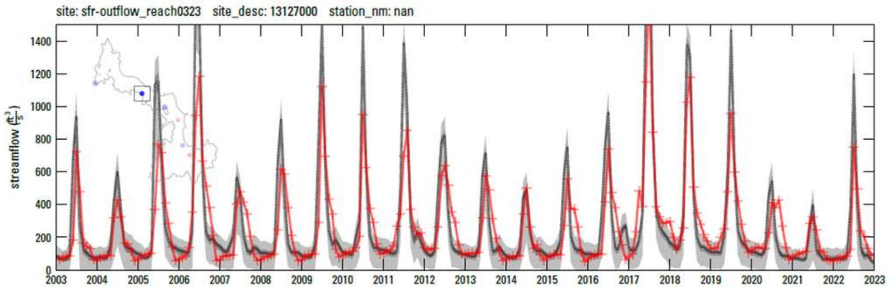

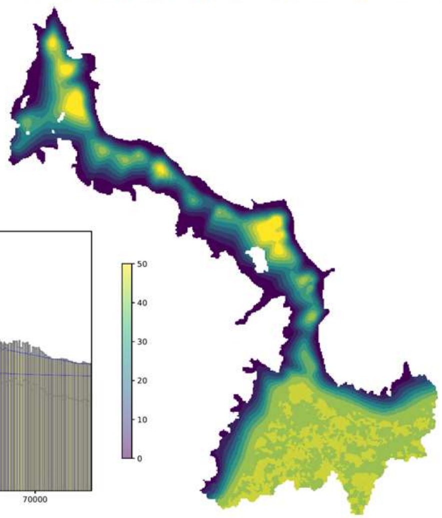

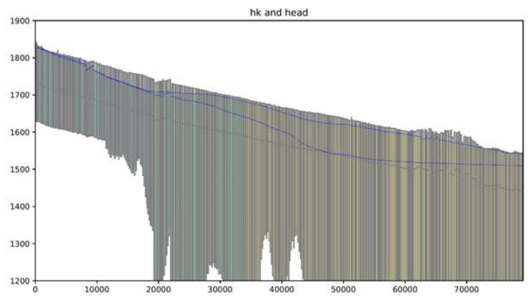

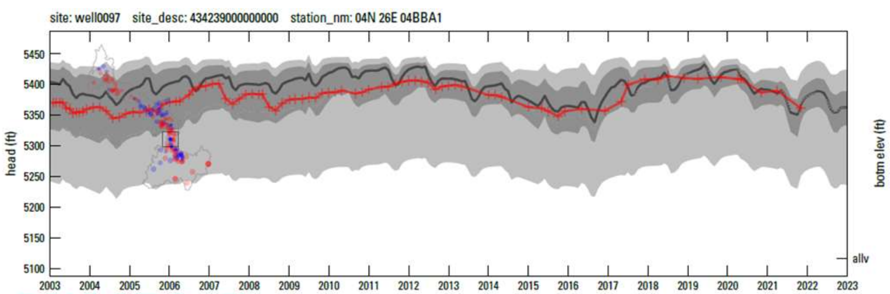

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Big Lost River Model

MTAC #7 Status Update
2024.05.15

Model status

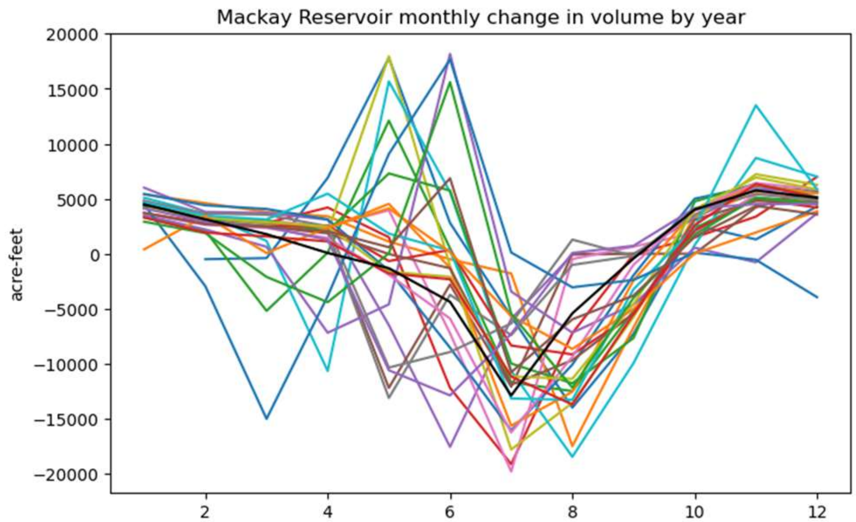
Implementation of conceptual model mostly complete:

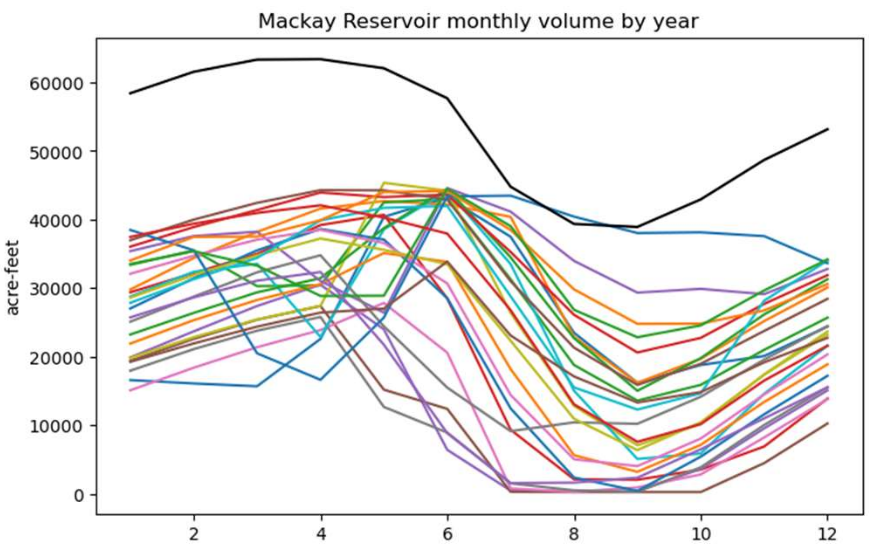
- 240 monthly transient stress periods Jan 2003 – Dec 2022
- Initial “Steady-state” stress period simulating temporal mean stresses of **1/1/2003 – 12/31/2009**
- Routed surface flow in Big Lost River and Antelope Creek, gains and losses to aquifer, non-routed diversions remove flow from river
- Mackay Reservoir and Dam **now simulated**. Reservoir receives water from upstream reaches as available and releases water to downstream reach as prescribed

Model changes

Majority of efforts since last MTAC have been to improve upper basin:

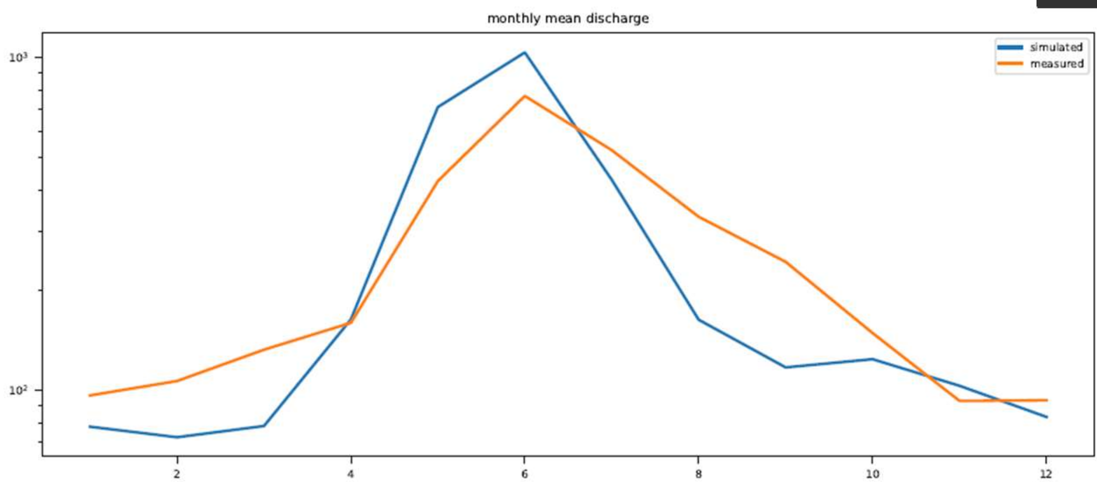
- Lake package simulates Mackay reservoir storage
- Drain package simulates groundwater rising to surface in Thousand Springs and riparian areas above reservoir
- Mover package delivers rising groundwater to stream and lake, and releases from dam to stream
- Head-dependent boundary condition added to simulate riparian evapotranspiration
- Second, deeper layer has been extended into upper basin

