Challenges Regarding Hourly Routing for Operations Models

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Acknowledgements

- Bureau of Reclamation, Yuma Area Office – Water Operations Staff

Background

- Hydros developed an hourly-timestep model of the Colorado River from Parker Dam to Imperial Dam (including Senator Wash and Brock Reservoirs) for Reclamation's Yuma Area Office
- Model Objective:
  - Estimate the flow arriving at Imperial Dam given water already in the river at/below Parker Dam and future orders from Parker Dam
    - Time horizon
  - Compute the forecasted excess/shortage at Imperial Dam
  - Recommend operations of Brock Reservoir and Senator Wash Reservoir to mitigate excess/shortage

Background

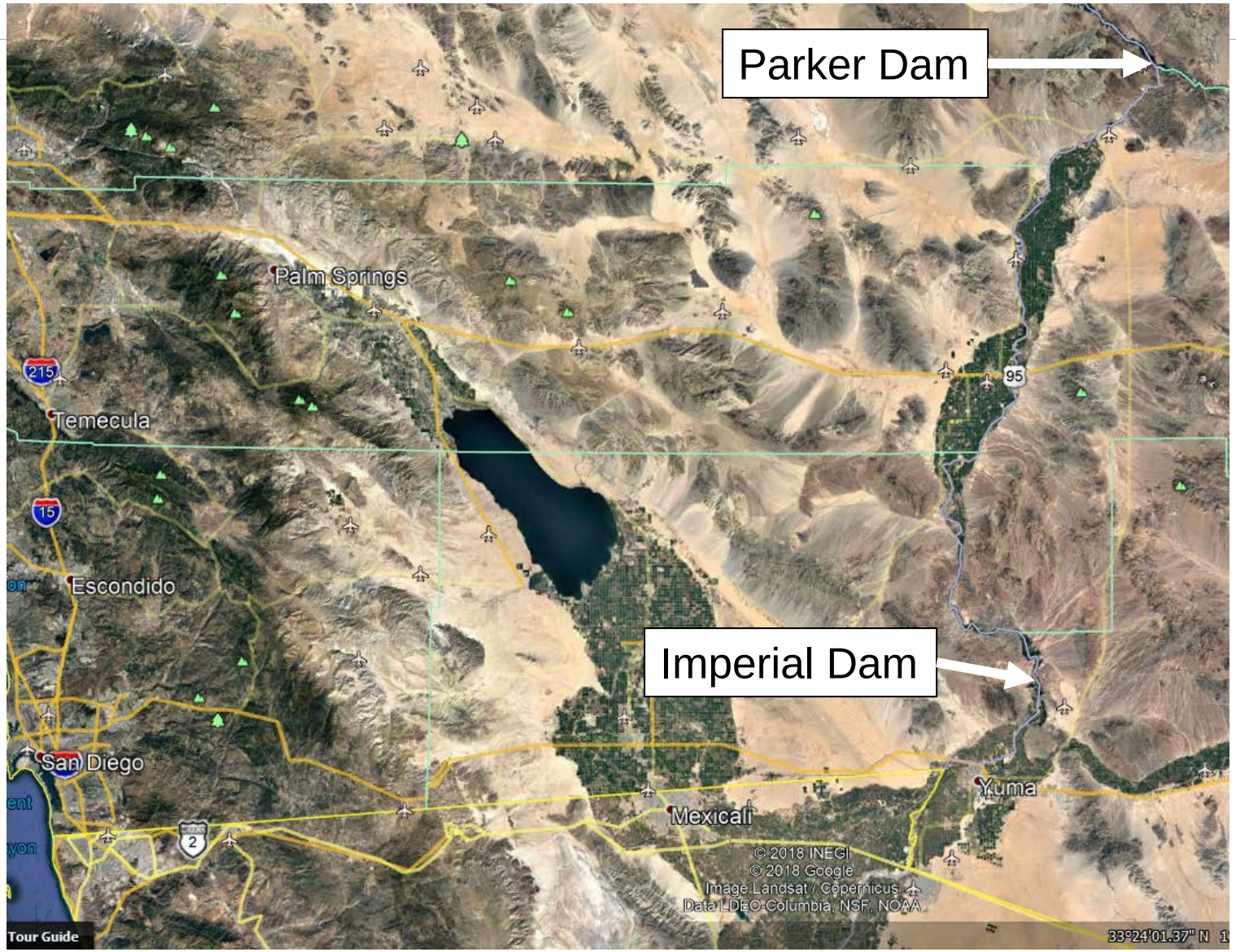
Parker Dam
Imperial Dam
Palm Springs
Temecula
Escondido
San Diego
Mexicali
Yuma
215
15
95
2
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Image Landsat / Copernicus
Data LDEO-Columbia, NSF, NOAA
Tour Guide
33°24'01.37" N

Caveat

- All values are approximate to give you a sense of the magnitudes

Operator's Challenge

- ~143 miles from Parker Dam to Imperial Dam (~ 3 days)
- ~5.3 million acre-feet per year at Imperial Dam (6,000 – 12,000 cfs daily)
- No storage at Imperial Dam (~ few hundred acre-ft)
- Off channel storage at Brock Reservoir and Senator Wash
- Orders at Imperial Dam can change at any time (not taking ordered water)

Operator's Challenge

- Best Case Scenario (both Brock and SW available):
  - ~1,800 – 2,400 cfs inlet/outlet capacity to/from storage
  - ~15,000 acre-ft storage

- "Not-Quite-Worst-Case" Scenario (Brock down, limited SW units)
  - ~6,700 acre-ft storage
  - 300 – 600 cfs inlet/outlet capacity to/from storage (3 units)

Model Accuracy

- In the not-quite-worst-case scenario there is little room for model error
  - 300 cfs based on numbers above (operators would like 200 cfs accuracy - daily mean)
  - Flow arriving at Imperial Dam 6,000 cfs to 12,000 cfs most of the year: 2.5% – 5%

