Appendix 5A7 Daily Pattern Development for the Estimation of Daily Flows and Weir Spills in CALSIM II

1. Objective

CALSIM II modeling has been updated with revised daily flow patterns for the Sites Reservoir Project Final Environmental Impact Report/Environmental Impact Statement (Final EIR/EIS). This improvement to CALSIM II has been incorporated into the No Action Alternative and each of the Sites Project alternatives included in the Final EIR/EIS. Daily flow estimates were improved to more accurately assess Sacramento River bypass flow requirements for Sites Reservoir diversions. Accurate representation of daily variability in river flows and weir spills is necessary to adequately evaluate diversion criteria. CALSIM II's representation of daily flows have been improved by accounting for more historic data at more locations between Sites Reservoir and Freeport. In addition, the simulation of daily variance for periods without historical records has been refined. Previous iterations of CALSIM II match daily patterns of months with historic records to months without historic records based on similar unimpaired total Delta inflow. However, this matching method has been improved by accounting for more river locations (along the Sacramento River, Sutter Bypass, Feather River, and American River), similar water year types, and more extensive period of records extending into 2020. Finally, new post-processing tools have been developed to verify the accuracy of CALSIM II's daily flows.

2. Methodology

2.1 Data Assembly and Input Development

An historical dataset for all rivers and tributaries contributing to the Sacramento River upstream of the Fremont Weir and Sacramento Weir was assembled to develop daily flow patterns at each location. Daily patterns were observed for the Sacramento River, Yuba River, Bear River, Feather River, Sutter Bypass, and American River. Only data later than WY 1964 were collected since gage records and operations data were sparse before that. Table 5A7-1 includes the source and availability of all the gages that were collected for this effort.

Table 5A7-1. Available Historical Gage Records

Location	Gage	Period Available
Yuba River near Grass Valley	USGS 11417500	10/1/1964 – 9/30/2019
Yuba River near Smartville	CDEC (YRS)	12/1/1996 – 5/14/2020
Yuba River at Parks Bar Ridge	CDEC (YPB)	2/1/2011 – 5/14/2020
Yuba River near Marysville	USGS 11421000	10/1/1964 – 5/14/2020
Bear River near Wheatland	USGS 11424000	10/1/1964 – 5/14/2020
Feather River at Oroville	USGS 11407000	10/1/1964 – 9/30/2019
Thermalito Release to Feather River	USGS 11406920	11/16/1997 – 09/30/2019
Feather River near Gridley	USGS 11407150	10/1/1964 – 9/30/1998
Feather River above Boyd's Landing	CDEC (FSB)	12/23/2010 – 5/14/2020
Feather River near Nicolaus	USGS 11425000	10/1/1964 – 9/29/1984
American River at Fair Oaks	USGS 11446500	10/1/1964 – 5/14/2020
Sacramento River at Knights Landing	USGS 11391000	10/1/1964 – 4/29/1981
Fremont Weir Spill (USGS)	USGS 11391021	10/1/1964 – 9/29/1975
Fremont Weir Spill (CDEC)	CDEC (FRE)	5/18/1984 – 5/14/2020
Sacramento River at Verona	USGS 11425500	10/1/1964 – 5/14/2020
Sacramento River Weir Spill	USGS 11426000	10/1/1964 – 10/1/2019
Sacramento River at Freeport	USGS 11447650	10/1/1964 – 9/30/2015

In addition, simulated results from USRDOM modeling were used to develop daily flows for the following parameters:

- Sacramento River flow above Fremont Weir
- Sutter Bypass outflow (inflow to the Sacramento River)
- Ord Ferry spill
- Moulton Weir spill
- Tisdale Weir spill
- Colusa Weir spill
- Sacramento River flow at Wilkins Slough

Daily patterns were computed for each of the parameters collected from the historical observations and USRDOM outputs listed above using Equations (5A7-1) and (5A72-2).

An adjustment factor is calculated based on observed (or simulated by USRDOM) monthly averages (ratio of daily flow to monthly average flow):

$$f_{adj} = \frac{Q_{Daily,observed}}{Q_{Monthly,avg,observed}} \tag{5A7-1}$$

Daily flows are then computed by multiplying the monthly flow simulated by CALSIM II with the corresponding adjustment factor:

$$Q_{Daily,simulated} = Q_{Monthly,simulated} \cdot f_{adj} \tag{5A72-2}$$

In the end, four daily pattern timeseries were selected as CALSIM II inputs and used to compute daily flows at the following locations:

1. Sacramento River flow above Ord Ferry – Regulated flow ($REGDAY_i$)
    a. Daily pattern based on USRDOM simulation (from WY 1964 – 2003)
        i. Regulated flow is taken as the sum of Sacramento River flow at Keswick, Clear Creek flow, and Stony Creek flow
    b. Applied to CALSIM II arc C116
2. Sacramento River flow above Ord Ferry – Unregulated flow ($SAC116DAY_i$)
    a. Daily pattern based on USRDOM simulation (from WY 1964 – 2003)
        i. Unregulated flow includes all other tributary flows simulated by USRDOM upstream of Ord Ferry. See Section 3.1.
    b. Applied to CALSIM arc C116
3. Feather River flow at confluence of Sacramento River ($FEATHER223DAY_i$)
    a. Daily pattern based on historical records (from WY 1968 – 2003) (Feather at Nicholas, Feather below Thermalito, Yuba River at Marysville, and Bear River near Wheatland)
        i. Feather River daily patterns exclude historic information prior to the regulation of Lake Oroville.
    b. Applied to CALSIM II arc C223
4. American River flow at confluence of Sacramento River ($AMER303DAY_i$)
    a. Daily pattern based on historical records (from WY 1965 – 2003) (American River at Fair Oaks)
    b. Applied to CALSIM II arc C303

2.2 Daily Pattern Mapping

Daily flow variability was created for two periods: pre-development and post-development of major dams or reservoirs in the river basins (Table 5A7-2). For the post-development period (10/1/1964 – 9/30/2003), CALSIM II daily flow patterns were generated by disaggregating CALSIM II monthly outputs based on daily observation data using the following equation:

$$Q_{daily}^{Calsim} = \frac{Q_{obs}^{daily}}{Q_{obs}^{monthly}} Q_{monthly}^{Calsim} \qquad (5A7\text{-}3)$$

where, Q_{daily}^{Calsim} is the daily CALSIM II flow, $Q_{monthly}^{Calsim}$ is the simulated monthly CALSIM II flow, Q_{obs}^{daily} is the daily observation flow, and $Q_{obs}^{monthly}$ is the monthly average observation flow. For development of daily flows in the Sacramento River upstream of Ord Ferry, the daily-to-monthly ratio was limited to 2.25 to reduce potential for instabilities in the CALSIM II model.

Table 5A7-2. List of reservoirs in the basin and their inception years

Reservoir	River	Year of Inception
Shasta	Sacramento River	1944
Folsom	American River	1955
Oroville	Feather River	1967
New Bullards Bar Reservoir	Yuba River	1969

For the pre-development period or when observation data was unavailable, each month was assigned the daily pattern of the month from the post-development period with the most similar average monthly flow. Then, the daily pattern of that matched month was used to disaggregate monthly CALSIM II flow. For February, if the pre-development period included 28 days and its matched month in the post-development period included 29 days, then the flow from February 29th in the post-development period was excluded from the calculation of the daily patterns. On the other hand, if the pre-development period included 29 days and its matched month in the post-development period only had 28 days, then the flow from February 28th in the post-development period was duplicated and used to determine daily patterns for a 29-day month. An example of the calculated daily flow ratios for the Feather River near Nicolaus station is shown in Figure 5A7-2. Figure 5A7-4 to Figure 5A7-6 illustrate examples of daily simulated CALSIM II flow at the Sacramento River at Verona station, and spills at Fremont and Sacramento weirs in WY 1998.

Evaluation of Daily Pattern Mapping Methods

The "No_WYT_match" lines in Figure 5A7-2, Figure 5A7-4, Figure 5A7-5, and Figure 5A7-6 show river flows estimated using the daily pattern matching method described above, in which months from the pre-development period are matched with months from the post-development period based on total monthly flow volume, regardless of water year type or any other factors.

In addition to the total flow criteria, a few more criteria were tested to find the matching month for simulated CALSIM II monthly flow in the pre-development period, which are outlined below:

- **Use_threshold method**: Visually-defined thresholds were established from daily anomaly plots for each month that separated wetter (Wet - W and Above normal – AN) and drier years (Below normal - BN, Dry - D and Critical – C). An example for the American River at Fair Oaks station is shown below (Figure 5A7-1, Figure 5A7-2, Use_threshold line). In December, if monthly CALSIM II flow was smaller than 5,000 cfs, the daily pattern matching only accounted for drier years to determine the month with the most similar average monthly flow in the observation records and vice versa.

Figure 5A7-1. Observed daily over monthly flow anomaly for the American River at Fair Oaks station. Points are color-coded based on WYT.

- **With_WYT_match method**: Only years assigned the same WYT with the simulated CALSIM flow were considered to determine the month with the most similar streamflow in the post-development observation records (Figure 5A7-2, With_WYT_match line).

