

A Simulation Tool for the Bay-Delta Water Quality Control Plan

SacWAM, Public Workshop
October 4, 2016



October 4, 2016

Acknowledgements

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Acknowledgements

- Jim Byer, Sunset Technologies, XA Developer
- DWR Bay Delta office.

Topics

Morning

- Introduction to WEAP
- Introduction to SacWAM

Break

- Base model performance

WEAP

- What is the Water Evaluation and Planning system?
- It is a water resources planning tool
- It compares supplies and demands
- It accounts for storage
- It allocates water during periods of shortage

WEAP

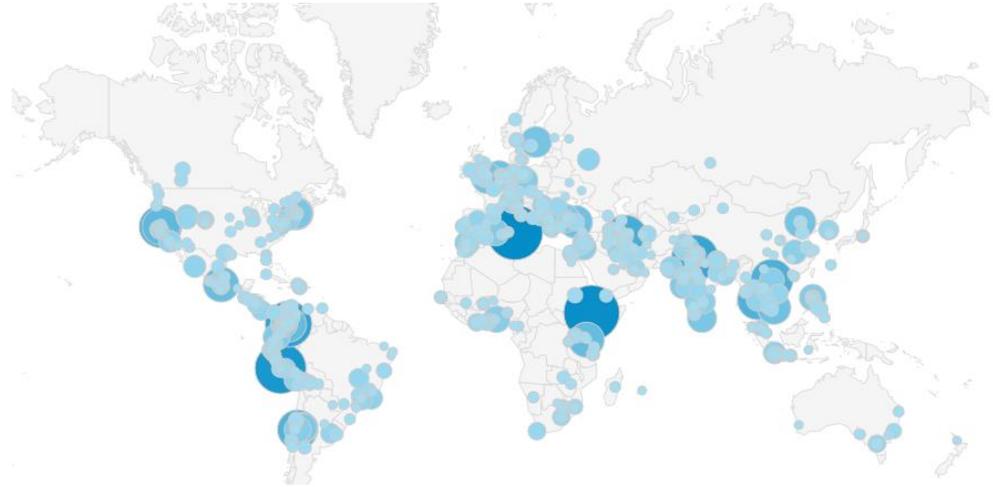
- Comprehensive accounting of water resources system
 - represents the rainfall runoff and snow processes
 - represents infrastructure such as dams, canals, diversions, etc
 - represents operations rules
 - represent elements of the model using a range of complexity
- Objects are pre-built which simplifies model construction
- Several options for the simulation of groundwater
- Does not simulate hydraulics

WEAP

- Flexible integration with other models through API and DLLs
- Modifiable interface through user defined variables
- WEAP is under continuous development and updates are provided automatically
- Training
 - Well developed tutorials
 - On-site and on-line training available

WEAP

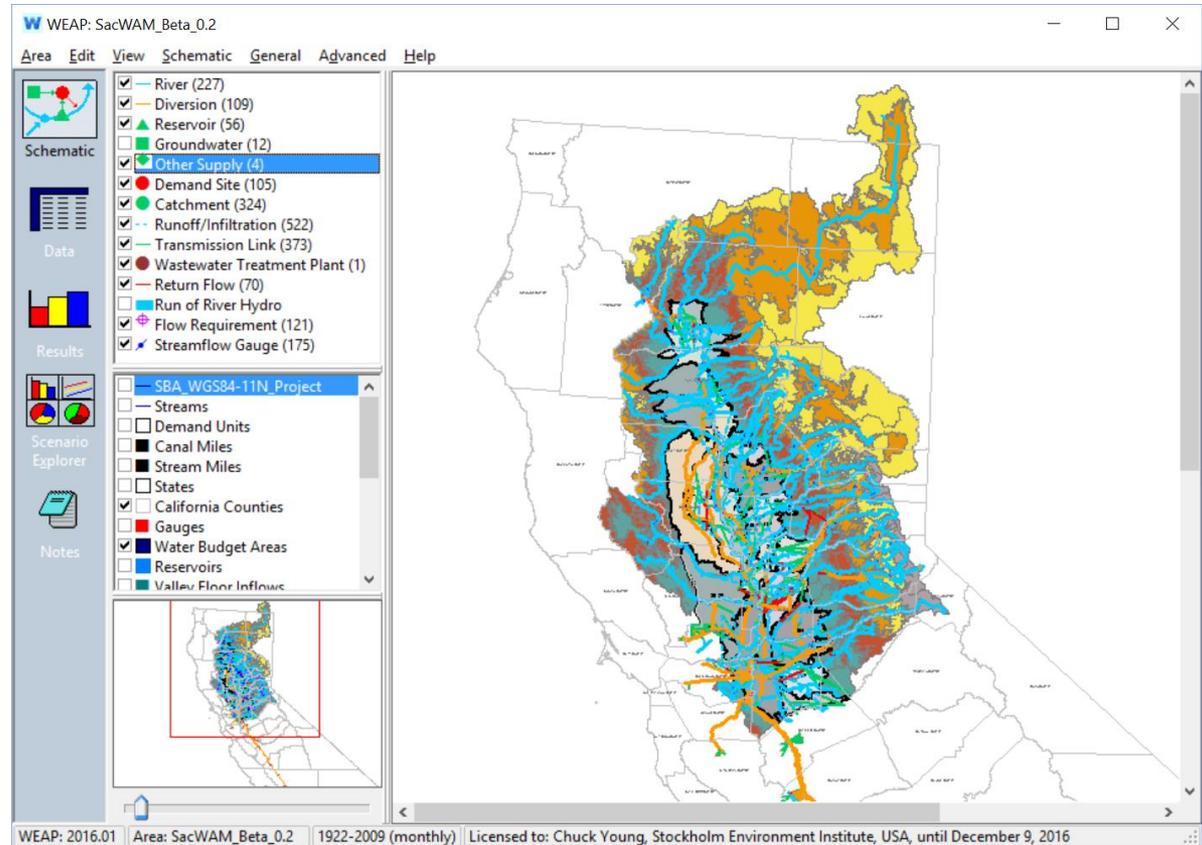
- Widely used
- Under development for 20 yrs
- User forum > 22,000 members
- Used in hundreds of scientific publications



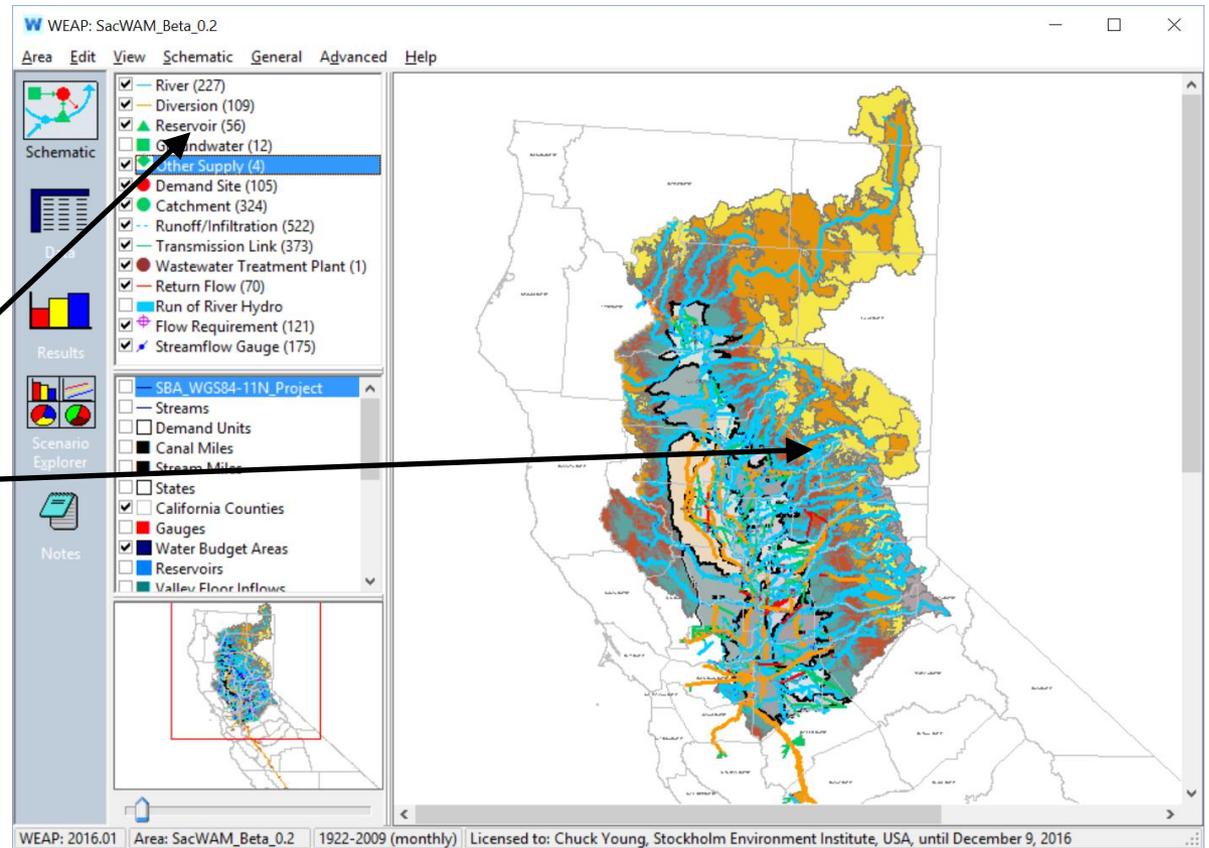
78,000 unique website visits during the past 2 years

WEAP

Well developed graphical user interface



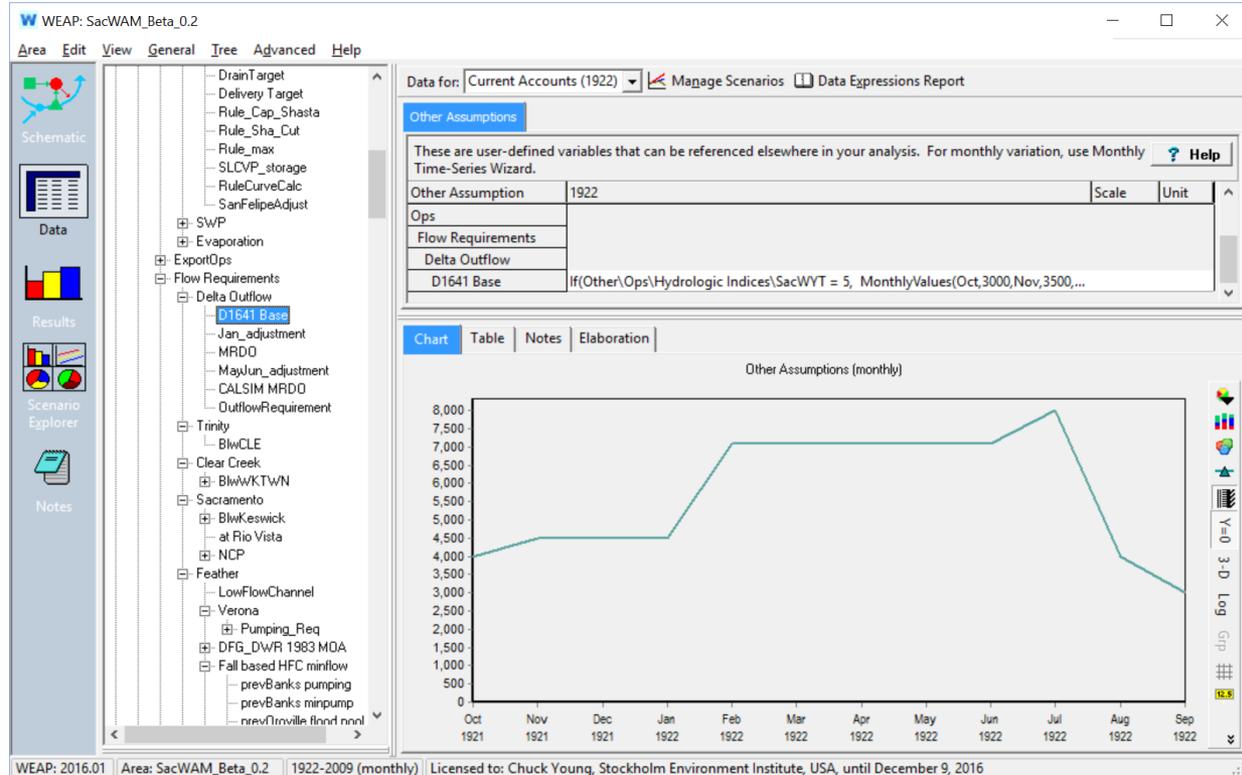
Schematic View



Click and drag
to create a new
schematic
element

Data View

All model parameters are easily accessed through a “data tree”



Data View

All parameters can be specified using the expression builder

The screenshot displays the WEAP software interface for a project named 'WEAP: SacWAM_Beta_0,2'. The main window is in 'Data' view, showing a tree structure of data elements. The 'Delta Outflow' element is selected, and its 'D1641 Base' parameter is highlighted. To the right, the 'Other Assumptions' table is visible, showing a value of 1922 for the year 1922. Below this, a chart titled 'Other Assumptions (monthly)' shows a line graph of values over time from February 1922 to September 1922. The values range from approximately 6,500 to 8,000. The 'Expression Builder' window is open, showing a tree of data elements and a text area containing the following expression:

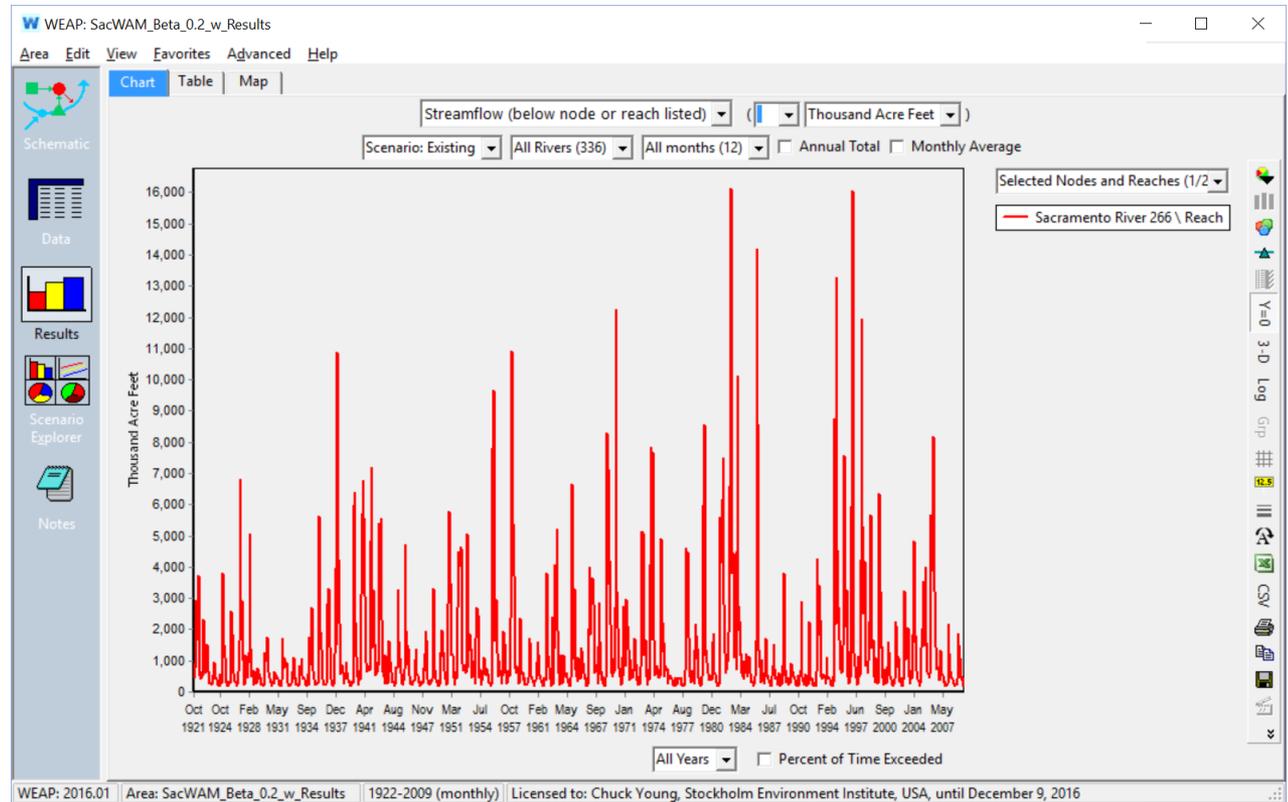
```

Other\Ops\Flow Requirements\Delta Outflow\D1641 Base =
If(Other\Ops\Hydrologic Indices\SacWYT = 5, MonthlyValues(Oct,3000,Nov,3500,Dec,3500,Jan,4500,Feb,7100,Jun,7100,Jul,4000,Aug,3000,Sep,3000),
Other\Ops\Hydrologic Indices\SacWYT = 4, MonthlyValues(Oct,4000,Nov,4500,Dec,4500,Jan,4500,Feb,7100,Jun,7100,Jul,5000,Aug,3500,Sep,3000),
Other\Ops\Hydrologic Indices\SacWYT = 3, MonthlyValues(Oct,4000,Nov,4500,Dec,4500,Jan,4500,Feb,7100,Jun,7100,Jul,6500,Aug,4000,Sep,3000),
Other\Ops\Hydrologic Indices\SacWYT = 2, MonthlyValues(Oct,4000,Nov,4500,Dec,4500,Jan,4500,Feb,7100,Jun,7100,Jul,8000,Aug,4000,Sep,3000),
MonthlyValues(Oct,4000,Nov,4500,Dec,4500,Jan,4500,Feb,7100,Jun,7100,Jul,8000,Aug,4000,Sep,3000))
    
```

The 'Expression Builder' window also includes a 'Functions' tab, a 'Click-and-drag a branch or function to add to the expression below...' instruction, and buttons for 'Finish', 'Verify', and 'Cancel'.

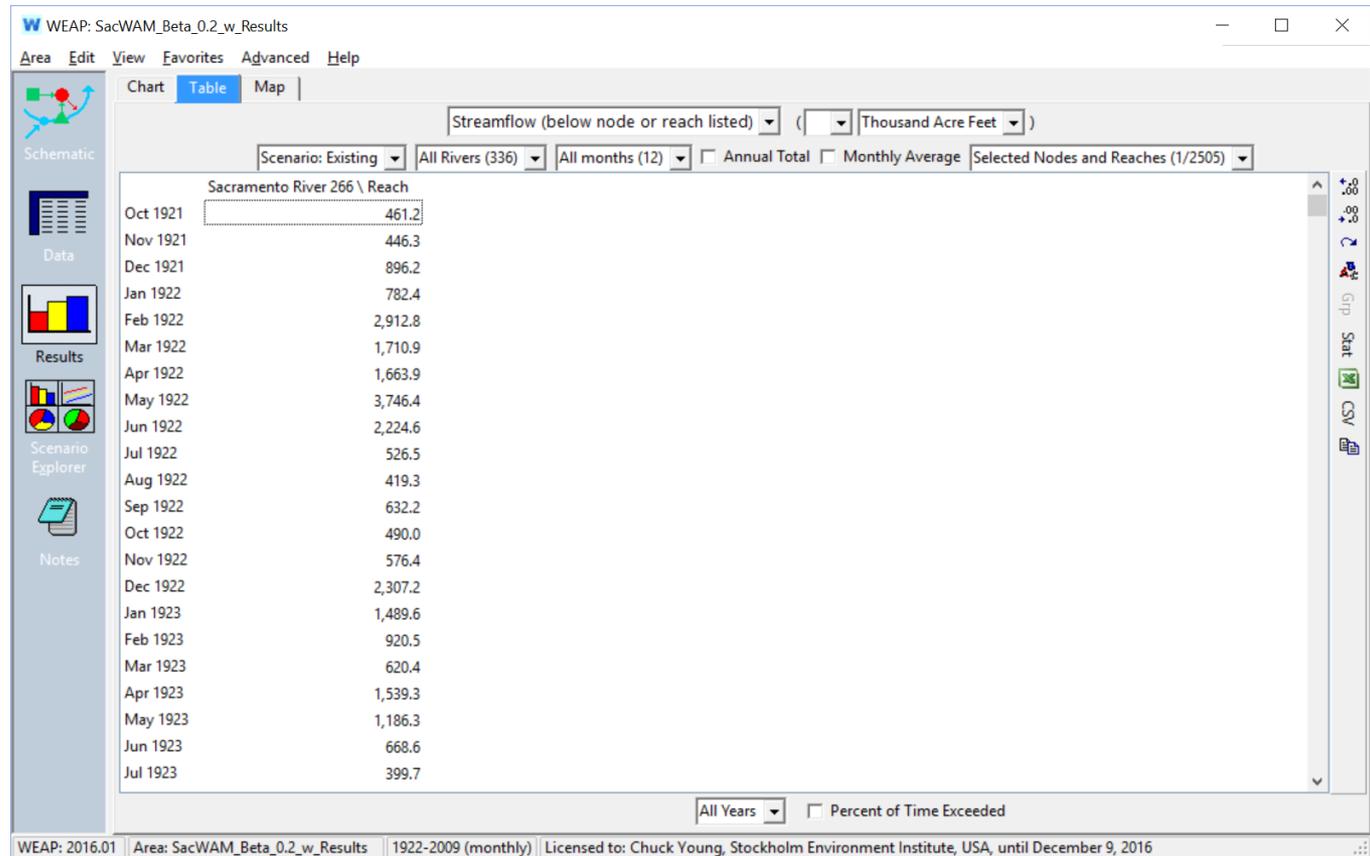
Results View

Results can be shown as graphs



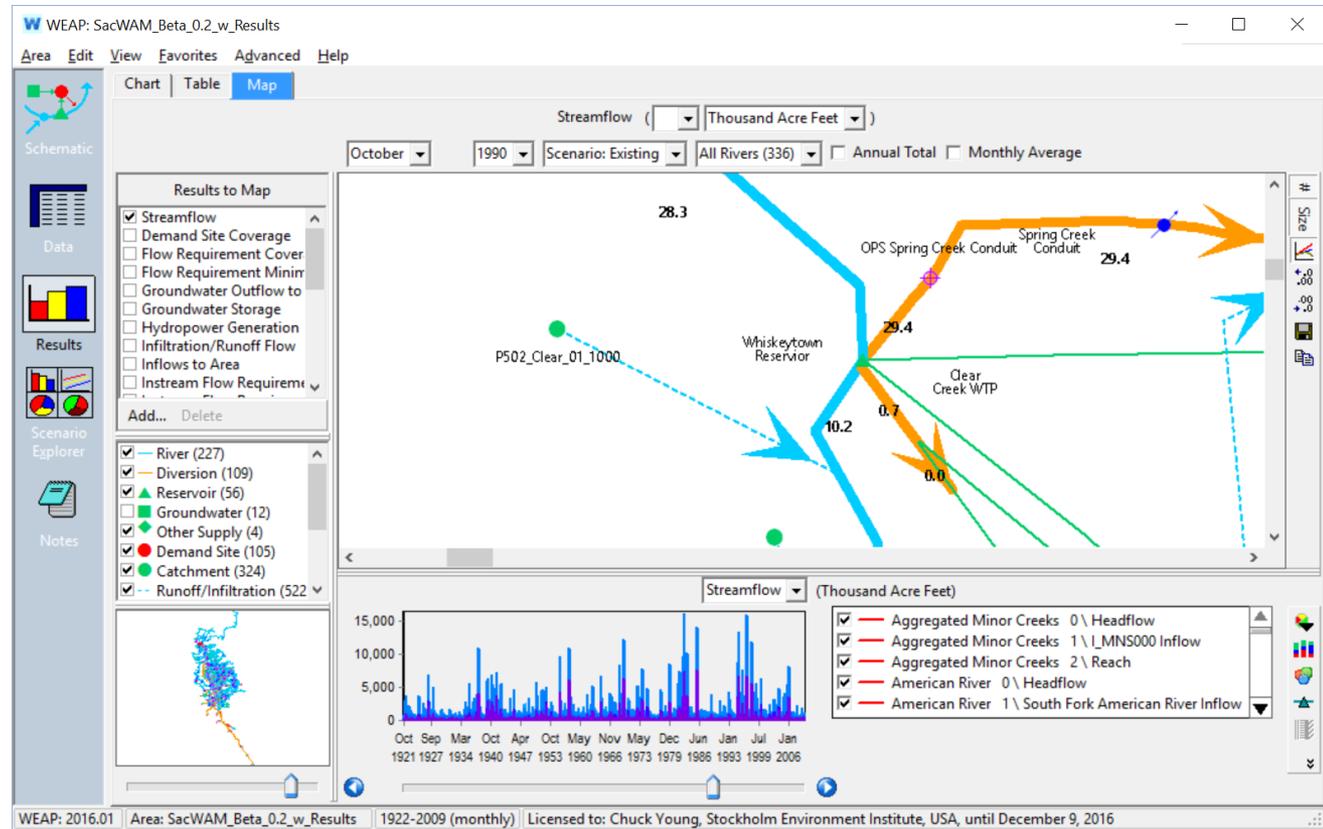
Results View

Results can be shown as tables



Results View

Results can be shown on a map



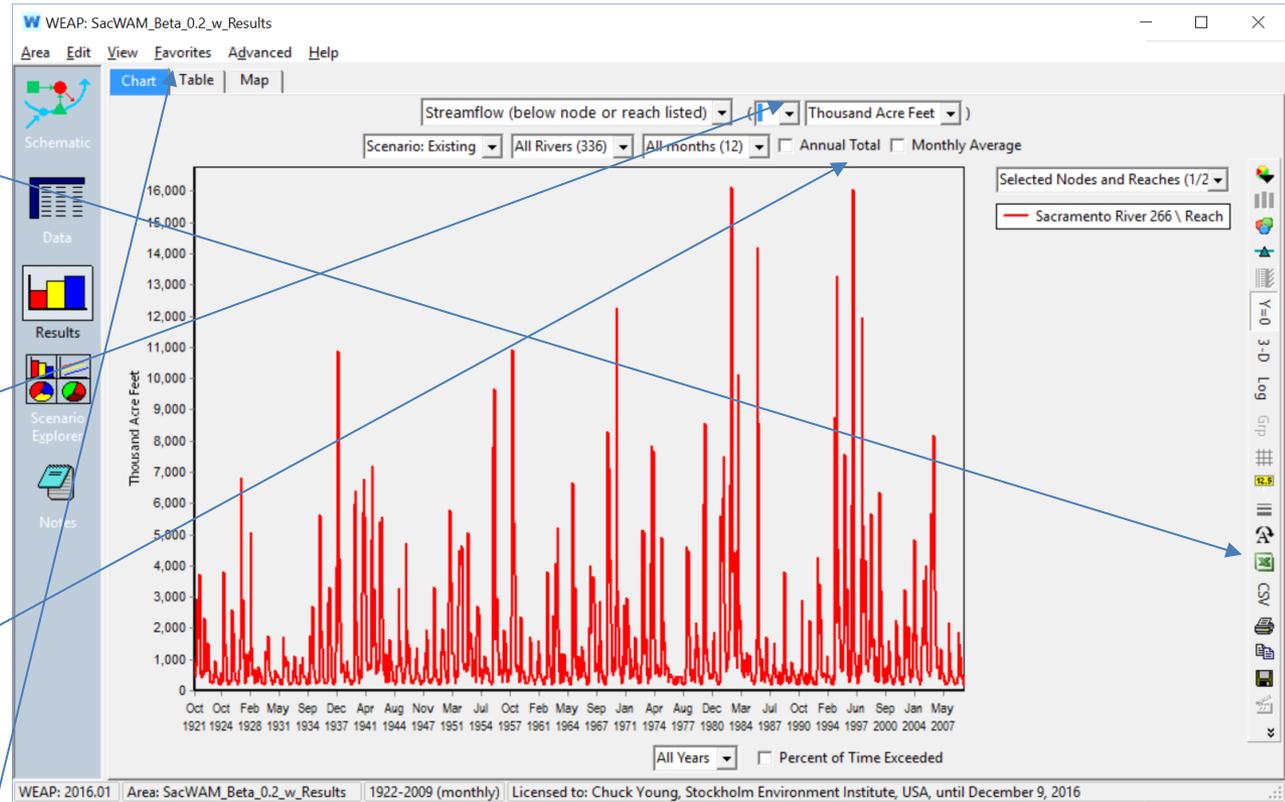
Results View

Data can be exported as .csv or .xls files

Units can be specified

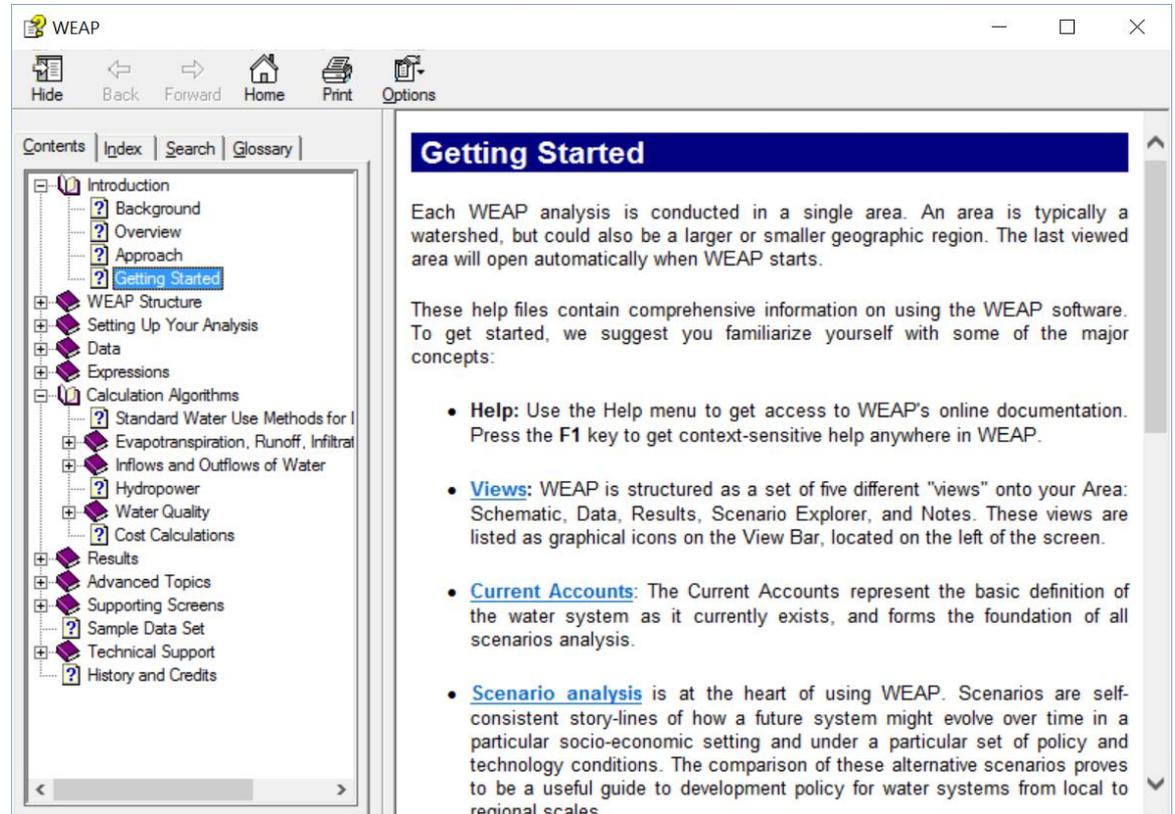
Monthly average and annual totals

Result Favorites



Help Screen

Help is available!



The screenshot shows the WEAP software interface with the help screen open. The window title is 'WEAP'. The top navigation bar includes 'Hide', 'Back', 'Forward', 'Home', 'Print', and 'Options'. The left sidebar contains a 'Contents' menu with the following items: Introduction, Background, Overview, Approach, Getting Started (highlighted), WEAP Structure, Setting Up Your Analysis, Data, Expressions, Calculation Algorithms (with sub-items: Standard Water Use Methods for I, Evapotranspiration, Runoff, Infiltrat, Inflows and Outflows of Water, Hydropower, Water Quality, Cost Calculations), Results, Advanced Topics, Supporting Screens, Sample Data Set, Technical Support, and History and Credits. The main content area is titled 'Getting Started' and contains the following text and list:

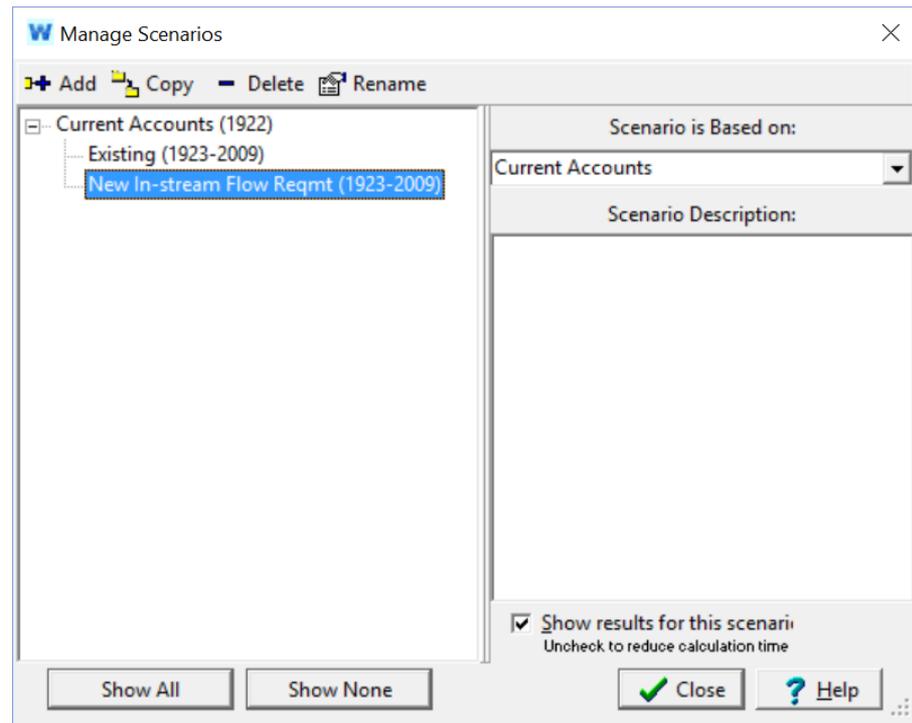
Each WEAP analysis is conducted in a single area. An area is typically a watershed, but could also be a larger or smaller geographic region. The last viewed area will open automatically when WEAP starts.

