Attachment 5: Incorporation of Daily Variability in the CalSim II and DSM2 Modeling

5.B.A.5 Incorporation of Daily Variability in the CalSim II and DSM2 Modeling

5.B.A.5.1 Introduction

In reality, daily operations in the overall CVP-SWP system that affect Delta flows depend on daily decisions under unique conditions, occasionally through consultation between several agencies. As the spatial extent of the system increases, the permutations of possible daily outcomes increase so much that it is difficult to assume rules to implement such decisions in a long-term planning model such as CalSim II. For the CWF BA modeling, updates were implemented for new CWF facilities that are sensitive to daily river flow pattern. Monthly river flows were downscaled to represent daily variability using historical data. The daily downscaling did not require any operational decisions. Daily modeling for Delta would require several assumptions on daily operations that cannot be modeled, and therefore, was not attempted. Most of the current Delta standards are 14-day average or monthly. Sub-monthly requirements have been attempted to be addressed conservatively at a monthly time step in CalSim II.

This technical memorandum summarizes the approach used to incorporate daily variability into CalSim II and DSM2 modeling performed for CWF BA. CalSim II results are based on operational decisions on a monthly timestep. It is important to note that this daily mapping approach does not in any way represent the flows resulting from operational responses on a daily time step. It is simply a technique to incorporate representative daily variability into the flows resulting from CalSim II's monthly operational decisions.

5.B.A.5.2 Sacramento River Daily Variability in CalSim II

The operation of the modified Fremont Weir under the CWF NAA and PA scenarios, and the bypass rules associated with the proposed North Delta intakes under the PA are sensitive to the daily variability of flows. Short duration, highly variable storms are likely to cause Fremont Weir spills. However, if flows are averaged for the month, as is done in a monthly model, it is possible to not identify any spill. Similarly, the operating criteria for the north delta intakes include variable bypass flows and pulse protection criteria. Storms as described above may permit significant diversion but only for a short period of time. Initial comparisons of monthly versus daily operations at these facilities indicated that weir spills were likely underestimated and diversion potential was likely overstated using a monthly time step.

Figure 1 shows a comparison of observed monthly averaged Sacramento River flow at Freeport and corresponding daily flow as an example. The figure shows that the daily flow exhibits significant variability around the monthly mean in the winter and spring period while remaining fairly constant in summer and fall months. Figure 2 shows the daily historical patterns by water year type. It shows that daily variability is significant in the winter-spring while the summer flows are holding fairly constant in the most water year types. The winter-spring daily variability is deemed important to species of concern.

In an effort to better represent the sub-monthly flow variability, particularly in early winter, a monthly-to-daily flow mapping technique is applied directly in CalSim II for the Fremont Weir, Sacramento Weir, and the North Delta intakes. The technique applies historical daily patterns, based on the hydrology of the year, to transform the monthly volumes into daily flows. Daily patterns are “borrowed” from the observed DAYFLOW period of 1956-2008. In all cases, the monthly volumes are preserved between the daily and monthly flows. It is important to note that this daily mapping approach does not in any way represent the flows resulting from operational responses on a daily time step. It is simply a technique to incorporate representative daily variability into the flows resulting from CalSim II’s monthly operational decisions.

5.B.A.5.2.1 Observed Daily Patterns

CalSim II hydrology is derived from historical monthly gauged flows for 1922-2003. This is the source data for monthly flow variability. DAYFLOW provides a database of daily historical Delta inflows from WY 1956 to present. This database is aligned with the current Delta infrastructure setting. Despite including the historical operational responses to various regulatory regimes existed over this period, in most winter and spring periods the reservoir operations and releases are governed by the inflows to the reservoirs. It is likely that the unimpaired daily patterns are preserved in these seasons in most years.

Daily patterns from DAYFLOW used directly for mapping CalSim II flows for water years 1956 to 2003. For water years 1922 to 1955 with missing daily flows, daily patterns are selected from water years 1956 to 2003 based on similar total annual unimpaired Delta inflow. The daily pattern for the water year with missing daily flows is assumed to be the same as the daily pattern of the identified water year. Correlation among the various hydrologic basins is preserved by selecting same pattern year for all rivers flowing into the Delta, for a given year in the 1922-1955 period. Table 1 lists the selected pattern years for the water years 1922 to 1955 along with the total unimpaired annual Delta inflow.

