APPENDIX B

DEPARTMENT OF WATER RESOURCES TECHNICAL MEMO

Study 30 – CalSim II Model with 50% unimpaired flow instream flow requirements

TECHNICAL MEMO

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FROM:	Chen, Richard (ZhiQiang)@DWR	**SUBJECT:**	Study 30 – CalSim II Model with 50% unimpaired flow instream flow requirements

1. Introduction

The State Water Resources Control Board (SWRCB) is evaluating the impacts of imposing a new set of instream flow requirements (IFRs) in terms of a percentage of unimpaired flow (%UF) at stream reaches in the Sacramento Valley for use in the update of the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). The SWRCB staff developed a set of model assumptions and the study design for three scenarios of IFRs (25%UF, 50%UF and 75%UF) and with various demand and settlement contract reductions. The Department of Water Resources (DWR) modelers were enlisted as technical support staff to apply these assumptions and study design to the CalSim II model. DWR participation was limited to hydrology input changes, model code changes, and model execution under the direction of SWRCB staff and they had no part in decisions related to development of the study design and assumptions, the new set of IFRs, or selection of the %UF values. This memorandum (memo) describes the updates and changes made to CalSim II in this modeling exercise and explains the main assumptions and logics used in the modeling.

All those models are developed based on the State Water Project Delivery Capability Report 2015 Base scenario CalSim II model (hereafter referred as DCR2015 Base Model). This DCR2015 Base Model is a CalSim II model for existing condition without climate change and it is labeled as "1_DRC2015_Base_ExistingNoCC". The detailed discussion of model assumptions for the DCR2015 Base Model can be found in the 2015 DCR at http://baydeltaoffice.water.ca.gov/modeling/hydrology/CalSim/Downloads/CalSimDownloads/CalSim-IIStudies/SWPCapability2015/index.cfm

We use three scenario parameters, "UFRATIO", "DRPCNT", and "SCAPCNT" in the new %UF models to control how these CalSim models run for different IFR scenarios.

The scenario parameter "UFRATIO" is the percentage (ratio) of unimpaired flow required. The scenario parameter "DRPCNT" is percentage of demand reduction due to landuse changes in different water years. The scenario parameter "SCAPCNT" is the percentage reduction of additional settlement contract allocation. It also varies for different water years.

All the newly developed %UF models use almost identical WERSL codes as the DCR2015 Base Model except the three scenario parameters, UFRATIO, DRPCENT, and SCAPCENT, are assigned to different values for different studies.

The 0%UF model (00UF100DR) represents the existing condition with full demands and no additional allocation logical changes and it serves as the baseline for this study, where UFRATIO is equal to 0%, DRPCNT and SCAPCNT are equal to 1 for all water year types. The 0%UF model (00UF100DR) is technically almost the same as DRC2015 Base Model.

This memo documents the updates/changes made to the DCR2015 Base Model in order to implement the UF IFRs. It uses the 50% UF IFR (hereafter referred as Study 30) as an example to show the changes. Highlight of changes in Study 30 are:

- Value of UFRATIO is changed to 50%
- Values of DRPCNT are changed to 1.0, 1.0, 0.9, 0.8, 0.8 for wet, above normal, below normal, dry, and critical water year, respectively
- Values of SCAPCNT are changed to 1.0, 1.0, 0.75, 0.7, 0.65 for wet, above normal, below normal, dry, and critical water year, respectively

More detailed discussions of the updates/changes made in Study 30 are described in the following orders in the rest of this memo:

- Implementing %UF instream flow requirements
- Implementing demand reductions
- Implementing settlement contract allocation reductions
- Effect of reservoir operation and UF IFRs
- Updating WSI-DI curves
- Delta standards in Study 30
- Summary of modifications to CalSim II WERSL codes

2. Implementing %UF Instream Flow Requirements

The time series of unimpaired flow in a channel reaches (UFC) from the Sacramento Valley Unimpaired Flow Model (SVUFM) are used to construct the IFRs at the implementation locations. The instream flow requirement at an IFR implementation location can be expressed as

$$IFR = UFRatio*UFC. \qquad (1)$$

In order to impose the UF IFR at a CalSim II channel flow arc Cxxx, it is required that the stream flow at the channel arc should always be larger or equal to the instream flow requirement, i.e.,

$$\text{Cxxx} \geq \text{IFR} \quad (2)$$

However, there may not be enough water meet the IFR as specified in **Equation (2)** under some special circumstances. The model allows IFR violations (i.e. Cxxx < IFR) when upstream cannot release enough water to meet the IFR.

Depending on the upstream conditions of an IFR location, IFR locations are classified as one of the following three types:

TYPE#1 – operations of reservoirs and/or diversions between upstream rim inflows and the downstream IFR location are explicitly simulated in CalSim II. **Table 1a** lists all the locations where TYPE#1 IFR has been imposed.

TYPE#2 – operations of both reservoirs and diversions that locate upstream of the IFR location are not explicitly simulated in CalSim II. **Table 1b** lists all the locations where TYPE#2 IFR has been imposed.

TYPE#3 – operations of reservoirs that locate upstream of the IFR location are not explicitly simulated in CalSim II. But there are diversions arcs in CalSim II between the upstream rim inflow location and the IFR location. **Table 1c** lists all the locations where TYPE#3 IFR has been imposed.

For TYPE#1 IFR, the reservoirs upstream will release water for the IFR. Furthermore, the diversions upstream of the IFR location can also be reduced in order to have more water instream for the IFR. The reservoir release and the diversion reduction may not be enough for the IFR when the reservoirs reach their dead pools, when their release capabilities are limited, or when the diversion is too large. Therefore, the IFR specified in **Equation (2)** is imposed in CalSim II using soft constraint with a penalty for violation, which allows an IFR violation to occur when upstream cannot release enough water to meet the IFR. The following statements (i.e. WERSL codes) are an example of implementation of the TYPE#1 IFR at the confluence of American River and Sacramento River in the model:

```
define UFC303_AMR004 {timeseries kind 'Unimpaired-Flow' units 'CFS'}
define C303_UFIFRsv     {value UFC303_AMR004*UFRATIO}
define C303_UFIFR        {alias C303_UFIFRsv kind 'UFIFR' units 'CFS'}
goal set_UFC303_MIF     {lhs C303 rhs C303_UFIFRsv
                                   lhs>rhs  penalty 0
                                   lhs<rhs penalty UFPENALTY  }
define UFC303_SHORT {alias max(0, C303_UFIFRsv-C303)  kind 'UF-SHORT' units 'CFS'}
```

UFC303_AMR004 represents the unimpaired flow time series at the IFR location of the American River confluence, C303 represents the stream flow at the IFR location (Cxxx), and C303_UFIFRsv represent the IFR. As shown in the GOAL statement "set_UFC303_MIF", it uses a zero penalty for flows larger than the IFR and a very high penalty "UPPENALTY" for flows smaller than the IFR. The stream flow C303 is allowed to be smaller than the IFR and the IFR is not met when there is not enough water from the upstream to meet the IFR.

Relative magnitude of weights on reservoir storage arcs and penalty "UFPENALTY" control when reservoir storage water should be released to meet the IFR. Since "UFPENALTY" is larger than the weights on the active storage zone acres above the dead storage, the reservoir water is released from the active storage zones to meet the downstream IFRs when there are no other constraints present to limit the stream flow.

When there are diversion demands between the reservoirs and the IFR location, water released from the reservoirs are shared by the IFR and the diversion demand based on the relative magnitudes of "UFPENALTY" and the weight on diversion arc. Since "UFPENALTY" to violate the IFR is usually larger than the weigh on the demand, water release from the reservoir is used first to meet the IFR and then to meet the diversion demand. An IFR shortage (UFC303_SHORT), which is defined as the difference between the IFR and the actual stream flow at the IFR location, occurs when the IFR is not met.

Freeport and Chipps Island are the two locations where IFRs can be met by both CVP and SWP reservoirs. In such cases, the flow demands to meet the UF IFRs are treated as in-basin-uses based on the COA. Therefore, the release ratio of CVP and SWP reservoirs for meeting the UF IFR at these common locations should be 75%:25% as specified in COA.

For TYPE#2 IFR, we assume that the existing reservoirs and diversions upstream of the IFR have been operated to satisfy the IFR and the IFR **Equation (2)** is always satisfied. In order to satisfy the TYPE#2 IFR at the confluence, we force the upstream rim inflow to be the larger value of the original rim inflow value and the IFR value. The following statements are an example of implementation of the TYPE#2 IFR at the confluence of Paynes Creek and Sacramento River:

```
define UFC11001_PYN001 {timeseries kind 'Unimpaired-Flow' units 'CFS'}
define C11001_UFIFR   {alias UFC11001_PYN001*UFRATIO kind 'UFIFR' units 'cfs'}
define I11001_UFRUN  {alias max(I11001, C11001_UFIFR)
                          kind 'FLOW-INFLOW' units 'cfs'}
goal continuity11001    {lhs C11001 rhs I11001_UFRUN }
define UFI11001_PLUS {alias I11001_UFRUN - I11001 kind 'UFI-ADJUST' units 'CFS'}
```

UFC11001_PYN001 represents the unimpaired flow time series at the IFR location of the Paynes Creek confluence, which is the unimpaired flow at SVUFM node "PYN001". C11001 represents the stream flow at the IFR location (Cxxx). C11001_UFIFR represents the IFR. I11001 is the original rim inflow, I11001_UFRUN is the final modified rim inflow. As shown in the GOAL statement "continuity11001", the TYPE#2 IFR is imposed by assigning the final modified rim inflow (I11001_UFRUN) to the stream flow at the IFR location (C11001). This may result more water available at downstream with a higher percentage UF IFR run. When the IFR is larger than the original rim inflow, additional inflow (UFI11001_PLUS) is added to the stream system. We have only one source of water for the TYPE#2 IFR, i.e. the modified rim/local inflow. The modified rim inflow formulae of TYPE#2 IFR arcs and the associated additional inflow amounts are listed in **Table 2**.

For TYPE#3 IFR, we assume that the existing reservoirs upstream of the rim inflow location will be operated to meet the downstream IFR, and that the diversion between the upstream rim inflow location and the IFR location can also be reduced in order to have more water for the downstream IFR. Two steps are used to impose the TYPE#3 IFR in Study 30. First, we modify the upstream rim inflow similar to that of TYPE#2 IFR by forcing the rim inflow to be the larger value of the original rim inflow value and the downstream IFR value. This is equivalent to impose the downstream IFR at the rim inflow location. Second, we impose the downstream IFR with soft constraint similar to that of the TYPE#1 IFR at the downstream confluence.