These help files contain comprehensive information on using the WEAP software. To get started, we suggest you familiarize yourself with some of the major concepts:

- **Help:** Use the Help menu to get access to WEAP's online documentation. Press the F1 key to get context-sensitive help anywhere in WEAP.
- **Views:** WEAP is structured as a set of five different "views" onto your Area: Schematic, Data, Results, Scenario Explorer, and Notes. These views are listed as graphical icons on the View Bar, located on the left of the screen.
- **Current Accounts:** The Current Accounts represent the basic definition of the water system as it currently exists, and forms the foundation of all scenarios analysis.
- **Scenario analysis** is at the heart of using WEAP. Scenarios are self-consistent story-lines of how a future system might evolve over time in a particular socio-economic setting and under a particular set of policy and technology conditions. The comparison of these alternative scenarios proves to be a useful guide to development policy for water systems from local to regional scales.

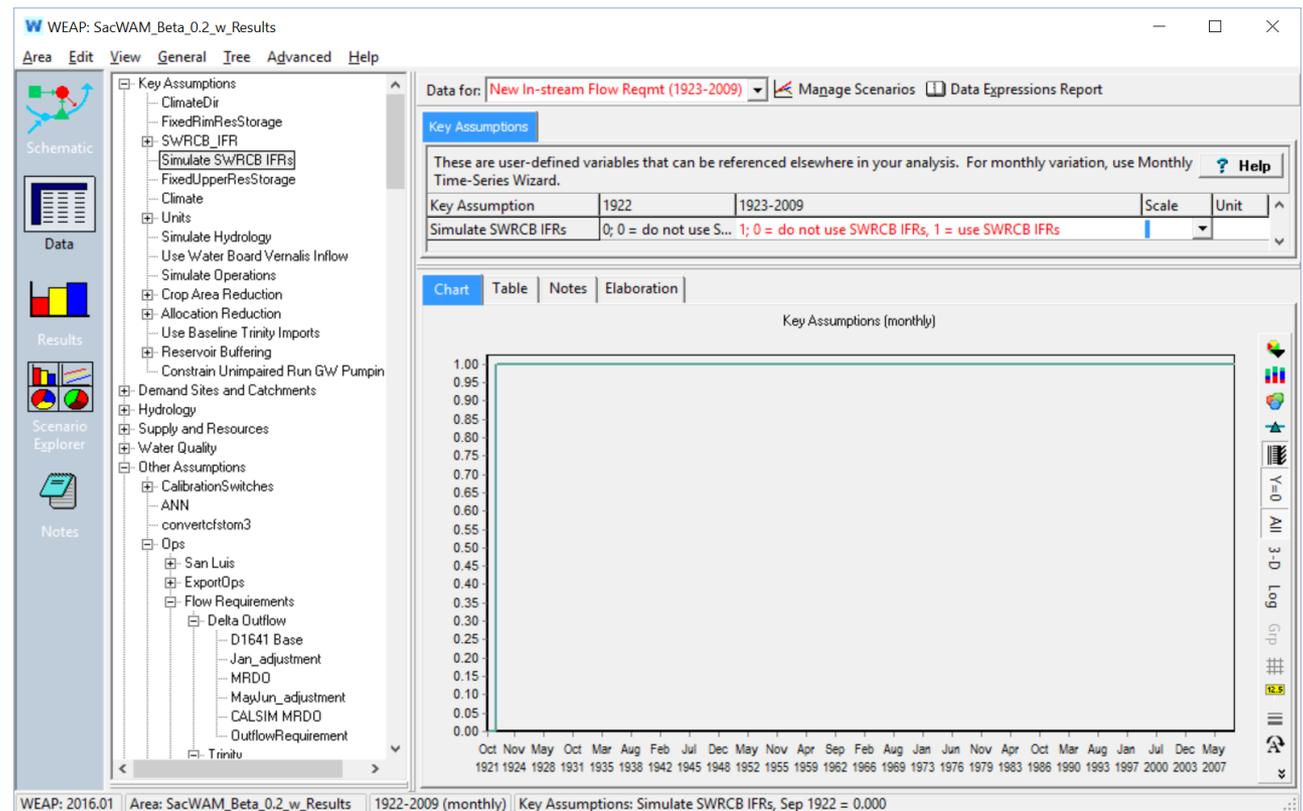
Scenarios

Scenarios are easily created



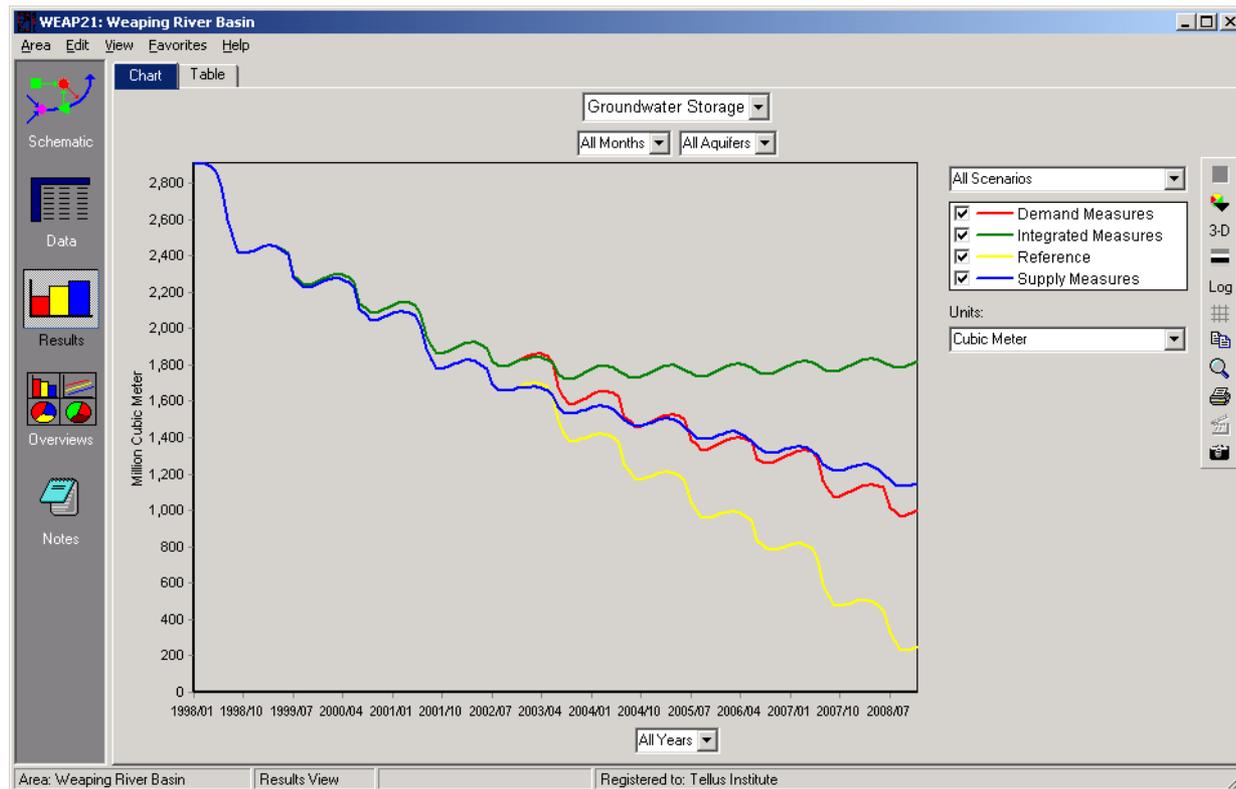
Scenarios

WEAP tracks parameters in each scenario

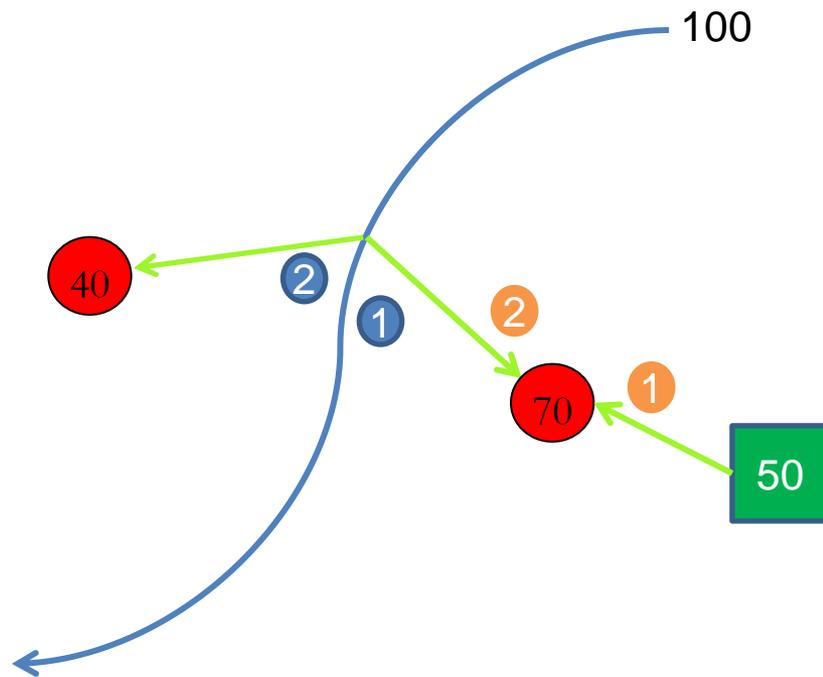


Scenarios

- Results from each scenario can be displayed simultaneously

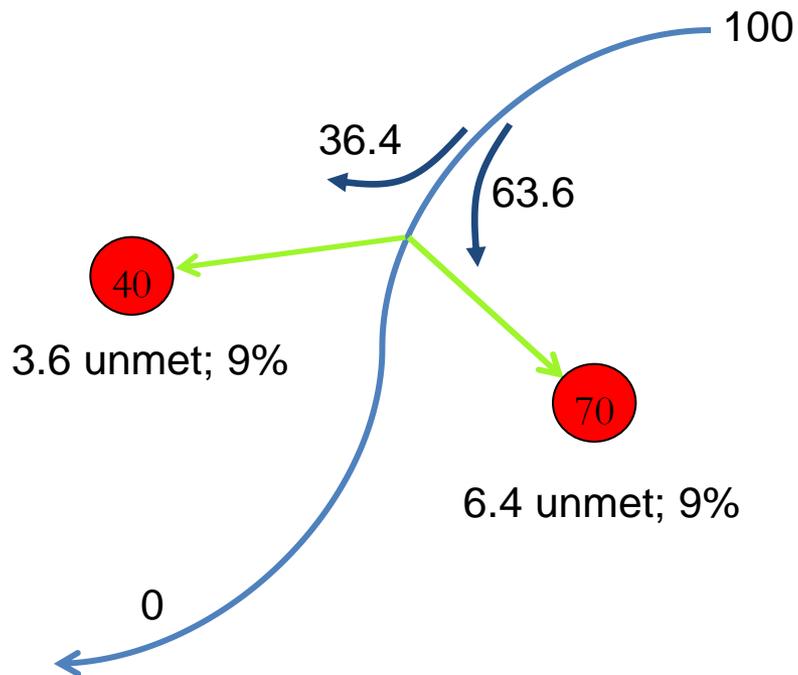


Water Allocation



- Solved within each time step
- Solved using a Linear Program (LP)
- Demands are assigned a “priority”
- Sources are assigned a “preference”
- Problem is solved using “allocation order”

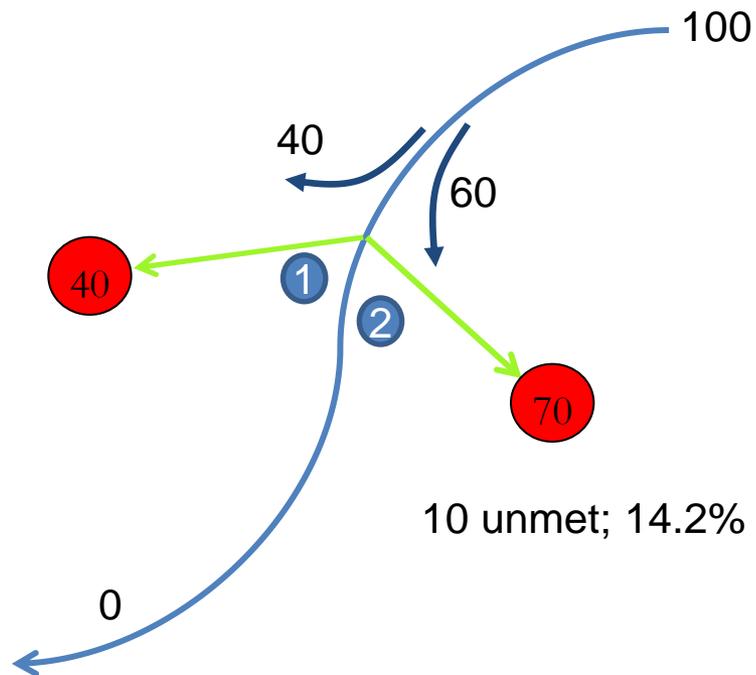
Same Demand Priorities



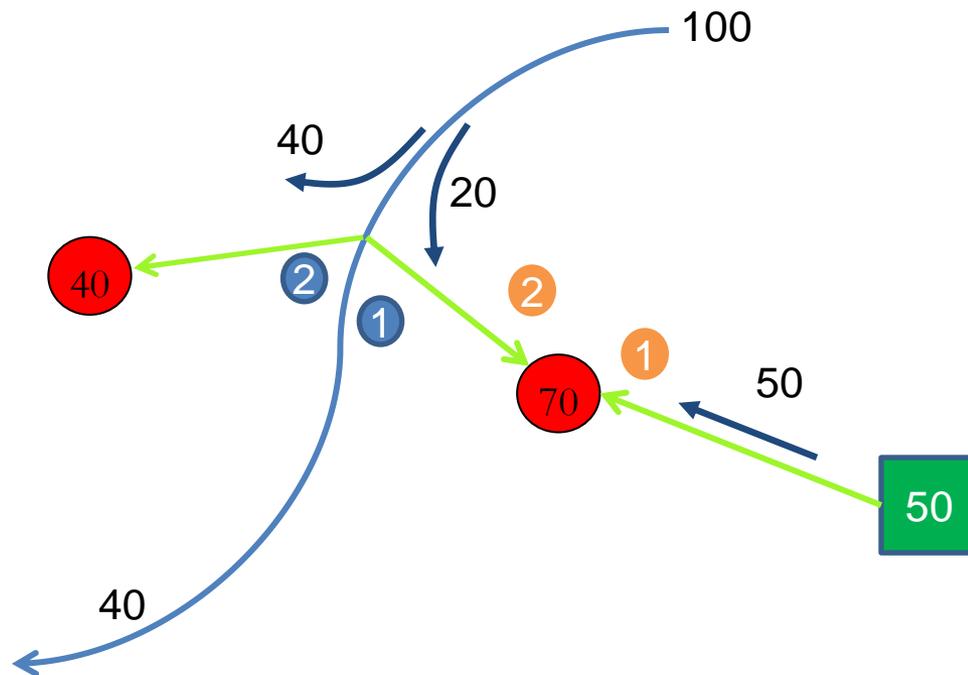
If there are two demands, both with the same priority and insufficient water to meet their needs fully, WEAP will provide **equal % of demand to each.**

Different Demand Priorities

If the priorities differ, WEAP will satisfy the first priority fully before giving water to the lower priority.



Different Supply Preferences



The large demand (70 units) has higher priority for river water, but has a greater preference for groundwater.

WEAP Licensing...

SacWAM Users

- CA public agencies – **Free**
 - This includes irrigation districts, flood control districts, water agencies, etc.
- University students – **Free (\$250)**
- Academic institutions – **Free (\$1,000)**
- Federal Gov/Non-Profits/etc. – **Free (\$3,000)**
- Consultants
 - Single project – **\$3,000**
 - Enterprise – **\$10,000**

Note: the unlicensed version can be used to explore a model

Web site...

www.weap21.org

- Licensing
- Downloads
- Tutorial
- Training videos

Water
Evaluation
And
Planning



WEAP is an initiative of the
Stockholm Environment
Institute.

About WEAP

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[New Version of WEAP Available \(August 2016\)](#)

Welcome to WEAP!

WEAP ("Water Evaluation And Planning" system) is a user-friendly software tool that takes an integrated approach to water resources planning.

Freshwater management challenges are increasingly common. Allocation of limited water resources between agricultural, municipal and environmental uses now requires the full integration of supply, demand, water quality and ecological considerations. The Water Evaluation and Planning system, or WEAP, aims to incorporate these issues into a practical yet robust tool for integrated water resources planning. WEAP is developed by the Stockholm Environment Institute's U.S. Center.

WEAP Highlights

Integrated Approach

Unique approach for conducting integrated water resources planning assessments

Summary

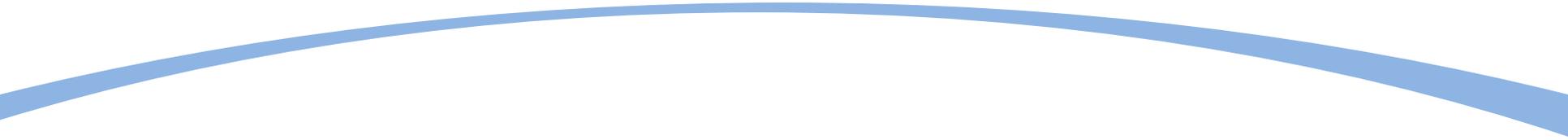
The WEAP software:

- compares demands and supplies
- combines hydrology and water management
- allocates water during shortages

The WEAP software has:

- a well designed interface
- a transparent data structure
- an easy to use scenario capability

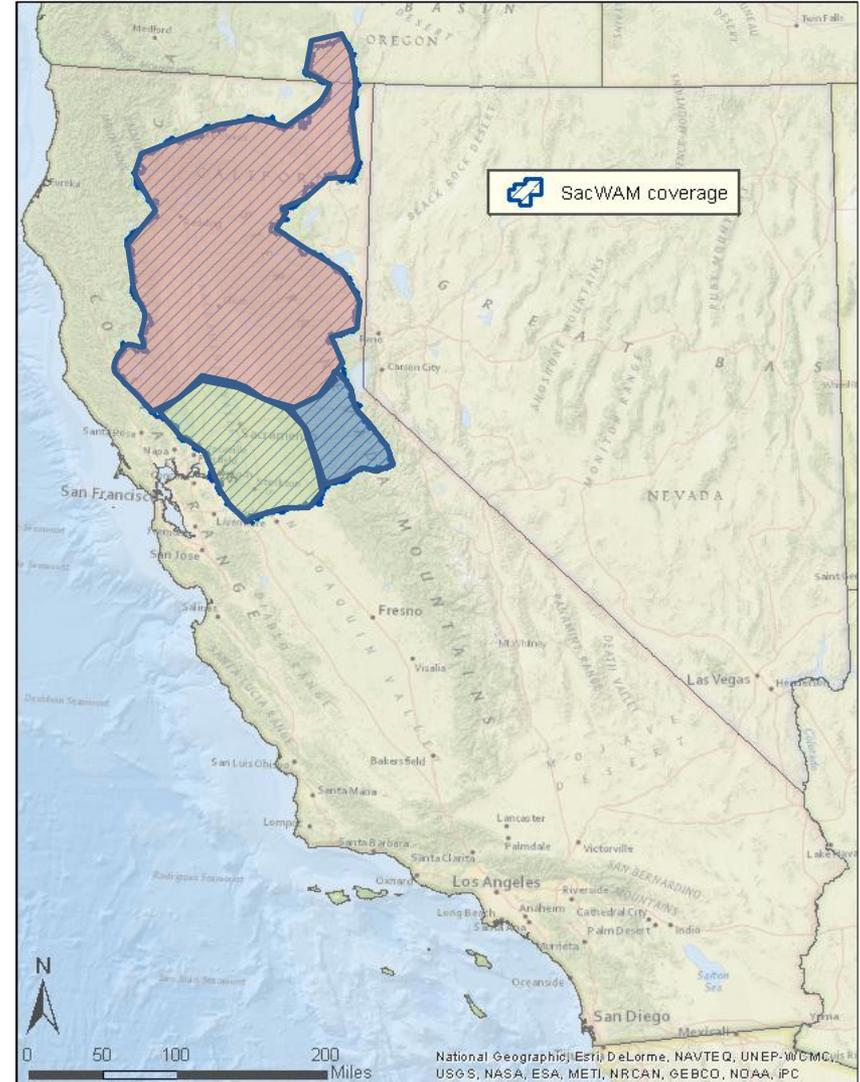
Questions?



AN INTRODUCTION TO SACWAM

Model Extent

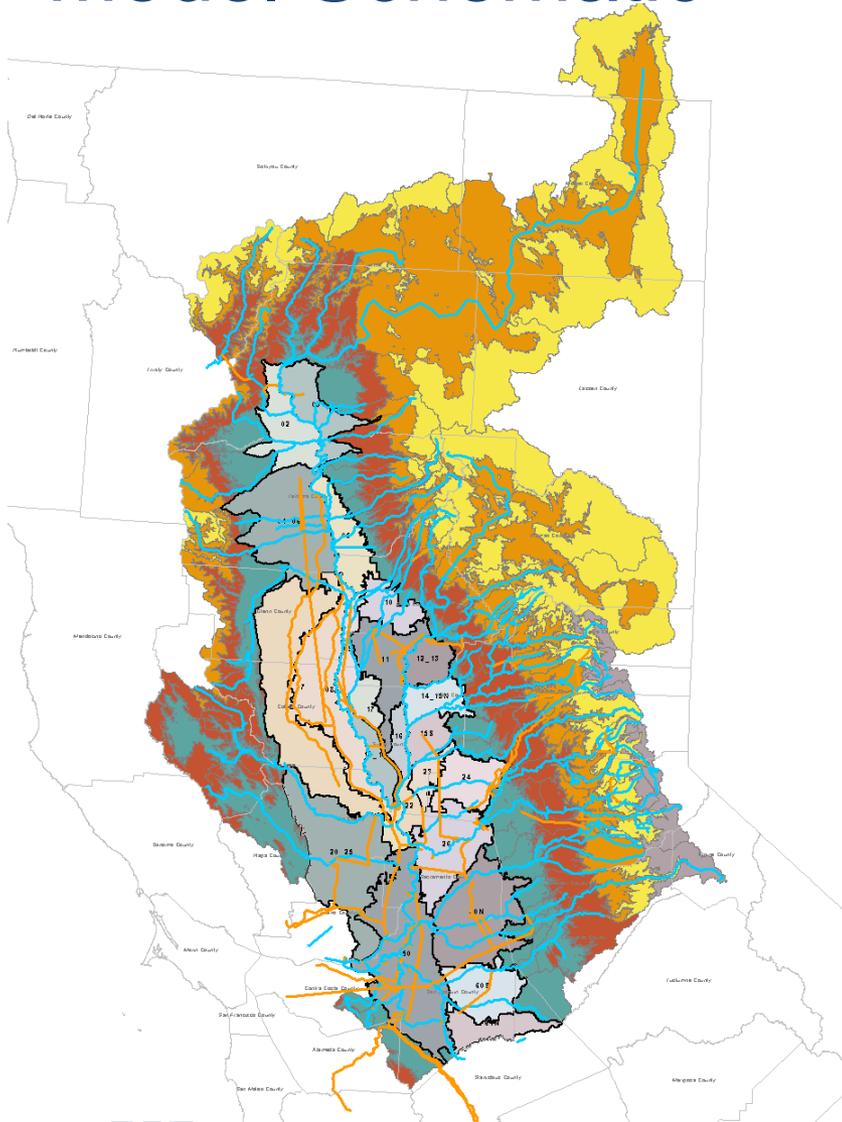
- Sacramento Basin and Trinity Imports
- East Side Streams
- Delta
- South of Delta



Model Features

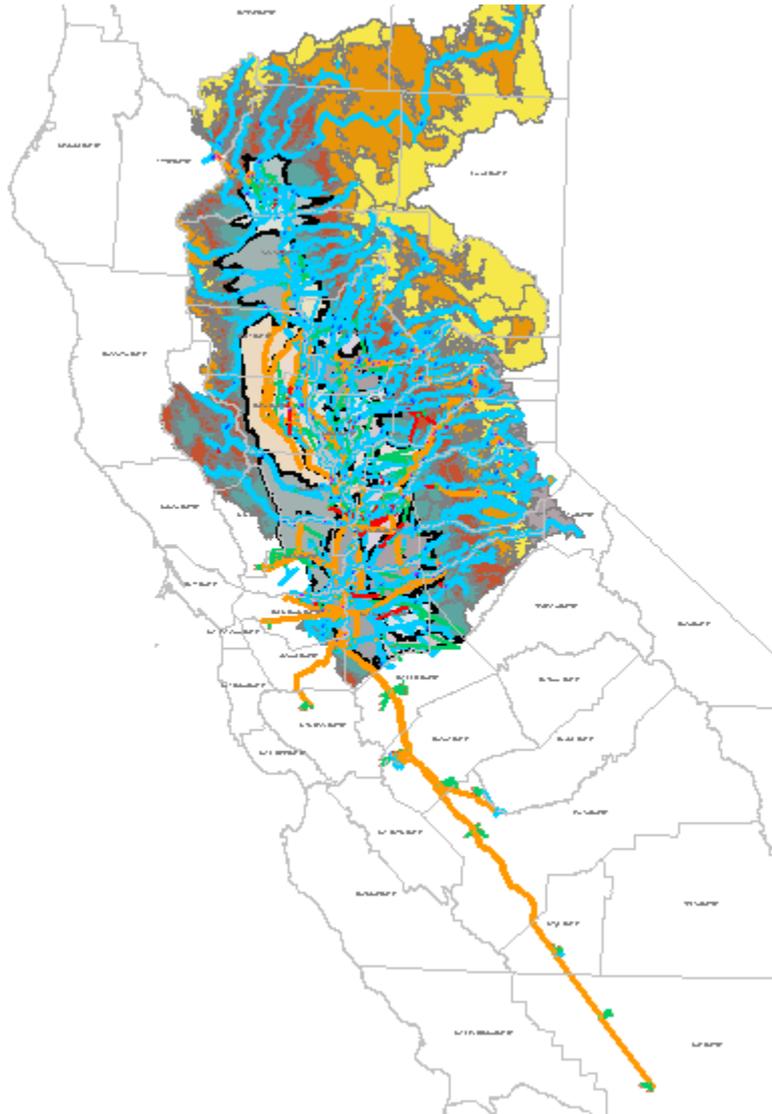
1. Current period of simulation 1922 – 2009
2. Monthly time step
3. Simulation of:
 1. upper watershed hydrology and operations
 2. unimpaired flows
 3. agricultural, urban, and refuge water use
 4. stream flows at points of interest to SWRCB
 5. Delta flows and salinity
 6. CVP/SWP operations
 7. Local project operations

Model Schematic



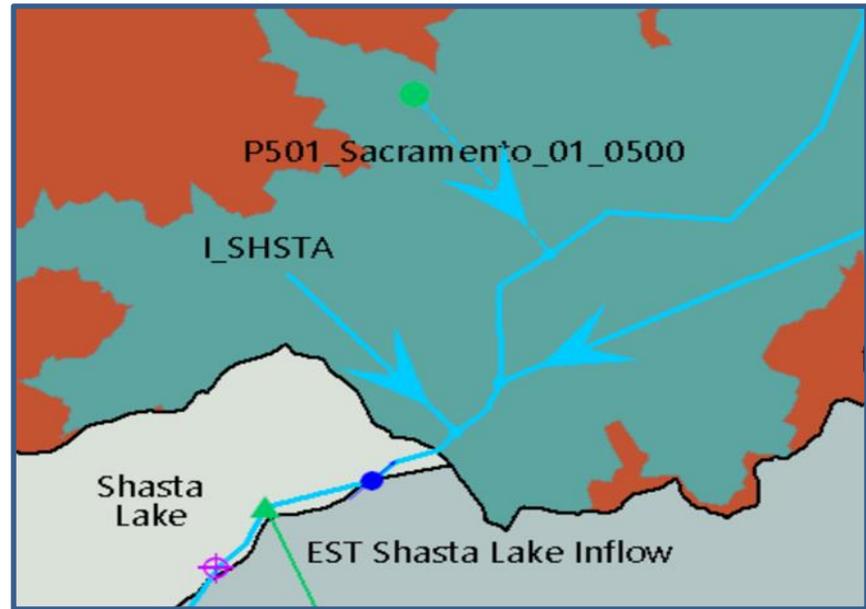
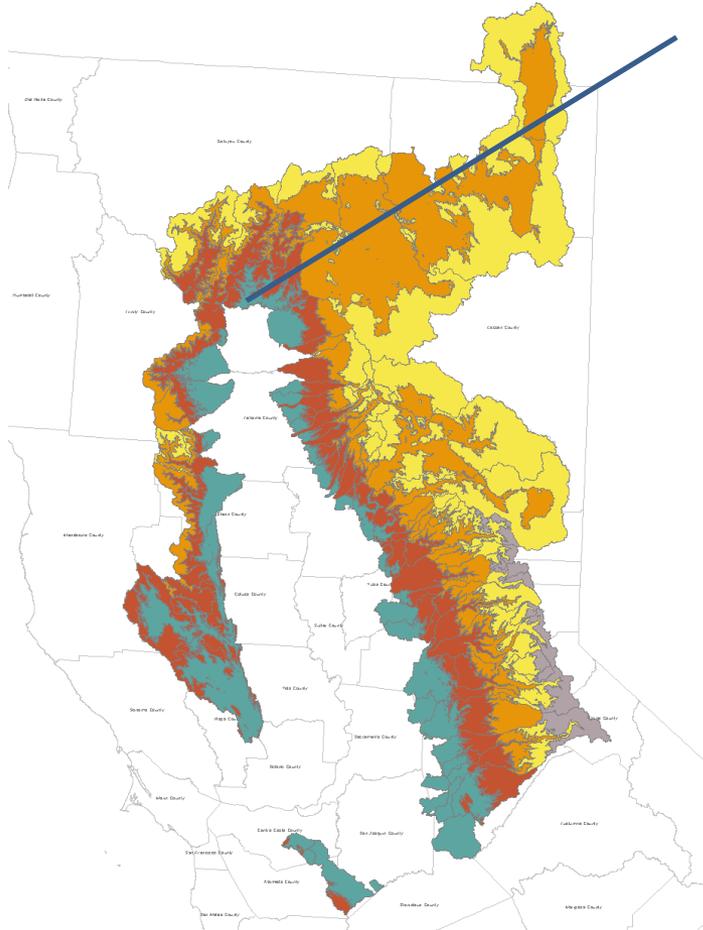
- Rivers and Streams
- Reservoirs (52)
- Urban Demands (103)
- Ag Demand Sites (76)
- Refuges (9)
- Streamflow Gauges (173)
- Flow Requirements (110)

Model Schematic



South of Delta has a simplified representation of San Luis Reservoir, Delta Mendota Canal, and the California Aqueduct

