

Stantec



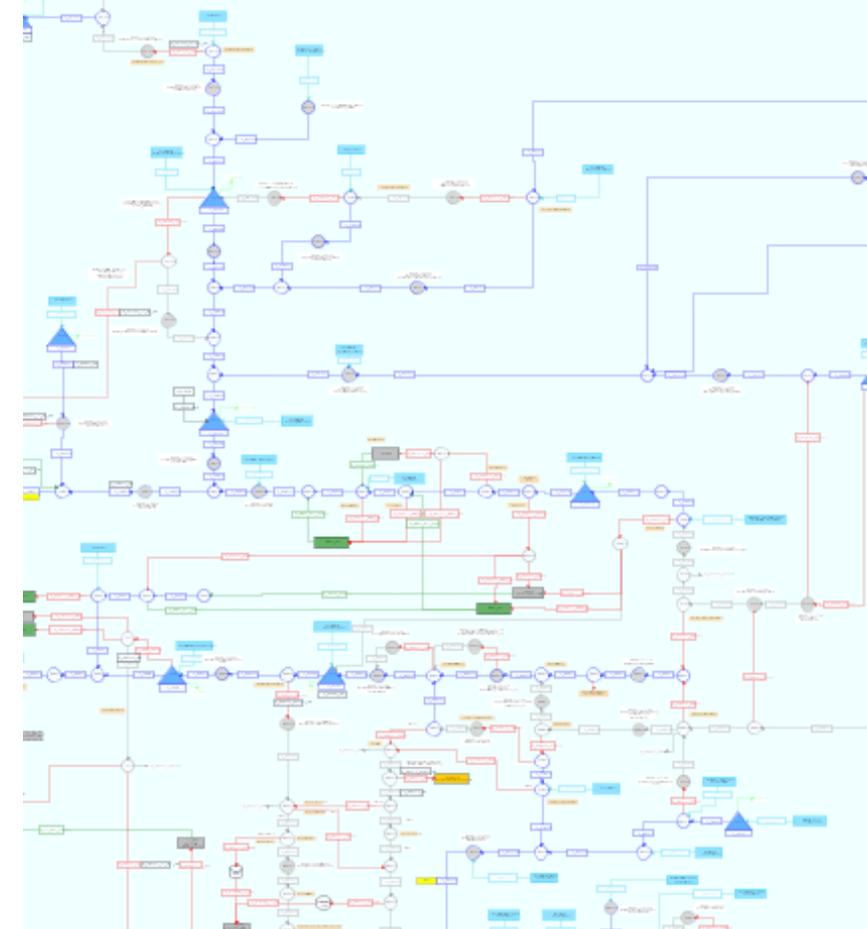
— BUREAU OF
RECLAMATION

CalSim3 Historical Model Development

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2025 CWEMF Annual Conference



CalSim3 Background

Purpose

U.S. Bureau of Reclamation and the California Department of Water Resources jointly developed the CalSim3 model to

“Evaluate the CVP and SWP operations at current or future levels of development, with and without various assumed future facilities, various regulatory requirements, and with different facility management options” (CalSim 3 Report, 2022)

