Chapter 7 Other Assumptions

The "Other Assumptions" branch in WEAP holds parameters that are developed for a specific application. Other Assumptions allows for the development of model logic that is more complex than that directly supported by the interface screens related to the schematic objects.

The Other Assumptions in SacWAM are used to formulate operational constraints which include the following:

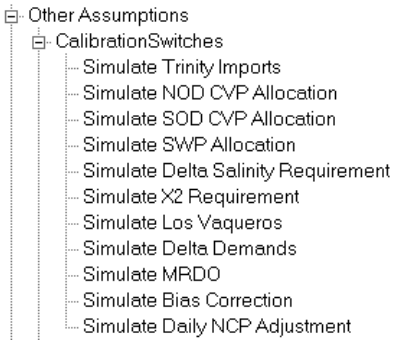
1. Project allocations
2. Project reservoir operations
3. Non-project reservoir operations
4. Flow requirements
5. Demand priorities
6. CVP/SWP water sharing agreements
7. Delta salinity and operations
8. Water supply forecasts and hydrologic indicies

This Chapter describes the Other Assumptions created for SacWAM, following the order of the WEAP data tree.

7.1 Calibration Switches

The Other Assumptions contain calibration switches that allow the user to force portions of the model to operate using predefined values. <u>These switches were used to calibrate the model and will generally not be altered by future users of SacWAM</u>. In general, "0" causes the model to use values derived from historical data or CalSim II; a value of "1" causes the model to use simulated values generated by SacWAM and catchments as defined in SacWAM. Switches are included for the following:

- Trinity imports
- North of Delta CVP allocation
- South of Delta CVP allocation
- SWP allocation
- Delta salinity requirement
- X2 requirement
- Los Vaqueros Reservoir
- Delta demands
- Minimum required Delta outflow



7.1.1 Simulate Trinity Imports

SacWAM offers two methods for setting Trinity River imports: the first sets these imports equal to a timeseries of historical Clear Creek Tunnel flows; the second uses import logic that assesses current storage levels in Trinity and Shasta to dynamically determine Trinity River imports. A "Simulate Trinity Imports" value of 1 indicates the decision to use the simulation logic, otherwise SacWAM will use historical import values. The import logic is discussed in Section 7.2.16.

7.1.2 Simulate NOD CVP Allocation

SacWAM includes a switch that allows the model user to fix CVP allocations north of the Delta to those simulated by CalSim II (as determined for the 2015 SWP Delivery Capability Report [DWR, 2015]). A "Simulate NOD CVP Allocation" value of 0 indicates SacWAM will use simulated values from CalSim II; a value of 1 indicates that SacWAM will use its own allocation logic.

7.1.3 Simulate SOD CVP Allocation

SacWAM includes a switch that allows the model user to fix CVP allocations south of the Delta to those simulated by CalSim II (2015 SWP Delivery Capability Report). A "Simulate SOD CVP Allocation" value of 0 indicates SacWAM will use simulated values from CalSim II; a value of 1 indicates that SacWAM will use its internal CVP allocation logic.

7.1.4 Simulate SWP Allocation

Similar to the CVP, SacWAM includes a switch that allows the model user to constrain SacWAM to SWP allocations from the CalSim II 2015 SWP Delivery Capability Report. A "Simulate SWP Allocation" value of 0 sets the model allocations equal to the CalSim II data; a value of 1 enables dynamic calculation in SacWAM.

7.1.5 Simulate Delta Salinity Requirement

Various switches allows the model user to constrain SacWAM to Delta salinity requirements from the CalSim II 2015 SWP Delivery Capability Report. For a "Simulate Delta Salinity Requirement" value of 0. The model uses CalSim II data to determine the net Delta outflow required for salinity control. A value of 1 enables dynamic calculation of the requirement using the ANN embedded in SacWAM. This is further discussed in section 7.2.6.3.

7.1.6 Simulate X2 Requirement

SacWAM includes an IFR object on net Delta outflow to simulate D-1641 and USFWS BiOP requirements for the X2 location. The "Simulate X2 Requirement" switch allows the model user to set this instream flow requirement to values determined by CalSim II for the 2015 SWP Delivery Capability Report. A "Simulate X2 Requirement" value of 0 sets SacWAM to use the CalSim II data; a value of 1 enables a dynamic calculation.

7.1.7 Simulate Delta Demands

The representation of in-Delta water use is discussed in section 3.8.3.14. The "Simulate Delta Demands" switch allows the user to choose between simulating Delta agricultural demands using the WEAP catchment objects or using a timeseries of Delta channel accretions and depletions based on the CalSim II 2015 SWP Reliability Report. A value of 0 sets SacWAM to use the CalSim II data, a value of 1 enables the SacWAM Delta catchment objects and dynamic calculation of Delta diversions and return flows.

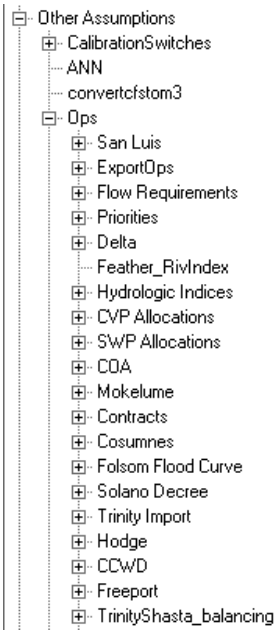
7.1.8 Simulate MRDO

The "MRDO" switch serves a purpose similar to Simulate X2 Requirement. When set to a value of 0, SacWAM uses CalSim II based values of D-1641 minimum required Delta outflow (MRDO) from the 2015

SWP Delivery Capability Report. A value of 1 enables dynamic calculation of this outflow requirement using SacWAM's internal rules.

7.1.9 Simulate Bias Correction

The "Simulate Bias Correction" switch allows the model user to activate inflow bias corrections implemented on the Sacramento River at Bend Bridge, Butte City, and Freeport. The corrections applied just upstream from the Bend Bridge gauge (RM 258) and Butte City gauge (RM 170) are based on a historical water balance of river inflows and outflows for the reach Shasta to Bend Bridge and the reach Bend Bridge to Butte City. Components of the flow balance include observed streamflow data, historical storage regulation and evaporation, historical trans-watershed imports, unimpaired inflows as used in SacWAM, historical stream diversions, and estimates of historical rainfall-runoff, historical irrigation return flows, and historical groundwater inflows. In the winter and spring, the residual or closure term in the flow balance is attributed to errors in the SacWAM unimpaired inflows. In many cases these inflows were derived from an extension of incomplete gauge data using statistical methods. Bias corrections are applied for the November – March period when unimpaired flows are the dominant component of the flow balance. Outside of these months, errors in the other flow balance terms are likely to be of similar magnitude to errors in in the SacWAM unimpaired inflows.



The correction at Freeport is different in nature. Its purpose is to give the model user the option of aligning the SacWAM hydrology to that of CalSim II. This option should be exercised when it is important to have consistency between the two models, e.g., in a comparison of simulated CVP/SWP operations. However, the model user should not infer any judgment regarding the relative accuracy of the two models. The correction is calculated as the difference between SacWAM and CalSim II combined simulated flows for the Sacramento River at Freeport and the Yolo Bypass at the Lisbon Weir, after removing the effects of upstream CVP/SWP storage regulation and Trinity imports. Thus, this correction adjusts for differences in model hydrology *and* for differences in model simulation of non-project tributaries.

7.1.10 Simulate Daily NCP Adjustment

The "Simulate Daily NCP Adjustment" switch allows the user to activate an adjustment to the Navigation Control Point (NCP) flow requirement for the Sacramento River below Wilkins Slough. This adjustment is used in CalSim II to determine the additional releases which are needed to meet the NCP requirement because of differences between monthly averaged inflows and daily flows. The switch is turned off by default in SacWAM, but can be activated for making comparisons to CalSim II.

7.2 Ops (Valley Floor Operations Rules)

Water management within the Sacramento Valley is subject to many regulatory standards. These standards are most commonly enacted as IFRs. These regulations influence the way that water

managers (including, but not limited to, the CVP and SWP) allocate and distribute water throughout the valley. SacWAM includes logic that represents the regulations and the project operations.

Operation rules parameters appear in the WEAP tree under *Other Assumptions\Ops*. The expressions that define various rules are grouped under different categories (e.g. demand priorities, flow requirements, COA, etc.). These parameters are explained in more detail in the following sections.

7.2.1 San Luis Reservoir

San Luis Reservoir is an off-stream facility in the eastern part of the Diablo Range, west of the San Joaquin Valley. Water from the Delta is delivered to San Luis Reservoir via the California Aqueduct and DMC for temporary storage during the rainy season. During the dry season, this stored water is released for use by CVP and SWP water contractors south of the Delta. San Luis Reservoir also provides water to the Santa Clara Valley Water District and the San Benito County Water District. Water is delivered to these users through CVP's San Felipe Division on the west side of the reservoir.

In SacWAM, San Luis Reservoir is represented using two reservoir objects, one for the CVP pool and one for the SWP pool, as shown in Figure 7-17-1 This was done in order to more accurately simulate the complex operations of the reservoir. Each reservoir has two routes for receiving water from their respective supply canals. Water is first drawn into the reservoir to fill the reservoir to its "rule curve" subject to water availability in north-of-Delta reservoirs and restrictions on flows in the Delta. If there is excess water available in the Delta, additional water is drawn into the reservoir using priorities that differentiate between volumes above (conservation storage) and below (buffer storage) rule curve. This allows the reservoir to be filled using "excess" water that is most typically present in wetter months of winter ().

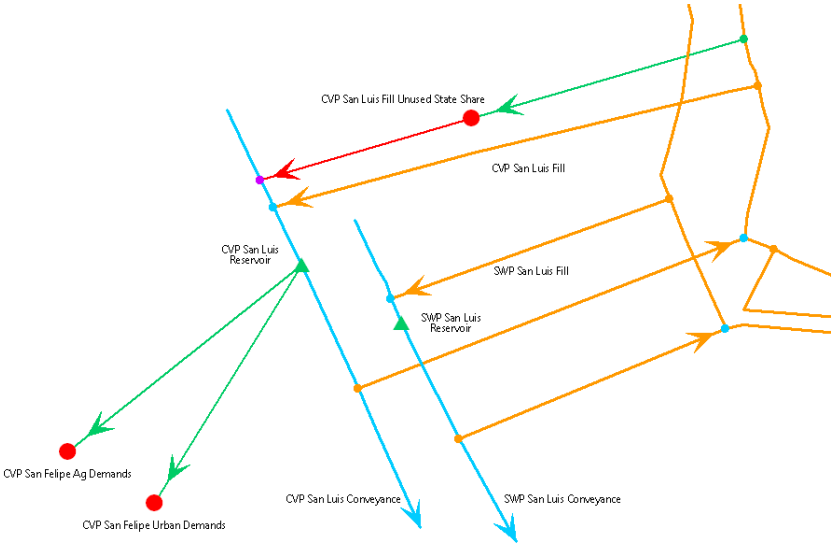


Figure 7-1. Schematic Representation of San Luis Reservoir

San Luis Reservoir is set up within SacWAM to fill during the fall and winter (October through March) and release during the spring and summer (April through September). This is accomplished by using a combination of priorities, target storages, and pumping limits. The priority for storage in San Luis

Reservoir is set such that water is pumped into the reservoir only after all other demands (agricultural, urban, and environmental) have been met, including meeting target storage for CVP/SWP reservoirs north of the Delta. The target storage for San Luis Reservoir is set to fill the reservoir from its low point—generally at the end of August—to its maximum capacity (2.04 million acre-feet, or MAF) by the end of March. Target storages defined by the rule curves define the desired volume of water to be released from north-of-Delta reservoirs to be pumped into San Luis.

There are separate parameters for CVP and SWP operations, which are identical to the parameters used in the CalSim II model. These parameters are explained in the following sections.

7.2.1.1 *Capacity*

Static values; 972 TAF for CVP, 1067 TAF for SWP. Sum represents total capacity of San Luis Reservoir (2.04 MAF).

7.2.1.2 *Carryover_est*

SWP Only: Estimate of SWP carryover deliveries based on relationship with Oroville storage in CalSim II. WEAP does not simulate carryover deliveries, but this value is used so that SWP San Luis rule curve mimics CalSim II in October-December.

7.2.1.3 *DrainTarget*

For CVP this is 90 TAF plus 10% of CVP South-of Delta Annual Delivery Target minus 2000 TAF. For SWP this is 110 TAF.

7.2.1.4 *Delivery Target*

Annual delivery target for South-of-Delta deliveries.

7.2.1.5 *FillTarget*

Defines the target fill volume based on the *Delivery Target*.

7.2.1.6 *InactiveStorage*

Static values; 45 TAF for CVP, 55 TAF for SWP. Sum represents inactive storage at San Luis Reservoir (100 TAF).

7.2.1.7 *Observed*

This parameter reads historical values of CVP and SWP San Luis storage.

7.2.1.8 *OroDrainAmt4SL*

SWP only: Volume that can be moved from Oroville to SWP San Luis through the end of September, based on *OroSepTarg* and space available in SWP San Luis.

7.2.1.9 *OroDrainAmtMon*

SWP only: Volume that could be moved from Oroville to SWP San Luis in current month.

7.2.1.10 *OroSepTarg*

SWP only: End of September storage target for Oroville.

7.2.1.11 *Orovillestorage*

SWP only: Previous month storage in Oroville.

7.2.1.12 *Rule_Cap_Oroville*

SWP only: Maximum rule curve value based on Oroville storage.

7.2.1.13 *Rule_Cap_Shasta*

CVP only: Maximum rule curve value based on Shasta storage.

7.2.1.14 *RuleCurve*

Final calculation of rule curve, not less than *InactiveStorage* or more than *Capacity.*

7.2.1.15 *RuleCurveCalc*

Calculation of rule curve based on reservoir and fill and release requirements.

7.2.1.16 *Rule_max*

CVP only: maximum rule curve amount (1100 TAF).

7.2.1.17 *Rule_Sha_Cut*

CVP only: Cut in rule curve based on low Shasta storage conditions.

7.2.1.18 *SLCVP_storage*

CVP only: Previous month storage in CVP San Luis.

7.2.1.19 *SLSWP_storage*

SWP only: Previous month storage in SWP San Luis.

7.2.2 ExportOps

Exports from the Delta into the North Bay Aqueduct, Contra Costa Canal, DMC, and the California Aqueduct are limited by the physical capacities of the pumping stations and by regulatory standards within the Delta. These regulations include export limits based on inflows to the Delta and export limits based on San Joaquin River inflows during the spring pulse period (April 16 to May 15).

The following sections describe how these regulations are applied within SacWAM.

See also the section on Reverse Flows in the User-Defined Decision Variables and Constraints chapter (8.7).

7.2.2.1 *Vernalis Flow*

This parameter is simply the flow data of the San Joaquin River at Vernalis, pulled from *Supply and Resources\River\Inflow at Vernalis: Headflow*[CFS]. It plays a role in the USFWS Opinion Action 2 (7.2.1.14), the San Joaquin exports (7.2.2.6), both the Banks and Jones pumping plants' operations (7.2.2.2), the D-1641 rule (7.2.2.5), and the SWP operations (0).Pumping from the Delta at the Banks and Jones pumping plants is sometimes limited by San Joaquin River flows at Vernalis. These limits are discussed in greater detail in the following sections. SacWAM does not consider San Joaquin River water management operations upstream from Vernalis. Instead, the model reads in pre-processed timeseries of flows at Vernalis. The model offers two options for San Joaquin River flows: (1) CalSim II simulated flows at Vernalis or (2) timeseries of Vernalis flows developed by SWRCB as part of Phase 1 of the update to the Bay-Delta Plan. These flows are specified in SacWAM in the Data Tree under *Key Assumptions\Use Water Board Vernalis Inflow* (see Section 9.6).

7.2.2.2 *Banks and Jones*

The amount of water pumped at Banks and Jones is limited by physical and permit capacities at the two pumping plants. Under normal conditions, pumping is limited to their permit capacities. However, this is relaxed during certain months of the year if San Joaquin River flows at Vernalis exceed a threshold of 1000 cfs.

DaysIncrease

SWP Only: The number of days in the month where pumping is allowed to exceed the lower level permit capacity (i.e. Permit Cap1).

EWAReservedCap

SWP Only: The amount of capacity at the Banks pumping plant that is set aside to provide water for the environmental water account.

MaxAllow

The maximum amount of pumping that may occur at Banks and Jones Pumping Plants. This takes into account the physical capacities, permit capacities, and San Joaquin River flows at Vernalis.

MaxDiversion

The *MaxDiversion* is the minimum of the permitted capacity or D-1641 export limits imposed during the April-May pulse period.

MinPump

The minimum amount of export that needs to occur in order to meet health and safety (H&S) standards.

Permit Capacity

The maximum amount of water that is permitted to be pumped at the Jones Pumping Plant.

Permit Cap1

The maximum amount of water that is permitted to be pumped at the Banks Pumping Plant under dry-to-normal conditions (i.e. San Joaquin River flow at Vernalis is less than 1000 cfs).

Permit Cap2

The maximum amount of water that is permitted to be pumped at the Banks Pumping Plant under wet conditions (i.e. San Joaquin River flow at Vernalis greater than 1000 cfs during the period December 15th to March 15th).

Physical Capacity

The maximum amount of water that can physically be pumped at the Banks (4600 cfs) and Jones (10300 cfs) Pumping Plants.

7.2.2.3 *OMR*

The 2008 USFWS BiOp determined that the continued operation of the CVP and SWP would likely result in adverse modification to critical habitat of the delta smelt that would jeopardize the species' existence within the Delta. This jeopardy determination led to the development of a Reasonable and Prudent Alternative (RPA) that was designed to avoid the likelihood of these threats. RPA includes Components 1 and 2 that are intended to reduce Delta exports, as indexed by Old and Middle River (OMR) flows, when the entrainment risk of delta smelt increases. The implementation of these actions in SacWAM is described in the sections below.

OMR_background sets background flow standards at -5000 cfs from January to March and -8000 cfs from April to December in accordance with the RPA (Table 7-1).

Table 7-1. Old and Middle River Background Flow Standards

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
OMR Background	-8000 cfs			-5000 cfs			-8000 cfs					

2008 USFWS Biological Opinion Action 1

Action1 is intended for adult delta smelt entrainment protection during the winter pulse (December through March) and limits Delta exports so that OMR flows (*A1_OMR_Target*) are no more negative than -2,000 cfs for a total duration of 14 days when the three-day average turbidity at Prisoner's Point, Holland Cut, and Victoria Canal exceeds 12 nephelometric turbidity units (NTU). SacWAM uses the unimpaired Sacramento Valley Four Rivers Index (*SAC_RI*) (i.e. Sacramento River at Bend Bridge, Feather River at Oroville, Yuba River near Smartville, and American River at Folsom) as a surrogate for the turbidity trigger for this action—assuming that 20,000 cfs (*Turbidity_Threshold*) is a conservative indicator of the 12 NTU threshold.[11]

[11] It is important to note that using flows in this way implies that the unimpaired Sacramento Valley Four Rivers Index needs to be preprocessed for each climate scenario that SacWAM will run.

2008 USFWS Biological Opinion Action 2

Action2 is implemented as an adaptive process following Action 1 and is intended to protect pre-spawning adult delta smelt from entrainment after the winter pulse (January through April). Action 2 limits Delta exports so that OMR flows are no less negative than -5,000 to -3,500 cfs depending on existing conditions within the Delta. SacWAM uses the X2 position (see Section 7.2.6.1 in the Delta section of this chapter) as an indicator of existing Delta conditions. *X2_A2* looks to see whether X2 at the previous time step was east of Roe (>64 miles) or west of Roe (<64 miles); the model then uses the corresponding OMR standards (*OMR_Target_X2_E_Roe* or *OMR_Target_X2_W_Roe*) to determine the target flow for each month (*A2_OMR_Target*). The considerations for setting the Action 2 OMR standards are summarized in Table 7-2.

Table 7-2. Action 2 Old and Middle River Standard

	Minimum Flow (cfs)	
Sacramento Valley Water-Year Type	**X2 East of Roe (X2 > 64 miles)**	**X2 West of Roe (X2 < 64 miles)**
Critical	-3500	-5000
Dry	-3500	-5000
Below Normal	-3500	-5000
Above Normal	-3500	-5000
Wet	-3500	-5000

OMR flow requirements under Action 2 are suspended when the 3-day flow average is greater than 90,000 cfs in the Sacramento River at Rio Vista (*RioVista_Threshold*) and 10,000 cfs in the San Joaquin River at Vernalis (*Vernalis_Threshold*). When the flow at Vernalis (*Vernalis*) exceeds the Vernalis threshold, the trigger (*Vernalis_Trigger*) is activated. SacWAM uses a methodology developed by Hutton (2008) that uses monthly values to estimate the probability of the 3-day average flows exceeding these thresholds. The model suspends Action 2 when the probability exceeds 50 percent.

OMR flow requirements under Action 2 are suspended when the 3-day flow average is greater than 90,000 cfs in the Sacramento River at Rio Vista and 10,000 cfs in the San Joaquin River at Vernalis. The Rio Vista threshold is triggered using a timeseries of trigger months based on flow at Freeport, developed for CalSim II. This trigger is contained in the branch *Ops\OMR and Health and Safety\Int_Freeport*. When the flow at Vernalis (*Vernalis*) exceeds the Vernalis threshold, the trigger (*Vernalis_Trigger*) is activated. SacWAM uses a methodology developed by Hutton (2008) that uses monthly flow values (*Vernalis_Threshold*) to estimate the probability of the 3-day average flows exceeding the 10,000 cfs threshold at Vernalis. The model suspends Action 2 when this probability exceeds 50 percent.

2008 USFWS Biological Opinion Action 3

Action 3 is implemented as an adaptive approach intended to protect larval and juvenile delta smelt from entrainment. Similar to Action 2, Action 3 limits Delta exports so that OMR flows are no more negative than -5,000 to -1,250 cfs based on existing conditions within the Delta (existing conditions are determined in *X2_A3* ("between" in October of the current accounts year; determined by X2 position in previous time step for all other months); named in *A3_OMR_Target*; and assigned values in *OMR_Target_X2_E_Roe*, *OMR_Target_X2_Between*, and *OMR_Target_X2_W_Roe*). The considerations for setting the Action 3 OMR standards are summarized in (Table 7-3).

Table 7-3. Action 3 Old and Middle River Standard

Sacramento Valley Water-Year Type	Minimum Flow (cfs)		
	X2 East of Roe (X2 > 74 mi)	X2 in between (64 mi < X2 < 74 mi)	X2 West of Roe (X2 < 64 mi)
Critical	-1250	-3500	-5000
Dry	-1250	-3500	-5000
Below Normal	-1250	-3500	-5000
Above Normal	-1250	-3500	-5000
Wet	-1250	-3500	-5000

Action 3 can be triggered either when the average temperatures from 3 stations within the Delta (Mossdale, Antioch, and Rio Vista) exceed 12 °C or when spent female delta smelt appear in the Spring Kodiak Trawl Survey or at Banks or Jones (*A3_Trigger_month* and *A3_Trigger_day*). These triggers are indicative of spawning activity and the probable presence of larval delta smelt in the South and Central Delta.

Both triggers are based on pre-processed data. The water temperature from the three monitoring stations has been found to be highly correlated to measured air temperature at the Sacramento Executive Airport. Therefore, SacWAM uses a timeseries of trigger dates based on air temperature developed for the CalSim II model (*Temp_Trigger_mo* and *Temp_Trigger_day*). Because SacWAM has no good way of tracking biological triggers within the model, it must also pre-process these data. For present purposes, the model is set up such that biological trigger is activated each year on May 15 (*Bio_Trigger_mo* and *Bio_Trigger_da*).

Action 3 is suspended after 30th June (*Temp_Offramp_mo* and *Temp_Offramp_day*) or once certain temperature thresholds have been reached, whichever comes first. The temperature 'off-ramp' used to suspend Action 3 is triggered whenever water temperature reaches a daily average of 25C for three consecutive days as Clifton Court Forebay. Unfortunately, there is no reliable correlation between water temperature at Clifton Court and nearby air temperature stations. Thus, for now, SacWAM uses only the temporal off-ramp criterion (June 30) to end Action 3.

The considerations for setting the USFWS BiOp OMR actions are summarized in Table 7-4.

Table 7-4. Schedule of USFWS Biological Opinion Old and Middle River Actions

Action 1 Triggered	Action 3 Triggered	December		January	February		March	April		May	June
December	February	OMR Bkgd	Action 1	Action 2			Action 3			Action 3 until Off-Ramp, then OMR Bkgd	
	March	OMR Bkgd	Action 1	Action 2				Action 3		Action 3 until Off-Ramp, then OMR Bkgd	
	April	OMR Bkgd	Action 1	Action 2					Action 3	Action 3 until Off-Ramp, then OMR Bkgd	
	After Apr.	OMR Bkgd	Action 1	Action 2					Action 3	Action 3 until Off-Ramp, then OMR Bkgd	
January	February	OMR Background		Action 1	Action 2		Action 3			Action 3 until Off-Ramp, then OMR Bkgd	
	March	OMR Background		Action 1	Action 2			Action 3		Action 3 until Off-Ramp, then OMR Bkgd	
	April	OMR Background		Action 1	Action 2				Action 3	Action 3 until Off-Ramp, then OMR Bkgd	
	After Apr.	OMR Background		Action 1	Action 2				Action 3	Action 3 until Off-Ramp, then OMR Bkgd	
February	February	OMR Background			Action 1	Action 3				Action 3 until Off-Ramp, then OMR Bkgd	
	March	OMR Background			Action 1	Action 2		Action 3		Action 3 until Off-Ramp, then OMR Bkgd	
	April	OMR Background			Action 1	Action 2			Action 3	Action 3 until Off-Ramp, then OMR Bkgd	
	After Apr.	OMR Background			Action 1	Action 2			Action 3	Action 3 until Off-Ramp, then OMR Bkgd	
March	February	OMR Background					Action 3			Action 3 until Off-Ramp, then OMR Bkgd	
	March	OMR Background				Action 1		Action 3		Action 3 until Off-Ramp, then OMR Bkgd	
	April	OMR Background				Action 1	Action 2		Action 3	Action 3 until Off-Ramp, then OMR Bkgd	
	After Apr.	OMR Background				Action 1	Action 2		Action 3	Action 3 until Off-Ramp, then OMR Bkgd	

Note that Action 3 may be triggered at any day of the month based on the pre-processed timeseries. (This is not shown in Table 7-4.)
Key: Bkgd=Background; OMR=Old and Middle River.

RPA

The RPA branches set the flow standards associated with each action depending upon the timing in which each action was triggered.

7.2.2.4 *ExportInflow*

In each month, total Delta exports are limited by a certain fraction of the inflow to the Delta. This is referred to as the Export/Inflow (or E/I) ratio (*ExpRatio*). The E/I ratio limits Delta exports to 65 percent of inflow February through June and to 35 percent July through January (*EI_base*). However, in February, the E/I ration may be increased to 70 percent if the Eight Rivers Index is less than 1.5 MAF or increased to 75 percent if the Eight Rivers Index is less than 1 MAF (*Feb_adjust*). Delta inflows are estimated as the sum of Sacramento River flows at Freeport, San Joaquin River flows at Vernalis, and Delta inflows from the Yolo Bypass, Mokelumne River, and Calaveras River.

Delta exports are also adjusted during the spring pulse period (April 16 – May 15) according the 2009 NMFS BiOp (NMFS, 2009), which limits export levels based on the 60-20-20 San Joaquin Valley Water Year Classification. According to this schedule, the projects are always allowed to export a minimum of 1500 cfs. If San Joaquin River flows at Vernalis exceed 1500 cfs, then exports during the pulse period are limited to a defined ratio of Vernalis flow to exports depending on the water-year type (WYT) (Table 7-5).

Table 7-5. Delta Export Limits during Spring Pulse Period

San Joaquin Valley Water-Year Type	Pulse Period Vernalis Flow: Export Ratio
Critical	1 to 1
Dry	2 to 1
Below Normal	3 to 1
Above Normal	4 to 1
Wet	4 to 1

The physical capacity to pump water into the California Aqueduct at the Banks pumping plant is 8,500 cfs. However, the permitted capacity at Banks, established under Section 10 of the Rivers and Harbors Act (1968), is only 6,680 cfs. SacWAM includes adjustments to the permitted capacity according to a proposal from DWR to increase the SWP diversions by one-third of the San Joaquin River flow at Vernalis during the period from mid-December through mid-March when Vernalis flows exceed 1,000 cfs.

7.2.2.5 *D1641_PulsePeriod*

D1641 is a SWRCB Decision outlining flow and water quality requirements in the Delta watershed. It includes a 31-day pulse flow period from April 15 to May 15 that is intended to facilitate fish migration. During this period, exports are limited to the greater of 1500 cfs or the San Joaquin River flow at Vernalis. The pumping limits defined here are applied using UDCs (see *AprMayPulse_CVP* and *AprMayPulse_SWP* under *UDC\Pumping Constraints*).