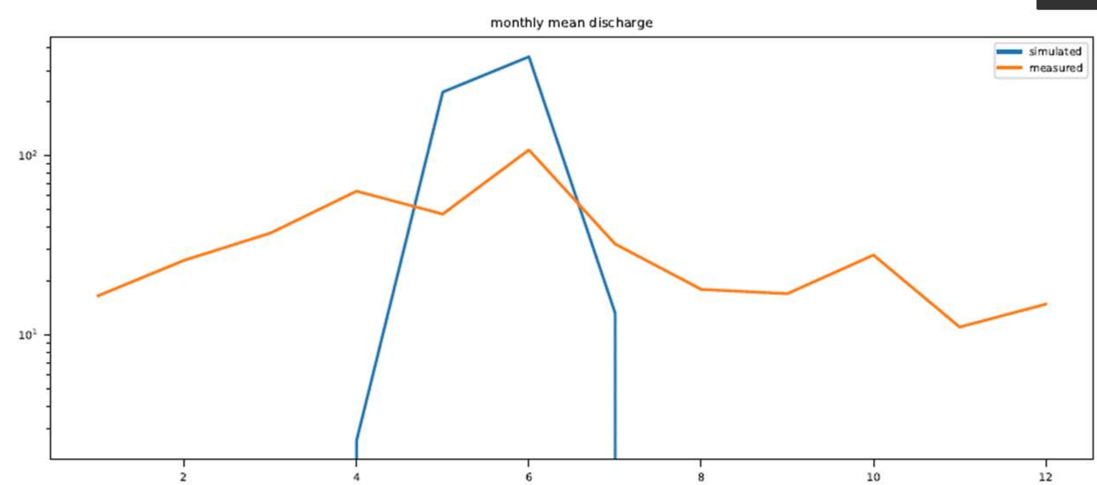




Mackay Reservoir

Simulating inflows/outflows/storage with:
LAK,
SFR,
DRN,
and MVR packages





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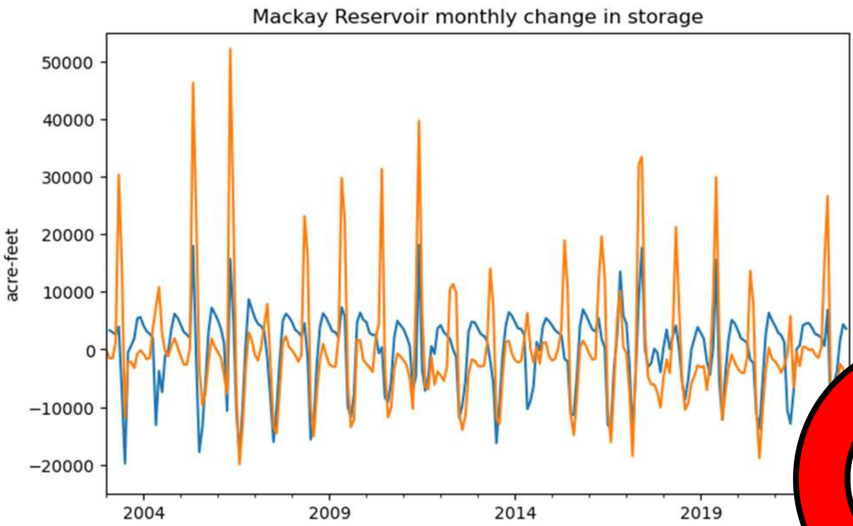
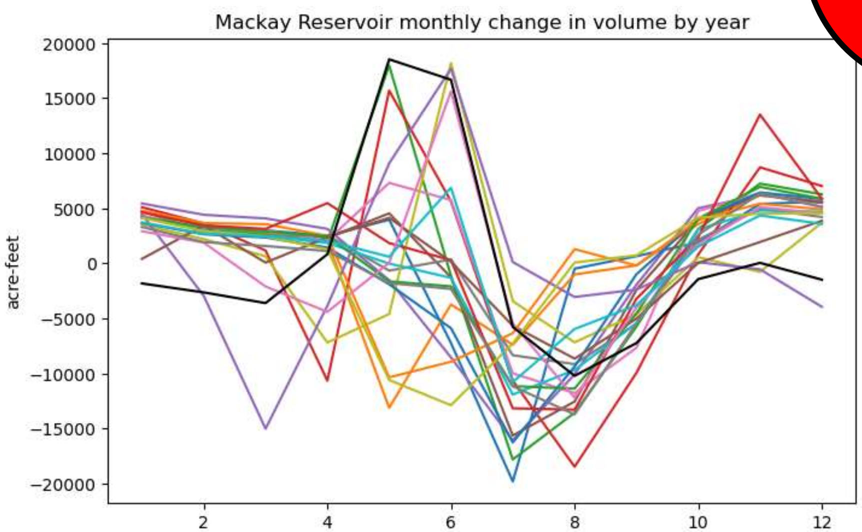
Motivation