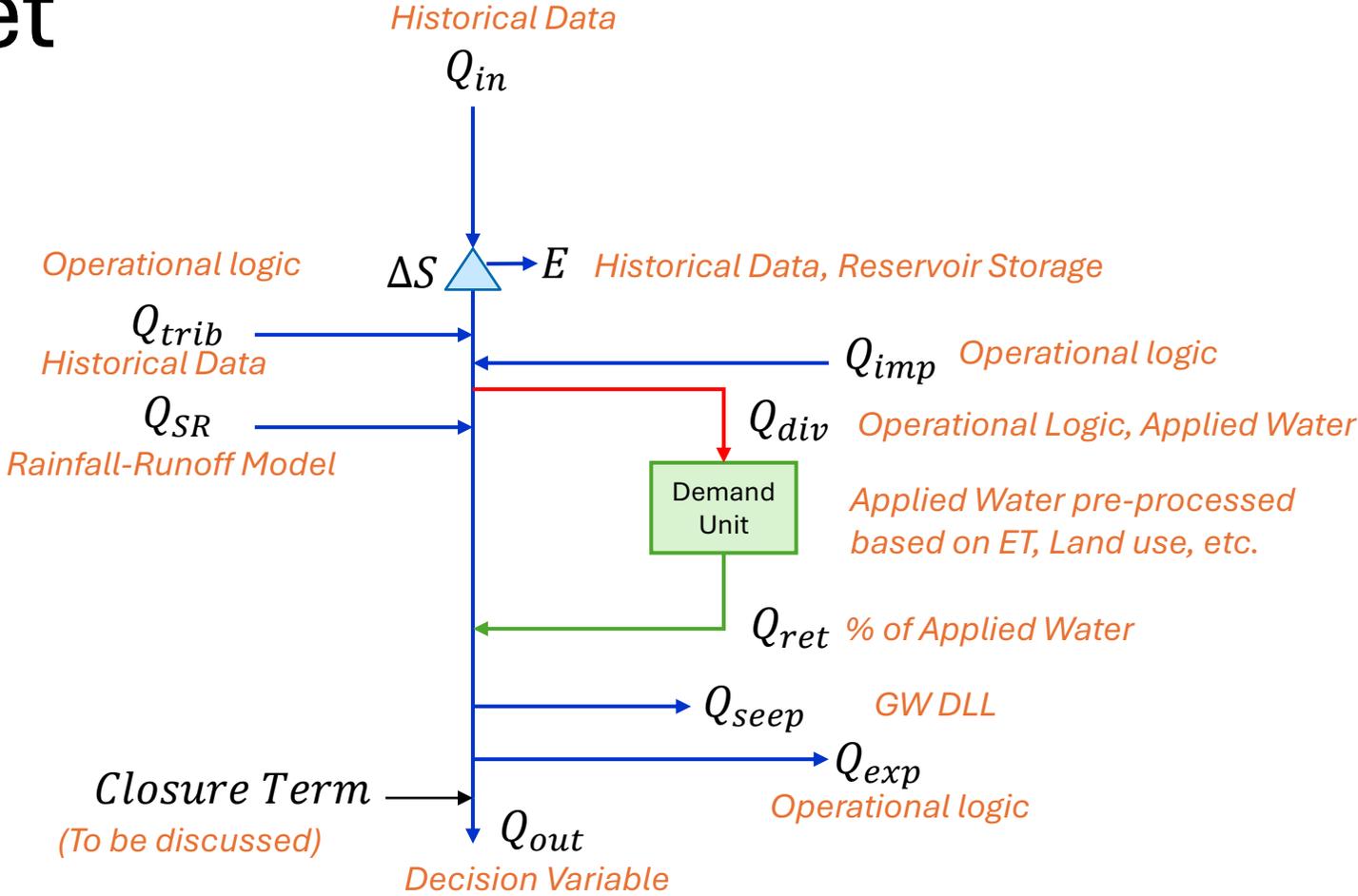
Level of Development

- CalSim3 uses a fixed “level of development” approach to simulate operation of water management facilities and flows in rivers, streams, and channels.
 - In this approach there are 100 realizations of possible annual water supplies each with different initial conditions (i.e., storage)
 - These realizations are implemented as a continuous 100-year simulation¹
 - Historical weather sequence Oct 1921 – Sep 2021
- Model results are best interpreted in terms of probabilities or exceedance representing the range of outcomes that could occur for the chosen level of development.

CalSim3 Planning Study

Stream Water Budget

- Q_{out} = Downstream Outflow
- Q_{exp} = Canal Exports
- Q_{div} = Stream Diversions
