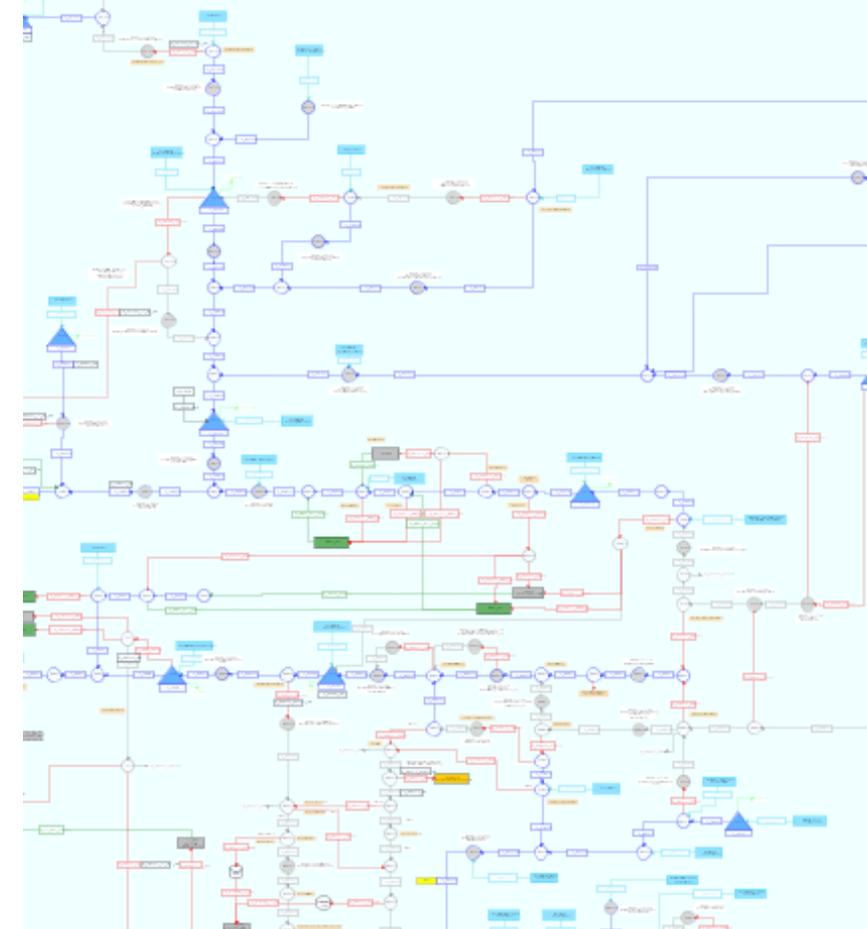# CalSim3 Historical

Model Development

Bridget Childs (Stantec)
Ryan Lucas (Reclamation)
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)
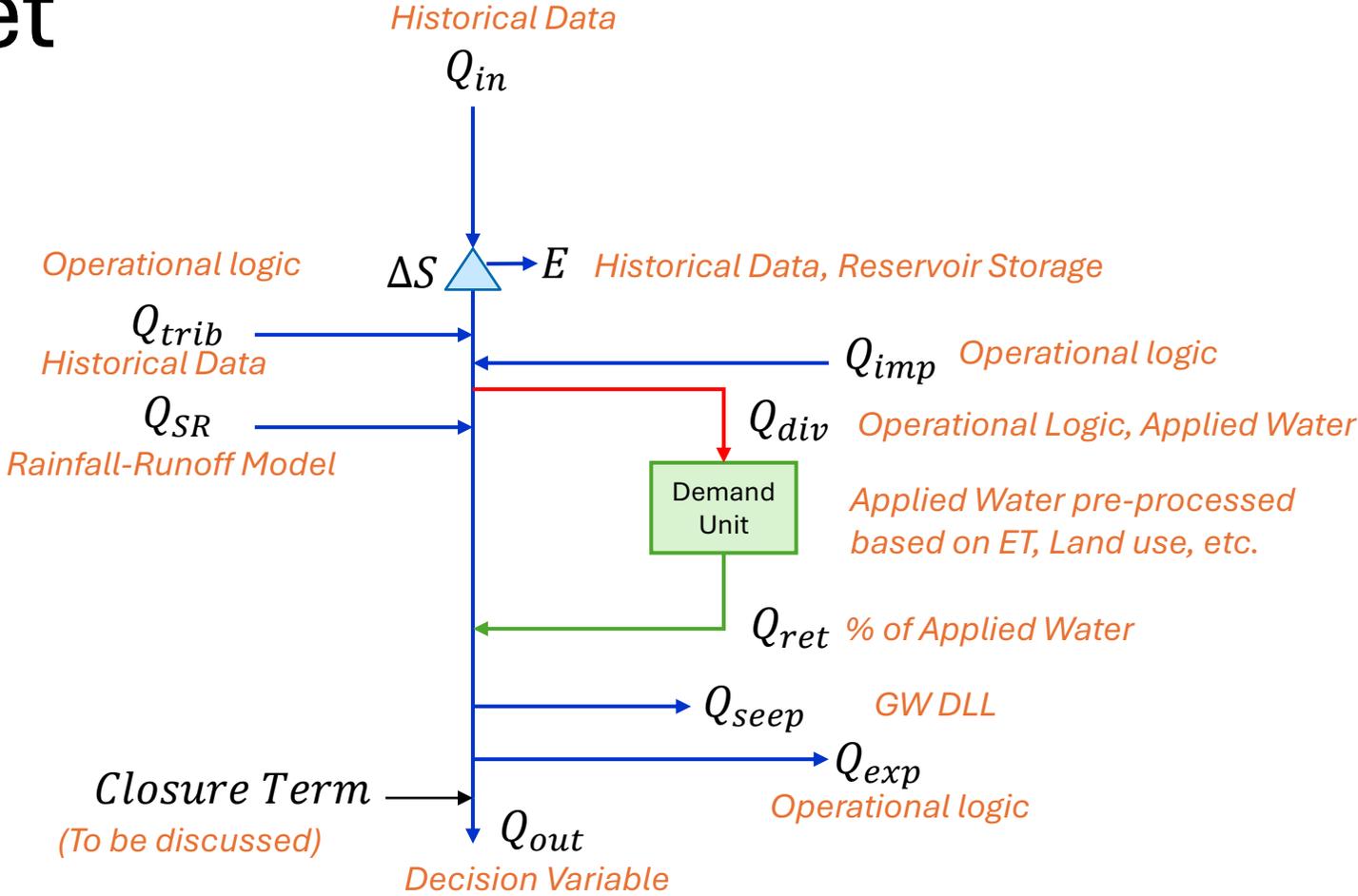
Level of Development

- 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 simulation[1]
        - 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

