal at Intake	11422000
Big Chico Creek	HIS Big Chico Ck nr Chico	11384000
Bowman Spaulding Conduit	HIS Bowman Spaulding Canal at Intake	11416000
Butte Creek	HIS Butte Ck nr Chico	11390000
Butte Creek	HIS Butte Ck nr Durham	11390010
Butte Slough	HIS Butte Slough nr Meridian	A02972
Butte Slough Outfall Gates	HIS Butte Slough Outfall Gates	A02967
Cache Creek	HIS Cache Ck ab Rumsey	11451760
Cache Creek	HIS Cache Ck at Yolo	11452500
Cache Creek	HIS Cache Ck nr Lower Lake	11451000
Camptonville Tunnel	HIS Camptonville Tunnel at Intake	11409350
Canyon Creek	HIS Canyon Ck bw Bowman	11416500
Clear Creek	HIS Clear Ck nr Igo	11372000
Colusa Basin Drain	HIS Colusa Basin Drain at Knights Landing	A02945
Colusa Basin Drain	HIS Colusa Basin Drain nr Highway 20	A02976
Colusa Weir	HIS Colusa Weir Spill to Butte Basin	A02981
Cosumnes River	HIS Cosumnes at Michigan Bar	11335000
Cottonwood Creek	HIS Cottonwood Ck nr Cottonwood	11376000
Cottonwood Creek	HIS Cottonwood Ck nr Olinda	11375810
Cow Creek	HIS Cow Ck nr Millville	11374000
Deer Creek Yuba	HIS Deer Ck nr Smartville	11418500
Deer Creek	HIS Deer Ck nr Vina	11383500
South Yuba Canal	HIS Deer Ck PH nr Washington	11414205
Drum Canal	HIS Drum Canal at Tunnel Outlet	11414170
Dry Creek Mok	HIS Dry Ck nr Ione	11328000
El Dorado Canal	HIS El Dorado Canal nr Kyburz	11439000
Elder Creek	HIS Elder Ck nr Paskenta	11379500
Feather River	HIS Feather at Oroville	11407000
Feather River	HIS Feather nr Nicolaus	11425000
Feather River	HIS Feather River nr Gridley	A05165
Fordyce Creek	HIS Fordyce Ck bw Fordyce Dam	11414100
Fremont Weir	HIS Freemont Weir Spill	A02930
French Meadows Hell Hole Tunnel	HIS French Meadows PH	11427200
Georgiana Slough	HIS Georgiana Slough	11447903
Gerle Creek	HIS Gerle Creek bw Loon Lake	11429500
Joint Board Canal	HIS Joint Board Canal	11406910
Jones Fork Tunnel	HIS Jones Fork PH	11440900
Clear Creek Tunnel	HIS Judge Francis Carr Powerhouse	11525430
Kelly Ridge Powerhouse	HIS Kelly Ridge PH nr Oroville	11396329
Lohman Ridge Tunnel	HIS Lohman Ridge Tunnel at Intake	11408870
Marsh Creek	HIS Marsh Ck nr Byron	11337500
McCloud River	HIS McCloud R above Shasta Lake	11368000
Middle Fork American River	HIS MF American at French Meadows	11427500
Middle Fork Feather River	HIS MF Feather nr Merrimac	11394500
Middle Fork Yuba River	HIS MF Yuba bw Milton Dam	11408550
Middle Fork Yuba River	HIS MF Yuba bw Our House Dam	11408880
Hell Hole Tunnel	HIS Middle Fork Powerplant	11428600
Mill Creek	HIS Mill Ck nr Los Molinos	11381500
Milton Bowman Tunnel	HIS Milton Bowman Tunnel at Outlet	11408000
Mokelumne River	HIS Mokelumne at Mokelumne Hill	11319500
Mokelumne River	HIS Mokelumne at Woodbridge	11325500
Mokelumne River	HIS Mokelumne River bw Camanche Dam	11323500

Table 3-12. Streamflow Gauges Represented in SacWAM contd.