- Q_{seep} = Stream Seepage to Aquifer
- E = Reservoir Evaporation
- ΔS = Reservoir Storage Change
- Q_{in} = Upstream Inflow
- Q_{trib} = Tributary or Rim Inflows
- Q_{ret} = Irrigation Return Flow
- Q_{SR} = Surface Runoff
- Q_{imp} = Canal Imports



Historical Stream Water Budget

Comparing a historical water budget using CalSim3 hydrology to available historical data allows for comparison. Error can be attributed to hydrology.

$$\text{Closure Term} = Q_{out} + Q_{exp} + Q_{div} + Q_{seep} + E + \Delta S - Q_{in} - Q_{trib} - Q_{ret} - Q_{SR} - Q_{imp}$$

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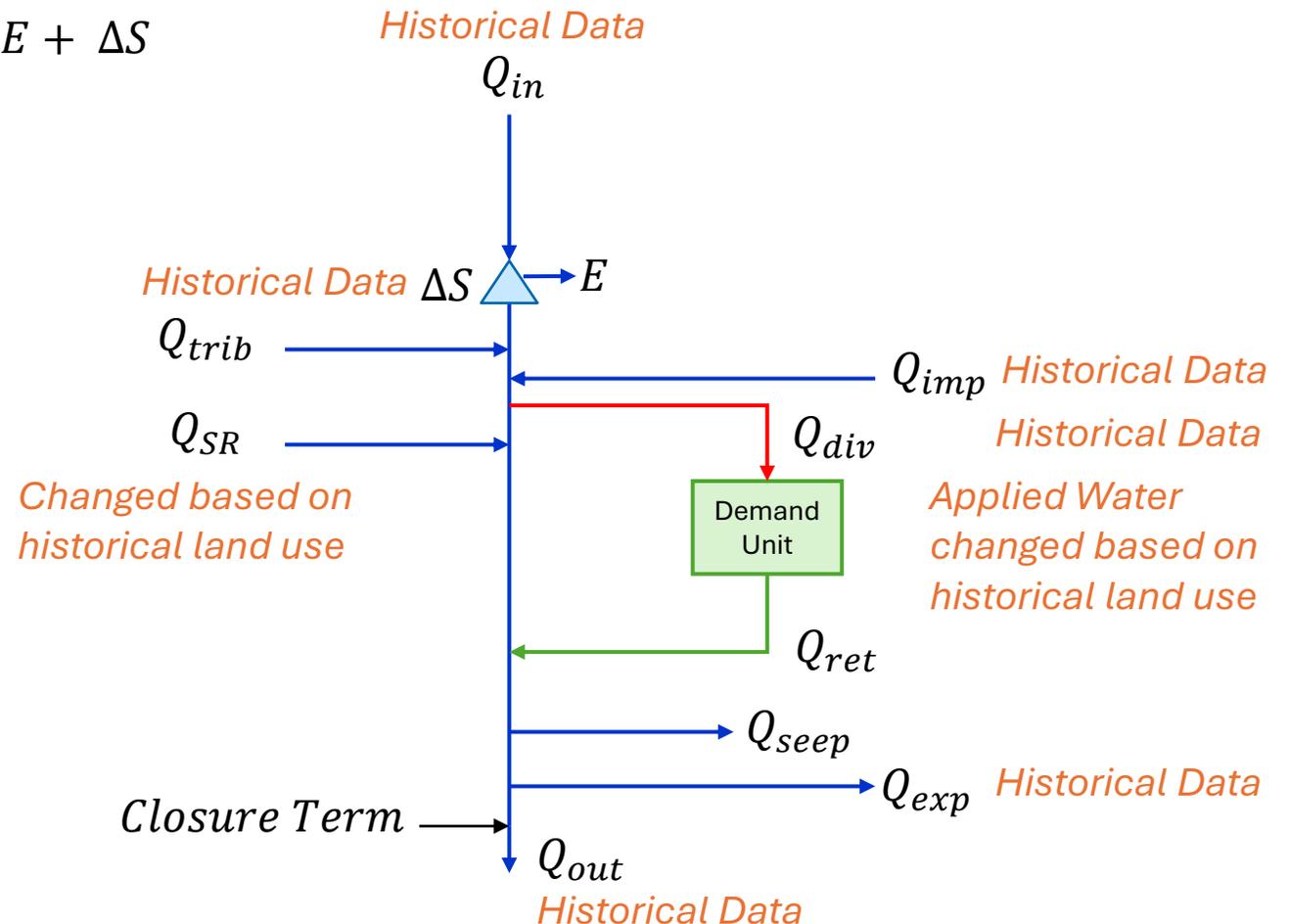
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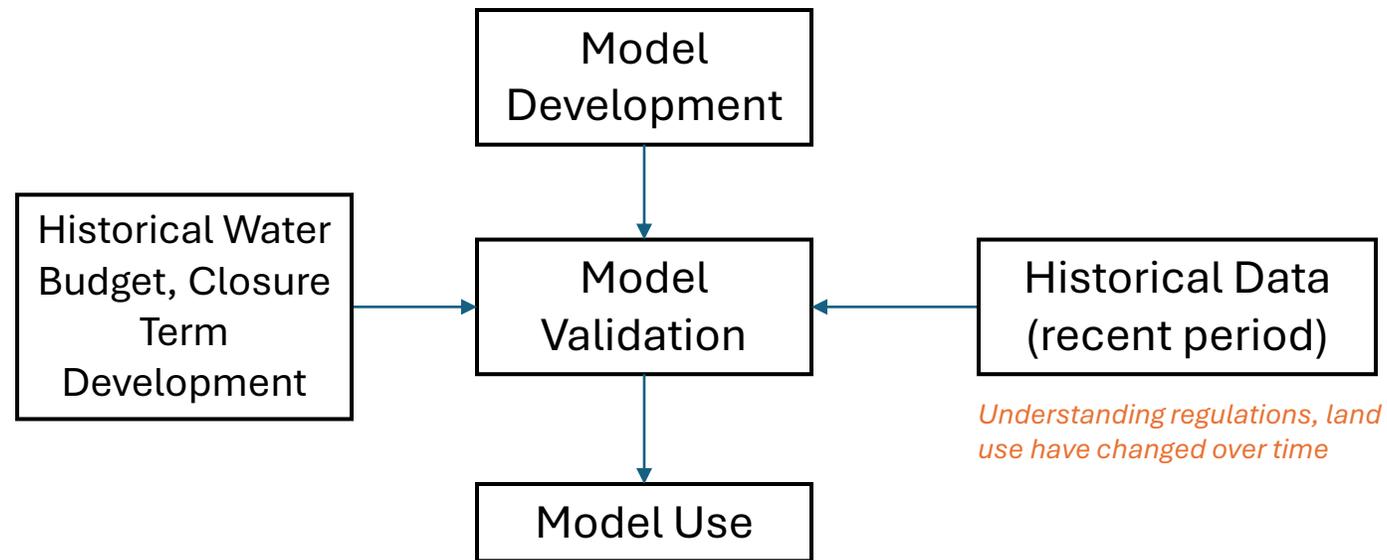
Q_{imp} = Canal Imports