Description of the physical locations along with model node IDs, where UF IFRs are imposed, and the source(s) of water used to meet these requirements at each location is given in **Table 1a, Table 1b, and Table 1c**.

IFR shortages occur in six locations where UF IFRs are implemented in Study 30, as shown in Figure 1. The detail months and magnitudes of the IFR shortages is given in the **Table 3**.

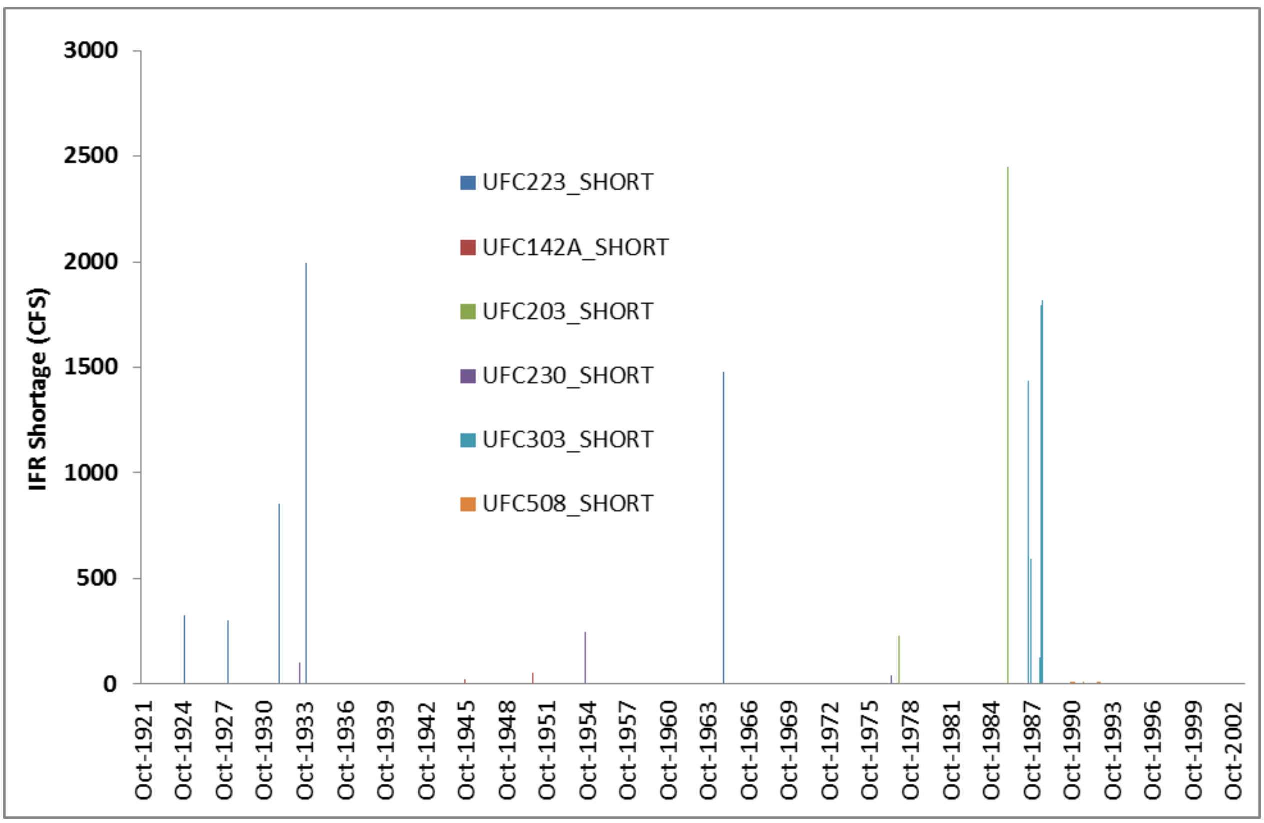


Figure 1 – Instream Flow Requirement (IFR) Shortage Occurrences in Study 30

Table 1a - List of Unimpaired Flow Locations Where TYPE#1 IFR is Imposed

No.	Location where IFR is imposed	CalSim II Arc Name	SVUFM Node ID	Source of water used to meet IFR	Source Flow ID's
1	Clear Creek Mouth at the Confluence w/ Sac. R.	C3	CLR009	Reservoir release from Whiskeytown, and Trinity import water	S3 & (I3, D100)
2	Sacramento River Downstream of Keswick Dam	C5	KSWCK	Shasta and Whiskeytown release, and Trinity import water	S4, S3 & (I4, I3, D100)
3	Sacramento River at Knights Landing	C134	SAC092	upstream reservoir release & tributary inflow return	S4, S3 & (upstream inflows and return)
4	Stony Creek confluence w/ Sac R	C142A	STN004	Reservoir release from East Park, Stony Gorge, and Black Butte	S40, S41, S42 & (I40, I41, I42)
5	Feather downstream Thermalito	C203	FTR059	Reservoir release from Oroville and Kelly Ridge Inflow	S6 & (I6, I200)
6	Feather River Mouth at the Confluence w/ Sac. R.	C223	FTR003	Oroville, other upstream reservoir releases, and tributary inflows	S6 & (I6, I200, I207, I230_UFRUN, I282_UFRUN, I285_UFRUN)
7	American River Mouth at the Confluence w/ Sac. R.	C303	AMR004	Reservoir release from Folsom and Natoma, local and import water	S8, S9 (I8, I9,I302)
8	Sacramento River at Freeport	C169	SAC049	Shasta, Oroville, Folsom, other upstream reservoir releases, and tributary inflows	S3, S4, S6, S8, S9 & (upstream inflows and return)
9	Calaveras River Mouth at the Confluence w/ San Joaquin R.	C508	CLV004	Reservoir Release from New Hogan Reservoir and Local Runoff	S92 (I506, I92)
10	Delta Outflow at Chipps	C406	SAC000	All reservoir storages, rim & local inflows, returns in Sac R. and San Joaquin R.	Too many to list

Table 1b - List of Unimpaired Flow Locations Where TYPE#2 IFR is Imposed

No.	Location Where IFR is Imposed	CalSim II Arc Name	SVUFM Node ID	Source Flow ID's
11	Cow Creek Mouth at the Confluence w/ Sac. R.	C10801	COW003	I10801_UFRUN
12	Cottonwood Creek Mouth at the Confluence w/ Sac. R.	C10802	CWD003	I10802_UFRUN
13	Battle Creek Mouth at the Confluence w/ Sac. R.	C10803	BTL006	I10803_UFRUN
14	Paynes Creek Mouth at the Confluence w/ Sac. R.	C11001	PYN001	I11001_UFRUN
15	Elder Creek Mouth at the Confluence w/ Sac. R.	C11303	ELD005	I11303_UFRUN
16	Thomes Creek Mouth at the Confluence w/ Sac. R.	C11304	THM005	I11304_UFRUN
17	Antelope Creek Mouth at the Confluence w/ Sac. R.	C11307	ANT010	I11307_UFRUN
18	Mill Creek Mouth at the Confluence w/ Sac. R.	C11308	MLC004	I11308_UFRUN
19	Deer Creek Mouth at the Confluence w/ Sac. R.	C11309	DRC005	I11309_UFRUN
20	Big Chico Creek Mouth at the Confluence w/ Sac. R.	C11501	BCC004	I11501_UFRUN
21	Butte Creek upstream C217A	I217	BTC007	I217_UFRUN
22	Butte Creek at Sutter Bypass	C217A	BTC007	I217_UFRUN
23	Yuba River Upstream C230	I230	YUB002	I230_UFRUN
24	Yuba River Mouth at the Confluence w/ Feather R.	C230	YUB002	I230_UFRUN
25	Bear River Local Inflow between mouth and CMPFW	I282	DHC001	I282_UFRUN
26	Downstream of Camp Far West Reservoir (Yuba River)	C285	CMPFW	I285_UFRUN
27	Cosumnes River Mouth at the Confluence w/ Moelumne R.	C501	CSM005	I501_UFRUN
28	Mokelumne River at the Confluence w/ Consumnes R.	I504_UFRUN	MOK022	I504_UFRUN

Table 1c - List of Unimpaired Flow Locations Where TYPE#3 IFR is Imposed

No.	Location Where IFR is Imposed	CalSim II Arc	SVUFM Node ID	Upstream Diversions	Source Flow ID's
1	Butte Creek at Sutter Bypass	C217A	BTC007	D217	I217_UFRUN
2	Yuba River Mouth at Confluence w/ Feather R.	C230	YUB002	D230	I230_UFRUN
3	Bear River Mouth at Confluence w/ Feather. R.	C282	BRR004	D283, D285	I282_UFRUN, I285_UFRUN
4	Combined Flow of Elder and Thomes Creeks at Confluences w/ Sacramento R.	C11301	N/A	D11301	I11303_UFRUN, I11304_UFRUN
5	Combined Flow of Antelope, Mill and Deer Creeks at Confluences w/ Sacramento R.	C11305	N/A	D11305	I11307_UFRUN, I11308_UFRUN, I11309_UFRUN