Thus, for each month in the 82-year CalSim II simulation period, the monthly flow is mapped onto a daily pattern for computation of spills over the Fremont Weir and Sacramento Weir and for computing water available for diversions through the North Delta intakes. A preprocessed timeseries of daily volume fractions, based on Sacramento River at Freeport observed flows, is input into CalSim II. The monthly volume as determined dynamically from CalSim II then is multiplied by the fractions to arrive at a daily flow sequence. The calculation of daily spills and daily diversions are thus obtained. In the subsequent cycle (but still the same month), adjustments are made to the daily river flow upstream of the Sacramento Weir and the North Delta intakes to account for differences between the monthly flows assumed in the first cycle and the daily flows calculated in subsequent cycles. For example, if no spill over Fremont was simulated using a monthly flow, but when applying a daily pattern spill does occur, then the River flow at the Sacramento Weir is reduced by this amount. In this fashion, daily balance and monthly balance is preserved while adding more realism to the operation of these facilities.

5.B.A.5.2.2 North Delta Diversion Operations

CWF PA includes three new intakes on Sacramento River upstream of Sutter Slough, in the north Delta. Each intake is proposed to have 3,000 cfs maximum pumping capacity. It is also proposed that the intakes will be screened using positive barrier fish screens to eliminate entrainment at the pumps. Water diverted at the intakes is conveyed to a new forebay in the south Delta via tunnels. The CWF proposes bypass (in-river) rules, which govern the amount of water required to remain in the river before any diversion can occur. Bypass rules are designed to avoid increased upstream tidal transport from downstream channels, to support salmonid and pelagic species transport to regions of suitable habitat, to preserve shape of the natural hydrograph which may act as cue to important biological functions, to lower potential for increased tidal reversals that may occur because of the reduced net flow in the River and to provide flows to minimize predation effects downstream. The bypass rules include three important components:

- a constant low level pumping of up to 300 cfs at each intake depending on the flow in the Sacramento River,
- an initial pulse protection, and
- a post-pulse operations that permit a percentage of river flow above a certain threshold to be diverted (and transitioning from Level I to Level II to Level III).

The bypass rules are simulated in CalSim II using daily mapped Sacramento River flows as described above to determine the maximum potential diversion that can occur in the north Delta for each day. The simulation identifies which of the three criteria is governing, based on antecedent daily flows and season. An example of the north delta flows and diversion is illustrated in Figure 3. As can be seen in this figure, bypass rules begin at Level I in October until the Sacramento River pulse flow develops. During the pulse flow, the constant low level pumping (Level 0) is permitted, but is limited to a certain percentage of river flow. After longer periods of high bypass flows, the bypass flow requirements moves to Level II and eventually Level III which permit greater potential diversion. CalSim II uses the monthly average of this daily potential diversion as one of the constraints in determining the final monthly north Delta diversion.

5.B.A.5.3 Daily Hydrologic Inputs in DSM2

DSM2 is simulated on a 15-minute time step to address the changing tidal dynamics of the Delta system. However, the boundary flows are typically provided from monthly CalSim II results. In all previous planning-level evaluations, the DSM2 boundary flow inputs were applied on a daily time step but used constant flows equivalent to the monthly average CalSim II flows except at month transitions. In an effort to better represent the sub-monthly flow variability, particularly in early winter, a monthly-to-daily flow mapping technique is applied to the boundary flow inputs to DSM2.

The daily mapping also helps in refining the monthly CalSim II operations by providing a better estimate of the Fremont and Sacramento weir spills which are sensitive to the daily flow patterns. It also allows in providing the upper bound of the available North Delta Diversion in the PA. The daily mapping approach used in CalSim II and DSM2 are consistent.

It is important to note that this daily mapping approach does not in any way represent the flows resulting from operational responses on a daily time step. It is simply a technique to incorporate representative daily variability into the flows resulting from CalSim II’s monthly operational decisions.

5.B.A.5.3.1 Observed Daily Patterns

CalSim II hydrology is derived from historical monthly gaged flows 1922-2003. Main Delta inflows are Sacramento River, San Joaquin River, Yolo Bypass, Mokelumne River, Cosumnes River and Calaveras River. All the monthly river inflows to Delta resulting from CalSim II are mapped according to “borrowed” observed daily patterns in this approach.