$Q_{out} = Downstream\ Outflow$

$Q_{exp} = Canal\ Exports$

$Q_{div} = Stream\ Diversions$

$Q_{seep} = Stream\ Seepage\ to\ Aquifer$

$E = Reservoir\ Evaporation$

$\Delta S = Reservoir\ Storage\ Change$

$Q_{in} = Upstream\ Inflow$

$Q_{trib} = Tributary\ or\ Rim\ Inflows$
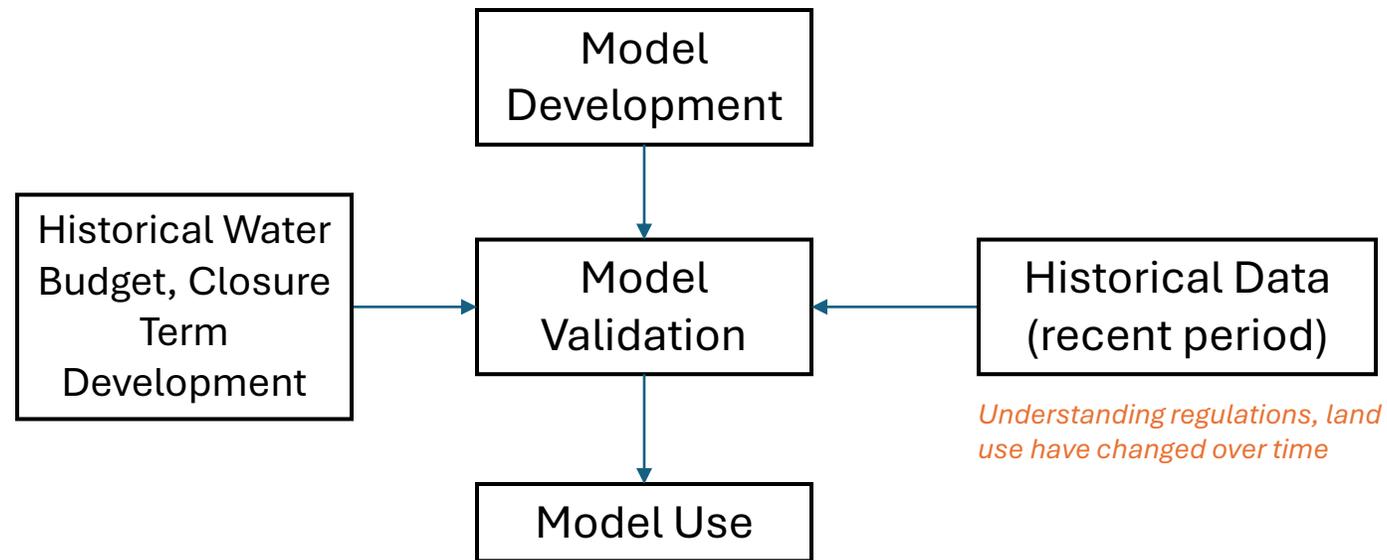
$Q_{ret} = Irrigation\ Return\ Flow$