7.2.2.6 *SJR_EIRatio*

San Joaquin exports depend on the month and on hydrologic indices (see Section 7.2.7.13). Maximum exports (*SJ_MaxExp*) are set at 99,999 in June through March and in April and May when *Vernalis Flow* is greater than 21,750 cfs. Further rules for April and May are explained in Table 7-6.

Table 7-6. San Joaquin Maximum Exports

Time Step	San Joaquin Hydrologic Index	SJ_MaxExp (cfs)	
June – March	N/A	99,999	
April, May	≤2	The greater of Health and Safety levels and…	Vernalis Flow/4
	3		Vernalis Flow/3
	4		Vernalis Flow/2
	Other		Vernalis Flow

*Health and Safety level explained in Section 7.2.2.7

7.2.2.7 *RPAHealthandSafety*

The H&S flow level (1500 cfs) is used in calculating the San Joaquin River export-import ratio (see Section 7.2.2.6).

7.2.2.8 *OMR and Health and Safety*

This section computes the OMR RPA reverse flow limits and maximum exports. It contains the following variables:

- **Q_SOD_HS,** calculates diversions from the Delta when total CVP and SWP exports are at H&S levels as specified under the USFWS BiOp (1500 cfs). This sums H&S pumping with *CCWD_EstimateDiversions* and *SODNetCU*.
- **CCWD_EstimatedDiversions,** estimated Delta diversions by Contra Costa WD.
- **Q_OMR_HS,** OMR flows if Delta diversions are at minimum H&S levels.
- **Q_OMR_Bound,** OMR maximum reverse flows under the OMR RPA.
- **Q_OMR_ReverseBound,** converts *Q_OMR_Bound* to a positive value (because reverse flows in SacWAM are calculated as a positive flow). This is the limit that is applied to flows in the OMR (see *UDCs\OMR_BO_Actions\OMR Constraints\Set Q_OMR_Final*).
- **Available Export,** computes the available export capacity for CVP and SWP combined under the OMR reverse flows standard. This is used to split available export capacity between CVP and SWP (see *UDCs\OMR_BO_Actions\OMR Constraints\ShareAvailableExport*).
- **Int_Freeport,** timeseries input data that defines when Rio Vista flows are above the threshold for suspending OMR RPA Action 2.
- **SODNetCU,** in-Delta consumptive use.

7.2.3 Flow Requirements

SacWAM considers specific river flow requirements for water quality, fish and wildlife, navigation, recreation, downstream, and others through specification of a flow requirement object associated with points on a river. Flow requirements are treated as a demand and are satisfied in accordance with the user-defined priority structure. Many of the flow requirements vary seasonally and are adjusted depending on WYT. Flow requirements associated with regulatory requirements are listed in Table 7-7. They are described in more detail in the sections that follow.

Table 7-7. Flow Requirements in SacWAM

River	Location	Alias in WEAP tree	Description	Water-Year Adjustment
Trinity	Below Lewiston Dam	BlwCLE	Trinity Record of Decision (2000)	Trinity River Index
Clear	Below Whiskeytown Dam	MinFlow	MOA with CDFW (1960)	Shasta Index
	Below Whiskeytown Dam	Temperature; CVPIA B2	CVPIA B2 (1992) and AFRP	None
		NMFS	NMFS BiOp (2009)	None
Sacramento	Below Keswick Dam	WR90_5	SWRCB WR 90-5 (1990)	Sacramento Valley Index
	Below Keswick Dam	NMFS BiOp	NMFS BiOp (2009)	None
	Wilkins Slough	NCP	NMFS BiOp (2009)	Shasta Storage
	Rio Vista	at Rio Vista	Water Right Decision 1641 (1999)	Sacramento Valley Index
Feather	Low Flow Channel	LowFlowChannel	SWRCB order WQ 2010-016	None
	High Flow Channel	HighFlowChannel	DWR/CDFW MOU (1983)	Forecasted Feather River April-July Runoff
	Mouth of Feather River	Verona	DWR/CDFW MOU (1983)	Forecasted Feather River April-July Runoff
Yuba	Smartville	nr Smartville	Lower Yuba River Accord (2008)	North Yuba Index
	Marysville	nr Marysville	Lower Yuba River Accord (2008)	North Yuba Index
Bear	Below CFWID diversion	BlwCampFarWest	Settlement Agreement (1994)	Sacramento Valley Index
American	Below Folsom Dam	FMS	Lower American River Flow Management Standard (2006)	Four Reservoirs Index, Impaired Folsom Inflow Index, Folsom Storage, and Sacramento Valley Index
Mokelumne	Below Camanche	blw Camanche	FERC Project No. 2916-004 Joint Settlement Agreement (1996)	Mokelumne Index
	Below Woodbridge	Woodbridge	FERC Project No. 2916-004 Joint Settlement Agreement (1996)	Mokelumne Index
Sacramento-San Joaquin Delta	*Delta Outflow*	D1641 Base, MRDO	Water Right Decision 1641 (1999)	Sacramento Valley Index and Eight Rivers Index
Putah		DroughtIndicator		

Key: AFRP=Anadromous Fish Restoration Program; BiOp=Biological Opinion; CDFW=California Department of Fish and Wildlife; CVPIA=Central Valley Project Improvement Act; DWR=California Department of Water Resources; FERC=Federal Energy Regulatory Commission; MOA= Memorandum of Agreement; MOU=Memorandum of Understanding; MRDO=minimum required Delta outflow; NMFS=National Marine Fisheries Service.
Note: Names of Flow Requirements as they appear in WEAP are italicized in this table.

Each of these MFRs is associated with a Flow Requirement object in SacWAM. They all reference flow schedules that are defined in the Data Tree under *Other Assumptions\Ops\Flow Requirements* and are described in more detail below.

7.2.3.1 *Trinity River*

Trinity River flow requirements are based on the December 19, 2000 Trinity River Mainstem Record of Decision, which allocates 368.6 TAF to 815 TAF annually for Trinity River flows. These are contained in *BlwCLE* and summarized in Table 7-8.

Table 7-8. Lewiston Dam Releases to the Trinity River

Trinity River Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	373			300			600	1,498	783		450	
Dry	373			300			540	2,924	783		450	
Normal	373			300			477	4,189	2,120	1,102	450	
Wet	373			300			460	4,709	2,526	1,102	450	
Extremely Wet	373			300			427	4,570	4,626	1,102	450	

7.2.3.2 *Clear Creek*

SacWAM defines a flow requirement on Clear Creek below Whiskeytown Reservoir according to the 1960 Memorandum of Agreement (MOA) with CDFW, flow and temperature requirements under the USFWS Anadromous Fish Restoration Program (AFRP), and the 2009 NMFS BiOp. The flow requirement (*BlwWKTN*) is the maximum of the MFRs set by the various regulations. The minimum flow schedules are summarized in Table 7-9. 1960 MOA flows are in branch *BlwWKTWN\MinFlow*. AFRP flows (*BlwWKTWN\CVPIA B2*) are released under authority CVPIA Section 3406(b)(2). The AFRP also has temperature requirements of 60 degrees F during July-Sep, so flow releases that will maintain those temperatures are also implemented (*BlwWKTWN\Temperature).* The values of these requirements were obtained from Derek Hilts and Matt Brown at USFWS, respectively. In addition to these flows, the 2009 NMFS BiOp requires a flow of 600 cfs for six days in May. Thus, the flow requirement below Whiskeytown in May is a daily weighted average of these pulse flows (*BlwWKTWN\NMFS)* and the maximum of other applicable requirements.

Table 7-9. Clear Creek Minimum Flow Requirements below Whiskeytown

Regulation	Flow Requirement (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960 MOA Shasta Critical years	30	70		30								
1960 MOA Otherwise	50	100		50								
AFRP (CVPIA b(2) flows)	200								150	85		150
AFRP flows for temperature	0								70	100		70

Key: AFRP=Anadromous Fish Restoration Program; CVPIA= Central Valley Project Improvement Act; MOA=Memorandum of Agreement.

7.2.3.3 *Sacramento River*

SacWAM defines a flow requirement on the Sacramento River below Keswick Dam (*BlwKeswick*). The final requirement is the minimum of a series of flow requirements described here. Table 7-10 shows minimum flows under SWRCB WR90-5 (*WR90_5*). A flow requirement of 3250 cfs all year round is also implemented in the model (*NMFS BiOp*), based on minimum flows in the 2009 NMFS BiOp and standard operations to meet downstream temperature requirements under WR90-5 and the 2009 NMFS BiOp. 3,250 cfs is a standard value used in the CalSim II model to represent minimum flows at Keswick for meeting temperature standards. Lastly, under CVPIA (b)(2) there are flow releases that are implemented in November and December under higher storage conditions. These requirements are 4,000 cfs in November, and the lower of 4,000 cfs or 75% of November flow in December. Values for these

requirements are from Derek Hilts (USFWS). These requirements are implemented in WEAP (*CVPIA_B2*) when Shasta storage in the prior September is > 2,400 TAF.

Table 7-10. Sacramento River Minimum Flow below Keswick: SWRCB WR90-5

Sacramento Basin Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	2,800		2,000			2,300						2,800
Otherwise	3,250					2,300						3,250

Historically there has been a flow requirement of 5,000 cfs at Wilkins Slough to maintain flows for navigation (*NCP*). In order to conserve Shasta cold water pool storage for summer releases, the 2009 NMFS BiOp allows for relaxation of this requirement in lower storage conditions. Relaxation is done on a discretionary basis (i.e. no fixed rules have been defined), so in the model the requirement is relaxed when Shasta storage is lower than the thresholds shown in Table 7-11 (*NCP_base*). This operation approximately mimics the current operation in the CalSim II model. Because of the distance between Shasta Dam and Wilkins Slough and the unpredictability of downstream unregulated flows, CalSim II includes an increase in reservoir releases in some months to take into account this uncertainty. This additional release requirement is included in SacWAM as a calibration factor (*Daily adjustment*) that can be turned on to facilitate comparisons to the CalSim II model. The default setting is to have this adjustment off.

Table 7-11. Sacramento River Minimum Flow for Navigation at Wilkins Slough

Shasta Storage (TAF) in April	Requirement (cfs)
<= 2,500	3,250
<= 3,500	3,500
<= 3,900	4,000
<= 4,100	4,500
Otherwise	5,000

SWRCB Decision 1641 includes flow requirements on the Sacramento River at Rio Vista as part of the suite of actions intended to protect water quality within the Delta. SacWAM implements these flow requirements according to Table 7-12 (*at Rio Vista*).

Table 7-12. Sacramento River Minimum Flow at Rio Vista - D-1641

Sacramento Basin Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	3,000	3,500	3,500	0								3,000
Otherwise	4,000	4,500	4,500	0								3,000

7.2.3.4 *Feather River*

Flow requirements on the Feather River are governed by a 1983 Memorandum of Understanding (MOU) between DWR and CDFW (formerly California Department of Fish and Game) and a 2010 SWRCB order (WQ 2010-016). The 1983 MOU establishes MFRs on the Feather River within the low-flow channel (i.e. main channel of Feather River below Oroville and above Thermalito Afterbay outlet) and the high-flow channel (i.e. Feather River below Thermalito Afterbay outlet and Verona at the confluence with the Sacramento River). Under WQ 2010-016 the low-flow channel requirements (*LowFlowChannel*) were increased from 600 cfs year-round to 800 cfs from September 9 to March 31, and 700 cfs the remainder

of the time. The flow requirement in the high-flow channel (*DFG_DWR 1983 MOA*) varies from 1000 to 1700 cfs, depending on the month and also on whether the April-to-July unimpaired inflow to Oroville (*DFG_DWR 1983 MOA/PrevAprJulRunoff*) is less than 55 percent of normal (*DFG_DWR 1983 MOA/PercentOfNormal*). Under certain low storage conditions in Oroville these requirements are lowered to an off-ramp level of flows. The storage criteria for this off-ramp is not explicitly modeled in SacWAM, but a timeseries of off-ramp periods is taken from CalSim II (*DFG_DWR 1983 MOA/Offramp*). These high-flow channel requirements are summarized in Table 7-13. A final aspect of the high-flow channel requirement is that if the highest peak streamflow between October 15 and November 30 is > 2500 cfs because of project operations and not flood flow, then the requirement for November to March is increased to 500 cfs below that peak flow (*Fall based HFC minflow*). In order to avoid this requirement, high-flow channel flows are constrained to be < 4000 cfs in October and 2500 cfs in November, except when Oroville is spilling (see *Fall based HFC minflow /HighFlow Channel max* and *User Defined LP Constraints\Oroville Fall Operations*). Lastly, flows at the mouth of the Feather (*Verona*) are also maintained at the flow levels in Table 7-13.

Table 7-13. Feather River Minimum Flow from Thermalito Afterbay Outlet to Mouth

Forecasted April through July Unimpaired Runoff (percent of normal)	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
55 percent or greater	1,700						1,000					
Less than 55 percent	1,200					1,000						
Off-ramp flows	900					750						

7.2.3.5 *Yuba River*

SacWAM sets flow requirements for the Yuba River near Smartville (*nr Smartville*) and at Marysville (*nr Marysville*) according to the Lower Yuba River Accord (2008). Flow schedules determinations begin in February and are updated through May based on refinements of the North Yuba Index. Thresholds for the flow schedules are summarized Table 7-14 and Table 7-15. The North Yuba Index values are defined under Hydrologic Indices (see Section 7.2.7.4).

Table 7-14. Yuba River Minimum Flow near Smartville

North Yuba Index (TAF)	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
<= 820	700						350	0				700
Otherwise	600		550				300	0				500

Table 7-15. Yuba River Minimum Flow at Marysville

North Yuba Index (TAF)	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
<= 693	350						425	450	225	150		350
<= 820	400	500					550	500	400			
<= 920	400	500					750		400			
<= 1040	500						700	900	500			
<= 1400	500					700	750	1,000	650	500		
Otherwise	500					700	1,000	2,000	1,500	700	600	500

7.2.3.6 *Bear River*

According to a 1994 settlement agreement between South Sutter WD, Camp Far West Irrigation District (CFWID), and DWR, water rights require a minimum streamflow below the diversion CFWID diversion works of 25 cfs from April 1 through June 30 and 10 cfs from July 1 through March 30 (*BlwCampFarWest\MinFlow*). The agreement also calls for flows to increase to 37 cfs for up to sixty days July through September in dry and critical years. For purposes of modeling, SacWAM assumes that these sixty days occur in July and August (*BlwCampFarWest\DryCritical_adjust*). See Table 7-16.

Table 7-16. Bear River Minimum Flows below Camp Far West Irrigation District Diversion

Sacramento Basin Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Dry and Critically Dry	0									37		0
Otherwise	10						25			10		

7.2.3.7 *American River*

The lower American River has two flow requirements. The first is D-893 (*D893*), which was established in 1958. Table 7-17 shows D-893 flow requirements. The critical year requirement applies only if March through September unimpaired inflow into Folsom is projected to be < 600 TAF *(D893WYT*).

Table 7-17. D-893 Requirements

Month	Flow Requirements (cfs)	
	Normal Year	Critical Year
Jan-Mar	250	250
Apr-Aug	250	188
Sep	375	281
Oct-Nov	500	375
Dec	500	500

The second flow requirement is governed by the Flow Management Standard (*FMS*), which was established in 2006 as a framework to improve the condition of aquatic resources in the lower American, particularly fall-run Chinook and steelhead. The FMS is intended to provide 800-2,000 cfs in the lower American River depending on the time of the year. These MFRs are set by the FMS with consideration to hydrologic indices, which take into account the vast majority of water availability conditions in the basin. The implementation of the FMS in SacWAM is based on the Lower American River FMS 2008 Technical Report, which included revisions to an earlier 2006 report.

The FMS uses three main indicators of water availability to make adjustments to MFRs depending on the time of the year. These three indices are the Four Reservoir Index (FRI), the Sacramento River Index (SRI), and the Impaired Folsom Inflow Index (IFII). The FRI is an index of the end-of-September combined carryover storage in Folsom, French Meadows, Hell Hole, and Union Valley reservoirs (*FRI*). FRI is used to adjust flow requirements early in the water year (i.e. October through December) when there is little or no data available to support runoff forecasts. Table 7-18 summarizes how SacWAM uses FRI to set MFRs October to December (*OctDecIndexFlow*).

Table 7-18. October-December Adjustments to Lower American River Flow Requirement

Four Reservoir Index	Minimum Flow Requirement (cfs)
0	800
600	800
746	1,750
796	1,750
848	2000
Maximum Storage	2000

In January and February, FMS uses SRI to make adjustments to flow requirements on the lower American. SRI is an index of the forecasted water year runoff for the entire Sacramento River Basin and is a better measure of near-term water availability. SacWAM adjusts flow requirements based on SRI using the criteria in Table 7-19.

Table 7-19. January-February Adjustments to Lower American Flow Requirement

SRI (MAF)	SRI Water-Year Type	Lower American River Flow Requirement
>= 15.7	Above Normal, or Wet	1750 cfs
>= 10.2 and < 15.7	Below Normal, or Dry	Minimum 1750 cfs or previous month MFR
< 10.2	Critically Dry	Maximum 800 cfs or 85 percent previous month MFR

MAF=million acre-feet; MFR= minimum flow requirement; SRI=Sacramento River Index

The January and February MFR is subject to further adjustments based on beginning-of-month storage in Folsom Reservoir. If Folsom Reservoir storage is less than 300 TAF in January or 350 TAF in February and storage is not at the flood curve, then the MFR is set to 85 percent of the previous month MFR or 800 cfs, whichever is greater (Table 7-19; *FMS\JanFeb*).

The IFII is an index of the volume of flow into Folsom Reservoir from May through September after all legal diversions take place in the upstream watershed. The IFII is used to set flow requirements from March through the remainder of the water year, when water supply availability is reasonably certain and can be used to make informed flow management decisions (Table 7-20 and Table 7-21). SacWAM sets MFRs March-May (*MarMay*) based on the IFII and the predicted end-of-May storage in Folsom Reservoir (*EoMayStorageEst*). It uses a similar approach for setting June-August MFRs (*JunAug*) based on the IFII (*InflowForecast*) and the end-of-September storage in Folsom Reservoir (*EoSepStorageEst*). Using only the IFII predictions of total inflow, SacWAM uses the following tables to set March-September MFRs. The MFR in September is the weighted average of the MFRs for the two parts of the month before and after Labor Day.

Table 7-20. March-Labor Day Adjustments to Lower American River Flow Requirement

IFII (TAF)	MFR (cfs)
0	800
375	800
550	1750
9000	1750

Key: IFII=Impaired Folsom Inflow Index; MFR=minimum flow requirement.

Table 7-21. Post–Labor Day-September Adjustments to Lower American River Flow Requirement

Impaired Folsom Inflow Index (TAF)	Minimum Flow Requirement (cfs)
0	800
375	800
504	1,500
9,000	1,500

Key: cfs=cubic feet per second; TAF=thousand acre-feet

However, if SacWAM estimates that the end-of-May Folsom storage will be less than 700 TAF when releasing the MFR, then the March-May MFR is set to the lesser of the IFII-based MFR and the February MFR. Similarly, if SacWAM estimates that the end-of-September Folsom storage will be less than 300 TAF when releasing the MFR, then the June-September MFR is set to the maximum of 250 cfs or the computed release throughout those months which will lead to an end-of-September storage of 300 TAF.

The FMS also has criteria for conference years and off-ramp conditions, which can apply in any month and if satisfied will reduce the flow requirement to the same as the D-893 Normal Year requirement. Conference years occur when the predicted March-November unimpaired inflow to Folsom Reservoir is < 400 TAF. Off-ramp conditions are triggered during October through February when storage at the end of the current month is projected to fall below 200 TAF (*OctDecStorage*, *JanFebStorage)*. They are triggered March through September if the projected end-of-September storage is less than 200 TAF (*MarSepStorage*). Off-ramp conditions are halted whenever storage is projected to be above 200 TAF.

7.2.3.8 *Mokelumne River*

The Mokelumne River has two flow requirements that are defined by the Mokelumne River Joint Settlement Agreement (JSA) (FERC Project 2916; Joint Settlement Agreement, 1996). These flow requirements are set below Camanche Dam (*blw Camanche*) and at Woodbridge (*Woodbridge*).

blw Camanche

Flow requirements below Camanche Reservoir for the months November through March (*blw Camanche\NovMar*; Table 7-22) are based on storage in Pardee and Camanche Reservoirs at the beginning of November (*blw Camanche\OctStorage*; Table 7-23). Flow requirements for the months April through October (*blw\AprOct*; Table 7-22) are based on the Mokelumne River hydrologic WYT (discussed in Section 7.2.7.5 on Hydrologic Indices in the Mokelumne). Additional flow (*blw Camanche\AprOct\Additional*) is possible in May normal and wet years when storage in the reservoirs is not far below the storage capacity less the flood space requirement (*blw Camanche\BMAS*).

Table 7-22. Mokelumne River Minimum Flow below Camanche Dam

Mokelumne River Water-Year Type	Minimum Flow (cfs)											
	Oct[1]	Nov[2]	Dec[2]	Jan[2]	Feb[2]	Mar[2]	Apr[1]	May[1]	Jun[1]	Jul[1]	Aug[1]	Sep[1]
Critically Dry	115	130						100				
Dry	220								100			
Below Normal	250									100		
Normal and Above Normal	325									100		

Notes:

1. Indicates minimum flow below Camanche is based on the Mokelumne River water-year type as determined by annual water yield.
2. Indicates minimum flow below Camanche is based on the Mokelumne River water-year type as determined by beginning-of-November storage in Pardee and Camanche reservoirs.

Table 7-23. Mokelumne River Water-Year Type Based on Beginning-of-November Reservoir Storage

Water-Year Type	Beginning of November Pardee/Camanche Storage
Critically Dry	269 TAF or less
Dry	270 TAF to 399 TAF
Below Normal	400 TAF to Max Allowable
Normal/Above Normal	Max Allowable

Woodbridge

The same as below Camanche, the flow requirements at Woodbridge (*Woodbridge*) for the months November through March (*Woodbridge\NovMar*; Table 7-24) are based on storage in Pardee and Camanche Reservoirs at the beginning of November (*blw Camanche\OctStorage*; Table 7-23); and for April through October (*Woodbridge\AprOct*) on Mokelumne River hydrologic WYT (discussed in Section 7.2.7.5 on Hydrologic Indices in the Mokelumne).

Table 7-24. Mokelumne River Minimum Flow at Woodbridge

Mokelumne River Water-Year Type	Minimum Flow (cfs)											
	Oct†	Nov*	Dec*	Jan*	Feb*	Mar*	Apr†	May†	Jun†	Jul†	Aug†	Sep†
Critically Dry	45	75						15				
Dry	80						150		20			
Below Normal	100						150	200		20		
Normal and Above Normal	100						150	300		25		

†Indicates minimum flow below Camanche is based on the Mokelumne River water-year type as determined by annual water yield.
*Indicates minimum flow below Camanche is based on the Mokelumne River water-year type as determined by beginning-of-November storage in Pardee and Camanche reservoirs.

Electra

Flow requirements at Electra (*ElectraDiversionDam*) depend on the WYT of the North Fork of the Mokelumne (discussed in Section 7.2.7.5 on Hydrologic Indices in the Mokelumne).

Table 7-25. Mokelumne River Minimum Flows below Electra Diversion Dam

North Fork Mokelumne Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	15	20			25	30	40	60	40	20	15	
Dry	20			25	30	50	80	95	50	20		
Below Normal	20	25	30	40		80	135	250	180	35	20	
Normal and Above Normal	20		40	60		110	190	490	270	40	20	
Wet	20	50		90	120	150	400	980	850	145	30	20

SaltandLowerBearDams

P137 places additional flow requirements below the Salt Spring and Lower Bear dams (*SaltandLowerBearDams*) based on the North Fork Mokelumne WYT (discussed in Section 7.2.7.5 on Hydrologic Indices in the Mokelumne) (Table 7-26).

Table 7-26. Mokelumne River Minimum Flows below the Salt and Lower Bear Dams

North Fork Mokelumne Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	19	24			31	36	50	68	46	24	19	
Dry	24	26		31	38	50	85	90	48	26	24	
Below Normal	24	26	33	50		85	135	250	180	40	26	24
Normal and Above Normal	26	28	40	64		110	200	500	270	45	26	
Wet	26	58		95	130	160	425	1040	790	175	35	26

Lodi Rqmnts

The baseflow requirement below Electra Power House (*ElectraPowerhouse*) is 300 cfs in May, June, and July and 200 in other months (*Lodi Rqmnts\Base*). Flow requirements are never below base values. The actual flow requirement is the maximum of the base and other monthly values, which are determined by whether PG&E storage in the previous May in the reservoirs of the Upper Mokelumne (*PGandEMayStorage*) was above 130 TAF (*Lodi Rqmnts\HiMayStorage*) or below 130 TAF (*Lodi Rqmnts\LoMayStorage*). The resulting flow requirements are presented in Table 7-27.

Table 7-27. Lodi Flow Requirements

Upper Mokelumne Reservoir Storage	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Hi May storage (>130 TAF)	500			400	200			300	500			
Low May storage (<130 TAF)	200							300				

7.2.3.9 *Delta Outflow*

SacWAM includes Delta standards that are specified in the 1995 Bay-Delta Plan (SWRCB, 1995) and D-1641[12] (SWRCB, 2000). Modeled standards for the Delta include the following:

- Net Delta Outflow Index (NDOI), expressed as a flow
- Salinity standards at Emmaton and Jersey Point expressed in electrical conductivity (EC)
- X2 location, expressed in kilometers

The NDOI and the outflow requirements to meet the salinity and X2 standards, combine to determine the minimum required net Delta outflow (*OutflowRequirement*). The Net Delta Outflows to meet water quality objectives for fish and wildlife beneficial uses as defined under D-1641 are summarized in Table 7-12. These flow requirements are adjusted in January according to the Eight Rivers Index and in May and June according to the Sacramento Valley Index. Flow requirements are increased to 6000 cfs in January if the Eight Rivers Index exceeds 800 TAF (*Jan_adjustment*). Flow requirements are decreased to 4000 cfs in May and June if the Sacramento Valley Water Year Index is less than 8.1 MAF (*MayJun_adjustment*).

[12] Decision 1641 (or D-1641) is the implementation plan for the 1995 Bay-Delta Plan, with respect to the operation of California's State Water Project and the USBR's Central Valley Project. D-1641 was adopted by SWRCB in December 1999 and subsequently revised in March 2000. It includes water quality objectives to protect beneficial uses for agriculture, municipal and industrial, and fish and wildlife in the Delta. It also defines water quality and flow objectives for various compliance monitoring stations throughout the Delta.

Table 7-28. Sacramento River Minimum Net Delta Outflow - D-1641

Mokelumne River Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	3,000	3,500		4,500	7,100					4,000	3,000	3,000
Dry	4,000	4,500			7,100					5,000	3,500	3,000
Below Normal	4,000	4,500			7,100					6,500	4,000	3,000
Above Normal	4,000	4,500			7,100					8,000	4,000	3,000
Wet	4,000	4,500			7,100					8,000	4,000	3,000

Outflow requirements to meet Delta salinity and standards are discussed in detail in Section 7.2.6.2.

7.2.3.10 *Putah Creek*

If March storage at Lake Berryessa is less than 750 TAF, the system is determined to be in drought (*DroughtIndicator*).

7.2.4 Priorities

WEAP uses LP to solve the allocation of water at each time step.[13] Two user-defined priority systems determine allocations of water supplies to demands (i.e. urban and agricultural), for IFRs, and for filling reservoirs—demand priorities and supply preferences.

Demand priorities are used to allocate water to competing demand sites and catchments, flow requirements, and reservoir storages. The *demand priority* is attached to the demand site, catchment, reservoir, or flow requirement and ranges from 1 to 99, with 1 being the highest priority and 99 the lowest. Many demand sites can share the same priority, which is useful in representing a system of water rights, where water users are defined by their water usage and/or seniority. In cases of water shortage, higher priority users are satisfied as fully as possible before lower priority users are considered. If priorities are the same, shortage will be shared equally (as a percentage of demand).

SacWAM uses several general categories of demand to define the system of priorities. In general, the highest priority is assigned to operations (water storage and delivery) in the upper watersheds. Sacramento Valley water users have the next highest priority level and water users relying on Delta exports have the lowest priority level. Within the Sacramento Valley, water users are further distinguished by their demand type (i.e. urban, agriculture, refuge, or flow requirement) and contract type (i.e. Non-Project, CVP, or SWP). The general demand priority structure of SacWAM is set up in WEAP's Data Tree under *Other Assumptions\Ops\Priorities*. Each demand within SacWAM then references the appropriate sub-branch within this structure. This demand structure is also presented in Table 7-29.