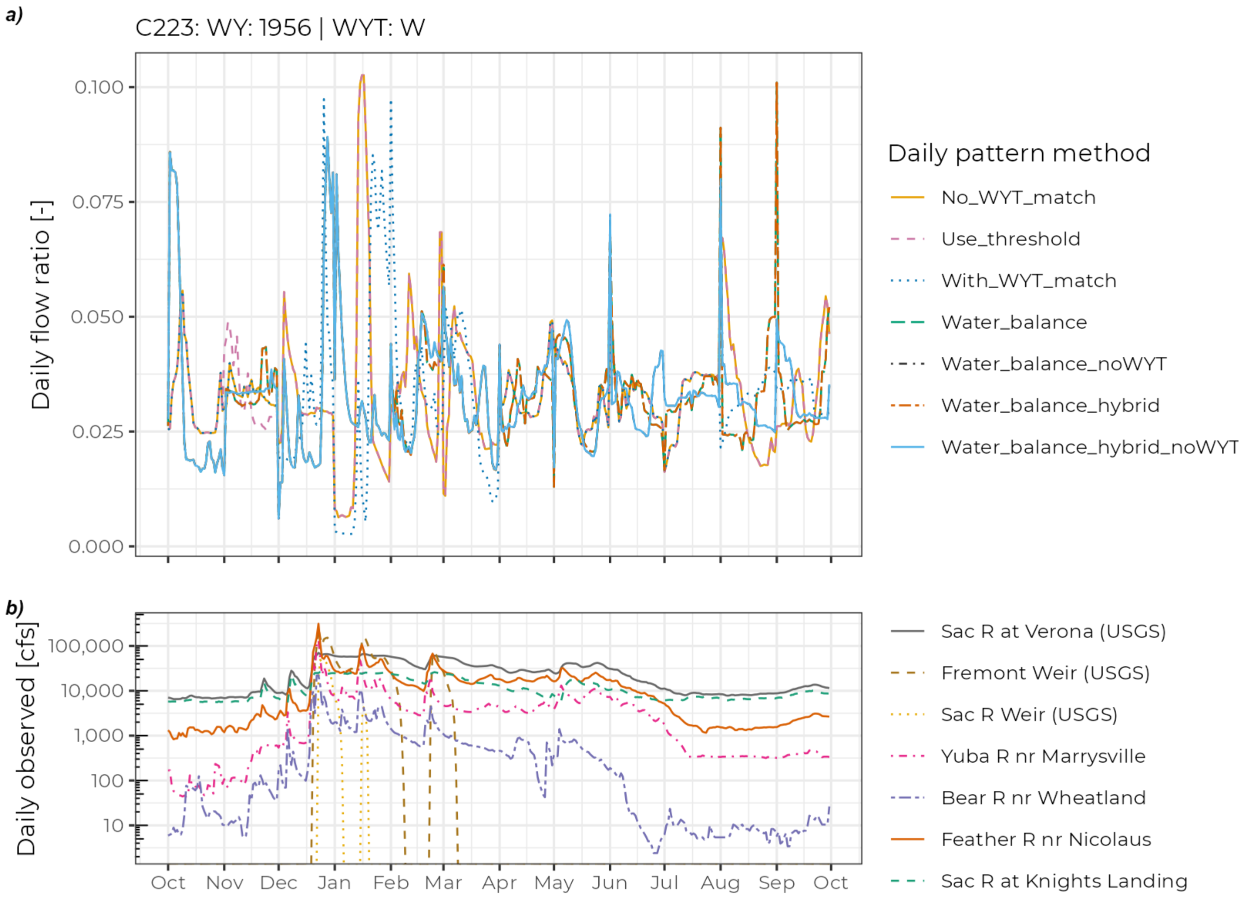

Figure 5A7-2. Daily flow ratio generated using five different methods (a) plotted together with observation flow (b) for the WY 1956 at Feather River near Nicolaus station. No_WYT_match: matching monthly flow regardless of WYT; Use_threshold: matching monthly flow based on a given threshold; With_WYT_match: matching flow based on both the total monthly flow and the same WYT; Water_balance: routing daily generated flows from tributaries; Water_balance_hybrid: same as Water_balance but only applied outside of the available observation data (from WY 1968 to 1984).

- **Special case for the Feather River Basin**: Since the Feather River near Nicolaus had only 16 usable years of observations in the post-development period (WY 1968 to 1984) for monthly flow matching, two additional methods (Water balance and Water balance hybrid) were developed. These methods made use of all three major upstream gages with longer observation records (Thermalito Afterbay, Yuba River near Marysville and Bear River near Wheatland) to generate daily flow pattern (Figure 5A7-2).
  - Water balance method: the daily flows for three upstream gages mentioned above were developed using either the without-WYT (Water_balance_noWYT) or with-WYT (Water_balance) matching methods. These flows are subsequently routed downstream to the Feather River near Nicolaus station based on the water travel time

published by DWR in 2016[1] (Figure 5A7-3). An example of the result for WY 1956 is shown in Figure 5A7-2 (Water_balance_noWYT and Water_balance lines). This method did not use any observation data at the Feather River near Nicolaus station.

- Hybrid water balance method: this method used the available observation data (WY 1968 to 1984) at the Feather River near Nicolaus station to generate daily pattern based on Eq. (5A7-3). For the years outside of the period, from WY 1968 to 1984, the Water balance method above was applied (see the Water_balance_hybrid_noWYT and Water_balance_hybrid lines in Figure 5A7-2).

[1] https://cdec.water.ca.gov/reportapp/javareports?name=water_travel_time_2016.pdf

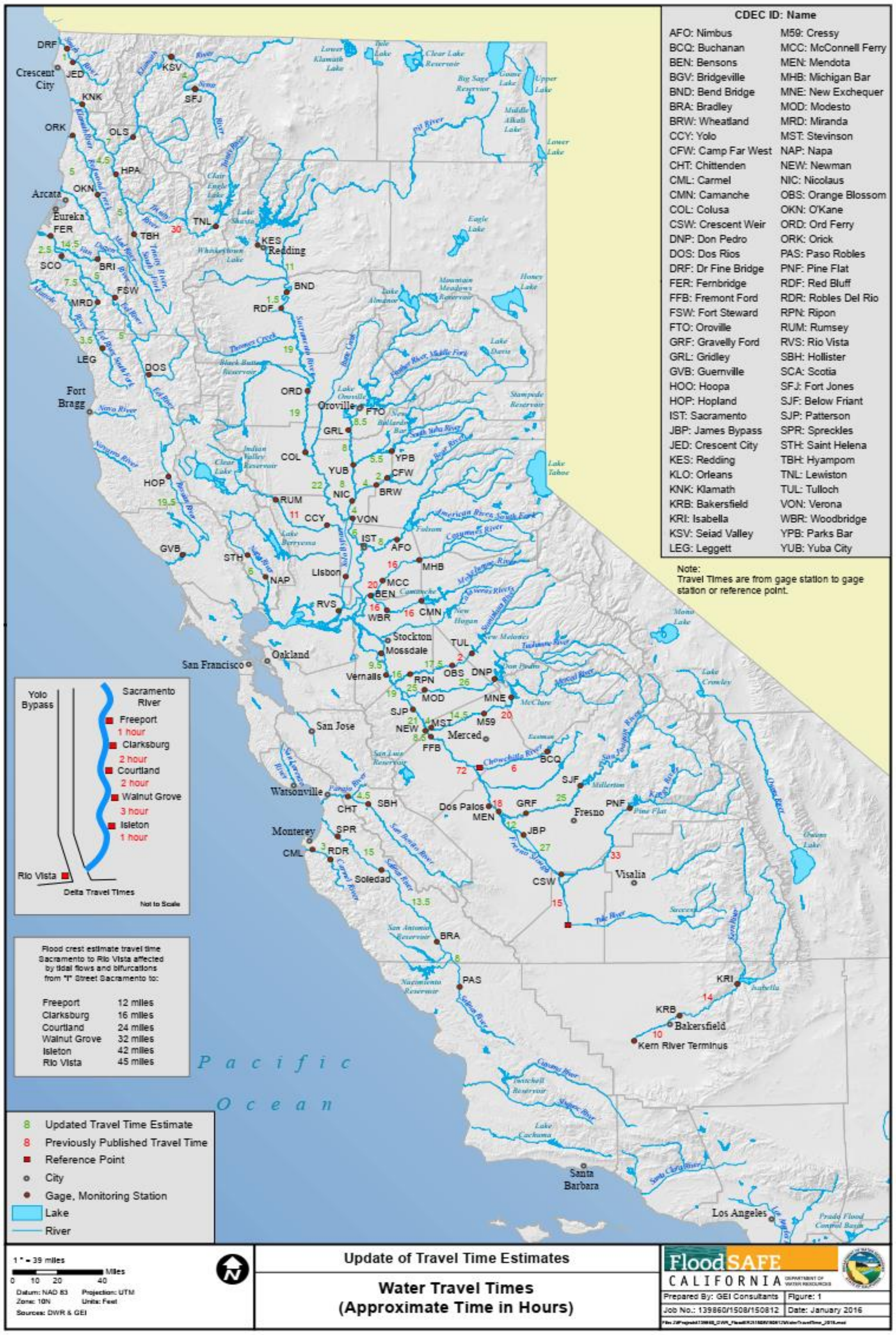

Figure 5A7-3. Water Travel Times (in hours) between gage stations or reference points (DWR, 2016).