CalSim3 Model Validation Process

Generally, water management models regarded as difficult to calibrate

Comparing the CalSim3 Planning Study model to historical data is not an apples-to-apples comparison due to fixed level of development



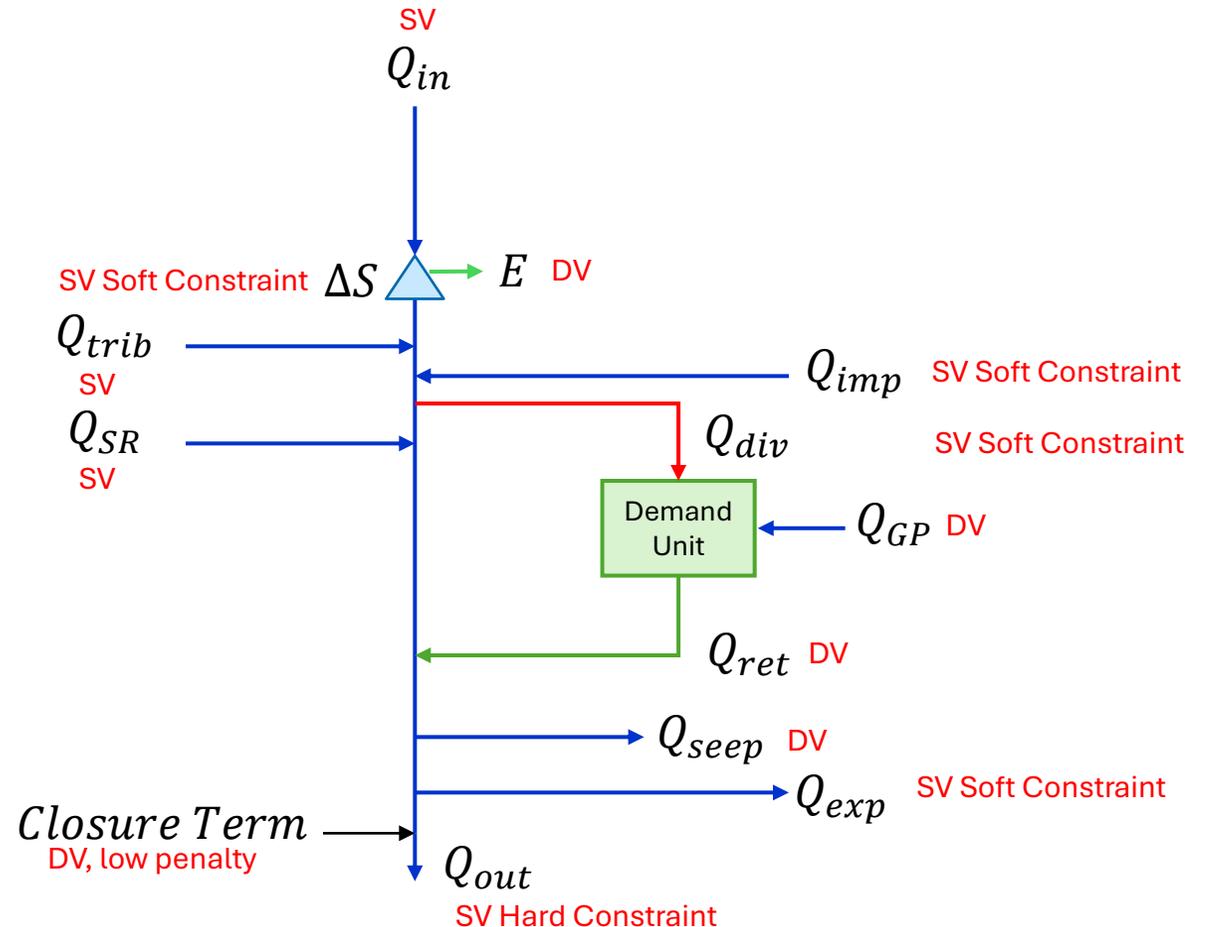
Historical Water Budget

- Previously completed in Excel Spreadsheets

	3	4	5	7	9	13	28	42	51	57	62	92	103	114	123	153	154	176
Maximum				212,175	31,607	4,662	7	41	1,788	23	2,969	29	1,355	616	3	20	1,798	368
Minimum				12,700	22,239	152	-	-	(629)	-	148	(20)	10	-	0	-	(665)	(383)
Annual Average 1922-2013				87,351	25,158	8,230	11.97	183.21	19.79	78.19	6,088.42	169.12	1,610.05	447.22	13.84	85.37	2,141.32	108.87
Write to DSS				0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Multiplication Factor				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Data Source				SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	SUMMARY	CALCULATED	CALCULATED
Description				TOTAL POPULATION	TOTAL AGRICULTURAL AREA	TOTAL OUTFLOW	TOTAL URBAN DIVERSION	TOTAL AGRICULTURAL DIVERSION	TOTAL STORAGE INCREASE	TOTAL EVAPORATION	TOTAL INFLOW	TOTAL GW INFLOW	TOTAL RIM INFLOW	TOTAL RUNOFF	TOTAL URBAN RETURN FLOW	TOTAL AGRICULTURAL RETURN FLOW	TOTAL ACCRETION	CLOSURE TERM
Node				None	(acres)	(TAF)	(TAF)	(TAF)	(TAF)	(TAF)	(TAF)	(TAF)	(TAF)	(TAF)	(TAF)	(TAF)	(TAF)	CT_BendBridge
f Date				Units														(TAF)
922 10/31/1921	1	12,700	26,491.00	265.36	0.05	10.85	-	-	230	20.76	23.48	0.82	0.17	5.73	35.36	(4.70)		
922 11/30/1921	2	12,700	26,491.00	281	0.04	0.00	-	-	235	17.68	35.83	21.74	0.17	-	45.74	(29.63)		
922 12/31/1921	3	12,700	26,491.00	529	0.05	0.00	-	-	332	7.42	141.19	147.50	0.17	-	196.63	(99.60)		
922 1/31/1922	4	12,700	26,491.00	413	0.05	0.00	-	-	299	14.44	114.84	21.27	0.17	-	114.18	(36.49)		
922 2/28/1922	5	12,700	26,491.00	933	0.04	0.00	-	-	542	19.19	283.44	87.66	0.17	-	391.48	1.06		
922 3/31/1922	6	12,700	26,491.00	853	0.05	0.00	-	-	604	18.03	209.38	11.26	0.17	-	249.22	10.43		
922 4/30/1922	7	12,700	26,491.00	1,030	0.06	11.62	-	-	772	10.20	273.35	0.21	0.17	6.61	258.42	(20.45)		
922 5/31/1922	8	12,700	26,491.00	822	0.10	20.36	-	-	623	18.96	234.88	9.99	0.17	10.71	198.73	(54.93)		
922 6/30/1922	9	12,700	26,491.00	417	0.09	27.67	-	-	335	21.23	116.67	1.67	0.17	14.68	82.47	(44.17)		
922 7/31/1922	10	12,700	26,491.00	264	0.15	33.65	-	-	238	21.75	45.54	0.44	0.17	17.82	25.56	(26.36)		
922 8/31/1922	11	12,700	26,491.00	235	0.16	31.72	-	-	212	21.41	22.88	0.36	0.17	16.47	22.57	(6.85)		
922 9/30/1922	12	12,700	26,491.00	221	-	22.30	-	-	200	20.34	19.14	0.28	0.17	11.83	20.58	(8.88)		
923 10/31/1922	13	12,800	26,491.00	280	0.05	8.38	-	-	230	20.76	30.71	1.43	0.17	3.85	49.59	1.10		
923 11/30/1922	14	12,800	26,491.00	329	0.04	0.00	-	-	252	17.68	67.86	36.94	0.17	-	76.99	(45.62)		
923 12/31/1922	15	12,800	26,491.00	623	0.05	0.00	-	-	333	7.42	226.24	75.95	0.17	-	289.97	(19.76)		
923 1/31/1923	16	12,800	26,491.00	656	0.05	0.00	-	-	395	14.44	152.91	26.29	0.17	-	261.42	67.65		
923 2/28/1923	17	12,800	26,491.00	426	0.04	0.00	-	-	309	19.19	93.66	0.38	0.17	-	117.33	3.97		
923 3/31/1923	18	12,800	26,491.00	405	0.05	2.56	-	-	330	18.03	72.73	0.53	0.17	1.99	75.18	(15.66)		
923 4/30/1923	19	12,800	26,491.00	852	0.06	7.59	-	-	584	10.20	162.39	63.10	0.17	3.67	268.23	36.35		
923 5/31/1923	20	12,800	26,491.00	424	0.10	21.36	-	-	353	18.96	70.77	0.25	0.17	11.40	71.43	(8.67)		
923 6/30/1923	21	12,800	26,491.00	306	0.09	25.32	-	-	264	21.23	45.66	3.51	0.17	12.97	42.01	(16.12)		

CS3 Historical WRIMS Model Approach

- Fix reservoir storage and diversions to historical values using soft constraints (higher weight on reservoir storage constraint)
- Fix closure term gauge location to historical values using hard constraints
- Leave closure terms as a decision variable (very small penalty for unique solution, but not to re-route upstream flows)
- Missing historical data left unconstrained and meeting applied water demand calculated by historical run of CalSimHydro (historical land use)