$Q_{SR} = Surface\ Runoff$

$Q_{imp} = Canal\ Imports$

Historical Data

Q_{in}

Operational logic ΔS E *Historical Data, Reservoir Storage*

Q_{trib} Q_{imp} *Operational logic*

Historical Data

Q_{SR} Q_{div} *Operational Logic, Applied Water*

Rainfall-Runoff Model

Demand Unit   *Applied Water pre-processed based on ET, Land use, etc.*

Q_{ret} *% of Applied Water*

Q_{seep} *GW DLL*

Q_{exp}

Closure Term   *Operational logic*

(To be discussed) Q_{out}

Decision Variable

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.

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

$Q_{out} = Downstream\ Outflow$
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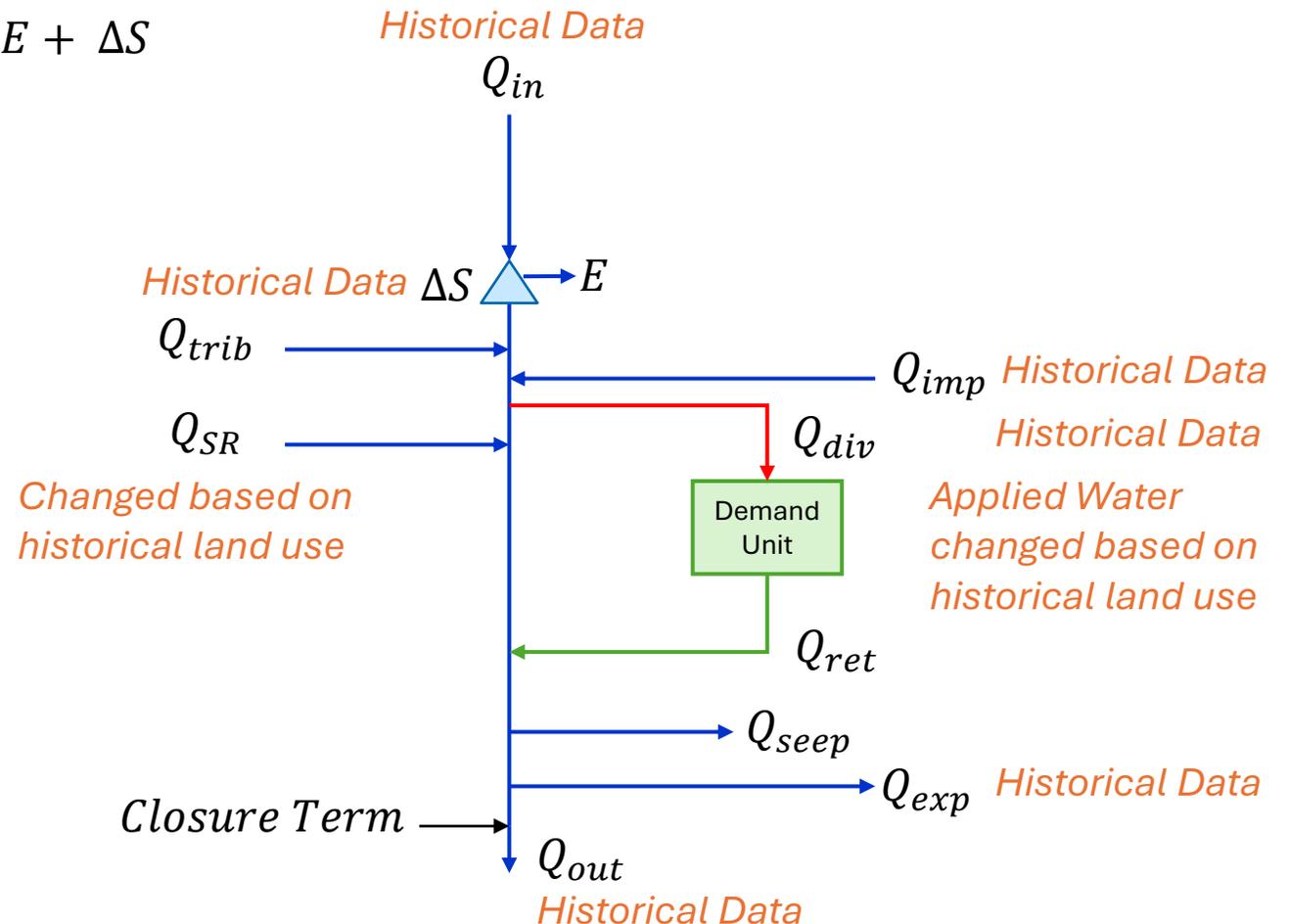
CalSim3 Model Validation Process