Table 2 – Formulae for Modified Inflows at TYPE#2 IFR Locations

New Inflow under %UF IFR	Original CalSim II rim inflow	New Inflow Formula for Study 30 (UFRATIO=50%)	Additional Rim Inflow (TAF/Y)	Location
I10801_UFRUN	I10801	max(I10801,0.5*UFC10801_COW003)	3.068	Cow Creek Mouth at Confluence w/ Sac. R.
I10803_UFRUN	I10802	max(I10803,0.5*UFC10803_BTL006)	2.656	Cottonwood Creek Mouth at Confluence w/ Sac. R.
I10802_UFRUN	I10803	max(I10802,0.5*UFC10802_CWD003)	0.061	Battle Creek Mouth at Confluence w/ Sac. R.
I11001_UFRUN	I11001	max(I11001,0.5*UFC11001_PYN001)	3.480	Paynes Creek Mouth at Confluence w/ Sac. R.
I11303_UFRUN	I11303	max(I11303,0.5*UFC11303_ELD005)	2.488	Elder Creek Mouth at Confluence w/ Sac. R.
I11304_UFRUN	I11304	max(I11304,0.5*UFC11304_THM005)	2.746	Thomes Creek Mouth at Confluence w/ Sac. R.
I11307_UFRUN	I11307	max(I11307,0.5*UFC11307_ANT010)	0.111	Antelope Creek Mouth at Confluence w/ Sac. R.
I11308_UFRUN	I11308	max(I11308,0.5*UFC11308_MLC004)	0.006	Mill Creek Mouth at Confluence w/ Sac. R.
I11309_UFRUN	I11309	max(I11309,0.5*UFC11309_DRC005)	0.000	Deer Creek Mouth at Confluence w/ Sac. R.
I11501_UFRUN	I11501	max(I11501,0.5*UFC11501_BCC004)	0.222	Big Chico Creek Mouth at Confluence w/ Sac. R.
I217_UFRUN	I217	max(I217,0.5*UFC217_BTC007)	0.000	Butte Creek upstream C217A
I230_UFRUN	I230	max(I230,0.5*UFC230_YUB002)	63.141	Yuba River Upstream C230
I282_UFRUN	I282	max(I282,0.5*(UFC282_BRR004 - UFC285_BRR_CMPFW))	19.665	Bear River Local Inflow between mouth and CMPFW
I285_UFRUN	I285	max(I285,0.5*UFC285_BRR_CMPFW)	24.436	Bear River Local Inflow between mouth and CMPFW
I501_UFRUN	I501	max(I501,0.5*UFC501_CSM005)	1.095	Cosumnes R. Mouth at Confluence w/ Moelumne R.
I504_UFRUN	I504	max(I504,0.5*UFC503_MOK022)	163.533	Mokelumne River at Confluence w/ Consumnes R.
Sac River Additional Rim Inflow Total			122.081	
Eastside Stream Additional Rim Inflow Total			164.628	

Table 3: List of Occurring Months and Magnitudes of IFR Shortage in Study 30

Location Where IFR is Imposed	Date at which IFR shortage occurs	IFR Shortage (CFS)
UFC203_SHORT	31-Dec-77	229.8
	28-Feb-86	2450.3
UFC223_SHORT	31-Dec-24	327.1
	29-Feb-28	305.0
	31-Dec-31	855.1
	31-Dec-33	1997.4
	31-Dec-64	1479.3
UFC142A_SHORT	30-Sep-24	1.7
	30-Nov-31	4.5
	31-Oct-45	21.5
	31-Oct-50	54.1
	30-Sep-77	2.6
	31-Oct-77	5.4
	30-Nov-77	5.6
	30-Nov-90	2.2
	31-Jan-91	1.1
UFC230_SHORT	30-Jun-33	100.0
	30-Sep-54	250.0
	30-Jun-77	44.3

Location Where IFR is Imposed	Date at which IFR shortage occurs	IFR Shortage (CFS)
UFC303_SHORT	31-May-70	0.1
	31-Jul-87	1434.0
	31-Aug-87	35.1
	31-Oct-87	593.3
	30-Jun-88	123.9
	31-Jul-88	1796.2
	31-Aug-88	1817.0
UFC508_SHORT	30-Sep-90	9.8
	31-Oct-90	10.9
	30-Nov-90	9.8
	31-Dec-90	8.0
	31-Jan-91	8.9
	30-Sep-91	9.7
	30-Sep-92	9.7
	31-Oct-92	8.1
	30-Nov-92	9.6

3. Implementing Demand Reductions

Study 30 uses DRPCNT to define the global water demand reduction factor, which varies with DWR 40-30-30 index for Sacramento Basin (wty_SAC) as shown in **Table 4**.

In CalSim II, the entire California is divided into study areas for planning purposes. The largest study areas consist of the ten Hydrologic Regions of the State's major drainage basins. The Central Valley is covered by four Hydrologic Regions: Sacramento, Sacramento-San Joaquin Delta, San Joaquin River, and Tulare Lake, which are further subdivided into a total of 55 Detailed Analysis Units (DAUs). However, the DAUs were too many to be handled by early computers which had limited capacity. In order to use those early computers to handle the complicated reservoir and river systems, the DAUs were combined to form fewer larger regions, termed Depletion Study Areas (DSAs) in CalSim II.

The CalSim II modeling domain of the Sacramento Valley floor is subdivided into 7 Depletion Study Areas (DSAs):

1. DSA58 – Upper Sacramento River Region
2. DSA65 – Yolo Bypass Region
3. DSA69 – Feather River Region
4. DSA70 – American River Region
5. DSA10 – Colusa Basin
6. DSA12 – Colusa Basin
7. DSA15 – Colusa Basin

Tehama-Colusa Canal and Glen-Colusa Canal deliver water to multiple DSAs in Colusa Basin (DSA10, 12, and DSA 15). A DSA might contain a large number of water users, all of whom hold different combinations of water rights, water contracts, and points of access to surface water. In order to deal with the complicated hydrology in Colusa Basin, the whole Colusa Basin region is subdivided into 13 small demand computational units (DCUs) as listed in **Table 5** as No. 5 to No. 17. All the 17 DCUs in the Sacramento Valley are subjected to demand reductions. DCUs No. 1 to No. 4 are the original DSA 58, DSA 65, DSA 69 and DSA 70.

We first modeled the water use hydrology of the whole Sacramento Valley floor in the 7 DSAs using the CU model and Excel spreadsheet tools and obtained several preprocessed time series, such as, accretion, depletion, diversion requirement (DR), and minimum groundwater pumping.

We also modeled the hydrology in Colusa Basin using the 13 smaller DCUs based on detailed land use and water use data, and obtained several preprocessed time series, such as, consumptive use of applied water (CUAW), minimum groundwater pumping, and contract diversion limit.

DR of a DSA is the total applied water needed to meet the demand in the DSA which is equal to the sum of surface diversion and groundwater pumping. CalSim II dynamically split each of the DRs in

DSA 58, DSA 65, DSA 69 and DSA 70 into surface diversion and groundwater pumping using their preprocessed DR time series and water availability in the system. The DR of a DSA can also be divided as its project (PJR) diversion requirement and its non-project (NP) diversion requirement. The project DR can be further divided into agriculture (AG) project demand, municipal and industrial (M&I) project demand, settlement contract (SC) demand and project water right (WR) demand.

Diversion simulation approach of Colusa Basin is different from that of DSA58, DSA65, DSA69, and DSA70. Surface diversions and groundwater pumping in Colusa Basin's DCUs are determined based the preprocessed time series of CUAW, minimum groundwater pumping, diversion contract, and water availability in the system.

Two water sources, surface water and ground water, are usually available to meet water demands in the Sacramento Valley. CalSim II assumes that the water demand in a DCU is met in the priority order of the minimum groundwater pumping, available surface water in the stream, and groundwater pumping. If the minimum groundwater pumping is higher than the water demand, no surface water diversion is needed. If the minimum groundwater pumping and the available surface water in the stream are not enough to meet the demand, more pumping will be required. Basically, the water demand of a DCU is always met by the combination of surface water and groundwater if pumping is allowed in the DCU. Groundwater pumping is used to compensate the shortage of surface water in the Sacramento Valley.

In order to implement the demand reduction in CalSim II, we not only multiply the DRPCNT value to the DR input time series and the CUAW input time series, but also multiply it to other demand related input time series. This is because these demand related variables are not dynamically determine during the CalSim run, but they were preprocessed time series. We have applied the demand reduction on other demand related input values such as project contract, diversion target, rice decomposition diversion, return flow, return flow from rice decomposition, recharge from applied water, and minimum pumping.

For coding purposes, the value of DRPCNT is also assigned to the following variables for different DSAs and Refuges:

DSA 58
- DR58SPCNT – DSA 58 demand reduction factor for settlement contract demands
- DR58PCNT – DSA 58 demand reduction factor for other demands

DSA 70
- DR70SPCNT – DSA 70 demand reduction factor for settlement contract demands
- DR70PCNT – DSA 70 demand reduction factor for other demands

DSA 65
- DR65SPCNT – DSA 65 demand reduction factor for settlement contract demands
- DR65PCNT – DSA 65 demand reduction factor for other demands

DSA 69
- DR69SPCNT – DSA 69 demand reduction factor for settlement contract demands
- DR69PCNT – DSA 69 demand reduction factor for other demands
- DR69DPCNT – demand reduction factor for Rice decomposition

Colusa Basin (DSA 10, DSA 12, DSA 15)

CBDPCNT – demand reduction factor for Rice Decomposition
CBSPCNT – demand reduction factor for CVP SC demand
CBCPCNT – demand reduction factor for Other Contract
CBRPCNT – demand reduction factor for Refuge demand
CBNPCNT – demand reduction factor for Non project demand
CBPPCNT – demand reduction factor for Project demand
CBGPCNT – demand reduction factor for minimum groundwater reduction

Other Refuges

REFPCNT – Refuge demand reduction factor for Sutter Refuge, Gray Lodge, and Butte Sink Duck Clubs

Table 4 –Reduction Factor Values as Function of Water Year Type in Study 30

Reduction Factor (% of Baseline)	Sacramento Valley Water Year Index				
	W	AN	BN	D	C
DRPCNT	100	100	90	80	80
SCAPCNT	100	100	75	70	65

Table 5 – List of Demand Computational Units (DCU)

No	DCU	Geographic Location	Groundwater Sources	Surface Sources
1	DSA58	Upper Sac River	GP60	Upper Sac River
2	DSA65	Yolo Bypass	GP64	Yolo Bypass, Putah Cr, and Cache Cr.
3	DSA69	Feather River	GP65	Feather River, Yuba River, and Bear River
4	DSA70	American River	GP66	American River and Import from Yuba/Bear
5	DCU17101	Colusa Basin	GP17101	Corning Canal (Sac River)
6	DCU17201	Colusa Basin	GP17201	Tehama-Colusa Canal (Sac River)
7	DCU17302	Colusa Basin	GP17302	Stony Creek
8	DCU17401	Colusa Basin	GP17401	Tehama-Colusa Canal (Sac River)
9	DCU17801	Colusa Basin	GP17801	Tehama-Colusa Canal (Sac River)
10	DCU11302	Colusa Basin	GP11302	Sac River, Elder Cr., and Thomas Cr.
11	DCU11306	Colusa Basin	GP11306	Sac River, Antelope Cr., Mill Cr., and Dear Cr.
12	DCU14301	Colusa Basin	GP14301	Sac River, Glenn-Colusa Canal, CBD
13	DCU14302	Colusa Basin	GP14302	Glenn-Colusa Canal (Sac River)
14	DCU14501	Colusa Basin	GP14501	Glenn-Colusa Canal (Sac River), CBD
15	DCU18201	Colusa Basin	GP18201	Glenn-Colusa Canal (Sac River), CBD
16	DCU18301	Colusa Basin	GP18301	Sac River, and CBD
17	DCU131	Colusa Basin	GP131	Sac River

4. Implementing Settlement Contract Allocation Reductions

The target delivery amount to a contractor in a water year is often less than the full contract amount. The ratio of the target delivery amount and the full contract demand is called “allocation”. Allocation of CVP and SWP water for a given year depends mainly on forecasted inflows, reservoir storage, projected carryover storage requirements, and in-basin and Delta regulatory requirements. The allocation factors perdel_cvpsc_sys and perdel_swp_fsc are used to represent the normal allocations for CVP settlement contractors and SWP settlement contractors, respectively.