[13] It is important to note that while WEAP uses an LP to allocate water, it is not an optimization tool. It allocates water hierarchically to demands with the highest priority at each time step. It does not consider how water is allocated across multiple time steps.

Table 7-29. General Priority Structure of Demands in SacWAM

SacWAM Demand Group	Demand Priority
Upper Watershed Reservoirs	5
Upper Watershed Demand	6
Upper Watershed Diversions	7
SWRCB IFRs	8
Non Project Tributary Demands	10
Non Project Tributary IFR	11
Non Project Tributary Storage	12
Agriculture Non Project	13
Urban Non Project	13
Los Vaqueros	14
CVP Settlement Contractors	17
SWP Settlement Contractors	17
Project Tributary IFR	22
Required Delta Outflow	27
CVP Refuge Contractors	35
CVP Urban Contractors	37
CVP Ag Contractors	39
CVP SOD Canal Losses	40
CVP SOD Exchange Contractors	41
CVP SOD Refuge Contractors	42
CVP SOD Urban Contractors	43
CVP SOD Ag Contractors	44
CVP SOD Storage	45
CVP NOD Storage	46
SWP Canal Losses	50
SWP Contractors	51
SWP NOD Storage	52
SWP SOD Storage	52
Fill CVP San Luis	55
Fill SWP San Luis	60
Bypass Demand	63
CVP Cross Valley Canal	99
Routing IFR	99

Key: CVP=Central Valley Project; IFR=instream flow requirement; NOD=north of Delta; SOD=south of Delta; SWP=State Water Project; SWRCB=State Water Resources Control Board.

7.2.5 Delta Channels

This section describes the operation of the structures that control flows through the Delta Cross-Channel (DXC) gates and from the San Joaquin River into the Head of the Old River (HOR).

7.2.5.1 *DXC*

DXC diverts flows from the main channel of the Sacramento River into the north branch of the Mokelumne River at Walnut Grove. The DXC and its head gates are a feature of Reclamation's CVP and are intended to maintain water quality for transfers from CVP reservoirs north of the Delta to the headworks of the DMC and Contra Costa canal.

The DXC gates are operated in accordance with SWRCB Decision 1641 (SWRCB, 1999), which specifies periods during which the gates should be closed to support fisheries protection. For modeling purposes, we use a lookup table that fixes the number of days in a month that the DXC gates are open (*DXC_days*, Table 7-30).

Other Assumptions

These are user-defined variables that can be referenced elsewhere in your analysis. For monthly variation, use Monthly Time-Series Wizard.

Other Assumption	1922	Scale	Unit
Ops			
Delta			
DXC	0		
DXC_fraction	DXC_days/Days		
DXC_days	MonthlyValues(Oct, 31, Nov, 20, Dec, 0, Jan, 0, Feb, 0, Mar, 0, Apr, 0, May, 0, Jun, 26, Jul, 31, Aug, 31, Sep, 30)		

Table 7-30. Number of Days Delta Cross Channel Gates Are Open

Month	Number of Days Open
October	31
November	20
December	0
January	0
February	0
March	0
April	0
May	0
June	26
July	31
August	31
September	30

Thus, we can use the following expression in WEAP to estimate the fraction of the month that the DXC gates are open (*DXC_fraction*):

Equation 7-1 Fraction of Month DXC Gates Are Open

DXC_fraction=MonthlyValues(Oct, 31, Nov, 20, Dec, 16, Jan, 11, Feb, 0, Mar, 0, Apr, 0, May, 0, Jun, 26, Jul, 31, Aug, 31, Sep, 30) / Days

For an explanation of DXC operations, UDCs, and their associated parameters, see Section 8.5.

7.2.5.2 *South Delta*

Head of Old River

Flows at HOR are expressed as a function of San Joaquin River flows at Vernalis using the following equation:

$$Q_{HOR} = C1 * Q_{Vernalis} + C2$$

Values for C1 and C2 vary depending upon time of year and level of flows at Vernalis. These are summarized in Table 7-31.

Table 7-31. Coefficients Used to Set Flows at Head of Old River

Condition	C1	C2
June, July, August	0.419	-26
April, May AND $Q_{Vernalis}$ < 5,000 cfs	0.079	69
October, November AND $Q_{Vernalis}$ < 5,000 cfs	0.238	-51
$Q_{Vernalis}$ < 16,000 cfs	0.471	83
16,000 cfs < $Q_{Vernalis}$ < 28,000 cfs	0.681	-3008
$Q_{Vernalis}$ > 28,000 cfs	0.633	-1644

SacWAM uses a diversion object to take water off of the San Joaquin River into the Old River. Flows into this diversion are set using the *Fraction Diverted* parameter associated with the diversion model object, which is entered as a percentage of river flow above the diversion. This parameter references the branch of the Data Tree *Other\Ops\Delta\South Delta\Head of Old River\Percent_SJ_to_HOR,* which is defined as Q_{HOR} / $Q_{Vernalis}$.

7.2.6 Delta Salinity

This section describes the routines that are used to calculate flow requirements needed to satisfy X2 and D-1641 water quality standards within the Delta.

SacWAM offers two methods for computing Delta outflow requirements for salinity control: the G-model and Artificial Neural Network (ANN). Both options compute Delta outflow requirements using external functions called from SacWAM. They are described in separate sections below. Only one option can be selected when the model is run. The default option selects ANN to compute Delta salinity.

7.2.6.1 *X2*

The X2 operation rule exists to address the salinity requirement. The X2 standard is expressed in terms of the location of the 2 parts per thousand bottom isohaline as measured in kilometers upstream from the Golden Gate Bridge. SacWAM offers two methods to compute the net Delta outflow required to meet this standard. It can either call the same Delta ANN used to compute other salinity compliance or it can use the Kimmerer-Monismith equation (Jassby et al., 1995). Either approach can be selected by changing the value of the Other\Ops\Delta\X2\UseANN (where a value of 1 indicates SacWAM will use ANN and a value of 0 indicates that SacWAM will use the Kimmerer-Monismith equation). The default approach is to use ANN.

7.2.6.2 *GMOD*

Outflow requirements to meet Delta salinity standards may be determined by linking SacWAM to Contra Costa WD's salinity-outflow model, commonly referred to as the "G-model" (Denton and Sullivan, 1993). The G-model is based on a set of empirical equations, developed from the one-dimensional advection-dispersion equation. The G-model predicts salinity caused by seawater intrusion at a number of key locations in Suisun Bay and the western Delta as a function of antecedent Delta outflow. The antecedent Delta outflow is a surrogate for directly modeling salinity distribution within the Delta and incorporates the combined effect of all previous Delta outflows. That is, the G-model assumes that salinity is a function of both current outflow and outflows from the previous 3 to 6 months. Because this salinity-outflow model was developed from the one-dimensional advection-dispersion equation, it accounts for the transport of salt by both mean flow (advection) and tidal mixing (dispersion).

One limitation of the G-model is that the equations were developed under current sea level conditions. As such, SacWAM includes an alternative method for setting Delta flows to meet salinity standards (i.e. the Delta *ANN*), which is discussed in the next section. This model has been trained to handle four sea level rise scenarios (1-foot rise, 2- foot rise, 1-foot rise plus 4-inch amplitude increase, and 2-foot rise plus 4-inch amplitude increase).

7.2.6.3 *ANN*

In addition to the G-model, SacWAM also includes an option to use an ANN, developed by DWR for CalSim II, to calculate Delta salinity and outflow requirements. The switch to activate ANN is discussed in Section 7.8.

The ANN was developed by DWR in an attempt to integrate into CalSim II model a faithful representation of the flow-salinity relationships as modeled by the Delta Simulation Model (DSM2). These relationships were then used by CalSim II to set Sacramento River flow targets and export limits in order to meet salinity standards at various locations in the Delta. The ANN also determines salinity (micro-mhos/cm) at these locations given estimates of Delta inflows, outflows, and exports and the position of Delta cross-channel. It is described in more detail in several DWR reports (Finch and Sandhu 1995; DWR, 2000b; Hutton and Seneviratne, 2001; Wilbur and Munevar, 2001; Mierzwa, 2002; Seneviratne, 2002; and Smith, 2008)[14].

The basic formulation of the ANN has remained the same for some years and still relies upon the same set of modeled inputs as noted by Wilbur and Munevar (2001), who pointed out that the ANN

> *predicts salinity at various locations in the Delta using the following parameters as input: Sacramento River inflow, San Joaquin River inflow, Delta Cross Channel gate position, and total exports and diversions. Sacramento River inflow includes Sacramento River flow, Yolo Bypass flow, and combined flow from the Mokelumne, Cosumnes, and Calaveras rivers (East Side Streams). Total exports and diversions include State Water Project (SWP)*

[14] At the time of this writing these reports were all available for download at http://modeling.water.ca.gov/delta/models/ann/index.html

Banks Pumping Plant, Central Valley Project (CVP) Tracy Pumping Plant, North Bay Aqueduct exports, Contra Costa Water District diversions, and net channel depletions. A total of 148 days of values of each of these parameters is included in the correlation, representing an estimate of the length of memory in the Delta.

The ANN itself is configured as a Fortran-compiled Dynamic-Link Library (DLL) that contains several functions. These functions include routines for calculating the EC at various locations for previous time steps and for calculating the parameters used in equations to set flow targets and export constraints. The ANN has been updated several times since its first introduction. The ANN included with SacWAM is taken from the existing conditions study included within the 2015 SWP Delivery Capability Report (DWR, 2015).

For the purposes of linking WEAP to the ANN it was necessary to recompile the DLL such that it could be called from WEAP. This required creating new functions within the DLL that received from WEAP a single double precision array of values, rather than several individual real and integer values as it is done with CalSim. To do this, we wrote Fortran code that created new functions callable from WEAP that are essentially "wrappers" to the existing DLL functions. The DLL functions that are used in the PA model are:

- ANNECARRAY which calculates the salinity from the previous month at different stations within the Delta
- ANNEC_MATCHDSM2ARRAY which calculates the salinity from 2 months prior at different stations within the Delta
- ANNLINEGENARRAY which calculates the slope and intercept of the linear equation that is used to constrain Delta exports as a function of inflows from the Sacramento River and Yolo Bypass

To access these routines within the DLL, WEAP uses a 'Call' function which takes the following form: Call(DLLFileName ! DLLFunctionName, parameter1, parameter2, ...). Where there is only one DLLFileName (e.g. Ann7inp_ROA0SLR0cm_SA.dll) for every call to the DLL; the DLLFunctionName was one of the three functions listed above; and the parameters differ between the three functions and are listed in Table 7-32, Table 7-33, and Table 7-34.

It should be noted here that in both CalSim II and SacWAM only the last function (AnnLineGen in CalSim and AnnLineGenArray in SacWAM) is needed to set flow targets and export constraints. The other two functions are called only to report the estimated Delta water quality from the previous months.

Table 7-32. List of Parameters for ANN Function AnnECArray

Parameter Number	Description	Parameter(s)
1-5	Sacramento River flows at Hood over previous 5 months	C400_5, C400_4, C400_3, C400_2, C400_1
6-10	CVP and SWP Delta Exports over previous 5 months	D409_5, D409_4, D409_3, D409_2, D409_1
11-15	San Joaquin River flows at Vernalis over previous 5 months	C639_5, C639_4, C639_3, C639_2, C639_1
16-20	Number of days the delta cross channel gates are open for each of the previous 5 months	DXC_5, DXC_4, DXC_3, DXC_2, DXC_1
21-25	Net in-Delta consumptive use over previous 5 months	net_DICU_5, net_DICU_4, net_DICU_3, net_DICU_2, net_DICU_1
26-30	Other Sacramento River Basin inflows to the Delta over previous 5 months	sac_oth_5, sac_oth_4, sac_oth_3, sac_oth_2, sac_oth_1
31-35	Other Delta Exports over previous 5 months	exp_oth_5, exp_oth_4, exp_oth_3, exp_oth_2, exp_oth_1
36-40	San Joaquin River water quality at Vernalis over previous 5 months	VernWQFinal_5, VernWQFinal_4, VernWQFinal_3, VernWQFinal_2, VernWQFinal_1
41-45	Number of days in the month over previous 5 months	daysin_5, daysin_4, daysin_3, daysin_2, daysin_1
46	Station identifier[1]	Jersey Point (JP) = 1, Rock Slough (RS) = 2 Emmaton (EM) = 3, Collinsville (CO) = 5
47	Average type[2]	Monthly average = 1 Maximum 14-day value = 6
48	Previous month index	Mo = 12 if October Otherwise, Mo = TS-1
49	Previous month water year	Year = Water Year - 1 if October, Otherwise, Year = Water Year

Notes:
[1] The ANN functions were developed to consider twelve different stations. However, only four are used.
[2] The average type is used for the functions that return estimates of water quality - i.e. AnnECArray and AnnEC_matchDSM2Array. There are eight different types of averages that the can be calculated by various functions within the DLL. Only two are used in both CalSim II and WEAP.
Key: CVP=Central Valley Plan; SWP=State Water Plan.

Table 7-33. List of Parameters for ANN Function AnnEC_matchDSM2Array

Parameter Number	Description	Parameter(s)
1-7	Sacramento River flows at Hood over previous 7 months	C400_7, C400_6, C400_5, C400_4, C400_3, C400_2, C400_1
8-12	CVP and SWP Delta Exports over previous 2 to 6 months	D409_6, D409_5, D409_4, D409_3, D409_2
13-19	San Joaquin River flows at Vernalis over previous 7 months	C639_7, C639_6, C639_5, C639_4, C639_3, C639_2, C639_1
20-24	Number of days the delta cross channel gates are open for each of the previous 2 to 6 months	DXC_6, DXC_5, DXC_4, DXC_3, DXC_2
25-29	Net in-Delta consumptive use over previous 2 to 6 months	net_DICU_6, net_DICU_5, net_DICU_4, net_DICU_3, net_DICU_2
30-34	Other Sacramento River Basin inflows to the Delta over previous 2 to 6 months	sac_oth_6, sac_oth_5, sac_oth_4, sac_oth_3, sac_oth_2
34-39	Other Delta Exports over previous 2 to 6 months	exp_oth_6, exp_oth_5, exp_oth_4, exp_oth_3, exp_oth_2
40-44	San Joaquin River water quality at Vernalis over previous 2 to 6 months	VernWQFinal_6, VernWQFinal_5, VernWQFinal_4, VernWQFinal_3, VernWQFinal_2
45-51	Number of days in the month over previous 7 months	daysin_7, daysin_6, daysin_5, daysin_4, daysin_3, daysin_2, daysin_1
52	Station identifier[1]	Jersey Point (JP) = 1, Rock Slough (RS) = 2 Emmaton (EM) = 3, Collinsville (CO) = 5
53	Average type[2]	Monthly average = 1 Maximum 14-day value = 6
54	Index for 2 months prior	Mo = 11 if October Mo = 12 if November Otherwise, Mo = TS-2
55	Water year for 2 months prior	Year = Water Year - 1 if October or November, Otherwise, Year = Water Year

[1] The ANN functions were developed to consider twelve different stations. However, only four are used.
[2] The average type is used for the functions that return estimates of water quality - i.e. AnnECArray and AnnEC_matchDSM2Array. There are eight different types of averages that the can be calculated by various functions within the DLL. Only two are used in both CalSim II and WEAP.
Key: CVP=Central Valley Plan; SWP=State Water Plan.

Table 7-34. List of Parameters for ANN Function AnnLineGenArray

Parameter Number	Description	Parameter(s)
1-4	Sacramento River flows at Hood over previous 4 months	C400_4, C400_3, C400_2, C400_1
5-8	CVP and SWP Delta Exports over previous 4 months	D409_4, D409_3, D409_2, D409_1
9-12	San Joaquin River flows at Vernalis over previous 4 months	C639_4, C639_3, C639_2, C639_1
13	Estimate of current month's San Joaquin River flows at Vernalis	SJR_ann_est
14-17	Number of days the delta cross channel gates are open for each of the previous 4 months	DXC_4, DXC_3, DXC_2, DXC_1
18	Estimate of current month's number of days with delta cross channel gates open	DXC_est
19-22	Net in-Delta consumptive use over previous 4 months	net_DICU_4, net_DICU_3, net_DICU_2, net_DICU_1
23	Estimate of current month's net in-Delta consumptive use	Net_delta_cu
24-27	Other Sacramento River Basin inflows to the Delta over previous 4 months	sac_oth_4, sac_oth_3, sac_oth_2, sac_oth_1
28	Estimate of current month's inflow to Delta from other Sacramento River Basin sources	sac_oth_est
29-32	Other Delta Exports over previous 4 months	exp_oth_4, exp_oth_3, exp_oth_2, exp_oth_1
33	Estimate of current month's other Delta Exports	exp_oth_est
34-37	San Joaquin River water quality at Vernalis over previous 4 months	VernWQFinal_4, VernWQFinal_3, VernWQFinal_2, VernWQFinal_1
38	Estimate of current month's San Joaquin River water quality at Vernalis	VernWQFinal_est
39-42	Number of days in the month over previous 4 months	daysin_4, daysin_3, daysin_2, daysin_1
43	Number of days in current month	daysin
44	Water quality standards	Water year dependent, monthly varying EC standards at Jersey Point, Rock Slough, Emmaton, and Collinsville
45	Lower bound for linearization of export constraint[1]	JP_line_lo, CO_line_lo, EM_line_lo, RS_line_1_lo, RS_line_2_lo, RS_line_3_lo
46	Upper bound for linearization of export constraint[1]	JP_line_hi, CO_line_hi, EM_line_hi, RS_line_1_hi, RS_line_2_hi, RS_line_3_hi
47	Station identifier[2]	Jersey Point (JP) = 1 Rock Slough (RS) = 2 Emmaton (EM) = 3 Collinsville (CO) = 5
48	Constant type[3]	Slope = 1 Intercept = 2
49	ANN type[4]	Value = 1
50	Previous month index	Mo = 12 if October Otherwise, Mo = TS-1
51	Previous month water year	Year = Water Year - 1 if October, Otherwise, Year = Water Year
52	Other Parameter	Value = 1 for RS linearization #1 Value = 2 for RS linearization #2 Value = 3 for RS linearization #3 Value = 4 for JP, CO, and EM

Notes:
[1] Parameters and associated values derived directly from CalSim model inputs
[2] The ANN functions were developed to consider twelve different stations. However, only four are used.
[3] The constant type is used for the function (i.e. AnnLinGenArray) that returns to WEAP the constants that are used in equations that constrain Delta exports based on Sacramento River and Yolo Bypass flows.

Key: CVP=Central Valley Plan; SWP=State Water Project.

Each of the ANN input parameters listed in Table 7-32, Table 7-33, and Table 7-34 were added as user-defined variables within SacWAM. These were added into WEAP's data tree structure under Other Assumptions. Specifically, they were added under the branch *Other\Ops\Delta\ANN*. The WEAP expressions used to calculate values for these are shown in Table 7-35, where we show expressions only for calculating the previous month's values. This is easily and logically extended to earlier months using WEAP's PrevTSValue function.

Most of these ANN input parameters were easily calculated using SacWAM. However, the San Joaquin River flows at Vernalis and its water quality, *VernWQFinal*, posed a particular challenge because the model does not cover the region from which these flows originate. Instead, we used timeseries of flows obtained from Phase 1 of the Bay-Delta Plan and timeseries of water quality estimates obtained from CalSim II.[15]

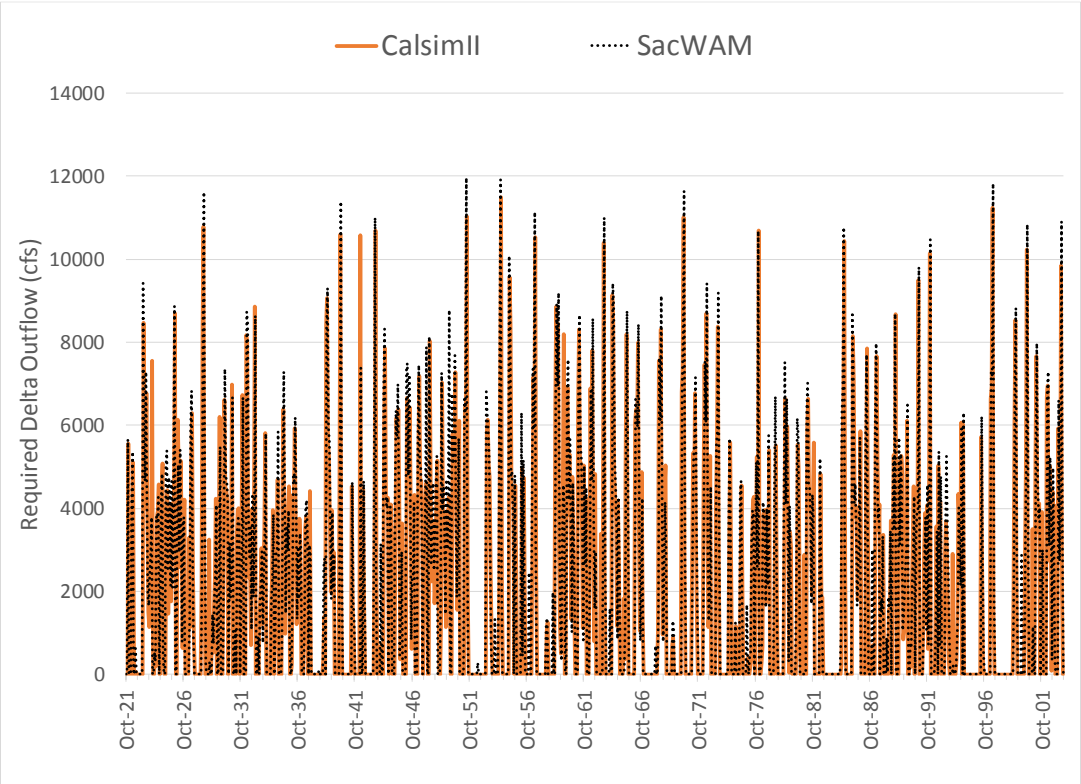
To check that SacWAM is both passing data to the ANN and returning values correctly, ANN results from SacWAM and CalSim II were compared for the same set of flow-based inputs. The model results for previous month salinity at compliance locations matched. However, there were minor differences in the required Delta outflow for salinity control as shown in Figure 7-2. The reasons for these discrepancies has not been identified.

[15] Based on a 1921-2003 CalSim II simulation of existing condition (1_DCR2015_Base_ExistingNoCC) from DWR's 2015 SWP Delivery Capability Report.

Table 7-35. WEAP Parameters Used as Input to Delta ANN

ANN Input Parameter	Description	WEAP Expression Used to Calculate Parameter Value
C400_1	Previous month's Sacramento River flows at Hood	PrevTSValue(Supply and Resources\River\Sacramento River\Reaches\Below SAC to PA510_outdoor:Streamflow[CFS])
D409_1	Previous month's combined CVP pumping at Jones and SWP pumping at Banks	PrevTSValue(Supply and Resources\River\Delta Mendota Canal\Reaches\Below Delta Mendota Canal Diverted Inflow:Streamflow[CFS]) +~PrevTSValue(Supply and Resources\River\California Aqueduct\Reaches\Below California Aqueduct Diverted Inflow:Streamflow[CFS])
C639_1	Previous month's San Joaquin River flows at Vernalis	PrevTSValue(Supply and Resources\River\San Joaquin River\Reaches\Below Vernalis:Streamflow[CFS])
DXC_1	Previous month's number of days with delta cross channel open	If(C400>25000, 0, 1) * MonthlyValues(Oct, 31, Nov, 20, Dec, 16, Jan, 11, Feb, 0, Mar, 0, Apr, 0, May, 0, Jun, 26, Jul, 31, Aug, 31, Sep, 30)
Net_DICU_1	Previous month's net in-Delta consumptive use	PrevTSValue(Demand Sites and Catchments\PA510:Water Demand[CFS]) + PrevTSValue(Demand Sites and Catchments\PA602_North:Water Demand[CFS]) -PrevTSValue(Demand Sites and Catchments\PA510:Interflow[CFS]) - PrevTSValue(Demand Sites and Catchments\PA510:Base Flow[CFS]) - PrevTSValue(Demand Sites and Catchments\PA602_North:Interflow[CFS]) - PrevTSValue(Demand Sites and Catchments\PA602_North:Base Flow[CFS])
Sac_oth_1	Previous month's other Sacramento River Basin inflows to the Delta	PrevTSValue(Supply and Resources\River\Yolo Bypass\Reaches\Below Yolo Bypass to PA510:Streamflow[CFS]) +PrevTSValue(Supply and Resources\River\Mokelumne River\Reaches\Below Cosumnes River Inflow:Streamflow[CFS]) +PrevTSValue(Supply and Resources\River\Calaveras River\Reaches\Below CAL to PA603S PA603_indoor PA602_indoor:Streamflow[CFS])
Exp_oth_1	Previous month's other exports from the Delta	PrevTSValue(Supply and Resources\Transmission Links\to PA601andCC_Indoor\from SAC to PA601andCC_Indoor:Flow[CFS]) + 0.1 * PrevTSValue(Supply and Resources\Transmission Links\to PA602_North\from SJR to PA602N:Flow[CFS])
VernWQFinal_1	Previous month's San Joaquin River water quality at Vernalis	If(Other\Ops\Environmental Requirements\SacWYT = 1, MonthlyValues(Oct, 508, Nov, 582, Dec, 704, Jan, 600, Feb, 457, Mar, 387, Apr, 296, May, 292, Jun, 405, Jul, 499, Aug, 451, Sep, 459), Other\Ops\Environmental Requirements\SacWYT = 2, MonthlyValues(Oct, 581, Nov, 667, Dec, 815, Jan, 740, Feb, 678, Mar, 555, Apr, 383, May, 390, Jun, 498, Jul, 601, Aug, 548, Sep, 542), Other\Ops\Environmental Requirements\SacWYT = 3, MonthlyValues(Oct, 550, Nov, 622, Dec, 790, Jan, 785, Feb, 670, Mar, 671, Apr, 407, May, 415, Jun, 568, Jul, 633, Aug, 566, Sep, 567), Other\Ops\Environmental Requirements\SacWYT = 4, MonthlyValues(Oct, 541, Nov, 628, Dec, 834, Jan, 854, Feb, 908, Mar, 904, Apr, 483, May, 514, Jun, 634, Jul, 646, Aug, 611, Sep, 598), MonthlyValues(Oct, 611, Nov, 667, Dec, 877, Jan, 903, Feb, 947, Mar, 951, Apr, 580, May, 594, Jun, 648, Jul, 647, Aug, 664, Sep, 654))

Key: CVP=Central Valley Plan; SWP=State Water Plan.



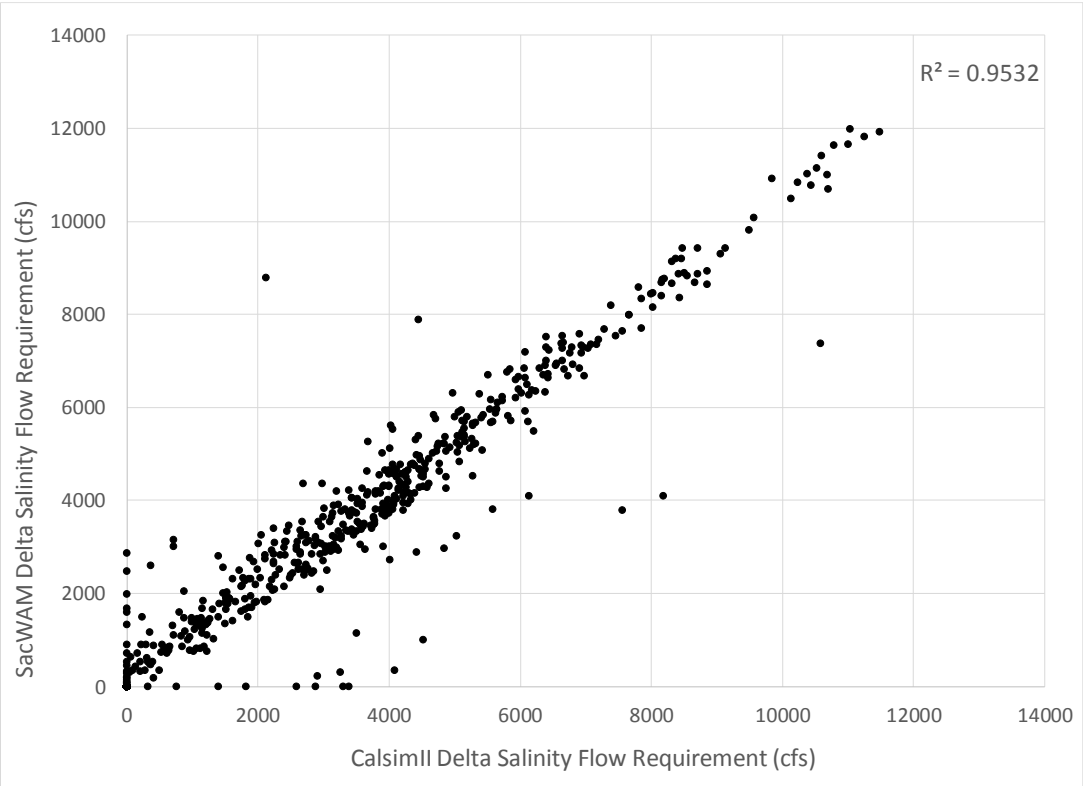


Figure 7-2. Required Delta Outflow for Salinity Control as Simulated by CalSim II and SacWAM

To use the ANN to calculate Delta salinity flow requirements, SacWAM must provide the ANN estimates of current time step values for each of the parameters listed in Table 7-34 except the first two, i.e. Sacramento River flows at Hood and combined CVP and SWP pumping from the Delta. To estimate these values, we used a statistical approach that used a baseline SacWAM run from 1950 to 2005 to derive flow estimates. The development of these estimates is described below.