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

Historical Water Budget

- Previously completed in Excel Spreadsheets

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)

SV
Q_{in}

SV Soft Constraint ΔS E DV

Q_{trib}
SV

Q_{imp} SV Soft Constraint

Q_{div} SV Soft Constraint

Q_{SR}
SV

Demand Unit

Q_{GP} DV

Q_{ret} DV

Q_{seep} DV

Q_{exp} SV Soft Constraint

Closure Term
DV, low penalty

Q_{out}
SV Hard Constraint
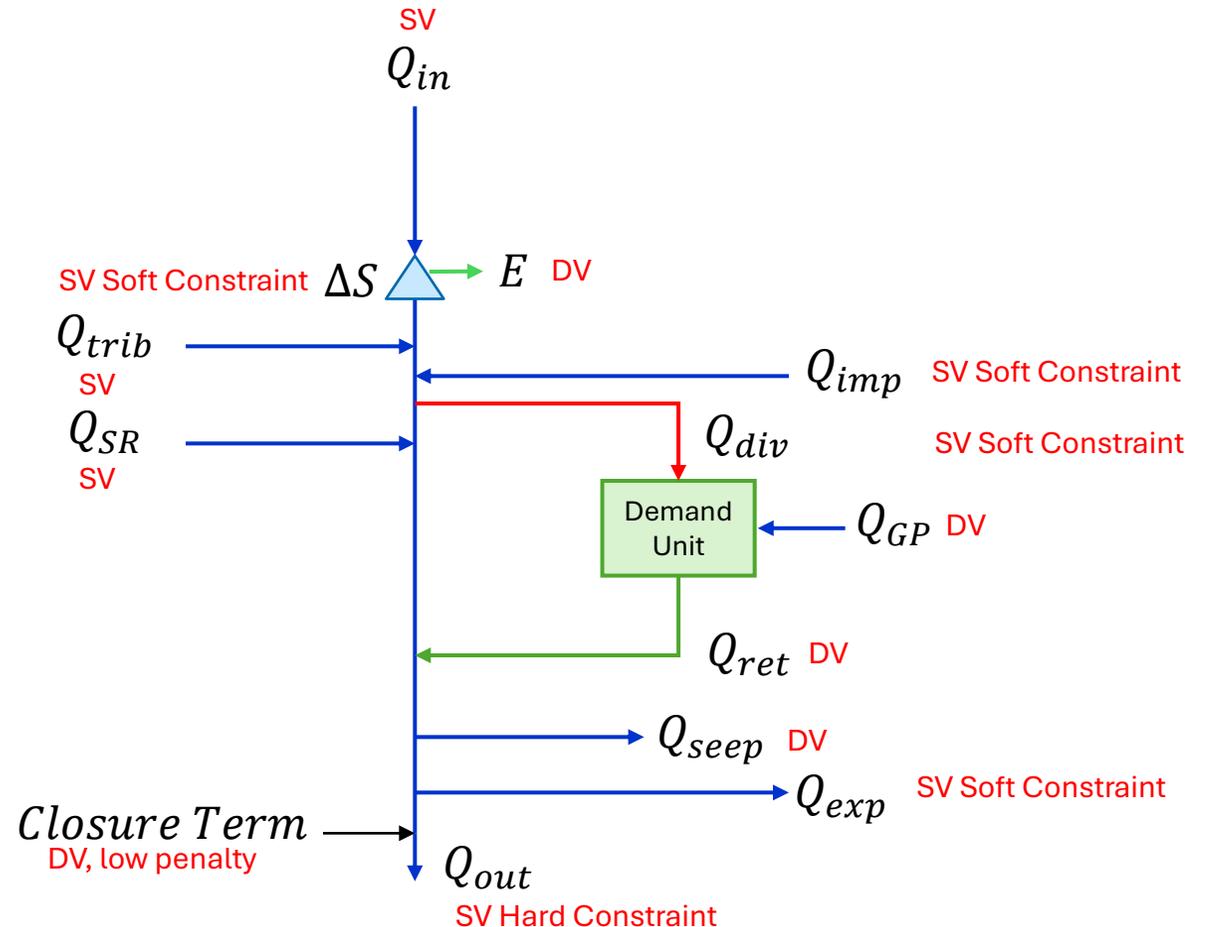
*DV = Decision Variable, SV = State Variable
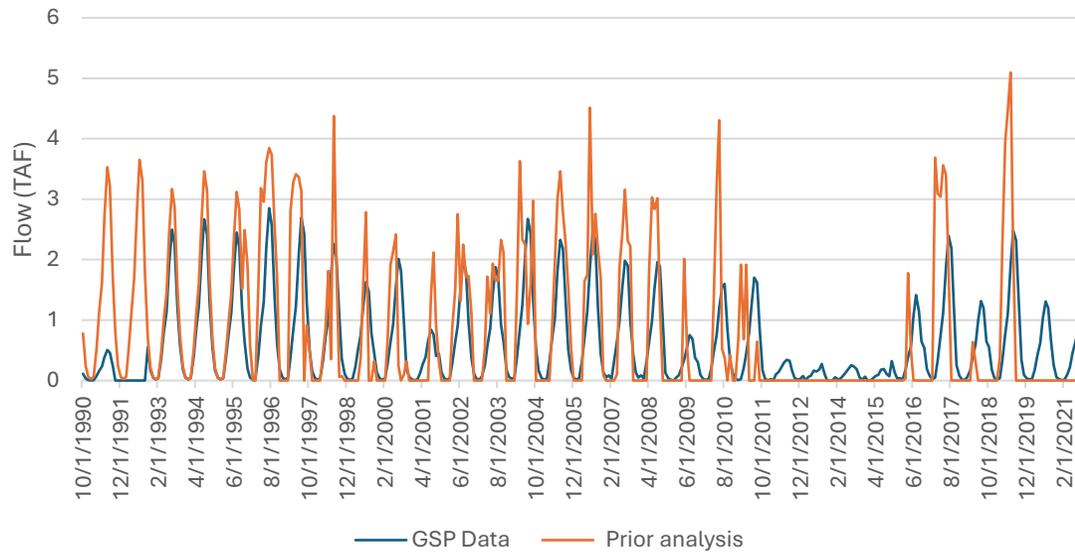
CS3 Historical Model Approach - Benefits