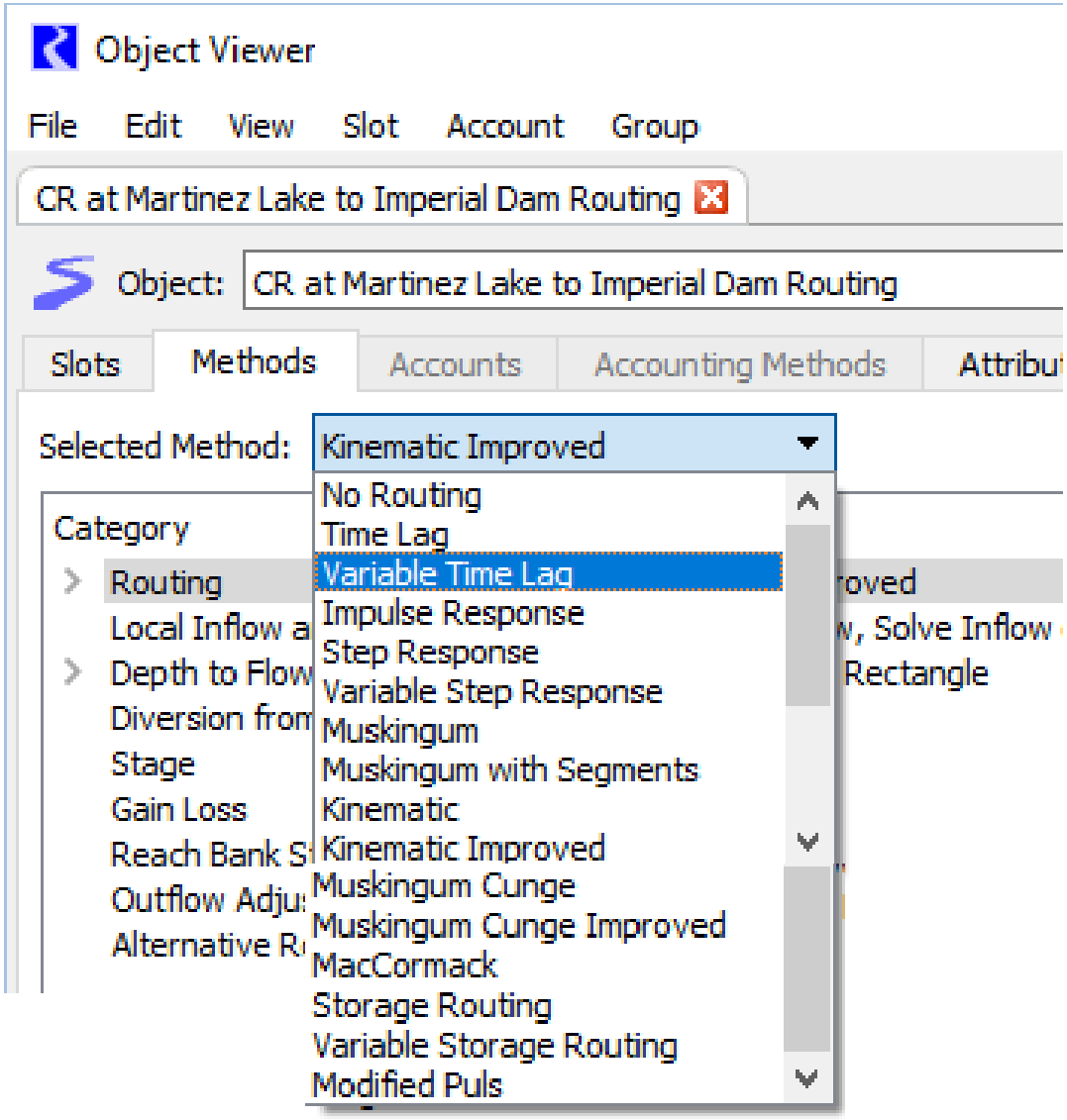
- 2.5% - 5% Routing accuracy: Is this possible?

- Excellent = within 5% of the true value 95% of the time
- Good = within 10% of the true value 95% of the time
- Fair = within 15% of the true value 95% of the time
- Poor = less than fair

The good news…

- Lower Colorado River interesting case study for routing
- Does not rain (3 inches/year)
- Stable with respect to gain/loss
  - Monthly % gain/loss in the model – I won't discuss this
- Diversions and return flows are all gaged
- 10 main-stem gages between Parker Dam and Imperial Dam
- Dedicated team of hydrologists with state of the art flow metering