*DV = Decision Variable, SV = State Variable

CS3 Historical Model Approach - Benefits

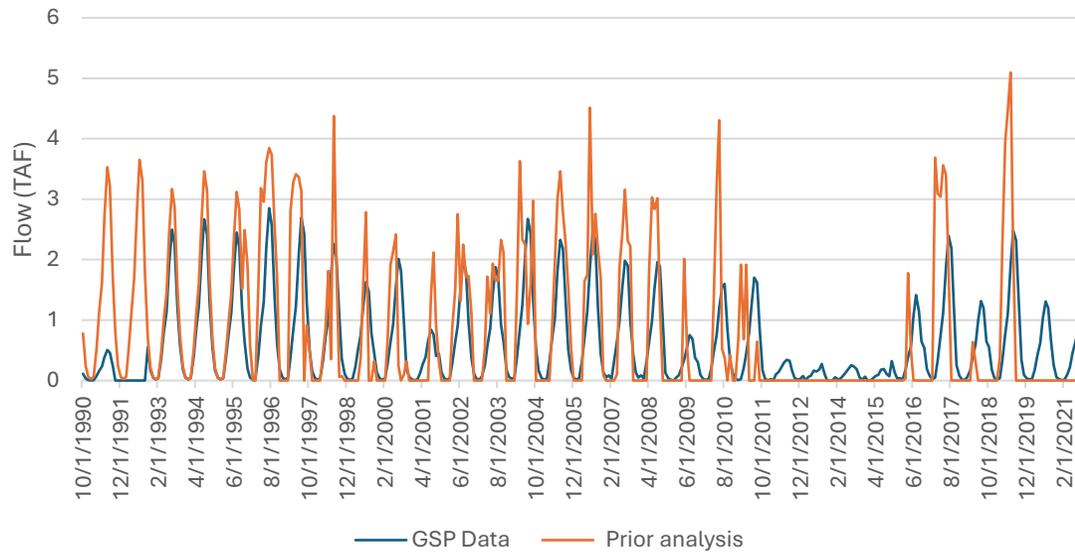
- Dynamic GW DLL Interaction
- Ability to pair with automated model calibration
 - Ongoing work with Reclamation, DWR, Stantec, and Woodward and Curran
- Consolidation of historical data

Included SV?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of -2	0	0	0	816	0	0	0	504	0	0	0	480	0
avg	4.0	36.2	0.5	1319.2	1124.6	291.3	747.8	265.4	50.0				
WRESL Code Comment	BVID via MBK, retrie	EBMUD	USGS 11433930	Table 10, 1957 Joint	C_SAC081	USGS11378000 (192)	USGS11377100 (196)	1957 JHS, USGS 1131	DWR B07400	MBI			
Name	C_MERLC	C_MCK035	C_MRM001	C_SAC049	C_SAC081	C_SAC247	C_SAC257	C_SJR070	C_SJR131	C_SJR131			
Data Source	BVID via MBK Used the following formula: IF(DATE< 1967, ...)		USGS 11433930	0121-09148; Table 10, 19	1946- USGS 11425500 includes gage	USGS11378000	USGS11377100	1922-1929; 1957 JHS 1965-2021 USGS 11303500	B07400	missing data were infilled with USGS 11261500 1951 San Joaquin River near Stevinson (Lavender Avenue)	1941	1125	1951
Notes		Mokelumne River at Woo	Missing data: infilled with		correction made 03/87			San Joaquin River at Vernalis					
Spreadsheet	CS3_L_MERLC_Rev2021	CS3_Historical_Mokelumne	CS3_Historical_Folsom	CS3_CT_Freepoint	CS3_CT_Verona			CS3_Historical_SanJoaquin@Vernalis_Rev1	1	CS3_Historical_SanJoaquin@FremontFord_Rev1			
Historical Beg. Date:	10/31/1921 to 12/31/1963	31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-63	31-Oct-21	31-Oct-61			
Historical End Date:	10/31/1967 to 9/30/2003	30-Sep-21	30-Sep-21	30-Sep-21	30-Sep-21	30-Sep-21	30-Sep-68	30-Sep-21	30-Sep-21	30-Sep-21			
Part A:	CALSIM	CALSIM	CALSIM	CALSIM	CALSIM	CALSIM	CALSIM	CALSIM	CALSIM	CALSIM			
Part B:	C_MERLC_HIST	C_MCK035_HIST	C_MRM001_HIST	C_SAC049_HIST	C_SAC081_HIST	C_SAC247_HIST	C_SAC257_HIST	C_SJR070_HIST	C_SJR131_HIST	C_SJR131_HIST			
Part C:	HISTORICAL	HISTORICAL	HISTORICAL	HISTORICAL	HISTORICAL	HISTORICAL	HISTORICAL	HISTORICAL	HISTORICAL	HISTORICAL			
Part D:													
Part E:	1MON	1MON	1MON	1MON	1MON	1MON	1MON	1MON	1MON	1MON			
Part F:	L2020A	L2020A	L2020A	L2020A	L2020A	L2020A	L2020A	L2020A	L2020A	L2020A			
Beg. Date:		31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-21	31-Oct-21			
Beg. Time:		2400	2400	2400	2400	2400	2400	2400	2400	2400			
End Date:		30-Sep-21	30-Sep-21	30-Sep-21	30-Sep-21	30-Sep-21	30-Sep-21	30-Sep-21	30-Sep-21	30-Sep-21			
End Time:		2400	2400	2400	2400	2400	2400	2400	2400	2400			
Units:	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF			
Data Type:	PER-AVER	PER-AVER	PER-AVER	PER-AVER	PER-AVER	PER-AVER	PER-AVER	PER-AVER	PER-AVER	PER-AVER			
	10/31/1995	3.91	28.57	0.24	870.05	688.05	0.00	384.91	349.99	3.93			
	11/30/1995	0.11	14.09	0.09	750.35	603.97	0.00	363.87	144.48	2.70			
	12/31/1995	0.00	13.36	0.41	1510.75	1312.76	0.00	565.19	138.35	6.80			
	1/31/1996	2.50	14.59	0.45	2021.10	1852.62	0.00	814.71	149.48	10.36			
	2/29/1996	6.95	113.80	0.40	4329.58	3542.70	0.00	2173.13	653.76	60.28			
	3/31/1996	7.43	161.90	0.43	3458.06	3022.12	0.00	1425.90	926.62	122.26			
	4/30/1996	7.16	71.92	0.27	2140.96	1771.44	0.00	556.96	446.28	11.35			
	5/31/1996	5.56	53.50	0.45	2466.27	1939.32	0.00	837.46	517.85	70.71			
	6/30/1996	4.43	50.14	0.43	1400.13	1066.91	0.00	875.31	222.49	9.68			
	7/31/1996	5.27	55.53	0.42	1271.56	1048.98	0.00	900.79	135.83	6.45			
	8/31/1996	5.28	30.83	0.45	1309.69	1099.40	0.00	887.27	125.07	7.13			

Historical Consolidation Spreadsheet

Continued Refinement of Historical Data

Diversion to Gravelly Ford, Root Creek WD
D_SJR227_64_PA3



Historic Surface Water Usage and Water Balance

Table 2-1 shows GFWD's historical surface water deliveries for a period from 1989 thru 2014.