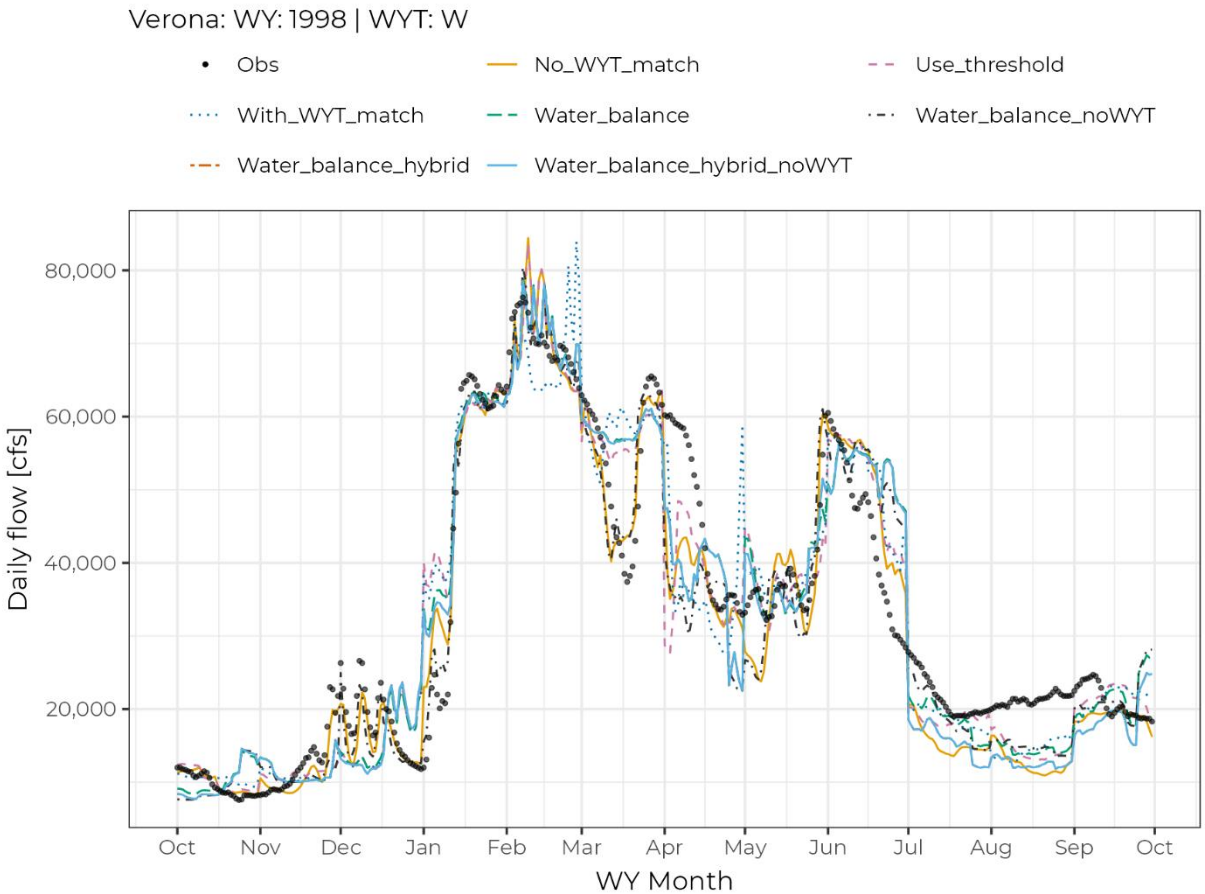

Figure 5A7-4. Daily simulated CALSIM II flows using different daily pattern generation methods compared to observed flow (black dots) in the Sacramento River at Verona station in WY 1998.

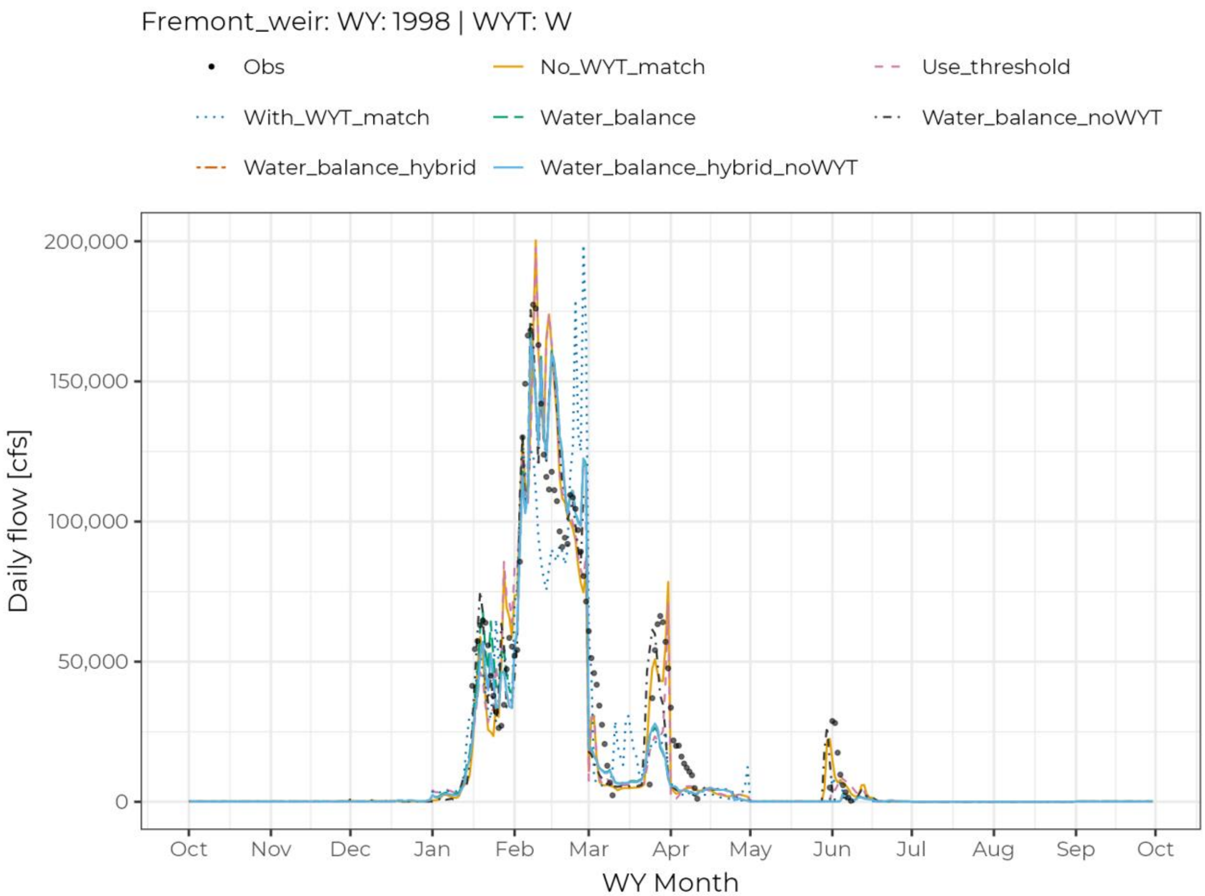

Figure 5A7-5. Daily simulated CALSIM II spills using different daily pattern generation methods compared to observed spills (black dots) at Fremont weir in WY 1998.

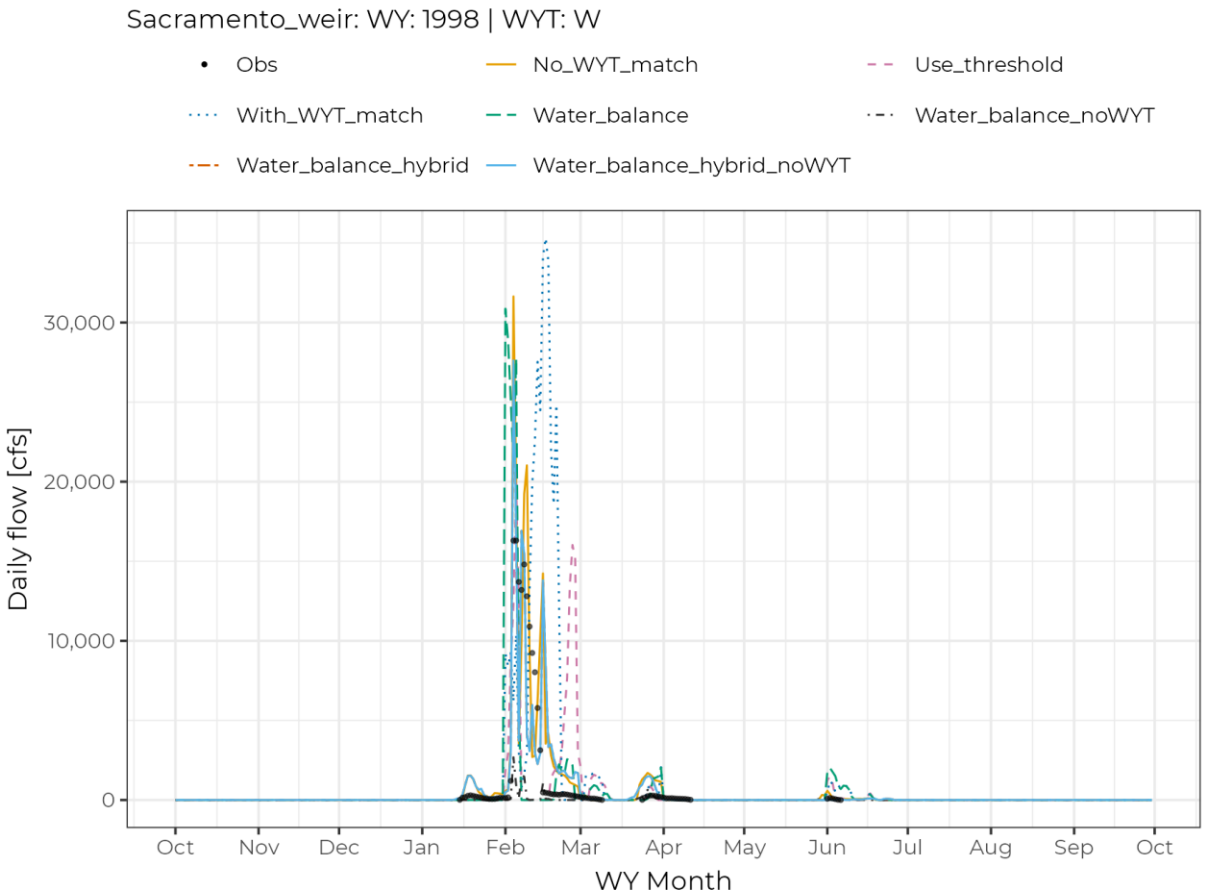

Figure 5A7-6. Daily simulated CALSIM II spills using different daily pattern generation methods compared to observed spills (black dots) at Sacramento weir in WY 1998.