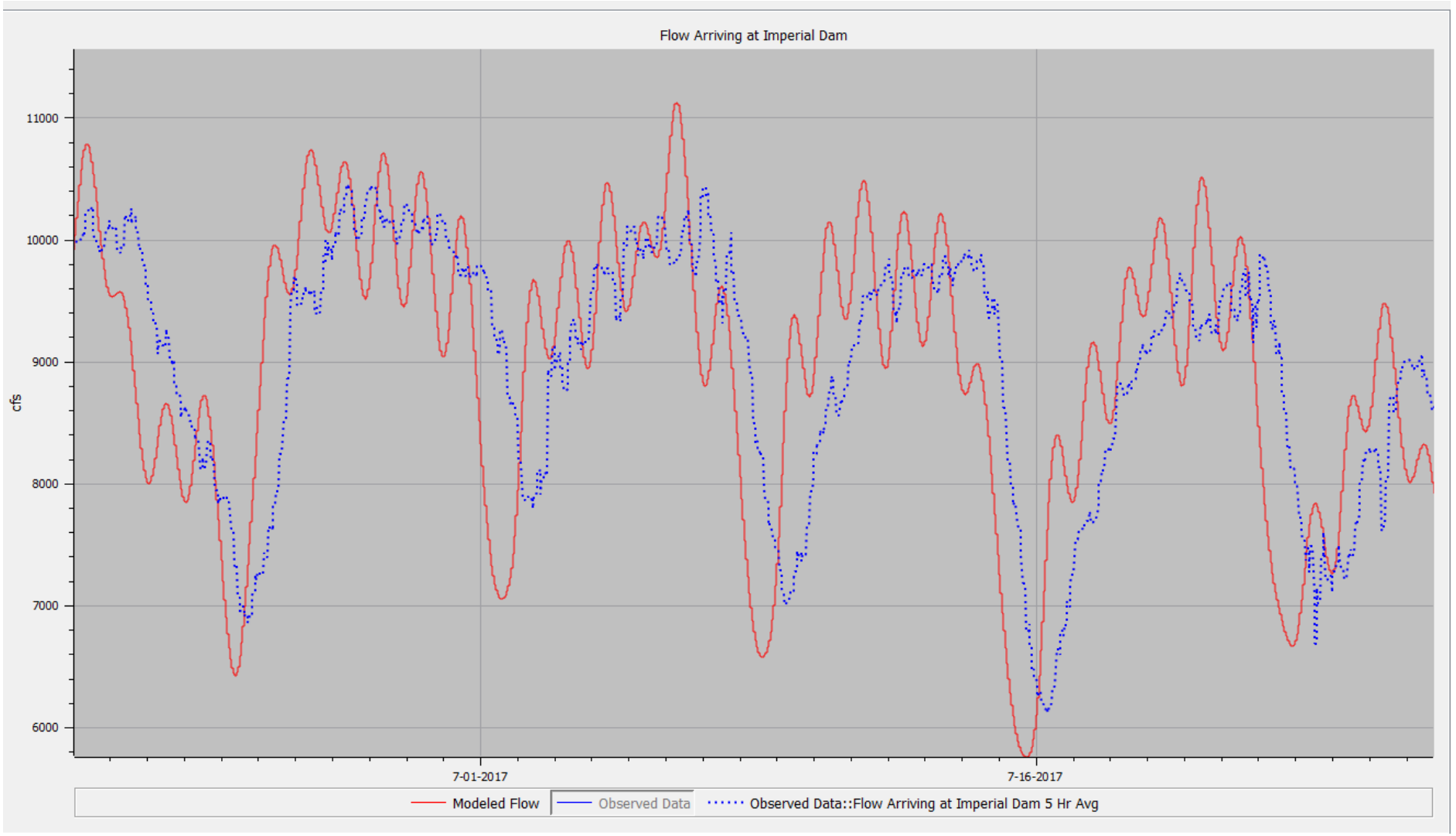
RiverWare Routing Methods



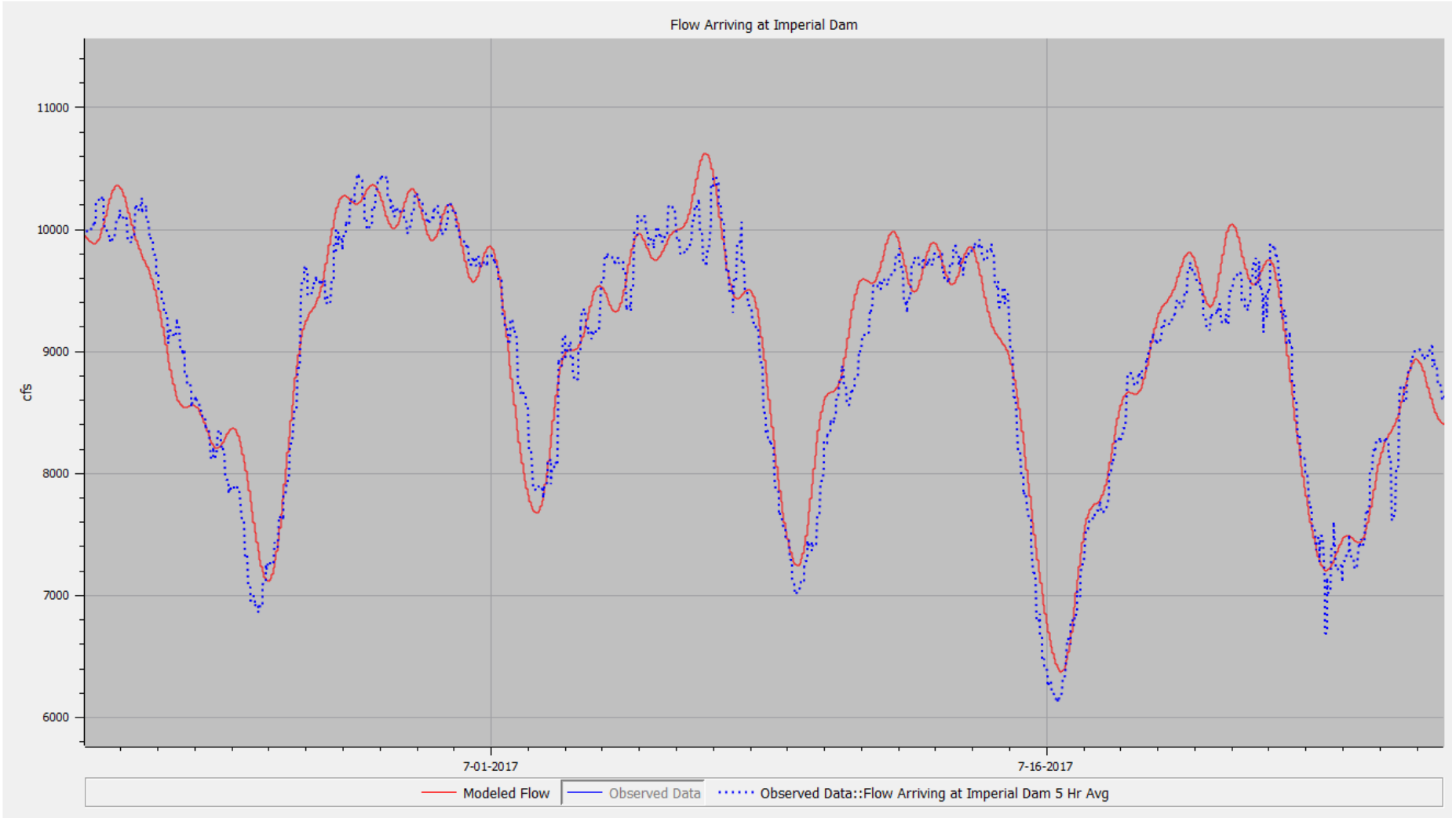
Kinematic Improved Routing

- Need reach length, width, slope, and Manning's n
- Need for different sets of parameters for different flow regimes
  - E.g. High flow, mid flows, low flows

RiverWare Routing Methods



RiverWare Routing Methods



Thus far…

- Pick a good routing method
- Need multiple sets of routing parameters determined by calibration
- Next… backwaters/bank storage