DAYFLOW provides a database of daily historical Delta inflows from WY 1956 to present. This database is aligned with the current Delta infrastructure setting. Even though it includes the historical operational responses to various regulatory regimes existed over this period, in most winter and spring periods the reservoir operations and releases are governed by the inflows to the reservoirs. It is likely that the unimpaired daily patterns are preserved in these seasons in most years.

Daily patterns from DAYFLOW used directly for mapping CalSim II flows for water years 1956 to 2003. For water years 1922 to 1955 with missing daily flows, daily patterns are selected from water years 1956 to 2003 based on similar total annual unimpaired Delta inflow. The daily pattern for the water year with missing daily flows is assumed to be the same as the daily pattern of the identified water year. Correlation among the various hydrologic basins is preserved by selecting same pattern year for all rivers flowing into the Delta, for a given year in the 1922-1955 period. Table 1 lists the identified pattern years for the water years 1922 to 1955 along with the total unimpaired annual Delta inflow.

5.B.A.5.3.2 Daily Patterning of Delta River Inflows

Based on the pattern years identified for WY 1922-1955 and the DAYFLOW data for WY 1956-2003, daily flow timeseries are prepared for all the observed Delta inflows for the 82-year period. Based on the 82-year daily timeseries, monthly average timeseries are computed for all the observed Delta inflows over the 82-year period. When preparing the 82-year daily and monthly observed database, adjustments may be needed for February months. If a water year is a leap year and the corresponding selected pattern water year is not, then March 1st flow in the selected pattern year is used to compute the monthly average flow for February and to pattern the flow on the 29th day of February. Converse to that if the selected pattern year is a leap year and the water year is not, then the February average for the selected pattern year is computed from the first 28 days in February. Table 2 shows the years with adjustments made to February monthly averages.

The 82-year observed daily flows are scaled based on the ratio of simulated to observed monthly flows.

i. Adjustment factor is calculated based on monthly average flows:

$$f_{adj} = Q_{monthly\ simulated} / Q_{monthly\ observed}$$

ii. Simulate daily flows are estimated by scaling the observed daily flows using the adjustment factor:

$$q_{simulated} = f_{adj} * q_{observed}$$

Under some extreme observed flow conditions that are not present in the simulated flows, the patterning produces unrealistic swings in daily flows and corrections to constant patterns were implemented. In order to reduce this effect, a set of criteria was introduced for each boundary flow. The criteria allow daily mapping only when the simulated monthly flow is greater than a minimum flow target and the adjustment factor is falling within a certain range reducing the risk of introducing unrealistic variability into daily mapped flows. If either criterion is not met the mapping is not performed and constant monthly average flow is assigned to all the days in the month. The observed daily river flow record used for mapping each simulated monthly Delta inflow is listed in the Table 3 below along with the criteria for the daily mapping. As with CalSim II, in all cases the monthly flows and diversions are maintained as the daily mapping is implemented.

5.B.A.5.3.2.1 Sacramento River

Daily mapping of Sacramento River flow is performed in CalSim II using the approach described above. The daily Sacramento River flow simulated in CalSim II is used to map the monthly C169 output from CalSim II for use in DSM2. The Freeport Regional Water Project (FRWP) diversions from CalSim II (D168B and D168C) are added to the daily mapped C169 as FRWP diversion is explicitly simulated in DSM2.

5.B.A.5.3.2.2 Yolo Bypass

Yolo Bypass receives water from the Sacramento River via Fremont Weir and Sacramento Weir spills and other local flows such as Knight’s Landing Ridge Cut, Cache Creek, Willow Slough and Putah Creek. The daily flow values for Fremont Weir and Sacramento Weir spills are simulated directly in CalSim II based on the daily mapped Sacramento River flows. The Yolo Bypass flow from local sources, computed from monthly CalSim II results by subtracting spills (D160 and D166A) from Yolo Bypass flow into Delta (C157), are mapped using the daily residuals computed from QYOLO and observed Fremont and Sacramento Weir spills. For observed Fremont weir spill CDEC FRE gage data is used for 1984 – 2003 period. The missing values were filled based on a flow correlation with Sacramento at Verona (USGS 11425500, 1929-2009) using 2006 weir rating curve. For observed Sacramento Weir spill USGS 11426000 gage data is used.

Finally, the simulated daily Fremont Weir and Sacramento Weir spills from CalSim II are added to the daily mapped Yolo Bypass local flows to estimate the daily inflow for Yolo Bypass into the Delta.