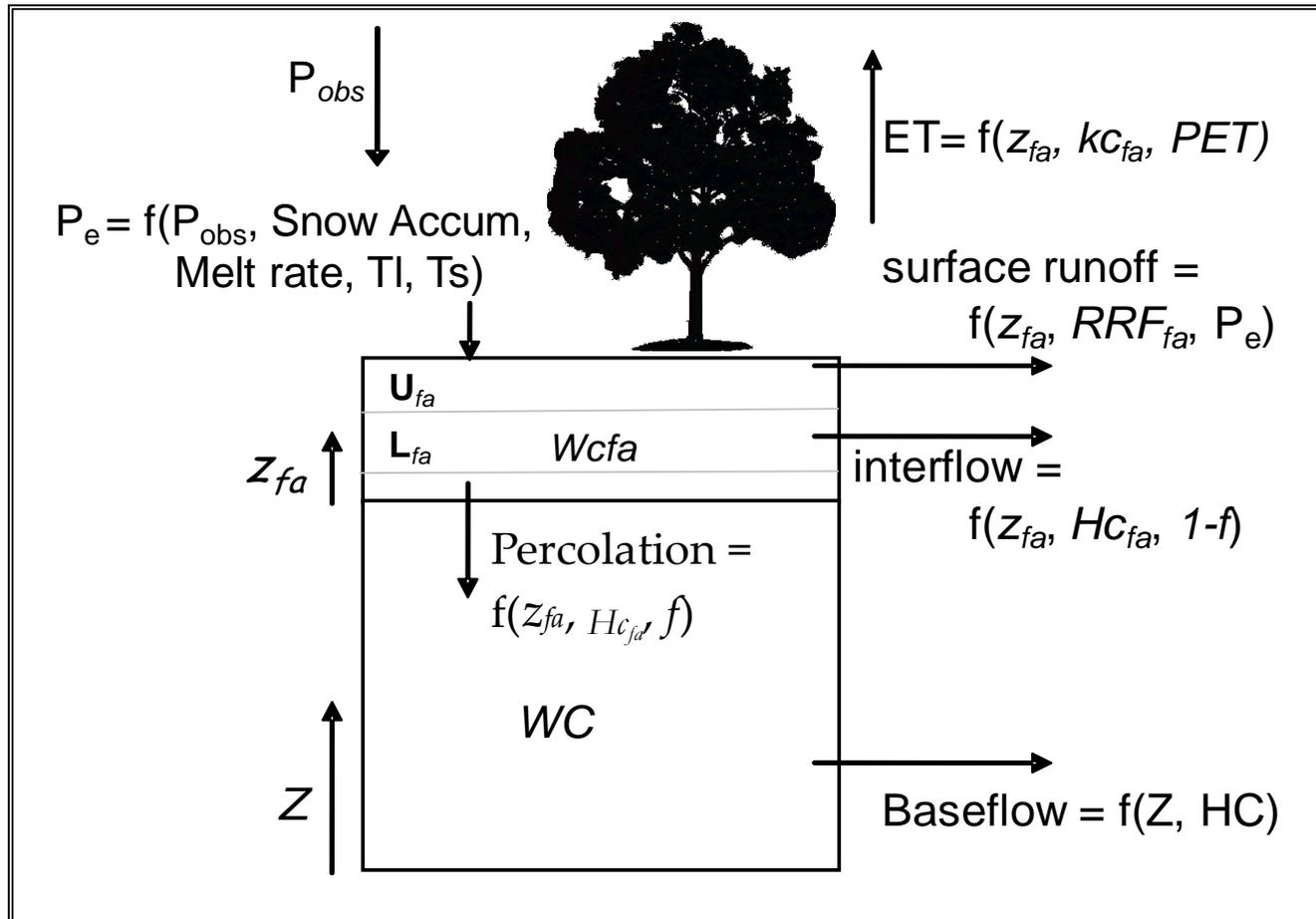
Upper Watersheds



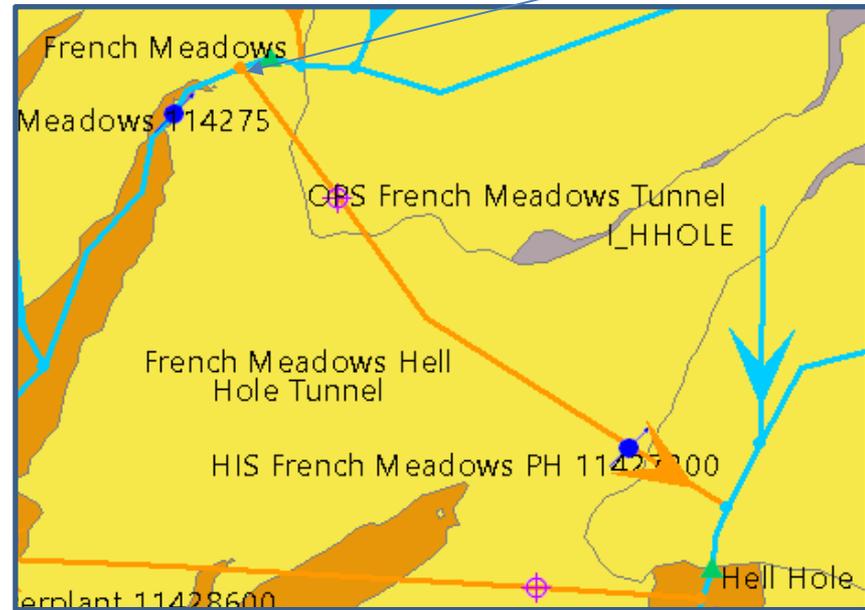
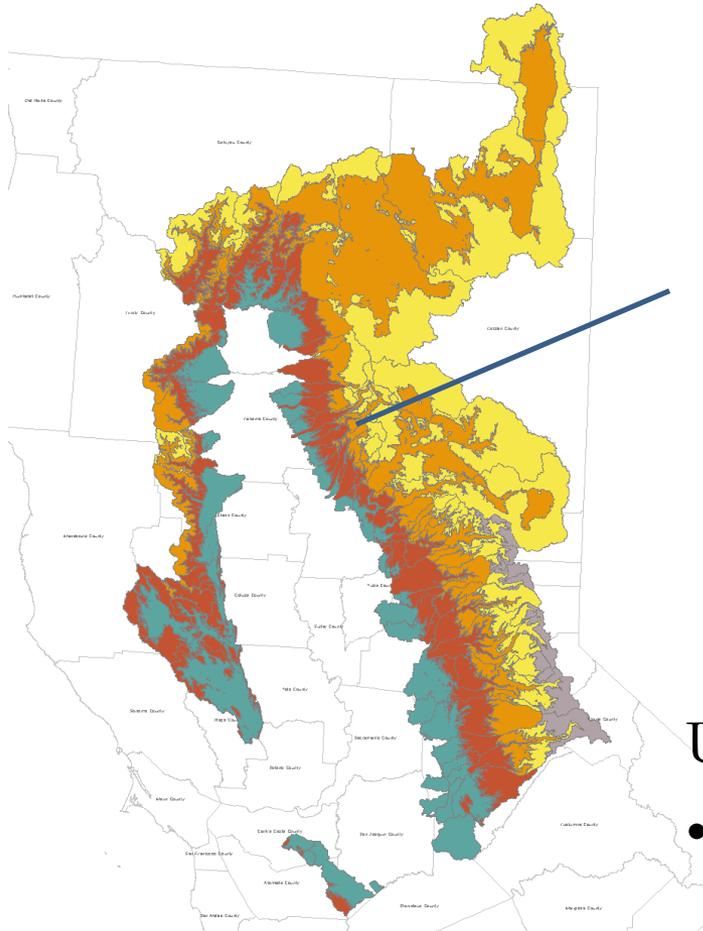
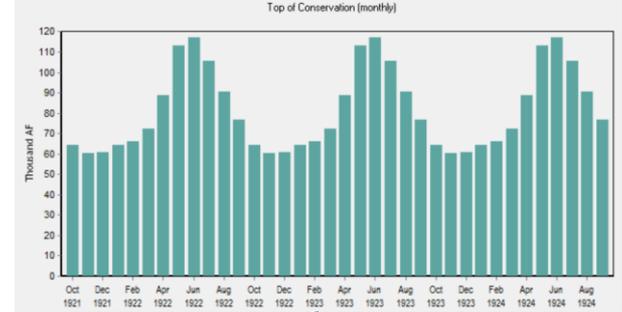
Two simulation options:

1. Specified inflows
2. Catchments

Upper Watershed Hydrology

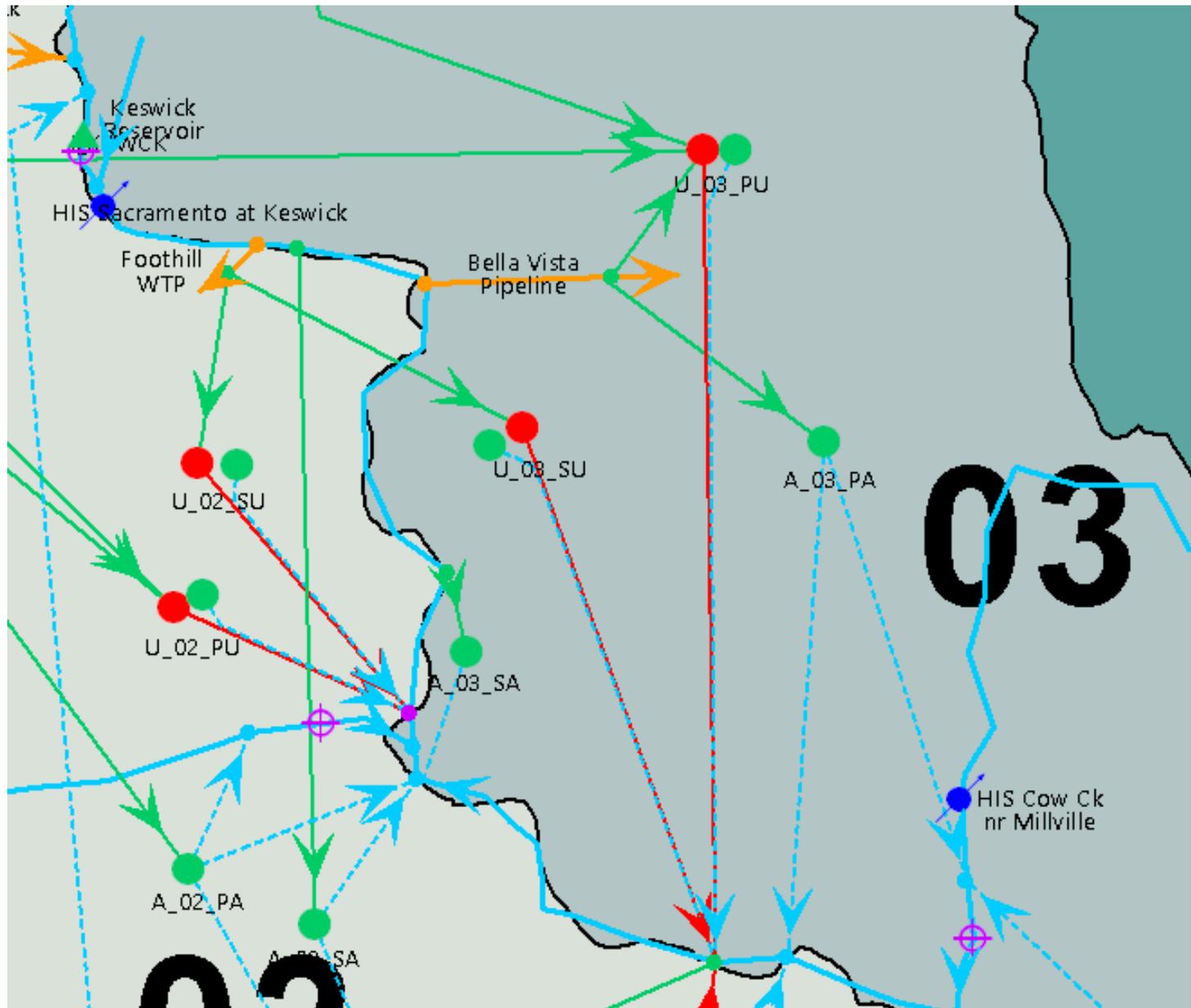


Upper Watersheds



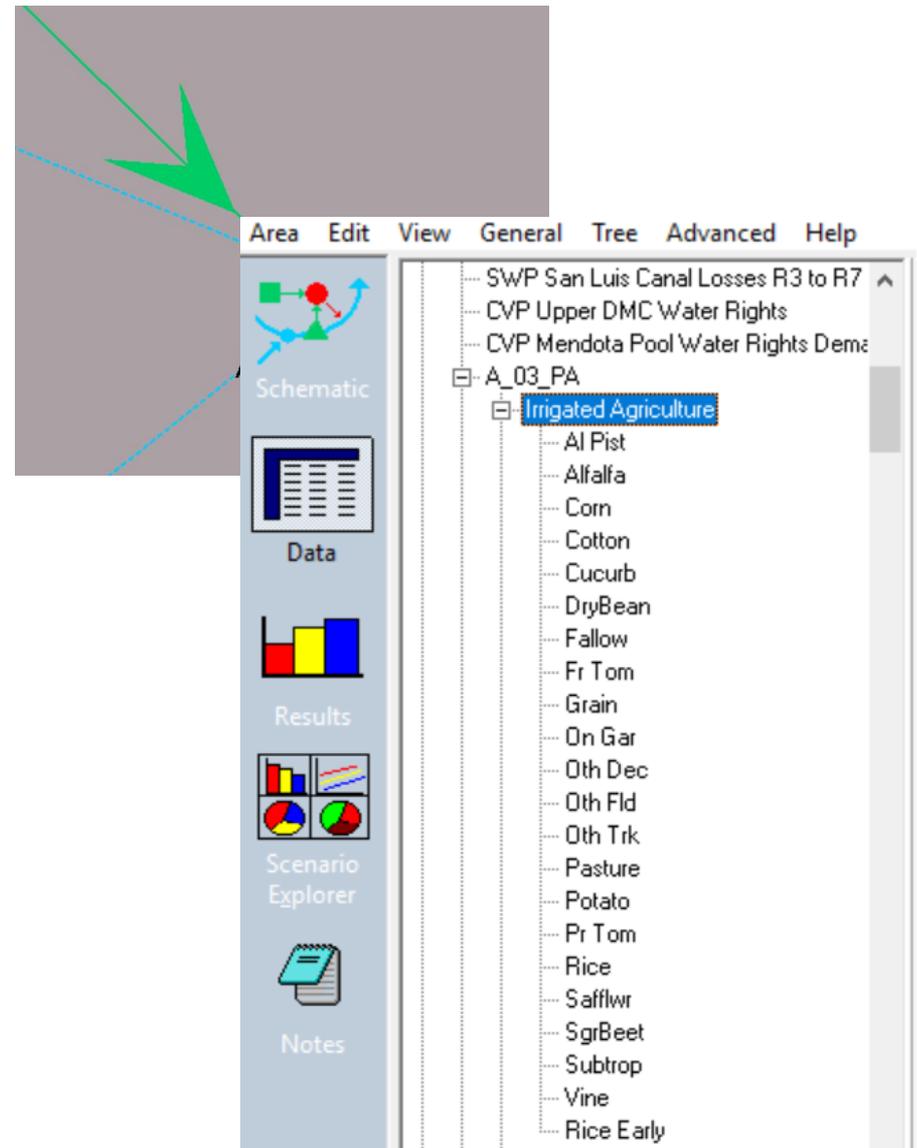
Upper watershed operations

- based on average monthly historical operations
- will soon be refined



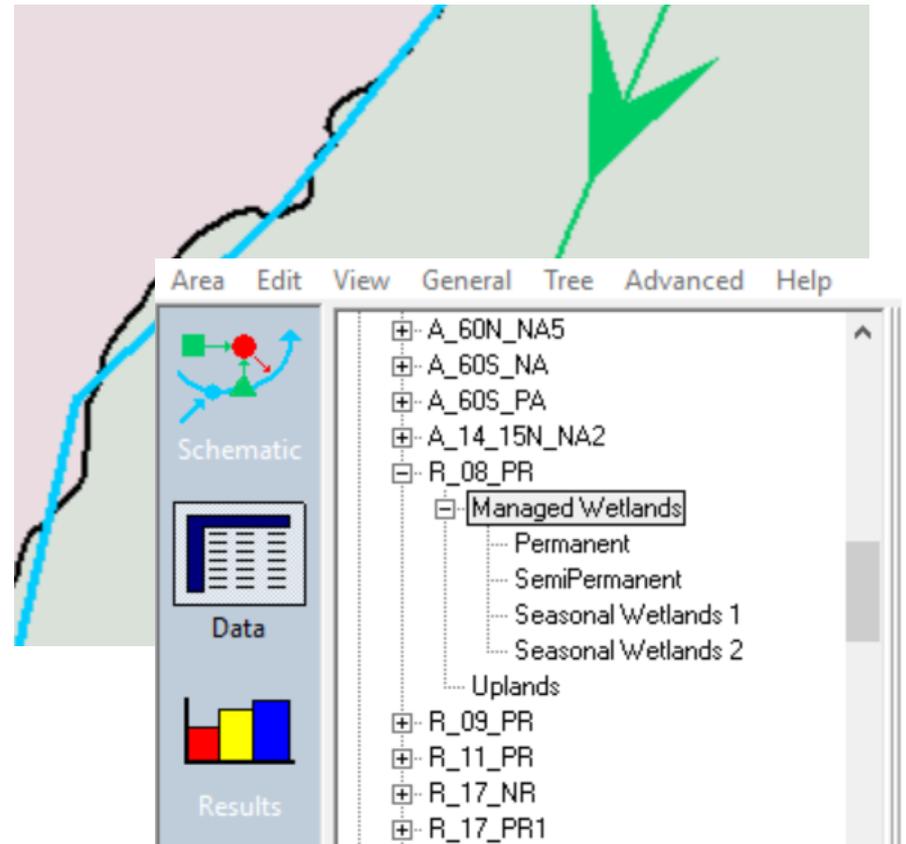
Irrigated Area

- Represented using the “Catchment” node
- 22 crops
- Includes rice flooding



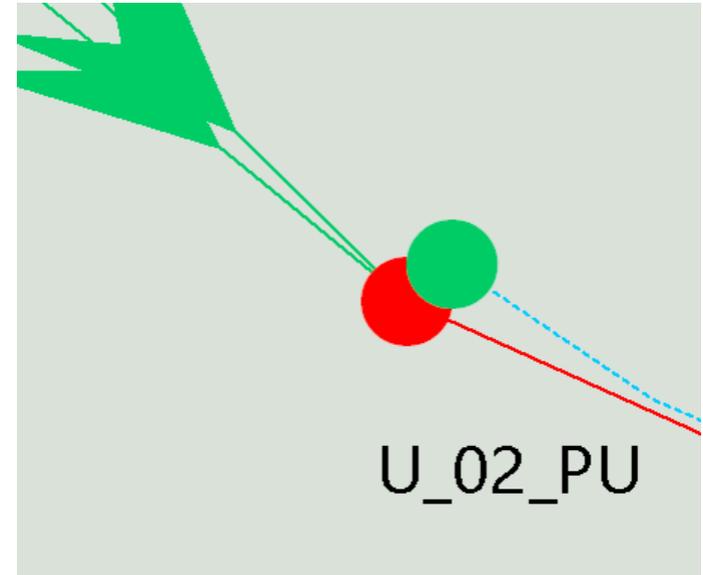
Wildlife Refuges

- Represented using the “Catchment” node
- 4 flooded land types and 1 upland
- Includes permanent and seasonal flooding

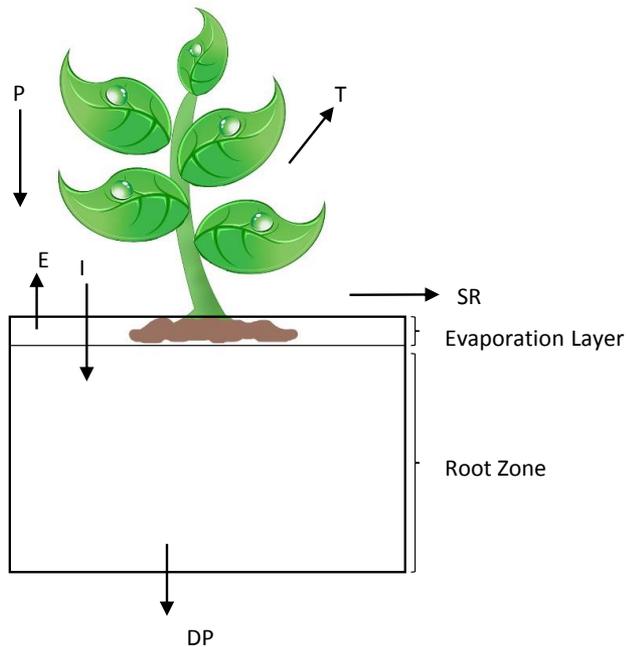


Urban Areas

- Represented using a “Catchment” node and a “Demand” node
- Water use is based on purveyor data

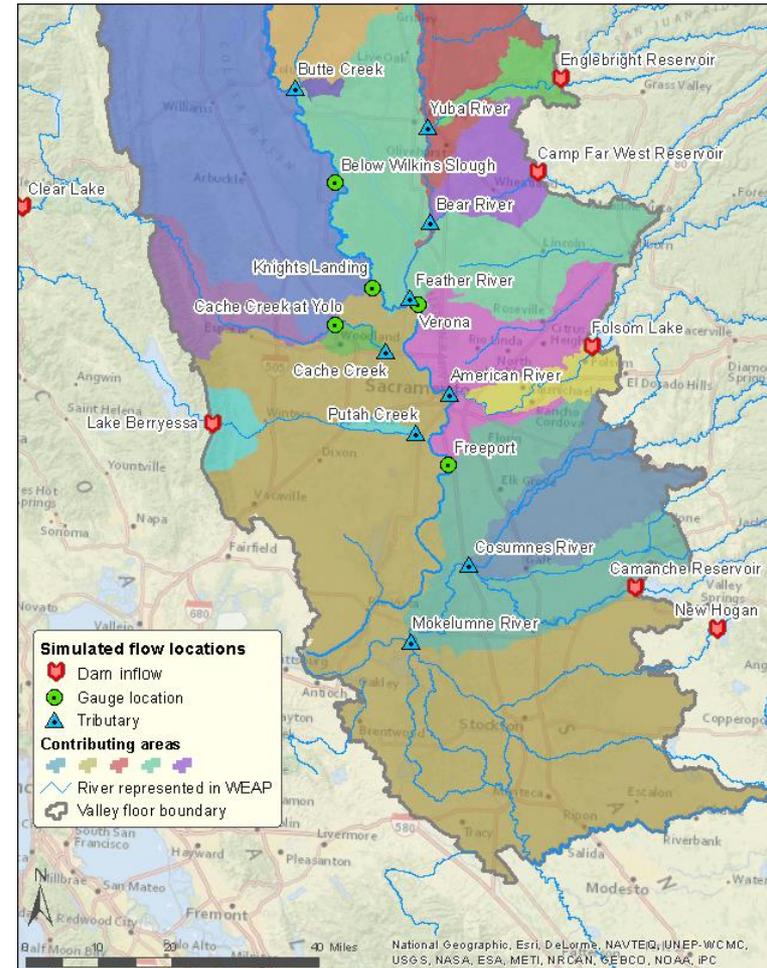
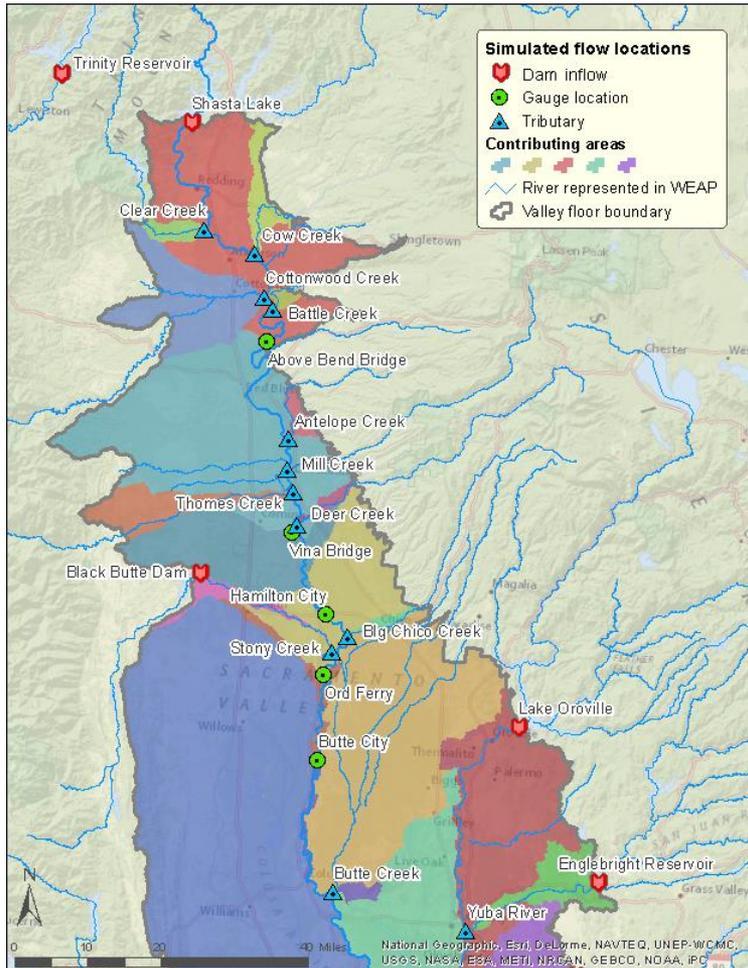


Valley Floor Hydrology

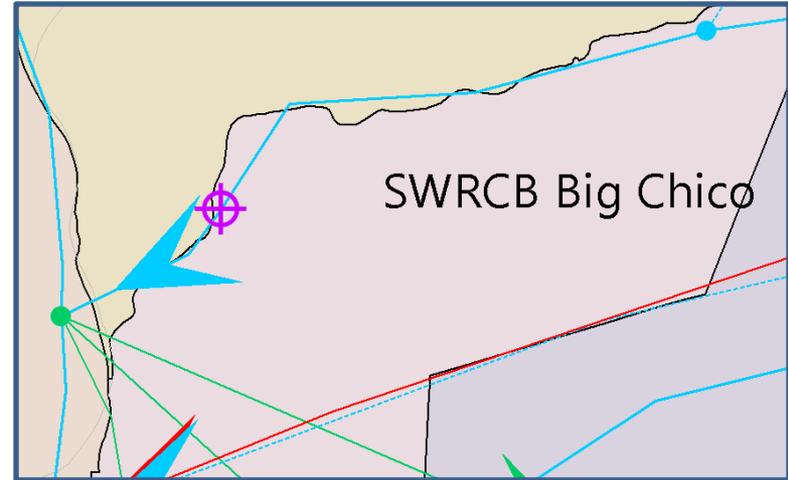
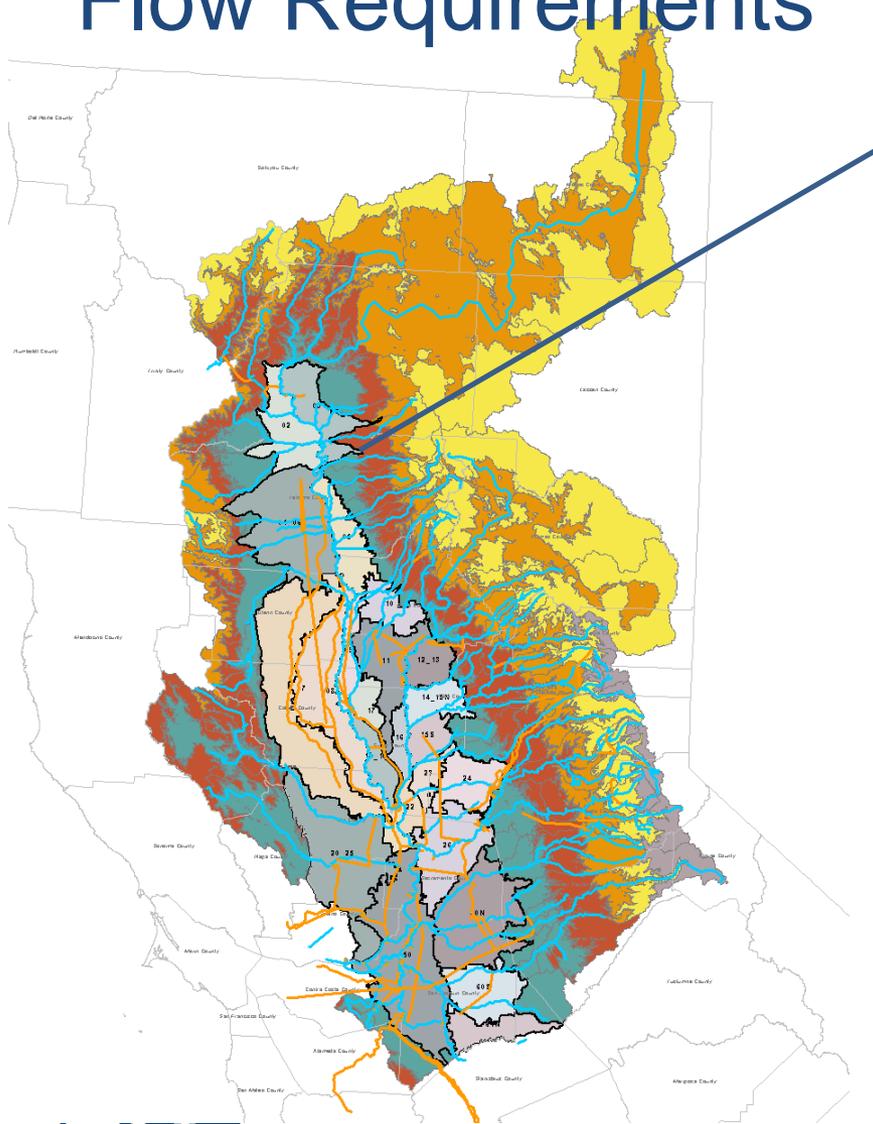


- Daily model (MABIA)
- ET is based on the dual crop coefficient approach in FAO 56
- Infiltration is based on a curve number approach
- ET was calibrated to DWR CUP model

Streamflow Simulation



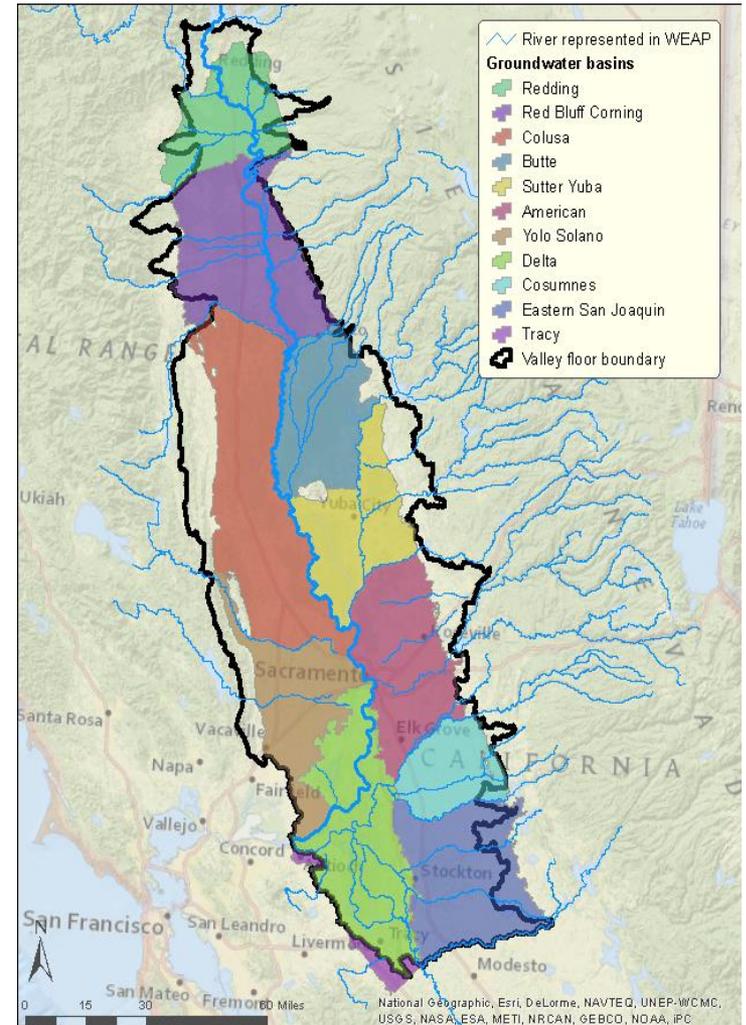
Flow Requirements



New flow requirements are easily added. Currently they exist at the mouth of each stream, below the main reservoirs, and at important locations on the Sacramento River.