When we apply the demand reduction factor DRPCNT, both demand and associated contract amounts are reduced. The new full contract is equal to the original full contract amount multiplied by DRPCNT.

Table 6a lists the Sacramento Valley settlement contractors who were subjected to the settlement contract allocations in CalSim II. **Table 6b** lists the diversion arcs in the Feather River Service Area (FRSA) and the associated annual contract quantities in normal years (100%) and deficiency years (50%) based on Oroville criteria (perdel_swp_fsc). **Table 6c** lists the CVP diversion arcs and the associated annual contract quantities in normal years (100%) and deficiency years (75%) based on Shasta criteria (perdel_cvpsc_sys).

In order to achieve additional diversion reduction on the settlement contractors, we use the settlement contract allocation reduction factor “SCAPCNT” to gain additional diversion reduction beyond the normal allocation. Settlement contract allocation reduction is implemented in CalSim II by multiplying SCAPCNT to both CVP and SWP settlement contract allocation factors, perdel_cvpsc_sys and perdel_swp_fsc. Both DRPCNT and SCAPCNT are applied to the settlement contractors. SCAPCNT varies with DWR 40-30-30 index for Sacramento Basin (wty_SAC) as shown in **Table 4**.

For critical dry water years (C) in Sacramento Valley, an additional 35% allocation reduction was applied to settlement contracts of CVP and SWP by multiplying 0.65 to the two allocation factors, perdel_cvpsc_sys and perdel_swp_fsc.

For dry water years (D), an additional 30% allocation reduction was applied to settlement contracts of CVP and SWP by multiplying 0.70 to the two allocation factors, perdel_cvpsc_sys and perdel_swp_fsc.

For below normal water years (BN), an additional 25% allocation reduction was applied to settlement contracts of CVP and SWP by multiplying 0.75 to the two allocation factors, perdel_cvpsc_sys and perdel_swp_fsc.

For wet water years (W) and above normal water years (AN), there is no additional allocation reduction on settlement contracts since by multiplying 1.0 to the two allocation factors, perdel_cvpsc_sys and perdel_swp_fsc, does not change their values.

Table 7a and Table 7b provide example calculations which show how the two types of reduction factors work for the Settlement Contract diversion D104_PSC in DSA 58 in Study 30 (Alt:50UF_NewWSIDI) and the baseline (Base:00UF100DR).

A water year begins in October and ends in September, as shown in Col#2 and so does the Sacramento Valley water year index (SACindex) in Col#3. The month-by-month DWR 40-30-30 index for Sacramento Basin (wty_SAC) in Col#4 is different from SACindex. The index value of wty_SAC starts to change in February each year. This month-by-month water year type table is constructed based the annual SACindex in wytypes.table and wytypes.wresl in CalSim II. The DR reduction percentage (DRPCNT) and the additional settlement contract allocation reduction percentage (SCAPCNT) varies based the wty_SAC index, as shown in Col#5 and Col#6, respectively.

The initial CVP SC Allocation values (perdel_psc_sysdv) before applying SCAPCNT are listed in Col#7. The final CVP SC Allocation perdel_psc_sysdv were obtained by multiplying SCAPCNT to the initial CVP SC allocation values in Col#8. The original CVP SC Demand values (dem_d104_psc) before applying DRPCNT are listed in Col#9. The final demand dem_d104_psc values in Col#10 were obtained by multiplying DRPCNT in Col#5 to the original CVP SC Demand values in Col#9.

The model calculated the delivery target value for d104_psc in Col#11A by multiplying the final CVP SC allocation in Col#8 to the final SC demand in Col#10.

This targeted diversion and all other targeted diversions in system will be met with available surface water in the system based on priority and location of the diversion. The final diversion values (d104_psc) are listed in Col#11, and the shortages are listed in Col#12.

If there is enough water to meet this targeted diversion in Col#11, the final diversion value of d104_psc will be equal to the target value, and there is no shortage. For example, shortage is zero during Feb-1923 to Feb-1925 as shown in **Table 7b**. Otherwise, shortages will occur and more groundwater pumping will be used to compensate the shortages. As shown in **Table 7a,** same amounts of shortage occurred both in Study 30 and the base study from May 1941 to September 1941, and different amounts of shortage occurred in Study 30 and the base study from Apr 2000 to September 2000.

The water in the active zones of the upstream reservoirs is usually available to the settlement contractors unless there are release capability limitation and other regulatory constraints. Water users upstream or downstream may have priority over the settlement contractors depending on weights/penalty associated with the relevant diversion arcs. For example, the downstream IFR at Knights Landing (C137) needs to be met first before diversions to settlement contractors in DSA58 (D104_psc) are allowed since the IFR has a higher penalty (UFPENALTY = 99999 vs Weight on D104_PRJ = 5000).

There are also contractors who are also subjected to the settlement contract allocation, and are the CVP service contractors diverting water from TC canal in Corning WD, Proberta WD and Thomes

Creek WD, Kirkwood WD, Glide WD, Kanawha WD, Orland-Artois WD, Colusa County, Davis WD, Dunnigan WD, La Crande WD, Westside WD. They have annual contracts of 318.7 TAF.

Table 6a –Settlement Contractors Subjected to the Settlement Contract Allocation Reductions

Settlement Contractor	Diversion Arc	CalSim II Input Time Series Subject to SC Allocation Reduction	DCU	Water Supply Source
Western Canal WD	D7A	dem_D7A_PAG	DSA69	SWP
Joint WD Board	D7B	dem_D7B_PAG	DSA69	SWP
Feather WD	D206A	dem_D206A_PAG	DSA69	SWP
Garden Highway MWC	D206B	dem_D206B_PAG	DSA69	SWP
Oswald WD	D206B	dem_D206B_PAG	DSA69	SWP
Joint WD Board	D206B	dem_D206B_PAG	DSA69	SWP
Plumas MWC	D206C	dem_D206C_PAG	DSA69	SWP
Tudor MWC	D206C	dem_D206C_PAG	DSA69	SWP
Anderson Cottonwood ID	D104	dem_D104_PSC	DSA58	CVP
Sac R. Misc Users	D104	dem_D104_PSC	DSA58	CVP
Redding, City of	D104	dem_D104_PSC	DSA58	CVP
Sac R. Misc Users (Right Bank)	D163	dem_D163_PSC	DSA65	CVP
City of West Sacramento	D165	dem_D165_PSC	DSA65	CVP
Sac R. Misc Users	D162A	dem_D162A_PSC	DSA70	CVP
Natomas Central MWC	D162B	dem_D162B_PSC	DSA70	CVP
Pleasant Grove-Verona MWC	D162C	dem_D162C_PSC	DSA70	CVP
Glenn Colusa ID	D143A	con_114GCID	DCU14301	CVP
	D145A	con_114GCID	DCU14501	CVP
Colusa Drain M.W.C.	D180	con_14301SC	DCU14301	CVP
Colusa Drain M.W.C.	D182A/ D18302	con_14501SC	DCU14501	CVP
Princeton-Cordova-Glenn ID	D122A	con_14301SC	DCU14301	CVP
Provident ID	D122A	con_14301SC	DCU14301	CVP
Maxwell ID	D122A	con_14301SC	DCU14301	CVP
Maxwell ID	D122B	con_14501SC	DCU14501	CVP
Sycamore Family Trust	D122B	con_14501SC	DCU14501	CVP
Roberts Ditch IC	D122B	con_14501SC	DCU14501	CVP
Sac R. Misc Users	D122A	con_14301SC	DCU14501	CVP
Sac R. Misc Users	D122B	con_14501SC	DCU14501	CVP
Reclamation District 108	D122B	con_14501SC	DCU14501	CVP
	D129A	con_18301SC	DCU18301	CVP
River Garden Farms	D129A	con_18301SC	DCU18301	CVP

Settlement Contractor	Diversion Arc	CalSim II Input Time Series Subject to SC Allocation Reduction	DCU	Water Supply Source
Sac R. Misc Users	D129A	con_18301SC	DCU18301	CVP
	D128	con_131SC	DCU131	CVP
Meridian Farms WC	D128	con_131SC	DCU131	CVP
Pelger Mutual WC	D128	con_131SC	DCU131	CVP
Reclamation District 1004	D128	con_131SC	DCU131	CVP
Carter MWC	D128	con_131SC	DCU131	CVP
Sutter MWC	D128	con_131SC	DCU131	CVP
Tisdale Irrigation & Drainage Co.	D128	con_131SC	DCU131	CVP

Table 6b – FRSA Diversion Arcs and Associated Annual Contract Quantities

Diversion Arc	Annual Contract Quantity (TAF/yr)		Monthly Contract Time Series	Demand Computational Unit (DCU)	Water Supply Source
	Normal	Deficiency			
	100%	50%			
D7A	150.0	75.0	dem_D7A_PAG	DSA69	SWP
D7B	550.0	275.0	dem_D7B_PAG		
D206A	17.0	8.5	dem_D206A_PAG		
D206B	65.7	32.9	dem_D206B_PAG		
D206C	13.09	6.55	dem_D206C_PAG		