5.B.A.5.3.2.3 San Joaquin River

Monthly San Joaquin River flow at Vernalis simulated in CalSim II (C639) is mapped using QSJR daily flow pattern from DAYFLOW. The daily mapping is not performed if C639 is less than 2,000 cfs or if the adjustment factor is not within 0.25 and 7.0 for all months except April and May. The minimum flow target for April and May months is dependent on the 60-20-20 Water Year Type for San Joaquin River Valley. Table 4 shows the long-term minimum flow target to be used for daily mapping of San Joaquin River flow at Vernalis in April and May. The higher minimum flow targets are used to ensure that the daily flows do not fall below the values shown in the Table 4.

The daily mapped C639 flows are then added to R644 return flow from CalSim II to estimate the daily inflow for San Joaquin River at Vernalis boundary.

5.B.A.5.3.2.4 Eastside Streams

Monthly Mokelumne River inflow (C603) to Delta from CalSim II is estimated by subtracting Cosumnes River flow (C601) from C604 flow. It is mapped using the 82-year daily flow pattern prepared from QMOKE data from DAYFLOW. Monthly Cosumnes River (C601) is mapped using the daily flow pattern based on the CSMR data from DAYFLOW.

Monthly Calaveras River flow from CalSim II (C508) is mapped based on the daily pattern of QMISC data from DAYFLOW. The daily pattern for Calaveras inflow from WY 1956-1960 was based on the CALR daily flow data from the 1930-1960 DAYFLOW dataset and based on QMISC daily flow data from the current DAYFLOW dataset for WY 1960 - 2003. The reason for this is that the current DAYFLOW QMISC data set records reports monthly averages for WY 1956 – 1960 as shown in the Figure 4. The daily patterned C508 data is added to the R514 return flow from CalSim II to estimate the daily inflow for Calaveras River into the Delta.

5.B.A.5.3.2.5 Daily Patterning of North Delta Diversion

Daily mapping of the Sacramento River flow in CalSim II allows to accurately implementing the bypass rules proposed in the CWF so that a refined estimate of potential north Delta diversion can be estimated. Daily north Delta diversion flows used in DSM2 are estimated by patterning the actual monthly north Delta diversion (D400) from CalSim II based on the potential daily north Delta diversion from CalSim II operations. Adjustment factors are computed as the ratio of simulated north Delta diversion in CalSim II (D400) and the monthly average of potential daily north Delta diversion from CalSim II. The daily CalSim II outputs for potential north Delta diversion are then scaled using the adjustment factor to compute the initial estimate of the daily north Delta diversion boundary condition for DSM2.

The final north Delta diversion is computed by adjusting its initial estimate using the daily south Delta exports and constraining the total daily pumping (combined north and south) to the available maximum total pumping capacity of 9,000 cfs. The north Delta diversion is adjusted by reallocating the amount of total daily pumping in excess of 9,000 cfs to the days when the total pumping is less than 9,000 cfs within each month while making sure that daily Sacramento River flow if at least 5,000 cfs. The monthly averages of the final daily north Delta diversion are checked against the CalSim II (D400) results to ensure the mass balance.

5.B.A.5.3.2.6 Daily Patterning of South Delta Exports

The initial estimate of the daily south Delta exports at Jones Pumping Plant and Banks Pumping Plant is simply setting all the days in a month equal to the constant monthly average values from CalSim II (D418_TD and D419_TD). The initial estimates are then adjusted by constraining combined north and south Delta pumping at Jones to 4,600 cfs (maximum pumping capacity at Jones Pumping Plant) and by constraining combined north and south Delta pumping at Banks to

10,300 cfs (maximum pumping capacity at Banks Pumping Plant). The daily Jones and Banks components in the north Delta are computed from initial estimate of the daily north Delta diversion using the monthly fractional volumes from CalSim II (D418_IF and D419_IF).

The initial daily south Delta export at Jones is adjusted by reallocating the amount of daily combined Jones pumping in excess of 4,600 cfs to the days when total Jones pumping is less than 4,600 cfs within each month. Similarly, the initial south Delta export at Banks is adjusted by reallocating the amount of daily combined Banks pumping in excess of 10,300 cfs to the days when total Banks pumping is less than 10,300 cfs within each month. The monthly averages of the final south Delta exports at Jones and Banks Pumping Plants are checked against the CalSim II (D418_TD and D419_TD) results to ensure the mass balance. It is important to note that in the absence of the north Delta diversion as in the case of No Action scenario this approach results in constant monthly south Delta exports across all the days in the month similar to the traditional method.