- 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

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 (Bureu Class 2)	Diversions from MID 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
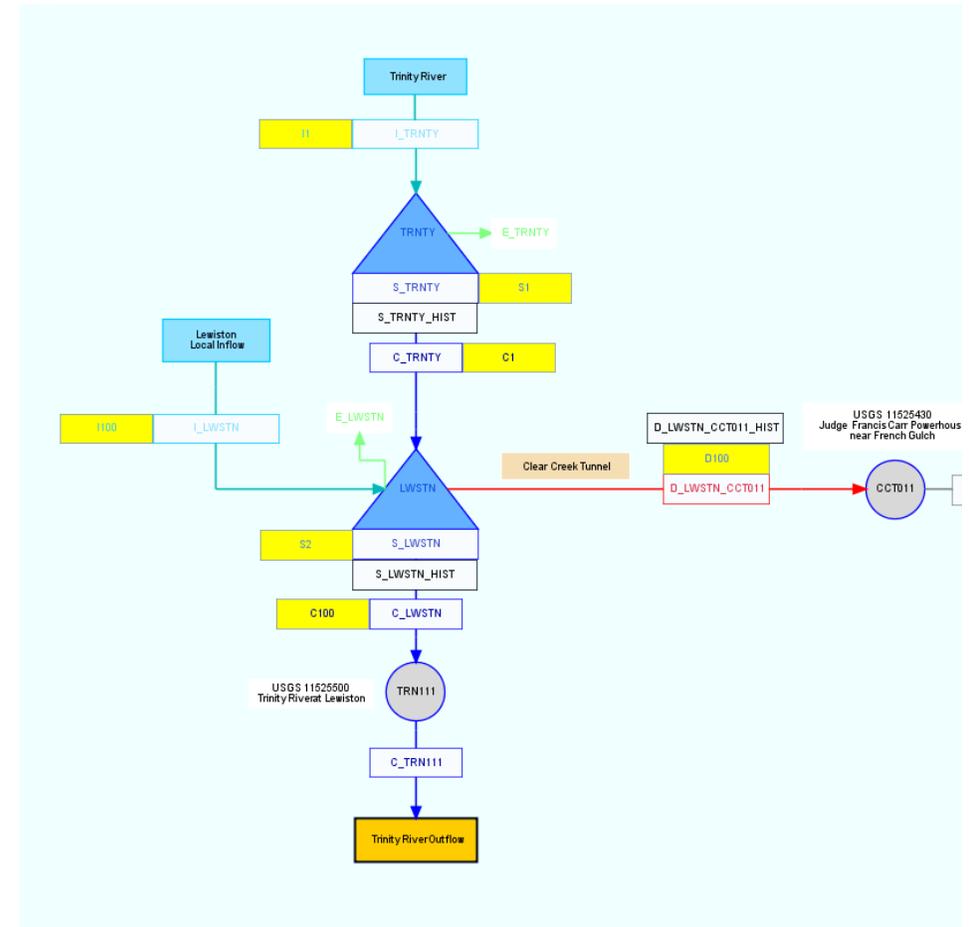
Closure Term Locations – Simplified Schematics