The implementation of the ANN to enforce water quality standards is set up in SacWAM in *User Defined LP Constraints*. For information about these constraints, see Section 8.7.

Net in-Delta Consumptive Use

SacWAM estimates the current month's net in-Delta consumptive use using average monthly values derived from a 1950-2005 WEAP baseline simulation (Table 7-36). The agreement of this estimation (*net_Delta_cu_est*) with simulated values of net in-Delta consumptive use (*net_DICU*) are shown in Figure 7-3.

Table 7-36. Simulated Average Monthly Net in-Delta Consumptive Use by Water-Year Type

Sacramento Valley Water-Year Type	Average Monthly Flow 1950-2005 (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wet	208	266	(358)	(499)	(306)	104	870	1,902	3,500	2,917	2,861	514
AboveNormal	195	338	(277)	(467)	(362)	123	1,149	1,804	3,582	2,966	2,871	536
BelowNormal	422	444	(144)	(215)	(75)	601	1,611	2,415	3,676	2,957	2,890	516
Dry	259	387	(149)	(193)	149	626	1,537	2,370	3,665	2,982	2,871	505
Critical	204	452	(71)	(44)	162	739	1,537	2,097	3,573	2,978	2,893	531

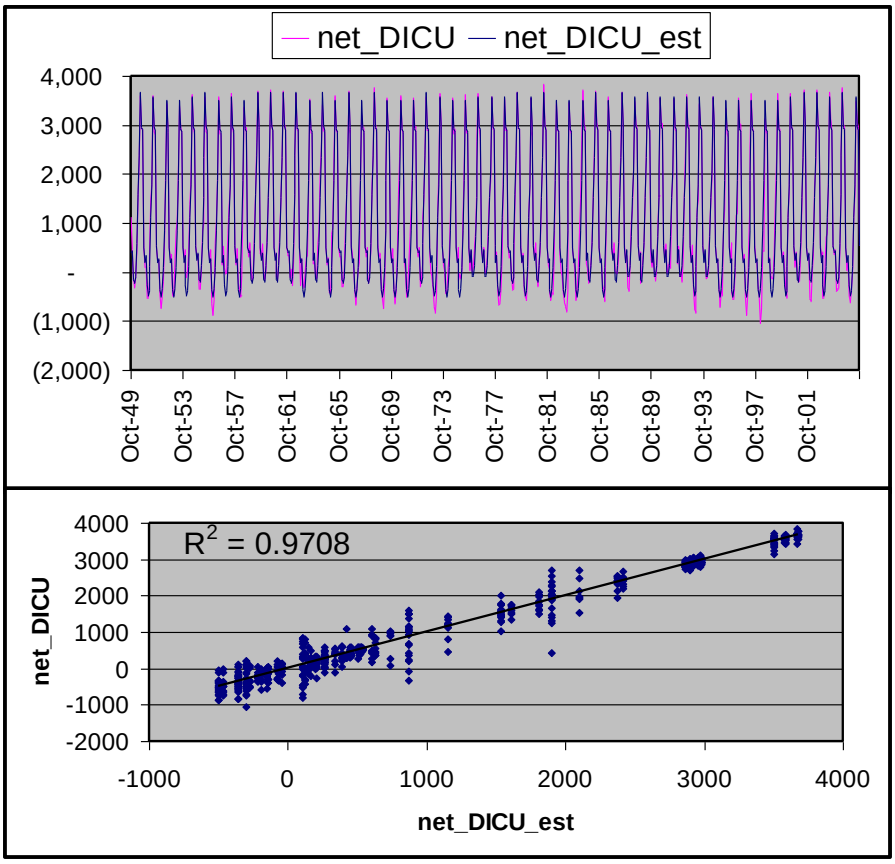


Figure 7-3. Statistical Estimation of In-Delta Net Consumptive Use

Other Delta Exports

The current month's other Delta exports are estimated by the following equation:

exp_oth_est = 0.90 * average monthly 'other exports' +
(1 - 0.90) * previous month's 'other exports' * monthly perturbation

where the monthly perturbation is the ratio of average current month's other exports over the average of the previous month's other exports and is shown with the average monthly other exports in Table 7-37. The agreement of this estimation (*exp_oth_est*) with simulated values of other exports (*exp_oth*) are shown in Figure 7-4.

Table 7-37. Simulated Average Monthly Other Delta Exports

Sacramento Valley Water-Year Type	Average Monthly Flow 1950-2005 (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wet	238	262	231	231	231	253	294	347	429	391	375	249
AboveNormal	238	263	231	231	231	251	308	336	433	393	375	249
BelowNormal	241	266	232	231	231	267	328	367	436	392	376	249
Dry	238	265	232	231	234	270	325	366	436	393	375	249
Critical	238	266	232	232	234	274	325	351	432	393	376	249
Monthly Pertubation	0.96	1.11	0.88	1.00	1.01	1.13	1.20	1.12	1.23	0.91	0.96	0.66

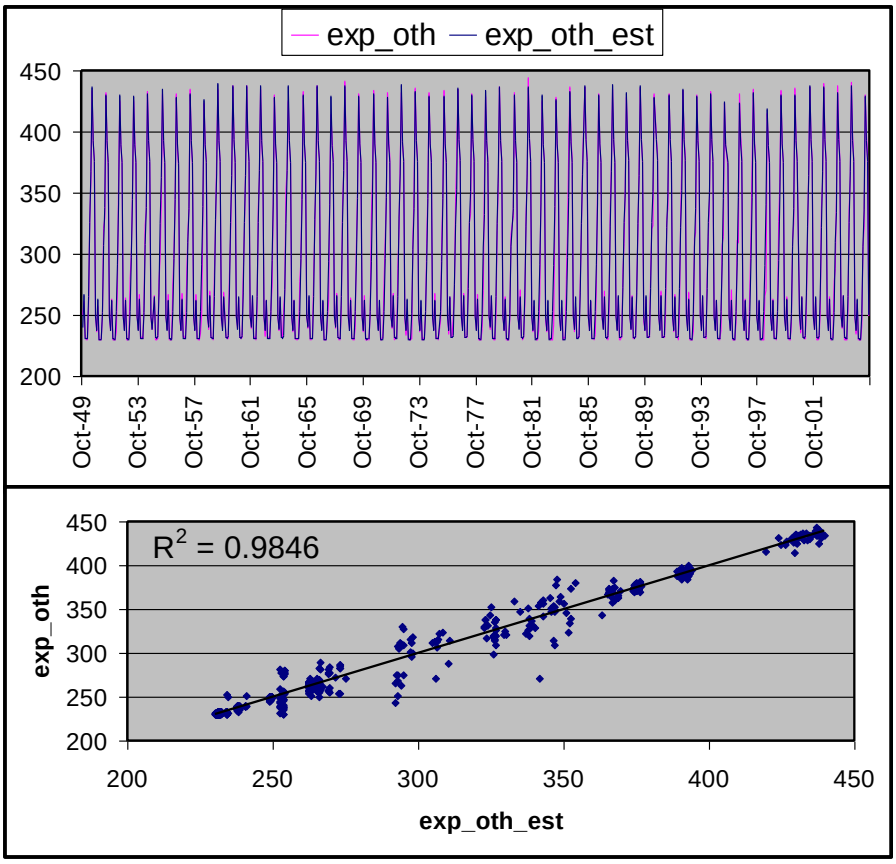


Figure 7-4. Statistical Estimation of Other Delta Exports

Other Sacramento River Basin Inflows to the Delta

The current month's other Sacramento River basin inflows to the Delta is estimated by the following equation:

sac_oth_est = 0.75 * average monthly (Mokelumne+Cosumnes+Calaveras) inflows +
(1 - 0.75) * previous month's Mok+Cos+Cal inflows * monthly perturbation +
average monthly Yolo Bypass inflows

where the monthly perturbation is the ratio of average current month's inflows over the average of the previous month's combined inflows and is shown with the average monthly values in Table 7-38. Average monthly Yolo Bypass inflows are shown in Figure 7-5.

The agreement of this estimation (*sac_oth_est*) with baseline simulated valued (*sac_oth*) is shown in Figure 7-5.

Table 7-38. Simulated Average Monthly Eastside Streams Inflows to the Delta

Sacramento Valley Water-Year Type	Average Monthly Flow 1950-2005 (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wet	980	688	2,619	6,052	7,078	6,371	4,773	2,897	863	474	363	681
AboveNormal	1,523	1,229	3,029	3,554	5,404	3,625	2,570	1,507	676	438	360	555
BelowNormal	937	562	1,159	1,804	2,362	2,080	2,318	1,175	550	344	270	387
Dry	1,329	640	1,091	1,437	2,054	1,821	1,182	740	439	320	275	391
Critical	1,129	355	401	552	843	1,195	1,029	560	357	240	197	195
Monthly Pertubation	2.67	0.59	2.39	1.61	1.32	0.85	0.79	0.58	0.42	0.63	0.81	1.51

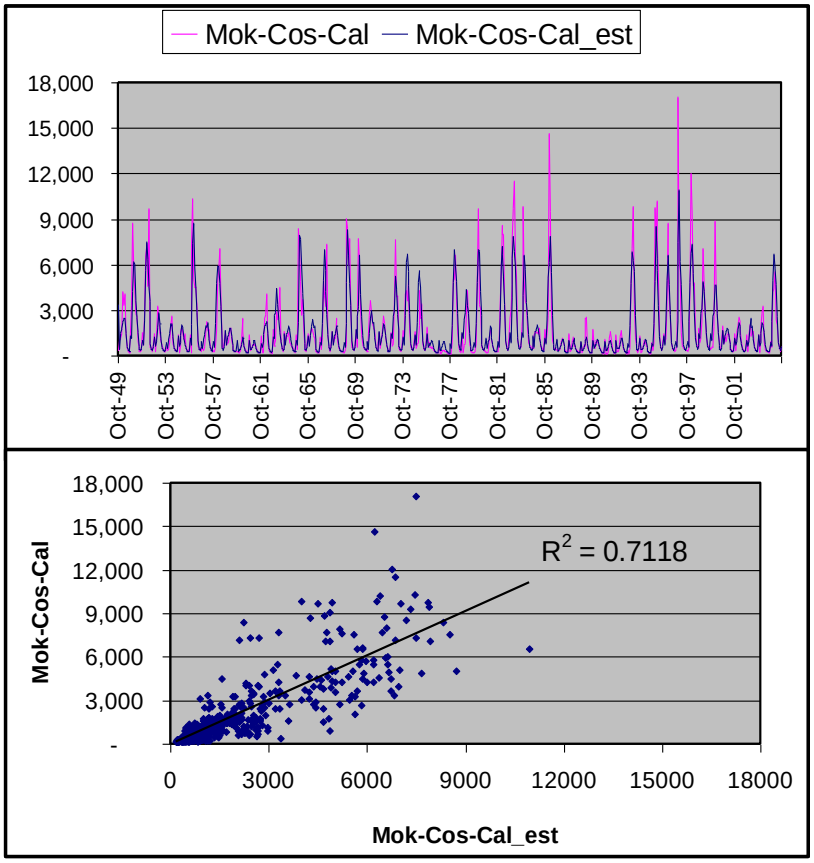


Figure 7-5. Statistical Estimation of Combined Mokelumne-Cosumnes-Calaveras River Inflows to the Delta

Delta Cross Channel Gates

Within the current time step, SacWAM uses the Bay-Delta Plan (SWRCB, 1995) monthly varying estimate of the number of days that the gates are open (Table 7-39), which was taken from the CalSim II model.

Table 7-39. Days Open for Delta Cross-Channel Gate

Month	Number of Days Open
October	31
November	20
December	16
January	11
February	0
March	0
April	0
May	0
June	26
July	31
August	31
September	30

7.2.7 Hydrologic Indices

SacWAM contains routines for tracking hydrologic indices for different watersheds within the Sacramento and San Joaquin River basins. These indices are used within the model to adjust environmental flow requirements and to guide curtailment of deliveries to CVP and SWP water contractors.

SacWAM offers two methods for determining hydrologic indices: (1) read in historical values from an external file or (2) estimate indices using WEAP's hydrologic module. The first method is used when the model is run with fixed timeseries of historical inflows. In this case, annual values are read in for the historical period 1922-2009. The second method is used when WEAP hydrologic routines are used to estimate runoff. While this method may introduce some error because it relies on forecasting flows with imperfect information, it allows the model to be run under climatic conditions that are different from the historical record.

When the hydrologic routines are used in SacWAM, annual water yields are estimated in the winter and early spring (Feb-May) so that water allocations may be adjusted to match estimates of available water supply for the year. Threshold criteria are applied to these water yield estimates to determine water-year types (WYTs), which influence both water allocations and environmental flow standards.

Annual water yields are estimated using a combination of cumulative runoff since the beginning of the water year and runoff forecasts for the remainder of the water year. Cumulative runoff is simply the sum of the simulated unimpaired flows (i.e. runoff from all upstream catchments) since October 1st. Runoff forecasts are estimated using regression equations that are based on a combination of simulated snowpack and cumulative runoff as the independent variables. Regression equations were developed for each month February through May to estimate runoff through the remainder of the water year. These regression equations took the following form:

$$\sum_{t}^{t=12} Q_t = C_1 + C_2 \sum_{t=1}^{t-1} Q_t + C_3 S_{t-1}$$

where t is the water-year month (i.e. t=1 in October and t=12 in September), Q_t is the runoff at some location, S_{t-1} is the snowpack at the end of the previous month, and C_1, C_2, and C_3 are the regression coefficients.[16]

The sections below summarize the results of applying this approach to estimate runoff forecasts for several locations: Trinity River at Lewiston, Sacramento River at Lake Shasta, Sacramento River at Bend Bridge, Feather River at Oroville, Yuba River at Smartville, American River at Folsom Lake, and Mokelumne River at Pardee.

Some general trends were observed. First, the correlation between runoff forecasts and the simulated runoff are poor at the beginning of the process (February) and become stronger as we move into spring (April-May). This is largely due to the fact that the two independent variables that we are using —i.e. October-January runoff and end-of-January snowpack—are poor indicators of water-year hydrology; there is too much uncertainty this early in the water year.

Another thing to note is that higher correlations between snowpack and runoff result in more reliable estimates of runoff forecasts. This implies two things. First, in locations where there is a strong correlation to snowpack, the regression equations tend to weight the snowpack more heavily in April and May. Second, these correlations are stronger in high-elevation watersheds that have hydrographs dominated by spring snowmelt. Thus, the correlations tend to become stronger as we move south in the Sierra watersheds.

7.2.7.1 *Trinity*

Trinity River WYTs (Table 7-40) are based on the total annual (October-September) water yield upstream from Lewiston Dam. Five water-year classes are defined based on the Trinity *Index* (*CumInflow* + *Runoff Forecast*) for the Trinity River under *Ops\Hydrologic Indices\Trinity* (USFWS and Hoopa Valley Tribe, 1999).

Table 7-40. Trinity River Water-Year Classifications

Water-Year Class	Annual Water Yield (TAF)	Code in WEAP
Extremely Wet	>= 2000	1
Wet	1350 to 2000	2
Normal	1025 to 1350	3
Dry	650 to 1025	4
Critically Dry	< 650	5

CumInflow

The cumulative inflow consists of the total cumulative flow to the river of the upstream catchments since the beginning of the water year (October 1) adjusted by the *Simulate Hydrology* parameter (see Section 9.4).

[16] Note that in the case of estimating runoff forecasts for the Sacramento River at Bend Bridge, we use snowpack values from four separate upstream watersheds: Upper Sacramento River, Pitt River, Clear Creek, and Cottonwood Creek. Thus, this equation is expanded to include six regression coefficients.

Runoff Forecast

Table 7-41 shows the regression coefficients (*Runoff Forecast\C1*, *C2*, and *C3*) that are used in estimating runoff forecasts for the Trinity River at Lewiston (*Runoff Forecast*). These calculations relied on snowpack from one upstream catchment (*Runoff Forecast\Snowpack*).

Table 7-41. Regression Coefficients Used to Forecast Runoff for Trinity River

Regression Coefficient	February	March	April	May
C1	404.2974	131.6744	41.8316	53.1807
C2	0.5226	0.5472	0.2841	0.1506
C3	1.0669	0.9302	0.8739	0.7013
r-square	0.474	0.672	0.856	0.839

Figure 7-6 shows the relationship between the simulated runoff forecast (through September) and the cumulative runoff and representative snowpack for each month February through May. The graphs in the far-right column compare the runoff estimate using regression equations based on the cumulative runoff and snowpack against SacWAM simulations of runoff through September.

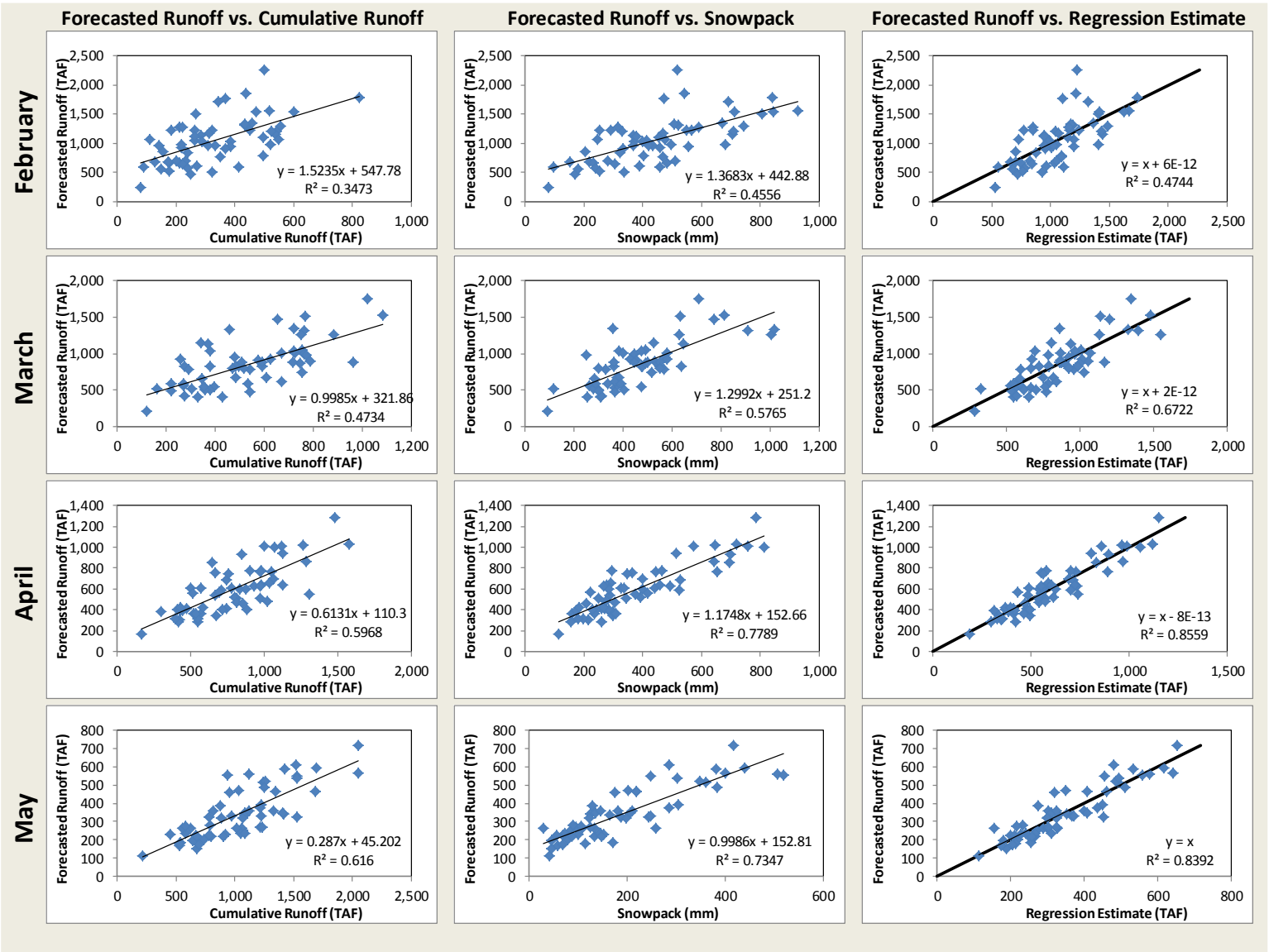


Figure 7-6. Development of Runoff Forecast Estimates Using Cumulative Runoff and Snowpack: Trinity River at Lewiston Dam

7.2.7.2 *SacWYT*

The Sacramento Valley index (*SRI 403030*) is determined using unimpaired runoff estimates from four locations: Sacramento River at Bend Bridge (*Sac Inflow Forecast*), Feather River inflow to Lake Oroville (*Fea Inflow Forecast*), Yuba River at Smartville (*Yub Inflow Forecast*), and American River inflow to Folsom Lake (*Amr Inflow Forecast*). The index also uses the previous year's value to take into consideration antecedent conditions within the basin. The index is sometimes referred to as the Sacramento Valley 40-30-30 index, because it considers 40 percent of the April-July Runoff Forecast, 30 percent of the October-March runoff, and 30 percent of the previous water year's index to calculate the current year's index. The Sacramento Valley index has five water-year classifications (Table 7-42).

Table 7-42. Sacramento Valley Water-Year Classifications

Water-Year Class	Annual Water Yield (TAF)	Code in WEAP
Wet	>= 9200	1
Above Normal	7800 to 9200	2
Below Normal	6500 to 7800	3
Dry	5400 to 6500	4
Critical	< 5400	5

Table 7-43 shows the regression coefficients that are used in estimating runoff forecasts for the Sacramento River at Bend Bridge. This relied on snowpack from four upstream catchments:

Table 7-43. Runoff Forecast Regression Coefficients for Sacramento River at Bend Bridge

Regression Coefficient	February	March	April	May
C1	1943.5467	848.0206	444.1380	541.3330
C2	0.5316	0.4581	0.2105	0.1161
C3	-3.6511	-0.4514	-1.7650	-1.3773
C4	3.1094	0.6741	4.6631	2.6186
C5	-3.5308	-3.1641	-9.1402	0.3465
C6	10.4702	10.1683	13.2429	-1.3175
r-square	0.407	0.608	0.826	0.807

Table 7-44 shows the regression coefficients that are used in estimating runoff forecasts for the Feather River at Lake Oroville. This relied on snowpack from one upstream catchment.

Table 7-44. Runoff Forecast Regression Coefficients for Feather River Inflows into Lake Oroville

Regression Coefficient	February	March	April	May
C1	1213.6026	582.0690	293.6549	291.8108
C2	0.6509	0.5578	0.2727	0.1179
C3	3.7878	2.3723	2.6826	2.3051
r-square	0.529	0.625	0.842	0.795

Table 7-45 shows the regression coefficients that are used in estimating runoff forecasts for the Yuba River at Smartville. This relied on snowpack from one upstream catchment.

Table 7-45. Runoff Forecast Regression Coefficients for Yuba River at Smartville

Regression Coefficient	February	March	April	May
C1	866.7323	461.1509	167.2367	141.6308
C2	0.4149	0.4195	0.1995	0.0793
C3	1.4127	1.0042	1.2248	1.1898
r-square	0.496	0.559	0.766	0.806

Table 7-46 shows the regression coefficients that are used in estimating runoff forecasts for the American River at Folsom Lake. This relied on snowpack from one upstream catchment.

Table 7-46. Runoff Forecast Regression Coefficients for American River Inflows into Folsom Reservoir

Regression Coefficient	February	March	April	May
C1	656.1048	151.9844	-276.4494	-74.1189
C2	-0.1730	0.2013	-0.1303	-0.0424
C3	2.8117	1.8706	2.2392	1.5050
r-square	0.537	0.636	0.872	0.920

Figure 7-7, Figure 7-8, Figure 7-9, and Figure 7-10 show the relationship between the simulated runoff forecast (through July) and the cumulative runoff and representative snowpack for each month February through May. The graphs in the far-right columns compare the runoff estimates using regression equations based on the cumulative runoff and snowpack against SacWAM simulations of runoff through July.