5.B.A.5.3.2.7 Daily Patterning of DCC Gate Operations

DCC gate operations are determined based on the CalSim II output "//DXC/GATE-DAYS-OPEN//1MON//", which provides the number of days DCC gates are open for each month in the 82-year period. For the months where GATE-DAYS-OPEN is zero, the gate operation is set to close on all the days in the month. For the months where GATE-DAYS-OPEN is greater than zero, the gate operation is determined based on daily Sacramento River flow upstream of the Delta Cross Channel estimated from daily mapped Sacramento inflow and subtracting the north Delta diversion from it. From beginning of the month, the gates are set to open on the days if Sacramento River flow upstream of the Delta Cross Channel is less than 25,000 cfs, otherwise the gates are assumed to be closed. The cumulative sum of the number of days with the gates open is tracked. If the number of the days specified by CalSim II is met in a month, then the gates are closed for the rest of the month.

The monthly total number of days with DCC gates open is computed from the final daily timeseries and compared to the CalSim II result. This approach could result in discrepancy with CalSim II result if daily Sacramento River flow is greater than 25,000 cfs while the monthly average in CalSim II was not. The discrepancy was not corrected since the daily approach is more realistic.

5.B.A.5.3.2.8 End-of-month Smoothing

The daily mapped Delta inflows are smoothed at the month transition to avoid abrupt change in flow. The smoothing approach used computes 4-day forward moving average and 4-day backward moving average and averages the two moving averages in the last 5 days of a month and the first 5 days of the next month. Once the smoothing is performed the resulting daily timeseries is scaled to conserve the monthly average of the inflow.

Smoothing is performed on all the main Delta River inflows. Sacramento River is an exception since the daily pattern needs to be consistent with the daily mapping of Sacramento River flow in CalSim II as the north Delta diversion is mapped based on the daily potential estimated in

CalSim II. There is a chance that with smoothing the daily Sacramento flow could change from the CalSim II pattern and may not be sufficient to meet the daily north Delta diversion.

Table 1. Identified "Pattern" Water Year for the Water Years 1922 to 1955 with Missing Daily Historical Flows

Water Year	Total Annual Unimpaired Delta Inflow (TAF)	Selected "Pattern" Water Year	Total Annual Unimpaired Delta Inflow (TAF)
1922	32,975	1975	31,884
1923	23,799	2002	23,760
1924	8,174	1977	6,801
1925	26,893	1962	25,211
1926	18,534	1959	17,967
1927	38,636	1984	38,188
1928	26,363	1962	25,211
1929	12,899	1994	12,456
1930	20,326	1972	19,863
1931	8,734	1977	6,801
1932	24,179	2002	23,760
1933	14,126	1988	14,019
1934	12,895	1994	12,456
1935	28,486	2003	28,228
1936	30,698	2003	28,228
1937	25,448	1962	25,211
1938	56,949	1998	56,482
1939	12,743	1994	12,456
1940	37,185	1963	36,724
1941	46,746	1986	46,602
1942	42,301	1980	41,246
1943	36,870	1963	36,724
1944	17,158	1981	17,131
1945	26,757	1962	25,211
1946	28,823	2003	28,228
1947	16,206	2001	15,460
1948	23,741	1979	22,973
1949	19,176	1960	19,143

Water Year	Total Annual Unimpaired Delta Inflow (TAF)	Selected "Pattern" Water Year	Total Annual Unimpaired Delta Inflow (TAF)
1950	23,272	1979	22,973
1951	39,110	1984	38,188
1952	49,270	1986	46,602
1953	30,155	2003	28,228
1954	26,563	1962	25,211
1955	17,235	1981	17,131

Table 2. Adjustment in Number of Days to Calculate February Monthly Average in the Selected Pattern Years

Water Year	Selected Pattern Water Year	Water Year Days in February	Pattern Year Days in February	Adjustment (days)
1922	1975	28	28	0
1923	2002	28	28	0
1924	1977	29	28	1
1925	1962	28	28	0
1926	1959	28	28	0
1927	1984	28	29	-1
1928	1962	29	28	1
1929	1994	28	28	0
1930	1972	28	29	-1
1931	1977	28	28	0
1932	2002	29	28	1
1933	1988	28	29	-1
1934	1994	28	28	0
1935	2003	28	28	0
1936	2003	29	28	1
1937	1962	28	28	0
1938	1998	28	28	0
1939	1994	28	28	0
1940	1963	29	28	1
1941	1986	28	28	0
1942	1980	28	29	-1