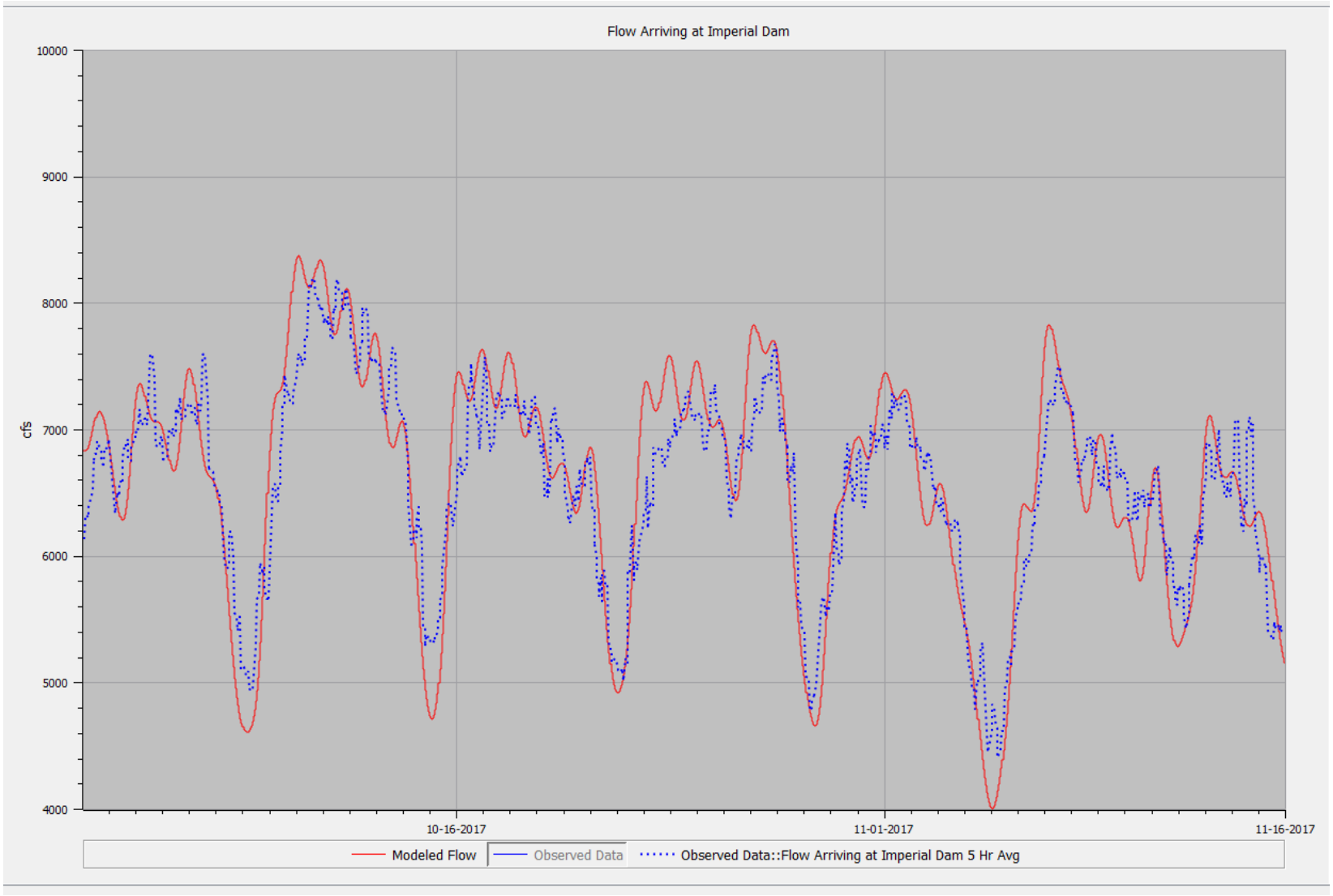
Backwater Areas

Average Flow Bank Storage

$$\text{Bank Storage Return} = \frac{\text{Average Flow Coefficient} \times (\text{Routed Flow}_t - \text{routed flow average})}{\sqrt{\text{timestep length}}}$$

The routed flow average is the average flow over the number of timesteps specified in **Timesteps to Average** prior to the current timestep. For the first (timesteps to average - 1) timesteps, some routed flows are being set on timesteps prior to the initial timestep. These values, set equal to the routed flow at the initial timestep, are used so that calculations for routed flow average don't used routed flows equal to zero. A warning message will remind users this is occurring.

Bank Storage



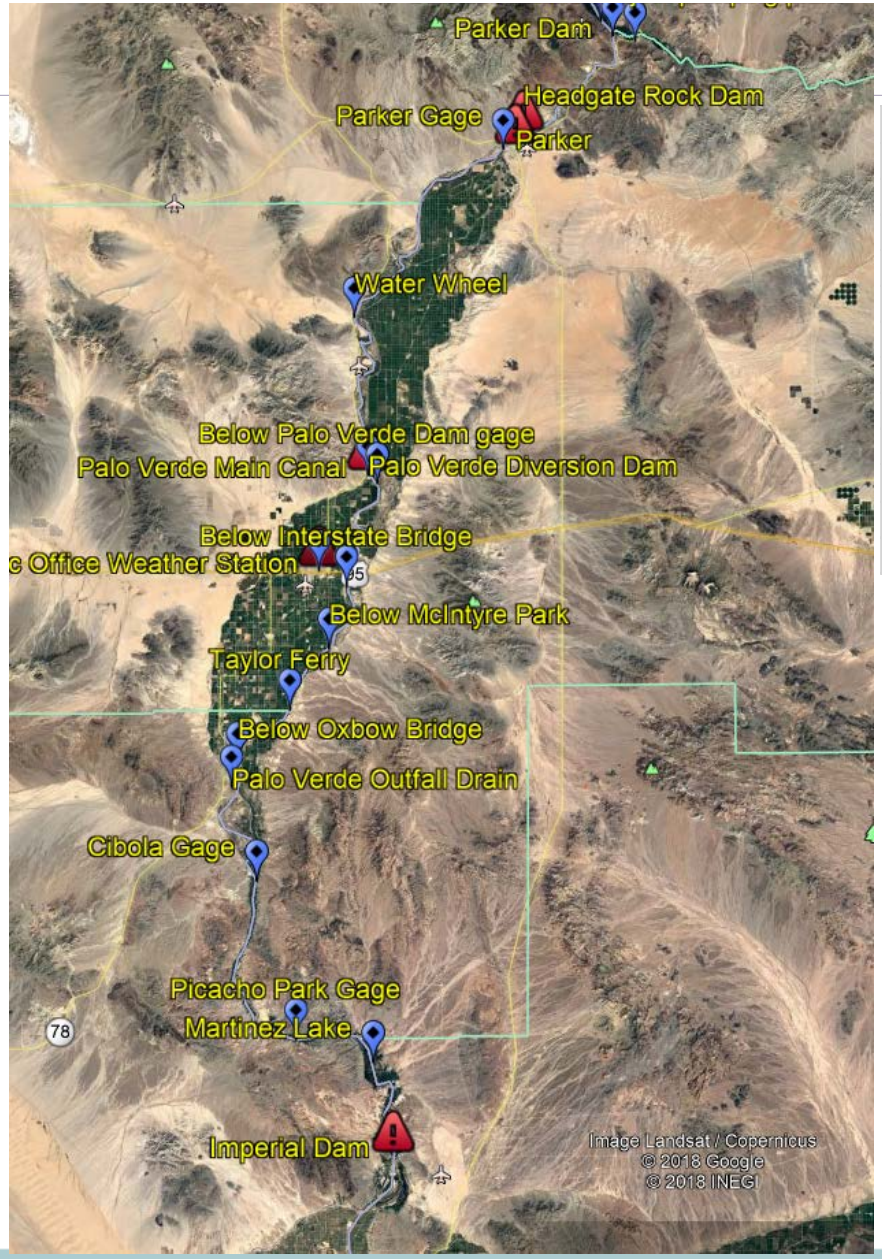
Bank Storage

Thus far…

- Pick a good routing method
- Need multiple sets of routing parameters determined by calibration
- Use bank storage method for additional attenuation during large swings in flow

