Channel Routing and Multi-Timestep Optimization with WRIMS2 – WY 1997 Case Study

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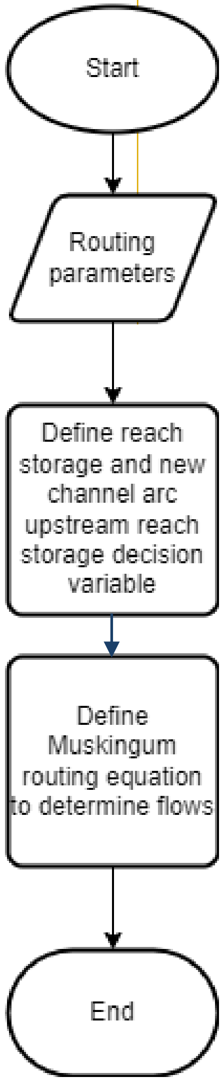
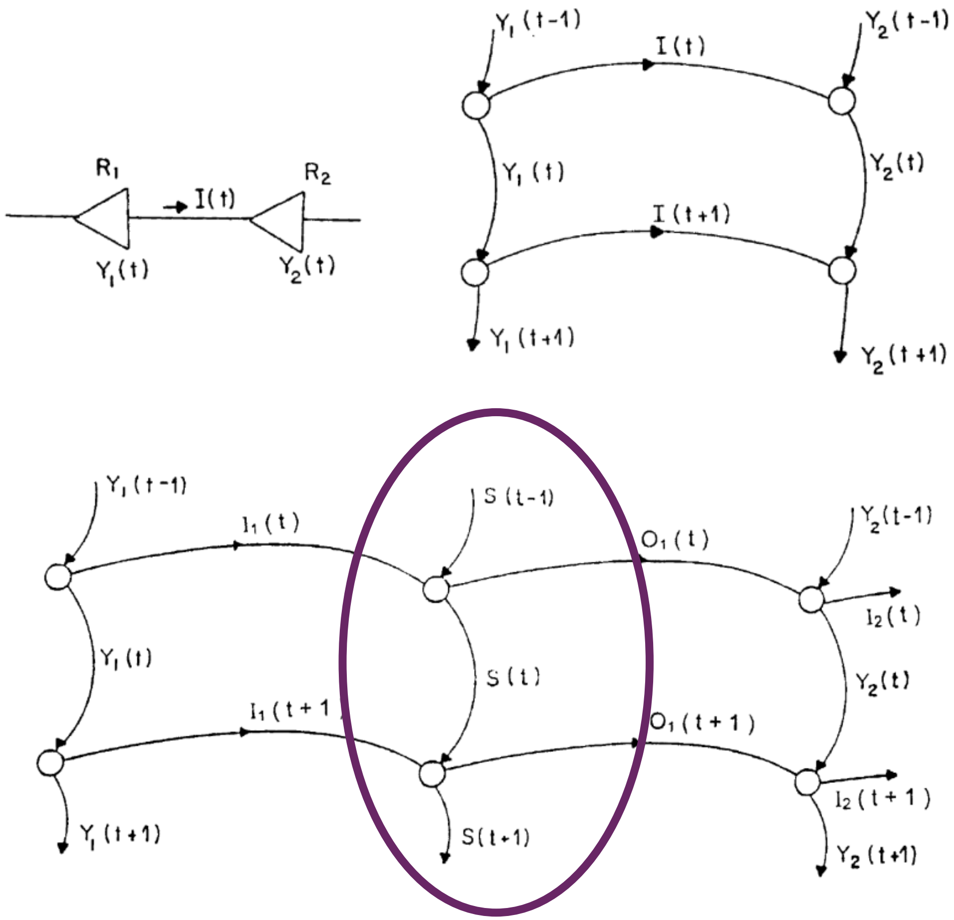
Problem statement

- A daily version of a planning/system operations model is desired because it can better represent:
  - Flood management
  - Environmental flow requirements
  - Delta regulations
- What is needed?
  - Channel routing
  - Multi-timestep optimization (Ilich 2007)
- **How to make the two concepts work together in WRIMS-based models like CalLite/CalSim?**

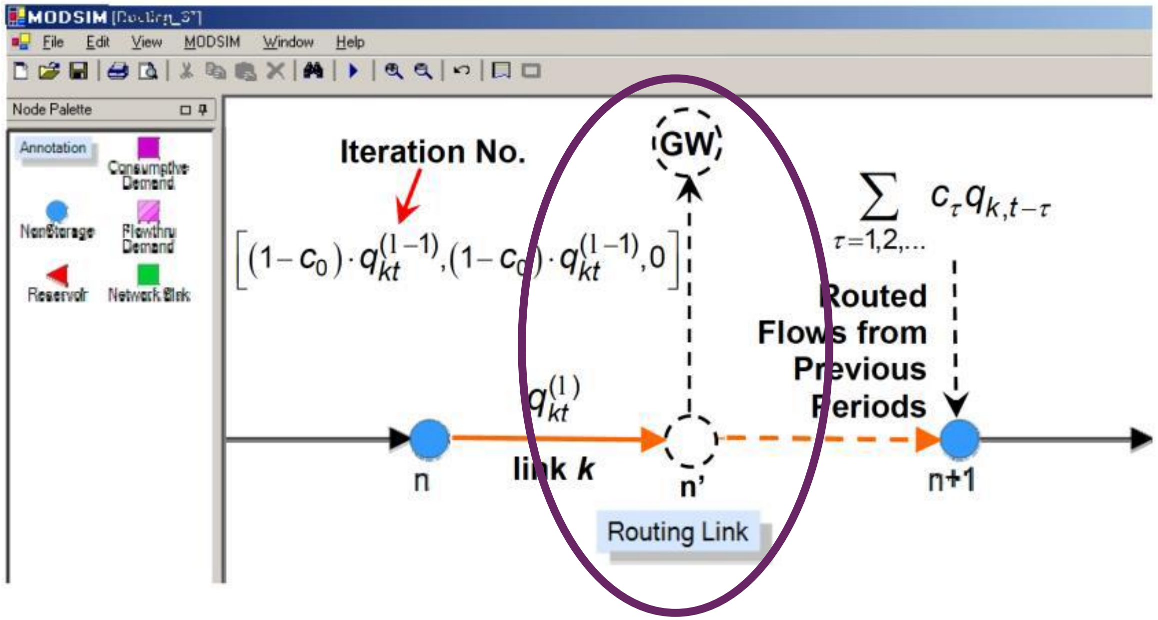
Linear hydrologic routing in WRIMS2





Braga and Barbosa (2001)