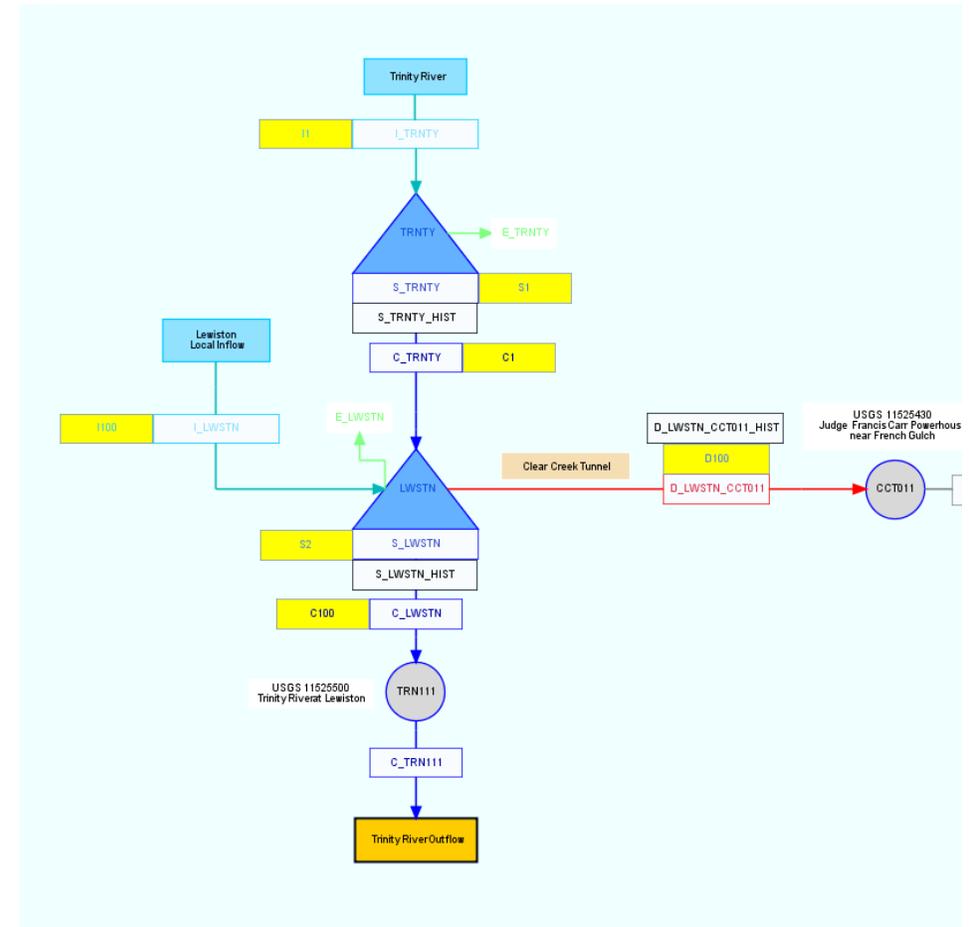
Table 2-1
Surface Water Deliveries

Surface Water Deliveries (Acre Feet)					
Water Year	Diversion from San Joaquin River (Bureau Class 2)	Diversions from MD Conveyance System	Diversions from Cottonwood Creek via MID	Diversions from Cottonwood Creek (Natural Flow)	Total (Inflow)
1989 (C)	-	65	0	72	137
1990 (C)	-	0	0	0	0
1991 (C)	2,225	247	0	0	2,472
1992 (C)	-	424	0	0	424
1993 (W)	10,999	4,247	6,610	5,195	27,051
1994 (C)	11,754	1,588	340	294	13,976
1995 (W)	10,796	4,120	6,274	7,305	28,495
1996 (W)	12,569	4,126	6,106	3,999	26,800
1997 (W)	11,871	3,429	4,850	2,398	22,548
1998 (W)	9,969	2,809	3,999	9,078	25,855
1999 (AN)	7,174	1,850	3,197	5,287	17,508
2000 (AN)	8,864	2,102	3,189	3,635	17,790
2001 (D)	3,707	872	1,308	841	6,728
2002 (D)	5,732	1,338	1,000	721	8,791
2003 (BN)	7,509	1,367	1,386	1,374	11,636
2004 (D)	11,472	1,517	2,340	89	15,418
2005 (W)	9,562	1,281	2,736	1,611	15,190
2006 (W)	9,730	1,921	3,560	1,211	16,422
2007 (C)	7,940	1,183	1,202	291	10,616
2008 (C)	7,854	949	545	0	9,348
2009 (BN)	2,556	373	0	0	2,929
2010 (AN)	5,965	31	53	1,117	7,166
2011 (W)	6,302	2,876	3,604	3,475	16,257
2012 (D)	823	442	126	82	1,473
2013 (C)	-	0	0	0	0
2014 (C)	-	0	0	0	0
2015 (C)	-	0	0	0	0
Total (AF)	165,373	39,157	52,425	48,075	305,030
Average (AF/yr)	6,361	1,506	2,016	1,849	11,732