- Defined release flows at Mackay Dam are necessary to match hydrographs downstream, making surface water available in stream at the right times for defined diversions
- Defining release flows without collecting and storing upstream flows as they appear at Mackay Reservoir would break the hydrologic budget and risk creating or vanishing water without trace

Solution

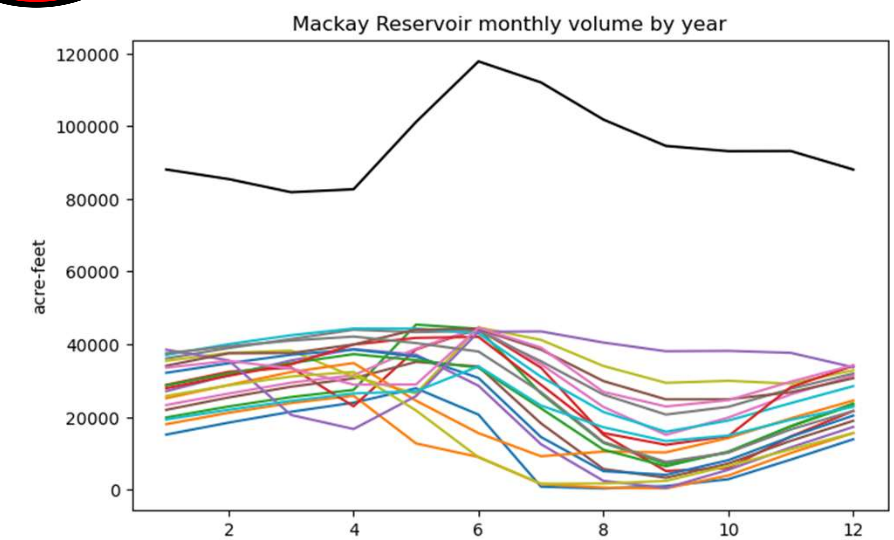
- MODFLOW 6 Lake Package & Mover Package





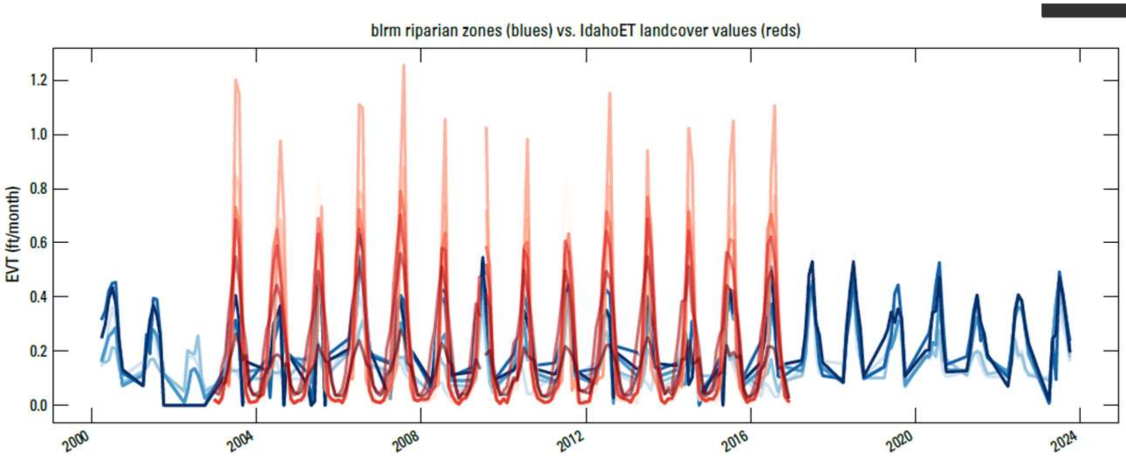
Iterative Process:

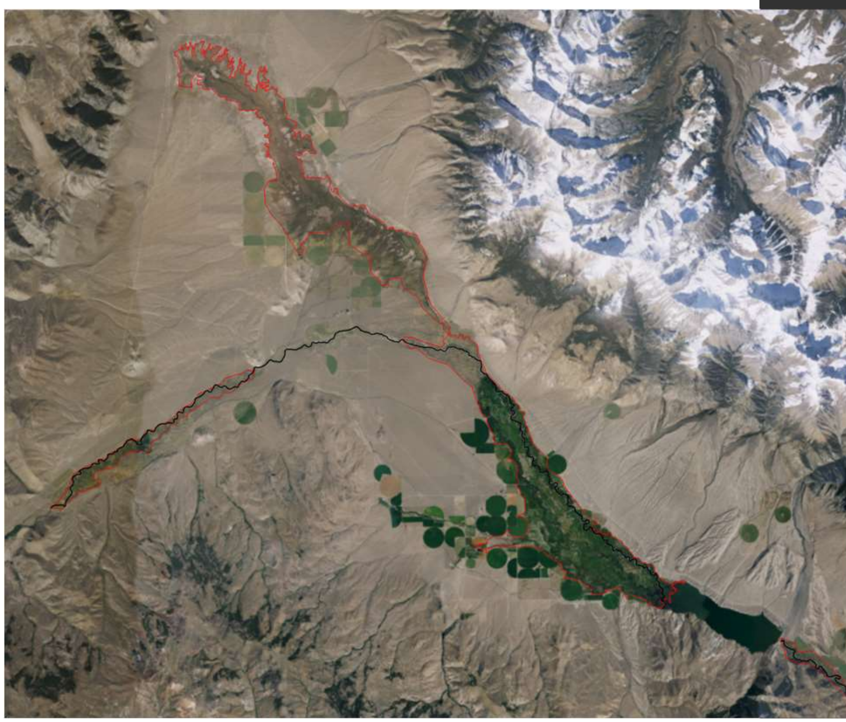
1. **Define release flows**
2. **(Break model)**
3. **Add/modify hydrologic processes in the model**
4. **(fix model) (?)**
5. **Match simulated to observed Mackay storage changes**



Upper Basin Updates

- Specified-flux boundary conditions added to riparian areas to simulate EVT (water removed from model)
- Head-dependent boundary conditions added to low-lying areas above reservoir to simulate groundwater rising to surface (water routed to stream network/reservoir)
- Increased streambed HK between Howell gage and Chilly Sinks
- Layer 2 activated in upper basin (previously only active in middle/lower basin)





Upper Basin Updates

Riparian Evapotranspiration

- Intersected monthly METRIC EVT rasters to model cells within 5 defined riparian areas, masked out irrigated lands, and calculated average monthly EVT rate for the remainder of each area.
- WEL package removes water from the identified cells in each riparian area as a specified flux in each monthly stress period