Sacramento Valley

San Joaquin Valley

Legend:

- Model Closure Term Location
- Channel flow within valley watershed, subject to inflow from rainfall-runoff and groundwater
- Reservoir simulated in CalSim3
- Major gage/flow location
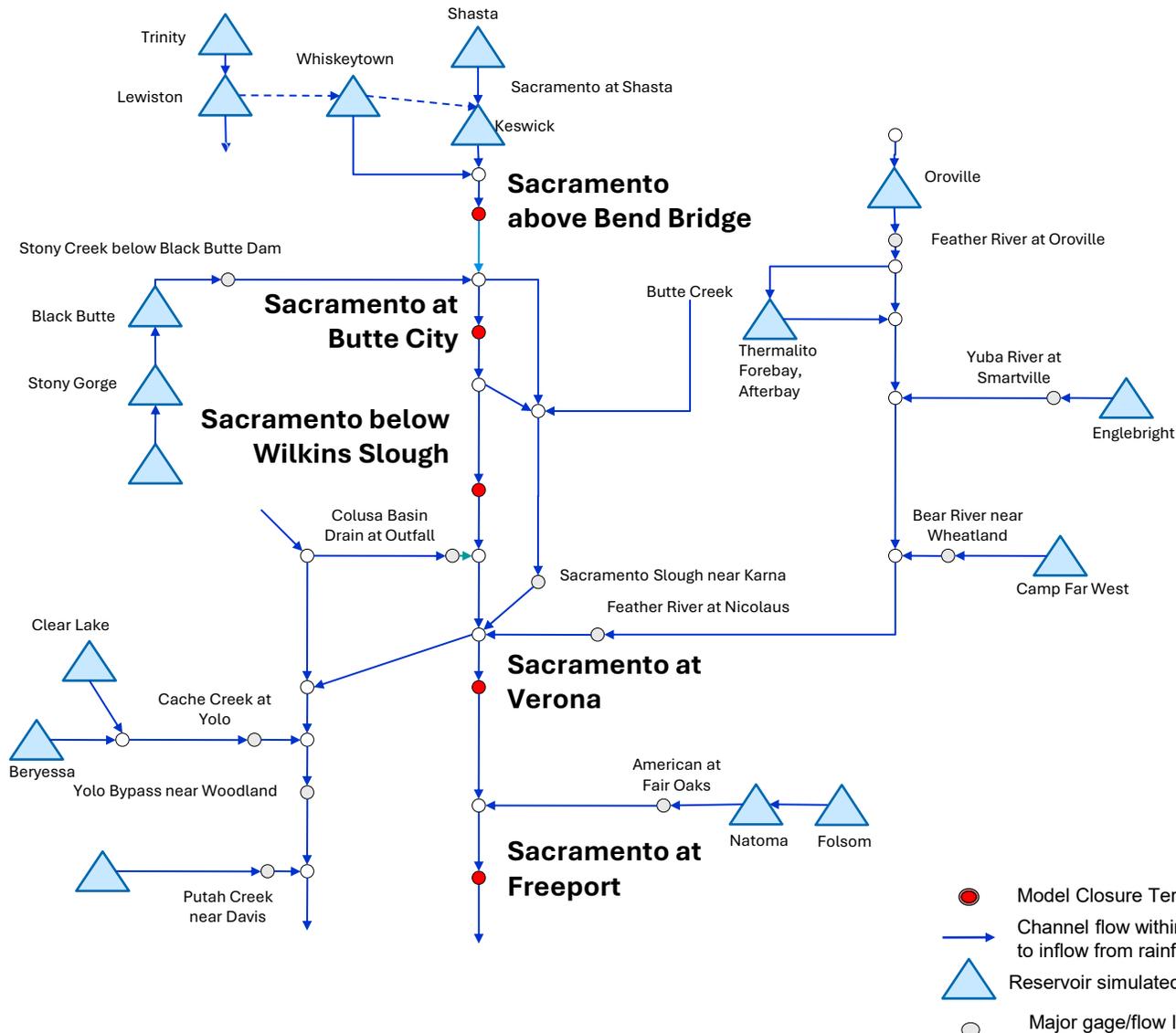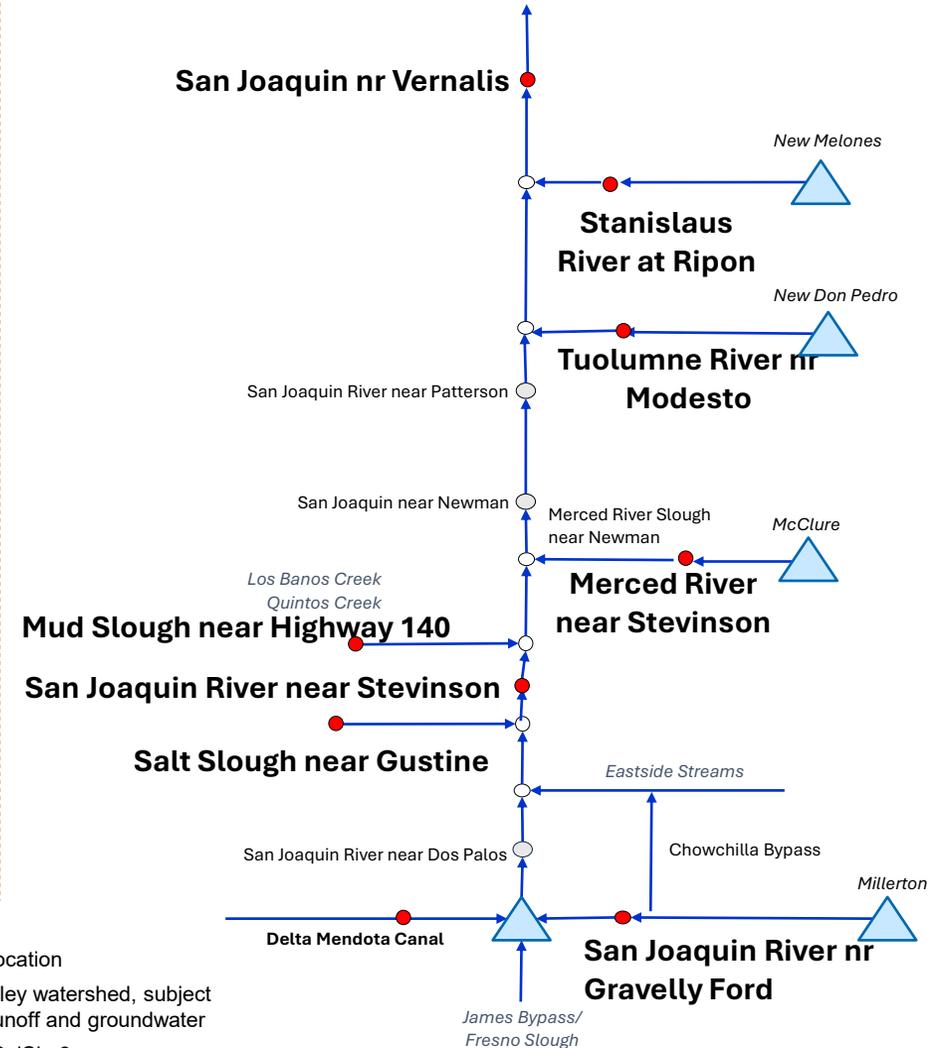