Based on this analysis, the "No_WYT_match" daily pattern mapping method resulted in the best fit with respect to daily historic flow patterns in the Upper Sacramento River. In the Feather River Basin, the "Water_balance_ noWYT" method was chosen to develop the daily patterns.

3. CALSIM II Code Update

The daily patterns for the Sacramento River upstream of Ord Ferry, Feather River, and American River are included in "weir_steps_dailyops.wresl" and used to estimate daily flows and weir spills. A list of all daily flow estimates is shown in

Table 5A7-3. All calculations included in this section assume units of cubic feet per second (cfs).

Table 5A7-3. CALSIM II Parameters used to Estimate Daily Weir Spills.

Parameter	CALSIM II Arc	Computation Method	Formula
Regulated flow upstream of Ord Ferry	$QsacREG_i$	Daily patterns from USRDOM	$QsacREG * daysin * regday_i$
Unregulated flow upstream of Ord Ferry	$QsacUNREG_i$	Daily patterns from USRDOM	$QsacUNREG * daysin * \min(sac116day_i, 2{,}25)$
Sacramento River flow above Ord Ferry	$Qsac116_i$	Daily patterns from USRDOM (regulated and unregulated flows)	$QsacREG_i + QsacUNREG_i$
Ord Ferry spill	$Ordspill_i$	Rating curve	See Section 3.2
Sacramento River flow below Ord Ferry	$Qsac117_i$	Mass balance	$Qsac116_i - Ordspill_i$
Change in flow between Ord Ferry and Moulton Weir	$Qsac117sac123chng_i$	Mass balance, using daily pattern of Sacramento River flow above Ord Ferry	$C123_{prv} * daysin * sac116day_i - C117_{prv} * daysin * sac116day_i$
Sacramento River flow above Moulton Weir	$Qsac123_i$	Mass Balance	$Qsac117_i + Qsac117sac123chng_i$
Moulton Weir spill	$Mouspill_i$	Rating curve	See Section 3.2
Sacramento River flow upstream of Colusa Weir	$Qsac124_i$	Mass balance	$Qsac124_i = Qsac123_i + C17603_{prv} - D124A_{prv} - Mouspill_i$
Colusa Weir spill	$Colspill_i$	Rating curve	See Section 3.2
Sacramento River flow upstream of Tisdale Weir	$Qsac125_i$	Mass balance	$Qsac124_i - Colspill_i$
Tisdale Weir spill	$Tisspill_i$	Rating curve (with and without notch)	See Section 3.3
Sacramento River flow downstream of Tisdale Weir	$Qsac126_i$	Mass balance	$Qsac125_i - Tisspill_i$
Sacramento River flow upstream of Fremont Weir	$Qsac134_i$	Mass balance	$Qsac126_i + Qsac134_{prv} - Qsac126_{prv}$
Sutter Bypass flow upstream of Sacramento River confluence	$Qsut137_i$	Mass balance	See Section 3.4
Feather River flow upstream of Sacramento River confluence	$Qfeather223_i$	Daily patterns of historic records	$C223 * daysin * feather223day_i$
Total flow rating at Fremont Weir	$QsacFth_i$	Mass balance	$qsac134_i + qsut137_i + qfeather223_i$
Fremont Weir spill	$Frespill_i$	Rating curve (with and without notch)	
Sacramento River flow at Verona	$Qsac160_i$	Mass balance	$qsac134_i + qsut137_i + qfeather223_i - frespill_i$
American River flow upstream of Sacramento River confluence	$Qamer303_i$	Daily patterns of historic records	$C303 * daysin * amer303day_i$
Total flow rating at Sacramento Weir	$Qsac165amr303_i$	Mass balance	See Section 3.7
Sacramento Weir spill	$Sacspill_i$	Rating curve	See Section 3.7

Formula definitions:

i = Day of the month

$daysin$ = Number of days in the month

prv = Indicates the value of a parameter from the previous cycle of the CALSIM II simulation

$regday_i$ = Daily pattern factor for regulated flows on day i of the month

$sac116day_i$ = Daily pattern factor for unregulated flows on day i of the month

$feather223day_i$ = Daily pattern factor for Feather River flows on day i of the month

$amer303day_i$ = Daily pattern factor for Feather River flows on day i of the month

Some of the parameters listed in

Table 5A7-3 are described in more detail in the following sections.

3.1 Regulated and Unregulated Flow Upstream of Ord Ferry

Daily patterns for regulated and unregulated flow upstream of Ord Ferry were determined using a USRDOM simulation of historic conditions for WY 1922 – 2003. The following USRDOM outputs were considered regulated flows: Sacramento River flow at Keswick, Clear Creek flow, and Stony Creek flow. All other flows upstream of Ord Ferry were considered unregulated sources of inflow. Table 5A7-4 and Table 5A7-5 show all regulated and unregulated flows considered in USRDOM and used to develop daily patterns upstream of Ord Ferry.

Table 5A7-4. Regulated Flows Upstream of Ord Ferry in USRDOM.

Regulated Flow	USRDOM Output
Sacramento River flow downstream of Keswick Dam	200-KESWICKDAM
Clear Creek flow downstream of Whiskeytown	230-CLRCKBLWWS
Stony Creek inflow to the Sacramento River	142-STONYCKINF

Table 5A7-5. Unregulated Flows Upstream of Ord Ferry in USRDOM.

Unregulated Flow	USRDOM Output
Cow Creek inflow to the Sacramento River	190-COWCKINF
Cottonwood Creek inflow to the Sacramento River	186-COTTONWDIN
Battle Creek inflow to the Sacramento River	185-BATTLECKIN
Paynes Creek inflow to the Sacramento River	180-PAYNESCKIN
Redbank Creek inflow to the Sacramento River	REDBANK_CK_AT_GAGE
Antelope Creek inflow to the Sacramento River	170-ANTELOPEIN
Mill Creek inflow to the Sacramento River	165-MILLCKINF
Elder Creek inflow to the Sacramento River	ELDER_CK_AT_GAGE
Thomes Creek inflow to the Sacramento River	162-THOMESCKIN
Deer Creek inflow to the Sacramento River	160-DEERCKINF
Big Chico Creek inflow to the Sacramento River	145-BIGCHICOIN

The regulated and unregulated daily patterns were applied to monthly CALSIM II outputs for the Sacramento River at Keswick, Clear Creek, and Stony Creek. An upper limit of regulated flow was established for each CALSIM II parameter – 15,000 cfs for Sacramento River flow at Keswick, 500 cfs for Clear Creek flow, and 2,000 cfs for Stony Creek flow. All flows exceeding these upper limits were classified as unregulated flows. Moreover, the regulated daily pattern factors are applied to the portion of flows below the defined upper thresholds and the unregulated daily pattern factors are applied to the portion of flows above the defined upper thresholds.

3.2 Ord Ferry, Moulton Weir, and Colusa Weir Spill

The Ord Ferry, Moulton Weir, and Colusa Weir spill rating curves are shown in Figure 5A7-, Figure 5A7-, and Figure 5A7-. Sacramento River flow is assumed at the location of each weir. These curves were developed in the Sacramento and San Joaquin River Basins Comprehensive Study (California Reclamation Board and Corps, 2002) and is used in USRDOM and CALSIM II modeling.

Sacramento River flow at Ord Ferry ($Qsac116_i$) is computed using daily patterns of regulated and unregulated flows simulated by USRDOM, as computed by the Equation (5A7-4).

$$qsac116_i = QsacREG_i + QsacUNREG_i \qquad (5A7\text{-}4)$$

Where:

$QsacREG_i$ = Regulated Sacramento River flow at Ord Ferry on day i of the month

$QsacUNREG_i$ = Unregulated Sacramento River flow at Ord Ferry on day i of the month

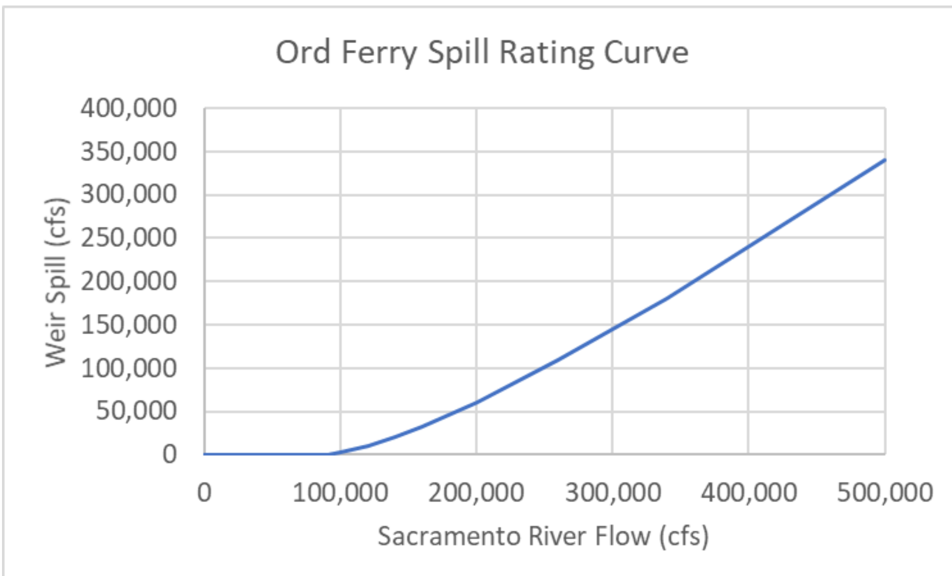

Figure 5A7-7. Ord Ferry Spill Rating Curve used in CALSIM II and USRDOM modeling.