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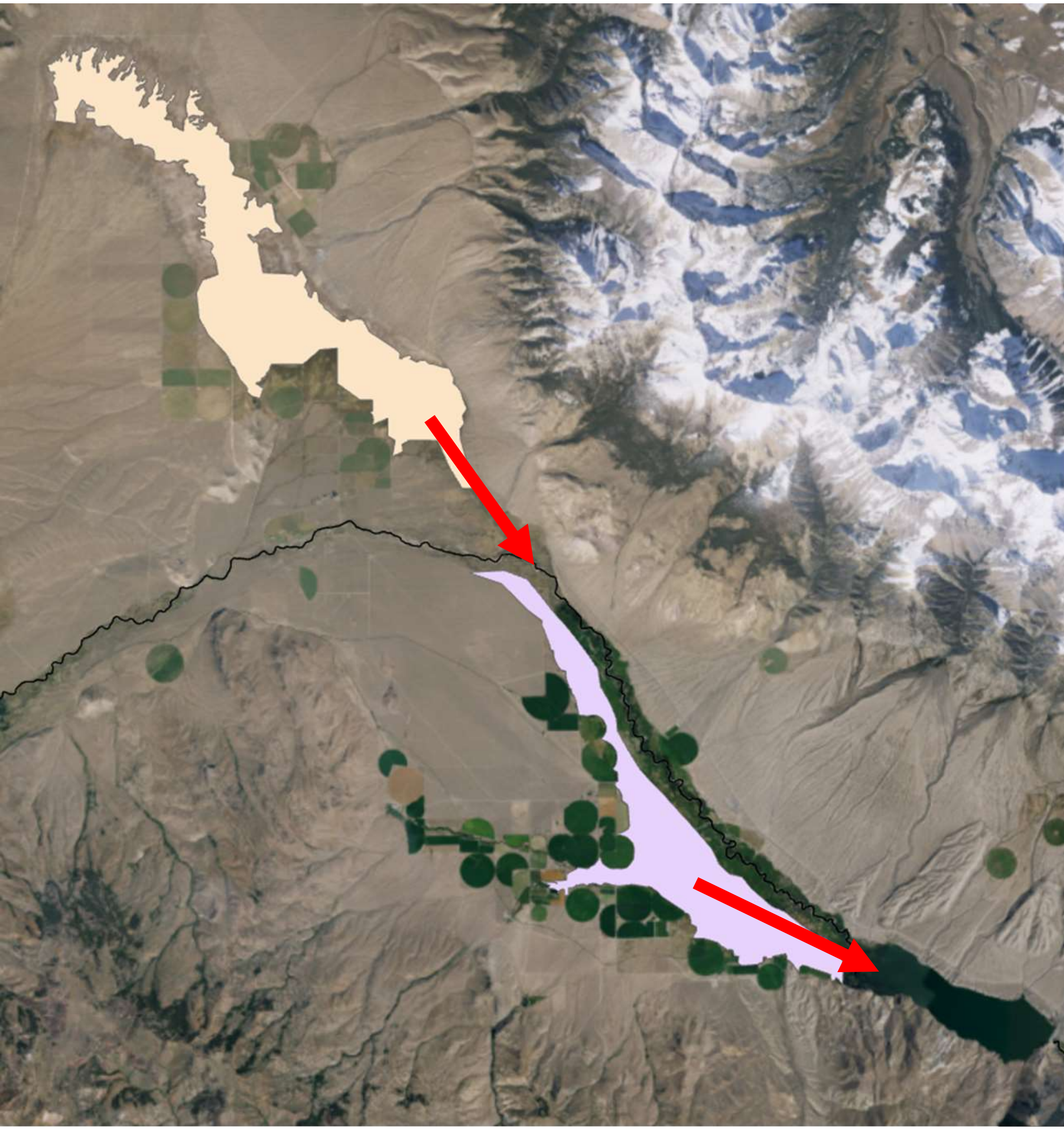
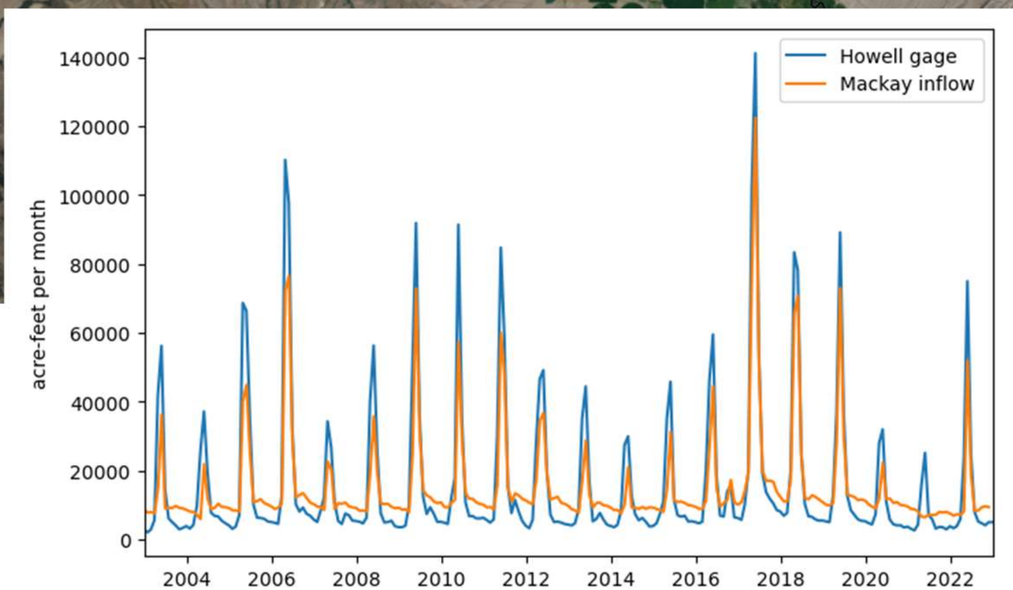