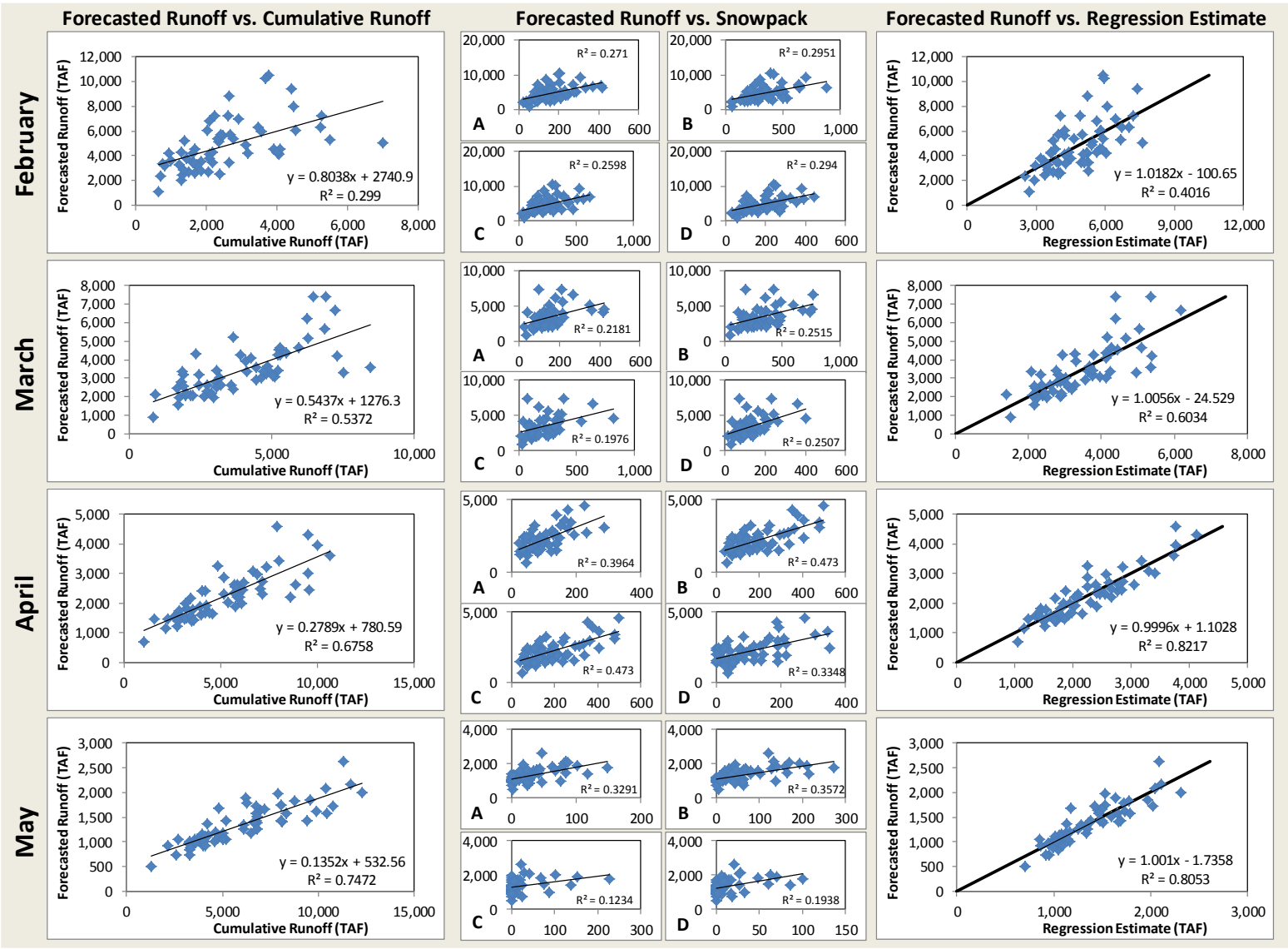


Figure 7-7. Development of Runoff Forecast Estimates Using Cumulative Runoff and Snowpack: Sacramento River at Bend Bridge

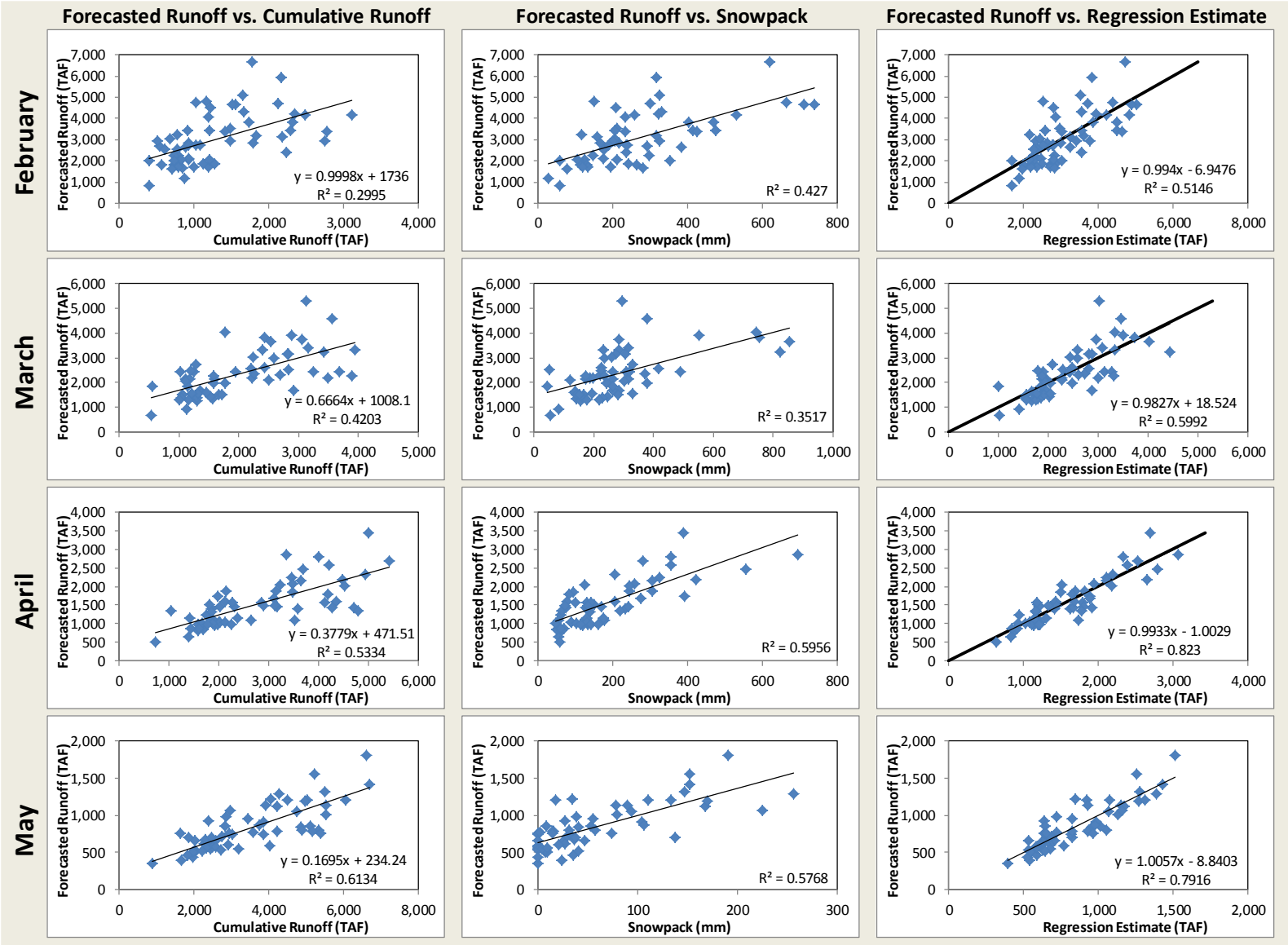


Figure 7-8. Development of Runoff Forecast Estimates Using Cumulative Runoff and Snowpack: Feather River at Lake Oroville

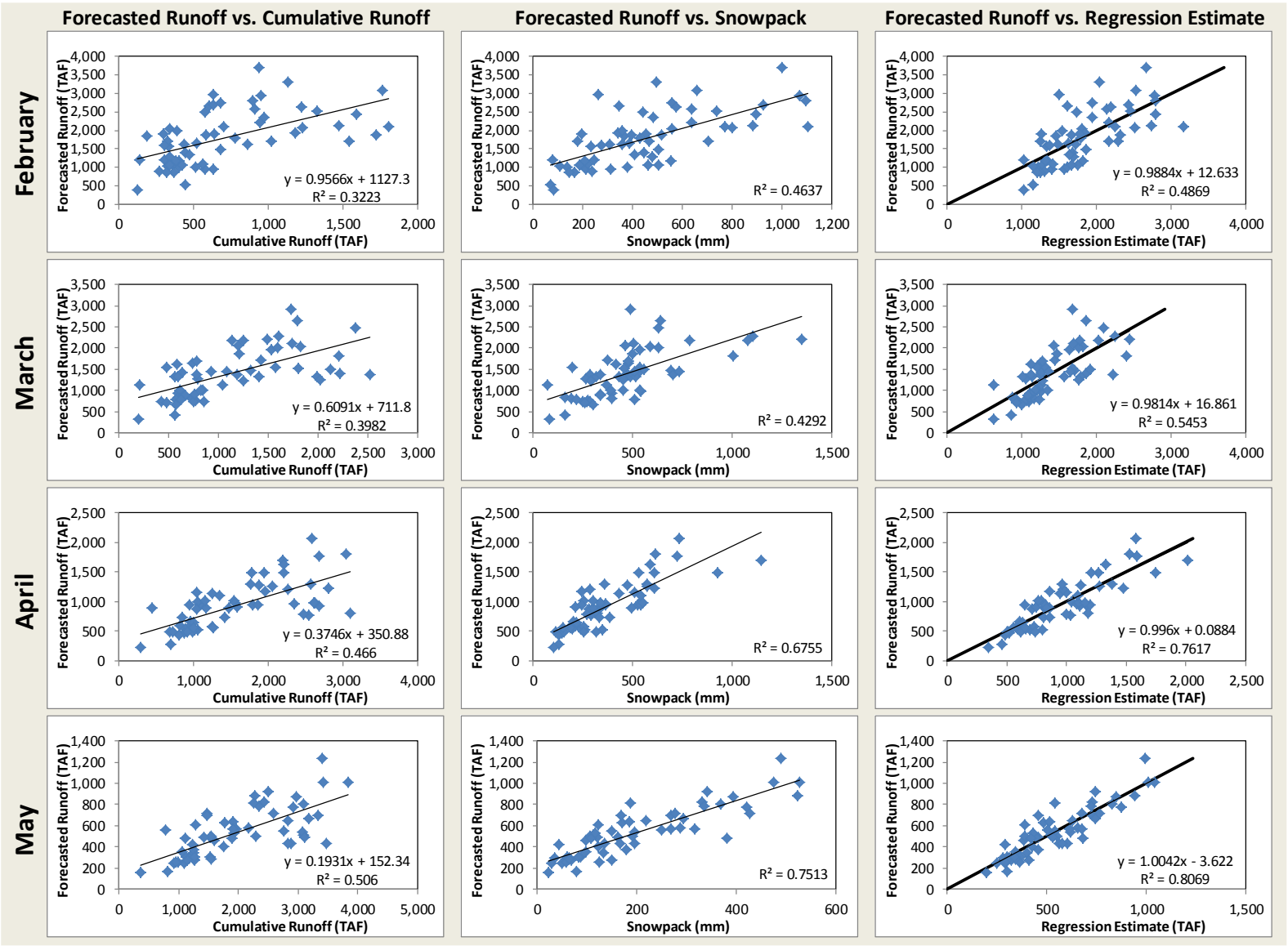


Figure 7-9. Development of Runoff Forecast Estimates Using Cumulative Runoff and Snowpack: Yuba River at Smartville

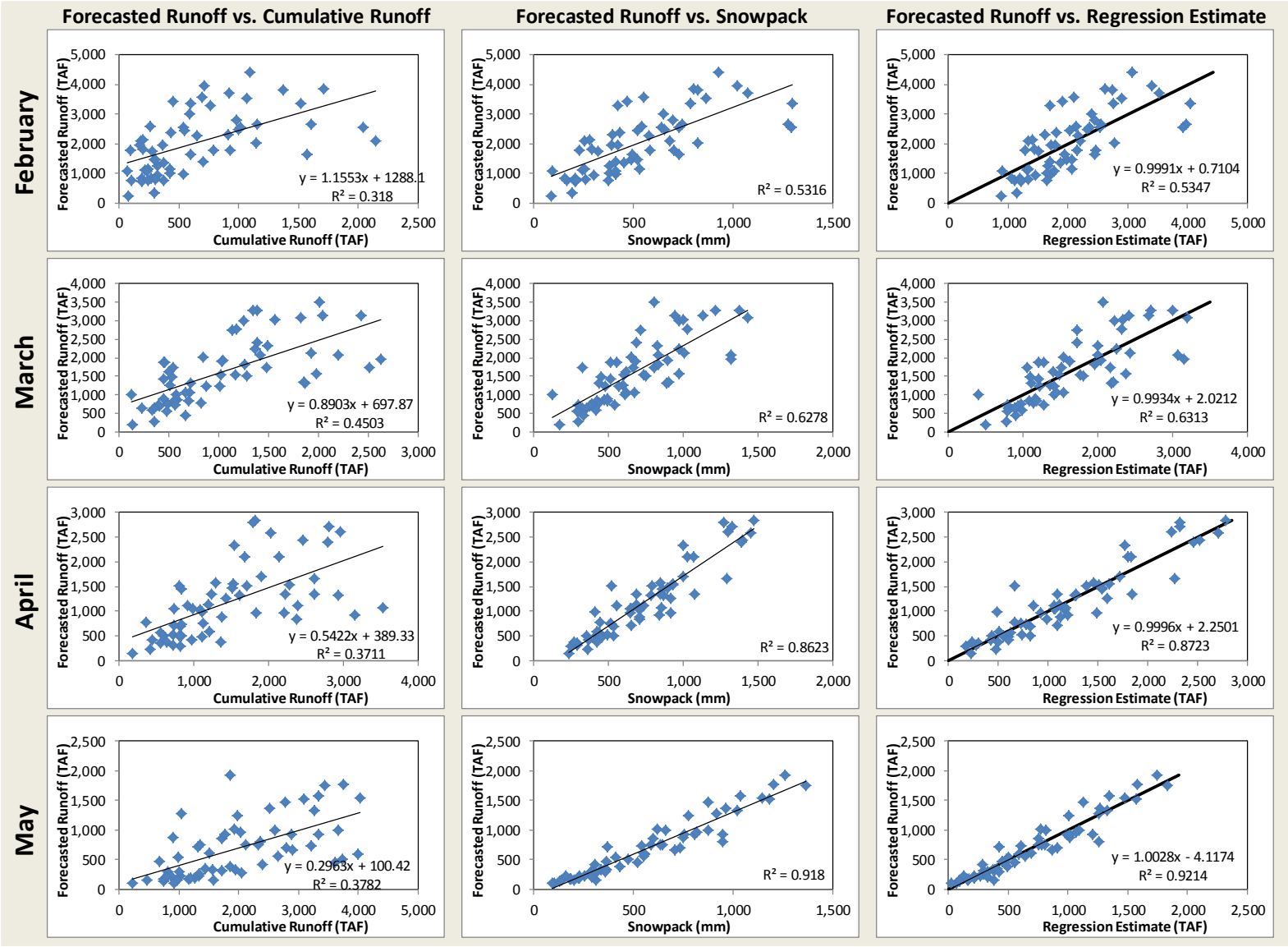


Figure 7-10. Development of Runoff Forecast Estimates Using Cumulative Runoff and Snowpack: American River at Folsom Lake

Figure 7-11 and Figure 7-12 show a comparison of the SacWAM estimate of the Sacramento 40-30-30 Water-Year Index to historical values over the period 1950-2009. The model generally agrees well the observed. It tracks the inter-annual variation well. However, it is slightly drier (less 4.76%) on average than the historical.

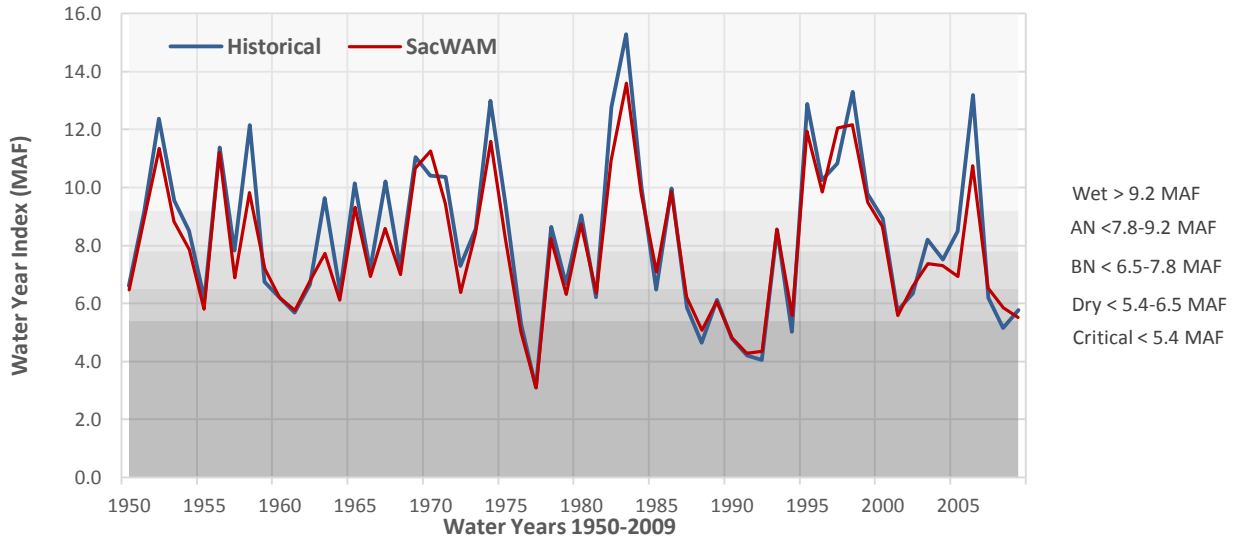


Figure 7-11. Comparison of SacWAM Forecast and Historical Sacramento Valley Water-Year Index

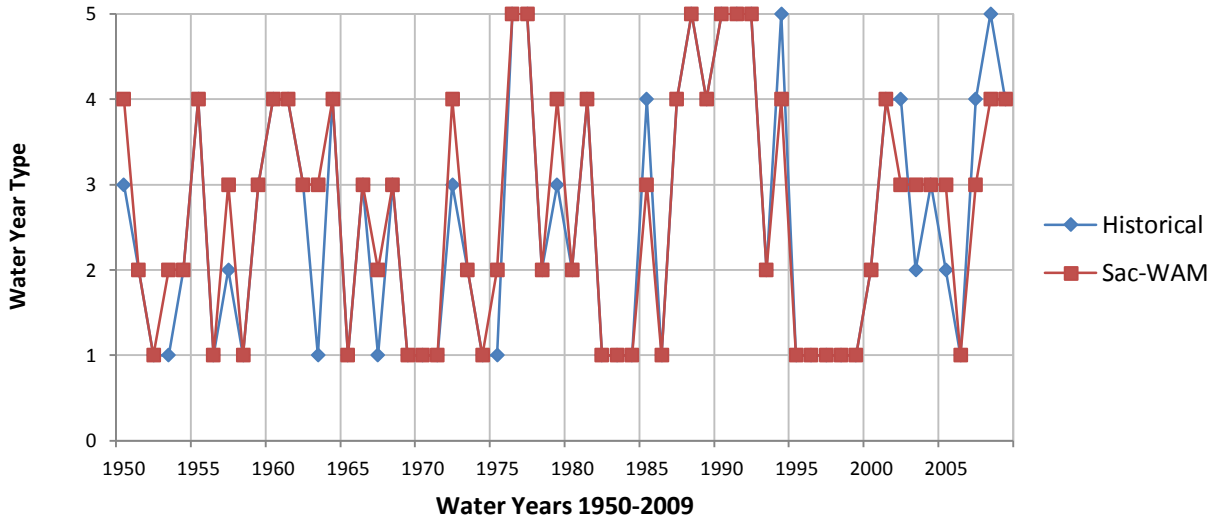


Figure 7-12. Comparison of SacWAM Forecast and Historical Sacramento Valley Water-Year Type

Wet=1; Above Normal=2; Below Normal=3; Dry=4; Critical=5

7.2.7.3 *Shasta*

Shasta reservoir has its own index, which is used to reduce water allocations to CVP Settlement and Exchange contractors when the index drops below a critical threshold. If the total full natural inflow (*Index*) into Shasta is less than 3.2 MAF in any given year, then it is declared a "Shasta critical" year. Also, if the total inflow in two consecutive years is less than 7.2 MAF, then the second year is determined to be a Shasta critical year.

The index is calculated as the sum of the flows to river in all the catchments above Shasta (*CumInflow*) and the *Runoff Forecast*, which is estimated using a regression equation based on runoff, upstream inflow, and snowpack in one of the watershed's high-altitude catchments.

Using this approach, SacWAM estimates that there were four Shasta critical years that occurred during the 1950-2005 historical period: 1976, 1977, 1991, and 1992. This compares well to the observed record, in which there were Shasta critical years in 1977, 1991, 1992, and 1994. The fact that the model did not accurately characterize the water years in 1976 or 1994 is a reflection of our modeling approach that does not rely upon perfect foresight. It should also be noted that the WEAP-estimated cumulative inflows in both of these years were close to the 3.2 MAF threshold—i.e. 3.02 MAF in 1976 and 3.77 MAF in 1994.

Table 7-47 shows the regression coefficients that are used in estimating runoff forecasts for the Sacramento River at Lake Shasta. This relied on snowpack from one upstream catchment.

Table 7-47. Runoff Forecast Regression Coefficients for Sacramento River Inflows into Lake Shasta

Regression Coefficient	February	March	April	May
C1	1790.9826	777.0032	462.7882	429.6317
C2	0.6847	0.5239	0.2754	0.1409
C3	7.1599	5.0095	6.2453	3.6454
r-square	0.345	0.577	0.737	0.786

Figure 7-13 shows the relationship between the simulated runoff forecast (through September) and the cumulative runoff and representative snowpack for each month February through May. The graphs in the far-right column compare the runoff estimate using regression equations based on the cumulative runoff and snowpack against SacWAM simulations of runoff through September.

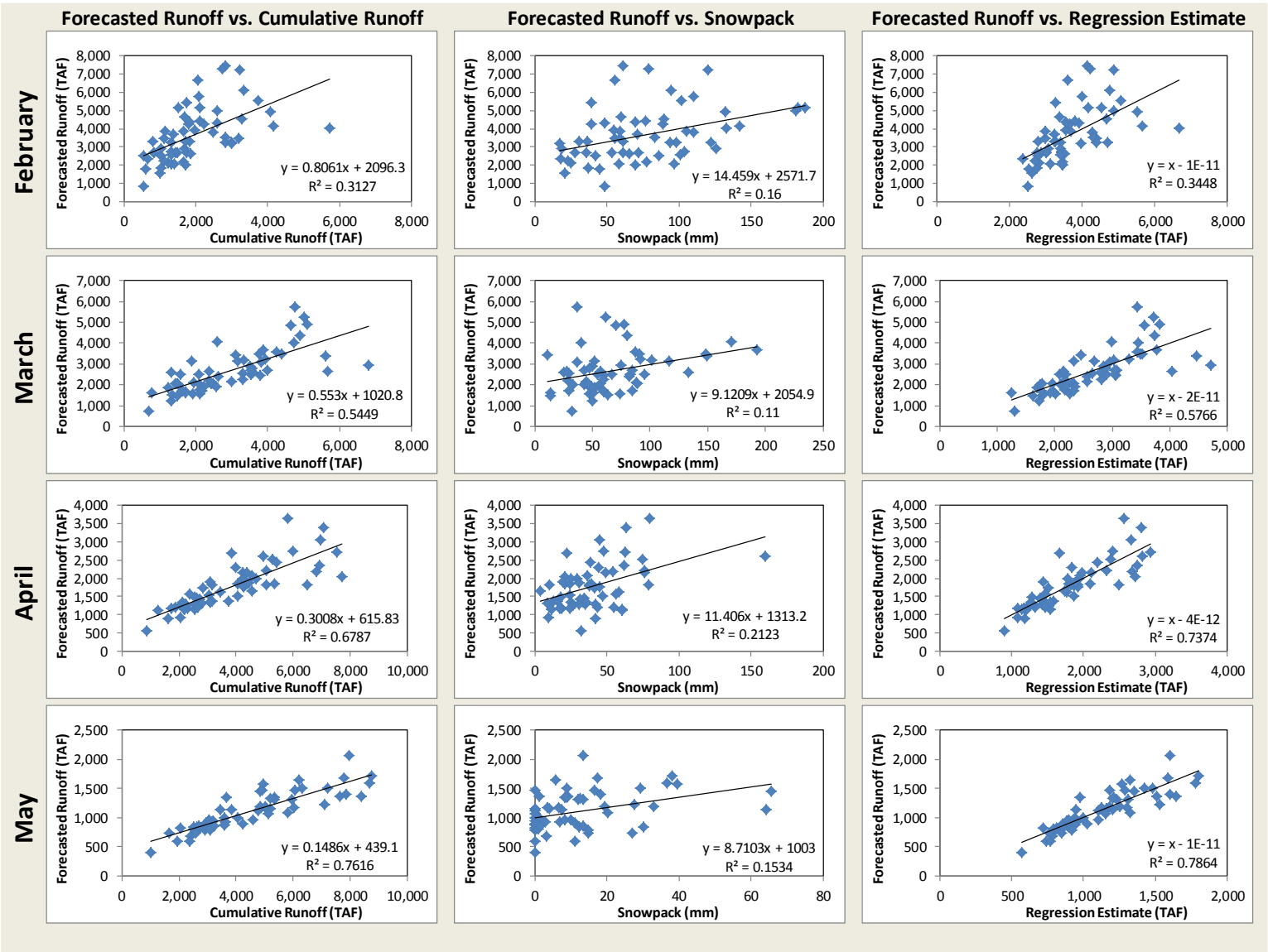


Figure 7-13. Development of Runoff Forecast Estimates Using Cumulative Runoff and Snowpack: Sacramento River at Lake Shasta

7.2.7.4 *North Yuba*

The North Yuba Index is a measure of the amount of water available in the North Yuba River at New Bullards Bar Reservoir. The index considers total inflow into New Bullards Bar for the current water year (including runoff forecasts) and carryover storage in New Bullards Bar from the previous water year minus the Federal Energy Regulatory Commission (FERC) Project License minimum pool amount of 234 TAF. The index is used to determine different flow schedules for the Yuba River at Smartville and Marysville. Thresholds for these flow schedules are summarized in Table 7-48.

Table 7-48. Flow Schedule Thresholds for the Yuba River

Flow-Schedule Year Type	North Yuba Index (TAF)
Schedule 1	>= 1400
Schedule 2	1040 to 1400
Schedule 3	920 to 1040
Schedule 4	820 to 920
Schedule 5	693 to 820
Schedule 6	<= 693

Table 7-49 shows the regression coefficients that are used in estimating runoff forecasts for the Yuba River at Smartville. This relied on snowpack from one upstream catchment.

Table 7-49. Runoff Forecast Regression Coefficients for the Yuba River at Smartville

Regression Coefficient	February	March	April	May
C1	928.7676	514.2141	209.3818	184.6664
C2	0.4348	0.4434	0.2179	0.0943
C3	1.4456	1.0289	1.2780	1.2827
r-square	0.494	0.557	0.765	0.810

Figure 7-14 shows the relationship between the simulated runoff forecast (through September) and the cumulative runoff and representative snowpack for each month February through May. The graphs in the far-right column compare the runoff estimate using regression equations based on the cumulative runoff and snowpack against SacWAM simulations of runoff through September.

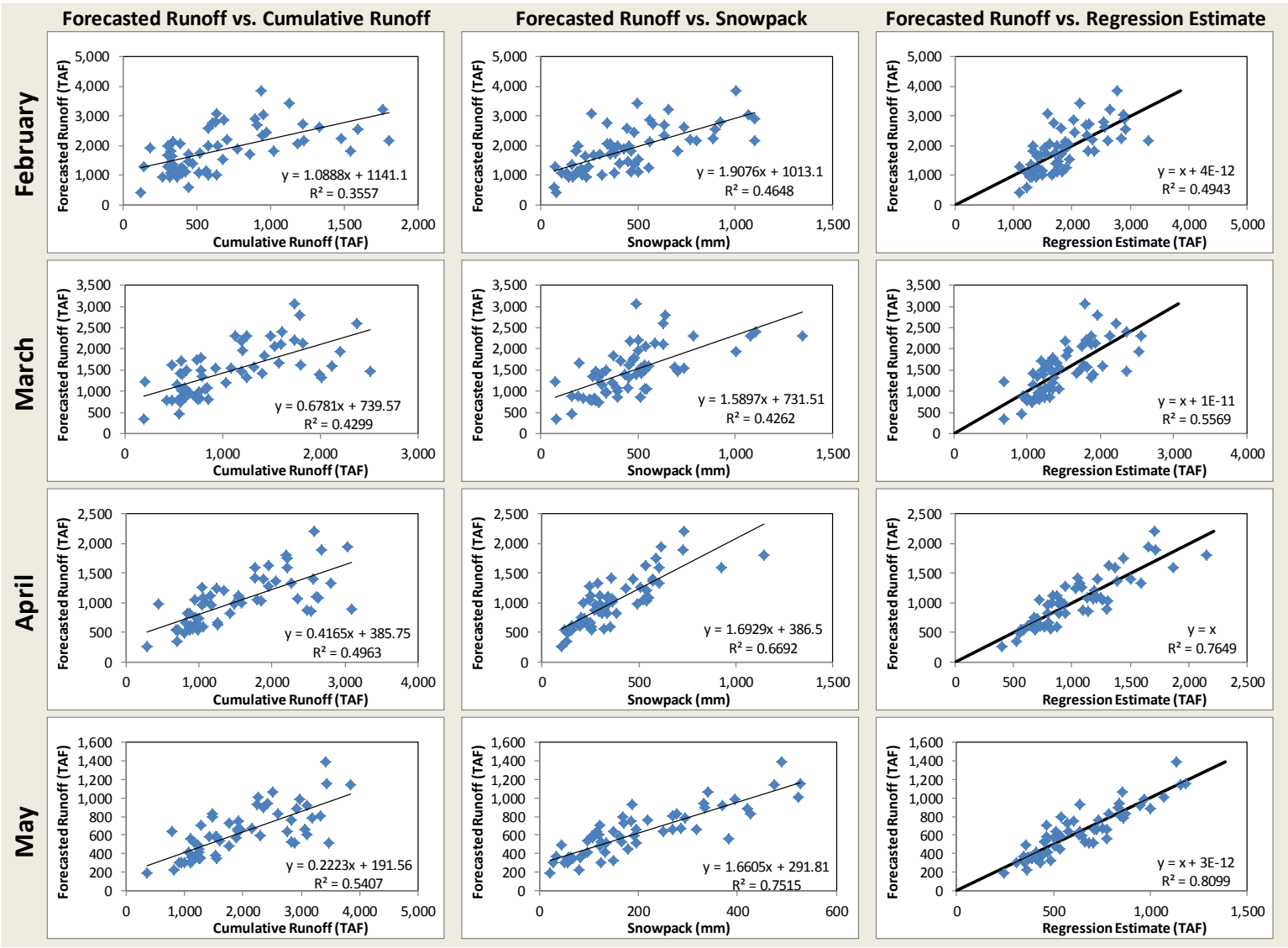


Figure 7-14. Development of Runoff Forecast Estimates Using Cumulative Runoff and Snowpack: Yuba River at Smartville

7.2.7.5 *Mokelumne*

Water-year classifications in the Mokelumne system are based on annual water yield.

JSA_AprSep_WYType

The JSA involving EBMUD, USFWS, and California Department of Fish and Wildlife (CDFW)…(Table 7-50). The flows

Table 7-50. Mokelumne River JSA April-to-September Water-Year Classifications

Water-Year Class	Annual Water Yield (TAF)	Code in WEAP
Normal/Above Normal	>= 890	1
Below Normal	500 to 889	2
Dry	300 to 499	3
Critical	<=299	4

Runoff Forecast

Table 7-51 shows the regression coefficients that are used in estimating runoff forecasts for the Mokelumne River at Pardee Lake. The total forecasted runoff is equal to *C1* + *C2* * *CumulativeInflowtoDate* + *C3* * *Snowpack* where *CumulativeInflowtoDate* consists of the Flow to River in the six upstream catchments, and *Snowpack* is the snowpack in the one catchment above 2000 m elevation.