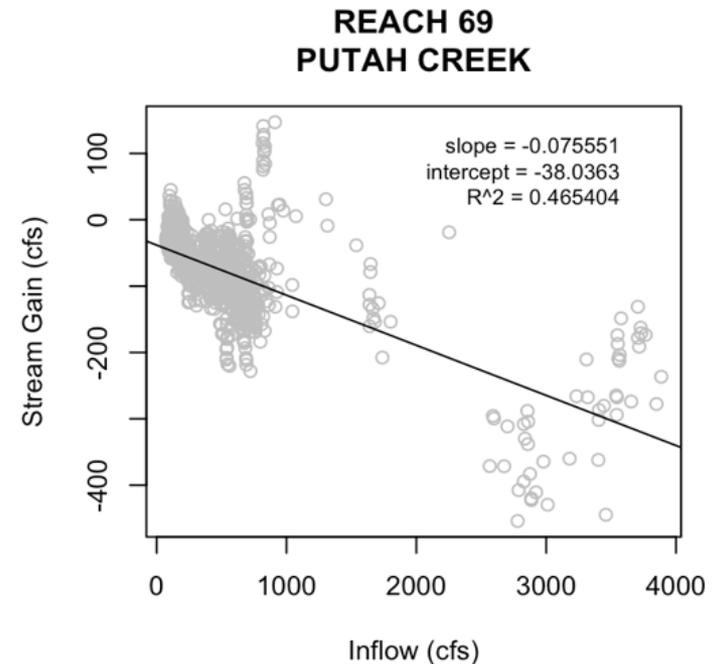
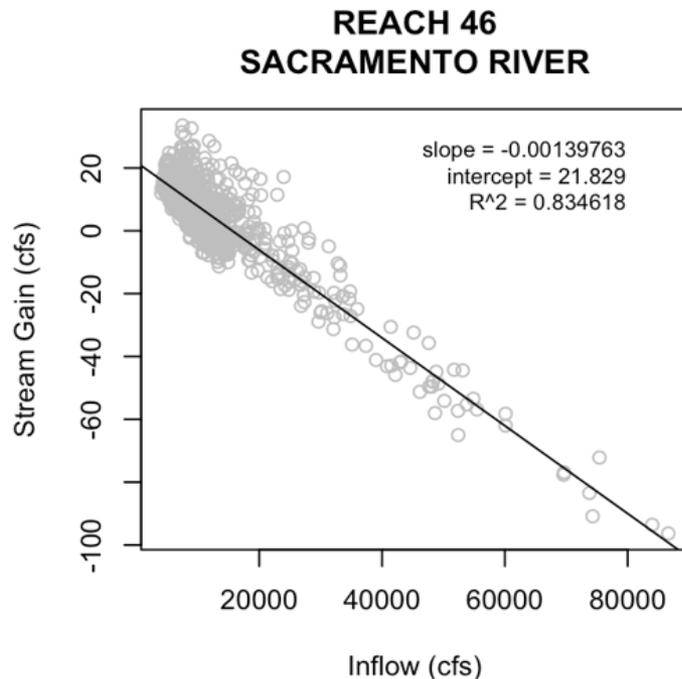
Groundwater Simulation

- Eleven groundwater basins based on Bulletin 118.
- Interactions include:
 - Areal recharge
 - Canal losses
 - Groundwater pumping
 - Stream-aquifer interactions



Groundwater Simulation

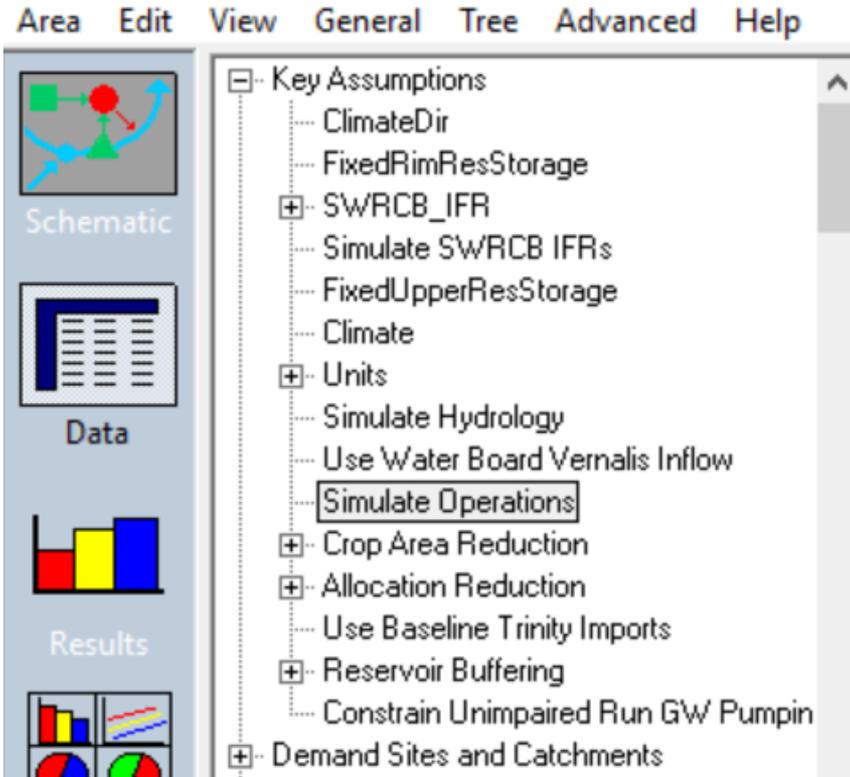
- Stream aquifer interactions are based on a linear approximation of C2VSim



Unimpaired Flows

WEAP: SacWAM_Beta_0.2_w_Results

Area Edit View General Tree Advanced Help



Key Assumptions

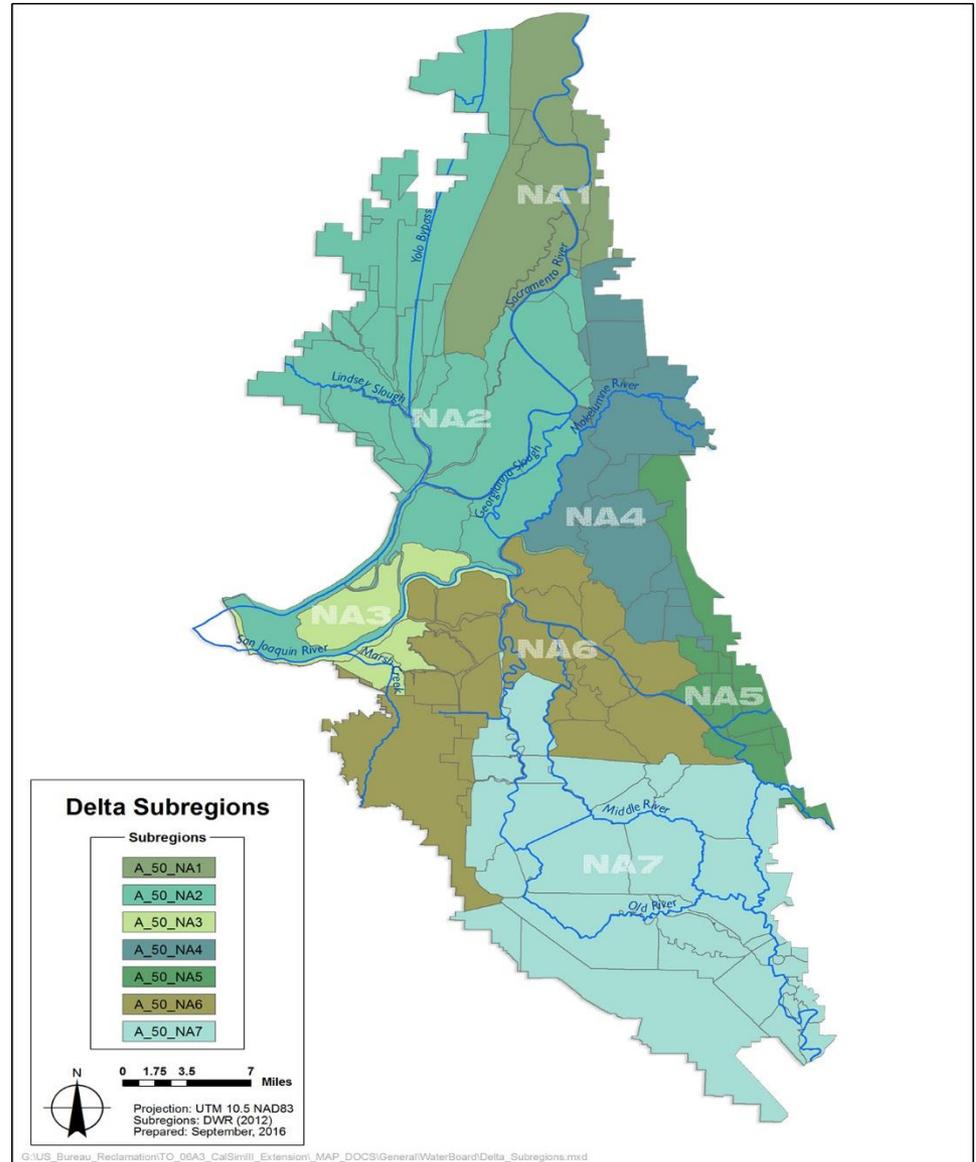
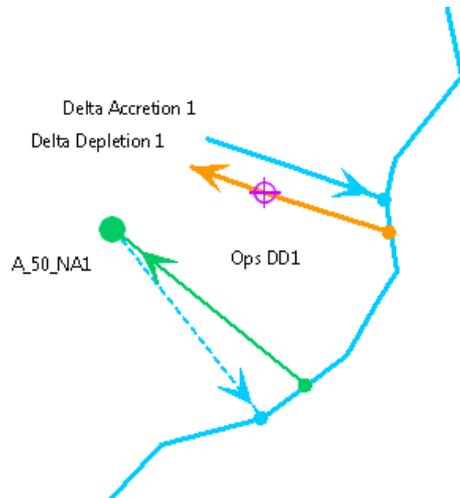
- ClimateDir
- FixedRimResStorage
- SWRCB_IFR
- Simulate SWRCB IFRs
- FixedUpperResStorage
- Climate
- Units
- Simulate Hydrology
- Use Water Board Vernalis Inflow
- Simulate Operations
- Crop Area Reduction
- Allocation Reduction
- Use Baseline Trinity Imports
- Reservoir Buffering
- Constrain Unimpaired Run GW Pumpin
- Demand Sites and Catchments

- Surface water diversions, in-stream flow requirements, and reservoirs are turned off
- Bypasses remain on
- Stream aquifer interactions remain on
- Groundwater pumping is restricted to base run

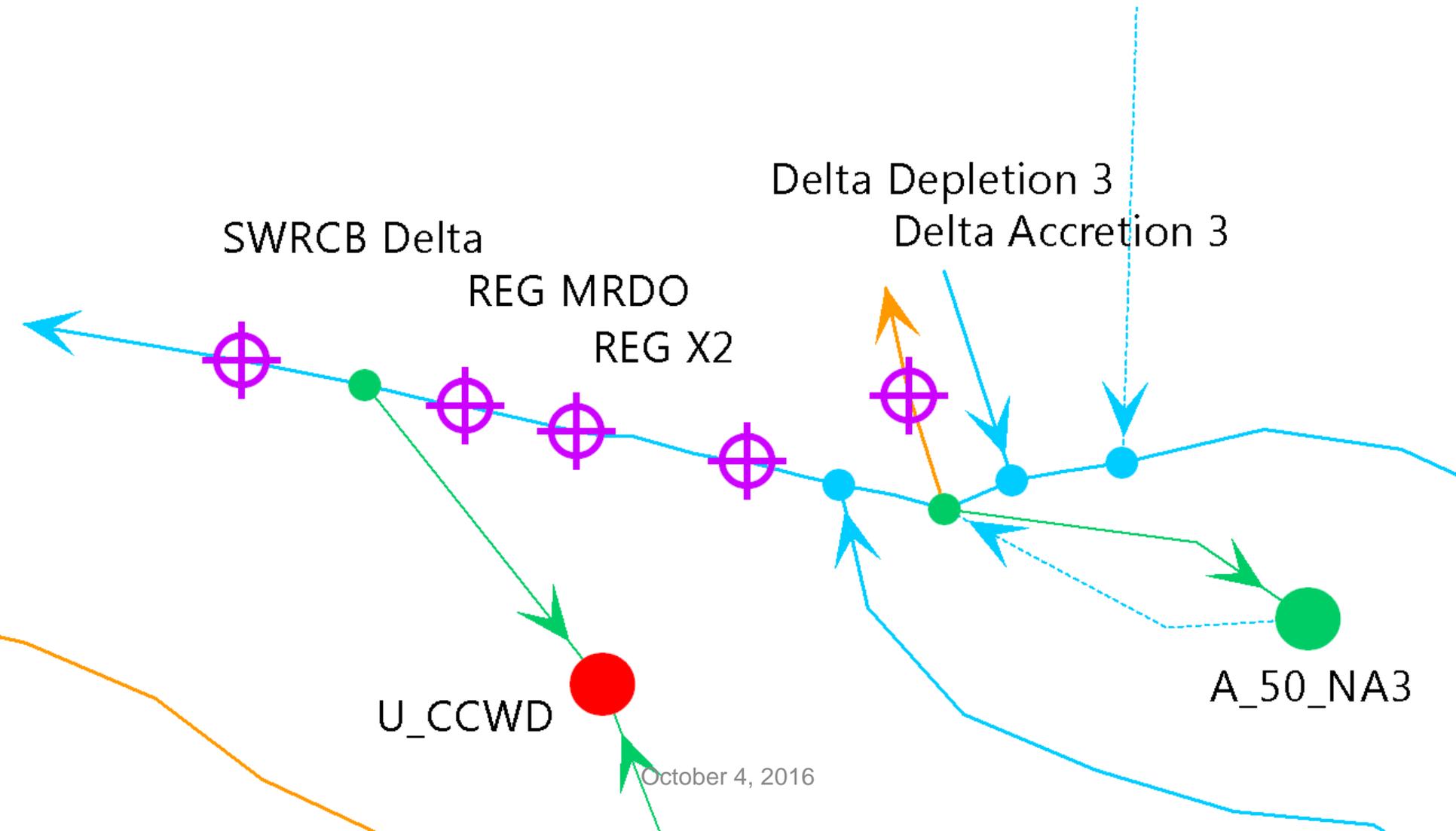
DELTA REPRESENTATION



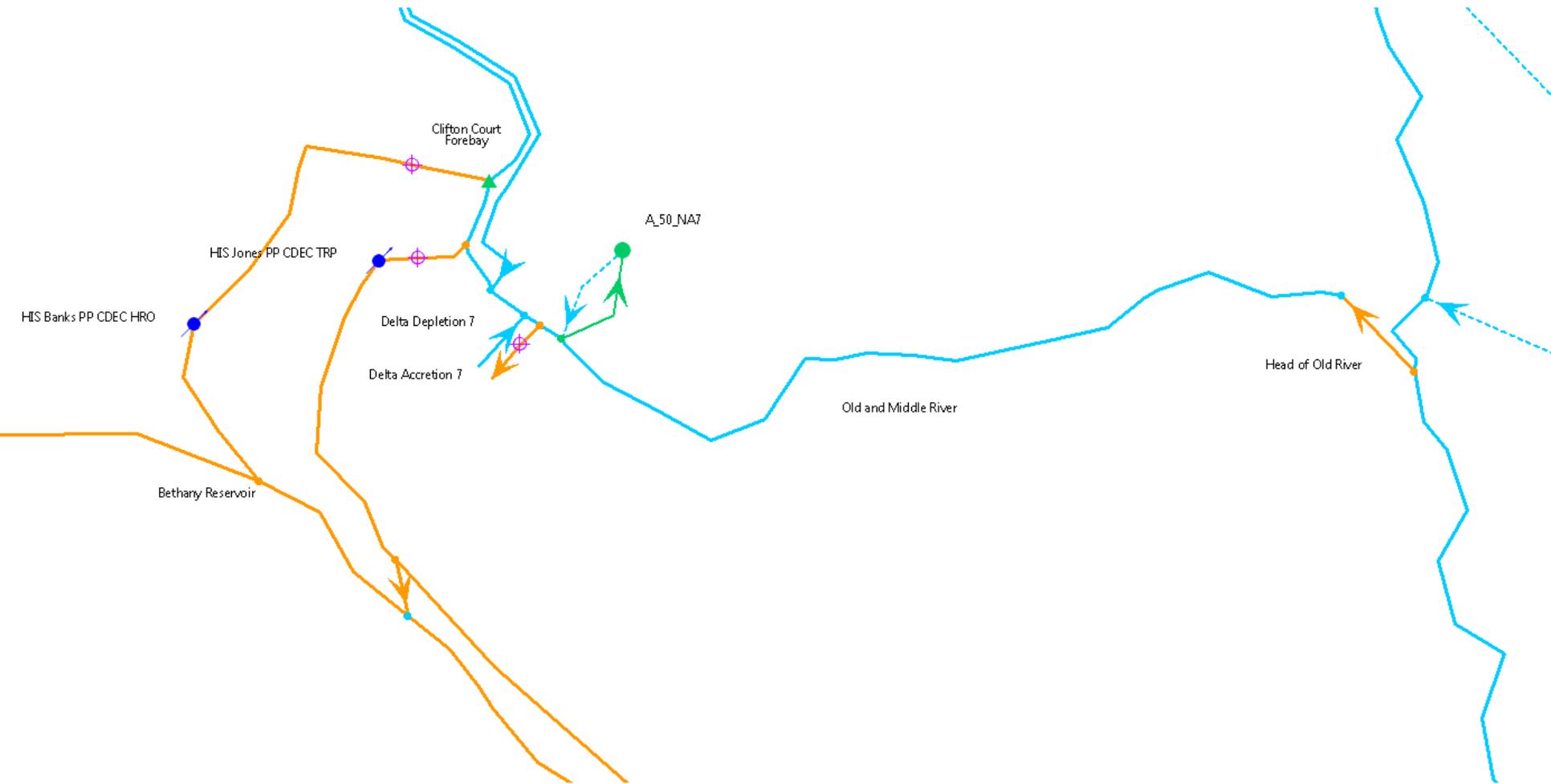
Delta Regions



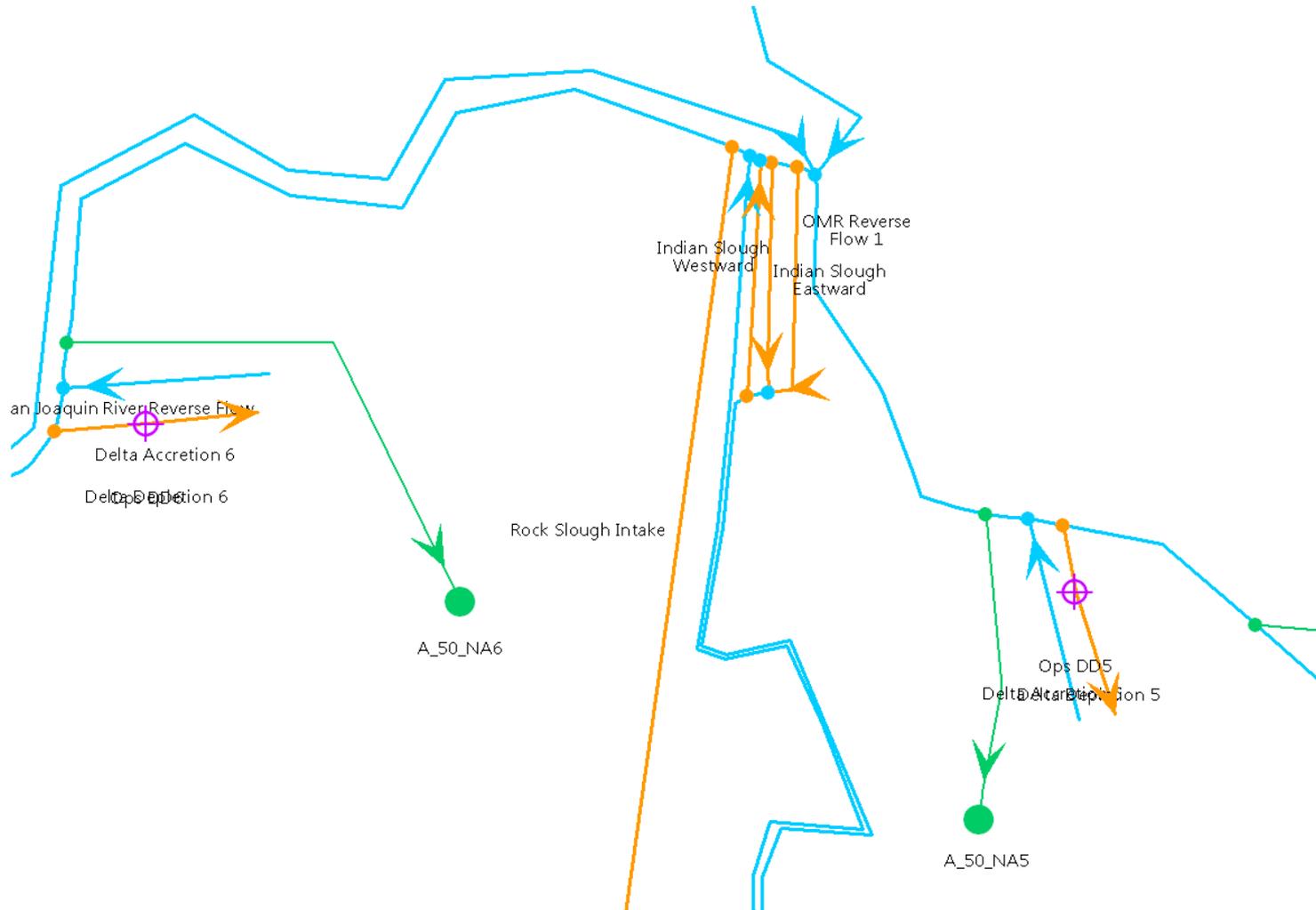
Delta Outflow



South Delta



Old and Middle River



October 4, 2016

CVP-SWP REPRESENTATION



Central Valley Project

- Facilities Included
 - Trinity, Shasta, Folsom Reservoirs
 - Whiskeytown, Keswick, Natomas
 - Black Butte Dam
 - Bella Vista Pipeline, Tehama-Colusa Canal
 - Delta Cross Channel
 - Jones Pumping Plant, Delta-Mendota Canal, Mendota Pool
 - CVP San Luis Reservoir
 - San Luis Canal
 - Cross Valley Canal
 - San Felipe Unit
- Facilities not included
 - New Melones Reservoir
 - Friant Division

State Water Project

- Facilities Included
 - Frenchman, Davis Reservoirs
 - Oroville/Thermalito Complex
 - Banks Pumping Plant, California Aqueduct
 - North Bay Aqueduct
 - South Bay Aqueduct
 - SWP San Luis

- Facilities Not Included
 - Antelope Lake
 - Del Valley Reservoir
 - Terminal Reservoirs

CVP/SWP Demands

- North of Delta
 - Agriculture and Refuges – catchment nodes (MABIA)
 - M&I – demand nodes (fixed annual volume based on historical production data, fixed monthly pattern)
- South of Delta
 - Agriculture, Refuges, M&I – demand nodes (fixed annual volume based on full contract amounts, allocation dependent monthly pattern)

CVP/SWP Allocations

CVP

- Settlement and Exchange contractors
- North of Delta water service contractors
 - Ag, M&I, and Refuge
- South of Delta water service contractors
 - Ag, M&I, and Refuge

SWP

- Feather River Service Area
- Long-term water contractors
 - Table A (no distinction between north and south of Delta)
 - Article 21 (no Article 56)

CVP/SWP Operations

- 1986 Coordinated Operations Agreement
- WRD 1641 (MRDO, X2, Water Quality)
- 2008 USFWS B.O.
- 2009 NMFS B.O.

LOCAL PROJECTS

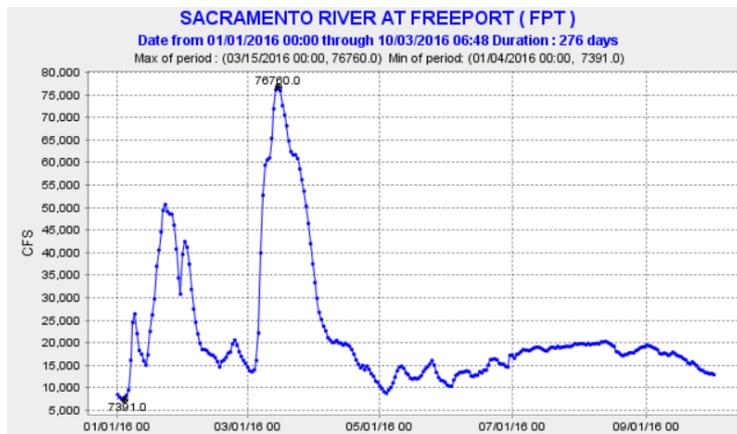


Local Project Operations

- Reservoirs in the following watersheds are operated to meet downstream demand
 - Bear
 - Cache
 - Calaveras
 - Cosumnes
 - Mokelumne
 - Putah
 - Stony
 - Yuba

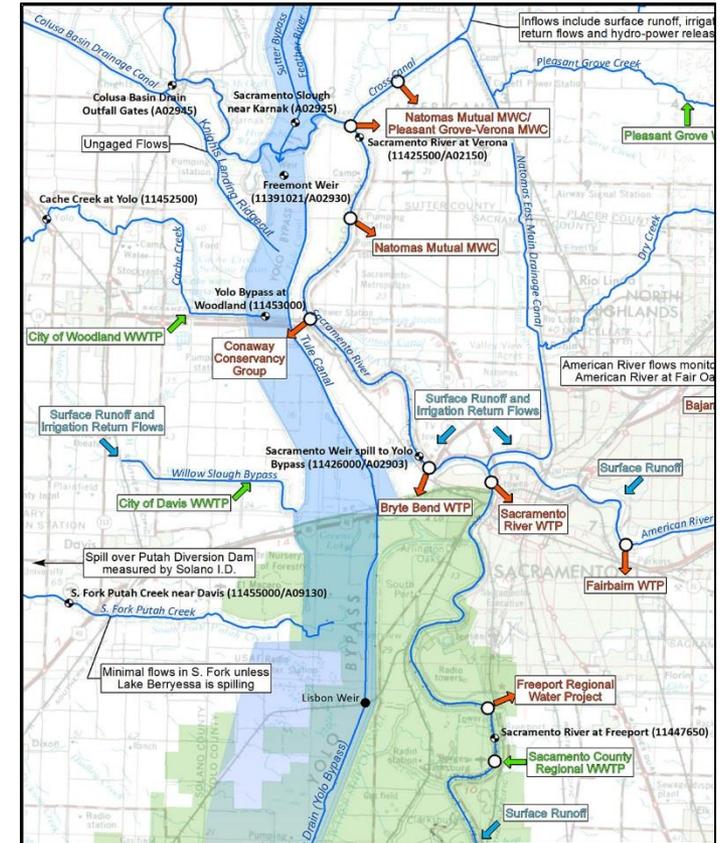
MODEL ASSESSMENT

VALLEY FLOOR HYDROLOGY 1990-2009

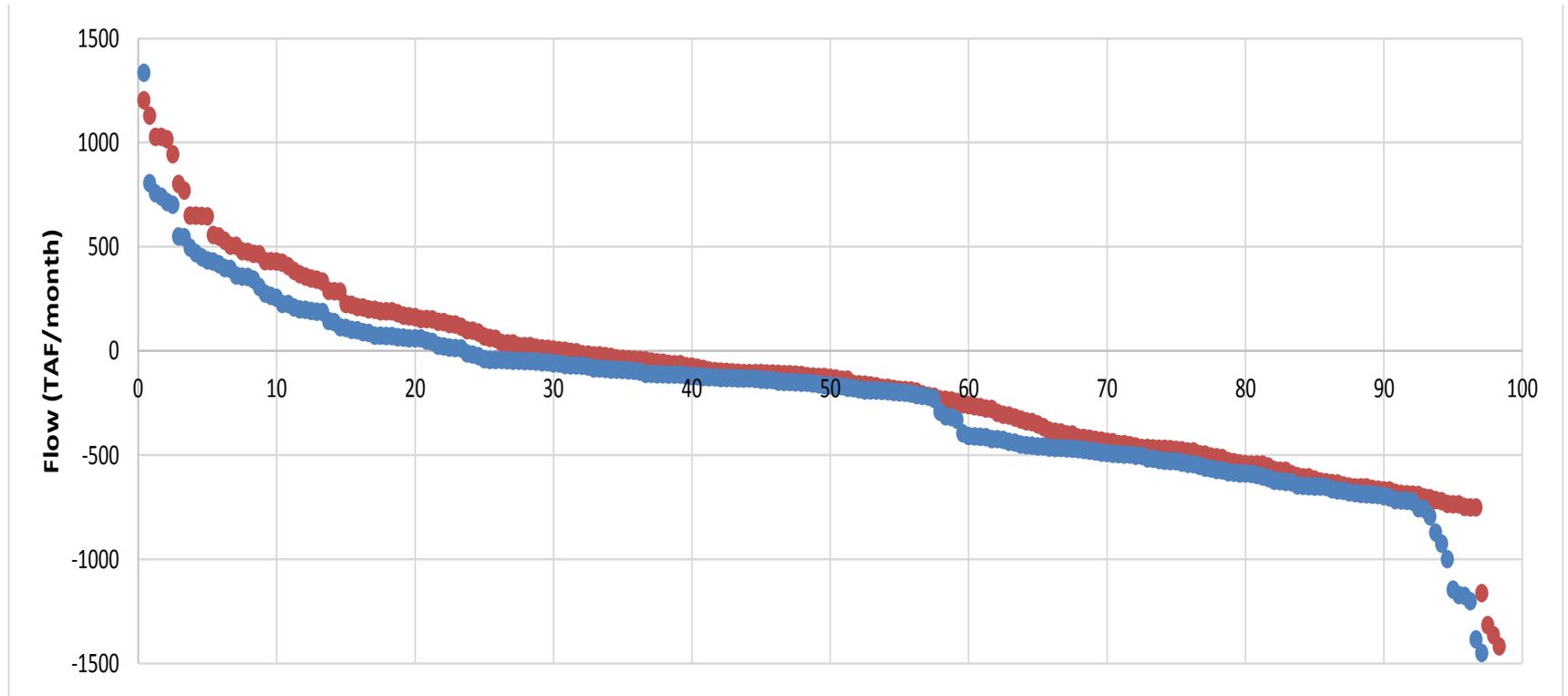


Valley Floor Accretions

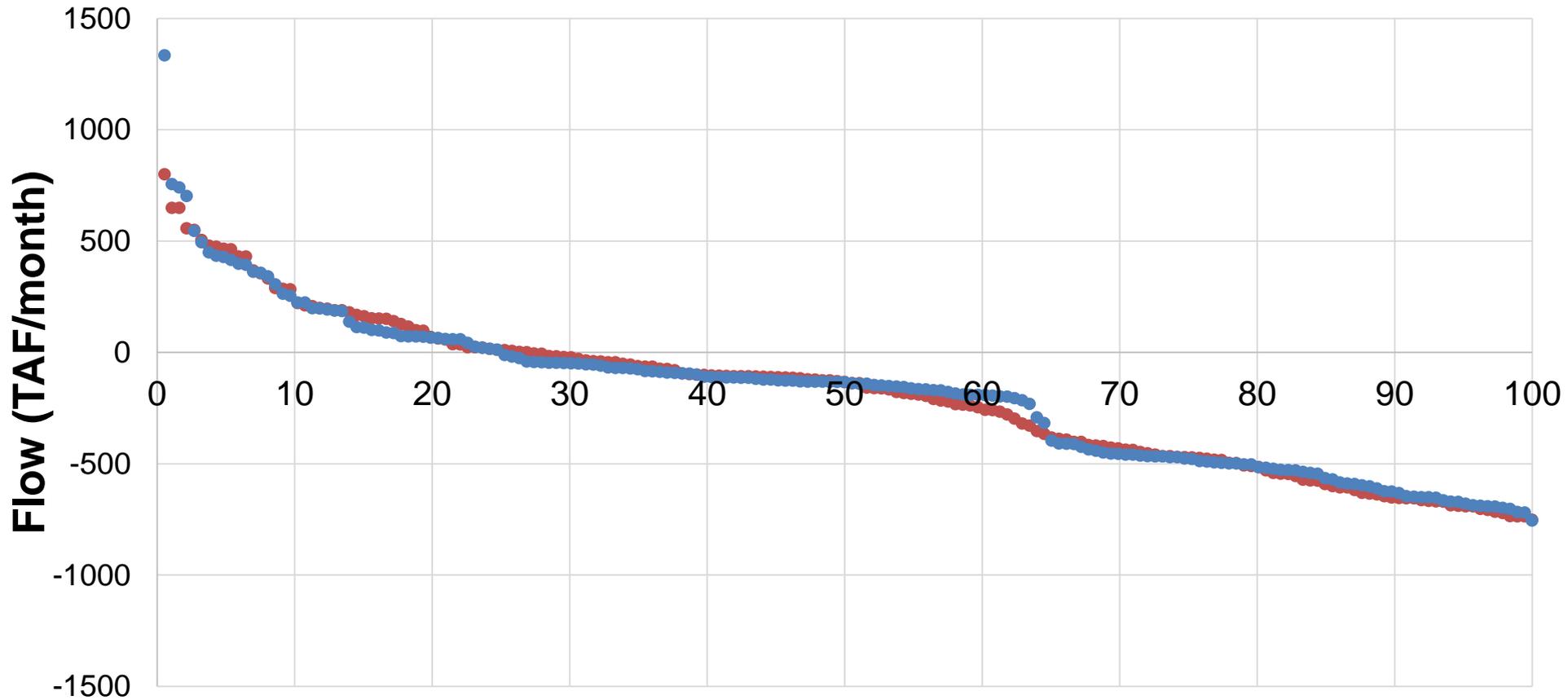
- Downstream boundary flows
 - Sacramento River at Freeport
 - Sacramento Regional WWTP
 - Knights Landing Ridge Cut
- Upstream boundary below foothill dams and rim of the valley floor
- Focus on months when no weir spills at Fremont and Sacramento weirs