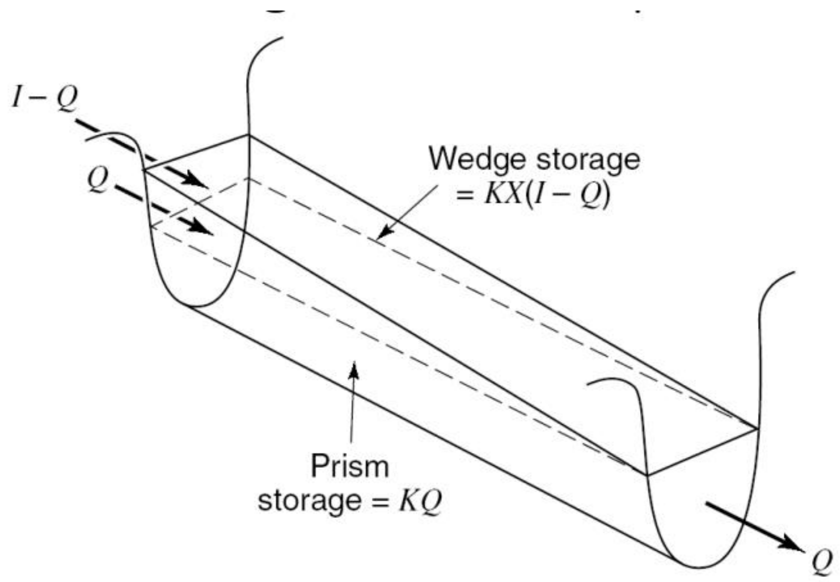
The main thing is introducing some kind of “storage” node.



Labadie (2010)

Muskingum Routing

- Two main parameters are X and K
- X is the weighting factor to distribute between wedge and prism storage
- K is attenuation factor or storage time constant for the reach



$$Q_{j+1} = C_1 I_{j+1} + C_2 I_j + C_3 Q_j$$

Q at the next timestep is just a weighted average of information you already have!

C_KSWCK_UPS – C_KSWCK = RS_KSWCK – RS_KSWCK(-1)

https://www.colorado.edu/lab/krg/sites/default/files/attached-files/13_sp20_routing-revised.pdf

Multi-timestep optimization (MTO)

- Optimizes objective function over a specified period
- Requires ability to access future timesteps
- Available in OASIS, RIVERWARE, and WRIMS2 but not commonly used (Ilich 2007)

$$Max \sum_{i=1}^{n} \sum_{t=1}^{m} X_{i,t} \, P_i$$

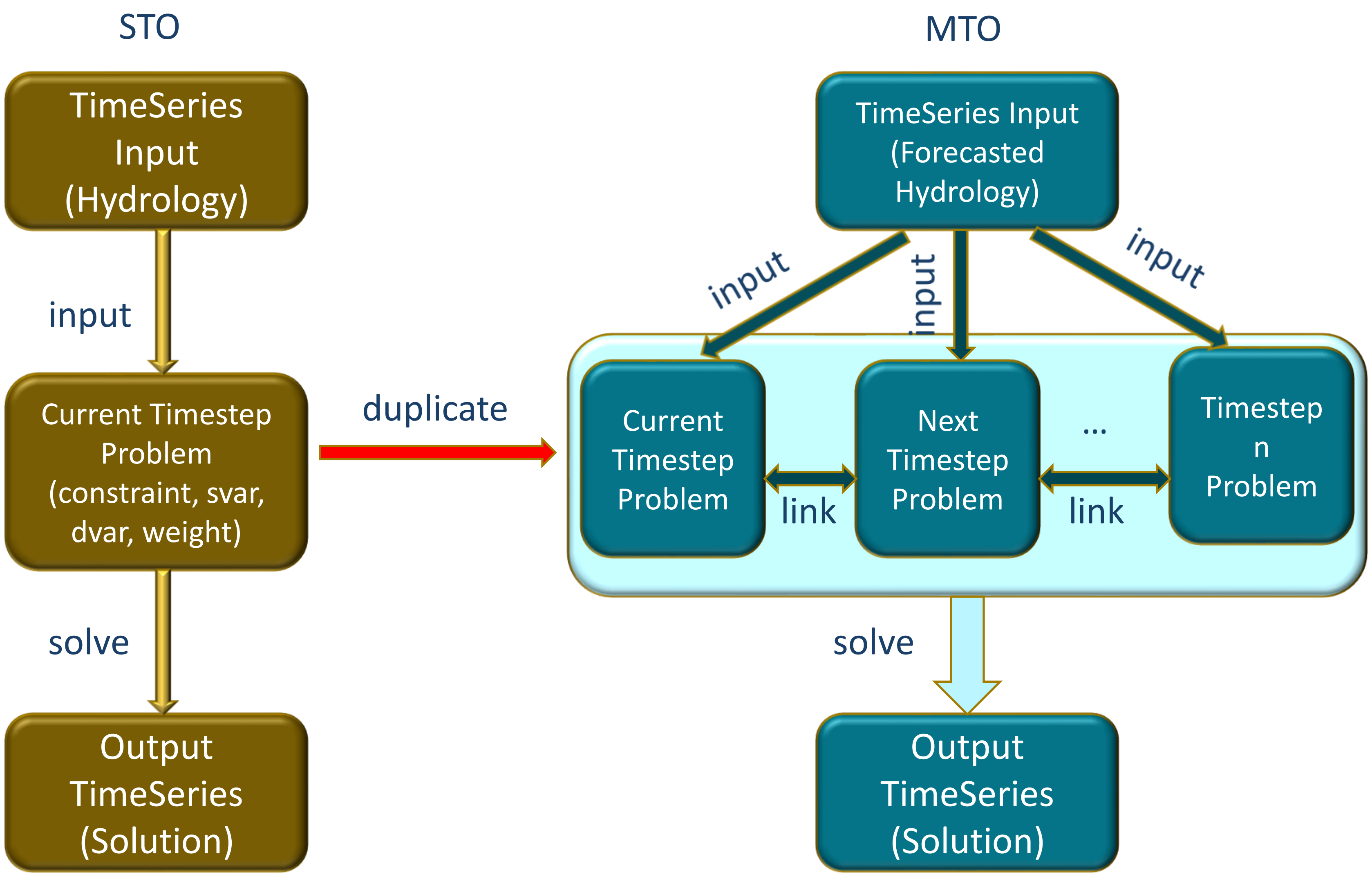
$$Max \sum_{i=1}^{n} X_i P_i$$

STO

Where:

- n is the number of components *m* is the total number of time intervals
- Variable *X* represents flows while *P* is a weight/priority in component *i* and time interval *t*. Note that carry over storage also acts as a variable, since it allows the model to balance storage among various time intervals.