- Next… gage bias correction

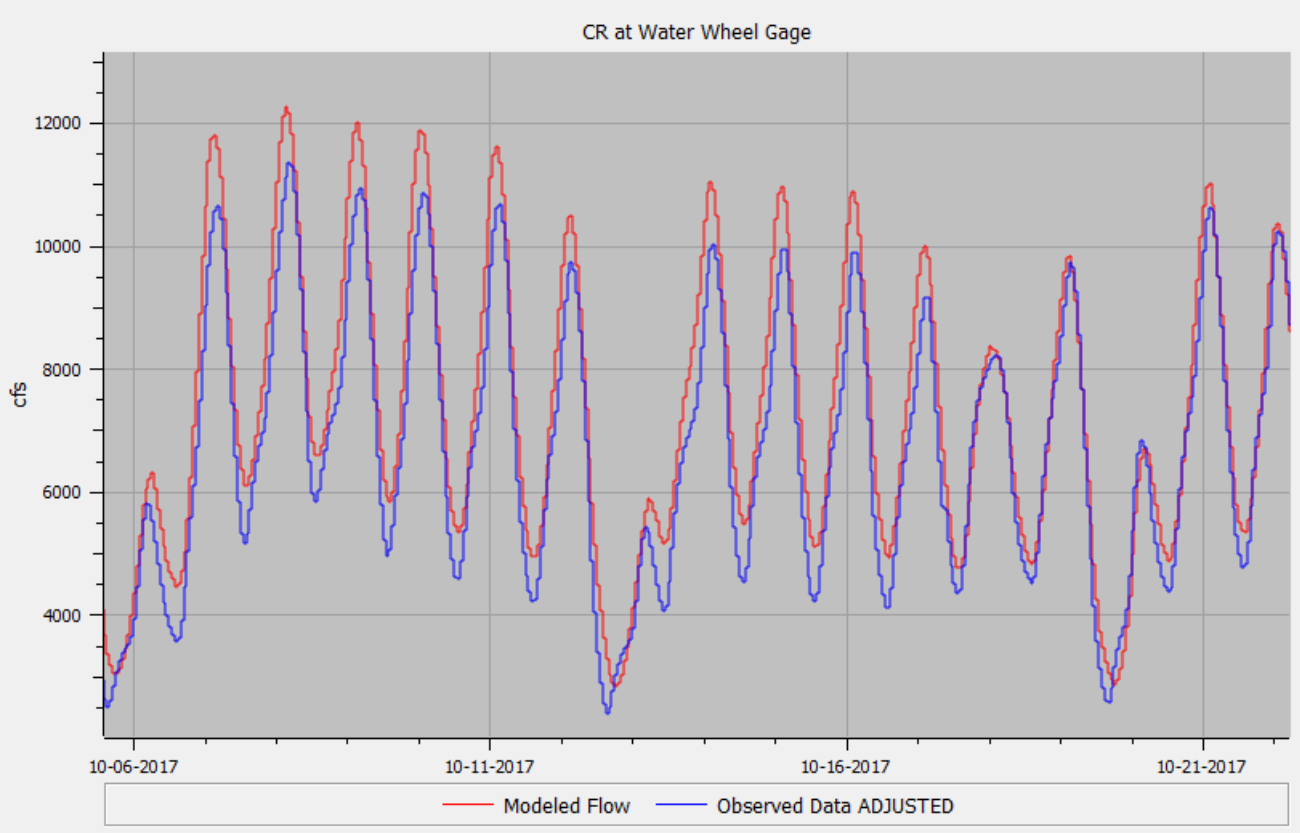
Main Stem Gages



Reach	u/s point	d/s point	Actual Distance (miles)
1	Parker Dam	Gage below Parker	17.0
2	Gage below Parker	Waterwheel	24.1
3	Waterwheel	Below Palo Verde	20.0
4	Below Palo Verde	Below Interstate Bridge	11.9
5	Below Interstate Bridge	Below McIntyre Park	7.0
6	Below McIntyre Park	Taylor Ferry	6.6
7	Taylor Ferry	Below Oxbow Bridge	8.2
8	Below Oxbow Bridge	Cibola Gage	11.2
9	Cibola Gage	Picacho Park	19.2
10	Picacho Park	Imperial Dam	17.6
	Parker Dam to Imperial Dam Total Miles		142.8

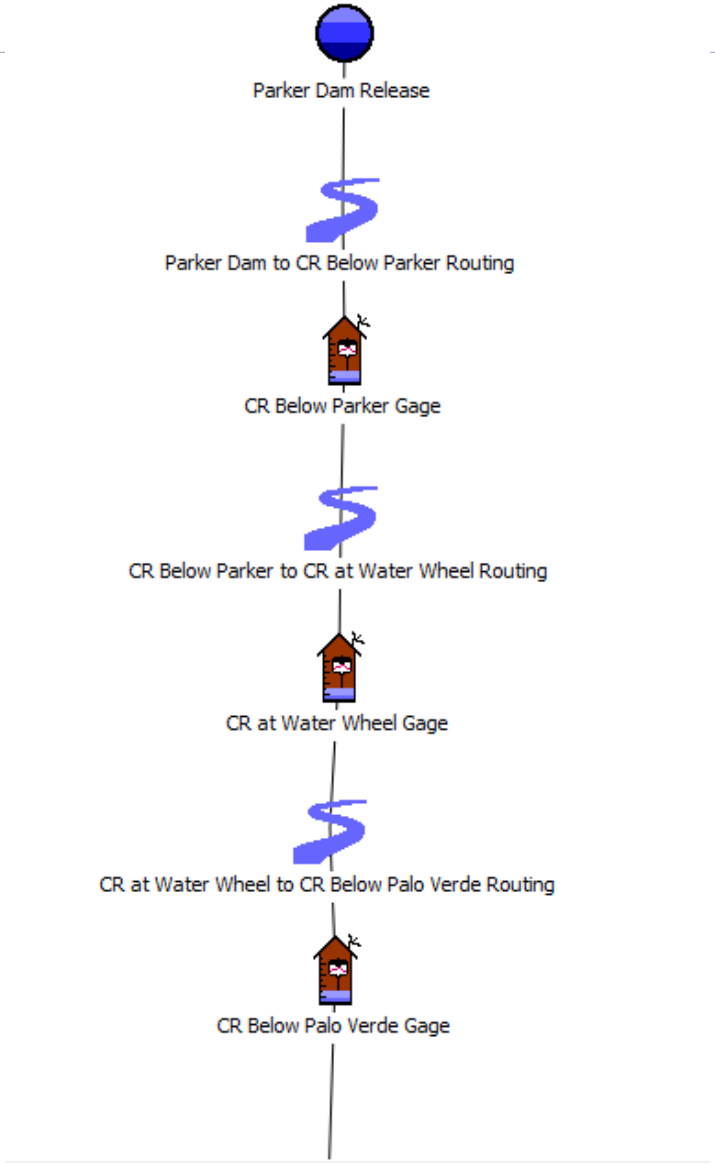
Gage Accuracy

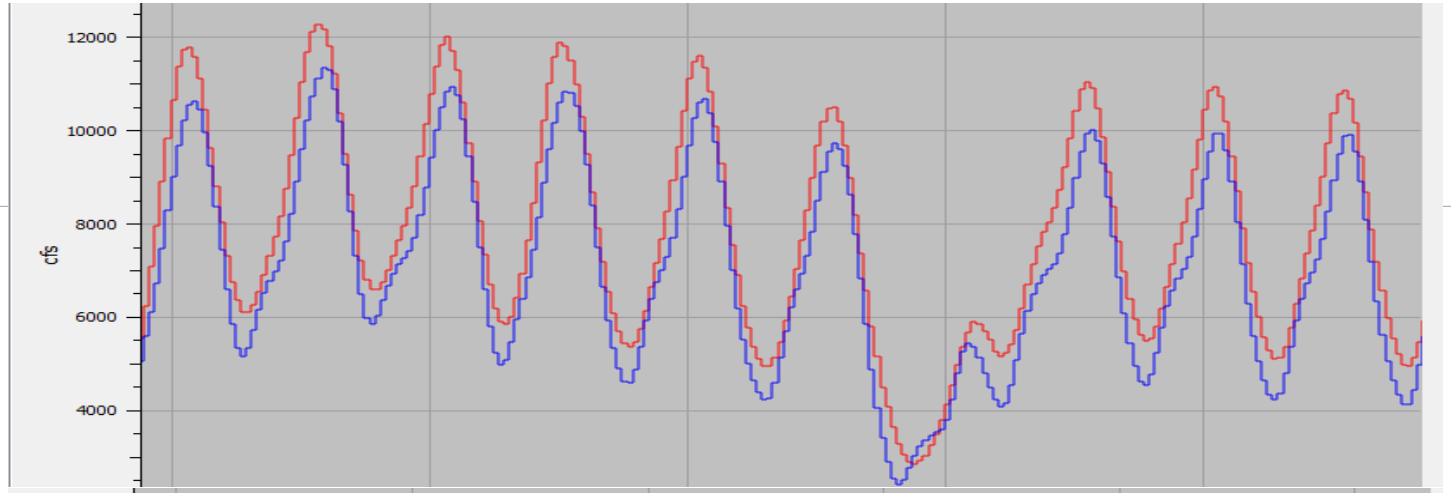
- How do you know if a gage is accurate?
- How do you know which gage is accurate?