CS3HIST_COMBO Model Specs

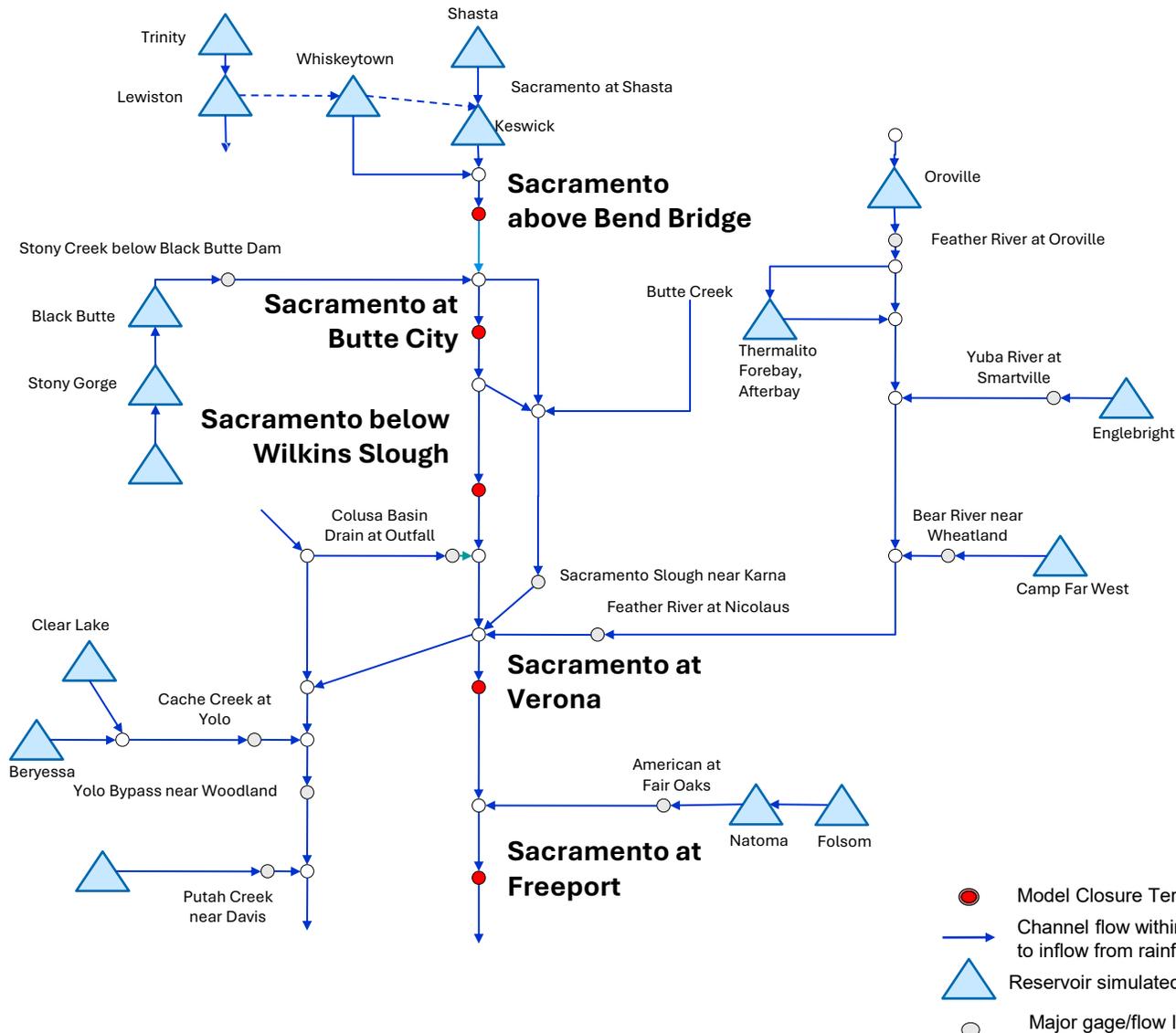
- 10 Model Cycles, approximately 200 WRESL files
 - Stripped out Operational Logic (800+ WRESL files)
- 400+ historical flow timeseries
- Model period: Oct 2000-Sep 2021
 - Sacramento Valley Stand-Alone Module (1921-2021)
- 10-minute run time
- CS3 Valley Watershed Domain
- Closure Term Post-Processing Procedures