From Hao Xie


STO
TimeSeries Input (Hydrology)
input
Current Timestep Problem (constraint, svar, dvar, weight)
solve
Output TimeSeries (Solution)
duplicate
MTO
TimeSeries Input (Forecasted Hydrology)
input
input
input
Current Timestep Problem
link
Next Timestep Problem
…
link
Timestep n Problem
solve
Output TimeSeries (Solution)

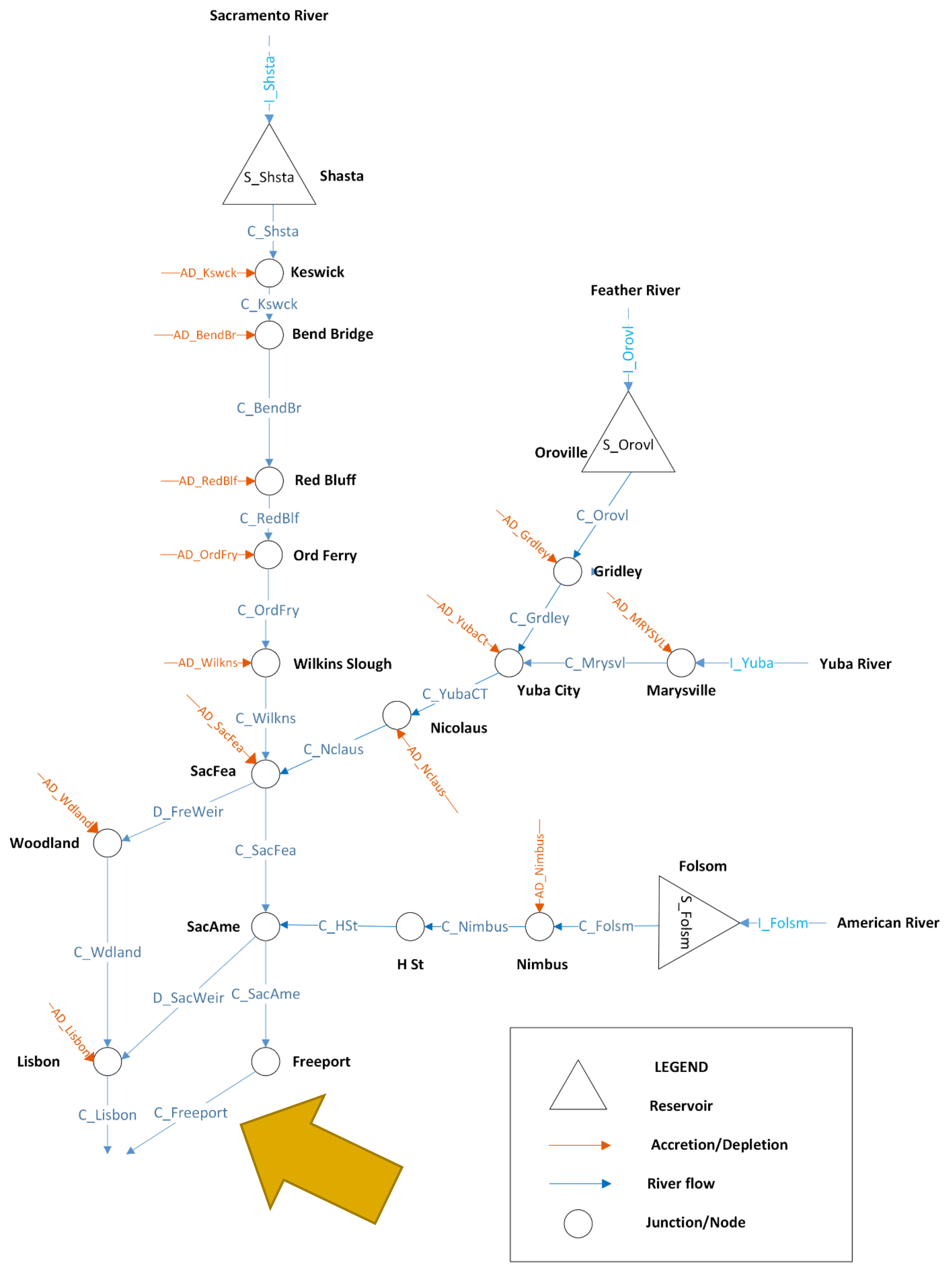
Why MTO?

- STO only solves each timestep as an independent problem. Decision variables can only rely on past time step values and NOT future values which is needed in forecasting (Fung 2011)
- Channel routing cannot work properly using STO unless system is so small that the entire travel time is shorter than the length of the routing timestep (Ilich 2007, 2022)

In summary, when travel time is longer than the timestep length (e.g., 1 day), STO mode will cause model to flood the system to overcome routing constraints and meet the downstream demand as much as possible.

Modeling Schematic

- Delta inflow demand is set to historical flow at Freeport (source is DAYFLOW)
- Accretion-depletion (AD) terms (local inflows) determined using historical flow data