Valley Floor Accretions: 1990-2009

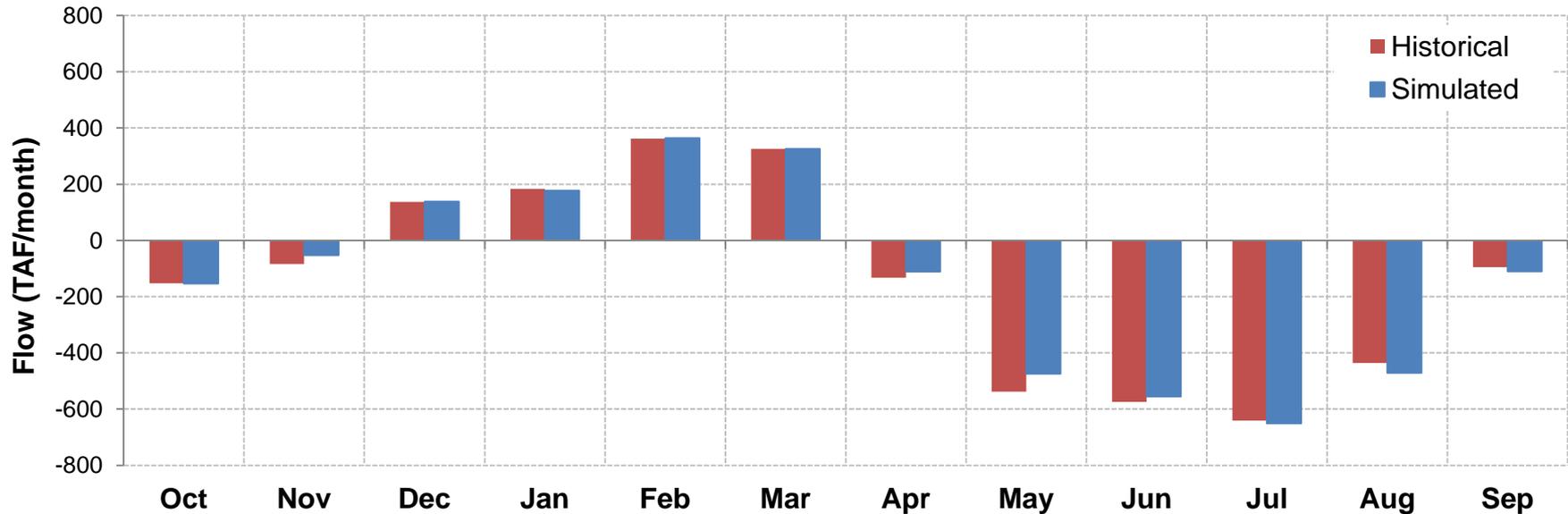


Valley Floor Accretions: Flood Months Excluded



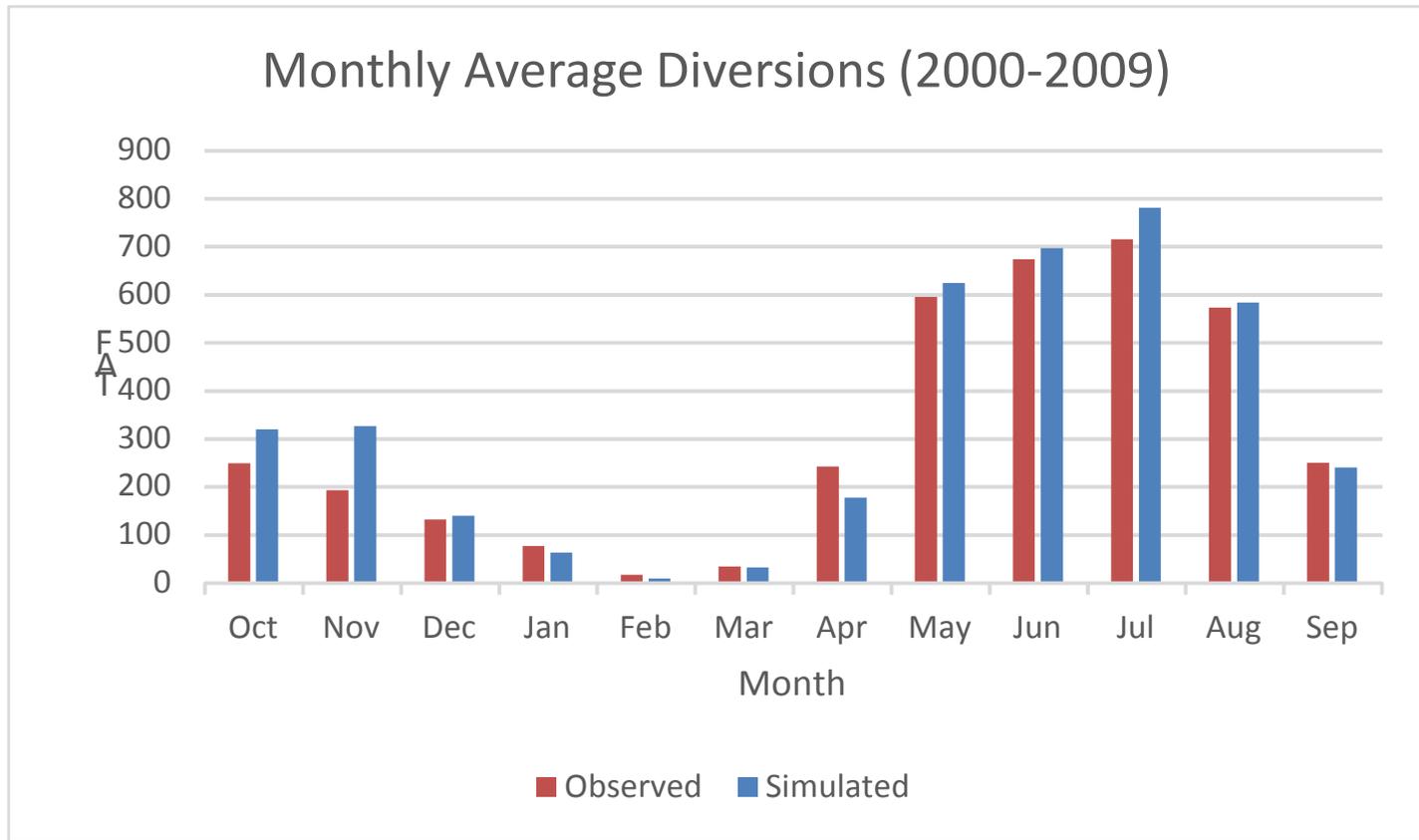
Valley Floor Accretions

Sacramento Valley Accretions: 1990-2009



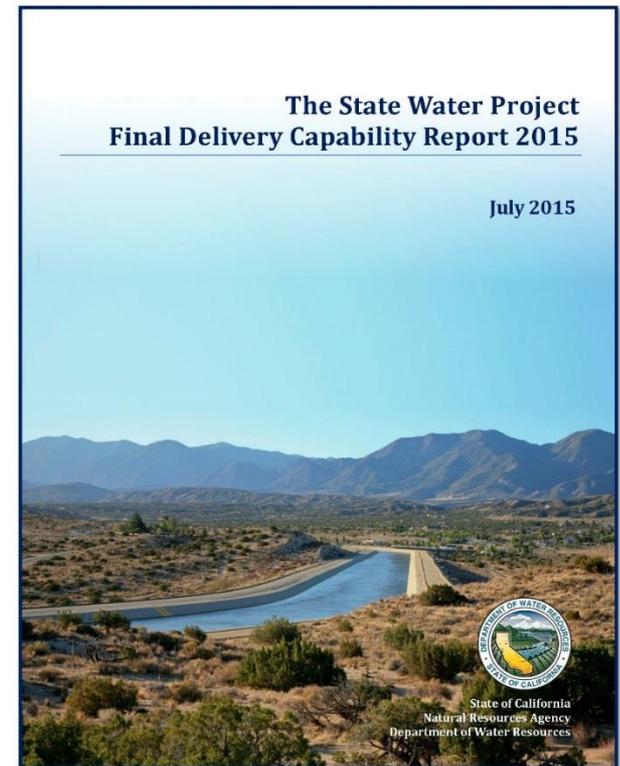
Diversions: 2000-2009

- 15 largest diversions representing 80% of total



VALIDATION OF CVP-SWP OPERATIONS

COMPARISON WITH CALSIM II



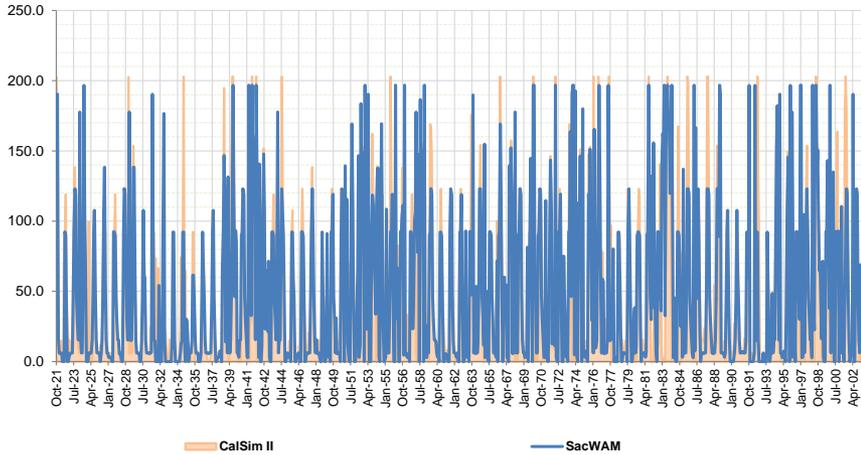
Validation of CVP-SWP Operations

- Trinity River imports
- CVP storage north of the Delta
- SWP storage north of the Delta
- Feather, American, Sacramento river flows
- Delta inflow
- Delta required outflow, surplus outflow
- CVP and SWP exports
- San Luis Reservoir

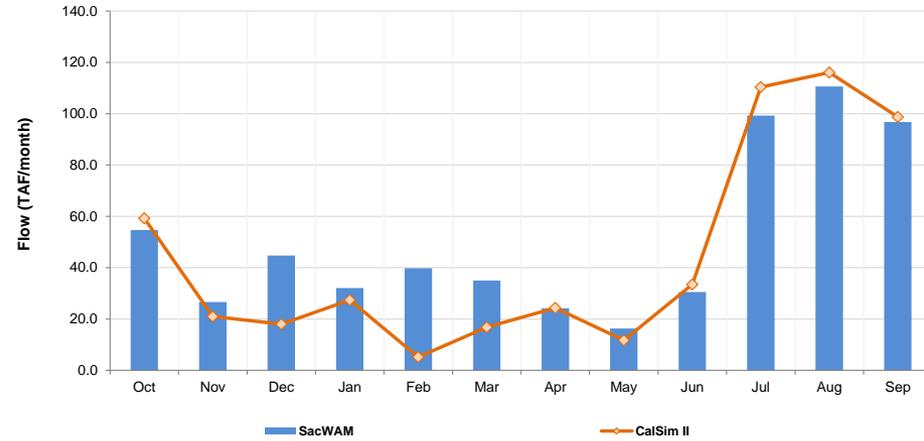
Trinity River Imports

CalSim II 542 TAF/yr, SacWAM +13%

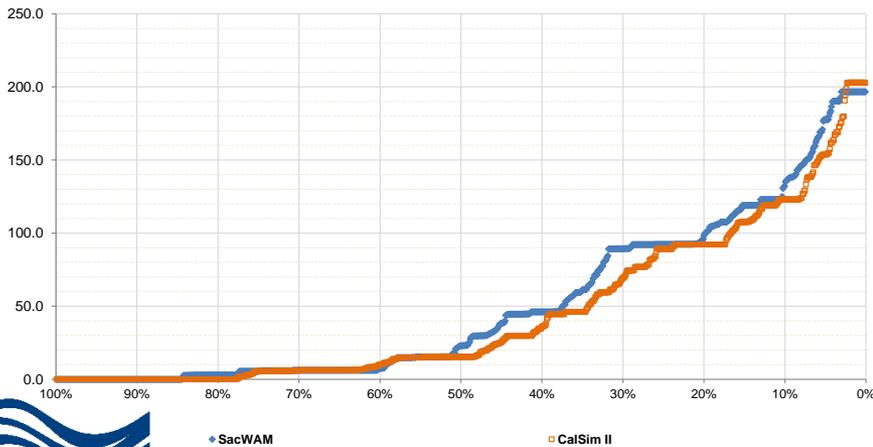
Clear Creek Tunnel Monthly Flows: 1922-2003



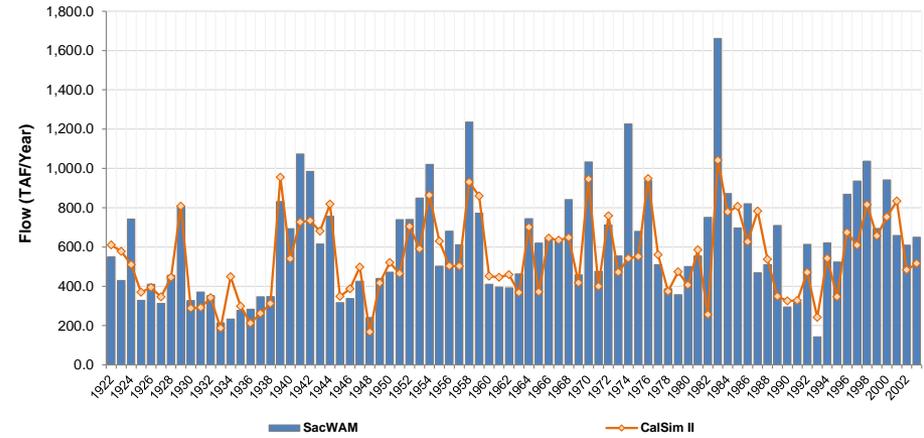
Clear Creek Tunnel Average Flows: 1922-2003



Clear Creek Tunnel Monthly Exceedence: 1922-2003



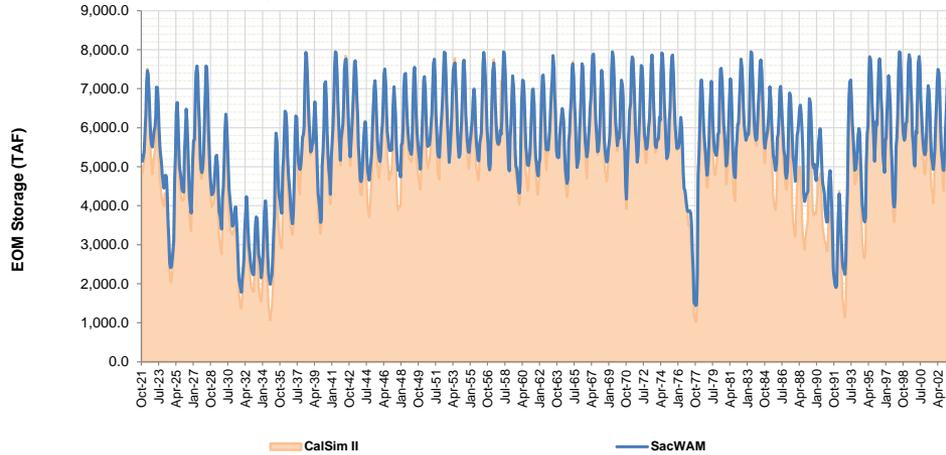
Clear Creek Tunnel Annual Flows: 1922-2003



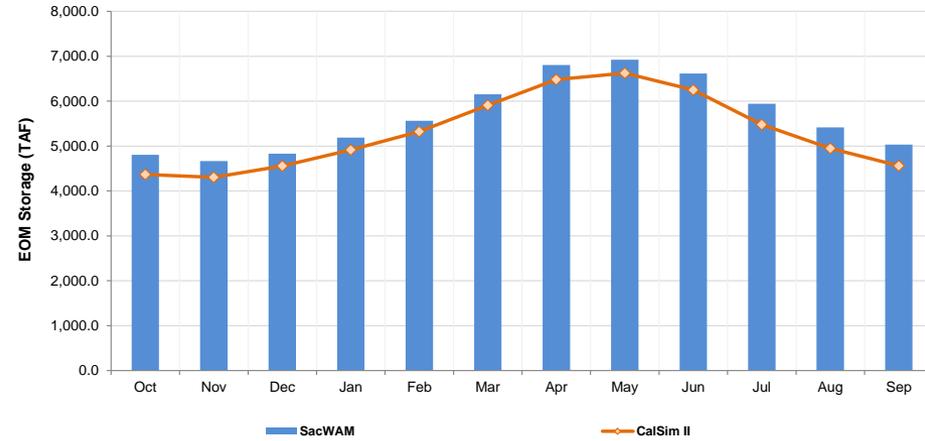
CVP North of Delta Storage – Trinity, Shasta, Folsom

CalSim II 4,561 TAF, SacWAM +10%

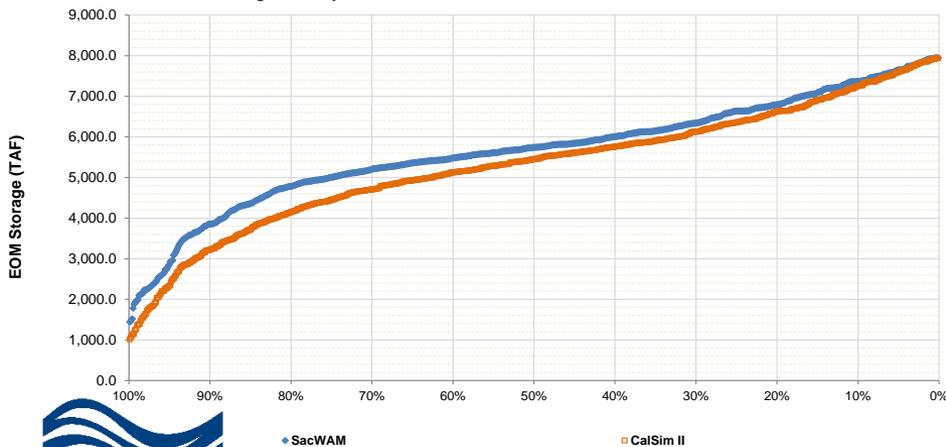
CVP NOD Storage Monthly EOM Storage: 1922-2003



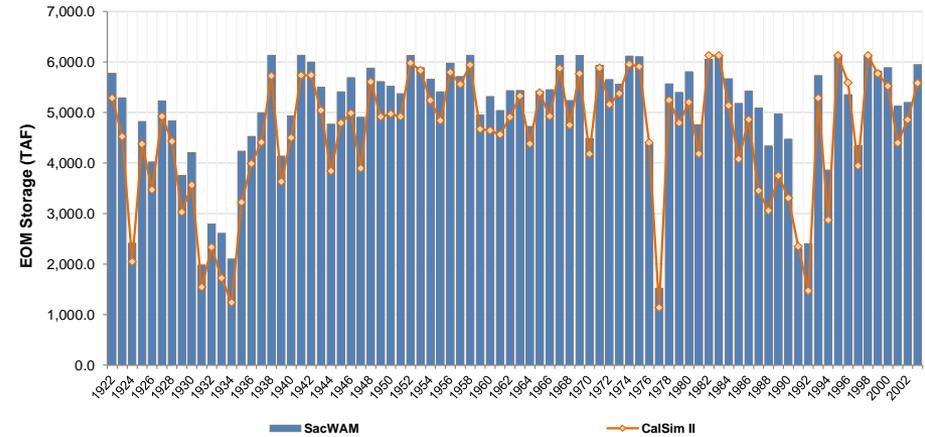
CVP NOD Storage Average EOM Storage: 1922-2003



CVP NOD Storage Monthly Exceedence: 1922-2003



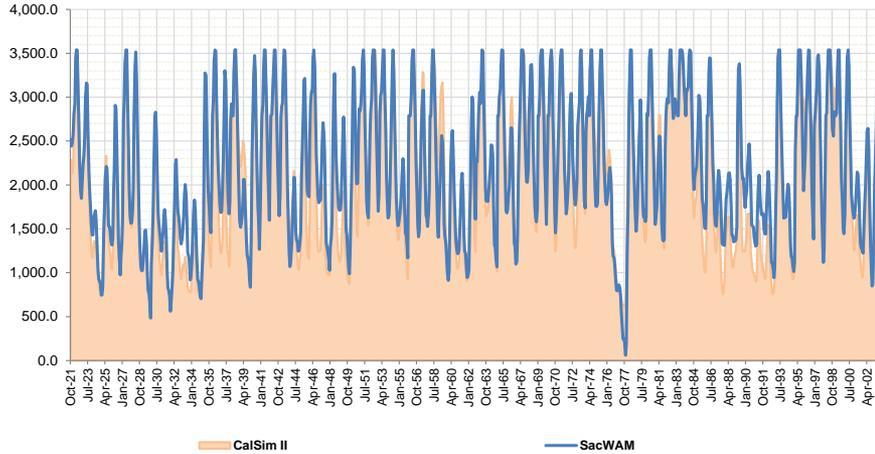
CVP NOD Storage September EOM Storage: 1922-2003



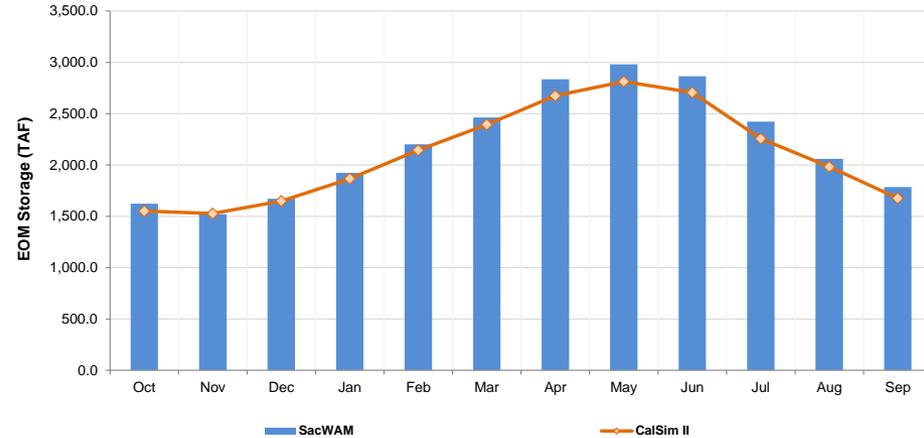
SWP North of Delta Storage - Oroville

CalSim II 1,677 TAF, SacWAM +6%

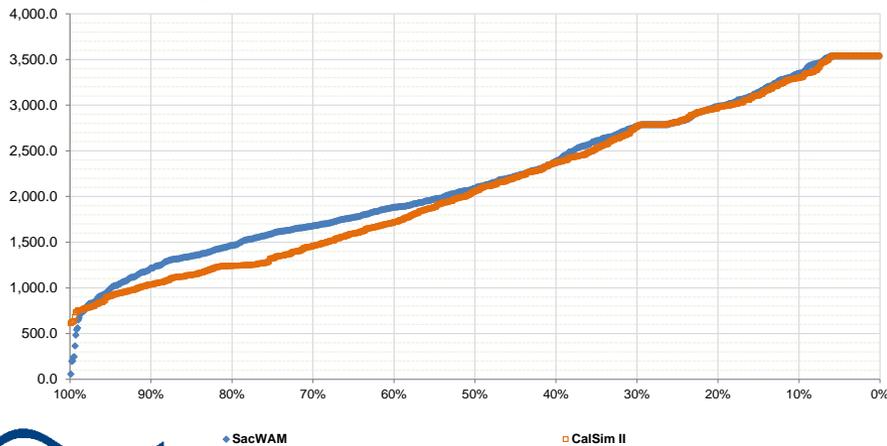
SWP NOD Storage Monthly EOM Storage: 1922-2003



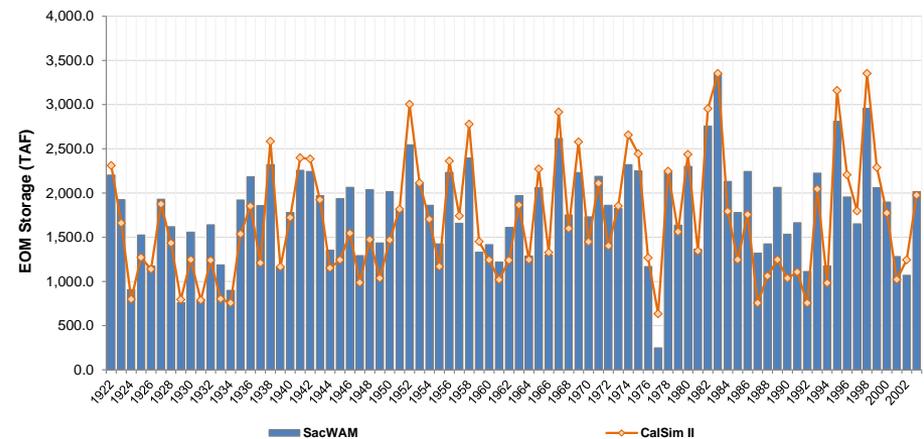
SWP NOD Storage Average EOM Storage: 1922-2003



SWP NOD Storage Monthly Exceedence: 1922-2003

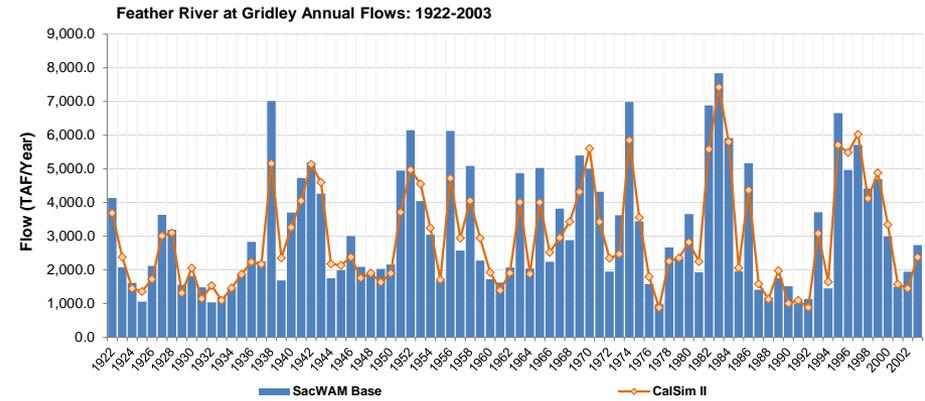
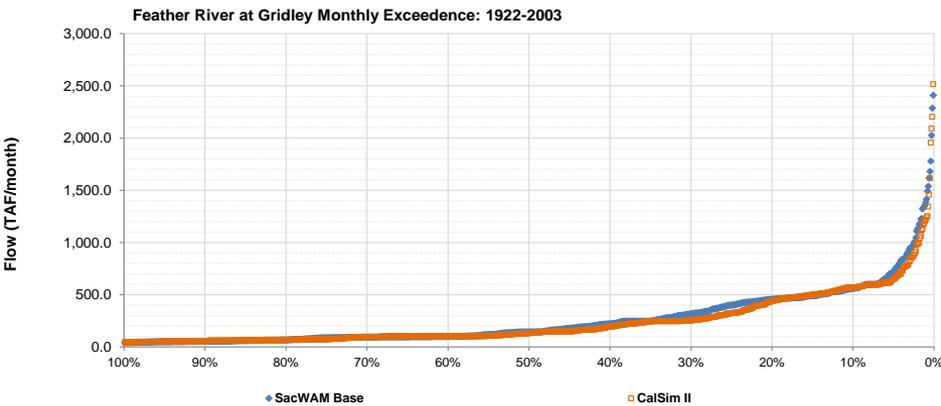
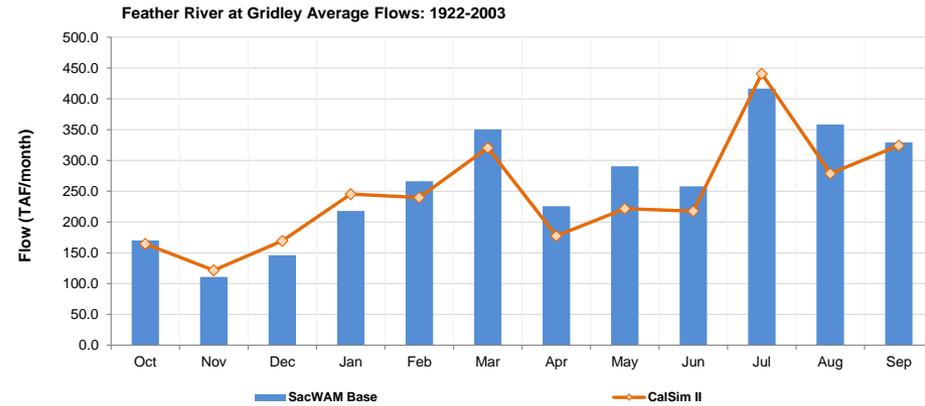
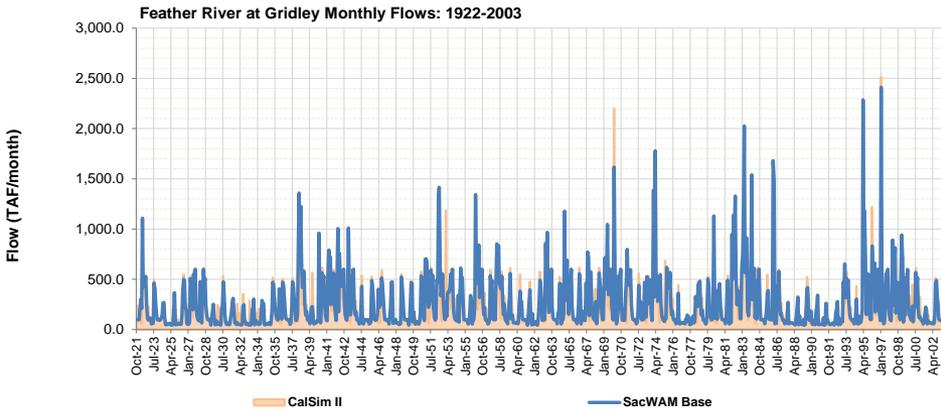


SWP NOD Storage September EOM Storage: 1922-2003



Feather River at Gridley

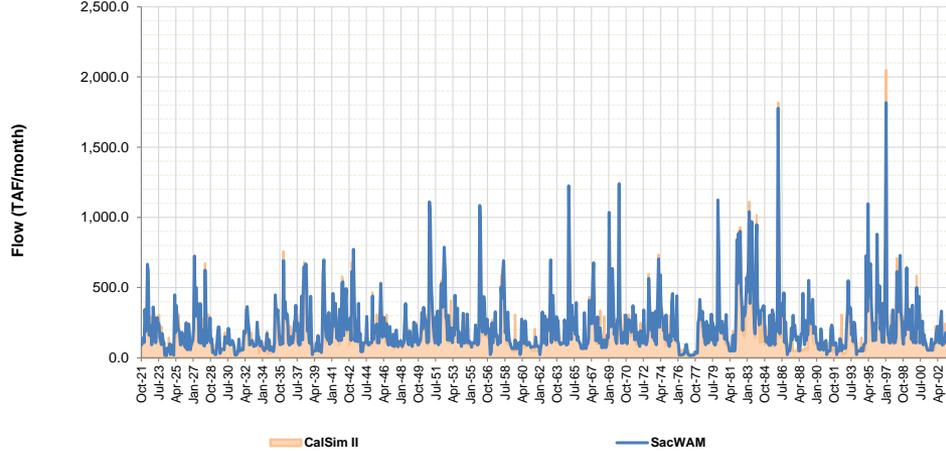
CalSim II 2,922 TAF/yr, SacWAM +10%



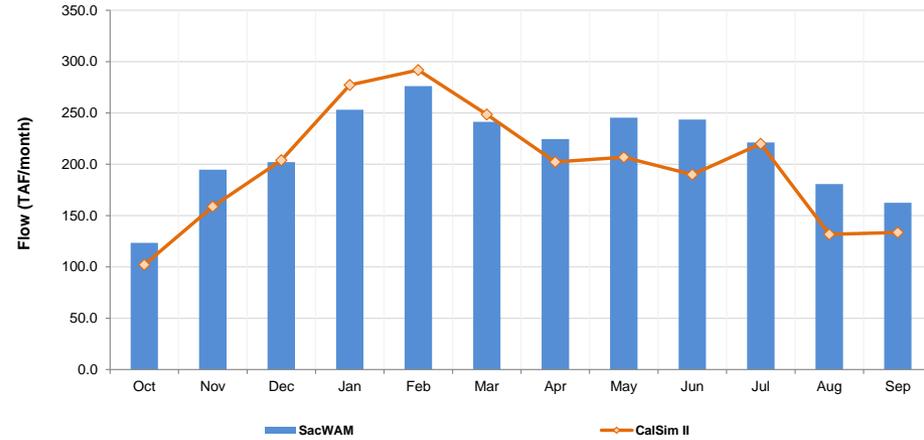
American River at Fair Oaks

CalSim II 2,367 TAF/yr, SacWAM +9%

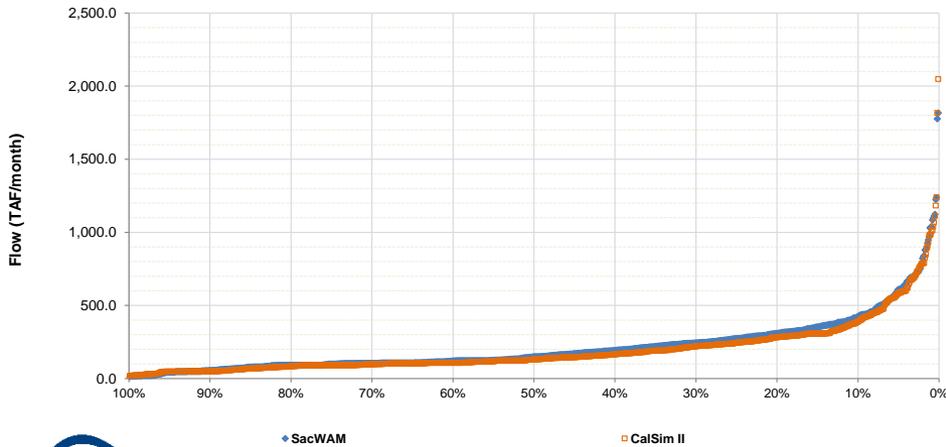
Nimbus Dam Release Monthly Flows: 1922-2003