Sacramento River flow at Moulton Weir ($Qsac123_i$) is estimated by adding the flow downstream of Ord Ferry to the change in flow between Ord Ferry and Moulton Weir ($Qsac117sac123chng_i$). The change in flow between Ord Ferry and Moulton Weir is computed by taking the difference between the CALSIM II monthly average estimates of flow upstream and downstream of Moulton Weir, C117 and C123. Both parameters are converted to daily timesteps by using the daily pattern ratios developed for flows in the upper Sacramento River as simulated by USRDOM.

$$qsac123_i = Qsac117_i + Qsac117sac123chng_i \qquad (5A7\text{-}5)$$

Where:

$$Qsac117sac123chng_i = C123_{prv} * daysin * sac116day_i - C117_{prv} * daysin * sac116day_i$$

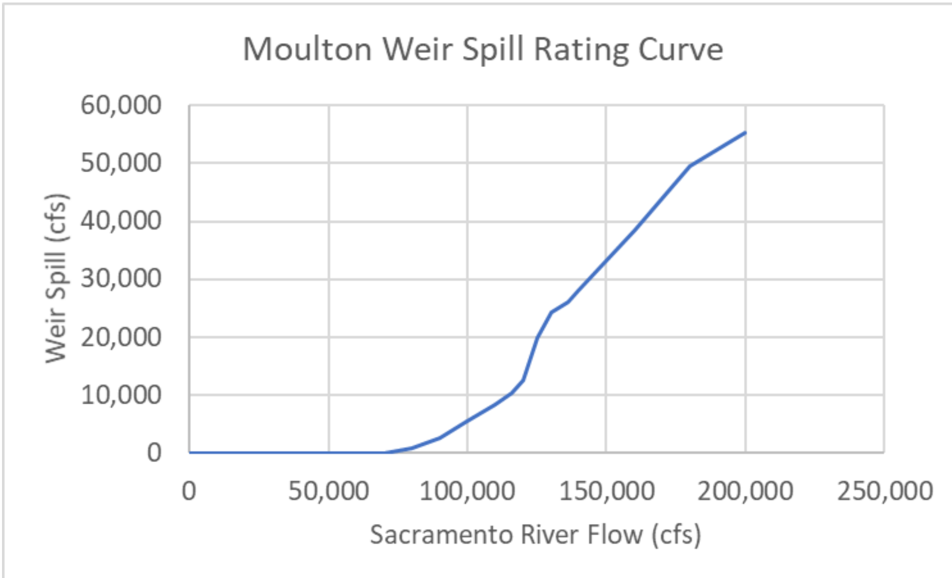

Figure 5A7-8. Moulton Weir Spill Rating Curve used in CALSIM II and USRDOM modeling.

The Colusa Weir is situated downstream of the Moulton Weir. Accordingly, the flow upstream of the Colusa Weir ($Qsac124_i$) is estimated using the following mass balance calculation:

$$Qsac124_i = Qsac123_i + C17603_{prv} - D124A_{prv} - Mouspill_i \quad (5A7\text{-}6)$$

Where:

$C17603_{prv}$ = Average monthly Sites Reservoir release through proposed Delevan Pipeline (not used in Final EIR/EIS modeling)

$D124A_{prv}$ = Average monthly diversion to Sites Reservoir through proposed Delevan Pipeline (not used in Final EIR/EIS modeling)

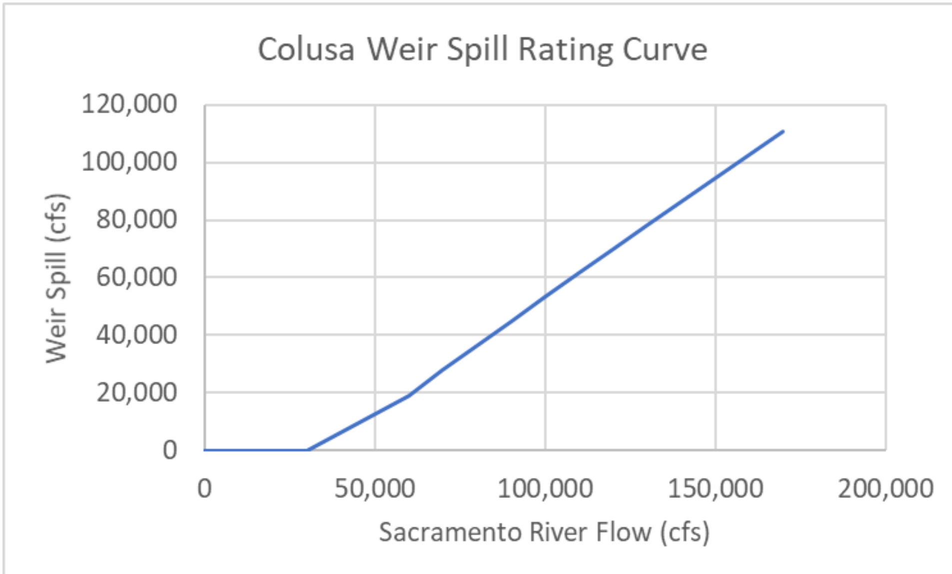

Figure 5A7-9. Colusa Weir Spill Rating Curve used in CALSIM II and USRDOM modeling.

3.3 Tisdale Weir Spill

Tisdale Weir spill is estimated based on daily Sacramento River flow ($qsac125_i$) using the rating curve shown in Figure 5A7-. The "without notch" curve was developed in the Sacramento and San Joaquin River Basins Comprehensive Study (California Reclamation Board and Corps, 2002) and is used in CALSIM II and USRDOM modeling. The "with notch" curve is consistent with the Tisdale Weir Project included in the Sacramento River Voluntary Settlement Agreement (MBK, 2019), which assumes the notch to operate from December 1st through March 15th each year. Although Tisdale Weir notch operations are included in the CALSIM II code, they are turned off and not used to determine Tisdale Weir spills in any of the alternatives modeled for the Final EIR/EIS.

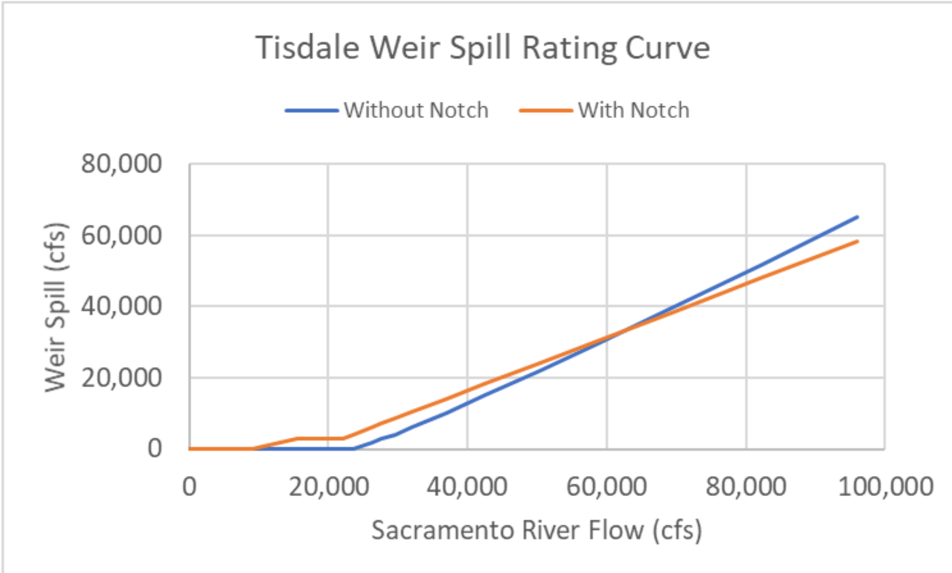

Figure 5A7-10. Tisdale Weir Spill Rating Curves in CALSIM II modeling.