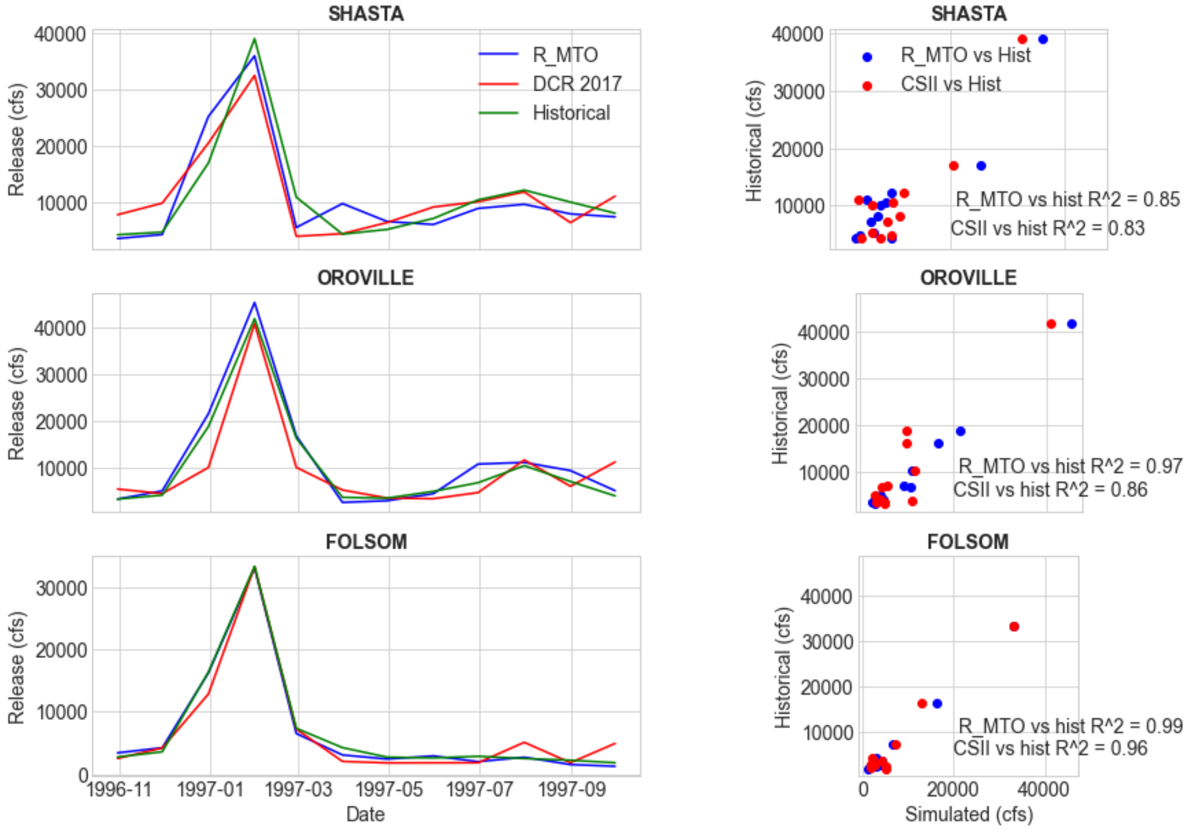


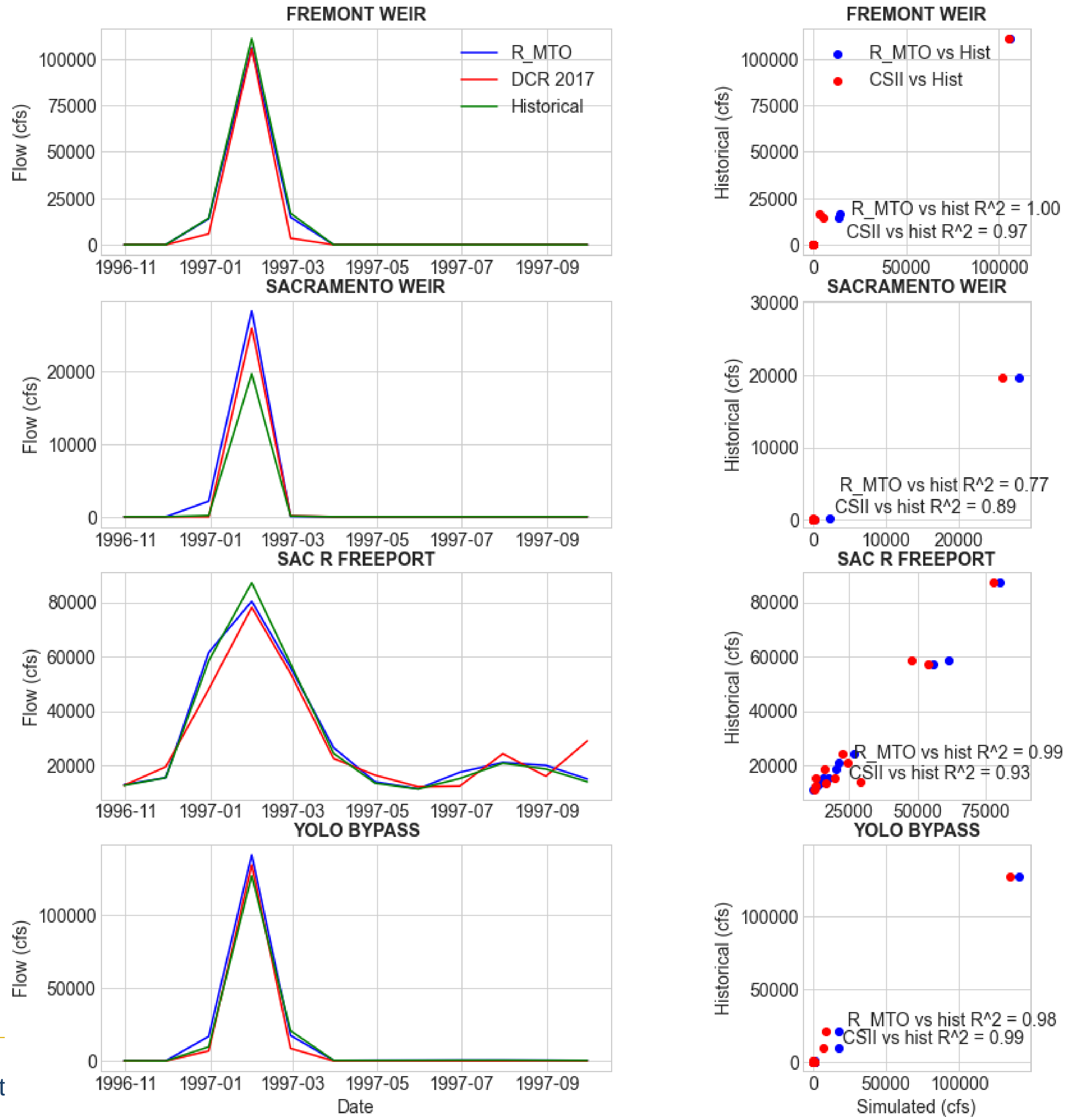
Modeling Framework

Component	Description
Simulation Period	Water Year 1997
Geographic scope	North of Delta only
Hydrologic Inputs and Data Sources	CDEC, USGS, DCR 2017 CalSim II model (using CS2CL)
Schematic basis	HEC-FCLP, CalLite
Flood management	US Army Corps of Engineers Water Control Manuals (1977 Shasta, 1970 Oroville, 2004 Folsom)
Minimum instream flow requirements	Sacramento River at Keswick, Red Bluff, Wilkins Slough Feather River – below Thermalito and at Mouth American R – below Nimbus, at H St. Bridge
Delta demand	Historical Freeport flow timeseries