River/Channel	Gauge[1]	Gauge ID
Moulton Weir	HIS Moulton Weir Spill A02986	A02986
South Canal	HIS Newcastle PP nr Newcastle	11425416
North Fork American River	HIS NF American at NF Dam	11427000
North Fork American River	HIS NF American nr Colfax	11426500
North Fork Feather River	HIS NF at Pulga	11404500
North Fork Cache Creek	HIS NF Cache Ck nr Clear Lake Oaks	11451300
North Fork Feather River	HIS NF Feather nr Prattville	1139950
Yuba River	HIS NF Yuba bw Goodyears Bar	11413000
Oregon Creek	HIS Oregon Ck bw Log Cabin Dam	11409400
Paynes Creek	HIS Paynes and Sevenmile Cks	11377500
Pit and Upper Sacramento River	HIS Pit R near Montgomery Ck	11365000
Pit and Upper Sacramento River	HIS Pit R nr Bieber	11352000
Putah Creek	HIS Putah Ck bw Diversion Dam	n/a
Putah Creek	HIS Putah Ck nr Winters	11454000
Putah South Canal	HIS Putah South Canal	11454210
Richvale Canal	HIS Richvale Canal	11406890
Robbs Peak Tunnel	HIS Robbs Peak PP	11429300
Rubicon River	HIS Rubicon bw Hell Hole Dam	11428800
Honcut Creek	HIS S Honcut Ck nr Bangor	11407500
Sacramento River	HIS Sacramento ab Bend Bridge	11377100
Sacramento River	HIS Sacramento at Butte City	11389000
Sacramento River	HIS Sacramento at Colusa	11389500
Sacramento River	HIS Sacramento at Freeport	11447650
Sacramento River	HIS Sacramento at Hamilton City	A02630
Sacramento River	HIS Sacramento at Keswick	11370500
Sacramento River	HIS Sacramento at Ord Ferry	A02570
Sacramento River	HIS Sacramento at Verona	11425500
Sacramento River	HIS Sacramento at Vina	A02700
Sacramento River	HIS Sacramento River above Delta	11342000
Sacramento River	HIS Sacramento River at Rio Vista	11455420
Sacramento River	HIS Sacramento River bw Wilkins Slough	11390500
Sutter Bypass	HIS Sacramento Slough nr Karnak	A02926
Sacramento Weir	HIS Sacramento Weir	11426000
San Joaquin River	HIS San Joaquin nr Vernalis	11303500
South Fork American River	HIS SF American nr Kyburz	11439500
South Fork American River	HIS SF American nr Placerville	11444500
South Fork Cottonwood Creek	HIS SF Cottonwood Ck nr Olinda	11375870
South Fork Feather River	HIS SF Feather bw Diversion Dam	11395200
South Fork Feather River	HIS SF Feather bw Forbestown	11396200
South Fork Feather River	HIS SF Feather bw Little Grass Valley	11395030
South Fork Silver Creek	HIS SF Silver Creek nr Ice House	11441500
South Fork Yuba River	HIS SF Yuba at Jones Bar	11417500
Slate Creek Tunnel	HIS Slate Ck Diversion Tunnel	11413250
Slate Creek	HIS Slate Creek bw Diversion Dam	11413300
South Fork Tunnel	HIS South Fork Tunnel nr Strawberry	11395150
South Yuba Canal	HIS South Yuba Canal nr Emigrant Gap	11414200
Spring Creek Conduit	HIS Spring Creek Powerhouse at Keswick	11371600
Power Canal	HIS Thermalito Afterbay Release	11406920
Power Canal	HIS Thermalito Power Plant	11406850
Thomes Creek	HIS Thomes Ck at Paskenta	11382000
Tisdale Weir	HIS Tisdale Weir Spill to Sutter Bypass	A02960
Toadtown Canal	HIS Toadtown Canal ab Butte Canal	11389800
Trinity River	HIS Trinity at Lewiston	11525500
Wise Canal	HIS Wise PH nr Auburn	11425415
Yolo Bypass	HIS Yolo Bypass nr Woodland	11453000
Yuba River	HIS Yuba bw Englebright nr Smartville	11418000
Yuba River	HIS Yuba River nr Marysville	11421000
Western Canal	HISWestern Canal and PGE Lateral	11406880

Note: SacWAM gauges are prefixed with 'HIS' to indicate associated data are historical observed mean monthly flows.

3.15 Data Directory

Table 3-13 provides file location information relating to the "SacWAM data and information" DVD for the datasets referenced in this chapter.

Table 3-13. File Location for SacWAM Schematic Construction

Referenced Name	File Name	File Location
American boundaries	AmRiv_blw_Ntms_Sheds_v20130730.shp	GIS\Boundaries
Bulletin 118 GW basins	B118_BasinBoundaries_v41.shp	GIS\Hydrology
canal miles	sac_val_canal_miles.shp	GIS\Hydrology
demand units	sac_val_demand_units.shp	GIS\Boundaries
flow accumulation	nhdplusfac18b, nhdplusfac18c	GIS\Hydrology
groundwater basin intersection	sac_val_groundwater_intersection.shp	GIS\Hydrology
groundwater basins	sac_val_groundwater_basins.shp	GIS\Hydrology
groundwater functions	GroundwaterFunctions.xlsm	Data\Supply_and_Resources\Groundwater\
gw basins spreadsheet	SACVAL_Groundwater.xlsx	Data\Supply_and_Resources\Groundwater\
HUC-12 watersheds	NRCS_HUC12s.shp	GIS\Hydrology
returns intersection	sac_val_returns_intersection.shp	GIS\Hydrology
river miles	sac_val_stream_miles.shp	GIS\Hydrology
surface returns	SACVAL_Surface_Runoff_and_Returns.xlsx	Data\Supply_and_Resources\Runoff_Infiltration_and_Return_Flows
valley floor returns	sac_val_returns.shp	GIS\Hydrology
water budget areas	water_budget_areas.shp	GIS\Boundaries
watershed boundaries	sac_val_watersheds.shp	GIS\Hydrology