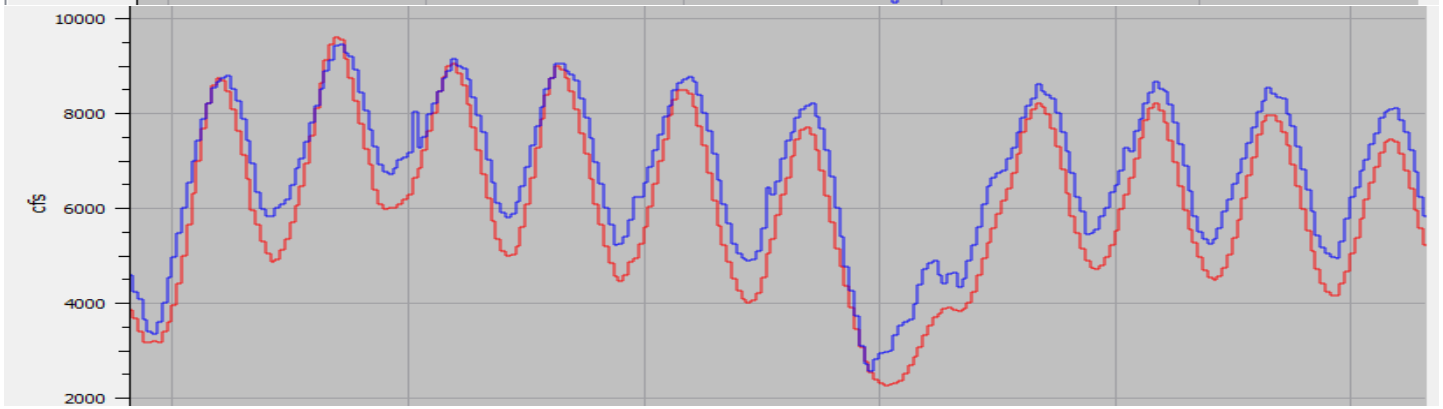
Example

- Three Gages
- Below Parker
  Water Wheel
  Below Palo Verde

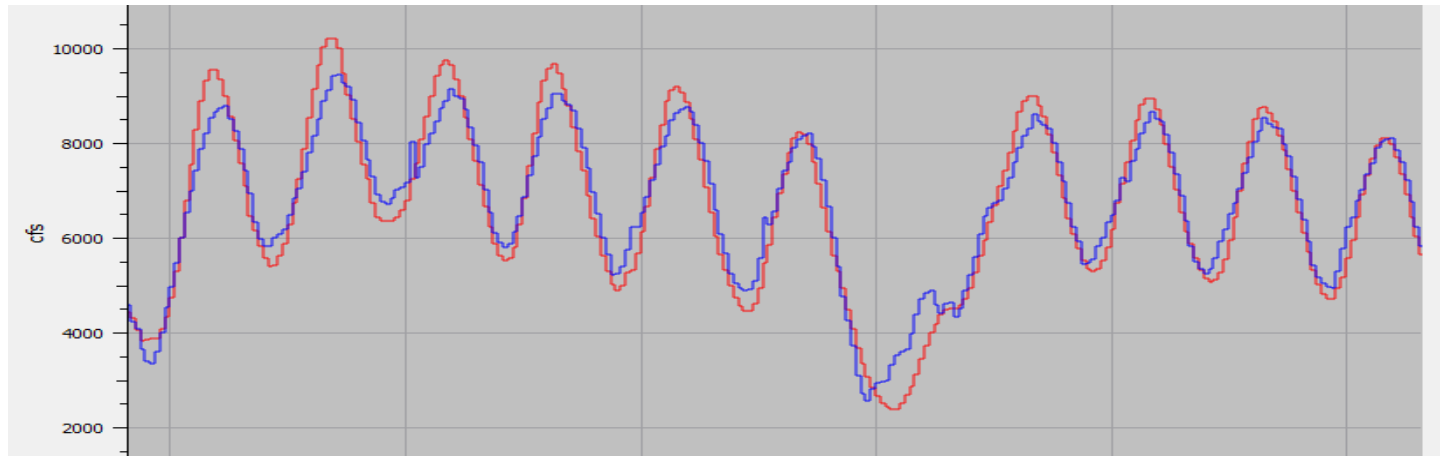




Blw Parker to Water Wheel



Water Wheel to Blw Palo Verde



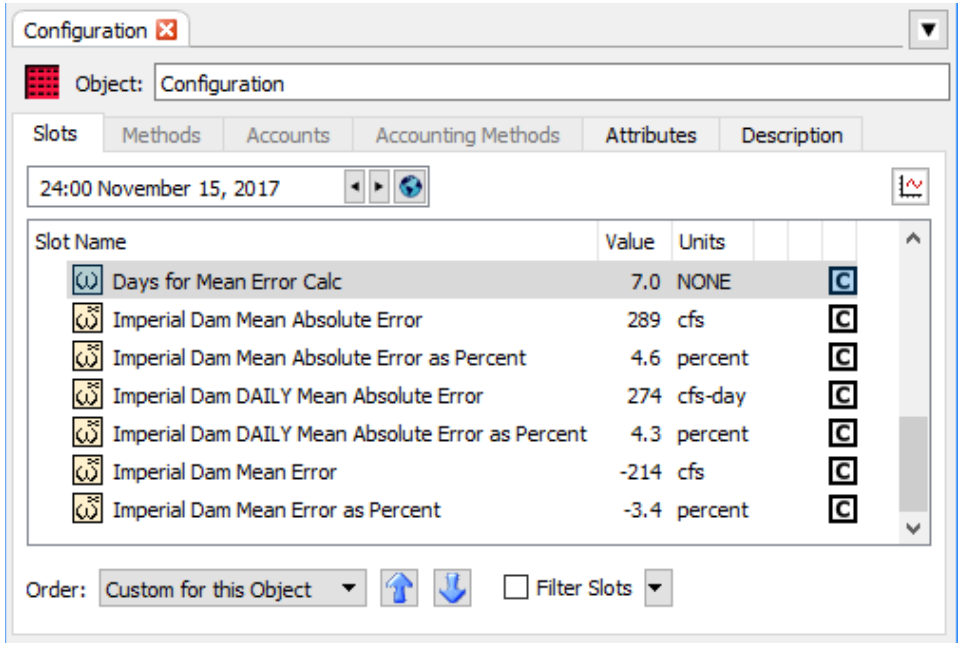
Blw Parker to Blw Palo Verde

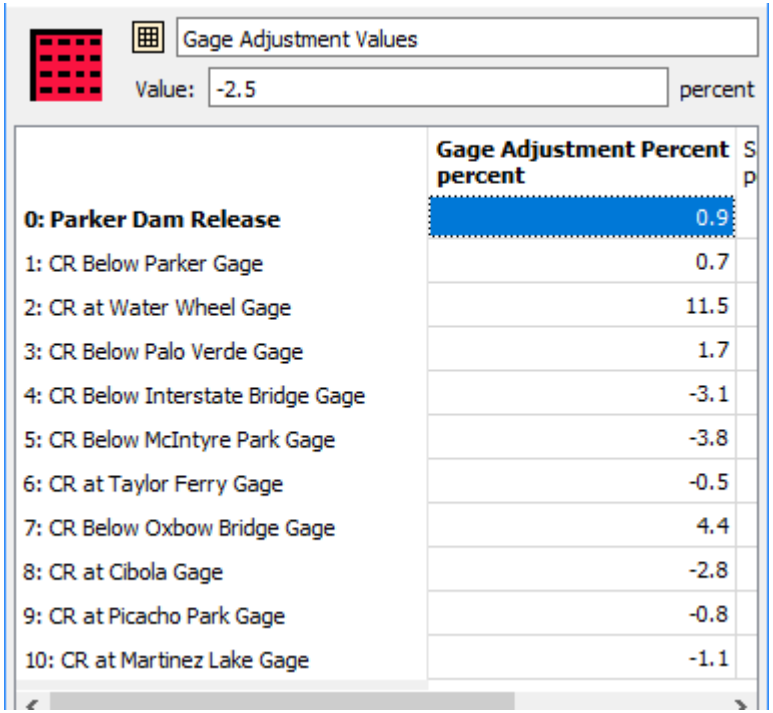
Gage Bias Correction

- We still don't know which gages are correct, but probably Water Wheel gage is reading low