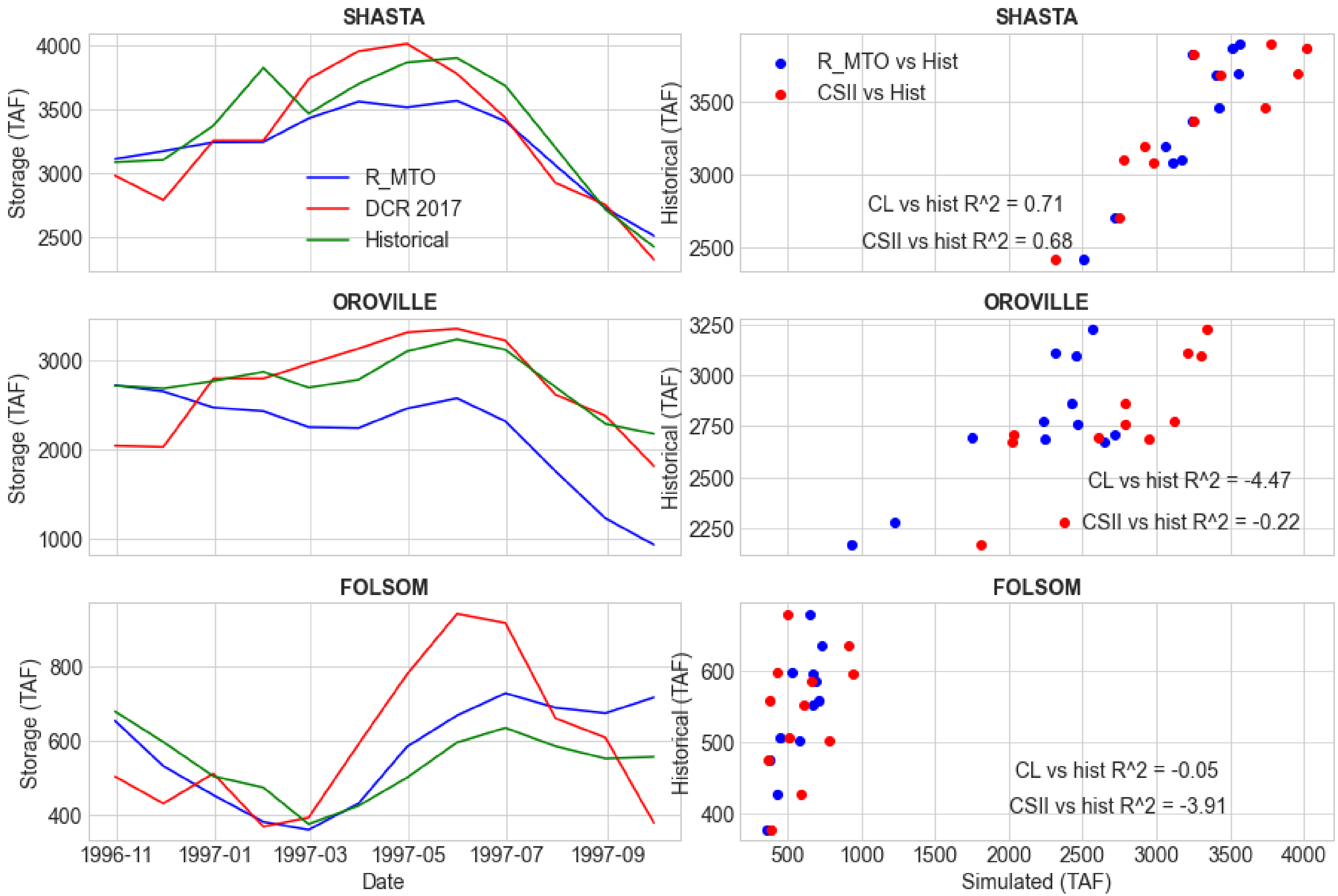
Results

Timeseries and Scatterplots with R-squared





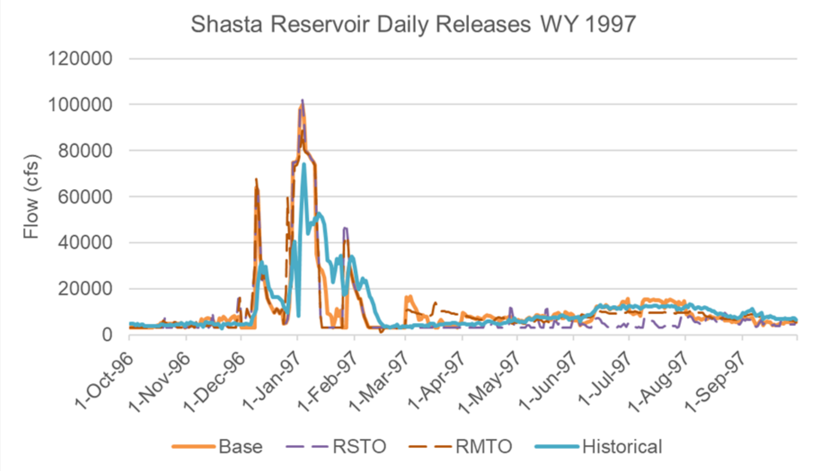
Storages

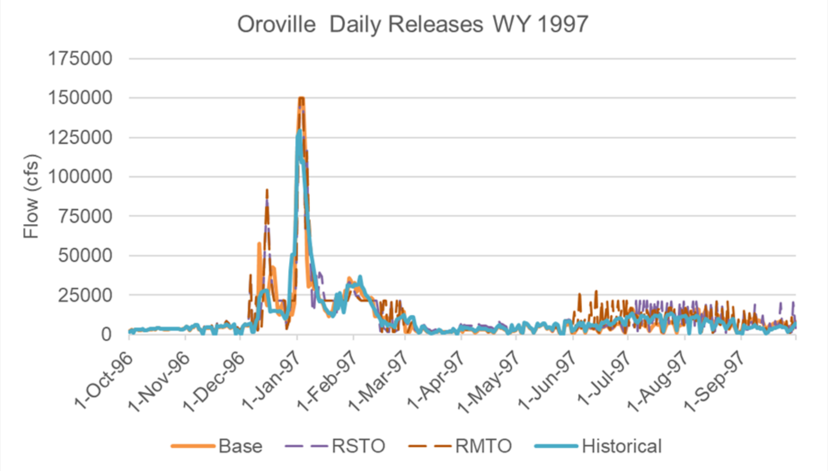


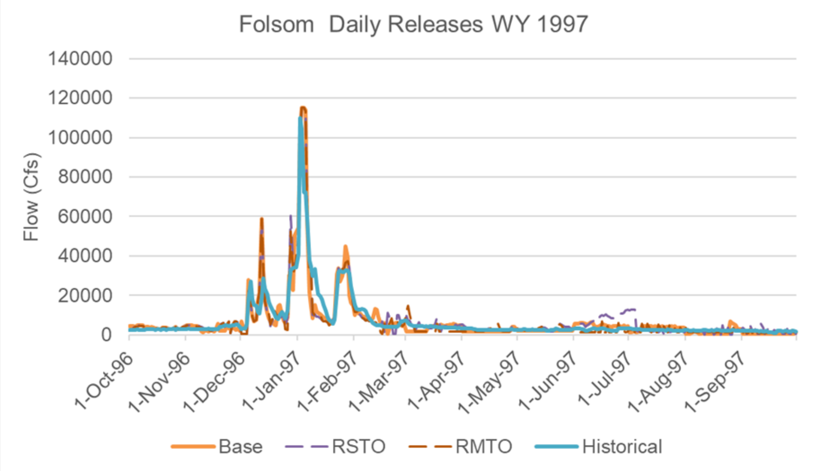
SHASTA
OROVILLE
FOLSOM
Storage (TAF)
Historical (TAF)
R_MTO
DCR 2017
Historical
R_MTO vs Hist
CSII vs Hist
CL vs hist R^2 = 0.71