Water Year	Selected Pattern Water Year	Water Year Days in February	Pattern Year Days in February	Adjustment (days)
1943	1963	28	28	0
1944	1981	29	28	1
1945	1962	28	28	0
1946	2003	28	28	0
1947	2001	28	28	0
1948	1979	29	28	1
1949	1960	28	29	-1
1950	1979	28	28	0
1951	1984	28	29	-1
1952	1986	29	28	1
1953	2003	28	28	0
1954	1962	28	28	0
1955	1981	28	28	0

Table 3. DSM2 Boundary Flow, CalSim II Output Used, Observed DAYFLOW Record Used for Daily Mapping and Applicable Constraints

DSM2 Boundary Flow	CALSIM Output	Observed DAYFLOW Records	Constraints [2]
Sacramento River at Freeport	C169	QSAC	None
Yolo bypass flow not including Fremont and Sacramento Weir Spills	(C157 – D160 – D166A)	QYOLO minus Historic Fremont and Sacramento Weir Spills	Allowed range for adjustment factor is 0.25 to 7.0
Cosumnes River	C501	CSMR	Allowed range for adjustment factor is 0.25 to 7.0
Mokelumne River	(C504 – C501)	QMOKE	Allowed range for adjustment factor is 0.25 to 7.0
Calaveras River at Stockton	C508	QMISC	Allowed range for adjustment factor is 0.25 to 7.0
San Joaquin River at Vernalis	C639	QSJR	Allowed range for adjustment factor is 0.25 to 7.0; Minimum flow target for simulated monthly flow is 2,000 cfs in most months [1]

Notes:

[1] In April and May months the minimum target flow to allow daily mapping for San Joaquin River is determined based on San Joaquin River 60-20-20 Water Year Type. Minimum target flow for Wet and Above Normal Years 7,000 cfs, Below Normal Years 5,500 cfs, Dry Years 4,000 cfs and Critical Years 2,500 cfs.

[2] Daily mapping is not performed and constant monthly average flow is assigned to all the days in the month if the listed criteria is not met

Table 4. San Joaquin River at Vernalis Minimum Flow Target in April and May for Daily Mapping

San Joaquin River Index (60-20-20)	Long-term Flow Target at Vernalis (cfs)
1	7,000
2	7,000
3	5,500
4	4,000
5	2,500
Notes: 2,000 cfs is used as the minimum flow target for other months	

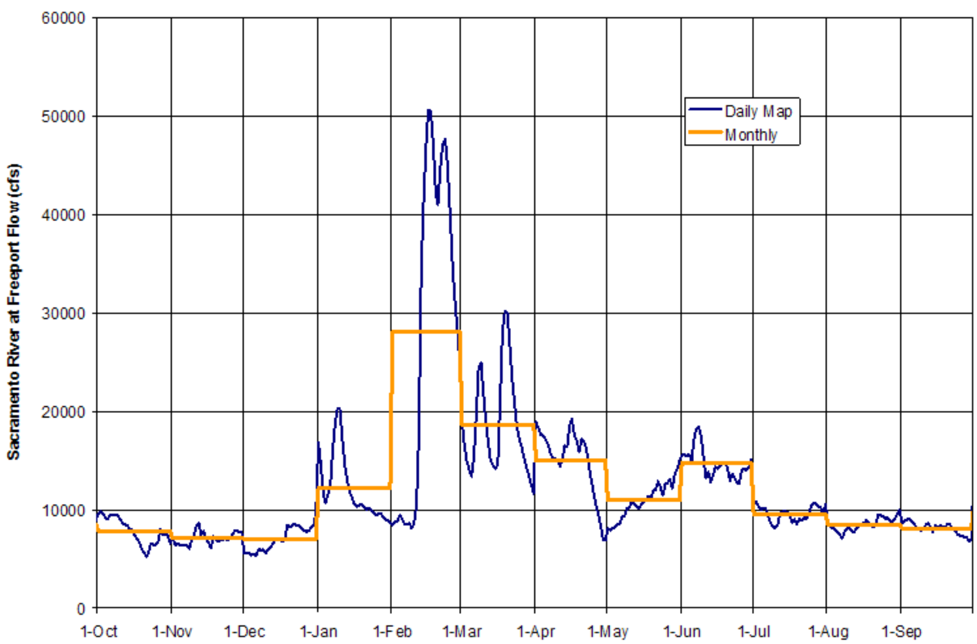

Figure 1: Example monthly-averaged and daily-averaged flow for Sacramento River at Freeport