Table 6c – CVP Diversion Arcs and Associated Annual Contract Quantities

Diversion Arc	Annual Contract Quantity (TAF/yr)		Monthly Contract Time Series	Demand Computational Unit (DCU)	Water Supply Source
	Normal	Deficiency			
	100%	**75%**			
D104	152.4	114.3	dem_D104_PSC	DSA58	CVP
D163	56.8	42.6	dem_D163_PSC	DSA65	CVP
D165	23.6	17.7	dem_D165_PSC		
D162A	4.8	3.6	dem_D162A_PSC	DSA70	CVP
D162B	120.2	90.2	dem_D162B_PSC		
D162C	26.3	19.7	dem_D162C_PSC		
D143A	441.5	331.1	con_114GCID	DCU14301	CVP
D180	7.7	5.8	con_14301SC		
D122A	129.2	96.9	con_14301SC		
D145A	383.5	287.6	con_114GCID	DCU14501	CVP
D182A/ D18302	62.3	46.7	con_14501SC		
D122B	74.9	56.1	con_14501SC		
D129A	249.8	187.4	con_18301SC	DCU18301	CVP
D128	459.3	344.5	con_131SC	DCU131	CVP
D171	32.9	24.7	con_171_pag	DCU17101	CVP
D172	2.1	1.6	con_172_pag	DCU17201	CVP
D174	108.5	81.4	con_174_pag	DCU17401	CVP
D178	175.2	131.4	con_178_pag	DCU17801	CVP

Table 7a –Calculation Example of Settlement Contract Diversion D104_PSC (WY1941 and WY 2000)

				Alt:50UF_NewWSIDI									Base:00UF100DR								
#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11A	#11	#12	#5	#6	#7	#8	#9	#10	#11A	#11	#12
Date	**WY**	**SACindex**	**wyt_SAC**	**DRPCNT**	**SCAPCNT**	**Initial CVP SC Allocation (perdel_psc_sysdv)**	**Final CVP SC Allocation (perdel_psc_sysdv*SCAPCNT)**	**Original Demand (dem_d104_psc)**	**Final Demand (dem_d104_psc*DRPCNT)**	**Final Delivery Target (Target_d104_psc)**	**Final Diversion (d104_psc)**	**Shortage (short_d104_psc)**	**DRPCNT**	**SCAPCNT**	**Initial CVP SC Allocation (perdel_psc_sysdv)**	**Final CVP SC Allocation (perdel_psc_sysdv*SCAPCNT)**	**Original Demand (dem_d104_psc)**	**Final Demand (dem_d104_psc*DRPCNT)**	**Final Delivery Target (Target_d104_psc)**	**Final Diversion (d104_psc)**	**Shortage (short_d104_psc)**
Oct-1940	1941	1	2	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Nov-1940	1941	1	2	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Dec-1940	1941	1	2	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Jan-1941	1941	1	2	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Feb-1941	1941	1	1	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Mar-1941	1941	1	1	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Apr-1941	1941	1	1	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
May-1941	1941	1	1	100%	100%	1.0000	1.0000	11.52	11.52	11.52	10.91	0.61	100%	100%	1.0000	1.0000	11.52	11.52	11.52	10.91	0.61
Jun-1941	1941	1	1	100%	100%	1.0000	1.0000	32.98	32.98	32.98	31.16	1.82	100%	100%	1.0000	1.0000	32.98	32.98	32.98	31.16	1.82
Jul-1941	1941	1	1	100%	100%	1.0000	1.0000	40.94	40.94	40.94	38.19	2.75	100%	100%	1.0000	1.0000	40.94	40.94	40.94	38.19	2.75
Aug-1941	1941	1	1	100%	100%	1.0000	1.0000	36.63	36.63	36.63	34.38	2.26	100%	100%	1.0000	1.0000	36.63	36.63	36.63	34.38	2.26
Sep-1941	1941	1	1	100%	100%	1.0000	1.0000	27.36	27.36	27.36	25.94	1.42	100%	100%	1.0000	1.0000	27.36	27.36	27.36	25.94	1.42
Oct-1999	2000	2	1	100%	100%	1.0000	1.0000	8.66	8.66	8.66	8.66	0	100%	100%	1.0000	1.0000	8.66	8.66	8.66	8.66	0
Nov-1999	2000	2	1	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Dec-1999	2000	2	1	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Jan-2000	2000	2	1	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Feb-2000	2000	2	2	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Mar-2000	2000	2	2	100%	100%	1.0000	1.0000	0	0	0.00	0	0	100%	100%	1.0000	1.0000	0	0	0.00	0	0
Apr-2000	2000	2	2	100%	100%	1.0000	1.0000	4.5	4.5	4.50	4.34	0.16	100%	100%	1.0000	1.0000	4.5	4.5	4.50	4.24	0.26
May-2000	2000	2	2	100%	100%	1.0000	1.0000	25.11	25.11	25.11	24.36	0.75	100%	100%	1.0000	1.0000	25.11	25.11	25.11	23.82	1.29
Jun-2000	2000	2	2	100%	100%	1.0000	1.0000	31.57	31.57	31.57	30.65	0.92	100%	100%	1.0000	1.0000	31.57	31.57	31.57	29.96	1.61
Jul-2000	2000	2	2	100%	100%	1.0000	1.0000	38.04	38.04	38.04	36.51	1.53	100%	100%	1.0000	1.0000	38.04	38.04	38.04	35.68	2.36
Aug-2000	2000	2	2	100%	100%	1.0000	1.0000	36.44	36.44	36.44	35.00	1.44	100%	100%	1.0000	1.0000	36.44	36.44	36.44	34.21	2.23
Sep-2000	2000	2	2	100%	100%	1.0000	1.0000	16.77	16.77	16.77	16.26	0.51	100%	100%	1.0000	1.0000	16.77	16.77	16.77	15.90	0.87

Table 7b – Calculation Example of Settlement Contract Diversion D104_PSC (2/1923~2/1925)

				Alt:50UF_NewWSIDI									Base:00UF100DR								
#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11A	#11	#12	#5	#6	#7	#8	#9	#10	#11A	#11	#12
Date	WY	SACindex	wyt_SAC	DRPCNT	SCAPCNT	Initial CVP SC Allocation (perdel_psc_sysdv)	Final CVP SC Allocation (perdel_psc_sysdv*SCAPCNT)	Original Demand (dem_d104_psc)	Final Demand (dem_d104_psc*DRPCNT)	Final Delivery Target (Target_d104_psc)	Final Diversion (d104_psc)	Shortage (short_d104_psc)	DRPCNT	SCAPCNT	Initial CVP SC Allocation (perdel_psc_sysdv)	Final CVP SC Allocation (perdel_psc_sysdv*SCAPCNT)	Original Demand (dem_d104_psc)	Final Demand (dem_d104_psc*DRPCNT)	Final Delivery Target (Target_d104_psc)	Final Diversion (d104_psc)	Shortage (short_d104_psc)
Feb-1923	1923	3	3	90%	75%	1.0000	0.7500	0.00	0.00	0.00	0.00	0	100%	100%	1.0000	1.0000	0.00	0.00	0.00	0.00	0
Mar-1923	1923	3	3	90%	75%	1.0000	0.7500	10.84	9.76	7.32	7.32	0	100%	100%	1.0000	1.0000	10.84	10.84	10.84	10.84	0
Apr-1923	1923	3	3	90%	75%	1.0000	0.7500	2.45	2.21	1.65	1.65	0	100%	100%	1.0000	1.0000	2.45	2.45	2.45	2.45	0
May-1923	1923	3	3	90%	75%	1.0000	0.7500	27.63	24.87	18.65	18.65	0	100%	100%	1.0000	1.0000	27.63	27.63	27.63	27.63	0
Jun-1923	1923	3	3	90%	75%	1.0000	0.7500	23.00	20.70	15.53	15.53	0	100%	100%	1.0000	1.0000	23.00	23.00	23.00	23.00	0
Jul-1923	1923	3	3	90%	75%	1.0000	0.7500	38.22	34.40	25.80	25.80	0	100%	100%	1.0000	1.0000	38.22	38.22	38.22	38.22	0
Aug-1923	1923	3	3	90%	75%	1.0000	0.7500	33.67	30.30	22.73	22.73	0	100%	100%	1.0000	1.0000	33.67	33.67	33.67	33.67	0
Sep-1923	1923	3	3	90%	75%	1.0000	0.7500	7.35	6.61	4.96	4.96	0	100%	100%	1.0000	1.0000	7.35	7.35	7.35	7.35	0
Oct-1923	1924	5	3	90%	75%	1.0000	0.7500	7.35	6.61	4.96	4.96	0	100%	100%	1.0000	1.0000	7.35	7.35	7.35	7.35	0
Nov-1923	1924	5	3	90%	75%	1.0000	0.7500	1.92	1.73	1.30	1.30	0	100%	100%	1.0000	1.0000	1.92	1.92	1.92	1.92	0
Dec-1923	1924	5	3	90%	75%	1.0000	0.7500	0.00	0.00	0.00	0.00	0	100%	100%	1.0000	1.0000	0.00	0.00	0.00	0.00	0
Jan-1924	1924	5	3	90%	75%	1.0000	0.7500	0.00	0.00	0.00	0.00	0	100%	100%	1.0000	1.0000	0.00	0.00	0.00	0.00	0
Feb-1924	1924	5	5	80%	65%	1.0000	0.6500	0.00	0.00	0.00	0.00	0	100%	100%	1.0000	1.0000	0.00	0.00	0.00	0.00	0
Mar-1924	1924	5	5	80%	65%	0.7500	0.4875	2.82	2.26	1.10	1.10	0	100%	100%	0.7500	0.7500	2.82	2.82	2.11	2.11	0
Apr-1924	1924	5	5	80%	65%	0.7500	0.4875	21.58	17.26	8.42	8.42	0	100%	100%	0.7500	0.7500	21.58	21.58	16.18	16.19	0
May-1924	1924	5	5	80%	65%	0.7500	0.4875	23.98	19.18	9.35	9.35	0	100%	100%	0.7500	0.7500	23.98	23.98	17.98	17.99	0
Jun-1924	1924	5	5	80%	65%	0.7500	0.4875	27.35	21.88	10.67	10.67	0	100%	100%	0.7500	0.7500	27.35	27.35	20.51	20.51	0
Jul-1924	1924	5	5	80%	65%	0.7500	0.4875	30.03	24.02	11.71	11.71	0	100%	100%	0.7500	0.7500	30.03	30.03	22.52	22.52	0
Aug-1924	1924	5	5	80%	65%	0.7500	0.4875	25.98	20.78	10.13	10.13	0	100%	100%	0.7500	0.7500	25.98	25.98	19.48	19.48	0
Sep-1924	1924	5	5	80%	65%	0.7500	0.4875	20.69	16.55	8.07	8.07	0	100%	100%	0.7500	0.7500	20.69	20.69	15.52	15.52	0
Oct-1924	1925	4	5	80%	65%	0.7500	0.4875	0.00	0.00	0.00	0.00	0	100%	100%	0.7500	0.7500	0.00	0.00	0.00	0.00	0
Nov-1924	1925	4	5	80%	65%	0.7500	0.4875	0.00	0.00	0.00	0.00	0	100%	100%	0.7500	0.7500	0.00	0.00	0.00	0.00	0
Dec-1924	1925	4	5	80%	65%	0.7500	0.4875	0.00	0.00	0.00	0.00	0	100%	100%	0.7500	0.7500	0.00	0.00	0.00	0.00	0
Jan-1925	1925	4	5	80%	65%	0.7500	0.4875	0.00	0.00	0.00	0.00	0	100%	100%	0.7500	0.7500	0.00	0.00	0.00	0.00	0
Feb-1925	1925	4	4	80%	70%	0.7500	0.5250	0.00	0.00	0.00	0.00	0	100%	100%	0.7500	0.7500	0.00	0.00	0.00	0.00	0