Table 7-51. Runoff Forecast Regression Coefficients for the Mokelumne River at Pardee Lake

Regression Coefficient	February	March	April	May
C1	202.9001	73.4181	-47.1397	15.9103
C2	0.0008	0.2998	0.1105	0.1577
C3	0.8238	0.6548	0.6150	0.4153
r-square	0.610	0.680	0.873	0.914

Figure 7-15 shows the relationship between the simulated runoff forecast (through September) and the cumulative runoff and representative snowpack for each month February through May. The graphs in the far-right column compare the runoff estimate using regression equations based on the cumulative runoff and snowpack against SacWAM simulations of runoff through September.

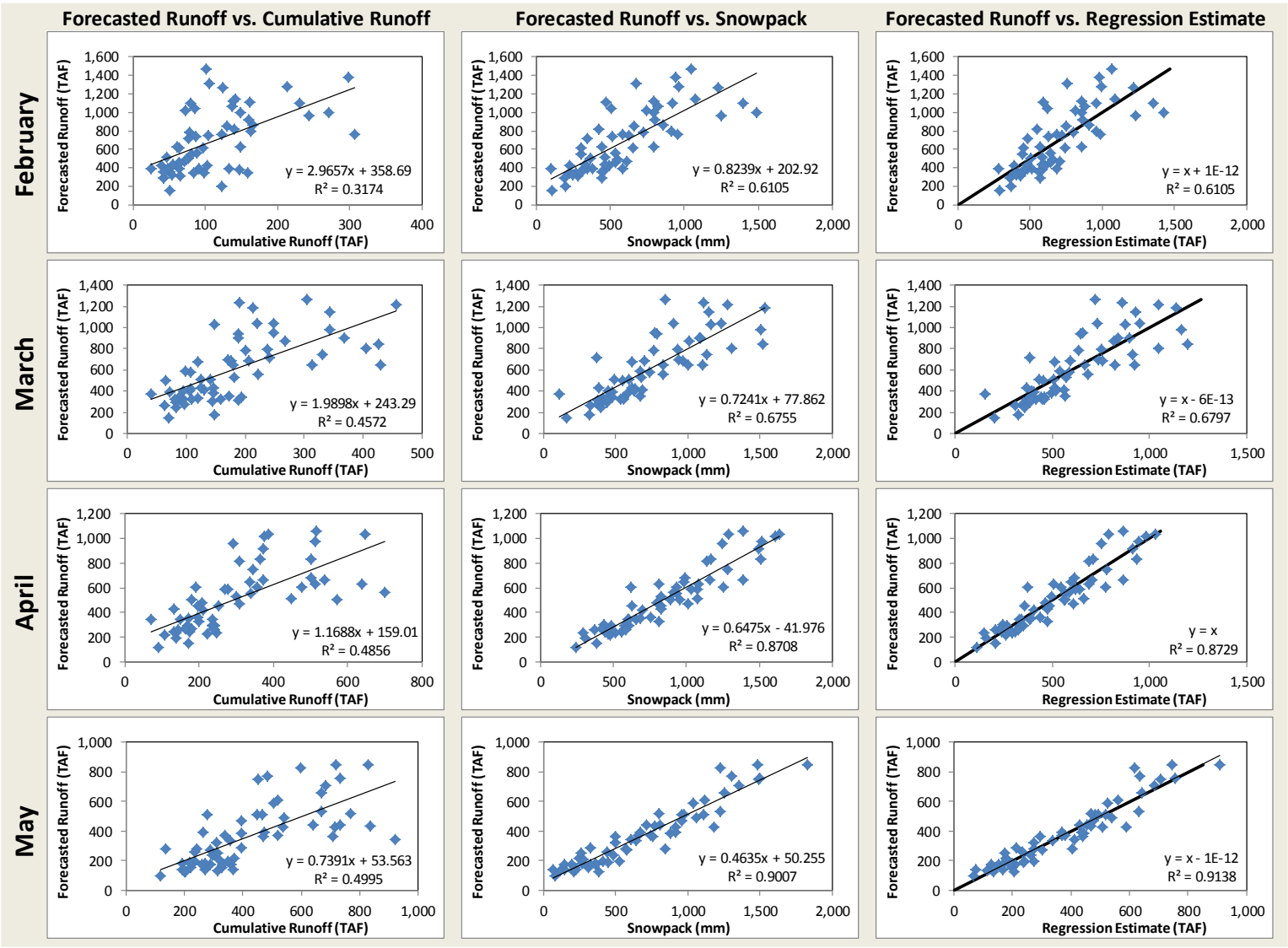


Figure 7-15. Development of Runoff Forecast Estimates Using Cumulative Runoff and Snowpack: Mokelumne River at Pardee

NorthFork_WYType

WYTs for the North Fork Mokelumne are revised based on Bulletin 120 forecasts. First determination of WYT is made in February. Final determination is made in May. WYT for the current account year is based on the average annual unimpaired flow (*AnnualUnimpairedFlowMokelumneHill*).

Table 7-52. North Fork Mokelumne River Water-Year Classifications

Water-Year Class	Annual Water Yield (TAF)	Code in WEAP
Wet	>= 958.7	1
Normal/Above Normal	724.4 to 958.7	2
Below Normal	518.1 to 724.4	3
Dry	376.1 to 518.1	4
Critical	<=376.1	5

7.2.7.6 *Eight Rivers*

The eight rivers index is the sum of the unimpaired Sacramento River flow at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River flow at Smartville, American River inflow to Folsom Lake, Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake. It is used from December through May to set flow objectives as implemented in D-1641.

Note: When SacWAM references the eight rivers index, it reads the runoff for the current month. Thus, these runoff values need to be pre-processed for each climate scenario that SacWAM considers.

7.2.7.7 *Folsom Hydro Forecast*

These are hydrologic forecasts used in setting FMS requirements on the American River. There are forecasts of diversions for the various periods from March to September (specifically, end-of-month values *EoSep Diversion Forecast* and *EoMay Diversion Forecast*), which are based on the maximum of demands, water rights, and CVP allocation/contract amounts for each diversion in the basin. There are also forecasts of runoff for similar periods (*EoMay Runoff Forecast, EoSep Runoff Forecast*), based on estimates of inflows into Folsom.

7.2.7.8 *James Bypass*

A timeseries of monthly flows from the James Bypass into the Mendota Pool. It is used to estimate the water supply index (WSI) for CVP South of Delta allocations.

7.2.7.9 *American*

UIMarNov

UIMarNov represents the unimpaired inflow to Lake Folsom from March through November of the current water year. It is calculated using *UInflow* that is described below.

UInflow

UInflow represents the monthly unimpaired inflow to Lake Folsom and is read from timeseries data.

7.2.7.10 *ShastaStorage*

Previous month's storage in Shasta Lake. This variable is referenced by routines used to set Sacramento River in-stream flow requirements below Keswick (see Section 7.2.3.3), to set the rule curve for CVP portion of San Luis storage (see Section 7.2.1), and to balance storage with Trinity (see Section 7.2.16).

7.2.7.11 *FolsomStorage*

Previous month's storage in Folsom Lake. This variable is referenced by routines used to set the rule curve for the CVP portion of San Luis storage (see Section 7.2.1) and to set the American River FMS (see Section 7.2.3.7).

7.2.7.12 *SRI Forecast*

The SRI forecast is a timeseries of forecasts of SRI for January and February. This forecast is used in setting FMS requirements on the American River in those months (Section 7.2.7.9). The timeseries is the same as that used in the CalSim II model.

7.2.7.13 *San Joaquin*

7.2.8 CVP Allocations

SacWAM uses the same basic approach as CalSim II (2013 SWP Reliability Report: DWR, 2014e) to set contract allocation levels to CVP and SWP contractors in the Sacramento Valley. For calibration purposes, SacWAM also includes switches that allow the user to fix CVP allocations north and/or south of the Delta to those simulated by CalSim II (in the 2013 SWP Reliability Report). These switches are located in *Other\Calibration Switches\Simulate NOD CVP Allocation* and *Other\Calibration Switches\Simulate SOD CVP Allocation* (Sections 7.1.2 and 7.1.3).

The procedure for setting the annual allocation to CVP contractors is found in WEAP's data tree structure under *Other Assumptions\Ops\CVP Allocations*. The allocation that is the end result of this procedure is referenced from each of the transmission links that divert surface water to CVP contractors. This allocation is applied to a monthly distribution of contract amounts to set an upper limit on diversions. These monthly values are based on Exhibit A of each contract, which specifies the distribution of the contractors' base supply and project water[17] over the irrigation season, April-October.

Figure 7-16 compares the estimated CVP allocations resulting from this procedure to both historic and simulated values from CalSim II over the period 1990-2009.

[17] Base supply is the quantity of water that Reclamation agrees may be diverted, without charge, each month from April through October. Project water refers to additional quantities of water that may be diverted from April to October, but are subject to pricing and other federal requirements.

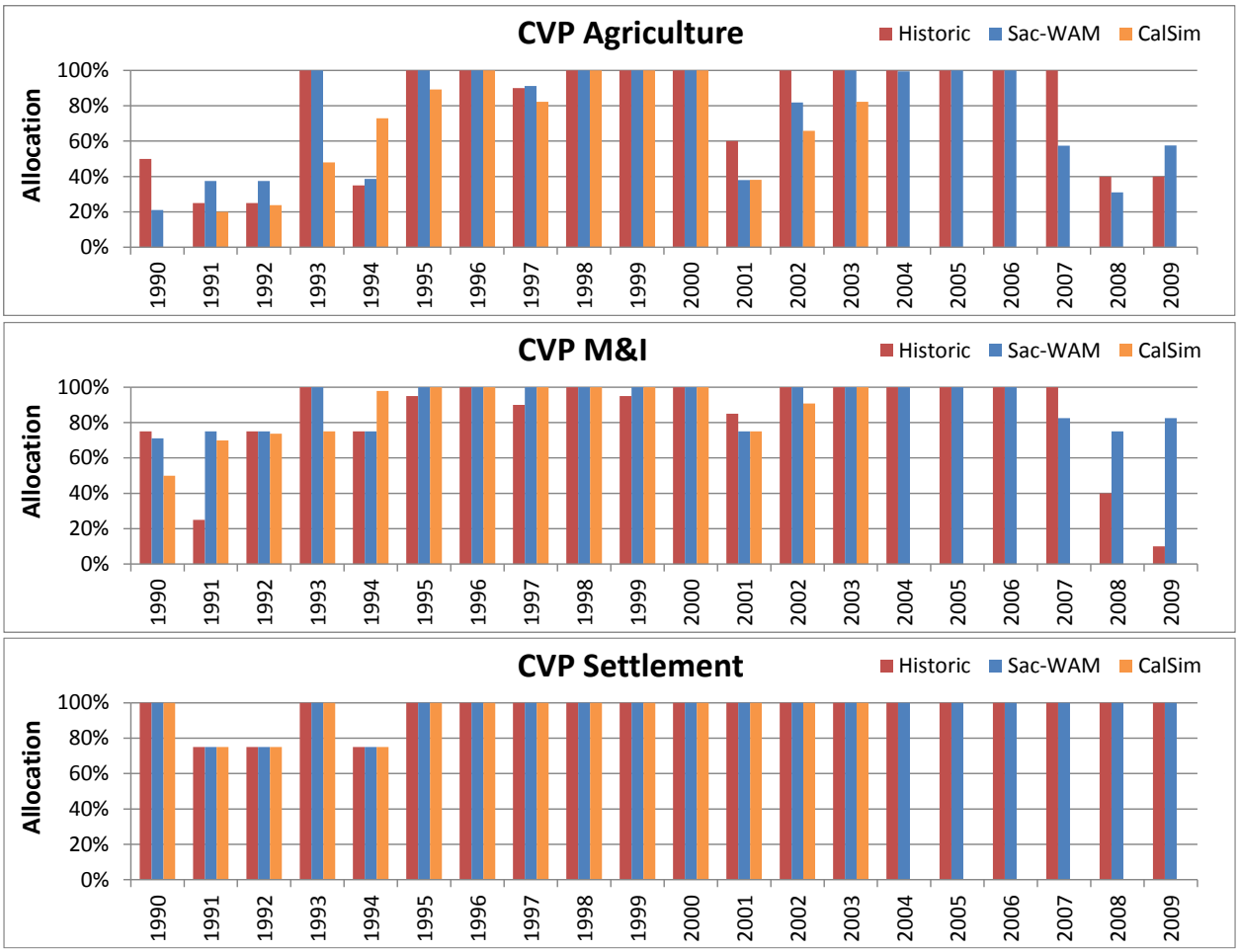


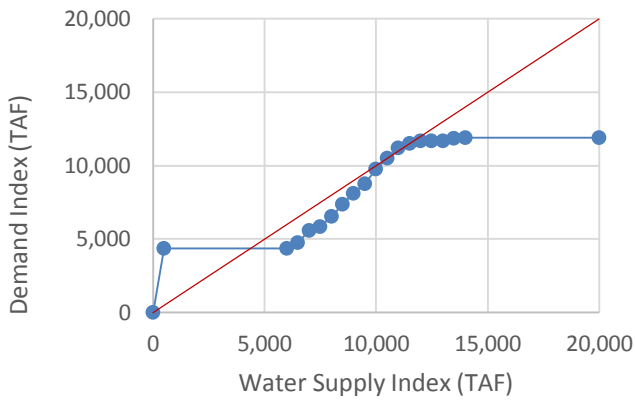
Figure 7-16. Comparison of SacWAM, Historical, and CalSim II CVP Allocations (1990-2009)

This approach for allocating water to CVP relies on using a series of curves to manage uncertainty in promising water to contractors. These curves are generally used as a way of mitigating the risk of promising water given an assessment of water supplies for the water year. That is, they are conditioned such that within the model the full allocations that are promised during the allocation period (Feb-May) are almost always satisfied.

The process occurs in the late winter and early spring as the water supply outlook is becoming clearer. It begins by estimating the available water supplies by summing the existing water in storage and the forecasted inflows—WSI. SacWAM then estimates the level of demand that can be met with this supply (i.e. the *DemandIndex*, or DI) using a WSI-DI curve. This is shown in Table 7-53 and the accompanying graph.

Table 7-53. CVP Water Supply Index – Demand Index Curve

Water Supply Index (TAF)	Demand Index (TAF)
0	0
500	4,381
6,000	4,381
6,500	4,779
7,000	5,607
7,500	5,855
8,000	6,553
8,500	7,375
9,000	8,093
9,500	8,765
10,000	9,755
10,500	10,509
11,000	11,194
11,500	11,490
12,000	11,677
12,500	11,698
13,000	11,698
13,500	11,879
14,000	11,904
20,000	11,904

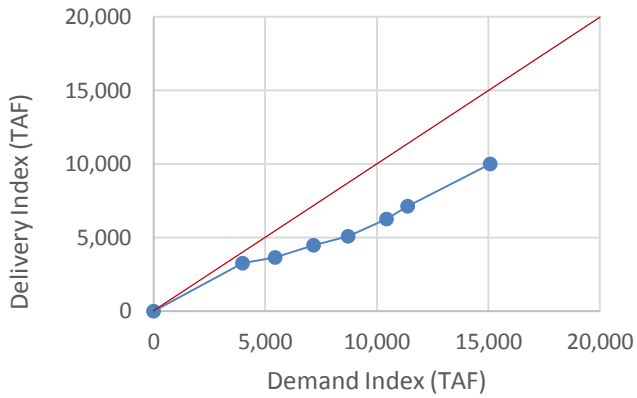


As the curve shows, under particularly low water supply conditions, DI is flat, which indicates that there exists some level of hard water demands that exist even in the driest conditions. DI is also flat at high levels of water supply because the system demand is not unlimited and above a certain water supply threshold all water demand can be satisfied. Under intermediate water supply conditions, an increase in water supply translates into an increase in the water demand that can be satisfied. However, the curve often falls below the 1:1 line, suggesting that a smaller percentage of the available supply is made available to meet demand. This is in itself an acknowledgement that water released from storage may not always reach demands due to regulatory and/or physical constraints, so the model is conditioned to reduce the risk of this occurring by promising to deliver less water.

DI is the sum of both delivery and carryover storage demands. Thus, once the DI has been established, the model then references another lookup table to determine how this water should be partitioned between water left in storage (i.e. carryover) and water delivered. This is shown in Table 7-54 and the paired graph.

Table 7-54. CVP Demand Index — Delivery Index

Demand Index (TAF)	Delivery Index (TAF)
0	0
3,990	3,227
5,442	3,657
7,162	4,476
8,717	5,079
10,434	6,245
11,395	7,110
15,100	9,999



Note that as DI decreases, a smaller percentage of the available supply is committed to carryover storage relative to the amount that is delivered to meet current water demands. This is the second component of risk management in the allocation process.

Once this delivery target has been established using the Delivery-Carryover curve, this total volume of water is evaluated relative to the total annual project demands. If the delivery target is less than the sum of these demands, then a series of cuts is applied to different water users to determine the allocations as a percentage of contracts. The sequence of these cuts is outlined in the following flowchart, Figure 7-17 (where all values are expressed as volumes of water).

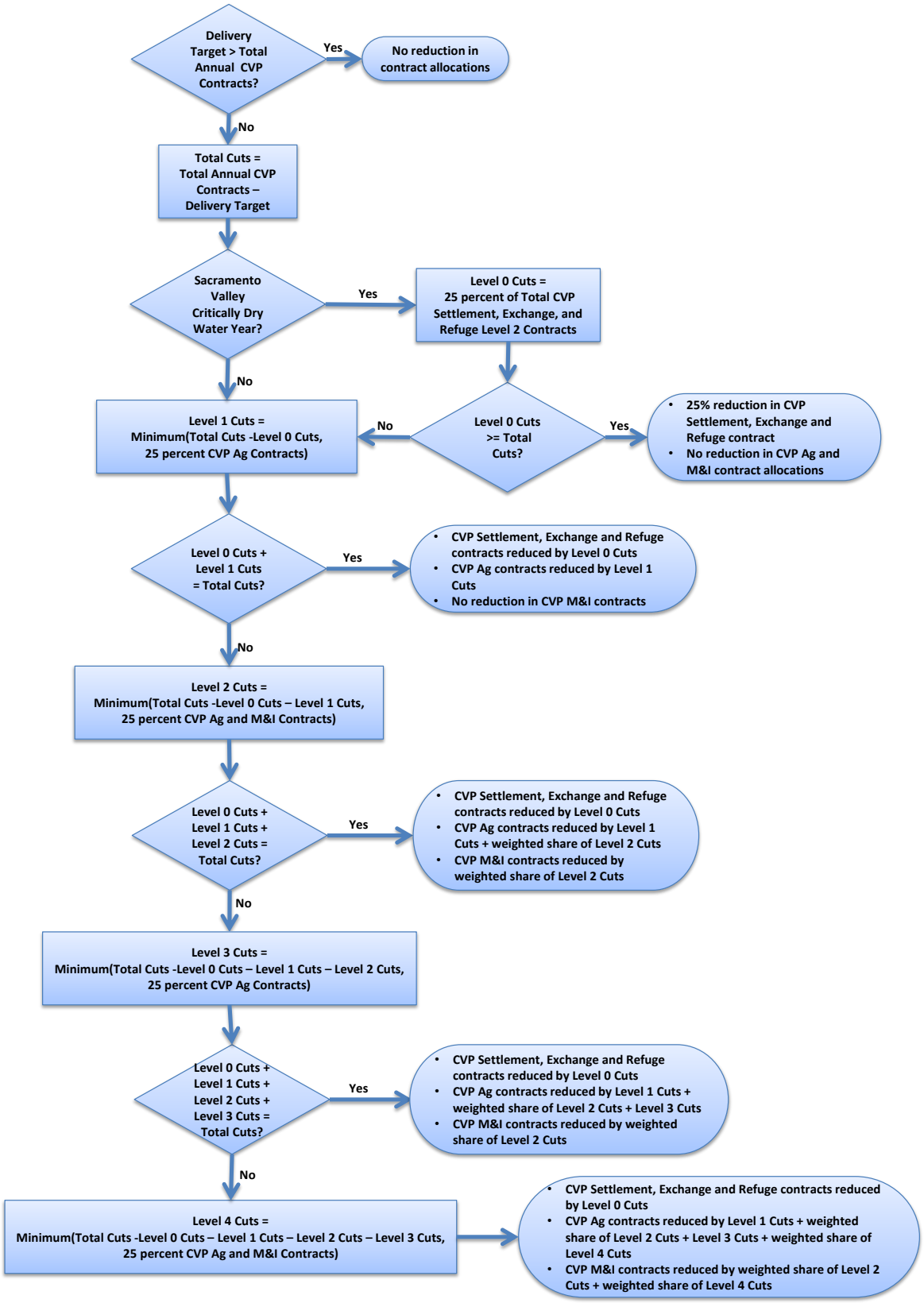


Figure 7-17. Central Valley Project Contract Allocation Logic

Sacramento Valley Settlement contractors and San Joaquin Valley Exchange contractors possess water rights that were secured before the construction of CVP, which by prior appropriation assures them a higher level of reliability for their supplies. According to their agreement with Reclamation, Settlement and Exchange contractors receive 100 percent of their contract amounts in all years except "critically dry" water years, as defined by the Shasta Hydrological Index. In Shasta critical years (i.e. when the total inflow to Shasta Reservoir is below 3.2 MAF), Settlement and Exchange contractors receive 75 percent of their contract amounts.

When making the yearly allocations for Settlement and Exchange contractors, the WEAP model must account for the cumulative inflows into Shasta in order to designate the Shasta Hydrological Index. In an effort to approximate the allocation process as it happens in reality, WEAP does not use perfect foresight to estimate inflows to Shasta for the remainder of the water year after allocations are set (i.e. April-September). Instead the model relies on a heuristic to estimate this quantity of water. This heuristic is explained in greater detail in Section 7.2.7.3.

7.2.8.1 *Contracts_XX*

These parameters contain the total contract values for their respective contracts. Table 7-55 shows abbreviations used in these parameter names.

Table 7-55 Abbreviations Used in Contract Parameters

Abbreviation	Water Service Contractor Type
AG	agriculture
EX	exchange
MI	municipal and industrial
north	north of Delta
RF	refuge
SC	settlement
south	south of Delta

7.2.8.2 *System*

The *System* branch contains the parameters described in the previous sections that are used to set the WSI, DI, Delivery Index, and to make subsequent adjustments to CVP water allocations in the Sacramento Valley (aka NOD CVP Allocations). Table 7-56 presents these parameters in their entirety. These include the corresponding CalSim II allocations that may be applied during model calibration (*Alloc_AG_CalSim, Alloc_MI_CalSim,* and *Alloc_SC_*CalSim) such that demand levels are fixed within SacWAM. The parameters also include total contract amounts (*Contracts_Total*) as well as expressions for WSI, DI (*DemandIndex*), and the Delivery Index. Final allocation levels for each demand category—agriculture (*Percent_Alloc_AG*), refuge (*Percent_Alloc_RF*), settlement (*Percent_Alloc_SC*), exchange (*Percent_Alloc_EX*), and M&I contractors (*Percent_Alloc_MI*)—are each located under this branch as well.

Table 7-56 CVP Allocations\System Sub-Branches

System\	Description
Alloc_AG_CalSim	Timeseries (1922-2003) of CalSim II allocation values for CVP NOD Agricultural Services contractors
Alloc_MI_CalSim	Timeseries (1922-2003) of CalSim II allocation values for CVP NOD Urban contractors
Alloc_SC_CalSim	Timeseries (1922-2003) of CalSim II allocation values for CVP NOD Settlement contractors
Contracts_Total	Total CVP contract amounts (TAF) north and south of the Delta
Cuts	*See following paragraph.*
DeliveryIndex	The lesser of *Contracts_Total* and *DeliveryIndex_first*
DeliveryIndex_first	The amount of DemandIndex that can be used for delivery
DemandIndex	The amount of the current water supply that can be allocated to delivery and carryover storage
DivReq	Diversion requirement
Percent_Alloc_AG	Final percentage allocation for CVP NOD Agricultural Services contractors
Percent_Alloc_EX	Final percentage allocation for CVP Exchange contractors
Percent_Alloc_MI	Final percentage allocation for CVP NOD Urban contractors
Percent_Alloc_RF	Final percentage allocation for CVP NOD Refuge contractors
Percent_Alloc_SC	Final percentage allocation for CVP Settlement contractors
WaterSupplyEst	Estimated water supply for the current water year

The *Cuts* sub-branch contains all of the parameters involved in applying the logic outlined in Figure 7-17. "Cuts" in this sense refers to the volume of water that is associated with allocation reductions for particular demand categories. There are five possible levels of cuts, beginning with cuts to settlement, refuge and exchange contractors in Shasta Critical years (level 0) and progressing through to final reductions for agriculture and M&I contractors (level 4). At each level, the maximum possible allocation reduction is 25 percent of contract demands. Thus, agriculture, which is involved in each step 1 through 4 may be reduced to zero percent allocation by the end of the cuts procedure. Whereas, M&I may only be reduced to 50 percent of their contract demand, because they are implicated in only level 2 and level 4 cuts. At each level, a percentage less than 25 percent may be selected if it is sufficient to meet the remaining deficit between contract demands and the target delivery volume (or delivery index).

7.2.8.3 *South*

This sub-branch contains parameters similar to those described in the previous section to set allocation levels for different categories of CVP contractors. These parameters focus on setting allocations for CVP contractors south of the Delta. In this case, however, SacWAM does not use the same set of WSI-DI curves to estimate available water supplies. Instead, it uses a Delta Index to estimate water supply conditions and an Export Index to estimate how much of that water supply may be diverted south of the Delta.

The Delta Index is set by evaluating the cumulative water year inflows (i.e. inflows since the previous October) plus the forecasted inflows for the remainder of the water year (i.e. through September) for the Sacramento River at Bend Bridge, Feather River at Oroville, Yuba River at Smartville, and American River at Folsom. The Export Index is set using a lookup table that relates the Delta Index to a volume of water that may be pumped from the Delta. The SOD Delivery Index is then determined by making adjustments to the Export Index based on the amount of water that the CVP has stored in San Luis reservoir.

Final allocation levels are calculated by first determining a demand deficit, which is equal to the difference between South of Delta contract demands and the Delivery Index, and then proceeding through a series of cuts (similar to those implemented for the Sacramento Valley) that systematically

reduce the volume of water available to the different demand categories until the total volume of cuts is equal to the demand deficit.

7.2.8.4 *CVP_SC*

CVP_SC represents the final percentage allocation for CVP settlement contractors. It is this parameter that is referenced throughout the model to constrain surface water diversions through transmission lines from the Sacramento River.

7.2.8.5 *CVP_Ag*

CVP_Ag represents the final percentage allocation for CVP agricultural contractors in the Sacramento Valley. It is this parameter that is referenced throughout the model to constrain surface water diversions through transmission lines to agricultural services contractors.

7.2.8.6 *CVP_Urb*

CVP_Urb represents the final percentage allocation for CVP M&I contractors in the Sacramento Valley. It is this parameter that is referenced throughout the model to constrain surface water diversions through transmission lines to M&I contractors.

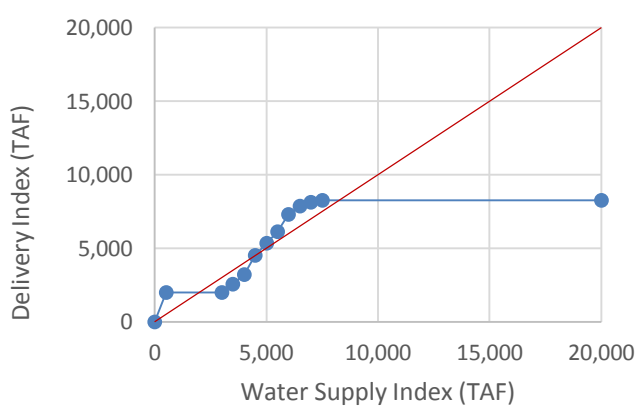
7.2.9 SWP Allocations

SacWAM uses the same basic approach as CalSim II (SWP Reliability Report: DWR, 2014e) to set contract allocation levels to CVP and SWP contractors in the Sacramento Valley.

The procedure for calculating SWP contract allocations has some similarities to the one used to calculate CVP allocations. This procedure also starts by assessing the available water supply, which for SWP is the sum of its available storage from the previous month in San Luis and Oroville plus the forecasted runoff (through September) of the Feather River into Oroville. DI is again calculated from WSI, with values shown in Table 7-57 (where a linear interpolation is used between points on this curve).