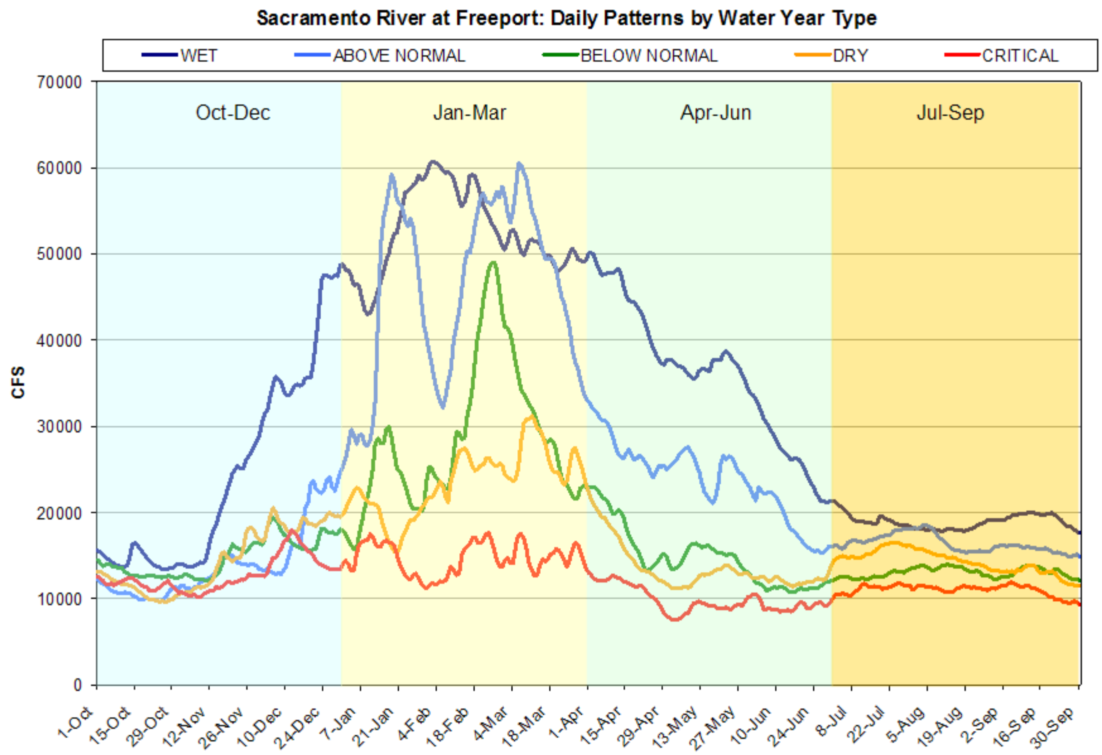

Figure 2: Mean daily flows by Water Year Type for Sacramento River at Freeport

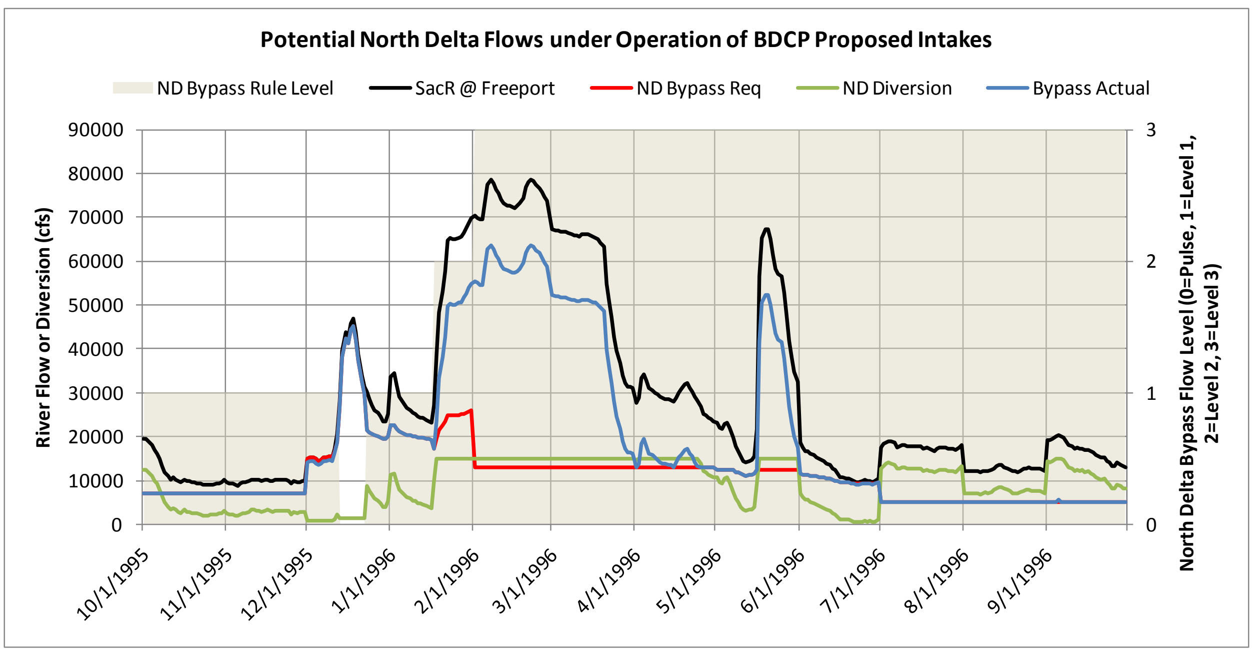

Figure 3: Example year daily patterns and operation of the North Delta intakes. Note: the grey