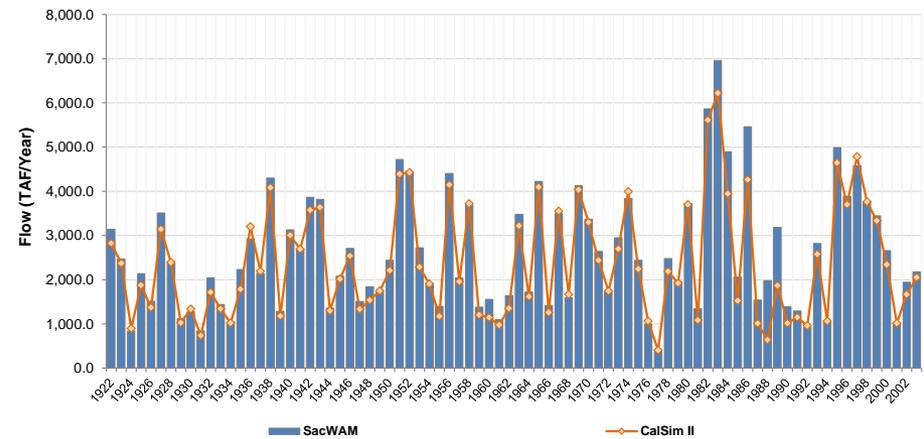
Nimbus Dam Release Average Flows: 1922-2003



Nimbus Dam Release Monthly Exceedence: 1922-2003



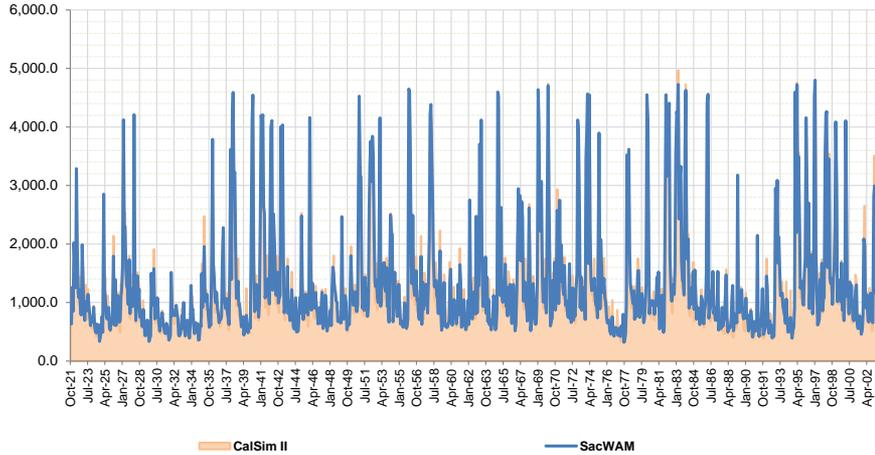
Nimbus Dam Release Annual Flows: 1922-2003



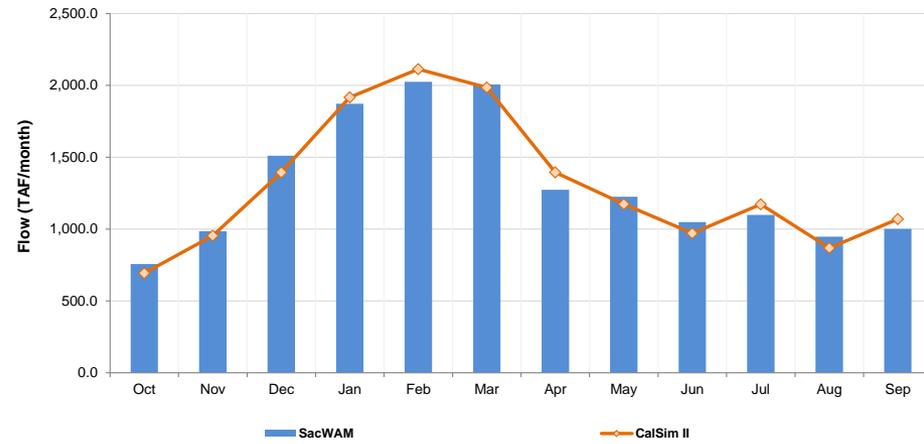
Sacramento River below Freeport

CalSim II 15,709 TAF/yr, SacWAM <+1%

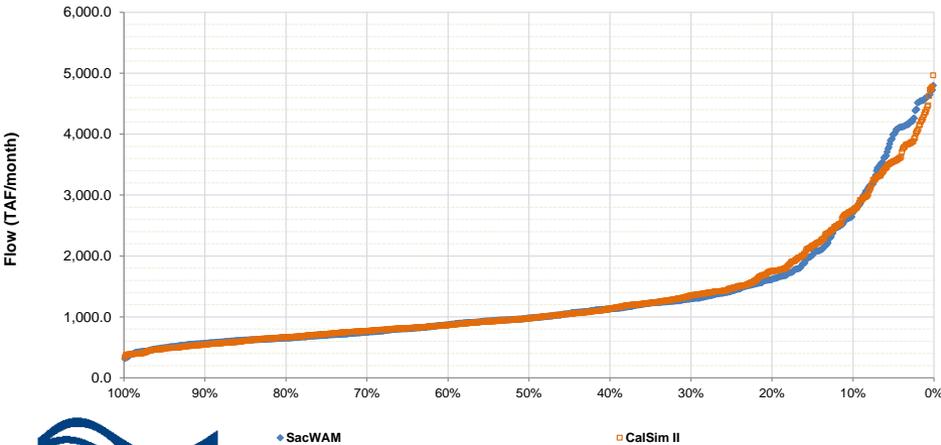
Sacramento River below Sacramento Regional WWTP Monthly Flows: 1922-2003



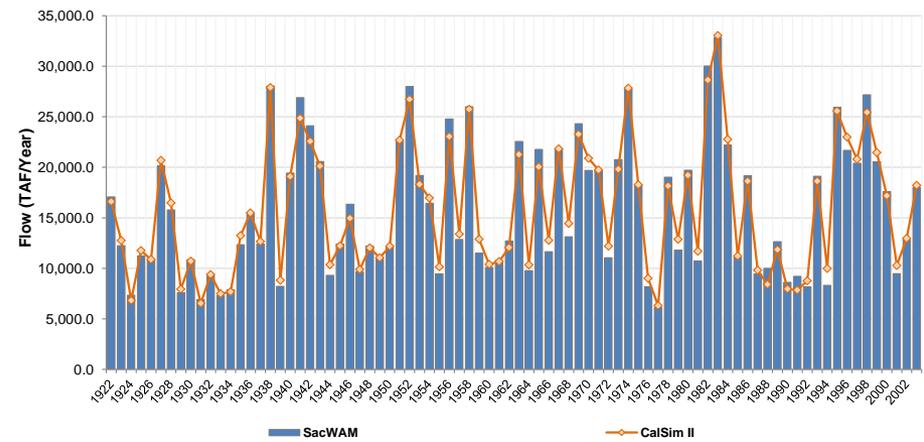
Sacramento River below Sacramento Regional WWTP Average Flows: 1922-2003



Sacramento River below Sacramento Regional WWTP Monthly Exceedence: 1922-2003



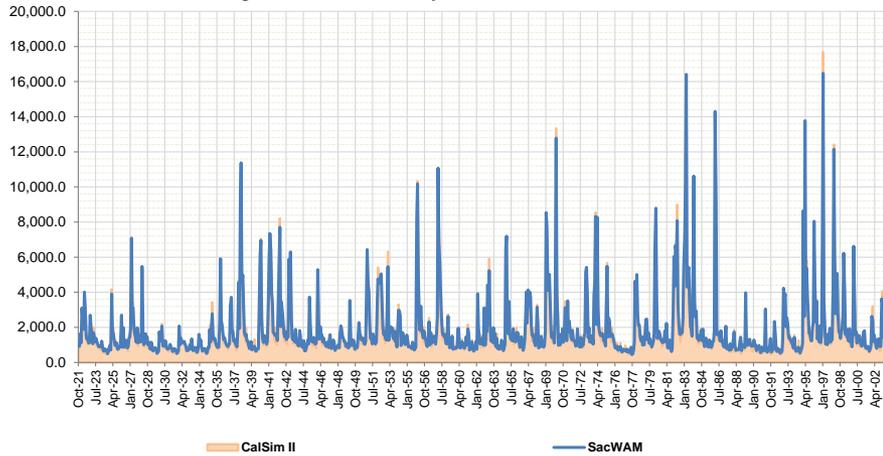
Sacramento River below Sacramento Regional WWTP Annual Flows: 1922-2003



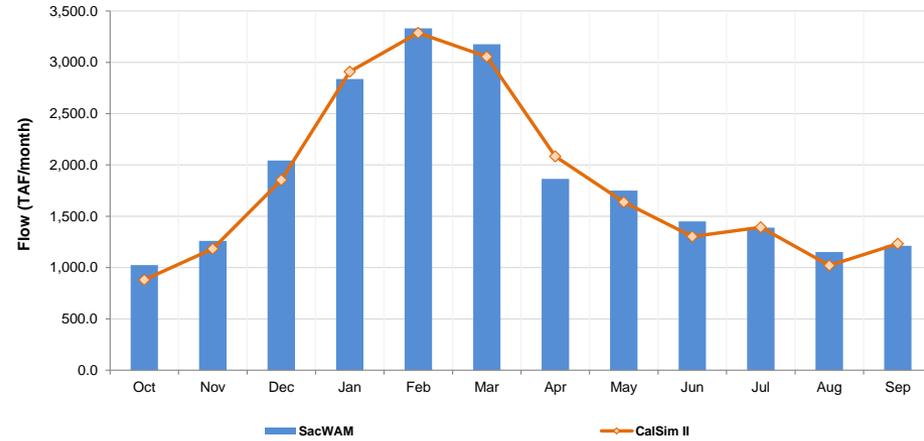
Delta Inflow

CalSim II 21,836 TAF/yr, SacWAM +3%

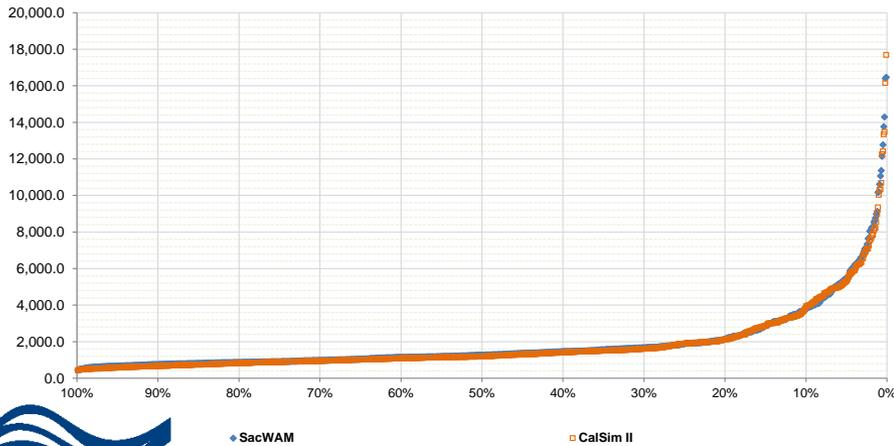
Delta Inflow excluding Bias Correction Monthly Flows: 1922-2003



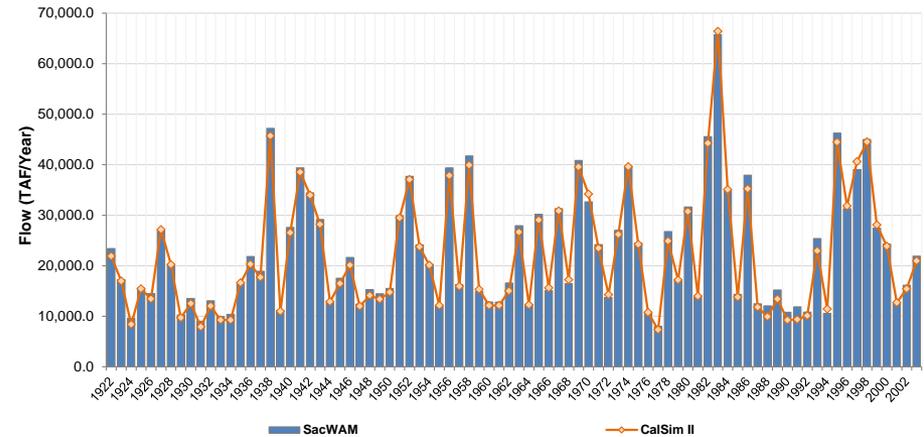
Delta Inflow excluding Bias Correction Average Flows: 1922-2003



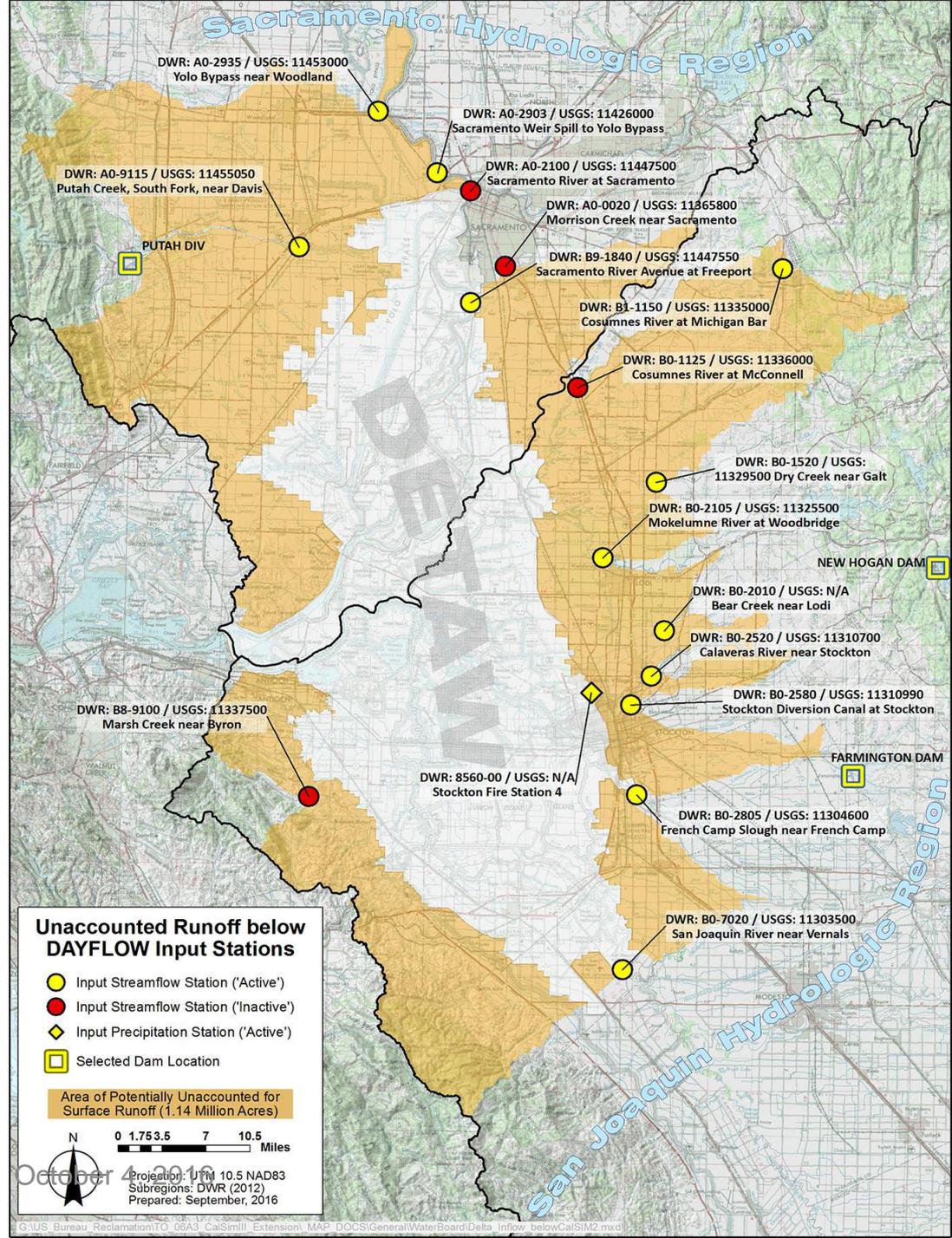
Delta Inflow excluding Bias Correction Monthly Exceedence: 1922-2003



Delta Inflow excluding Bias Correction Annual Flows: 1922-2003



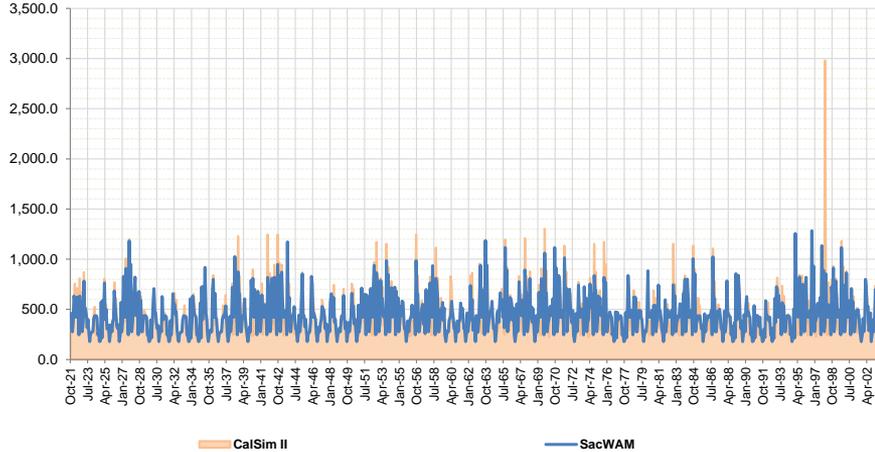
Delta Inflow



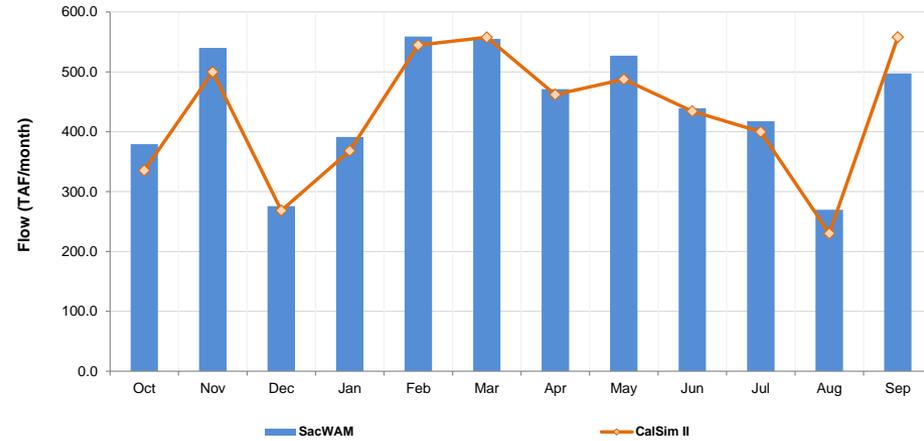
Required Delta Outflow

CalSim II 5,146 TAF/yr, SacWAM +3%

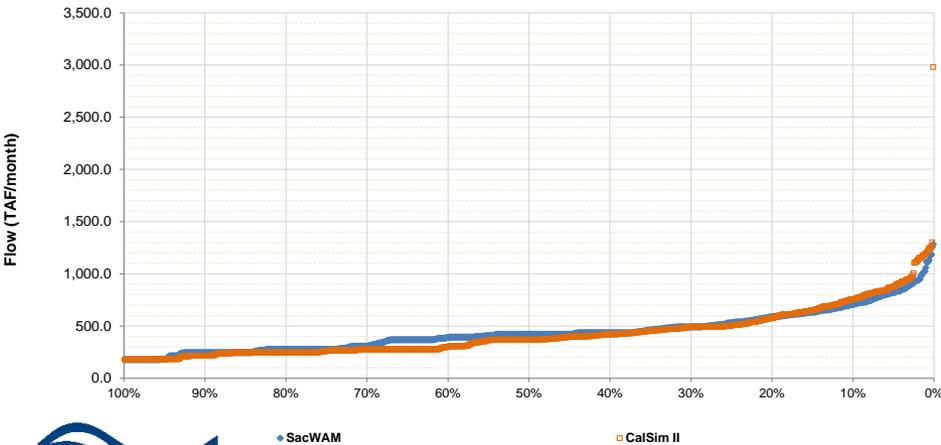
Required Delta Outflow Monthly Flows: 1922-2003



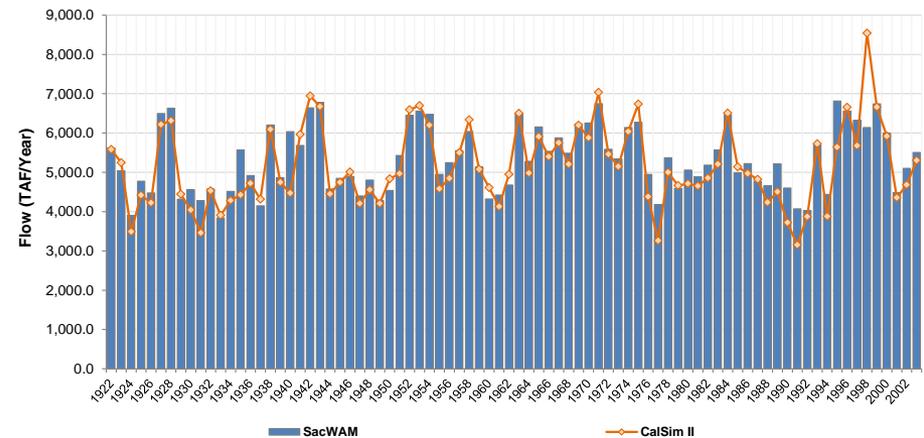
Required Delta Outflow Average Flows: 1922-2003



Required Delta Outflow Monthly Exceedence: 1922-2003



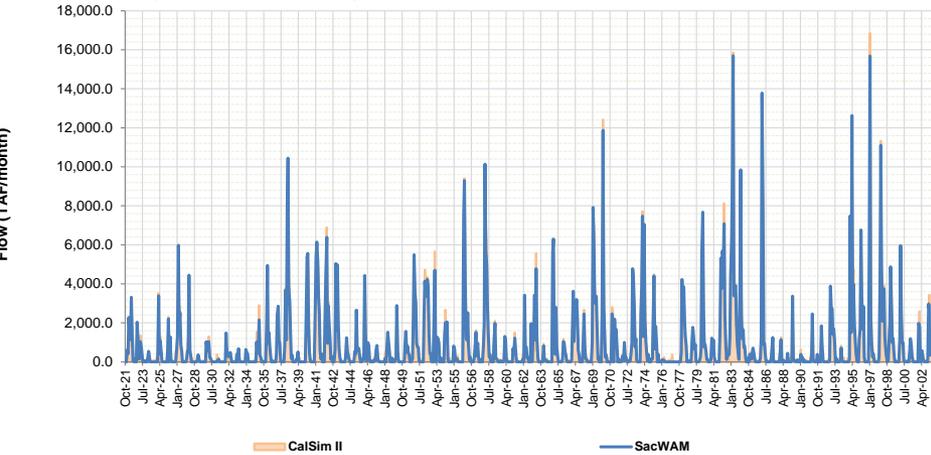
Required Delta Outflow Annual Flows: 1922-2003



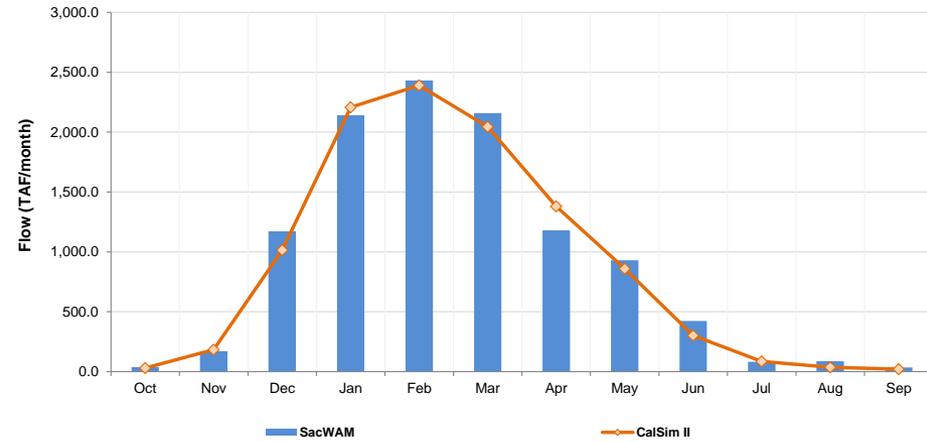
Surplus Delta Outflow

CalSim II 10,554 TAF/yr, SacWAM +4%

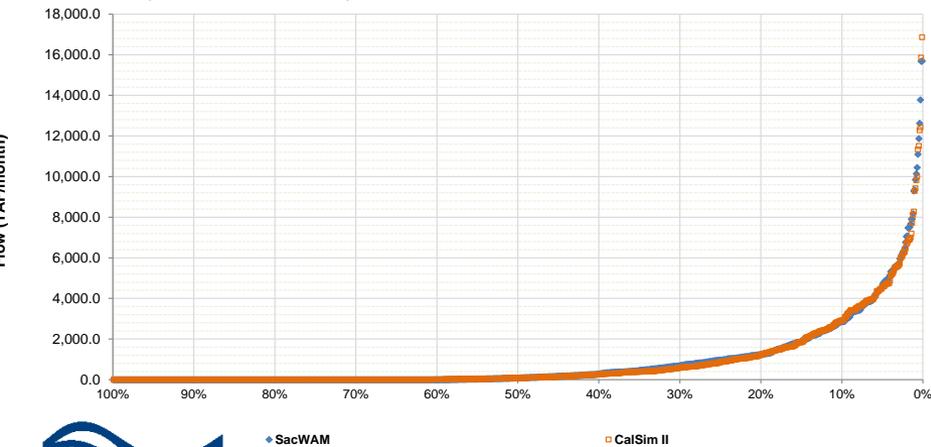
Surplus Delta Outflow Monthly Flows: 1922-2003



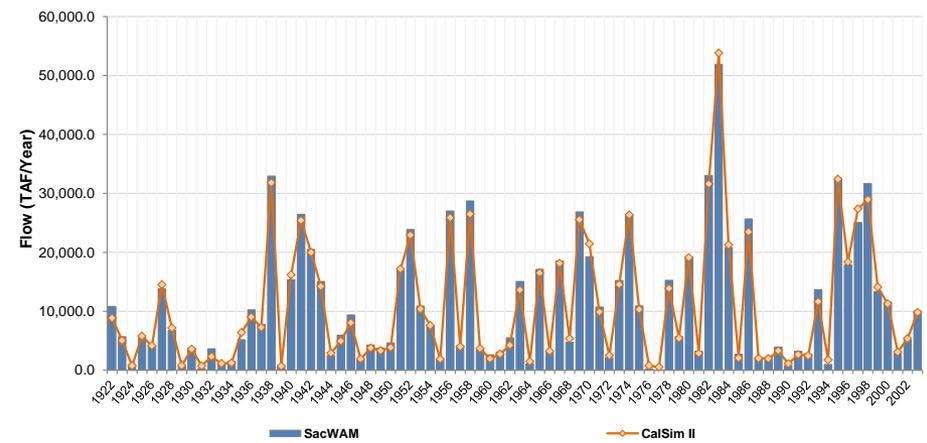
Surplus Delta Outflow Average Flows: 1922-2003



Surplus Delta Outflow Monthly Exceedence: 1922-2003

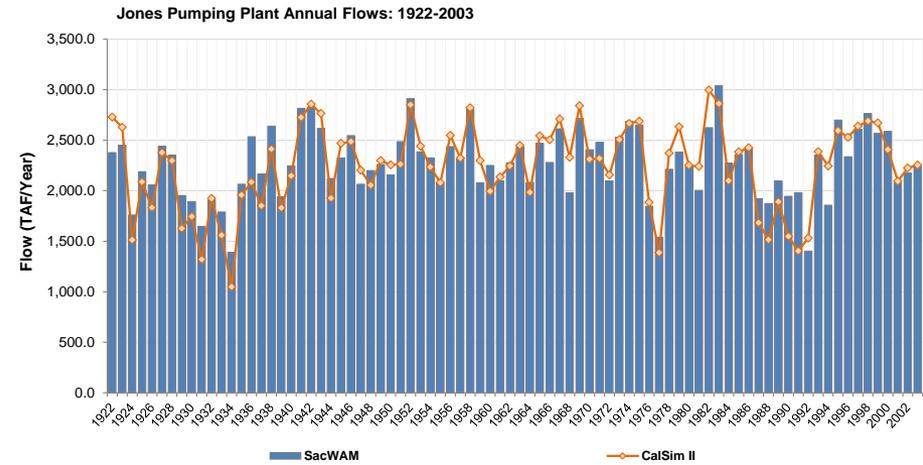
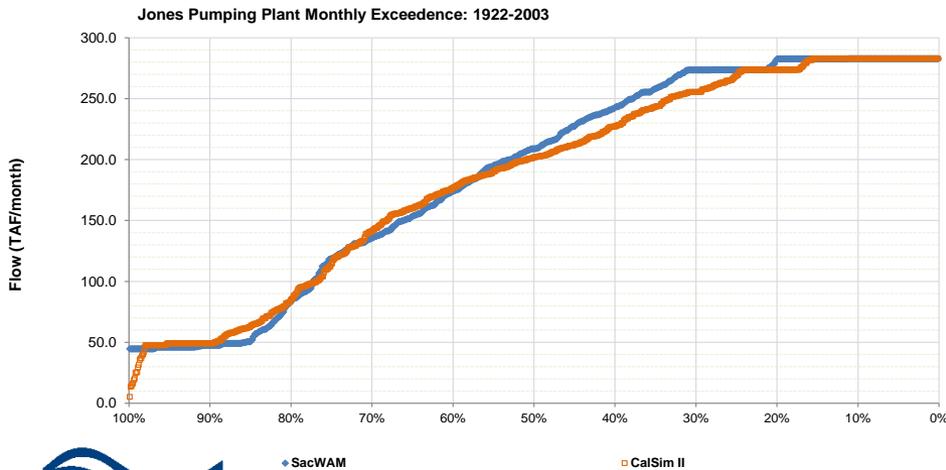
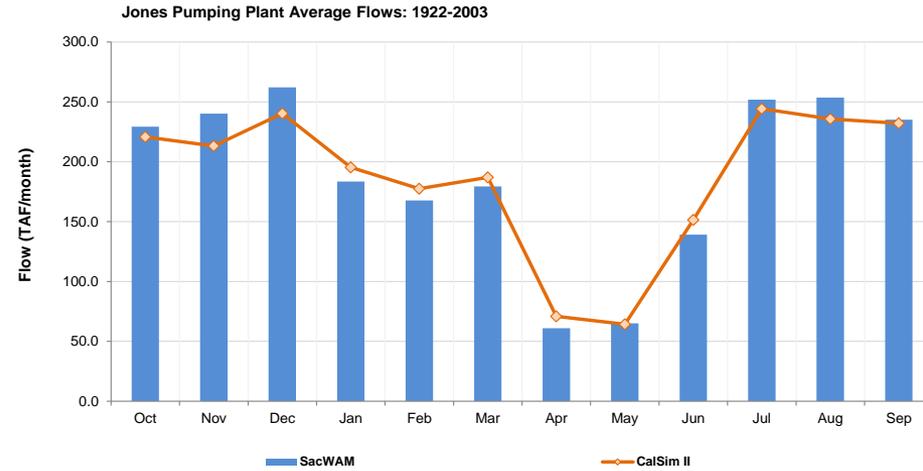
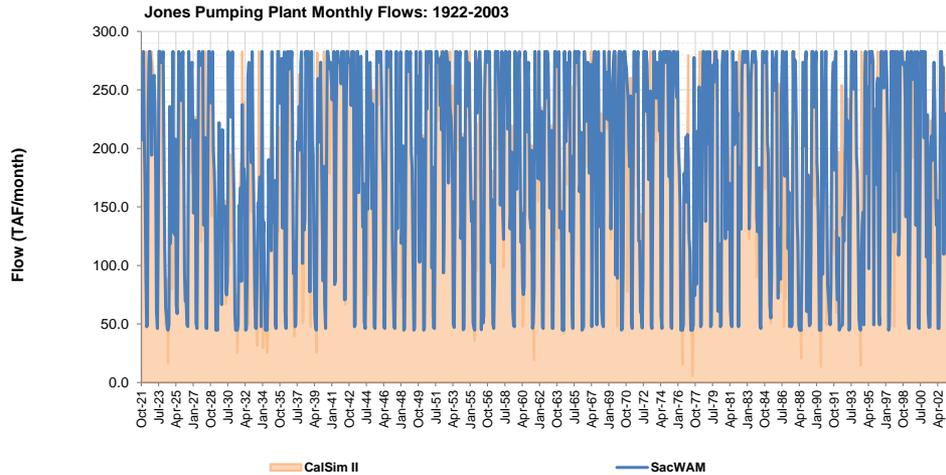