5. Effect of Reservoir Operation and UF IFRs

In general each reservoir is divided into five zones representing operational volumes, which are dead pool, lower conservation pool, intermediate conservation pool, upper conservation pool, and flood control pool. Lake Oroville is divided into six storages zones for operational purposes, as shown in **Table 8**. It is noticed that L3, L4, L5, L6 have the same maximum value of 3538. This is because:

- L5 = L6 in May and Zone 6 (flood pool) is always zero.
- L4 = L6 in May and Zone 5 (Upper conservation pool) is always zero.
- L3 = L6 in May for some wet years such as 1938, 1982, and 1995 and Zone6, Zone5 and Zone 4 (Intermediate conservation pool) are all zero. In those months, Oroville is operating within the lower conservation pool with a top level of 3538.

A non-operational power zone is added for Oroville. Storage in each of the zones depends on the storage at the end of previous months, inflow and release. **Table 9** lists conditions or regulations that may control the release from Oroville in CalSim II.

The maximum reservoir release is determined by the hydraulic properties of the outlet works and may be expressed as a piece-wise linear function of storage. The release is determined based the demand of allocated downstream diversions, exports, minimum instream flow requirement, Delta water quality standards, inflow forecast, and the storage zone where the reservoir surface locates. **Figure 2** shows the comparison of Oroville's storage zones between Study 30 (Alt:N30_50UF) and the baseline (Base:00UF100DR). Some of the zones can be zero when its upper level is equal to its lower level. For example, Zone6 is zero for most of the time except January 1970 and January 1997. Zone5 is zero in from October through May in all years.

The top level of Oroville dead pool is Level 1 (=29.6TAF) as shown in **Table 8**. However, Oroville's physical constraints, such as the location of the power plant inlets, and release capacity of its outlets limit the release from Oroville when Oroville reaches its lower elevation and they act as a "functional dead pool":

1. When Oroville storage is greater than 1250 TAF, all 6 power units (1,3,5, and 2,4,6) are operational.
2. When Oroville storage is between 850 TAF and 1250 TAF, only 3 power units (1,3, 5) are operational.
3. When Oroville storage is between 29.6 TAF and 850 TAF, all power units are not operational, but water can be release from the bottom valves.
4. The reservoir storage-release curve can also limit the release when the storage at the end of previous month is small and the current month inflow is large.

Water is allowed to be released downstream to meet its downstream UF IFRs in the five zones above the dead zone when there is no physical constrain to limit the release capacity. However, no more water is released to meet the UF IFRs and other requirements when the release is limited by the physical release capacity of the reservoir (functional dead pool) which can occur at any of the five zones above the dead pool.

We define "short requirement" as when channel flow is less than the UF IFR value. There may be instances of "short requirement" when upstream cannot release more water even the reservoir is above the dead pool storage. For example, the release curve of the reservoir does not allow more water to be released even there are water available in the reservoir at the end of the month.

Table 8 – Lake Oroville Storage Level and Zone

Level	Level Range	Zone Name (Storage)	Comments
L6	3538	Zone6 (L6-L5)	Flood control pool with constant top level
L5	2787 ~ 3538	Zone5 (L5-L4)	Upper conservation pool with fixed time series of top level
L4	1000 ~ 3538	Zone4 (L4-L3)	Intermediate conservation pool with top level varied by operating rule
L3	852 ~ 3538	Zone3 (L3-L2)	Lower conservation pool with top level varied by operating rule
L2	852	Zone2 (L2-L1)	Non-operational power pool with constant top level
L1	29.6	Zone1 (≤ L1)	Dead pool with constant top level

Table 9 – Oroville Release Controls

Control Label	Description
Flood	Oroville Flood Conservation Release
O&T.DP	Oroville Functional Dead Pool and Thermalito Dead Pool
RC&T.DP	Reservoir Release Capacity and Thermalito Dead Pool
T.DP	Thermalito Dead Pool
T.DP&B. Min	Thermalito Dead Pool and Banks Minimum Export
B. Min	Banks minimum exports
FTR.mif	Minimum Flow at C223
THM.mif	Minimum Flow at C203
THM&FTR	Both THM and FTR control
FTR.uif	%UF IFR at C223 (Feather River Mouth)
THM.uif	%UF IFR at C203 (downstream Thermalito)
--	Other (such as UF IFR at Freeport)

Figure 2 – Comparison of Oroville Lake Storage Zones in Study 30 and Baseline

6. Updating WSI-DI Curves

Water Supply Index versus Demand Index (WSI-DI) curves relate forecasted water supplies to deliverable "demand," and then use deliverable "demand" to assign subsequent delivery levels to estimate the water available for delivery and carryover storage. Updates of delivery levels occur monthly from January 1 through May 1 for the SWP and March 1 through May 1 for the CVP as runoff forecasts become more certain.

The WSI-DI allocation method develops an allocation decision for system-wide CVP and SWP deliveries based on stored water, forecasts of usable inflow, and storage carryover targets. A new set of WSI-DI curves named "N30_50UF_NewWSIDI" were developed for Study 30 using the WSI-Di Generator in WRIMS2_GUI_x64_20160713, as shown in Figure 3. This WSI-Di Generator uses an iterative process to generate the WSI-DI curves. It starts with two initial curves for system-wide CVP and SWP deliveries. The WSI-DI curves in 2015 DCR base study were used as the initial curves. No other specific tuning was done to meet IFRs, balance Delta Exports and Reservoir Storages.

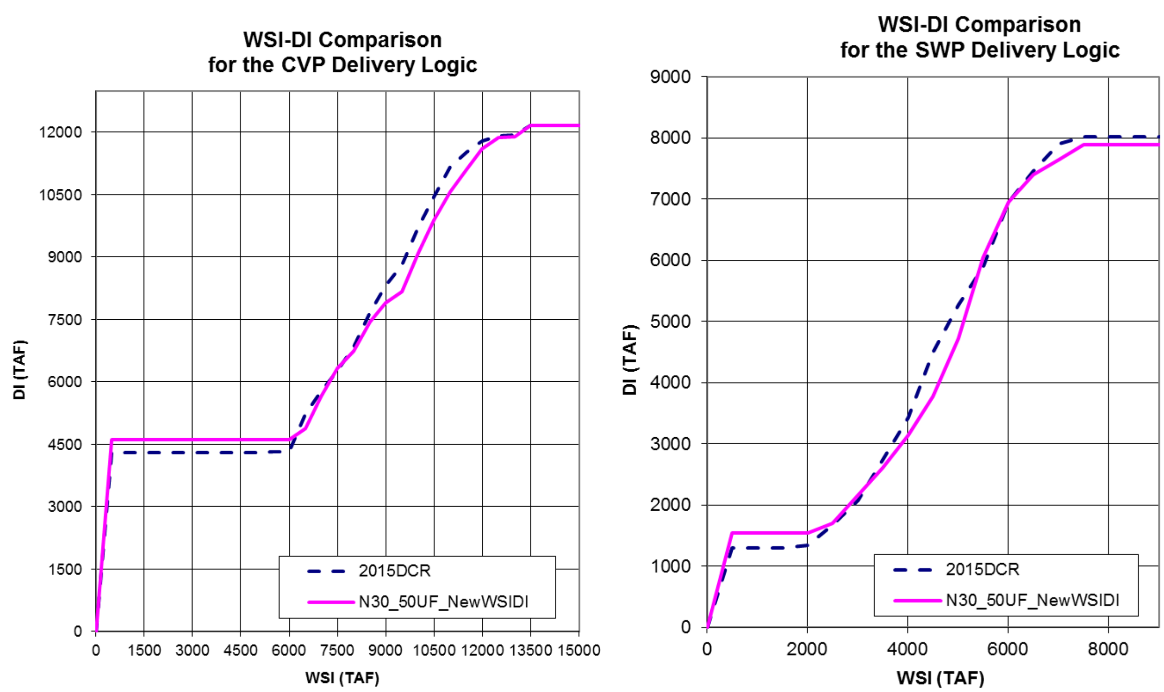


Figure 3 – WSI-DI Curves for Study 30

7. Delta Standards in Study 30

In Study 30, there are exceedances of the salinity standards at Rock Slough and Jersey Point: a total of 7 exceedances of the EC standards at Jersey Point in July, and a total of 19 exceedances of the EC standards at Rock Slough (2 in October, 3 in November, 7 in December, and 7 in January).

The following 8 Delta standards have been checked.

- Delta Cross Channel (DCC) gate operation
- Rio Vista Minimum Flow
- Minimum Net Delta Outflow
- Export-Inflow Ratio
- April & May maximum export (Vernalis Standard)
- Salinity Standards
- Old and Middle River
- X2

No other exceedance has been detected in the other 6 Delta Standards in the results of Study 30. The details of the checks are described in the following sections:

1) **DCC Gate Operation**
This standard defines the numbers of days that the DCC gates are open in each month. Study#30 uses DCC standard specified in the NMFS RPA Action 4.1.2. DCC operations under this RPA will always have no more days open than the D-1641 DCC standard, and in some months may have even fewer days open, as partially shown in Figure 4. There is no exceedance of DCC standard in Study#30 since the DCC gates strictly operated based on the standard in the model.