3.4 Sutter Bypass Flow

The Sutter Bypass flow is estimated based on daily weir spills and monthly flows that are converted to daily flows using regulated daily patterns.

$$Qsut137_i = ordspill_i + mouspill_i + colspill_i + tisspill_i + (qsut217A_{prv} + rsut135A_{prv} + rsut135B_{prv} + rsut135C\_DCMP_{prv} - qsut136B_{prv} + rsut137_{prv} + rsut160_{prv}) * daysin * regday_i \quad (5A7\text{-}7)$$

Where:

$qsut217A$ = Average monthly flow at Butte Slough

$qsut136B_{prv}$ = Average monthly flow for the Sutter National Wildlife Refuge

$rsut135A + rsut135B + rsut135C\_DCMP + rsut137 + rsut160$ = Average monthly return flows into the Sutter Bypass

$regday_i$ = daily pattern of regulated flows at Keswick, Clear Creek, and Stony Creek (based on USRDOM)

3.5 Fremont Weir Spill

The Sacramento River flow at the Fremont Weir is denoted $qsacFth_i$, where "i" represents the day of the month. This flow is computed as shown in Equation (5A7-8).

$$qsacFth_i = qsac134_i + qsut137_i + qfeather223_i \quad (5A7\text{-}8)$$

Where:

$qsac134_i = Sacramento\ River\ Flow\ at\ Wilkins\ Slough\ on\ day\ i\ of\ the\ month$

$qsut137_i = Sutter\ Bypass\ inflow\ to\ the\ Sacramento\ River\ on\ day\ i\ of\ the\ month$

$qfeather223_i = Feather\ River\ Flow\ at\ Nicholas\ on\ day\ i\ of\ the\ month$

Fremont Weir spill is estimated based on daily Sacramento River flow ($qsacFth_i$) using the rating curve shown in Figure 5A7-. It is assumed that the proposed Fremont Weir notch will be operated from November 1st through April 31st. Without the notch, CALSIM II assumes that Fremont Weir spills when flow in the river ($qsacFth_i$) exceeds 50,500 cfs. With the notch, spills are assumed when flow in the river exceeds 12,532 cfs. The rating curves used to estimate spills over the weir, with and without the notch, are shown in Figure 5A7-. These assumptions are consistent with those used for ROC on LTO analysis (2019). In CALSIM II, Fremont weir spills are denoted as $frespill\_wn_i$ when the notch is operating and as $frespill\_w_i$ when the notch is not operating.

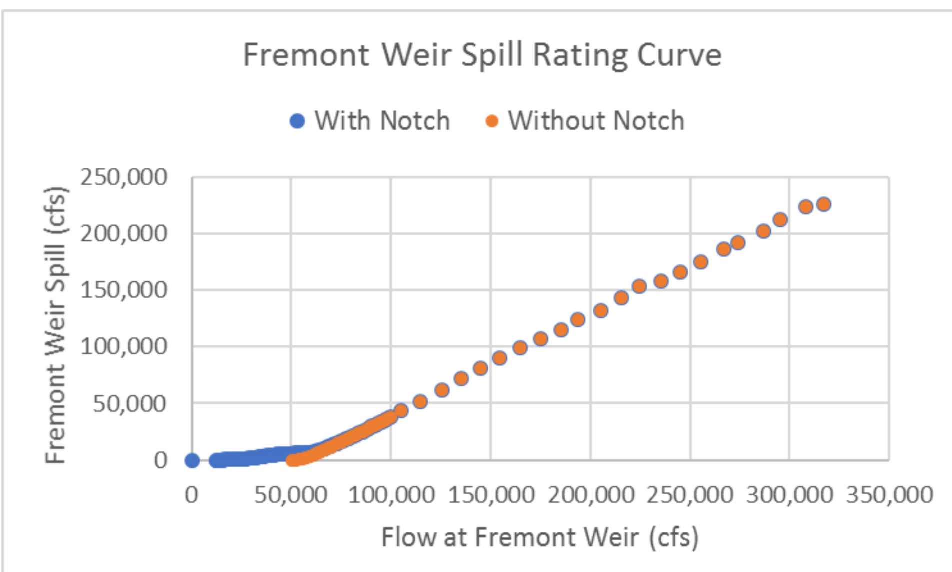

Figure 5A7-11. Fremont Weir Spill Rating Curves in CALSIM II and USRDOM modeling.

3.6 Sacramento River flow at Verona

For verification purposes, daily Sacramento River flow at Verona is computed using CALSIM's daily pattern parameters, averaged on a monthly basis, and compared to CALSIM's monthly output for Sacramento River flow at Verona, C160. The daily estimation of Verona flow is calculated using Equation (5A7-9).

$$qsac160_i = qsac134_i + qsut137_i + qfeather223_i - frespill\_w_i \qquad (5A7\text{-}9)$$

Where:

$$frespill_{w_i} = Fremont\ Weir\ spill\ without\ the\ notch\ on\ day\ i\ of\ the\ month$$

3.7 Sacramento Weir Spill

Daily Sacramento Weir spills ($sacspill_i$) are estimated based on Sacramento River overflow, as defined by Qsac165amr303 in Equation (5A7-10). In CALSIM II, the Sacramento Weir is located at node 166, which has 5 monthly arcs that feed into or out of it. CALSIM II does not have a daily parameter that corresponds directly to C165, which is the Sacramento River flow contribution to Node 166. Additionally, CALSIM II does not have daily computations for the inflow and outflows between the Sacramento Weir and Verona (i.e., D163, D165, D165A). As a result, CALSIM II estimates the daily Sacramento River flow contribution to Node 166 by taking the difference between the monthly Sacramento River flow at the Sacramento Weir (C165_prv) and the average daily-computed Sacramento River flow at Verona (qsac160_prv) of the previous cycle. This provides an estimate of the net inflow and outflow between Node 162 and Node 165 on a daily time-step.

$$\begin{aligned} Qsac165amr303_i &= qsac160_i + \left(C165_{prv} - qsac160_{prv}\right) * daysin * sac116day1 \\ &\quad + C308_{prv} + I166 - demand_{D166} + qAmerContrib_i \end{aligned} \qquad (5A7\text{-}10)$$

Where:

$$qsac160_i = Sacramento\ River\ flow\ at\ Verona\ on\ day\ i\ of\ the\ month$$

$$C165_{prv} = monthly\ average\ Sacramento\ flow\ upstream\ of\ the\ Weir\ of\ previous\ cycle$$

$$qsac160_{prv} = monthly\ average\ Sacramento\ River\ flow\ at\ Verona\ of\ previous\ cycle$$

$$daysin * sac116day1 = conversion\ from\ monthly\ to\ daily\ timestep$$

$$C308_{prv} = Net\ imports\ and\ exports\ between\ Verona\ and\ Sacramento\ Weir$$

$$I166 - demand_{D166} = accretions\ adjustment$$

$$qAmerContrib_i = American\ River\ contribution\ to\ Sacramento\ Weir\ overflow$$

The confluence of the Sacramento River and American River is just downstream of the Sacramento Weir. When the American River flow is high, it often contributes to the overflow at the Weir. As the proportion of American River flow that contributes to weir spills correlates to flow rate, an analysis of this correlation led to the following rules that govern the American River contribution to Sacramento Weir spills:

1. If $qamer303_i < 3{,}759\ cfs$:
    a. $qAmerContrib_i = 0.00\%$
2. If $3{,}759 \leq qamer303_i \leq 21{,}410\ cfs$:
    a. $qAmerContrib_i = 33.45\%$
3. If $21{,}410 \leq qamer303_i \leq 34{,}420 cfs$:
    a. $qAmerContrib_i = 75.60\%$
4. If $qamer303_i \geq 34{,}420\ cfs$:
    a. $qAmerContrib_i = 85.20\%$

The rating curve used to estimate spills over the Sacramento Weir is shown in Figure 5A7-. Spill begins when river flow ($qsac166_i$) exceeds 60,220 cfs.

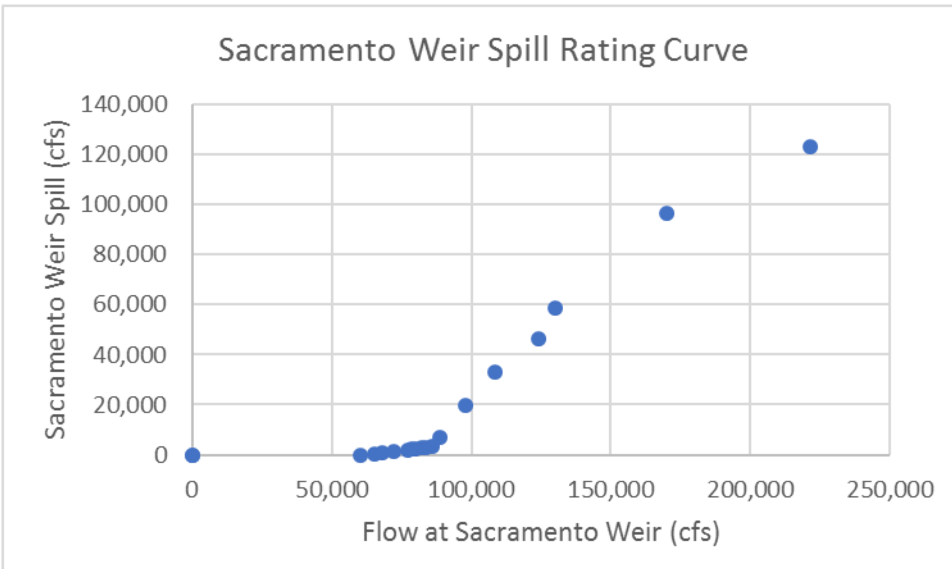

Figure 5A7-12. Sacramento Weir Spill Rating Curve in CALSIM II.

4. Results

Results of the No Action Alternative CALSIM II model used for the Final EIR/EIS were used to evaluate the effectiveness of the daily pattern logic in simulating Sacramento River flow and weir spills. Daily outputs from the model were compared against historic records from USGS. Table 5A7-6 includes the parameters and periods used in this analysis.

Table 5A7-6. Parameters and Dates used for Daily Pattern Verification.