CSII vs hist R^2 = 0.68
CL vs hist R^2 = -4.47
CSII vs hist R^2 = -0.22
CL vs hist R^2 = -0.05
CSII vs hist R^2 = -3.91
1996-11
1997-01
1997-03
1997-05
1997-07
1997-09
Date
Simulated (TAF)

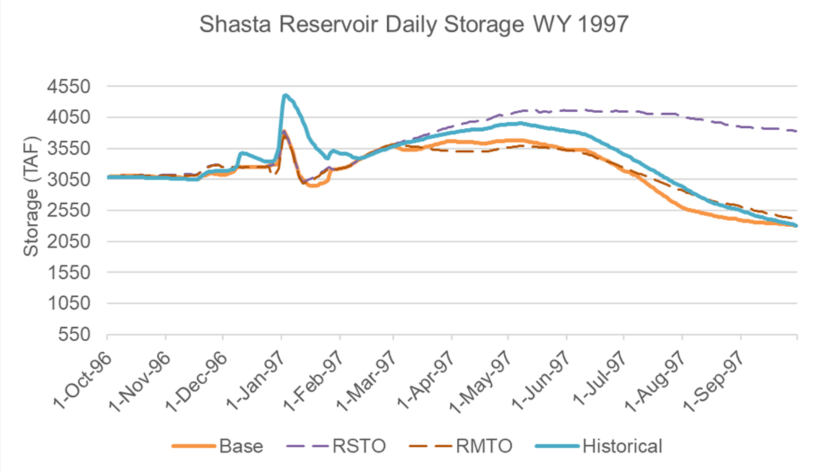
Results – Daily timeseries

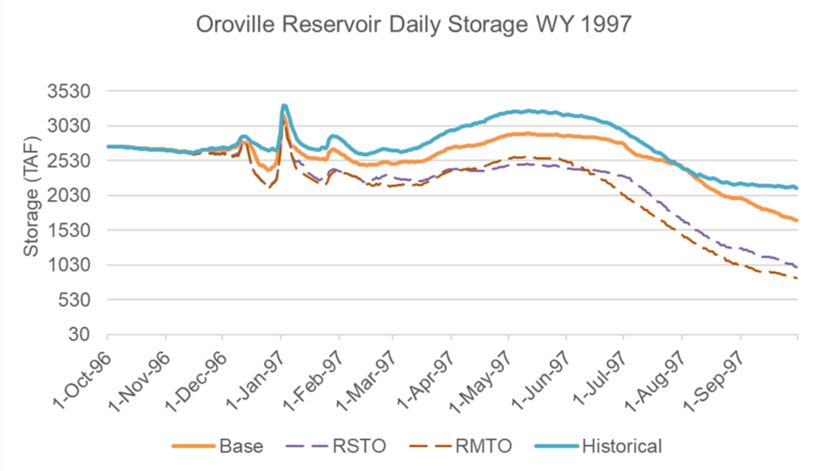
North of Delta storage releases and storage