- Either that or there is a loss between the upper two gages followed by a gain between the lower two gages of the same amount
- Or, maybe the other two gages are off by the same amount and Water Wheel is correct
- We need to hang our hat on something…
- Flow at Imperial Dam

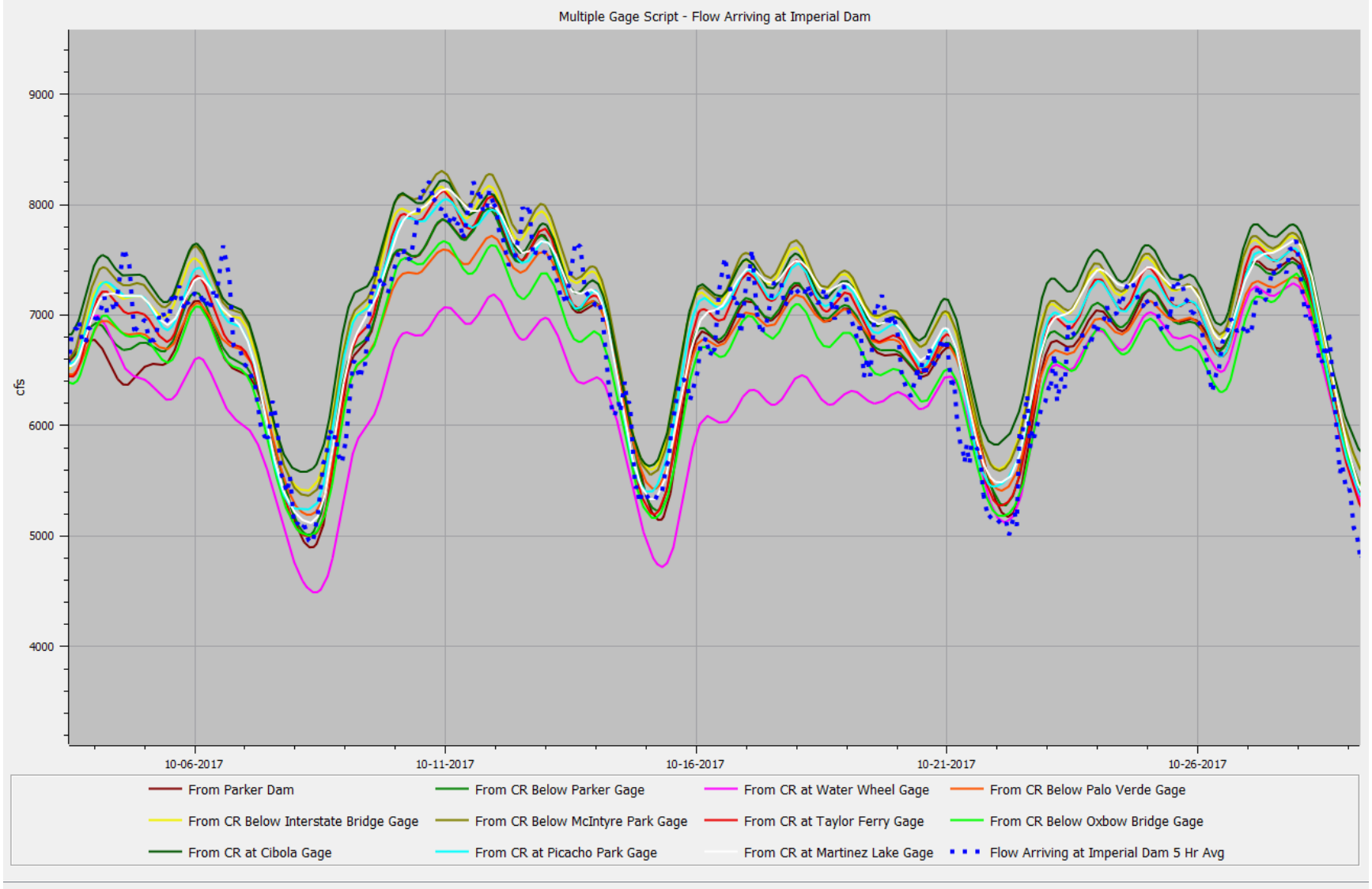
Gage Bias Correction

- We created a script to route from each gage individually (i.e. not using any other main stem gages) down to Imperial Dam
- Compute the Mean Error and Mean Error as percent