Parameter	**Historic Record ID**	**CALSIM II Daily Output**	**Period of Record**
Fremont Weir Spill	$Frespill_i$	USGS 11391021	01/01/1947 – 09/29/1975
Sacramento River Flow at Verona	$Qsac160_i$	USGS 11425500	10/1/1964 – 9/30/2003
Sacramento Wier Spill	$Sacspill_i$	USGS 11426000	09/30/1943 – 09/30/2003

Table 5A7-7 through Table 5A7-9 compare average annual weir spills into the Yolo Bypass simulated by CALSIM II and recorded by USGS gages for the complete period of record classified based on Water Year Type (WYT). These tables are presented to provide a sense of the differences between the No Action Alternative simulation and historic records. Often, the monthly CALSIM II outputs do not match with monthly average historic data. Consequently, the effectiveness of the CALSIM II daily pattern logic should be measured by evaluating sub-monthly trends in flow levels rather than total flow volumes.

Table 5A7-7. Fremont Weir Spill Average Annuals – Historic vs CALSIM II.

	Fremont Weir Spill (average) (cfs) (WY 1947-1975)			
WYT	Historic (USGS)	CALSIM II (No Action Alternative 051422)	Difference (cfs)	Difference (%)
Long-term	2,809	2,354	455	16%
Wet	5,755	4,916	839	15%
Above Normal	1,947	1,430	517	27%
Below Normal	453	347	106	23%
Dry	131	96	35	27%
Critically Dry	0	0	0	N/A

Table 5A7-8. Sacramento River Flow at Verona Average Annuals - Historic vs CALSIM II.

	Sacramento River flow at Verona (average) (cfs) (WY 1964-2003)			
	Historic (USGS)	CALSIM II (No Action Alternative 051422)	Difference (cfs)	Difference (%)
Long-term	20,471	19,329	1,142	6%
Wet	28,117	26,252	1,865	7%
Above Normal	22,389	21,810	579	3%
Below Normal	15,637	15,255	382	2%
Dry	13,950	13,103	847	6%
Critically Dry	10,645	9,944	700	7%

Table 5A7-9. Sacramento Weir Spill Average Annuals – Historic vs CALSIM II.

	Sacramento Weir Spill (average) (cfs) (WY 1944-2003)			
WYT	Historic (USGS)	CALSIM II (No Action Alternative 051422)	Difference (cfs)	Difference (%)
Long-term	223	175	48	22%
Wet	558	431	127	23%
Above Normal	179	147	32	18%
Below Normal	7	11	-4	-61%
Dry	0	0	0	-126%
Critically Dry	0	0	0	N/A

A post-processing tool was developed to compare historic records with the CALSIM II outputs (the "Daily Patterns CALSIM Verification" spreadsheet). For No Action Alternative, the tool shows that modeled flow and weir spills trend closely with historic data. Figure 5A7-3 through Figure 5A7- show the Fremont Weir spill, Sacramento River flow at Verona, and Sacramento Weir spill in WY 1970 from December through April. In general, the sub-monthly trends in flow increases and decreases between simulated and observed data are relatively consistent. For example, all the Fremont Weir spills in December are allocated towards the end of the month. Additionally, there are two distinguished spikes in Fremont Weir and Sacramento Weir spills in the second half of January. Typically, differences in flow volumes are caused by discrepancies in monthly average estimates, which cannot be completely addressed by daily pattern factors. Limitations are further discussed in Section 5.

Figure 5A7- through Figure 5A7- show Sacramento River flow and weir spills for WY 1965. These figures also include 7-day averages to compare the weekly flow trends between the CALSIM II simulation and historic records. For the most part, the CALSIM II simulation closely matches the historic flow trends. In December, for example, the simulated and historic Sacramento Weir spills peak within one day of each other. Additionally, although the volume of Fremont Weir spill differs between CALSIM II and historic records, the trends of 7-day average spill are often consistent between the two datasets.

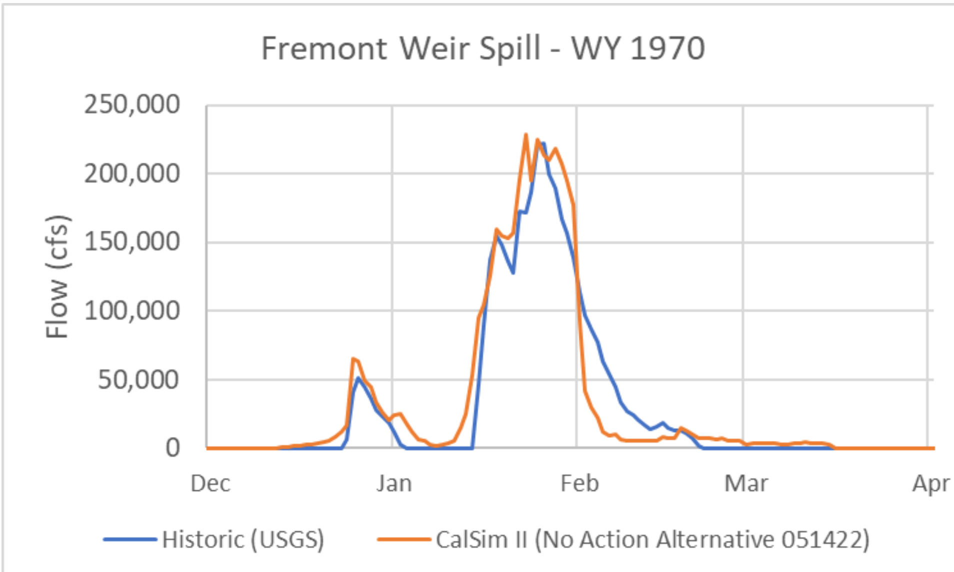

Figure 5A7-13.Fremont Weir Spill in WY 1970 - Historic vs CALSIM II.

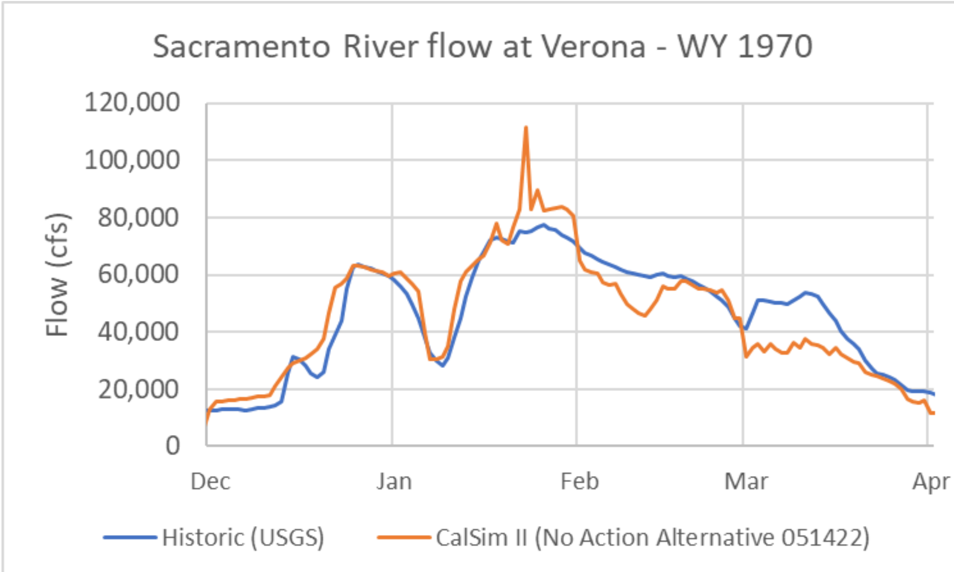

Figure 5A7-14. Sacramento River Flow at Verona in WY 1970 - Historic vs CALSIM II.

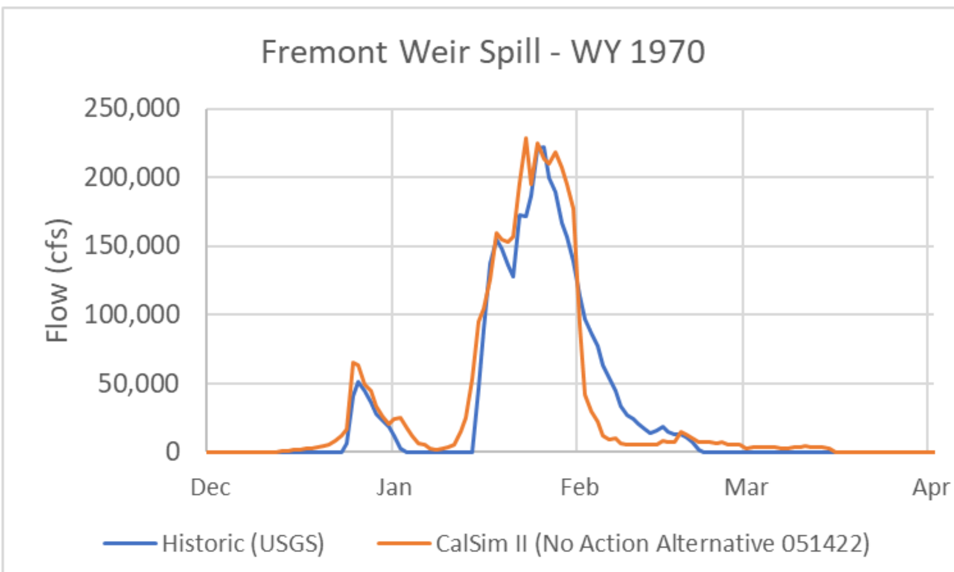

Figure 5A7-15. Sacramento Weir Spill in WY 1970 - Historic vs CALSIM II.