Closure Term Post-Processing

- 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

CalSim3 Historical Model Output → Post-Processing Routine → CalSim3 Planning Study Input File
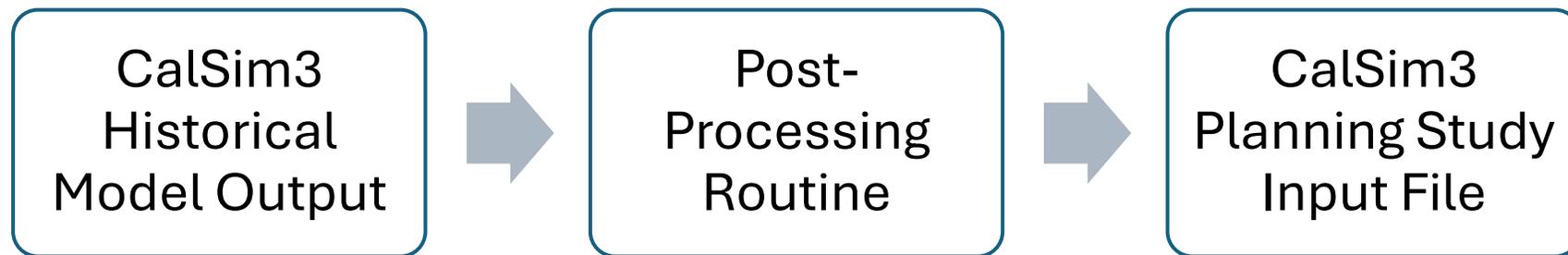
CS3HIST WRIMS Model Closure Terms