Updated XML Schematic for use in WRIMS

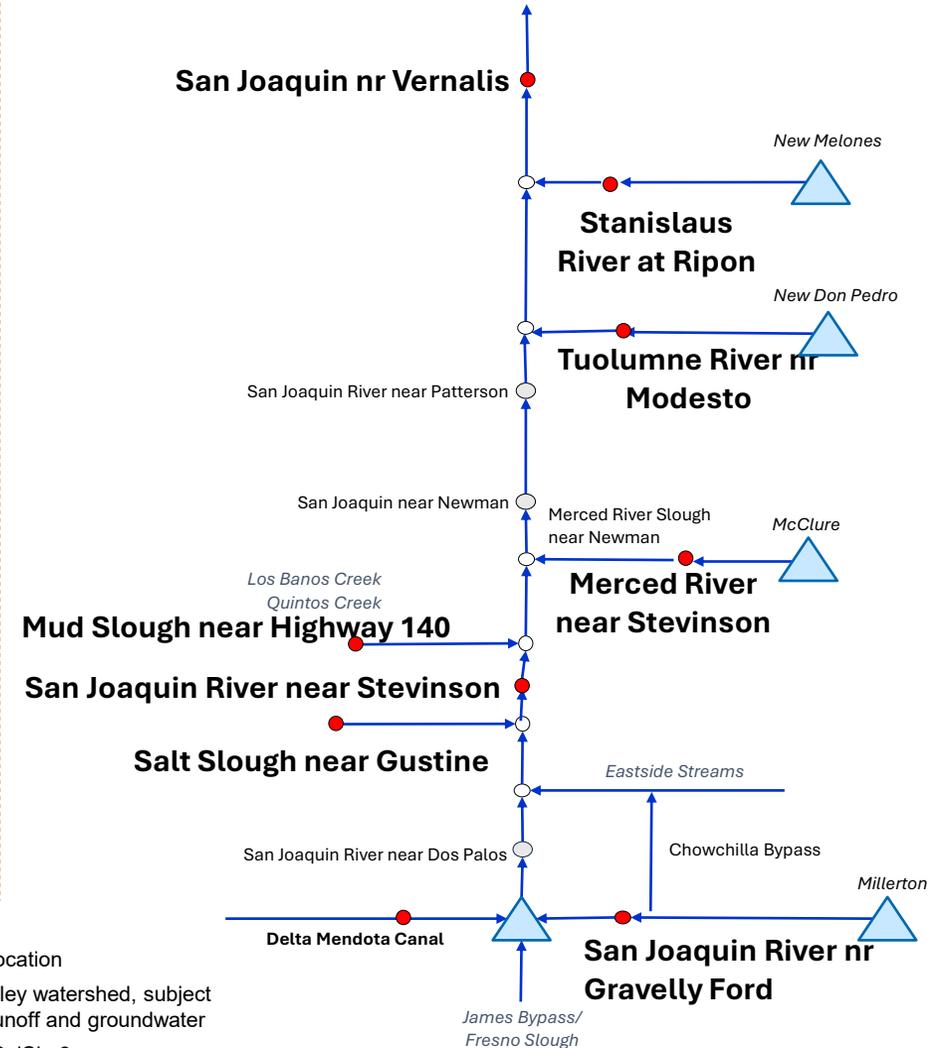


Closure Term Locations – Simplified Schematics

Sacramento Valley

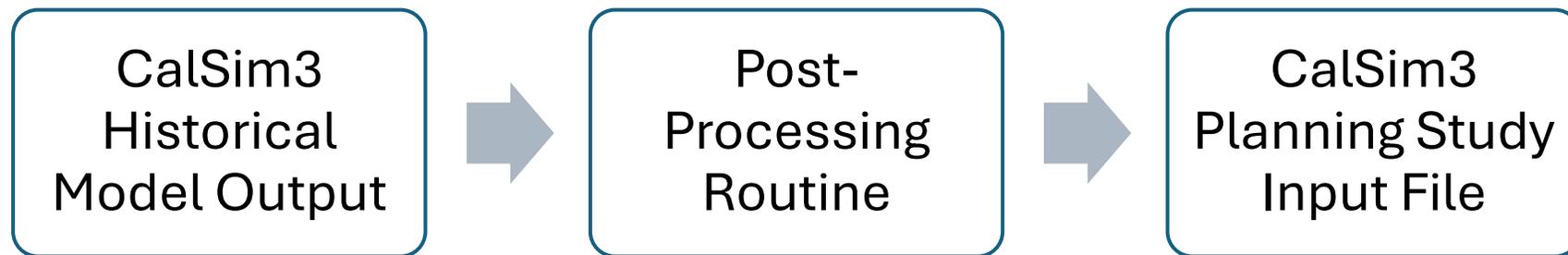


San Joaquin Valley

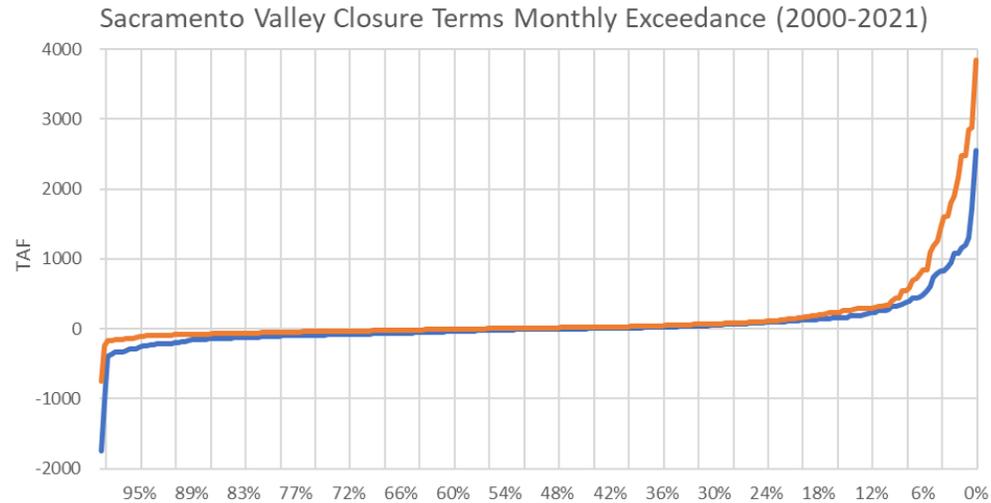


Closure Term Post-Processing

- Closure Terms and bias correction factors limited by quality of historical data.
 - San Joaquin Valley – post-processing needed to apply bias correction factors for 100-year CalSim3 period of simulation from 20-year historical model
 - Sacramento Valley – Sacramento Valley closure terms below Butte City - post-processing regime; historical water balance available for full CalSim3 period of simulation



CS3HIST WRIMS Model Closure Terms

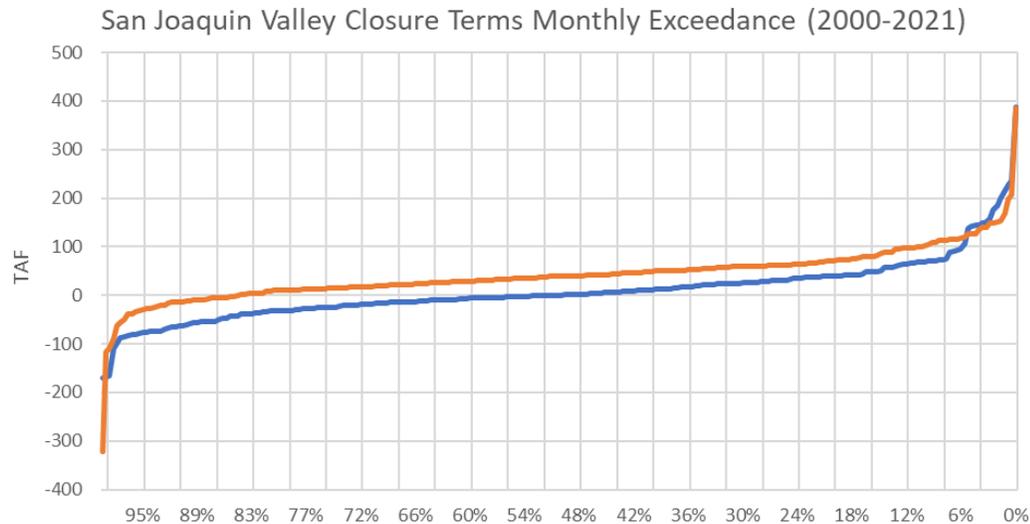


Blue = CS3 HIST WRIMS Model

Orange = Spreadsheet Water Budget

- **Sacramento Valley Closure Terms:**

- Average Annual Value ~ 500 TAF/year
- 4% Sacramento River at Freeport Average Annual Flow



- **San Joaquin Valley Closure Terms:**

- Average Annual Value ~ 250 TAF/year
- 10% San Joaquin River Flow near Vernalis

Important Takeaways

- Closure Terms are currently used in CS3 as bias correction accretion/depletion terms and address model hydrology errors
- Dynamic CS3 Historical Model can be used to:
 - Develop closure term timeseries inputs
 - Look at closure term accretions/depletions as indicators of where to focus attention on improving base hydrology
 - Introduce automated calibration (e.g., PEST) of the CalSim3 hydrology
 - Can be easily used for hydrology revision sensitivity analysis

Thank you!

Please direct any questions to:

- Bridget Childs (bridget.childs@stantec.com)
- Ryan Lucas (rlucas@usbr.gov)

Extra Historical (EH) Deliveries

- EH terms implemented when historical surface water delivery data exceeds applied water estimates
 - Negative penalty on the EH term – only activated in the above case
 - Demand Unit Water Balance:

Applied Water + EH = Historical Surface Water Deliveries + GW Pumping