Upper Basin Updates

Groundwater rising to surface

- DRN package cells collect water in cells where simulated water table is higher land surface)
- MVR package routes this water from Thousand Springs area to closest downstream stream reach.
- MVR package routes this water from riparian areas above Mackay reservoir directly to LAK package as simulated inflow



Upper Basin Updates

Increased streambed HK between Howell gage and Chilly Sinks

- Mackay reservoir inflows, calculated by comparing observed releases and storage change, show a consistent 10-15k acre-feet per month inflow during winter months, larger than flows at Howell gage
- Calculated summer inflows to Mackay Reservoir are 10-30k acre-feet smaller than flows at Howell gage
- Upstream losses return to stream/lake via SFR or DRN package

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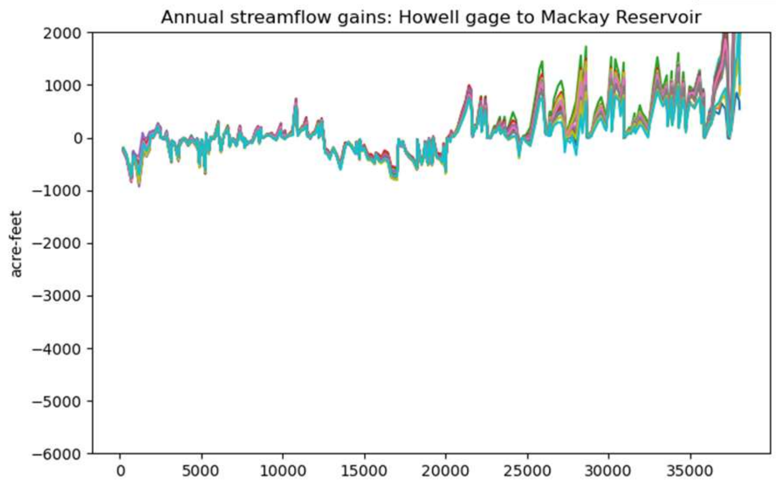
Upper Basin Updates

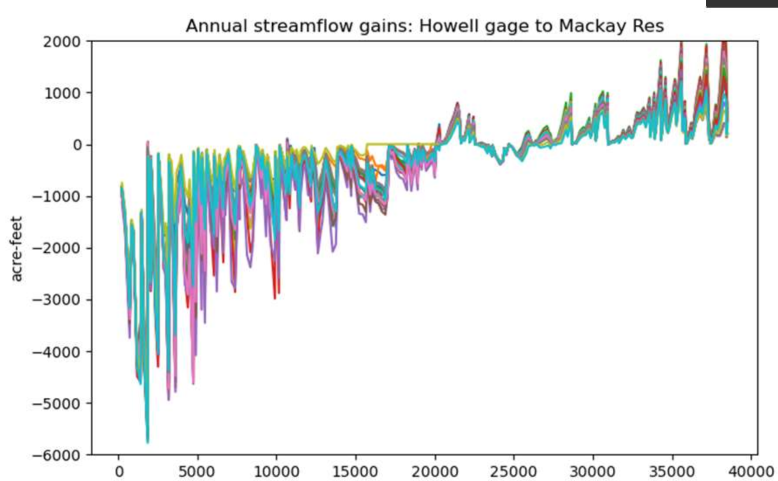
Increased streambed HK between Howell gage and Chilly Sinks

- Adjusting streambed hydraulic conductivity was necessary to simulate observed losses between Howell Gage and Chilly Sinks