shading indicates the active bypass rule (0=pulse/low level pumping, 1=level I, 2=level II, and 3=level III).

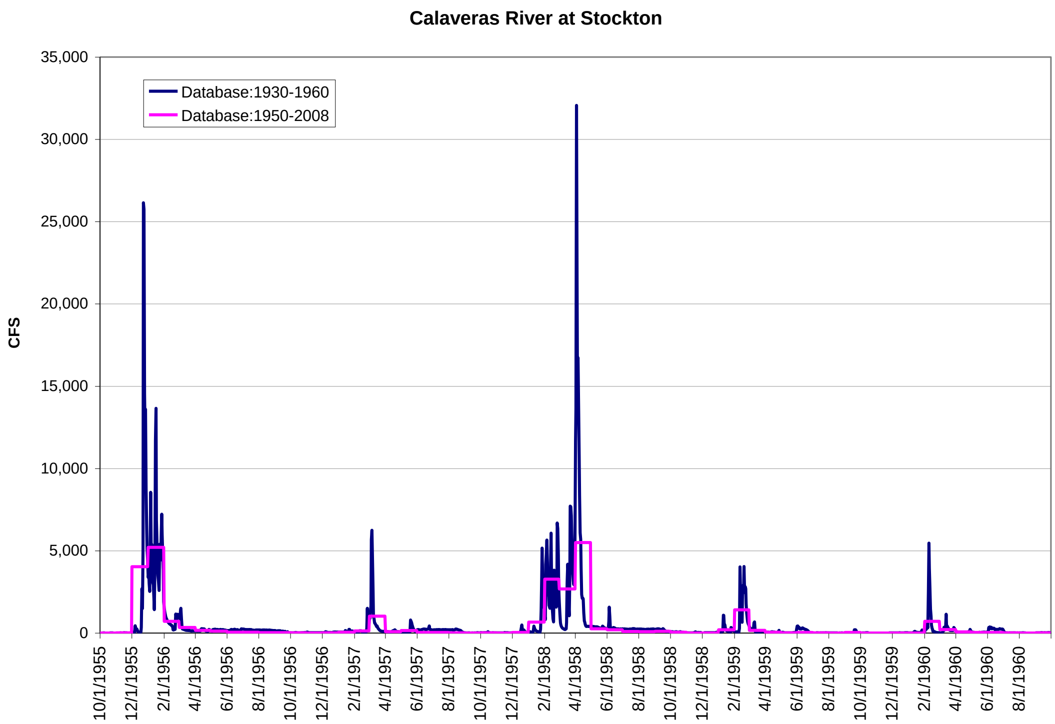

Figure 4: Calaveras River flow from 1930-1960 DAYFLOW and QMISC daily flow from the Current DAYFLOW Datasets