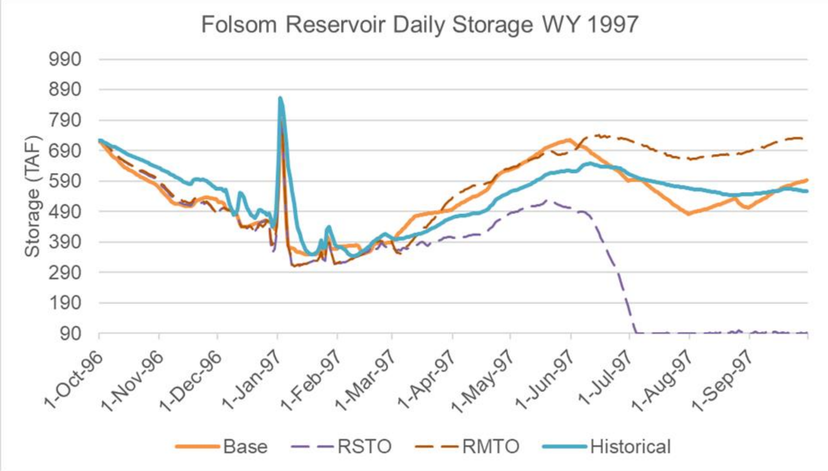




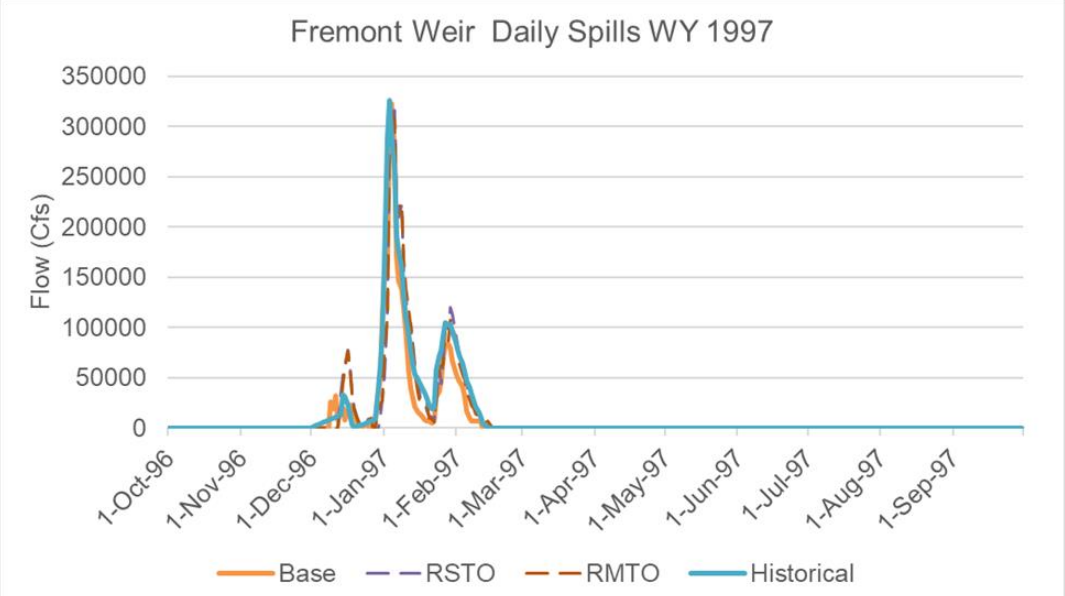


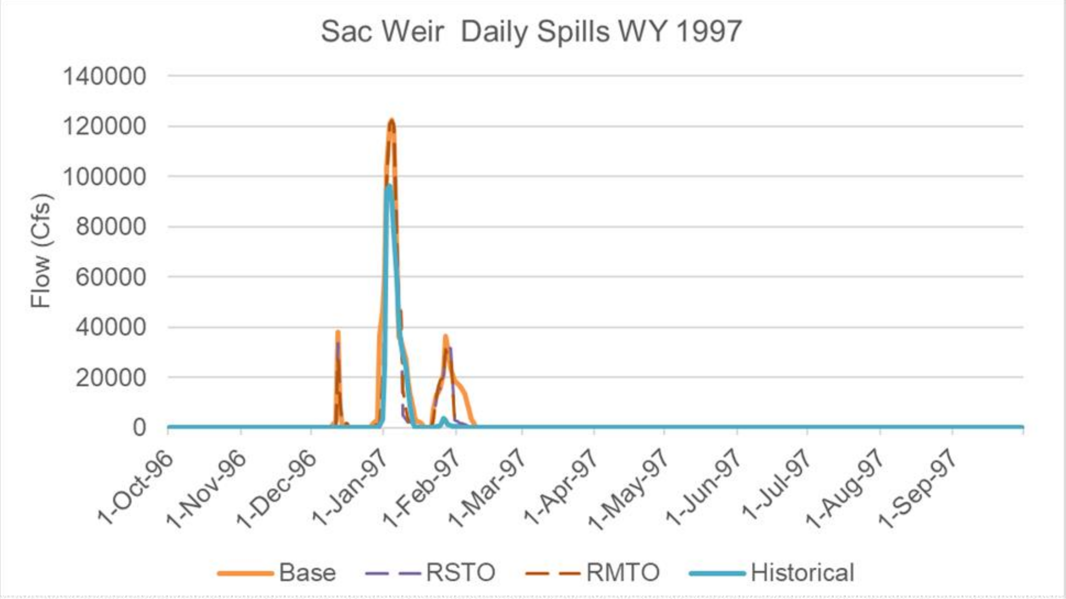


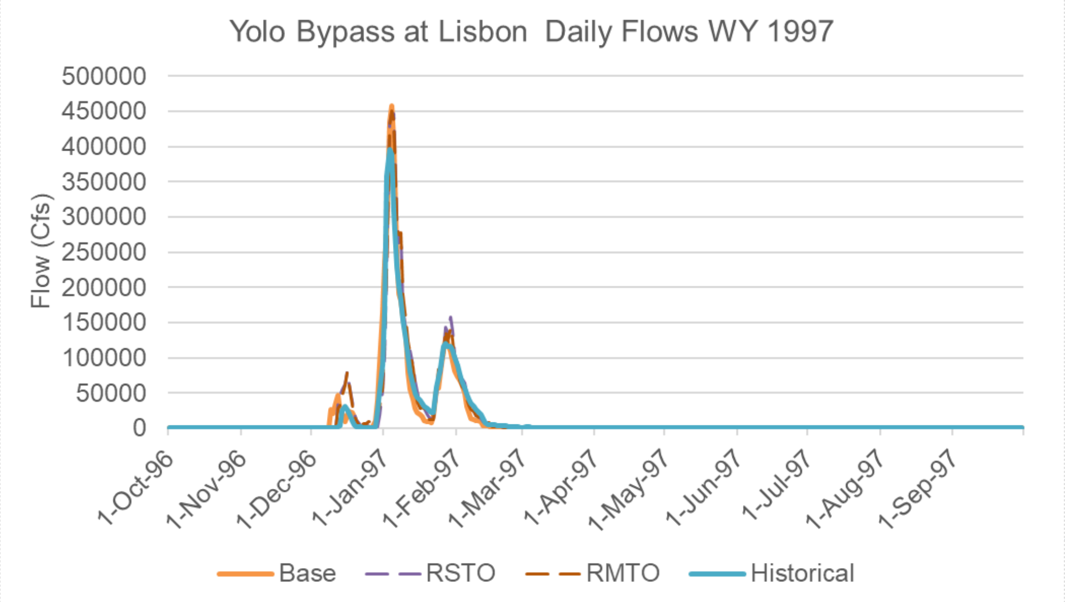


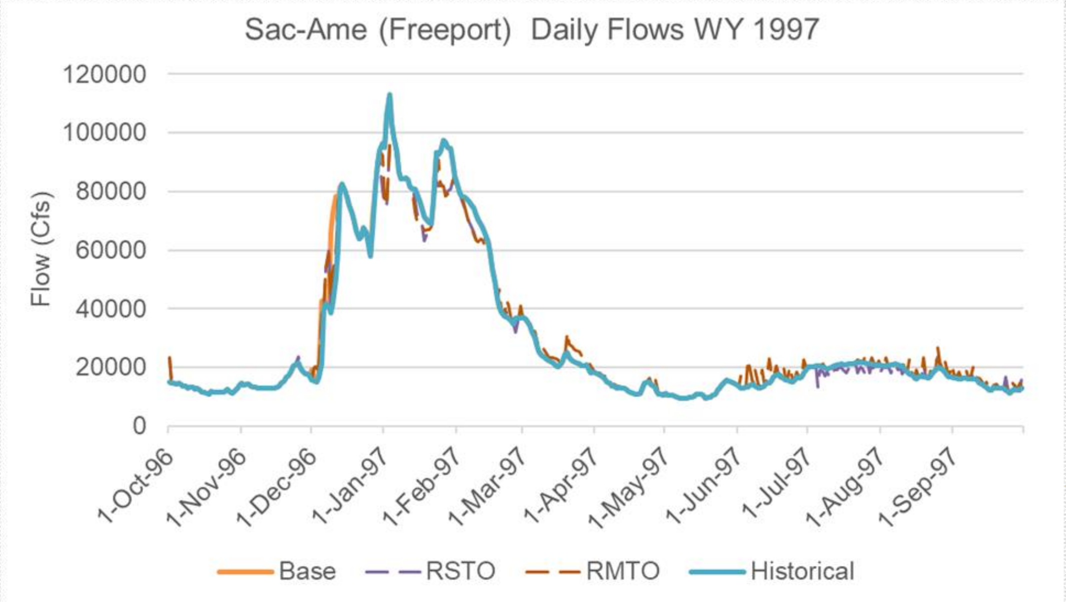


Lower Sacramento weir spills and flows



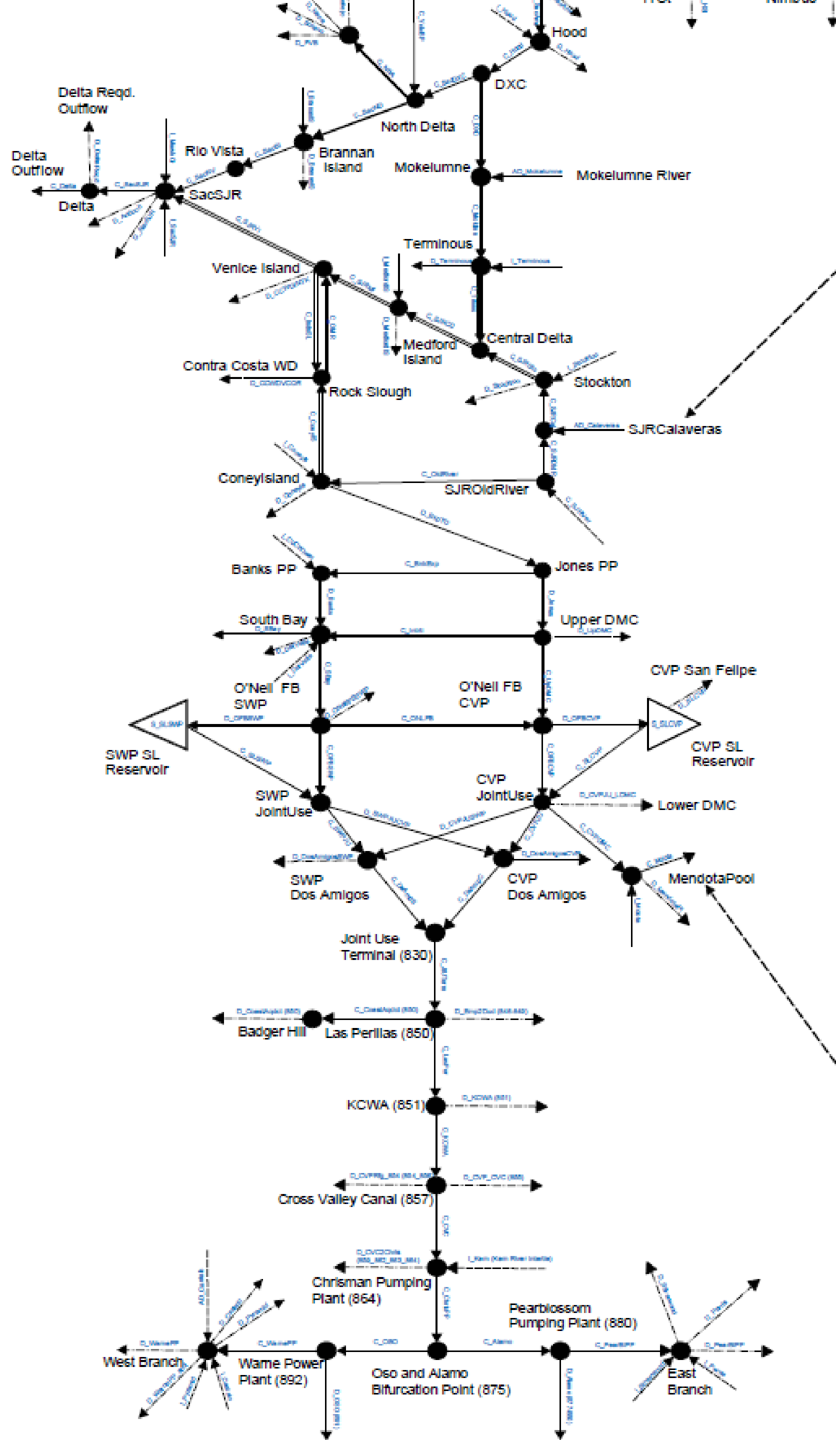






Limitations and Future Work

- Model coverage
- Channel routing method
- Hydrologic inputs and data gaps
- Recalibration and adjustments



Big ideas

- Implementing channel routing in some MILP model is relatively well-understood. The tricky parts are adjusting the **weighting strategy** with new reach storage arcs, using a non-linear routing method
- Applying MTO in a daily timestep manner is new within WRIMS2. More research is needed on how best to formulate **MTO-based goals and targets**
- Developing a full-fledged daily model will **take years of collaborative and peer-review effort**. But we know a little bit more now about what we need and how to get there which are helpful

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