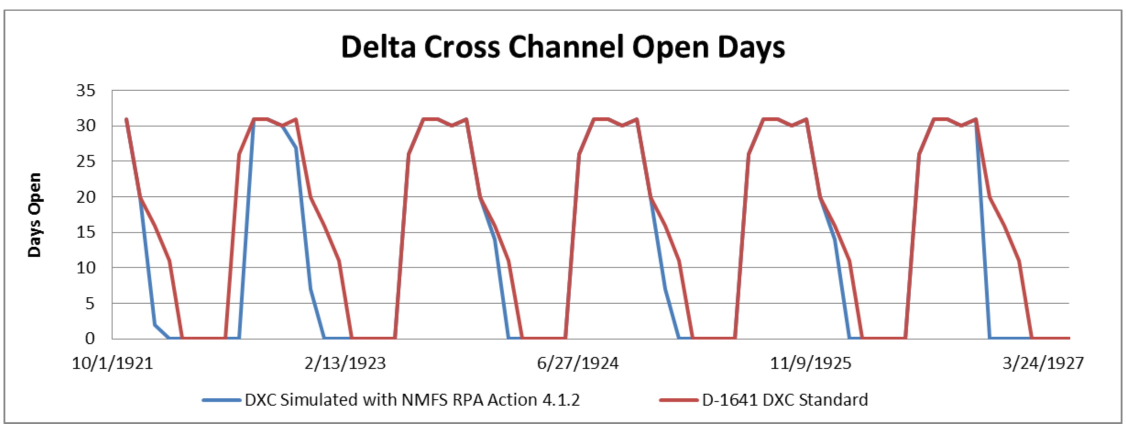


Figure 4 – Comparison of Delta Cross Channel Open Days Simulated in Study 30 and D-1652 DXC Standard

2) Rio Vista Minimum Flow

This standard defines Sacramento River Minimum Flow at Rio Vista. The Rio Vista flow is always higher than the Rio Vista minimum flow standard as partially shown in Figure 5. CVP and SWP were strictly operated with the standard using a hard constraint goal in Study#30. There is no exceedance of Rio Vista Minimum Flow standard in Study#30.

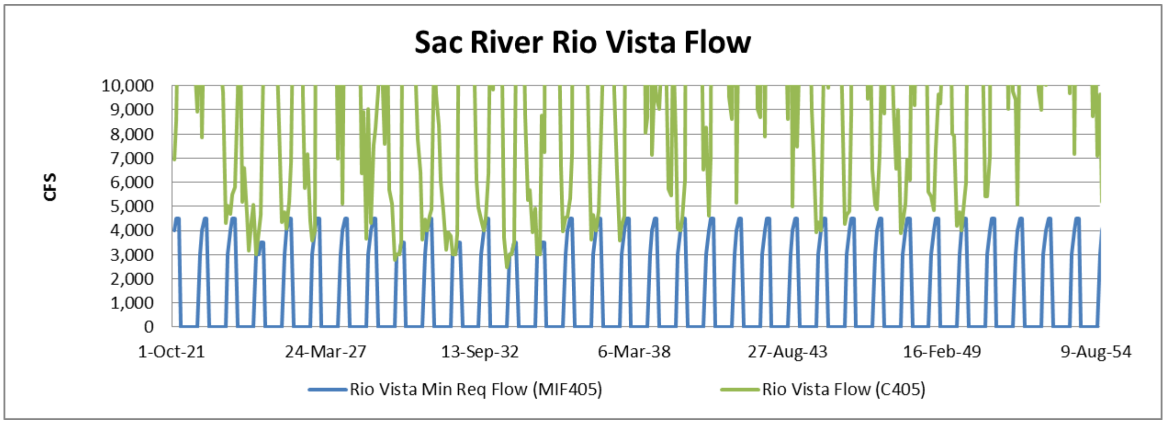


Figure 5 – Comparison of Simulated Flow (C405) and Minimum Instream Flow Required (MIF405) at Rio Vista in Study 30

3) Minimum Net Delta Outflow

This standard defines minimum outflows through the Delta. The flow standard varies depending on month, water year type, X2 required delta outflow, and other criteria as specified in D-1641. MRDO is the maximum value of Delta outflow requirements of all imposed Delta standards (Flow, Salinity and X2) computed by a DLL function in CalSim II. The simulated required Delta outflow (MRDO=D407) is always higher than the minimum net delta outflow standard (DO_REQ_FLOW_OUT) as partially shown in Figure 6.

CVP and SWP were strictly operated with the standard in Study#30. There is no exceedance of Minimum Net Delta Outflow standard in Study#30.

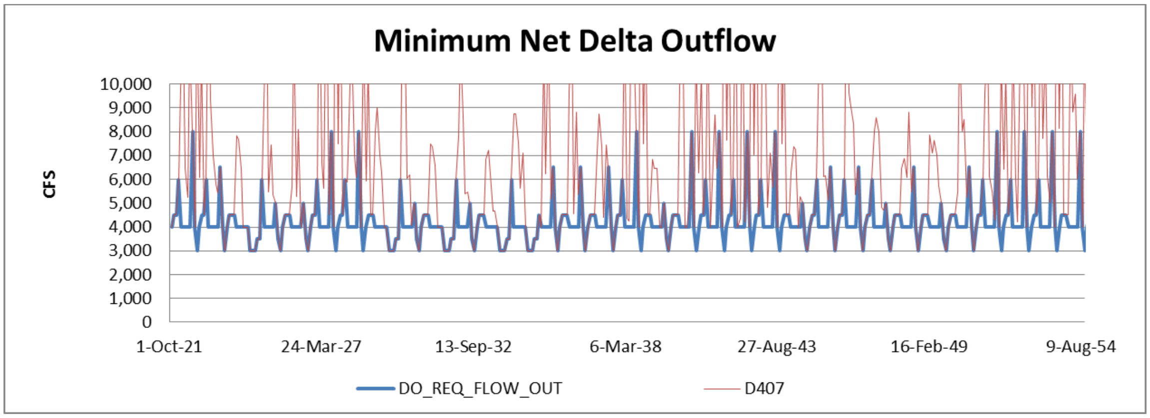


Figure 6 – Comparison of Minimum Net Delta Outflow and MRDO in Study 30

4) Export-Inflow Ratio

Export-Inflow Ratio Standard (D-1641) limits the combined exports of CVP and SWP to a specific proportion of total Delta inflow. A comparison between the Actual EI Ratio and the EI Ratio Standard is shown in Figure 7. Actual EI Ratio is defined as ExportActualTD/Inflow where ExportActualTD = (D418_TD +D419_TD +D408_P), and Inflow = (C400_ANN +D400B-I400 +C504 +C157 +C644 +C508 +I406). There is no exceedance of Export-Inflow Ratio since it is always met in Study#30.

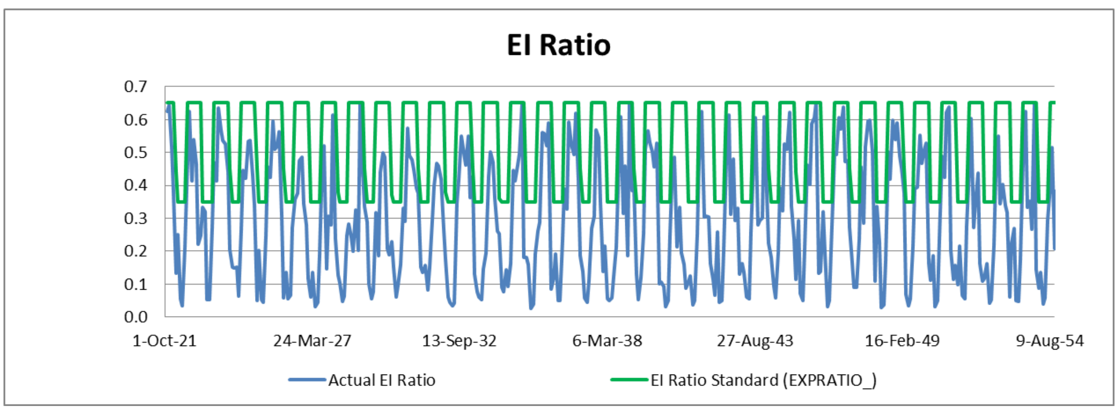


Figure 7 – Comparison of Simulated Actual EI Ratio and the EI Ratio Standard in Study 30

5) April & May Maximum Export (Vernalis Standard)

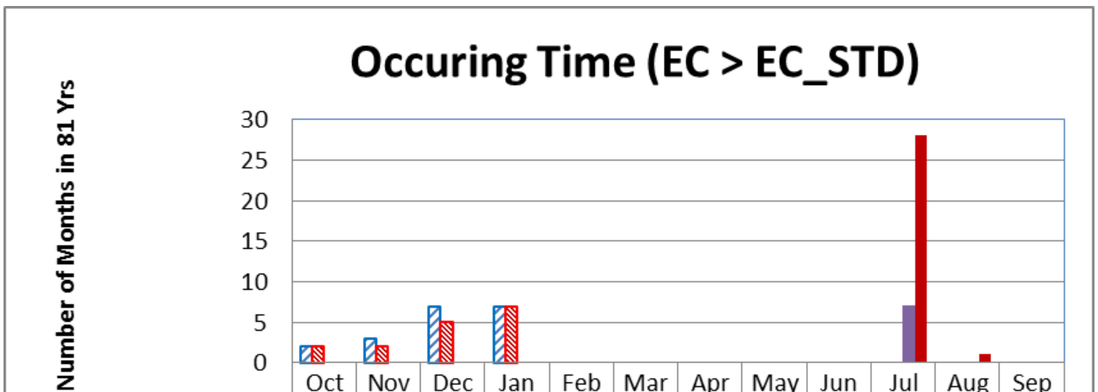
Vernalis standard (D-1641) limits the combined exports of CVP and SWP (ExportActualTD) to the maximum of 1500 cfs or San Joaquin River flow at Vernalis during the Apr 15-May 15 pulse period (AprMayExpCtrl). There is no exceedance of Vernalis Standard since it is always met in Study#30.

6) **Salinity Standards at Emmaton and Jersey Point (for agriculture), Rock Slough (for M&I), and Collinsville (for fish and wildlife).**

There is no exceedance in Collinsville (CO) and in Emmaton (EM). But, there are occurrences of (EC>EC_Standard) in Rock Slough (RS) and in Jersey Point (JP) which exceed the Salinity Standards, as shown in Figure 8.