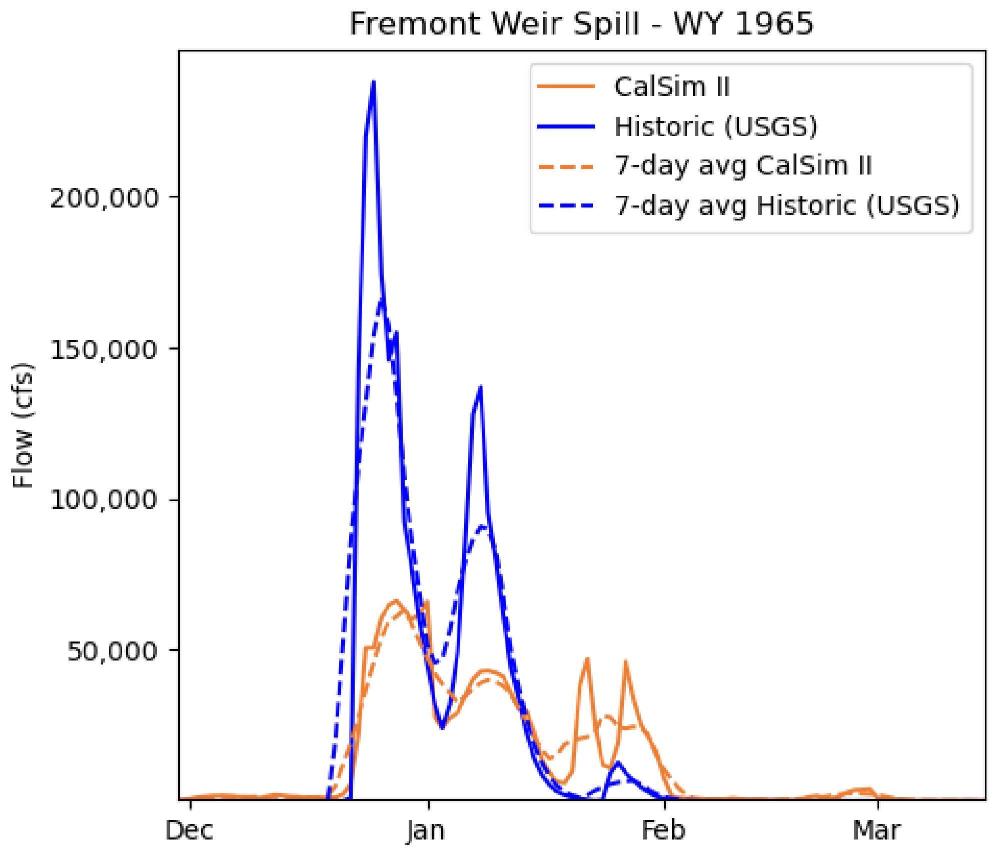

Figure 5A7-16. Fremont Weir Spill in WY 1965 - Historic vs CALSIM II (No Action Alternative 051422).

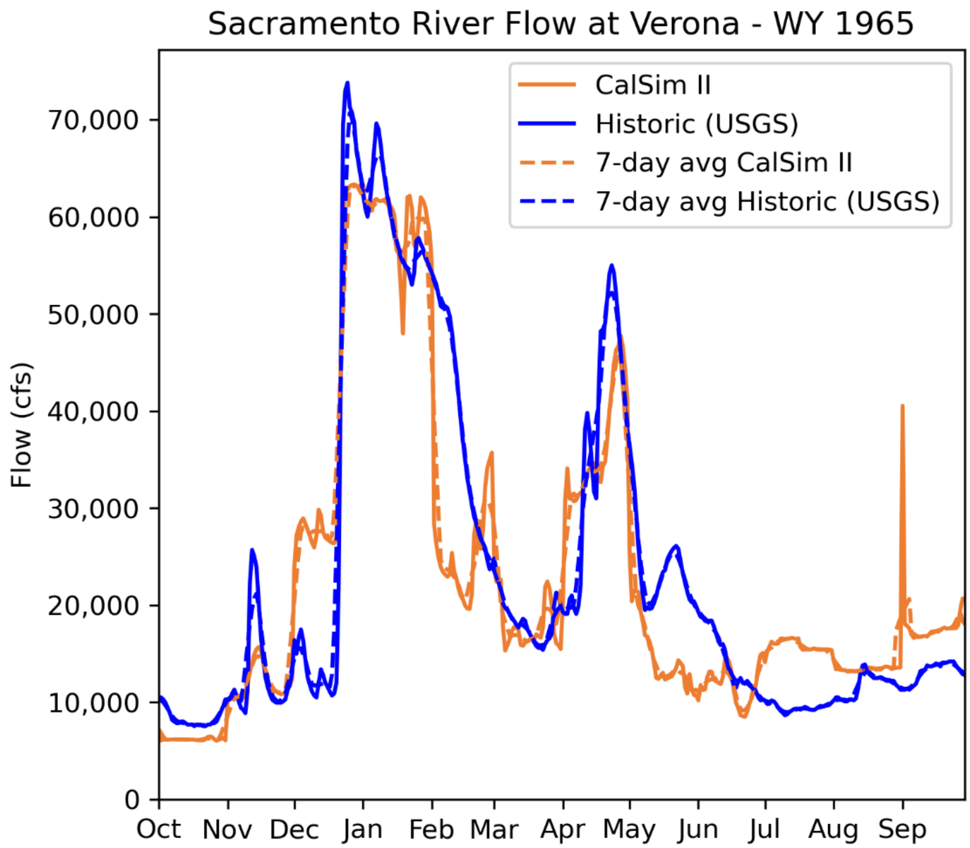

Figure 5A7-17. Sacramento River Flow at Verona in WY 1965 - Historic vs CALSIM II (No Action Alternative 051422).

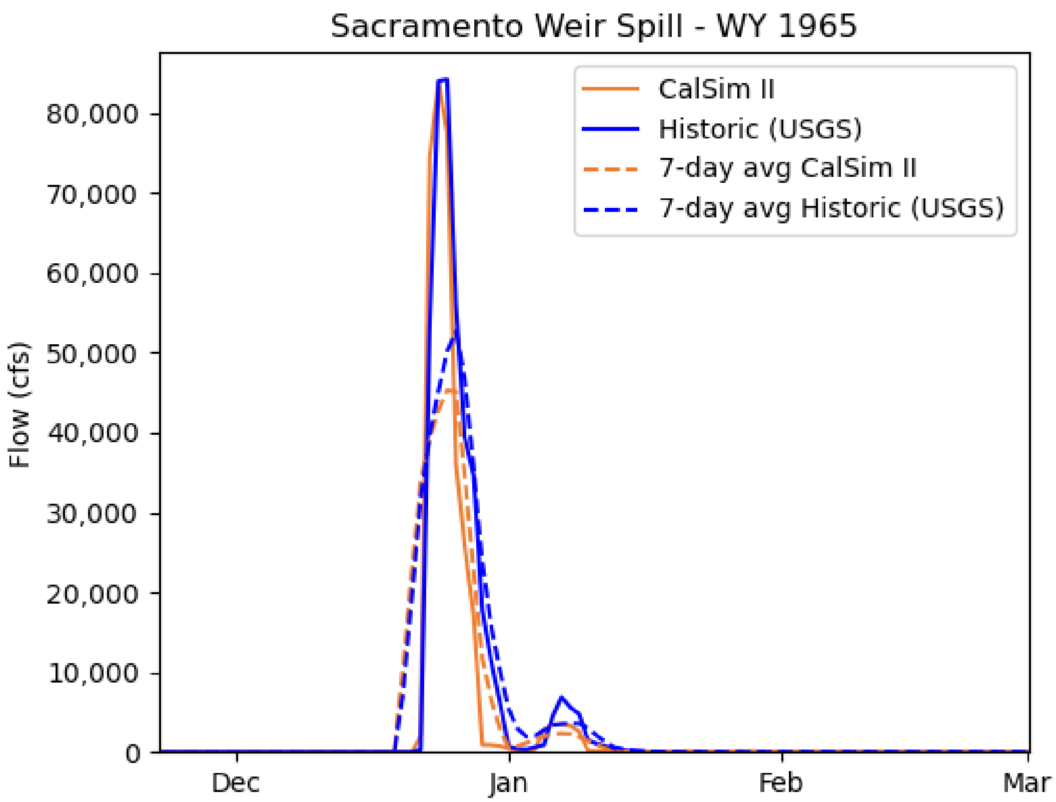

Figure 5A7-18. Sacramento Weir Spill in WY 1965 - Historic vs CALSIM II (No Action Alternative 051422).

5. Limitations

Daily patterns were developed for four parameters: (1) regulated Sacramento River flow above Ord Ferry, (2) unregulated Sacramento River flow above Ord Ferry, (3) American River flow at Sacramento River confluence, and (4) Feather River flow at the Sacramento River confluence. All other daily flow estimates are computed through mass balance calculations. Daily flow and weir spill estimates could be improved with more daily pattern inputs. However, doing so would require an increase in the availability of flow data.

The accuracy of daily flow estimates is limited by the accuracy of corresponding monthly flow estimates. If the monthly average volume of flow simulated by CALSIM II differs from the monthly average historic flow, then the daily volume of simulated flow will also differ from historic records. The daily pattern factors cannot improve the accuracy of CALSIM's average monthly estimates. Instead, the daily pattern factors serve to improve the daily shifts in flow throughout each month. The effectiveness of the daily pattern logic should be evaluated by comparing the day-to-day fluctuations in flows throughout each month.

6. References Cited

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