Surplus Delta Outflow Annual Flows: 1922-2003



CVP South of Delta Exports

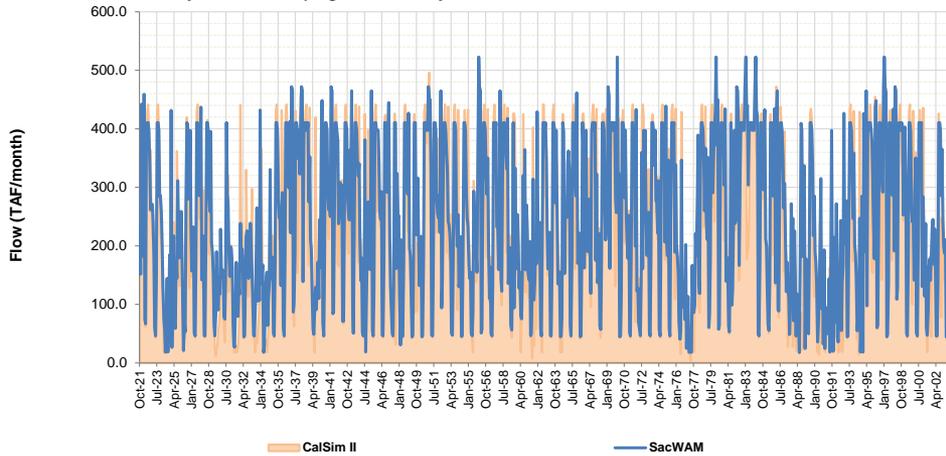
CalSim II 2,233 TAF/yr, SacWAM +2%



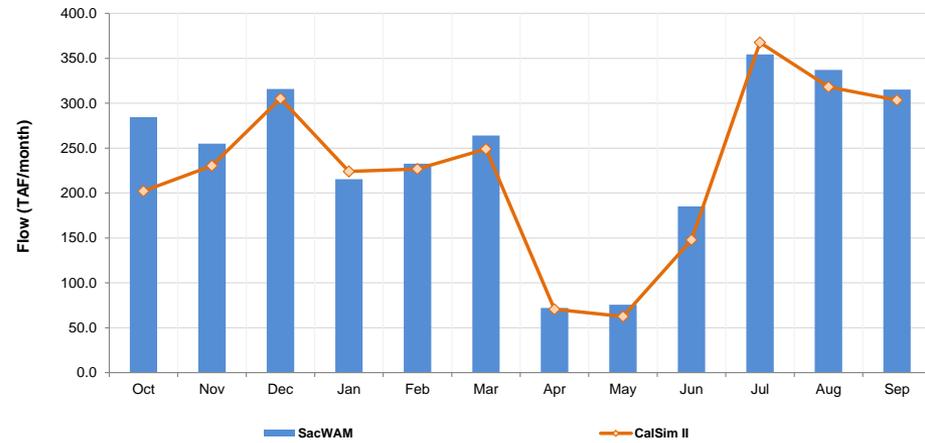
SWP South of Delta Exports

CalSim II 2,708 TAF/yr, SacWAM +7%

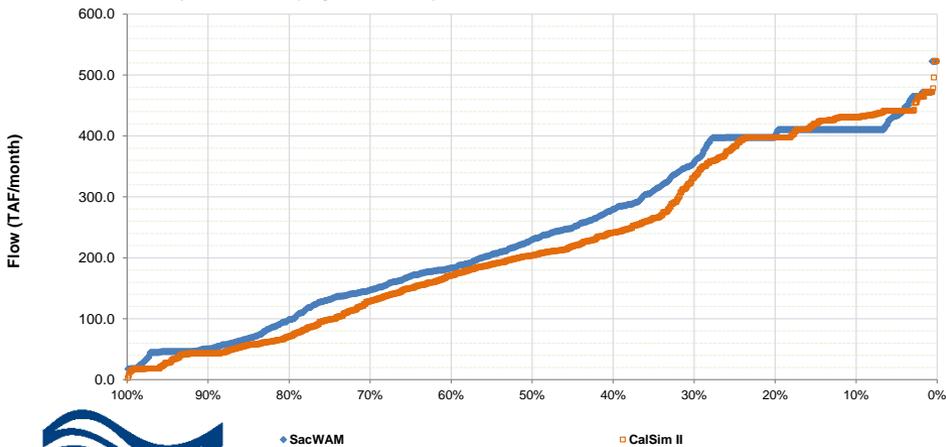
Harvey O'Banks Pumping Plant Monthly Flows: 1922-2003



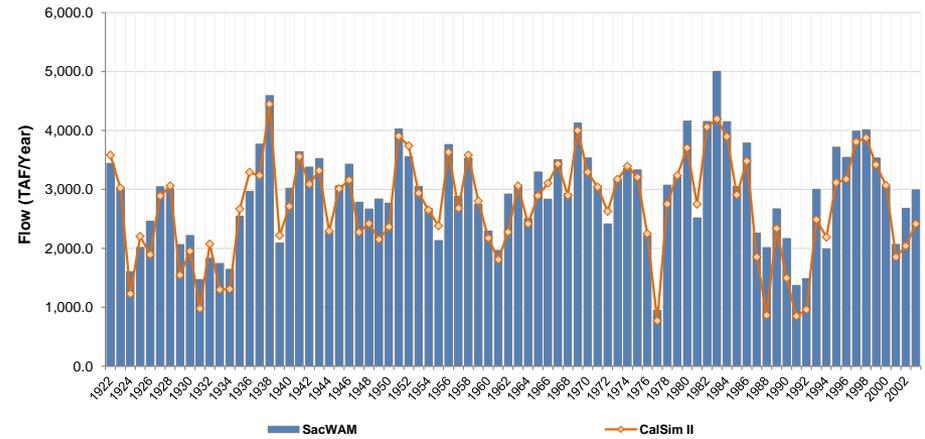
Harvey O'Banks Pumping Plant Average Flows: 1922-2003



Harvey O'Banks Pumping Plant Monthly Exceedence: 1922-2003



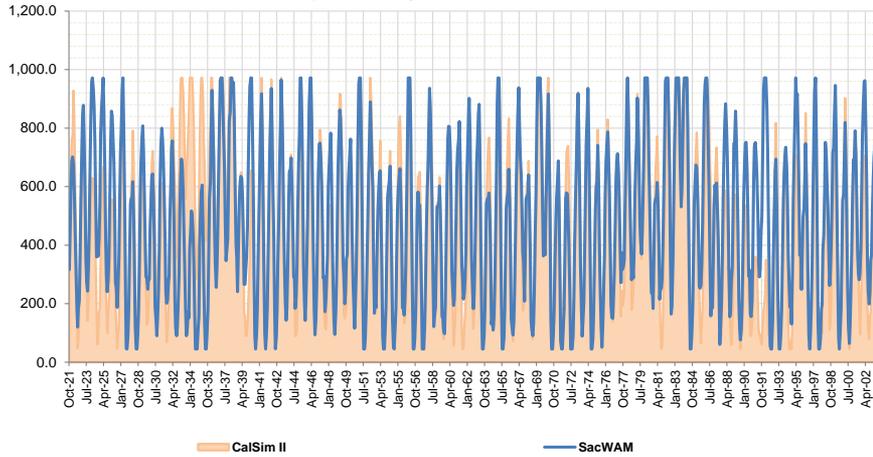
Harvey O'Banks Pumping Plant Annual Flows: 1922-2003



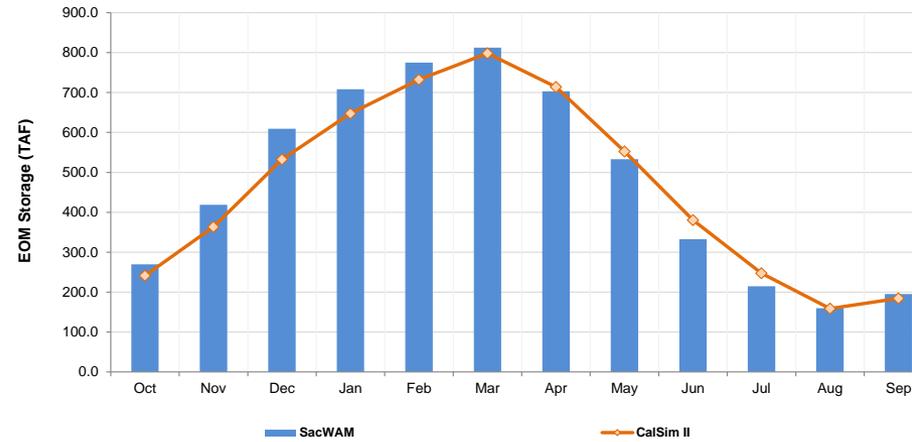
CVP San Luis Reservoir

CalSim II 184 TAF, SacWAM +6%

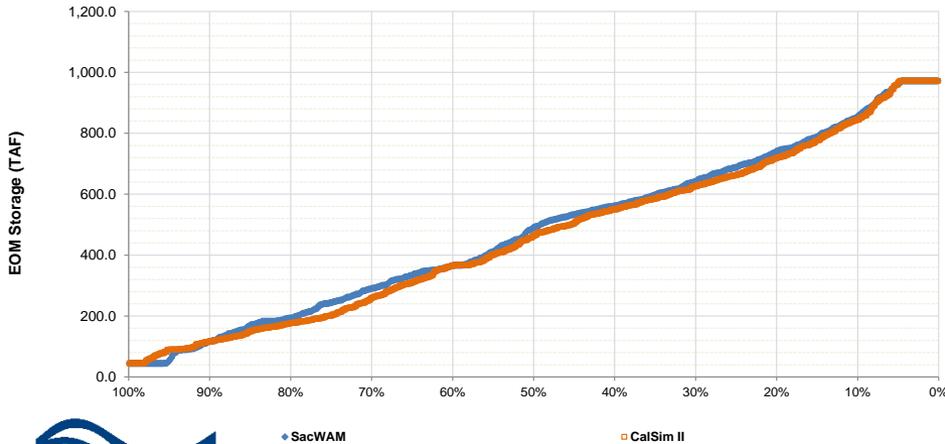
CVP San Luis Reservoir Monthly EOM Storage: 1922-2003



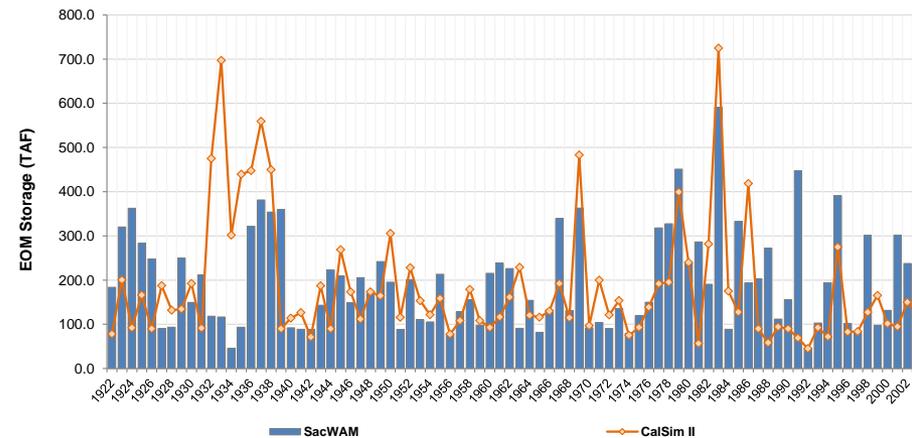
CVP San Luis Reservoir Average EOM Storage: 1922-2003



CVP San Luis Reservoir Monthly Exceedance: 1922-2003



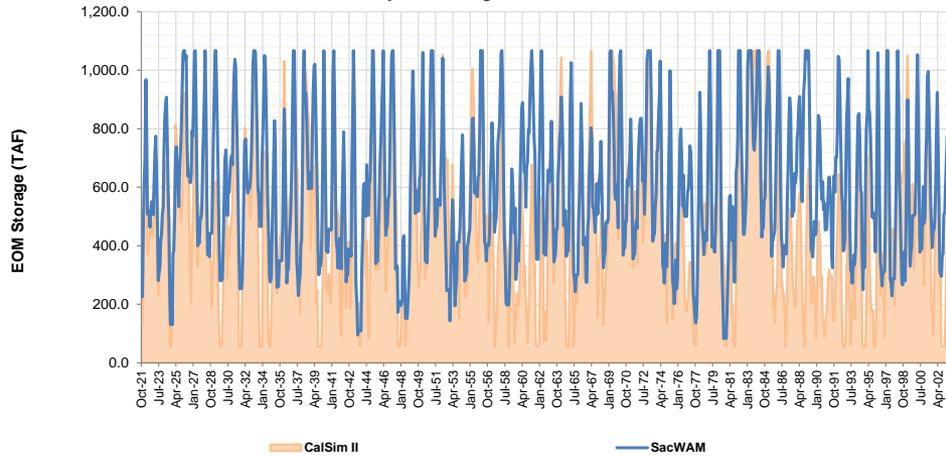
CVP San Luis Reservoir September EOM Storage: 1922-2003



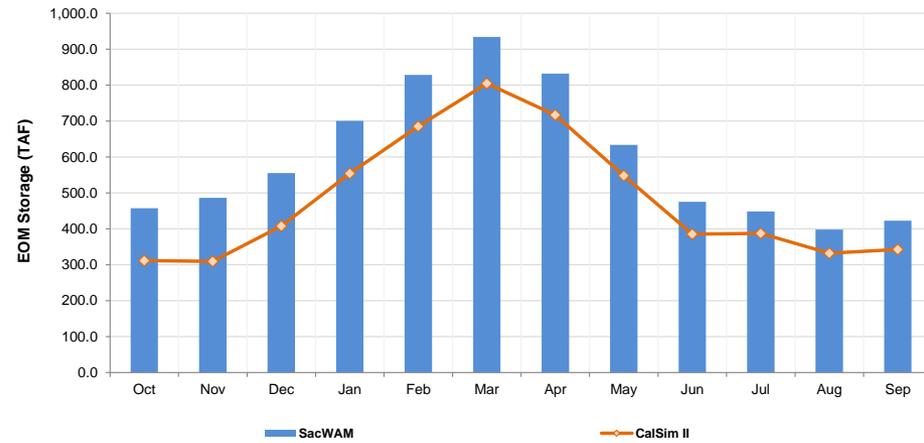
SWP San Luis Reservoir

CalSim II 342 TAF, SacWAM +23%

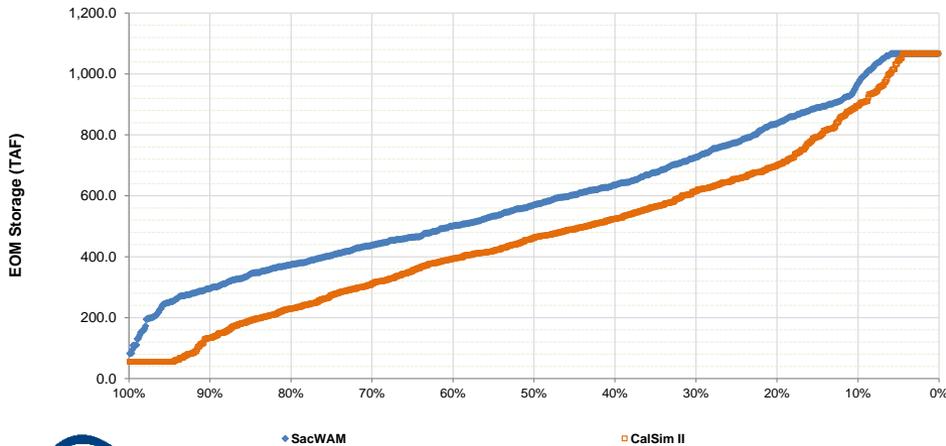
SWP San Luis Reservoir Monthly EOM Storage: 1922-2003



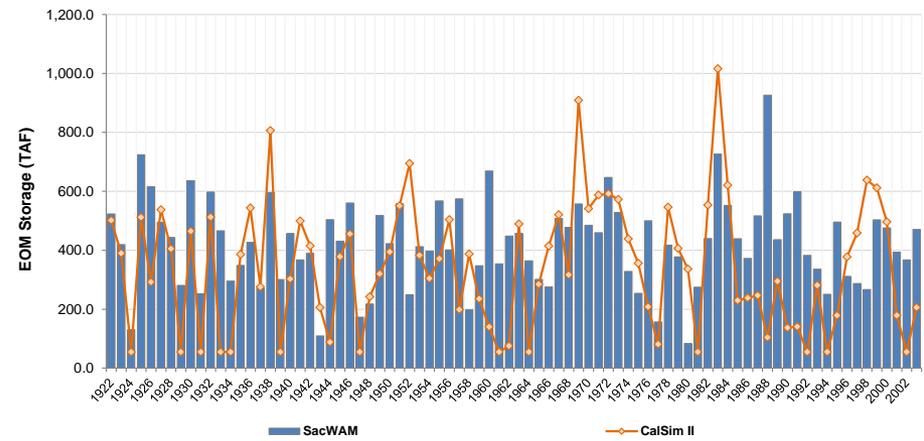
SWP San Luis Reservoir Average EOM Storage: 1922-2003



SWP San Luis Reservoir Monthly Exceedence: 1922-2003



SWP San Luis Reservoir September EOM Storage: 1922-2003



VALIDATION OF CVP-SWP NORTH-OF-DELTA DELIVERIES

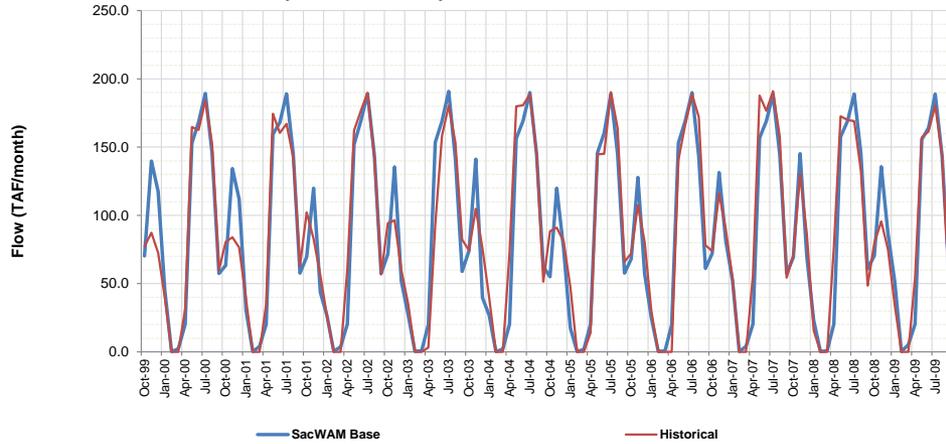
COMPARISON WITH HISTORICAL DATA 2000-2009



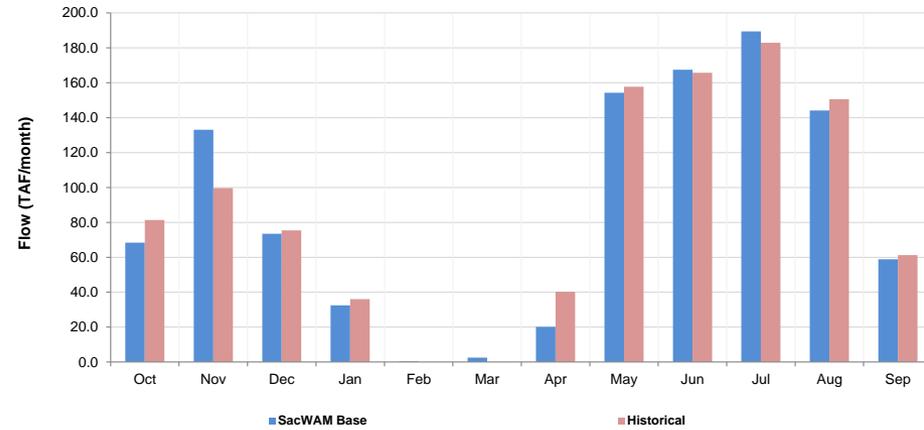
Thermalito Afterbay Diversions

Historical 1,051 TAF/yr, SacWAM Bias -1%

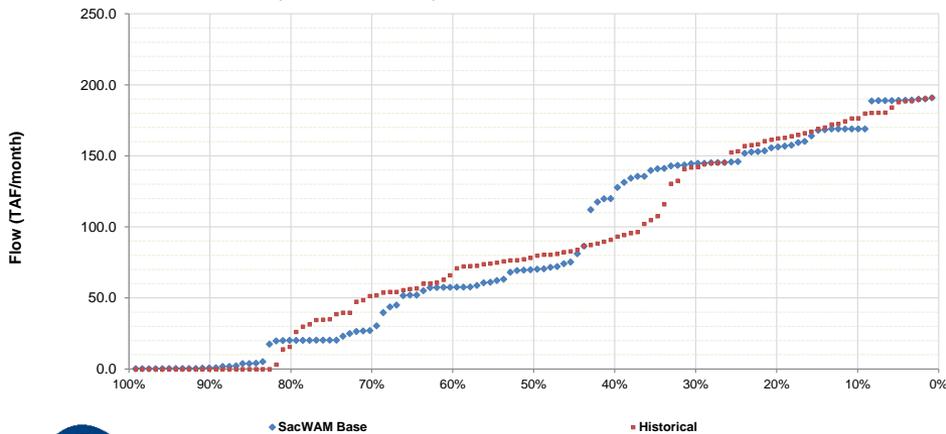
Thermalito Afterbay Diversions Monthly Flows: 2000-2009



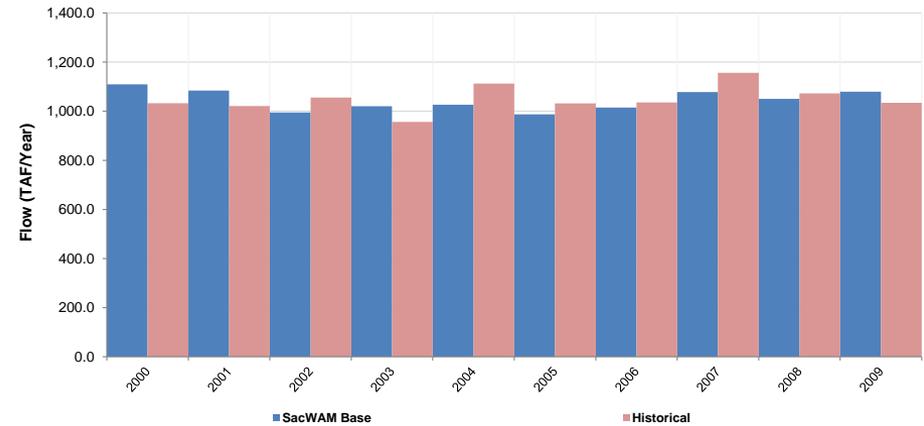
Thermalito Afterbay Diversions Average Flows: 2000-2009



Thermalito Afterbay Diversions Monthly Exceedence: 2000-2009



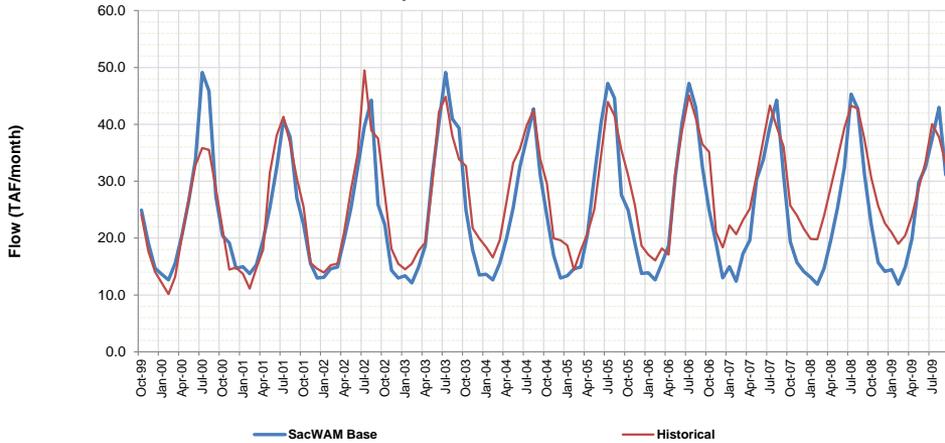
Thermalito Afterbay Diversions Annual Flows: 2000-2009



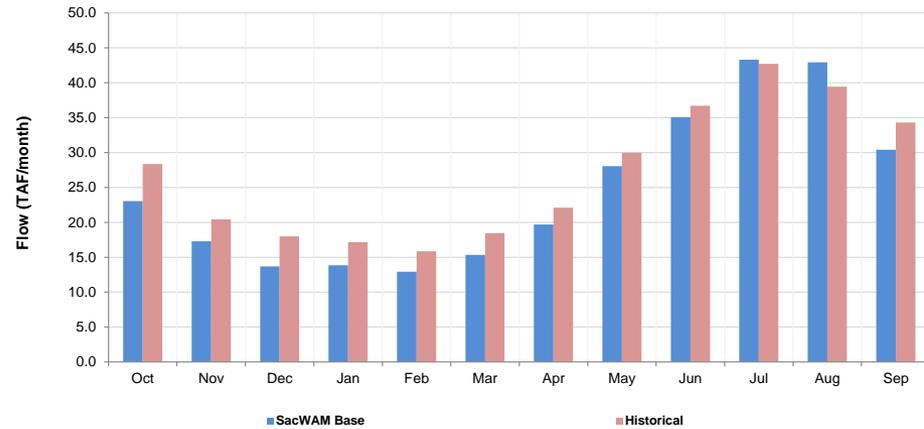
American River Diversions+ City of Sac.

Historical 323 TAF/yr, SacWAM Bias -9%

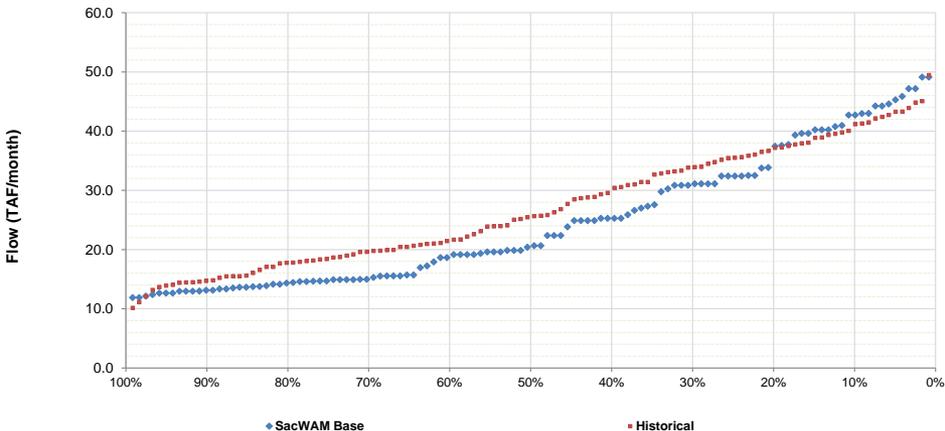
American River Diversions Monthly Flows: 2000-2009



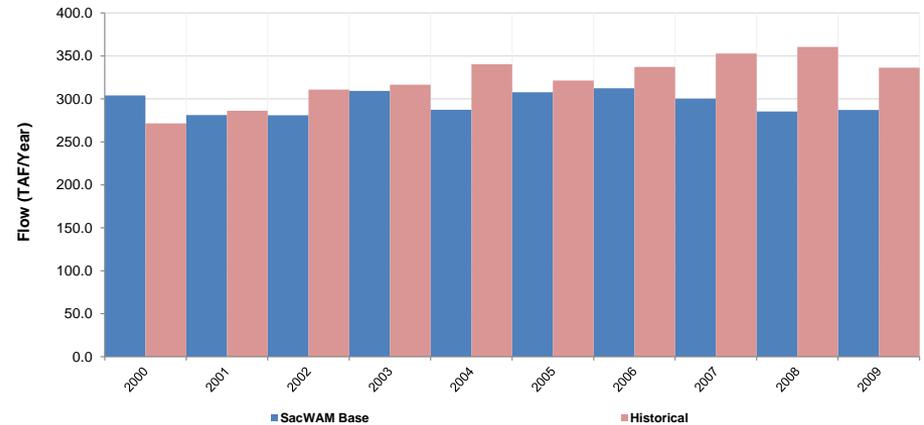
American River Diversions Average Flows: 2000-2009



American River Diversions Monthly Exceedence: 2000-2009



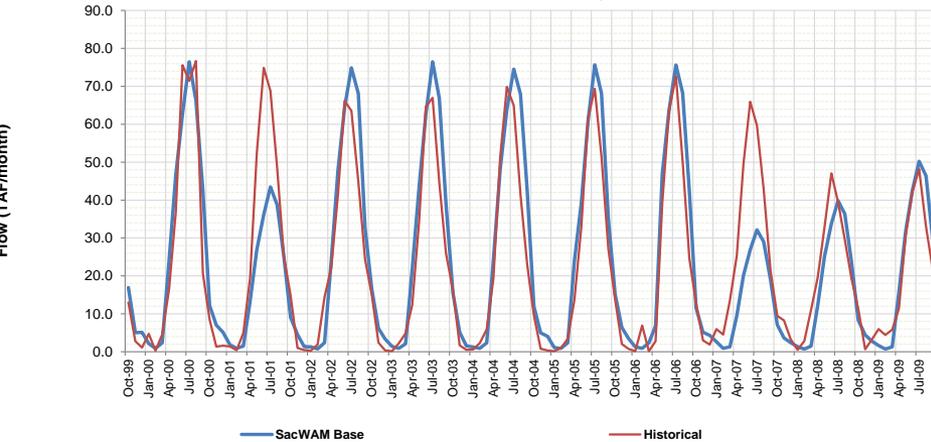
American River Diversions Annual Flows: 2000-2009



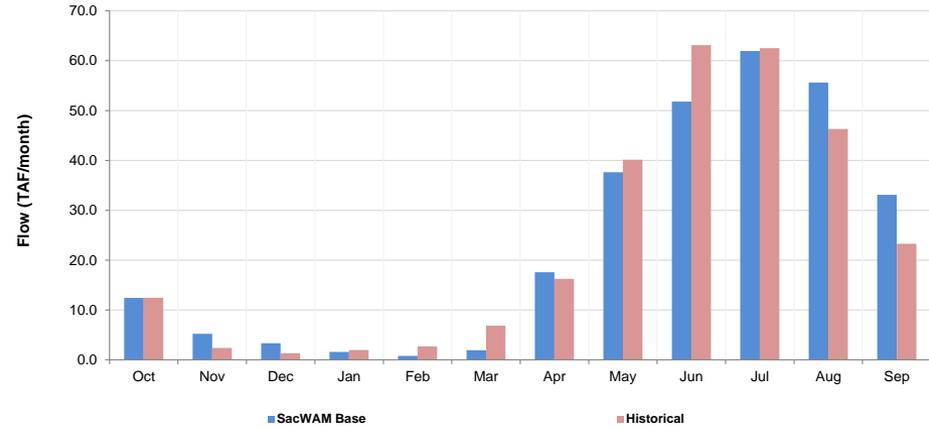
Sacramento River Diversions - WSC

Historical 279 TAF/yr, SacWAM Bias +1%

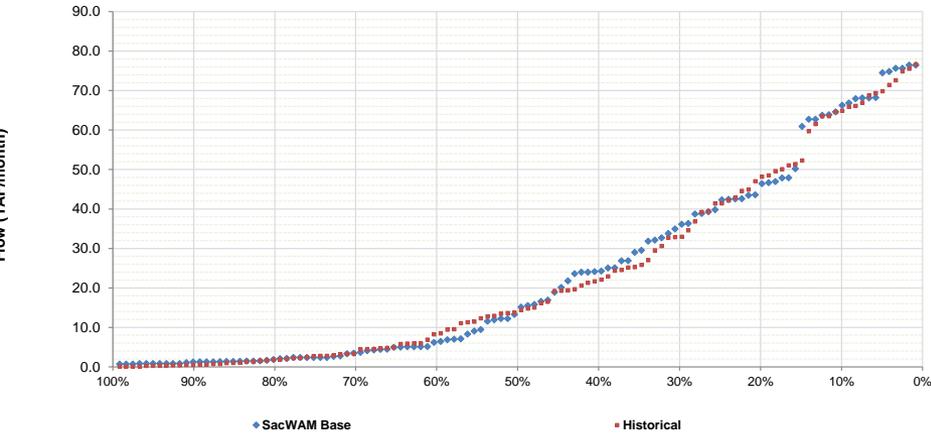
CVP Settlement Diversions from the Sacramento River Monthly Flows: 2000-2009