Sacramento Valley Closure Terms Monthly Exceedance (2000-2021)

San Joaquin Valley Closure Terms Monthly Exceedance (2000-2021)
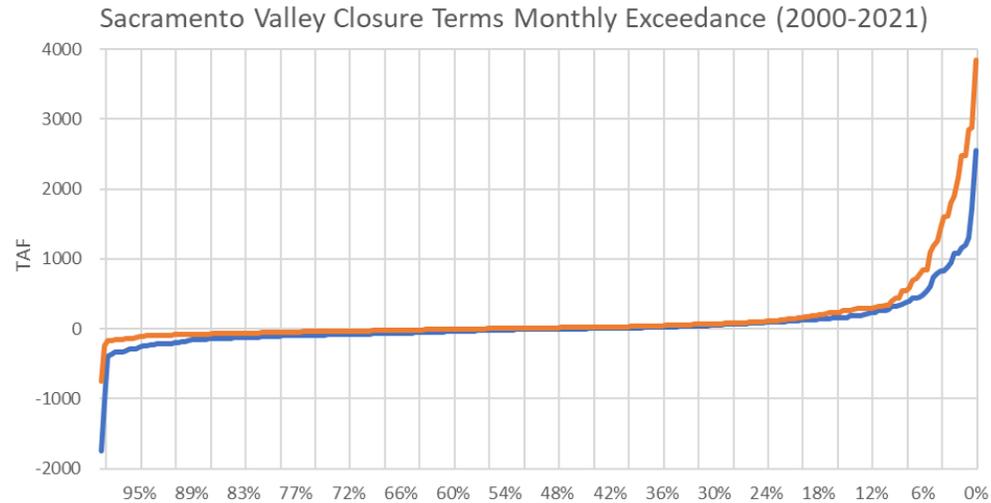
Blue = CS3 HIST WRIMS Model
Orange = Spreadsheet Water Budget

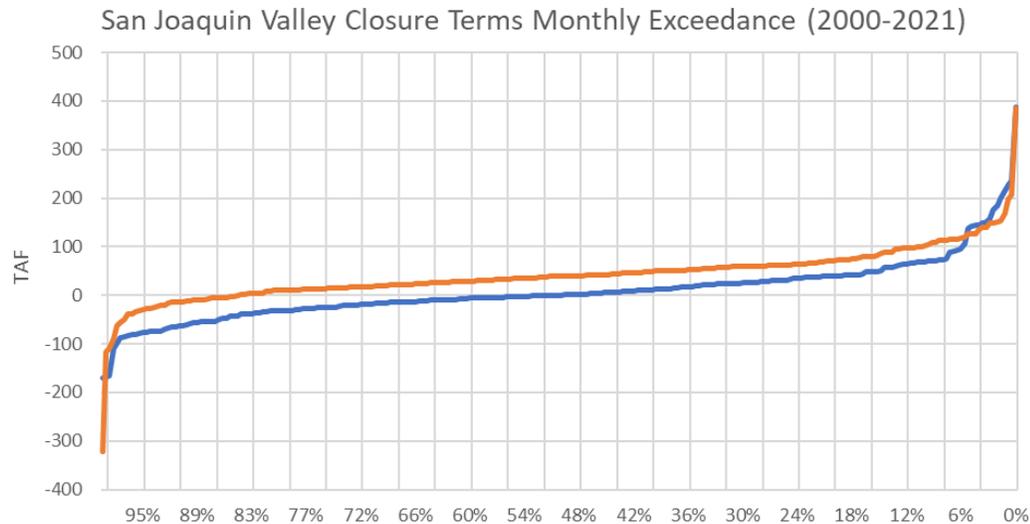- **Sacramento Valley Closure Terms:**
  - Average Annual Value ~ 500 TAF/year
  - 4% Sacramento River at Freeport Average Annual Flow

- **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