Table 7-57 SWP Water Supply Index – Demand Index Curve

Water Supply Index (TAF)	Demand Index (TAF)
0	0
500	1,994
3,000	1,994
3,500	2,534
4,000	3,212
4,500	4,513
5,000	5,343
5,500	6,106
6,000	7,298
6,500	7,852
7,000	8,111
7,500	8,242
2,0000	8,242



Unlike the procedure for the CVP, this allocation routine does not use a separate curve to separate the delivery and carryover storage components of DI. Instead, the routine assumes that the target carryover storage for SWP in Lake Oroville is 1,000 TAF plus half of the volume of water above 1,000 TAF carried over from the previous water year (i.e. one half end-of-September storage above 1,000 TAF). The initial allocation also assumes that the target SWP carryover storage in San Luis is 110 TAF. Thus, we use the following equation to calculate and initial percentage allocation.

$$Initial\ Percent\ Allocation = Maximum\left\{0, \frac{Demand\ Index - 110\ TAF - 1000\ TAF}{SWP\ Table\ A + Maximum[0, \frac{1}{2}(Oroville\ Carryover\ Storage - 1000\ TAF)]}\right\}$$

where the numerator is the estimated total SWP delivery and the denominator is the adjusted total demand.

SacWAM then uses this allocation estimate to update the carryover target for SWP storage in San Luis using the following equation.

$$SWP\ San\ Luis\ Drainage\ Target = Minimum\left\{\begin{matrix} SWP\ San\ Luis\ Storage\ Capacity, \\ 110\ TAF + Maximum[0, SWP\ Table\ A * (Initial\ Percent\ Allocation - 1) - 250\ TAF] \end{matrix}\right\}$$

This updated SWP San Luis carryover target is then used to update the percentage allocation.

$$Adjusted\ Percent\ Allocation = Maximum\left\{0, \frac{Delivery\ Index - SWP\ San\ Luis\ Drainage\ Target - 1000\ TAF}{SWP\ Table\ A\ + Maximum[0, \frac{1}{2}\ (Oroville\ Carryover\ Storage - 1000\ TAF)]}\right\}$$

This equation forms the basis of the SWP Table A contract allocation. It is updated February through May as the estimate of water supply becomes clearer. It is also adjusted during the spring pulse period (April-May) when regulatory constraints limit the ability of SWP to move water through the Delta to the export pumps at Banks. The allocation of water during these two months assumes the bulk of water will be delivered from San Luis after some minimum level of SWP export. So, the April-May allocation is conditioned upon the available SWP water in San Luis (see Section 7.2.1).

The procedure for setting the annual allocation to SWP Table A contractors is found in WEAP's data tree structure under *Other Assumptions\Ops\SWP Allocations*. The allocation that is the end result of this procedure is referenced from each of the transmission links that divert surface water to SWP contractors. This allocation is applied to a monthly distribution of contract amounts to set an upper limit on diversions.

Figure 7-18 compares the estimated SWP allocations resulting from this procedure to both historic and simulated values from CalSim II over the period 1990-2009.

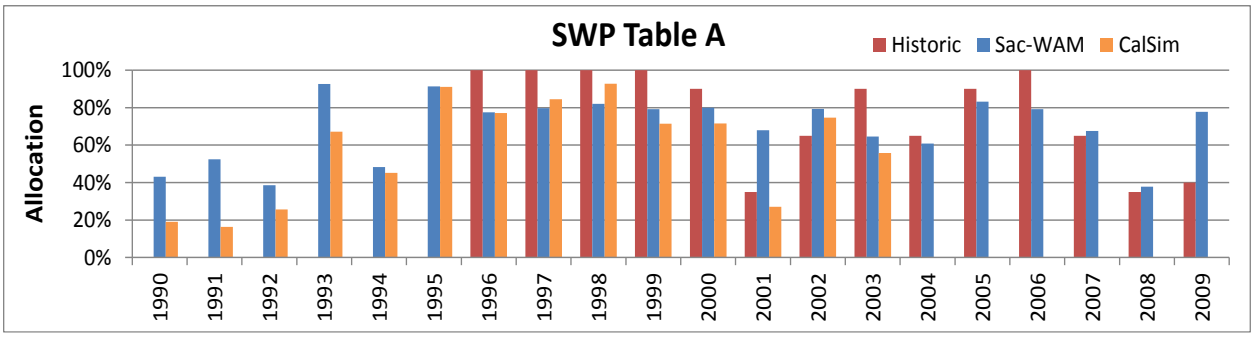


Figure 7-18. Comparison of SacWAM, Historic, and CalSim II SWP Allocations (1990-2009)

7.2.9.1 *TableA parameters*

SacWAM calculates a percentage of contract allocation for SWP Table A contract demands. It assumes that the total Table A contract demand is 4,228.4 TAF/year (*TableA_Max*) and that there is an annual delivery loss of 64.5 TAF (*TableA_Loss*). Thus, for calculation purposes, we use a value of 4,163.9 TAF for SWP Table A Contracts (*SWP_TableA*).

Other Assumptions

These are user-defined variables that can be referenced elsewhere in your analysis. For monthly variation, use Monthly Time

Other Assumption	1922	Scale	Unit
Ops			
SWP Allocations	0		
TableA_Max	4228.4	Thousand	AF
TableA_Loss	64.5	Thousand	AF
SWP_TableA	TableA_Max[Thousand AF] - TableA_Loss[Thousand AF]	Thousand	AF

7.2.9.2 *SOD parameters*

The South of Delta parameters describe what the model should do in case of a shortage (*SOD_TableAShortage*) and calculate cumulative SWP deliveries (*SOD_CumulativeDeliveries*), which is defined as the sum of South Bay Aqueduct (SBA)–, South Coast–, San Joaquin–, and Central Coast Tulare– cumulative deliveries (*SBA\CumulativeDeliveries*, *SouthCoast\CumulativeDeliveries*, *SJ\CumulativeDeliveries*, and *CCTL\CumulativeDeliveries*, respectively).

7.2.9.3 *Initial Allocation*

Initial Allocation parameters provide an initial estimate of the allocation to SWP Table A contractors for the current water year. This allocation estimate is represented in TAF with the variable *WSIDI_SWPdel.*

Brief descriptions of sub-branches under *InitialAllocation* are provided in Table 7-58.

Table 7-58. Other Assumptions\Ops\SWP Allocations\InitialAllocation Sub-Branches

InitialAllocation\	Description
co_correct	Timeseries (1922-2003) of CalSim II percent allocations for SWP Table A contractors (used for comparison or calibration only)
WaterSupplyEst	Estimated water supply for the current water year
DemandIndex	
DI_Buffer	Demand buffer
DrainTarget_Buffer	Buffer storage to add to end-of-September SWP storage
init_SWPRuleDrainTar	Initial end-of-September storage target
SWPRuleDrainTarget	See equation above for SWP San Luis Drainage Target
Allocation_init	See equation above for Initial Percent Allocation
Allocation_adjustment	See equation above for Adjusted Percent Allocation
WSIDI_SWPdel	Initial estimate of the volume of water available to State Water P contractors

Key: SWP=State Water Project.

7.2.9.4 *Export Capacity_Adjust*

The SWP allocation procedure also considers that the capacity to pump water from the Delta varies throughout the year and may be adjusted based on hydrologic conditions within the San Joaquin basin. Brief descriptions of sub-branches *Export Capacity_Adjust* are described in Table 7-59.

Table 7-59. Other Assumptions\Ops\SWP Allocations\ExportCapacity_Adjust Sub-Branches

ExportCapacity_Adjust\	Description
estSWPExp	Estimated capacity to export water from the Delta. Monthly values adjusted when San Joaquin Index is wet or flows at Vernalis exceed 16000 cfs
fact_SWP	SWP delivery factor
buff_SWP	SWP San Luis buffer storage
SWPDelCapEst	Estimated delivery capacity to SWP export zone. Equal to *estSWPExp* plus SWP storage in San Luis minus *buff_SWP*
deltar_expmax	Adjusted January-to-May delivery target for SWP export zone

Key: SWP=State Water Project.

7.2.9.5 *SL_Adjust*

The SWP allocation procedure considers that in some years there may be sufficient storage in San Luis to justify an increase in the allocation. This adjustment is made in the last two months of the allocation period (April and May). Brief descriptions of sub-branches *SL_Adjust* are presented in Table 7-60.

Table 7-60. Other Assumptions\Ops\SWP Allocations\SL_Adjust Sub-Branches

SL_Adjust\	Description
AprMay_Dry	Assessment of delivery capacity based on April-May storage in SWP San Luis
Allocation_1	Adjusted SWP allocation based on comparison of *AprMay_Dry* with *WSIDI_SWPExp* and *deltar_expmax*

Key: SWP=State Water Project.

7.2.9.6 *Final_Allocation*

These branches represent the calculations required to compute the final Table A allocations. Brief descriptions of sub-branches *Final_Allocation* are presented in Table 7-61.

Table 7-61. Other Assumptions\Ops\SWP Allocations\Final_Allocation Sub-Branches

Final_Allocation\	Description
TableA_Alloc	Timeseries (1922-2003) of CalSim II SWP Table A allocations (used for comparison/calibration only)
Allocation_2	Minimum of *Allocation_1* and *TableA_Max*
Allocation_Final	Fixes the allocation for the months outside the allocation period (July-January)
SWP_percent_delivery	Final allocation as a percentage of Table A demands
FSC_percent_delivery	Final allocation for SWP Feather River Settlement contractors. Reduced to 50 % only in critically dry years.

Key: SWP=State Water Project.

7.2.9.7 *SBA / SouthCoast / CCTL / SJ*

SWP water users in the export zone include contractors in the South Coast, the San Joaquin Valley (SJ), the Central Coast and Tulare basin (CCTL), as well as users taking water from SBA. SacWAM considers that in some months these users may not receive the entirety of their demand request. As such, the model includes a routine to augment demands in certain months based on delivery deficits that occur in previous months.

Table 7-62. Other Assumptions\Ops\SWP Allocations\SBA & SouthCoast & CCTL & SJ Sub-Branches

Sub-Branch	Description
TableA_XXX	Annual Table A contract amounts for SBA, SouthCoast, CCTL, or SJ
CumulativeDeliveries	Total deliveries to demand zone since January 1st
MonthlyDemandPattern	See Table 7-63
RemainingDemandPattern	See Table 7-64
MakeUpWater	The amount of water to add to the current month's demand based on delivery deficits in previous months

Table 7-63. Monthly Percentage of Annual Demand Under Different Table A Allocation Levels

	Percent Table A Allocation				
	0-30	30-45	45-60	60-70	70-100
October	11%	9%	11%	10%	9%
November	8%	9%	10%	9%	9%
December	10%	13%	9%	9%	9%
January	4%	4%	3%	5%	7%
February	4%	1%	3%	5%	6%
March	1%	2%	1%	5%	7%
April	1%	2%	5%	7%	8%
May	9%	8%	6%	7%	9%
June	13%	11%	10%	9%	8%
July	13%	14%	13%	11%	9%
August	14%	14%	15%	12%	10%
September	12%	13%	14%	11%	9%

Table 7-64. Percentage of Annual Demand Remaining Under Different Table A Allocation Levels

	Percent Table A Allocation				
	0-30	**30-45**	**45-60**	**60-70**	**70-100**
October	29%	31%	30%	28%	27%
November	18%	22%	19%	18%	18%
December	10%	13%	9%	9%	9%
January	100%	100%	100%	100%	100%
February	96%	96%	97%	95%	93%
March	92%	95%	94%	90%	87%
April	91%	93%	93%	85%	80%
May	90%	91%	88%	78%	72%
June	81%	83%	82%	71%	63%
July	68%	72%	72%	62%	55%
August	55%	58%	59%	51%	46%
September	41%	44%	44%	39%	36%

7.2.9.8 *ORO*

Beginning-of-month (*BoM*) storage and end-of-previous-September (*PrevSept*) storage in Lake Oroville are used in the procedure for setting initial SWP Table A allocations (see Section 7.2.9.3).

7.2.9.9 *SL_SWP*

BoM storage in SWP San Luis is used in the procedure for setting initial SWP Table A allocations (see Section 7.2.9.3) and for adjusting allocations based on an assessment of the Delta export capacity (see Section 7.2.9.4).

7.2.10 COA

COA (1986) obligates the CVP and SWP to coordinate their operations to meet the Delta water quality standards defined in SWRCB Decision 1485. The agreement establishes a framework with which the projects will operate to ensure that both CVP and SWP receive an equitable share of the Central Valley's available water. The agreement established a formula for sharing the obligation of providing water to meet water quality standards and other in-basin uses (IBUs). This formula is set up in SacWAM in the Data Tree structure under *Other Assumptions\Ops\COA*, but is controlled through *User Defined LP Constraints* and is thus summarized in Section 8.4. SacWAM implements the COA accounting procedure in each month as a post-process based on the previous month's result values.[18] It applies the sharing obligations as a transfer of project (SWP or CVP) storage within San Luis Reservoir.

7.2.11 Mokelumne

In SacWAM, all state variables associated with Mokelumne River operations, other than IFRs, are located under *Ops\Mokelumne*.

[18] It is possible to implement the COA dynamically in the same manner as CalSim, where the accounting is handled by the LP within each time step. However, initial attempts to do so resulted in model instabilities due to the use of integer variables applied in the context of change in reservoir storages.

- Mokelume
  - Camanche Flood Control
  - EBMUD Deficiency
  - JVID
  - NSJWCD

7.2.11.1 *Camanche Flood Control*

Pardee and Camanche Reservoirs, located on the Mokelumne River, are owned and operated by EBMUD. The USACE flood-control agreement with EBMUD requires that a combined reservation of up to 200 TAF be maintained in Pardee and Camanche Reservoirs from September 15 to July 31. However, up to a maximum of 70 TAF of this flood-control reservation may be transferable to available space in PG&E's Salt Springs and Lower Bear Reservoirs. The following sections describe state variables relating to flood space requirements for Pardee and Camanche Reservoirs.

- Camanche Flood Control
  - CamancheAprilStorage
  - FloodSpaceAdjustmentforPreRelease
  - FloodSpaceRequirement
  - MokFNFthruJuly
  - NonTransferableFloodSpace
  - PreReleaseofOctFloodWater
  - RainFloodSpaceRqment
  - SnowFloodSpaceRqment
  - TransferableRainFloodSpace
  - TransferableSnowFloodSpace

CamancheAprilStorage

The state variable *CamancheAprilStorage* is the previous April's storage in Camanche Reservoir. The variable is updated each April. The variable is used to determine releases from Pardee Reservoir to maintain thermal stratification in Camanche Reservoir. The variable is not related to flood control requirements, but is contained here for convenience.

MokFNFthrJuly

The state variable *MokFNFthruJuly* is the sum of the unimpaired monthly flows for the Mokelumne River at Mokelumne Hill from the current month (beginning in March) through July. This variable is used in the determination of flood space requirements during the snowmelt season.

RainFloodSpaceRqment

The state variable *RainFloodSpaceRqment* is the rain-flood reservation for Pardee and Camanche Reservoirs, combined, including any transferable space. The monthly requirements are constant from year to year.

SnowFloodSpaceRqment

The state variable *SnowFloodSpaceRqment* is the snowmelt-flood reservation in Pardee and Camanche Reservoirs, including any transferable space. The requirements depend on the natural runoff into Camanche Reservoir from the current date through July 31.

NonTransferableFloodSpace

The state variable *NonTransferableRainFloodSpace* is the flood space that must be maintained in Pardee and/or Camanche Reservoirs and cannot be transferred to upstream PG&E reservoirs. The variable is used to calculate the transferable flood space.

TransferableRainFloodSpaceRqment

The state variable *TransferableRainFloodSpaceRqment* is the reduction in the rain-flood reservation in Pardee and Camanche Reservoirs because of available space in PG&E's upstream reservoirs: Lower Bear Reservoir and Salt Springs Reservoir.

TransferableSnowFloodSpace

The state variable *TransferableSnowFloodSpace* is the reduction in the snowmelt-flood reservation in Pardee and Camanche reservoirs because of available space in PG&E's upstream reservoirs: Lower Bear Reservoir and Salt Springs Reservoir.

PreReleaseofOctFloodWater

Flood space requirements for Pardee and Camanche reservoirs are zero from July 31 through September 15, but subsequently increase to 180 TAF by the end of October. In wetter years, this may result in excessive reservoir spills in SacWAM's simulation. The state variable *PreReleaseofOctFloodWater* is used to gradually release water from storage during the summer months and avoid water spills caused by drawdown in October for flood control. For the months of July, August, and September the value of *PreReleaseofOctFloodWater* is one quarter of the October *RainFloodSpaceRqment.* This value was determined from inspection of recent historical reservoir operations.

FloodSpaceAdjustmentforPreRelease

The state variable *FloodSpaceAdjustmentforPreRelease* is the cumulative amount of water that must be released in July, August, and September to minimize reservoir spills in October. It is calculated as the cumulative value of *PreReleaseofOctFloodWater.* It is used to adjust the flood control diagram as a mechanism of forcing additional releases of water from storage.

FloodSpaceRequirement

The state variable *TransferableSnowFloodSpace* is the combined flood reservation in Pardee and Camanche Reservoirs. It is initially calculated as the *RainFloodSpaceRqment* plus *SnowFloodSpaceRqment* less *TransferableRainFloodSpaceRqment less TransferableSnowFloodSpace.* This volume is subsequently adjusted to force prerelease of water that would otherwise spill in later months (*FloodSpaceAdjustmentforPreRelease*).

7.2.11.2 *EBMUD Deficiency*

The following sections describe state variables relating to imposed deficiencies on EBMUD customer demands.

- EBMUD Deficiency
  - ProjectedDryYearCarryoverStorage
  - EBMUD Percent Cutback
  - DroughtTrigger

ProjectedDryYearCarryoverStorage

EBMUD adopted its first Water Supply Availability and Deficiency Policy in 1985. Beginning in 1989, EBMUD revised this policy so as to limit deficiencies to a maximum of 25 percent of total customer demand. In 2010, with the adoption of Policy 9.03, the maximum deficiency was reduced to 15 percent, based on the development of new dry-year supplies. In April of each year, EBMUD forecasts its total carryover storage at the end of the water year. If total carryover storage is projected to be less than 500 TAF, customer deficiencies may be imposed.

In SacWAM, the state variable *ProjectedDryYearCarryoverStorage* is a forecast of total carryover storage based on the previous month storage in Pardee, Camanche, and EBMUD's terminal reservoirs; and on the forecasted unimpaired flow at Mokelumne Hill, less river diversions, less Mokelumne Aqueduct draft, less evaporative losses, less groundwater seepage losses, less the MFR at Woodbridge (USGS 11325500).

EBMUD Percent Cutback

The state variable *EBMUD Percent Cutback* is the percent deficiency imposed on deliveries to EBMUD. If the *ProjectedDryYearCarryoverStorage* is greater than 500 TAF, there is no deficiency (*EBMUD Percent Cutback* = 0). Between 450 TAF and 500 TAF carryover storage, deficiencies increase linearly from zero to 15 percent. Between 300 TAF and 450 TAF carryover storage, deficiencies increase linearly from 15 to 25 percent. A larger deficiency is simulated in SacWAM, as the dry-year supply available as part of the Freeport Regional Water Project has currently not been implemented.

Deliveries through the transmission link connecting the Mokelumne Aqueduct to demand unit U_EBMUD are constrained using WEAP's *Maximum Flow Percent of Demand* property, which is set equal to (100- *EBMUD Percent Cutback*).

DroughtTrigger

The state variable *DroughtTrigger* is a flag used to indicate delivery deficiencies. It is determined in April based on *EBMUD Percent Cutback*.

7.2.11.3 *Jackson Valley Irrigation District*

Jackson Valley ID, located in southwest Amador County, provides water for irrigation and M&I use in Jackson Valley. District facilities include Jackson Dam, which impounds Lake Amador, an associated hydro-electric plant, and the Lake Amador Resort Area WTP. Jackson Valley ID has rights to store up to 36 TAF of Jackson Creek flows. The district may divert flows to Lake Amador between November and May at a maximum rate of 110 cfs. However, because of reservoir capacity constraints, the district

typically uses about 10 TAF of this right. Additionally, Jackson Valley ID has rights to divert up to 3.85 TAF from the Mokelumne River at a diversion rate of 50 cfs. Under an agreement with EBMUD, Mokelumne River water is delivered to Jackson Valley ID by gravity from the north arm of Pardee Reservoir to Lake Amador. The district requests and usually receives 3.85 TAF annually from EBMUD. However, if the elevation in Pardee Reservoir falls below 550 feet, equivalent to approximately 161 TAF, deliveries to the district are no longer possible.

PardeeElevFlag

The state variable *PardeeElevFlag* is used to determine whether deliveries from Pardee Reservoir to Jackson Valley ID are possible. The variable is assigned a value of 0 when the beginning of month storage in Pardee Reservoir is below 161 TAF; otherwise the variable is set equal to 1.

PrevDemand

The state variable *PrevDemand* is the previous month water demand based on Jackson Valley ID's annual water right of 3.85 TAF and recent historical monthly delivery patterns.

Shortage

The state variable *Shortage* tracks shortages in deliveries to Jackson Valley ID from Pardee Reservoir for the current water year based on cumulative monthly demand and cumulative deliveries.

In SacWAM, the *Maximum Diversion* property on the diversion arc from Pardee Reservoir to Lake Amador is set to the minimum of 50 cfs multiplied by *PardeeElevFlag* and the monthly demand plus any delivery shortage (*Shortage*) in the current water year.

7.2.11.4 *NSJWCD*

Cumulative Deliveries

North San Joaquin WCD (demand unit A_60N_NA3) includes approximately 157,000 acres east of the City of Lodi in eastern San Joaquin County. The service area covers land on both banks of the Mokelumne River, stretching from Dry Creek in the north to the Calaveras River and the boundary with Stockton East WD to the south.

In 1956, North San Joaquin WCD was issued a temporary water right (Permit 10477) as part of Decision 858 (D-858). Permit 10477 is for the temporary appropriation of up to 20 TAF of water from the lower Mokelumne River that is surplus to EBMUD's needs with a diversion season of December 1 to July 1. Through an agreement between both districts, EBMUD stores up to 20 TAF of water in the average to wettest years for delivery to North San Joaquin WCD during the irrigation season. The maximum diversion rate is 80 cfs. Historically, North San Joaquin WCD has used up to 9.5 TAF of water under Permit 10477. However, current demand for Mokelumne River water within the district service area is only approximately 3 TAF (Reclamation, 2014b).

In SacWAM, the state variable *CumulativeDeliveries* tracks annual water deliveries from February through September. Deliveries to the district are restricted using the *Maximum Flow Volume* property on the transmission link from the Mokelumne River to A_60N_NA3. The flow is restricted to the months of December through June and to 20 TAF less the previous month's deliveries (i.e., *CumulativeDeliveries*). The maximum flow rate is 80 cfs.

7.2.12 Contracts

The logic provided under the Contracts branch allows CVP Settlement Contractors to "move" unused water from non-critical to non-critical months and from critical months to non-critical months. Typically, contracts provide for two separate volumes of water. The first is to be used during April, May, June, September, and October. The second volume is to be used during July and August. Water that is unused in April-June can be used during September and October. Unused water from July and August can be used in September and October.

7.2.13 Cosumnes

The Cosumnes River watershed covers parts of El Dorado, Amador, and Sacramento Counties. The upper watershed, east of Highway 49, divides into the watersheds of the North, Middle, and South Forks of the Cosumnes River. Sly Park Reservoir is the only major storage facility in the upper watershed. Located on Camp Creek, a tributary of the North Fork Cosumnes River, the reservoir has a storage capacity of 41 TAF and supplies water to El Dorado ID. Sly Park Dam, which impounds Jenkinson Lake on Sly Park Creek, was constructed by Reclamation in 1955 as part of the Sly Park Unit of the CVP. The unit was transferred to El Dorado ID in 2003. Associated facilities include the Camp Creek Diversion Dam and tunnel connecting Camp Creek to Jenkinson Lake, and the Camino Conduit which delivers water from Jenkinson Lake to the El Dorado ID service area.

7.2.13.1 *AvailableInflow*

The *AvailableInflow* state variable represents the combined flow of Sly Park Creek to Jenkinson Lake and Camp Creek above the diversion dam. It is equal to the sum of inflow timeseries read from SACVAL_Headflows.csv for I_JNKSN and I_CMP001.

7.2.13.2 *EIDAllocation*

The *EIDAllocation* state variable represents the annual allocation of water from Jenkinson Lake to El Dorado ID as a fraction of the annual water demand. Deliveries through the transmission link connecting the Camino Conduit to the district are constrained using the *Maximum Flow Percent of Demand* property, which is set equal to *EIDAllocation*. The *EIDAllocation* varies from zero to one, depending on the storage in Jenkinson Lake, the forecasted inflow through the end of the water year, target carryover storage, and water demands. The allocation is determined in March based on perfect foresight of future inflows.

7.2.13.3 *ForecastWaterSupply*

The *ForecastWaterSupply* state variable is the sum of March through September inflows to Jenkinson Lake and Camp Creek Diversion Dam, i.e., the sum of *AvailableInflow*.

7.2.14 Folsom Flood Curve

The *Folsom Flood Curve* is based on the recently updated flood space diagram whereby between 400 and 600 TAF of flood space is specified, depending on creditable flood space in three upstream reservoirs—French Meadows (*FrenchM_FloodSpace*), Hell Hole (*HellH_FloodSpace*), and Union Valley (*UnionV_FloodSpace*). (*UpperAmer_CredSpace* sums the three to get the total upstream creditable space.) For purposes of computing creditable space, French Meadows can have a maximum of 45 TAF,

Hell Hole can have a maximum of 80 TAF, and Union Valley can have a maximum of 75 TAF. If the maximum 200 TAF of creditable space exists upstream, Folsom's flood space is 600 TAF. If there is 0 TAF of creditable space upstream, Folsom's flood space is 400 TAF. In between, the volume of flood space is interpolated, using the same rules as used in the CalSim II model. The full allowed volume of flood space is operated to in November through February, while flood space is 0 in May and June. The other months reflect a drawdown in the fall and a refill curve in the spring, both of which are also interpolated based on upstream creditable space. Table 7-65 shows the flood curve and flood space values by month. Maximum storage in Folsom is 977 TAF.

Table 7-65 Folsom Flood Space Rules

Month	Flood Curve (TAF)	Flood Space (TAF)
Oct	670-720	257-307
Nov-Feb	377-577	400-600
Mar	583-682	295-394
Apr	800	177
May-June	975	0
July	950	25
Aug	800	175
Sep	760	215

7.2.15 Solano Decree

Clear Lake, located in Lake County northwest of Sacramento, is a source of surface water for irrigated agriculture in Yolo County. The lake is one of the oldest lakes in North America with sediments at least 480,000 years old. In 1914 the Cache Creek Dam was constructed to add additional storage and to control lake releases to Cache Creek. Water released by the dam travels downstream into Yolo County and is used for irrigation by the Yolo County FC&WCD.

Releases of water from Clear Lake are controlled by the Solano Decree, an agreement between Lake and Yolo Counties that was drafted in 1978. The Decree is used to determine the total amount of water available for the entire irrigation season as a function of the lake level on April 1.

The other assumptions in this section are used to determine the lake level at the end of March. If the level is greater than or equal to 7.56 feet Rumsey (a local datum) then the District can divert 150 TAF of water from the Lake. If the lake level is less than 3.22 feet Rumsey then no water is available for release. For lake levels between those thresholds the equations in *RumseyEquation* are used to determine the volume that can be released. The equation is recalculated at the beginning of May using *RumseyAdjEquation*. The amount available in a particular month is calculated using *Monthly Allocation*. *Monthly Allocation* is used to restrict releases from Clear Lake using the *Maximum Hydraulic Outflow* parameter in *Supply and Resources\River\Cache Creek\Reservoirs\Clear Lake\Physical\Maximum Hydraulic Outflow*.

7.2.16 Trinity Import

Trinity River water is imported into the Sacramento River basin through the Clear Creek and Spring Creek tunnels. These transfers are made after minimum IFRs below Lewiston Dam are satisfied and are based on beginning-of-month storage in Trinity Reservoir and Shasta Reservoir. SacWAM offers two methods for setting Trinity River imports: the first reads in a timeseries of historical flows into the Clear

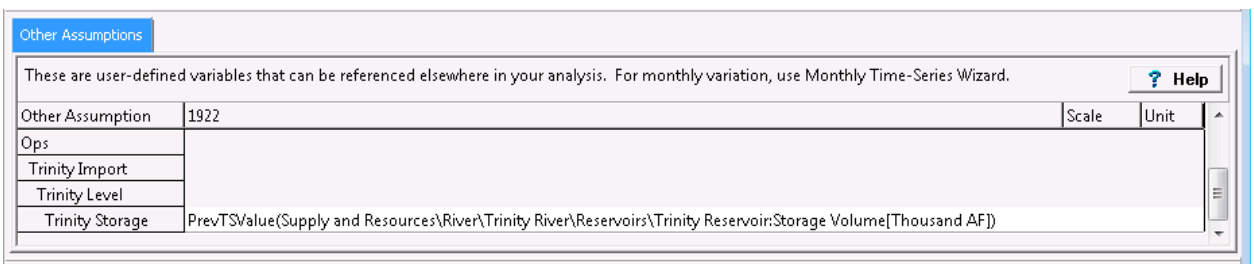
Creek Tunnel and the second uses transfer logic that assesses current storage levels in Trinity and Shasta. The switch that is used to choose between the two options is located in *Other\Calibration Switches\Simulate Trinity Imports* (Section 7.1.1).