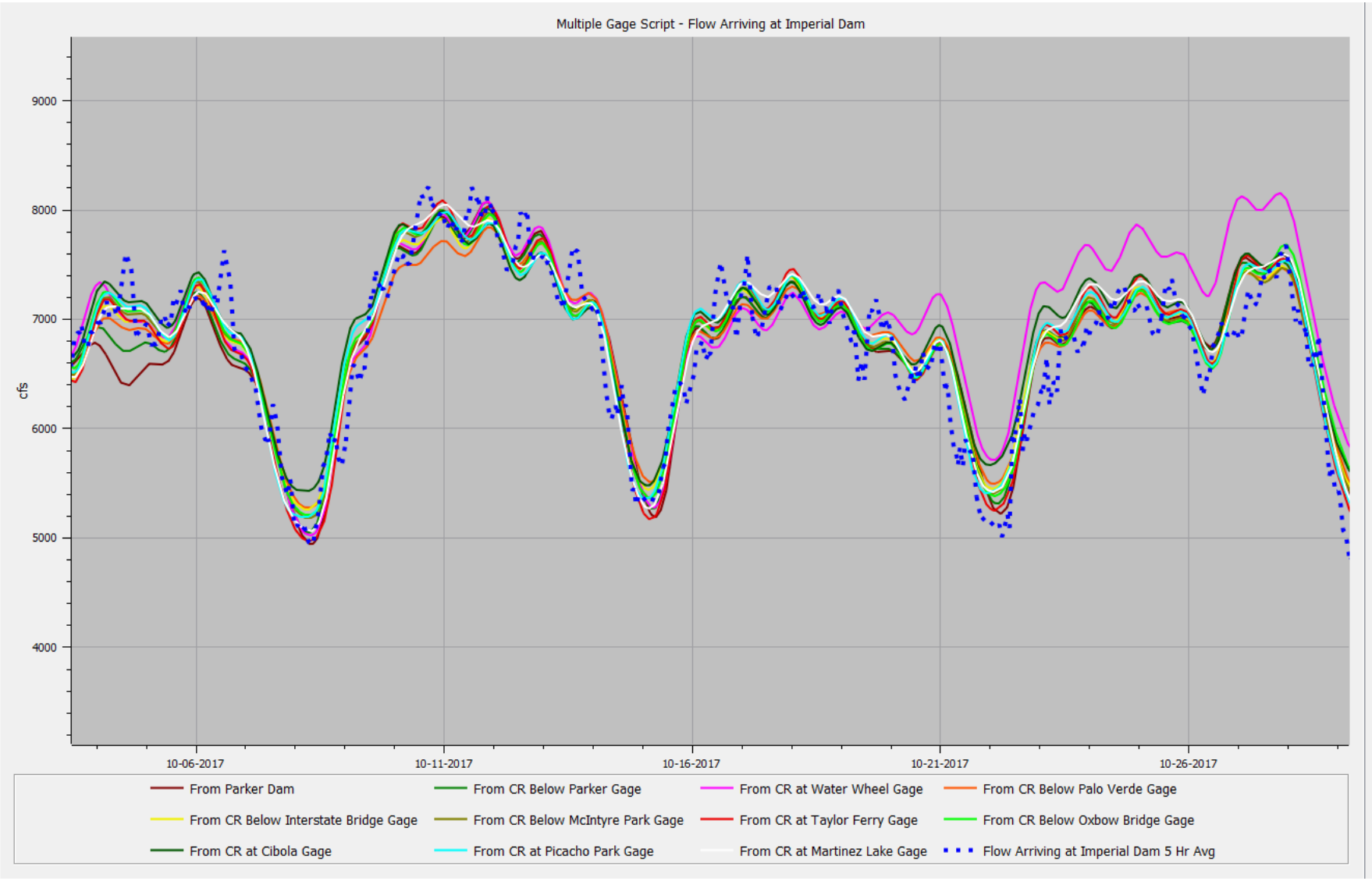




Gage Bias Correction



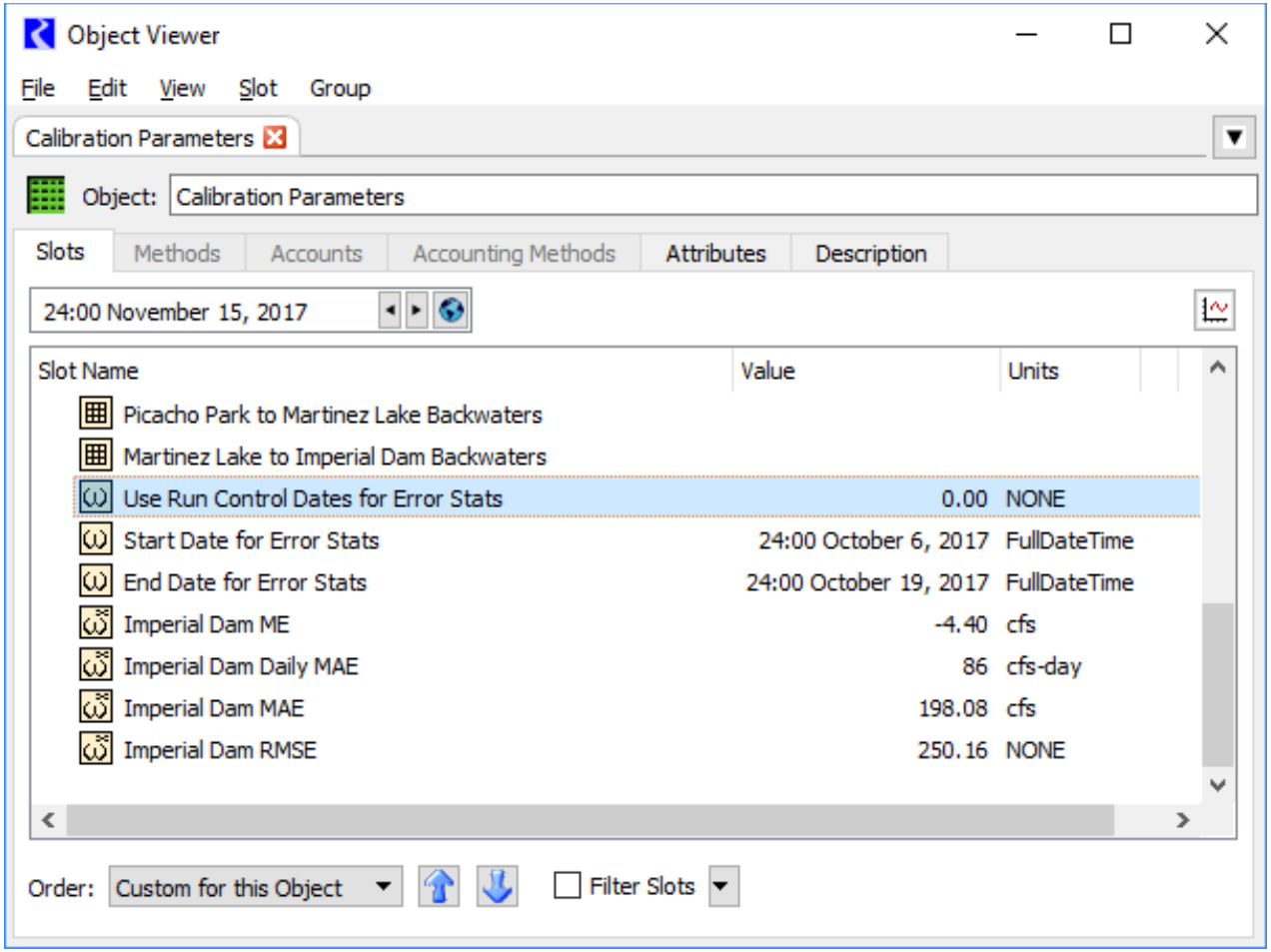
Gage Accuracy



Warnings

- Operators need to stay on top of gage adjustments
  - Need to know when adjustments to the rating curves take place
  - Need to re-compute weekly or even daily
- Caveat: I would never recommend this for a planning model or anything other than a very short term model
  - Normally do not want to mess with observed data

Results (13 day period)



Summary

- In addition to routing and other physical process modeling…
- Correct for gage bias (must do this constantly!)
  - It is possible to have a model that is more accurate that uncertainty in observed data as long as you correct it
- Helps to have 10 gages along 150 miles reach, monthly checking/re-rating, in a location where it never rains