At Jersey Point, a total of 7 EC values in July are higher than the EC standards in 81 years in Study 30 (Alt) with an average difference of 18.6 higher than the standards. In comparison, there are a total of 28 exceeding months in July in the base study (base) with an average difference of 22.2 higher than the standards. There is also an occurrence in August in the base study.

At Rock Slough, there are a total of 19 violating occurrences from October to January in Study 30 with an average difference of 38.6 higher than the standards. In comparison, there are a total of 16 exceeding occurrences from October to January in the base study an average difference of 48.8 higher than the standards.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Rock Slough (Alt)	2	3	7	7	0	0	0	0	0	0	0	0
Rock Slough (Base)	2	2	5	7	0	0	0	0	0	0	0	0
Jersey Point (Alt)	0	0	0	0	0	0	0	0	0	7	0	0
Jersey Point (Base)	0	0	0	0	0	0	0	0	0	28	1	0

Figure 8 – Comparison of Occurrences of EC Exceedances in Study 30 and Baseline

7) **Old and Middle River**

This OMR standard is a Biological Opinion Standard which limits CVP and SWP exports so that flow in the Old and Middle River is no more negative than a specified standard during Dec-June. For comparison, Figure 9 plots the actual OMR flow and the OMR Standard where their values in July to November have been set to zero for illustration purpose. There is no exceedance of OMR Standard since it is always met in Study#30 with the hard constraint goal: **C408 > C408_limit.**

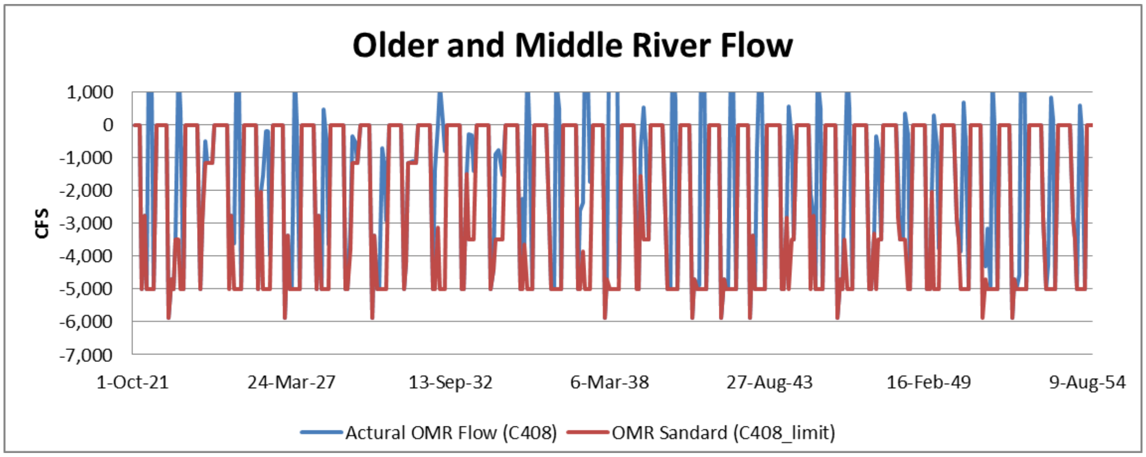
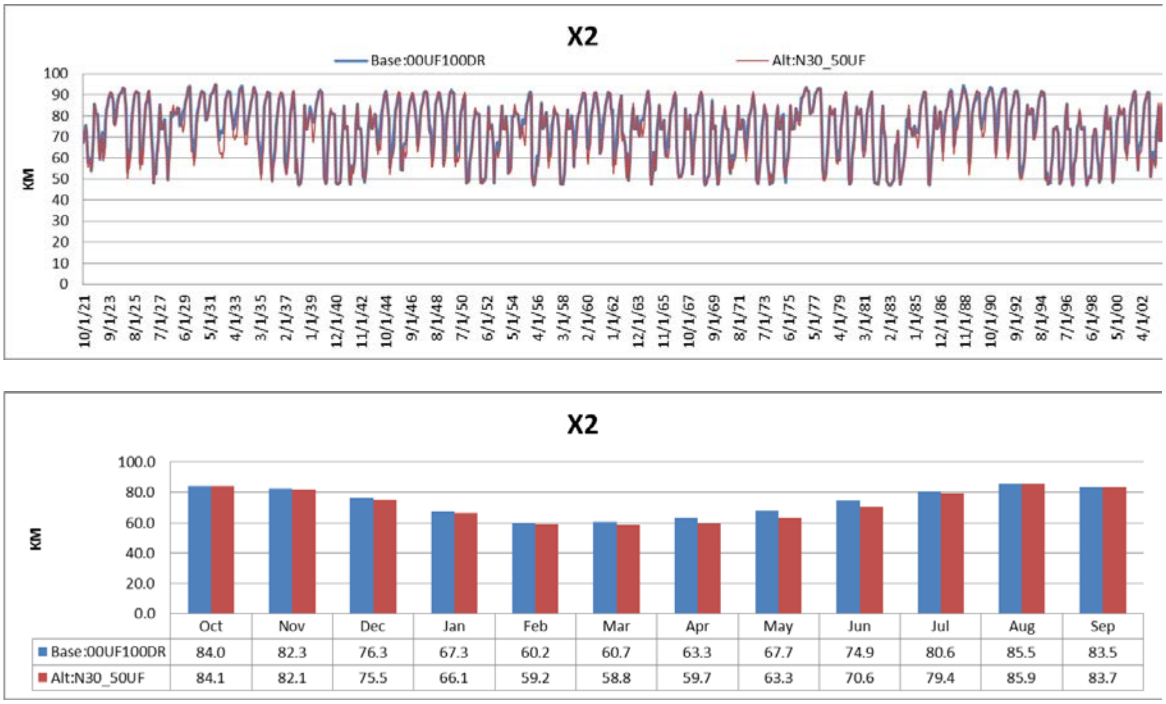


Figure 9 – Comparison of Simulated OMR Flow and OMR Standard in Study 30

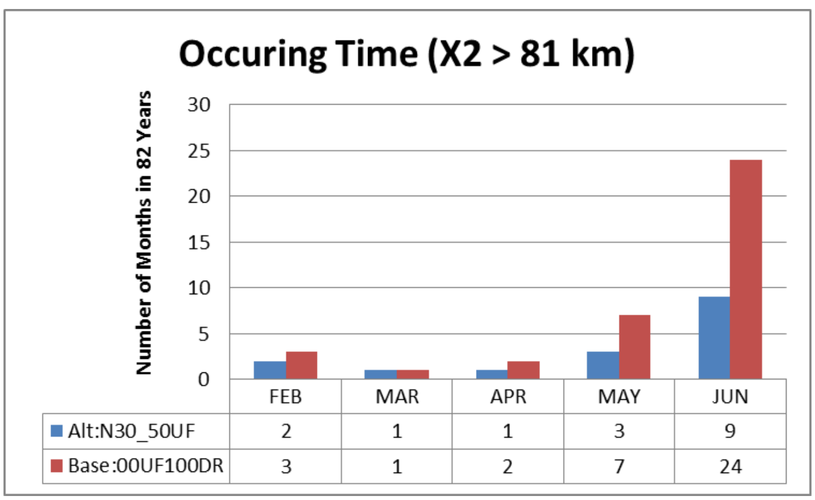
8) X2

There is no exceedance of X2 Standard since MDRO is always less than the Delta outflow at Chipps Island (C406). D-1641 mandates the X2 objectives which require that the X2 position must remain downstream of Collinsville (< 81 km) in the Delta for the entire 5-month period of February to June, and downstream of other specific locations in the Delta on a certain number of days each month from February through June. This means that Delta outflow must be at certain specified levels at certain times. On average, X2 increases in Aug to Oct, and X2 decreases other months when comparing X2 of Study 30 run (Alt) and that of the 2015 DCR run (Base) as shown in the plots of Figure 10. There are cases X2 > 81 km in February to June in both Study 30 and the baseline as shown in Figure 11. Those case occurs when the flow either larger the DO flow caps for each X2 stations (29200, 11400, 7100 cfs for Roe, Chipps, and Confluence, respectively), or when flow is less than 4000 cfs in May of dry years (Sac River Index is less than 8.1 maf). It is found that there are less occurrences of X2 > 81 km in Study 30. This is because there are higher Delta inflows under Study 30.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Base:00UF100DR	84.0	82.3	76.3	67.3	60.2	60.7	63.3	67.7	74.9	80.6	85.5	83.5
Alt:N30_50UF	84.1	82.1	75.5	66.1	59.2	58.8	59.7	63.3	70.6	79.4	85.9	83.7

Figure 10 – Comparison of X2 in Study 30 and Baseline



	FEB	MAR	APR	MAY	JUN
Alt:N30_50UF	2	1	1	3	9
Base:00UF100DR	3	1	2	7	24

Figure 11 – Comparison of Occurrences of X2 > 81 km in Study 30 and Baseline

8. Summary of Modifications to CalSim II WERSL Codes

In summary, the following changes have been made in Study 30 as compared to the DCR2015 Base Model:

1. Added unimpaired flow (UF) time series at selected IFR locations to the SV file. A time series of IFR for Chipps Island was added the SV files in order to impose an IFR at Chipps Island.
2. Added a new WERSL file "Unimpaired_SacTribu_Constraint.wresl" which contains most of the WRESL code for the UF IFR implementation.

   a. the state variable "**UFRATIO**" to represent the ratio of the IFR and the unimpaired flow at the corresponding tributary confluence
   b. the penalty UFPENALTY to set soft constraint for IFR

3. Changed weights on dead storage zone arcs and several penalty values in order to prevent diversion from dead pool. The original CalSim II code does not deal with extreme conditions for higher % UF IFA scenario. The changes have effects only when storage levels reach dead pools.
4. Connectivity equations (continuity goals) for some tributaries were changed in order to add the IFRs at selected locations.
5. Modified the WERSL file "demands_defs.wresl" by adding new state variables:

   a. Demand reduction factor "**DRPCNT**", which varies for wet, above normal, below normal, dry, and critical water years.
   b. Settlement contract allocation factor "**SCAPCNT**", which varies for wet, above normal, below normal, dry, and critical water years.

6. Some of rim inflows were modified to use the larger values of the current rim inflow and its IFR at the selected IFR location.
7. Trinity import was fixed at the values of the DCR 2015 existing condition run for all %UF IFR runs.
8. Updated WSI-DI curves.