The transfer logic is set up using the same approach used by CalSim II (SWP Reliability Report: DWR, 2014e) and is done in such a way as to balance reservoir storages in Trinity and Shasta. That is, imports are reduced when storage in Trinity is low or storage in Shasta is high. Storage levels in the two reservoirs at each time step are read as their respective storage volumes from the previous time step. There are three components to the import logic. The first is based on relative storage in the two reservoirs, as defined by reservoir zones which are based on reservoir levels. The second triggers additional imports when the proportion of storage in each zone is different. The third triggers imports for power generation when Trinity is spilling. The first component exactly replicates the logic in CalSim II. The second and third components replicate the operation in CalSim II, but with different implementation methods appropriate to WEAP. Total imports are the sum of these three components. Component 1 is defined in the requirement *OPS Trinity Import,* and the requirement *OPS Import Spills for Pow*er pulls in additional water for components 2 and 3.

Imports here are based on a comparison of the relative storages in Shasta and Trinity, defined by whether storage is above or below a series of pre-defined levels.

7.2.16.1 *Trinity Level*

As noted above, the *Trinity Storage* parameter reads the volume of the Trinity Reservoir at the previous time step of the model.



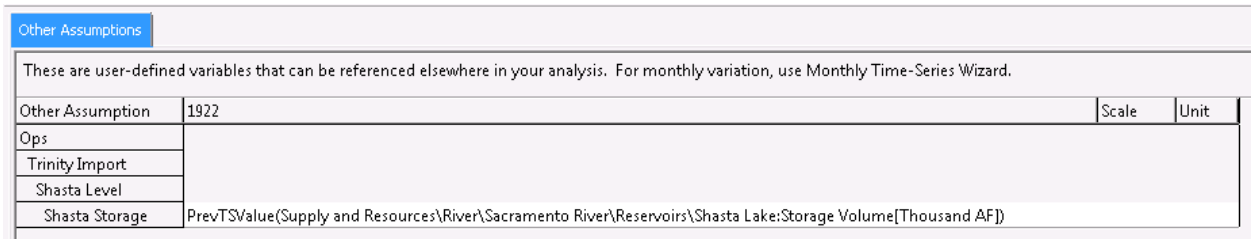
The Trinity storage conditions used to determine transfer amounts are summarized in Table 7-66.

Table 7-66. Trinity Reservoir Storage Levels for Determining Trinity River Imports

Storage Level	Storage Volume (thousand acre-feet)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Level 0	0											
Level 1	700				750		800		750	700		
Level 2	1,200				1,250		1,300		1,250	1,200		
Level 3	1,550			1,600	1,650	1,700	1,800		1,650	1,550		
Level 4	1,975		2,000		2,050	2,100	2,200		2,050	1,975		
Level 5	2,500											

7.2.16.2 *Shasta Level*

Similar to the Trinity, the *Shasta Storage* parameter reads the volume of the Trinity Reservoir at the previous time step of the model.


Other Assumptions

These are user-defined variables that can be referenced elsewhere in your analysis. For monthly variation, use Monthly Time-Series Wizard.

Other Assumption	1922	Scale	Unit
Ops			
Trinity Import			
Shasta Level			
Shasta Storage	PrevTSValue(Supply and Resources\River\Sacramento River\Reservoirs\Shasta Lake:Storage Volume[Thousand AF])		

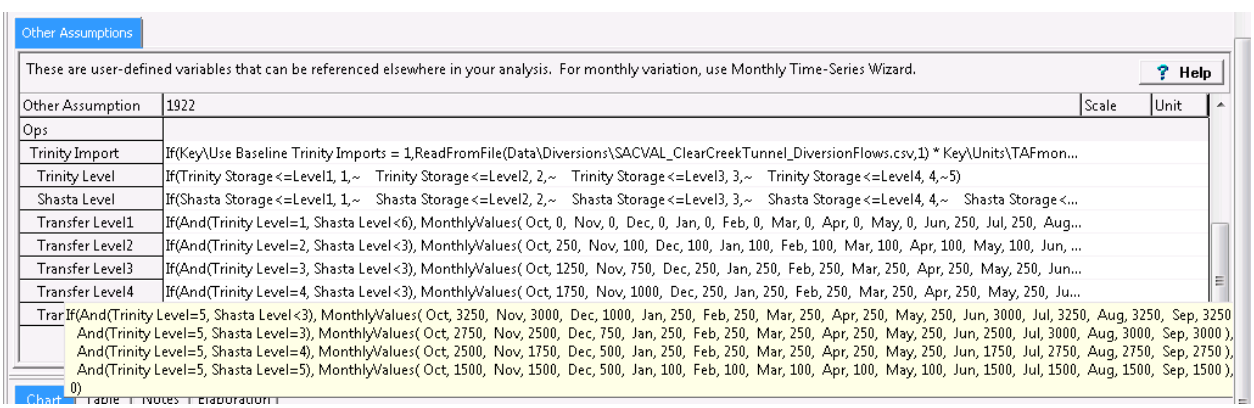
The level of the Shasta Reservoir is the other determining factor (along with Trinity Reservoir storage) in importing water from Trinity Reservoir to the Sacramento Basin. Shasta levels used in determining imports are summarized in Table 7-67.

Table 7-67. Shasta Reservoir Storage Levels for Determining Trinity River Imports

Shasta Level	Storage Volume (thousand acre-feet)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Level 0	0											
Level 1	1600						2200	2400		2200	2100	1900
Level 2	2000						2800	3000	2900	2800	2500	2300
Level 3	2400					2500	3200	3500	3300	3200	3000	2800
Level 4	3000					3200	3800	4200	3800		3600	3400
Level 5	3749	3149		3399	3799	4299	4529	4550	4399		4199	3899
Level 6	4600											

7.2.16.3 *Transfer LevelX*

Whether or not water is transferred from Trinity Reservoir to the Sacramento basin in a given month is determined by Trinity and Shasta storage levels as presented above. The Transfer Level parameters correspond to Trinity Storage levels. For each Transfer Level, there is an *if* statement that determines the outcome for the different combinations of reservoir levels.


Other Assumptions

These are user-defined variables that can be referenced elsewhere in your analysis. For monthly variation, use Monthly Time-Series Wizard.

Help

Other Assumption	1922	Scale	Unit
Ops			
Trinity Import	If(Key\Use Baseline Trinity Imports = 1,ReadFromFile(Data\Diversions\SACVAL_ClearCreekTunnel_DiversionFlows.csv,1) * Key\Units\TAFmon...		
Trinity Level	If(Trinity Storage <=Level1, 1,~ Trinity Storage <=Level2, 2,~ Trinity Storage <=Level3, 3,~ Trinity Storage <=Level4, 4,~5)		
Shasta Level	If(Shasta Storage <=Level1, 1,~ Shasta Storage <=Level2, 2,~ Shasta Storage <=Level3, 3,~ Shasta Storage <=Level4, 4,~ Shasta Storage <...		
Transfer Level1	If(And(Trinity Level=1, Shasta Level <6), MonthlyValues(Oct, 0, Nov, 0, Dec, 0, Jan, 0, Feb, 0, Mar, 0, Apr, 0, May, 0, Jun, 250, Jul, 250, Aug...		
Transfer Level2	If(And(Trinity Level=2, Shasta Level <3), MonthlyValues(Oct, 250, Nov, 100, Dec, 100, Jan, 100, Feb, 100, Mar, 100, Apr, 100, May, 100, Jun, ...		
Transfer Level3	If(And(Trinity Level=3, Shasta Level <3), MonthlyValues(Oct, 1250, Nov, 750, Dec, 250, Jan, 250, Feb, 250, Mar, 250, Apr, 250, May, 250, Jun...		
Transfer Level4	If(And(Trinity Level=4, Shasta Level <3), MonthlyValues(Oct, 1750, Nov, 1000, Dec, 250, Jan, 250, Feb, 250, Mar, 250, Apr, 250, May, 250, Ju...		
Trar	If(And(Trinity Level=5, Shasta Level <3), MonthlyValues(Oct, 3250, Nov, 3000, Dec, 1000, Jan, 250, Feb, 250, Mar, 250, Apr, 250, May, 250, Jun, 3000, Jul, 3250, Aug, 3250, Sep, 3250 And(Trinity Level=5, Shasta Level=3), MonthlyValues(Oct, 2750, Nov, 2500, Dec, 750, Jan, 250, Feb, 250, Mar, 250, Apr, 250, May, 250, Jun, 2500, Jul, 3000, Aug, 3000, Sep, 3000), And(Trinity Level=5, Shasta Level=4), MonthlyValues(Oct, 2500, Nov, 1750, Dec, 500, Jan, 250, Feb, 250, Mar, 250, Apr, 250, May, 250, Jun, 1750, Jul, 2750, Aug, 2750, Sep, 2750), And(Trinity Level=5, Shasta Level=5), MonthlyValues(Oct, 1500, Nov, 1500, Dec, 500, Jan, 100, Feb, 100, Mar, 100, Apr, 100, May, 100, Jun, 1500, Jul, 1500, Aug, 1500, Sep, 1500), 0)		

Table 7-68 shows the combinations of Trinity and Shasta storage levels (detailed in Table 7-66 and Table 7-67, respectively) that lead to various transfer amounts.

Table 7-68. Trinity River Imports

Trinity Storage Level	Shasta Storage Level	Clear Creek Tunnel Flow (cfs)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Level 1	< Level 6	0								250			
	Level 6	0											
Level 2	< Level 3	250	100							250	1,500		1,000
	Level 3	250	100							250	1,250		1,000
	Level 4	250	100							250	1,000		750
	Level 5	250	0							250	750		500
	Level 6	0											
Level 3	< Level 3	1,250	750	250						1,250	2,500		1,750
	Level 3	1,000	500	250						1,000	2,250		1,500
	Level 4	750	500	250						750	1,750		1,500
	Level 5	750	250	100						750	1,500		1,000
	Level 6	0											
Level 4	< Level 3	1,750	1,000	250						1,750	3,250		
	Level 3	1,500	750	250						1,500	2,500		
	Level 4	1,250	500	250						1,250	2,000		
	Level 5	750	500	100						750	1,500		
	Level 6	0											
Level 5	< Level 3	3,250	3,000	1,000	250					3,000	3,250		
	Level 3	2,750	2,500	750	250					2,500	3,000		
	Level 4	2,500	1,750	500	250					1,750	2,750		
	Level 5	1,500	1,500	500	100					1,500			
	Level 6	0											

7.2.16.4 *Shasta at Flood Pool*

In situations when Shasta is at the flood curve in the previous month, the import amount from Table 7-68 is reduced by 50% to conserve storage in Trinity as expressed in *Shasta at Flood Pool*.

7.2.16.5 *Imports of Trinity spills*

This IFR is controlled as a Flow Requirement Object (*OPS Import Spills for Power*) on the Clear Creek tunnel.

In months that Trinity Reservoir is at its flood curve, water that would otherwise have spilled is imported to the greatest extent possible, so that power can be generated in the Francis Carr Powerhouse at the end of the Clear Creek Tunnel. This volume is computed by taking the previous month's storage volume summed with the current month's inflow, and subtracting downstream flow requirements and imports triggered under component 1. Any remaining volume above the flood pool is imported if there is capacity in the Clear Creek Tunnel.

7.2.17 Hodge

The 1987 Hodge decision set diversion limits on pumping at Fairbairn WTP to the City of Sacramento, based on flow in the American River at that location. If flows (*Hodge flow*) are below the thresholds (*Hodge threshold*), a diversion limit is applied at the Fairbairn WTP (see Table 7-69 for thresholds and diversion limits). In cases where demands are greater than the diversion limit, additional diversions above the limit are diverted at the City's Sacramento River WTP instead. A maximum diversion of 310 cfs represents the physical capacity of the plant.

Table 7-69. Hodge Decision Flow Thresholds and Pumping Limits

Month	Threshold Flow at Fairbairn (cfs)	Diversion Limit at Fairbairn WTP (cfs)
Oct	1,879	100
Nov-Dec	2,000	100
Jan-Feb	2,000	120
Mar-May	3,000	120
June	3,000	155
Jul-Aug	1,750	155
Sep	1,750	120

7.2.18 Contra Costa WD

Contra Costa WD operates the Los Vaqueros Reservoir and Delta intakes at Rock Slough, Old River, Victoria Canal, and Mallard Slough. Los Vaqueros is an offstream reservoir that is operated to improve water quality and provide emergency storage for district customers. Los Vaqueros and Contra Costa WD operations are not fully dynamic in SacWAM, instead pumping at the Delta intakes is fixed to the same operation as the CalSim II model for the upcoming Environmental Impact Statement on Los Vaqueros Enlargement. Other aspects of the operation (Los Vaqueros fills and releases, and deliveries) adjust dynamically to meet demand as the first priority and also maintain storage in Los Vaqueros. SacWAM has values for Contra Costa WD's CVP contract (*CVP_WR*) and Los Vaqueros water right (*LV_WR*), but because the intake operations are fixed to CalSim II these values are not used in the model and pumping is not explicitly split between these two sources of water. SacWAM does not include transfers, so in cases where demands were met in CalSim II based on transfers, the full Contra Costa WD demands will not be met and Los Vaqueros storage will be lower than CalSim II.

SacWAM includes maximum capacities for the intakes and pipelines in the system (*Rock_Slough_max, Old_River_max, Victoria_Canal_max, OR_pipeline_max, LV_fill_max*) which are based on physical capacities and no-fill/no-diversion rules consistent with the biological opinions for the Reservoir (*Feb_Nofill, NoDiv_NoFill*). These include no-fill periods of March 15 to May 31 and 0-15 days in February based on Los Vaqueros storage conditions. No-fill and no-diversion rules are suspended when Los Vaqueros storage is at or below emergency pool levels (*Emergency Pool*). Emergency pool levels are 40 TAF when the Sacramento Valley WYT is Dry or Critical, and 70 otherwise. Reservoir releases are also constrained to not reduce storage below these levels (*Max_release_est*). Contra Costa WD's Mallard Slough intake is in SacWAM but is not used (*Mallard Slough*). Timeseries from CalSim II are read in and used to fix intake pumping (*RS timeseries, OR and VC timeseries*) and timeseries are read in for Los Vaqueros fills and releases but these are not currently used in the model (*LV Fill timeseries, LV Rel timeseries*). Intake pumping is set through the requirements *OPS RS pumping* and *OPS OR Pipeline pumping*. The timeseries are also applied as constraints under the *CCWD* User Defined LP Constraints (UDC) branch. Lastly, Kellogg Creek, which flows into and out of Los Vaqueros has a minimum IFR of 5 cfs or inflow, whichever is less.

7.2.19 Freeport

The Freeport Water Supply Project supplies Sacramento County WA and EBMUD from a point of diversion on the Sacramento River approximately 9 miles below the American River confluence. The project enables EBMUD to take delivery of CVP water to meet a portion of its drought year water

demands. The CVP contract allows EBMUD to divert up to 133,000 acre-feet of American River water each year with a total not to exceed 165,000 acre-feet in 3 consecutive years. This diversion can only occur in drought years when EBMUD's total system storage is forecast to be less than 500,000 acre-feet. The maximum diversion rate is 100 mgd.

Divert

This variable is a trigger for EBMUD diversions based on district storage conditions and the amount of water delivered in the previous 3 years.

Combine_Store

This variable is the sum of previous month storage in Pardee and Camanche reservoirs.

FPT_Diversion

This variable is the dry year deficiency that is imposed on EBMUD customers based on forecasted carryover storage in district reservoirs.

7.2.20 TrinityShasta_balancing

An additional component of imports is based on a more precise comparison of how proportionally full the different reservoir zones are in Shasta and Trinity, as opposed to just comparing which zone each reservoir is in. This provides a more precise balancing of reservoir storages and is achieved by setting zone boundaries to those that were computed in CalSim II. In CalSim II, Trinity has a total of 5 zones and Shasta has a total of 6. Imports here are determined by the relative storages in zones 2, 3, and 4 in the two reservoirs, and if Trinity has a larger proportion of storage in the appropriate zone, more imports will be made. This logic is in the branch *TrinityShasta_balancing.*

7.2.21 New Hogan Ops

New Hogan Reservoir was built by USACE in 1964 for flood control, water supply, and recreational purposes. The reservoir has a capacity of 317 TAF, with approximately 165 TAF reserved for flood control during the flood season. Inflows, derived primarily from precipitation, average approximately 150 TAF per year. The Corps operates New Hogan Reservoir when flood releases are required; otherwise, the reservoir is operated by Stockton East WD, which schedules releases from conservation storage. Calaveras County WD diverts water for its Jenny Lind WTP below New Hogan Reservoir. Stockton East WD diverts water downstream of New Hogan Reservoir at Bellota Weir for both agricultural and M&I purposes.

7.2.21.1 *New Hogan Water Supply Index*

The *New Hogan Water Supply Index* is a measure of the April through September available water supply in New Hogan Reservoir. It is calculated, based on perfect foresight, as the sum of end-of-March storage, April through September reservoir inflows, less the carryover storage target, less diversions to the Jenny Lind WTP and to riparian water holders, less estimates for reservoir evaporation and river seepage losses.

7.2.21.2 *New Hogan Carryover Target*

The *New Hogan Carryover Storage Target* defines the carryover storage objective for the current water year based on end-of-March storage.

7.2.21.3 *Allocation_MI_1*

The variable *Allocation_MI_1* is the initial allocation of Calaveras River water for use at Stockton East WD's water treatment plant.

7.2.21.4 *Allocation_Ag*

The variable *Allocation_Ag* is the allocation of Calaveras River water for agricultural purposes.

7.2.21.5 *Allocation_MI_2*

The variable *Allocation_MI_2* is an additional allocation of Calaveras River water for use at Stockton East WD's water treatment plant after agricultural allocations have been determined.

7.2.21.6 *Allocation_MI*

The variable *Allocation_MI* is the final allocation of Calaveras River water for use at Stockton East WD's water treatment plant. It is equal to the sum of *Allocation_MI_1 and Allocation_MI_2.*

7.2.22 Controls

This section implements a series of operational control indicators which show which regulations, permits, and physical capacities are controlling various aspects of CVP and SWP operations. Control is defined when pumping, flow, or storage is equal to the specified maximum limit. Most of the control indicators are binary (0,1), with a few exceptions.

7.2.22.1 *AprMay D1641 cap*

Identifies whether combined CVP and SWP exports are controlled by the D-1641 Pulse Period export cap (1= controlled, 0=not controlled).

7.2.22.2 *AprMayD1641 CVP split*

Identifies whether combined CVP exports are controlled by half of the D-1641 Pulse Period export cap (1= controlled, 0=not controlled).

7.2.22.3 *AprMayD1641 SWP split*

Identifies whether combined SWP exports are controlled by half of the D-1641 Pulse Period export cap (1= controlled, 0=not controlled).

7.2.22.4 *Banks HandS*

Identifies whether Banks pumping plant diversions are at minimum H&S level of 300 cfs (1=at or below H&S, 0=above H&S).

7.2.22.5 *Banks max capacity*

Identifies whether Banks pumping plant diversions are at maximum permit capacity (1=at capacity, 0=below capacity).

7.2.22.6 *CVP San Luis vs Rule*

Amount by which CVP San Luis Reservoir is above (+) or below (-) the rule curve.

7.2.22.7 *DeltaSurplus*

Identifies whether there is Delta Surplus under COA for the CVP and SWP combined (1=Delta Surplus, 0=No Delta Surplus).

7.2.22.8 *DeltaSurplus CVP*

Identifies whether there is Delta Surplus under COA for the CVP (1=Delta Surplus, 0=No Delta Surplus).

7.2.22.9 *DeltaSurplus SWP*

Identifies whether there is Delta Surplus under COA for the SWP (1=Delta Surplus, 0=No Delta Surplus).

7.2.22.10 *EI ratio*

Identifies whether combined CVP and SWP exports are controlled by the D-1641 E/I ratio export cap (1= controlled, 0=not controlled).

7.2.22.11 *EI split CVP*

Identifies whether CVP exports are controlled by half of the D-1641 E/I ratio export cap (not currently implemented).

7.2.22.12 *EI split SWP*

Identifies whether SWP exports are controlled by half of the D-1641 E/I ratio export cap (not currently implemented).

7.2.22.13 *Folsom Flood Pool*

Identifies whether Folsom Reservoir is at its flood pool (i.e. the reservoir is spilling) (1=at flood pool, 0=below flood pool).

7.2.22.14 *Folsom MIFs*

Identifies whether releases from Folsom Reservoir are controlled by (i.e. just meeting) either of the two downstream MFRs (1=at MFR, 0=above MFR). Requirements are D-893 and FMS.

7.2.22.15 *Folsom xD893 MIF*

Identifies whether releases from Folsom Reservoir are controlled by (i.e. just meeting) the D-893 MFR (1=at MFR, 0=above MFR).

7.2.22.16 *Folsom xFMS MIF*

Identifies whether releases from Folsom Reservoir are controlled by (i.e. just meeting) the FMS MFR (1=at MFR, 0=above MFR).

7.2.22.17 *Jones HandS*

Identifies whether Jones pumping plant diversions are at minimum H&S of 800 cfs (1=at H&S, 0=above H&S).

7.2.22.18 *Jones max capacity*

Identifies whether Jones pumping plant diversions are at maximum permit capacity (1=at capacity, 0=below capacity).

7.2.22.19 *MRDO*

Identifies whether Delta outflow is controlled by (i.e. just meeting) the D-1641 MRDO requirement (1=at MRDO, 0=above MRDO).

7.2.22.20 *OMR*

Identifies whether OMR reverse flow is controlled by the OMR RPA maximum reverse flow limit (1=at limit, 0=above limit).

7.2.22.21 *Oroville Flood Pool*

Identifies whether Lake Oroville is at its flood pool (i.e. the reservoir is spilling) (1=at flood pool, 0=below flood pool).

7.2.22.22 *Oroville MIFs*

Identifies whether releases from Lake Oroville are controlled by (i.e. just meeting) one of the three downstream MFRs (1=at MFR, 0=above MFR). MFRs are the High-Flow Channel, Low-Flow Channel, and Verona.

7.2.22.23 *Oroville xHighflow Ch MIF*

Identifies whether releases from Lake Oroville are controlled by (i.e. just meeting) the High-Flow Channel MFR (1=at MFR, 0=above MFR).

7.2.22.24 *Oroville xLowflow Ch MIF*

Identifies whether releases from Lake Oroville are controlled by (i.e. just meeting) the Low-Flow Channel MFR (1=at MFR, 0=above MFR).

7.2.22.25 *Oroville xVerona MIF*

Identifies whether releases from Lake Oroville are controlled by (i.e. just meeting) the Verona MFR (1=at MFR, 0=above MFR).

7.2.22.26 *Rio Vista*

Identifies whether Sacramento River flows are controlled by (i.e. just meeting) the Rio Vista D-1641 flow requirement (1=at requirement, 0=above requirement).

7.2.22.27 *RPA HandS*

Identifies whether combined CVP and SWP exports are at minimum H&S under the BiOp RPAs controlled by the D-1641 EI ratio export cap (1=at H&S, 0=above H&S).

7.2.22.28 *Salinity*

Identifies whether Delta outflow is controlled by (i.e. just meeting) the largest of the D-1641 Salinity requirements (1=at requirement, 0=above requirement).

7.2.22.29 *Shasta Flood Pool*

Identifies whether Lake Shasta is at its flood pool (i.e. the reservoir is spilling) (1=at flood pool, 0=below flood pool).

7.2.22.30 *Shasta MIFs*

Identifies whether releases from Lake Shasta are controlled by (i.e. just meeting) either of the two downstream MFRs (1=at MFR, 0=above MFR). MFRs are at Keswick and Wilkins Slough.

7.2.22.31 *Shasta xKeswick MIF*

Identifies whether releases from Lake Shasta are controlled by (i.e. just meeting) the Keswick MFR (1=at MFR, 0=above MFR).

7.2.22.32 *Shasta xRed Bluff MIF*

Identifies whether releases from Lake Shasta are controlled by (i.e. just meeting) the Red Bluff MFR (not currently implemented, Red Bluff MIF is not in the model).

7.2.22.33 *Shasta xWilkins Slough MIF*

Identifies whether releases from Lake Shasta are controlled by (i.e. just meeting) the Wilkins Slough MFR (1=at MFR, 0=above MFR).

7.2.22.34 *SJR IE ratio*

Identifies whether combined CVP and SWP exports are controlled by the April to May *SJR_EIRatio* export cap (1= controlled, 0=not controlled).

7.2.22.35 *SJR IE split CVP*

Identifies whether combined CVP exports are controlled by half of the April to May *SJR_EIRatio* export cap (not currently implemented).

7.2.22.36 *SJR IE split SWP*

Identifies whether combined SWP exports are controlled by half of the April to May *SJR_EIRatio* export cap (not currently implemented).

7.2.22.37 *SWP San Luis vs Rule*

Amount by which SWP San Luis Reservoir is above (+) or below (-) the rule curve.

7.2.22.38 *Trinity Flood Pool*

Identifies whether Trinity Reservoir is at its flood pool (i.e. the reservoir is spilling) (1=at flood pool, 0=below flood pool).

7.2.22.39 *Trinity MIF*

Identifies whether releases from Trinity Reservoir are controlled by (i.e. just meeting) the Trinity Record of Decision MFR (1=at MFR, 0=above MFR).

7.2.22.40 *UWFE IBU*

Identifies whether under COA, there is IBU or unstored water available for export (UWFE) (1=UWFE, 2=IBU).

7.2.22.41 *X2*

Identifies whether Delta outflow is controlled by (i.e. just meeting) the X2 requirement (1=at requirement, 0=above requirement).

7.3 Valley Floor Hydrology

7.3.1 Calibration Factors

Calibration factors are discussed in Appendix B.

7.3.2 Potential Application Efficiency

The Potential Application Efficiency is based on the concept that the applied water is sufficient to achieve average soil moisture across the least watered quarter of the field equal to field capacity. It represents the upper limit on irrigation efficiency imposed by irrigation technology assumed best management practices.

7.3.3 MiscellaneousET

Miscellaneous ET was introduced in to SacWAM to provide a means of increasing or decreasing crop ET to represent other miscellaneous evaporative losses. It is currently set to zero.

7.3.4 Groundwater

This section contains linear equations that determine stream gains and losses from and to groundwater.

7.3.5 SCS Curve Number

The SCS curve number method is used to calculate runoff from daily precipitation.

7.4 Upper Watersheds Hydrology

7.4.1 SAC

These parameters control some of the hydrologic characteristics of the upper watersheds.

7.4.1.1 *Snow*

Each three-letter code refers to a geography that encompasses multiple catchments. The *FreezePt* and *MeltPt* values for each of these codes are calibrated values that are used to assign freezing and melting points to the associated catchments. The list of codes and associated catchments can be found in the RegionalCalibNames tab of **Upper watershed expressions**, referenced in Table 5-6.

7.4.1.2 *Lower Store*

Catchment values for deep water capacity (*WC*) and deep conductivity (*CLbf*) are contained in *LowerStore*. The same three-letter codes used in the *Snow* parameters are used in the *LowerStore* parameters.

7.4.1.3 *Upper Store*

Parameters include Rf, HC, PfdElev, SWC, and Kc

7.4.2 Conversion

Different data sources use different units. The Other Assumptions under the *Upper Watersheds Hydrology\Conversion* heading contain conversion factors for TAF/month to cfs (*TAF2CFS*) and inches to mm (*in2mm)*.

7.5 Urban Outdoor

The values in this branch pertain to irrigation of residential and commercial landscaping.

7.5.1 Area Factors

Separate scaling factors were calculated for land classified as Residential and as Commercial.

7.5.2 Irrig

Schedule: value of 100 assigned to each month. Thresh: no value entered.

7.6 Conversion

Different data sources use different units. The Other Assumptions under the *Conversion* heading contain conversion factors for inches to mm (*in2mm)*.

7.7 Western Canal Outflow

Under a 1922 agreement between Western Canal WD and Butte Sink landowners, natural flows in Butte Creek are supplemented by releases from the district's Western Canal into the creek to maintain a flow of 200 cfs at the Sanborn Slough intake during the fall and early winter. The variable *Western Canal*

Outflow defines outflow targets based on flows in Butte Creek and recent historical canal deliveries to the creek.

7.8 ANN

To turn ANN on/off, the user needs to assign it a 0 or 1, where 1 turns the ANN on and disables the G-model and 0 leaves the G-model as the default method for calculating flow requirements for Delta salinity. See Sections 7.2.6.1 and 7.2.6.3, respectively, for a description of the G-Model and ANN.