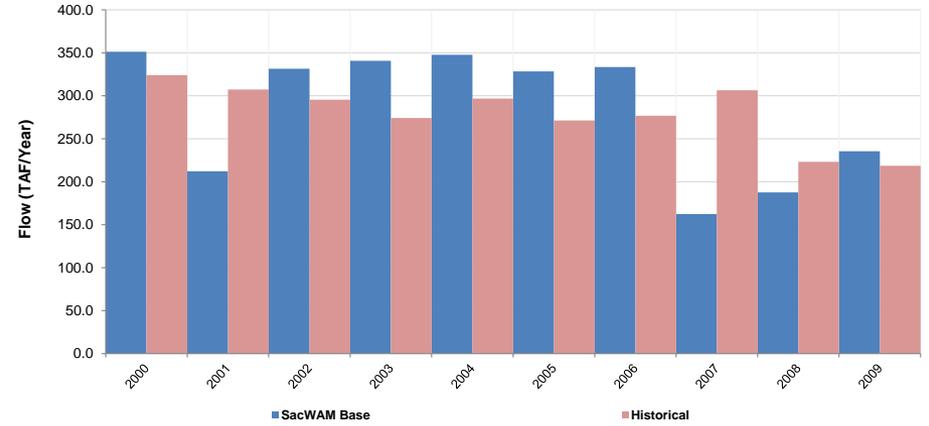
CVP Settlement Diversions from the Sacramento River Average Flows: 2000-2009



CVP Settlement Diversions from the Sacramento River Monthly Exceedence: 2000-2009



CVP Settlement Diversions from the Sacramento River Annual Flows: 2000-2009



VALIDATION OF LOCAL OPERATIONS

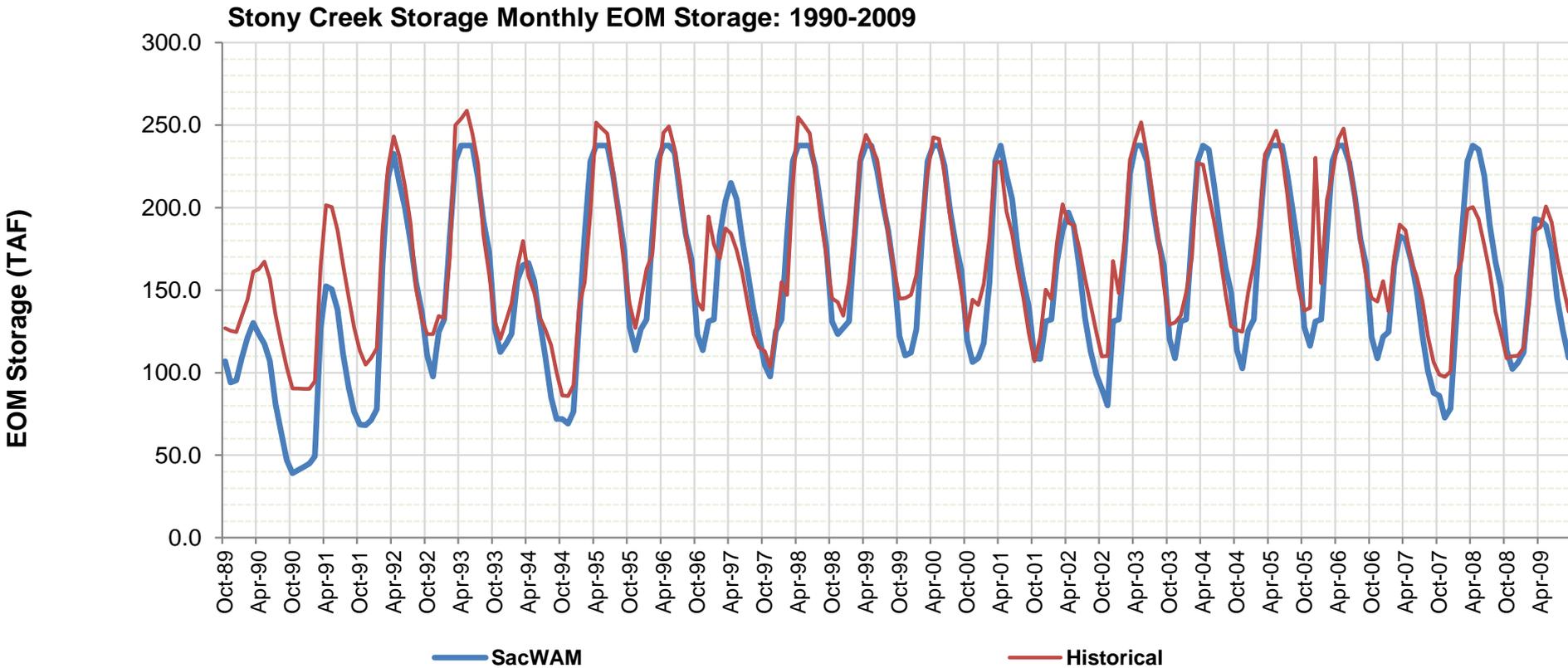
COMPARISON WITH HISTORICAL DATA



Validation of Local Project Operations

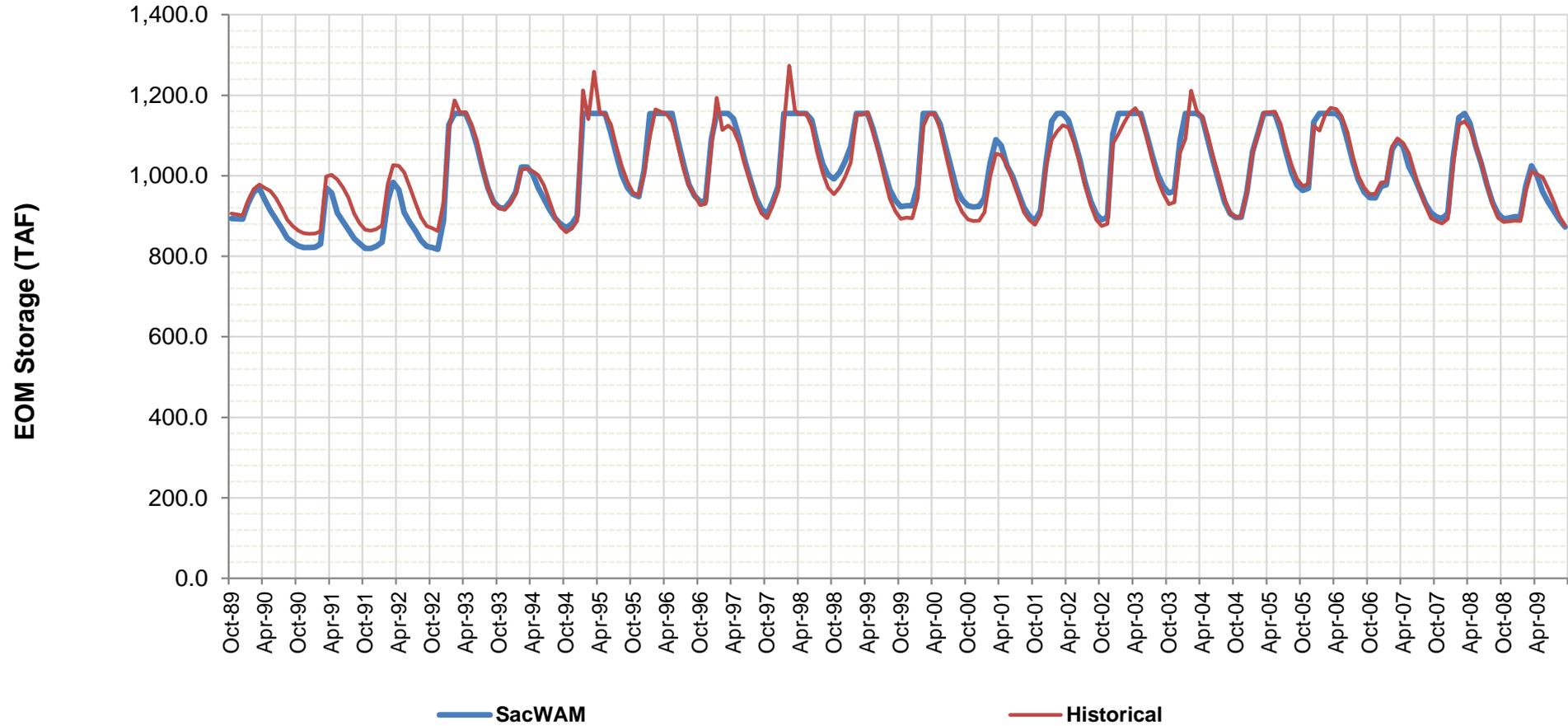
- Westside Sacramento Valley
 - Stony Creek
 - Cache Creek
 - Putah Creek
- Eastside Sacramento Valley
 - Yuba River
 - Bear River
- Eastside Streams
 - Cosumnes River
 - Mokelumne River
 - Calaveras River

East Park, Stony Gorge, Black Butte, Stony Creek



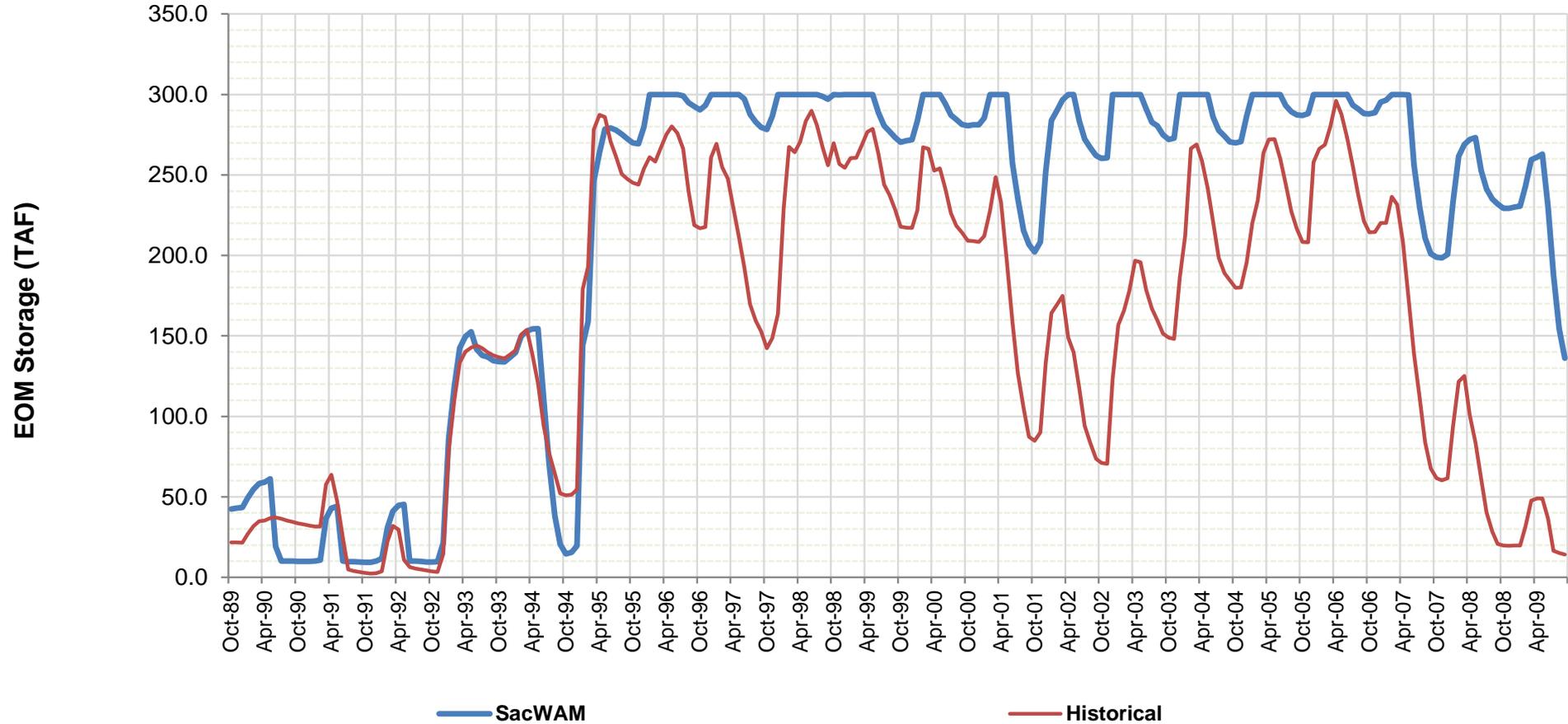
Clear Lake, Cache Creek

Clear Lake Monthly EOM Storage: 1990-2009



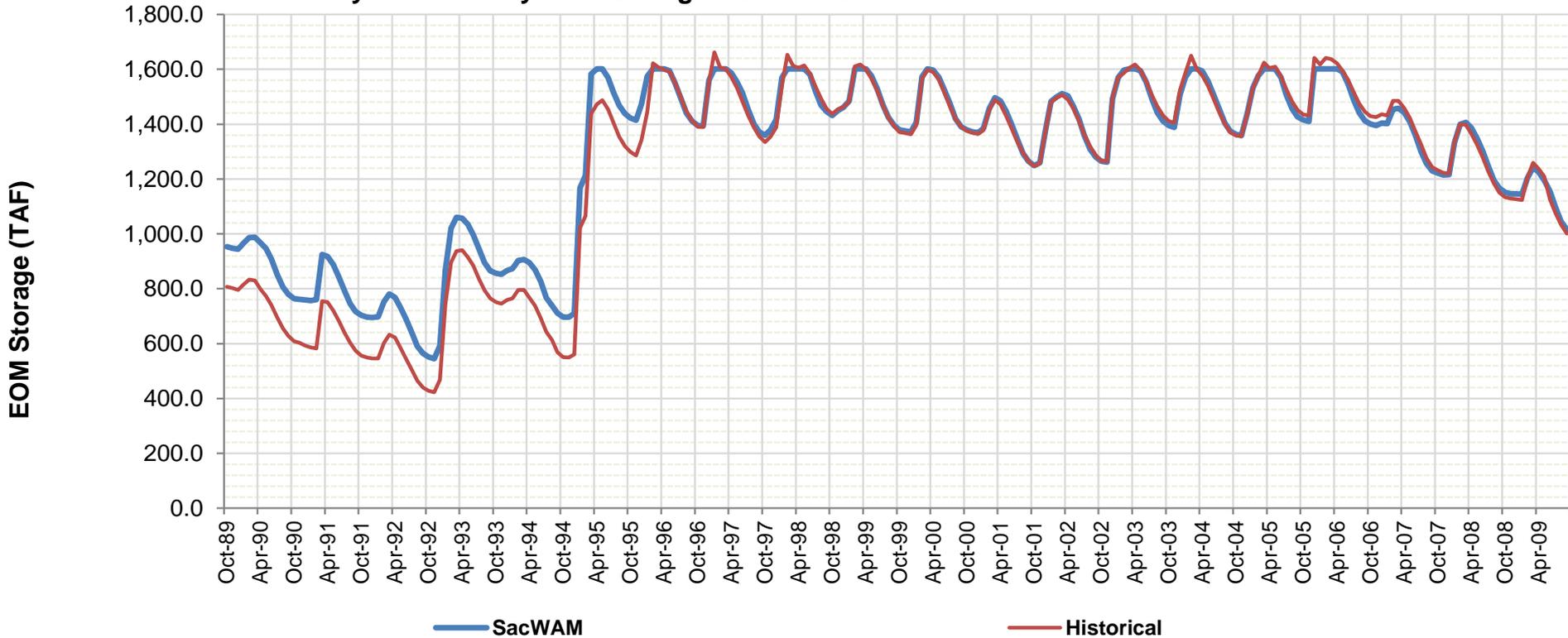
Indian Valley, NF Cache Creek

Indian Valley Reservoir Monthly EOM Storage: 1990-2009

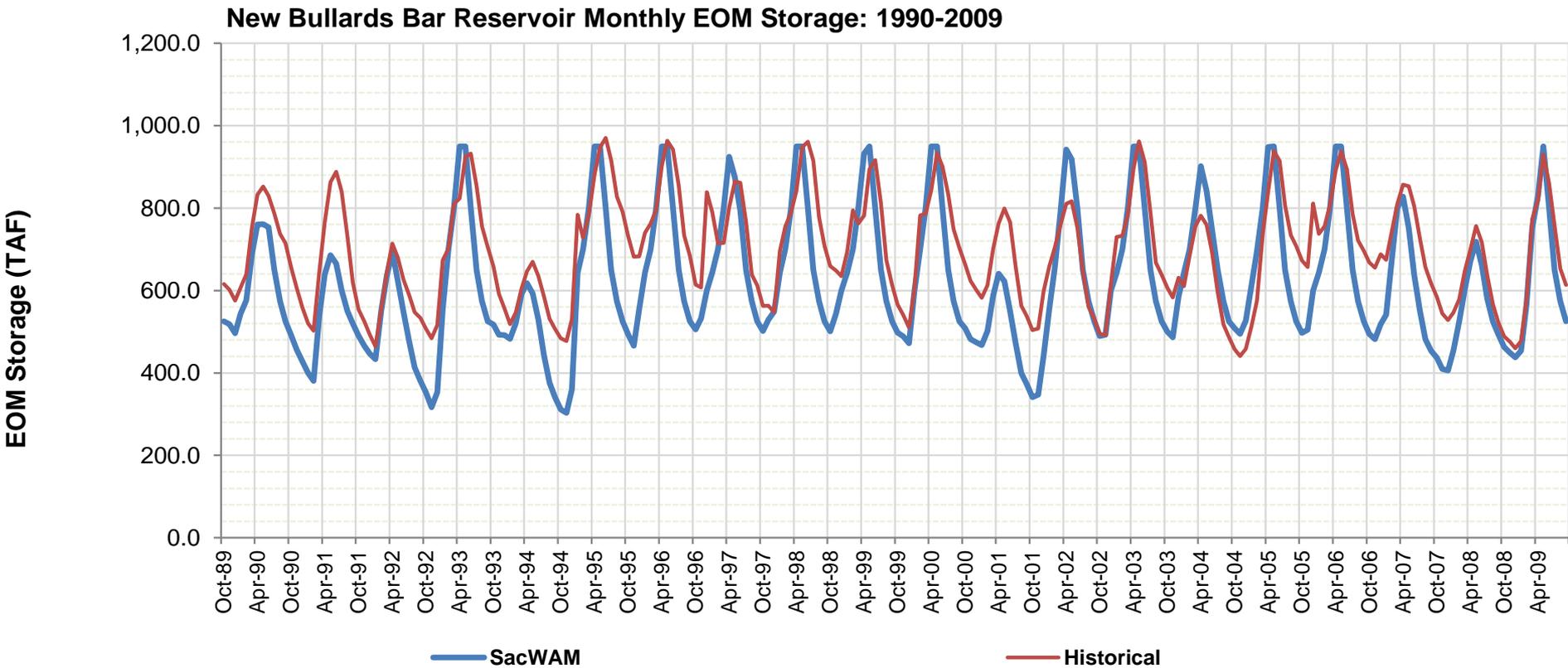


Lake Berryessa, Putah Creek

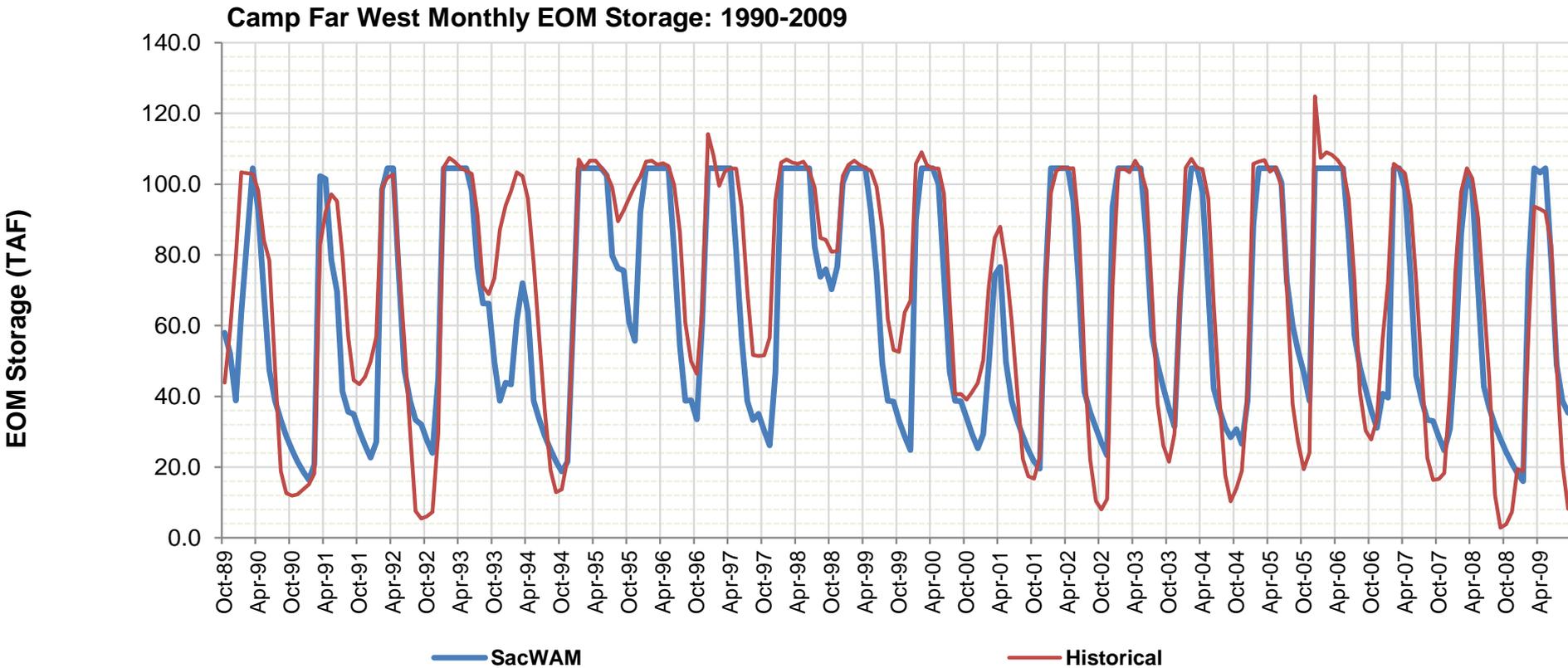
Lake Berryessa Monthly EOM Storage: 1990-2009



New Bullards Bar, NF Yuba River

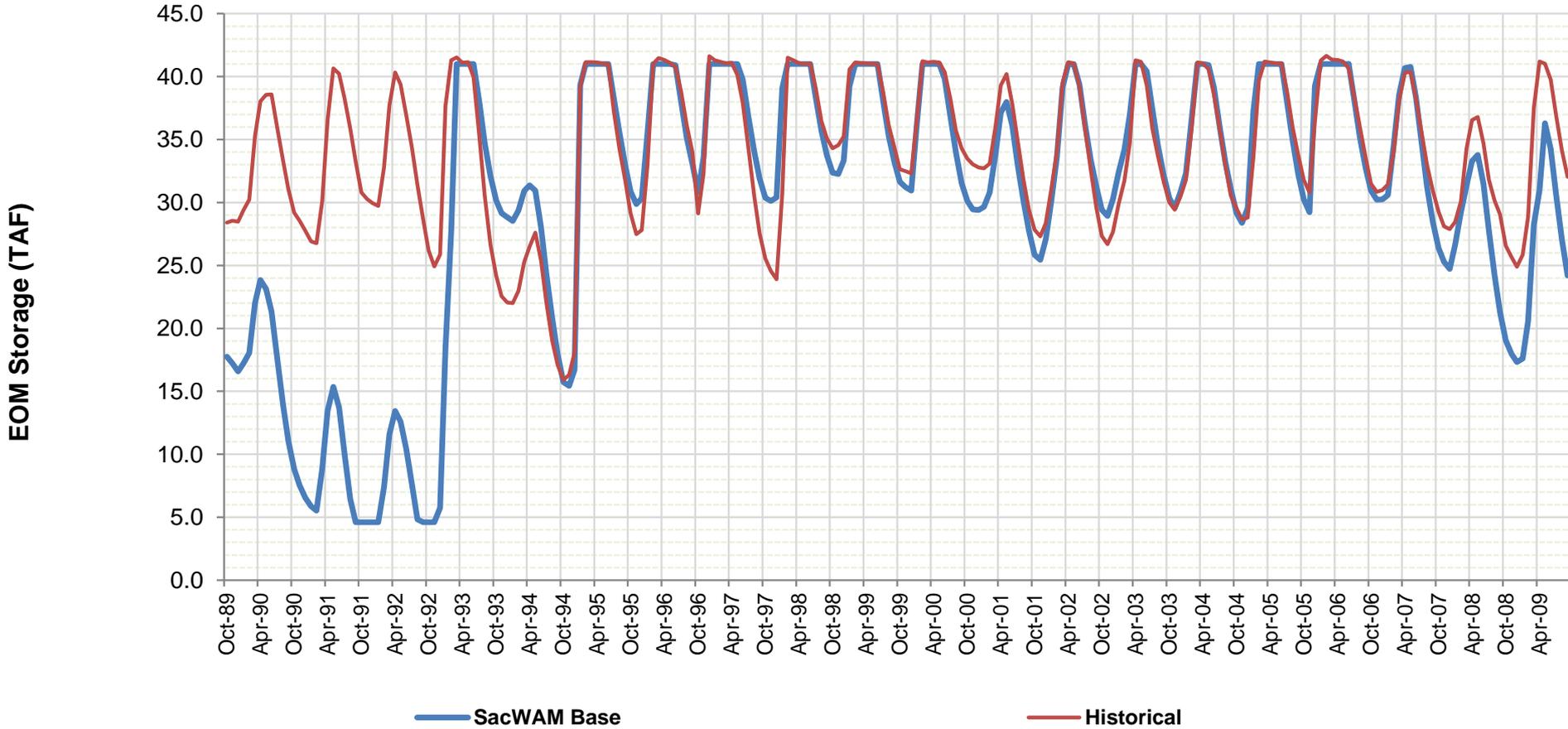


Camp Far West, Bear River



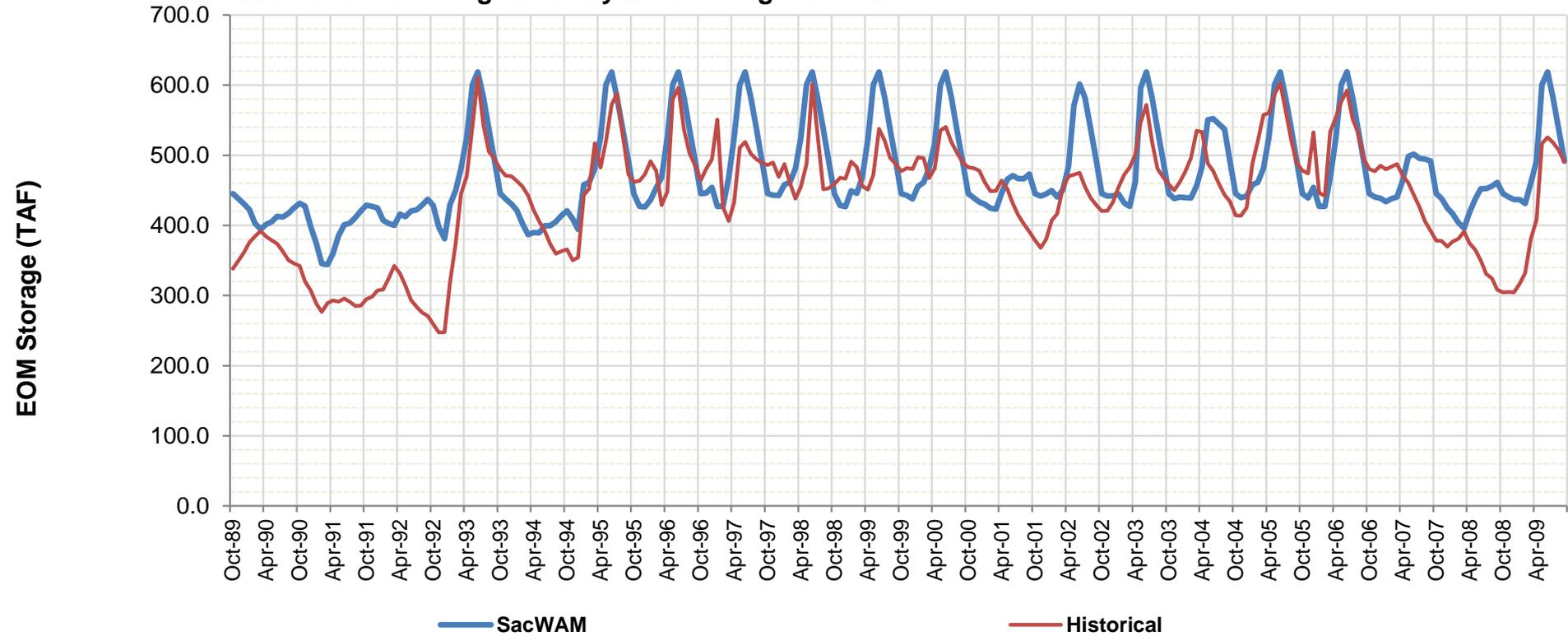
Jenkinson Lake, Cosumnes River tributary

Jenkinson Lake Monthly EOM Storage: 1990-2009



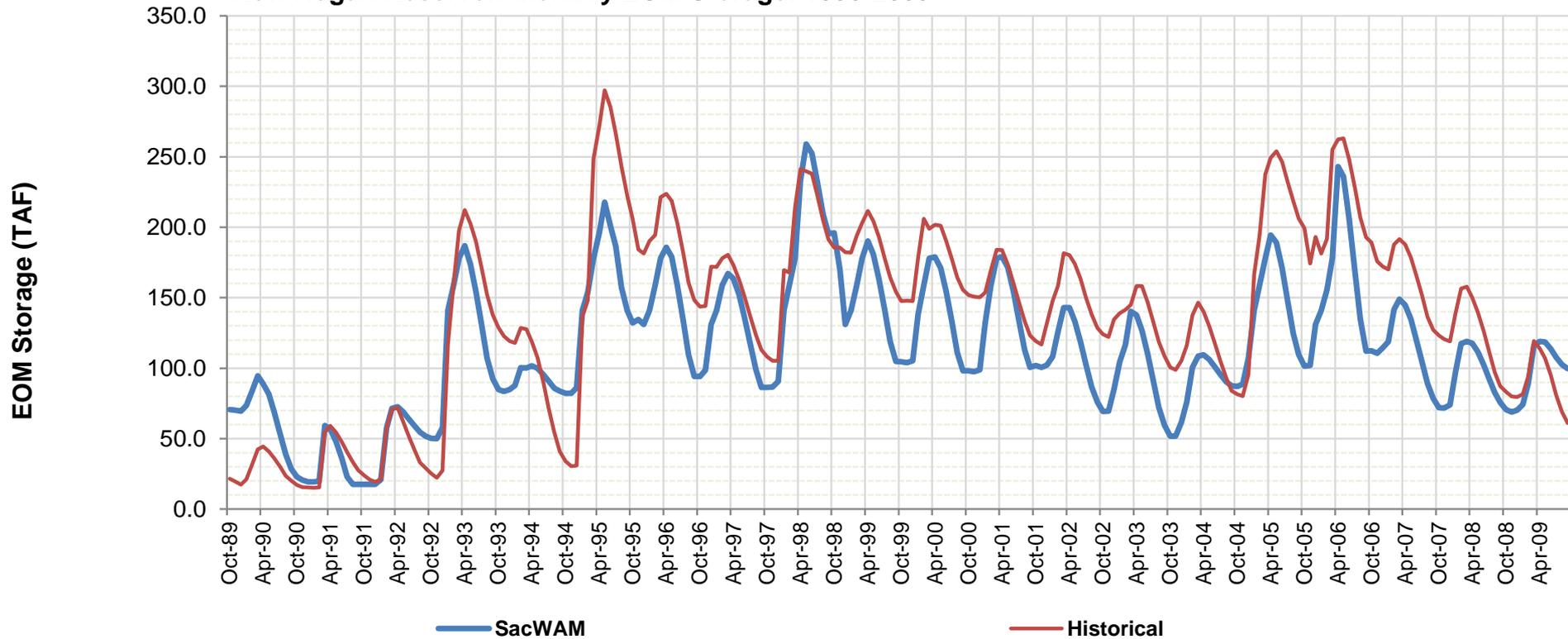
Pardee and Camanche, Mokelumne River

EBMUD Total Storage Monthly EOM Storage: 1990-2009



New Hogan, Calaveras River

New Hogan Reservoir Monthly EOM Storage: 1990-2009



Summary

- Reasonable match with CalSim II hydrology
- Reasonable match with CalSim II simulated CVP-SWP operations 1922-2003
- Reasonable match with historical data 2000-2009

- Some errors still to be addressed