sfrhk = 0.1 sfrhk = 0.1



sfrhk = 2.0 sfrhk = 0.1



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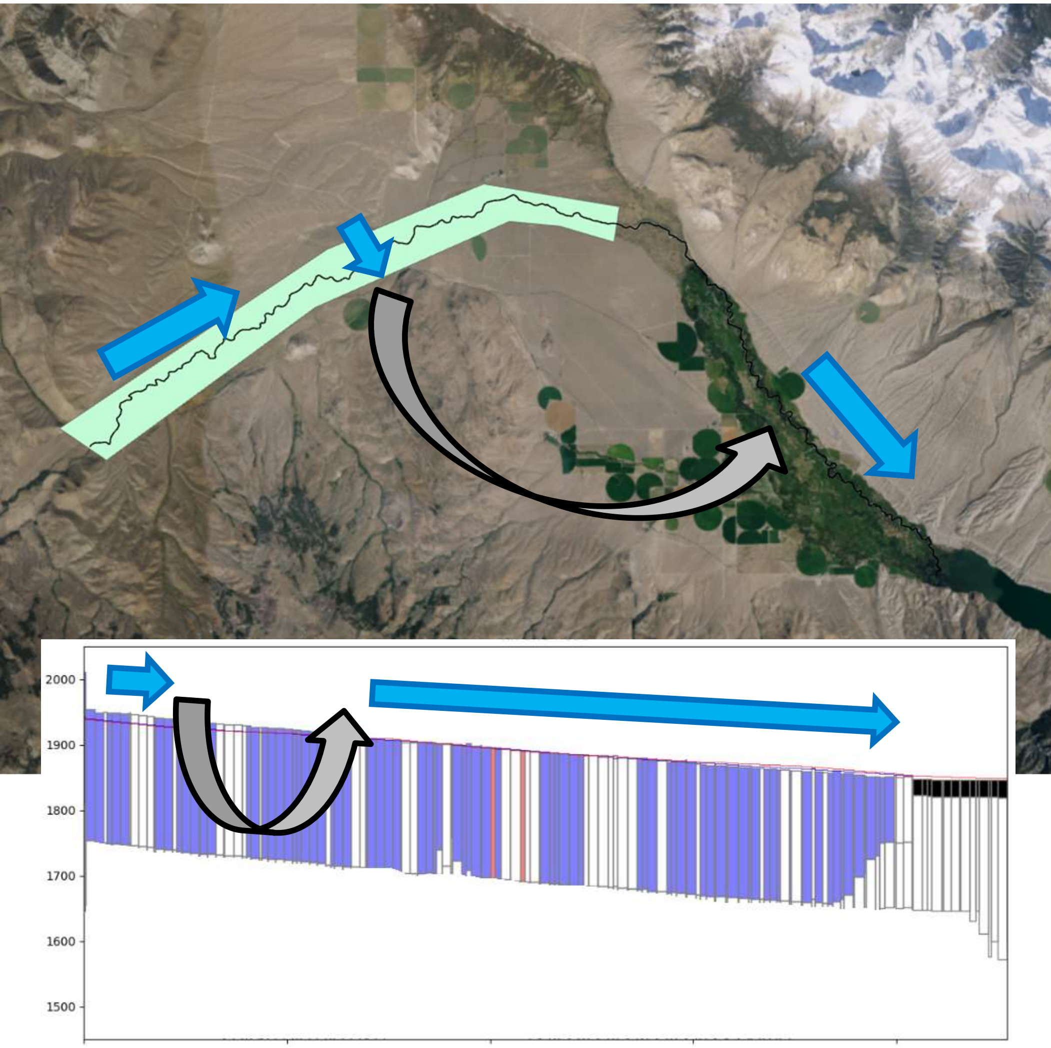
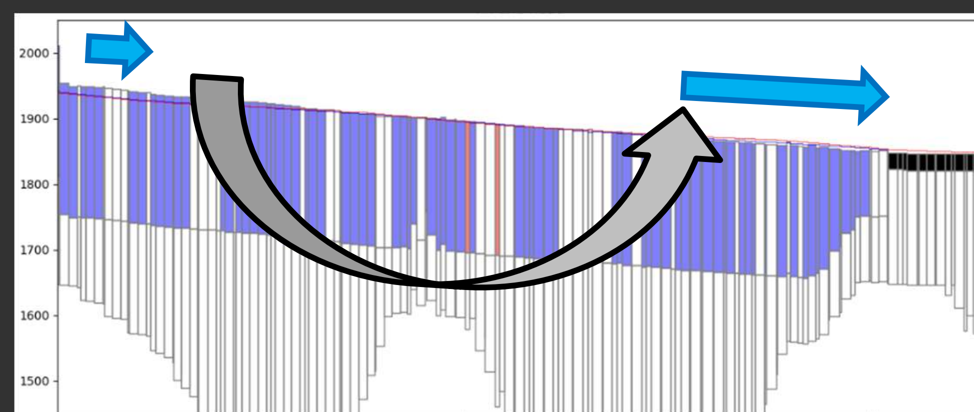


Upper Basin Updates

Layer 2 activated in upper basin

- Vertical discretization was needed to prevent all river seepage from immediately re-surfacing via one of the many head-dependent boundary condition cells



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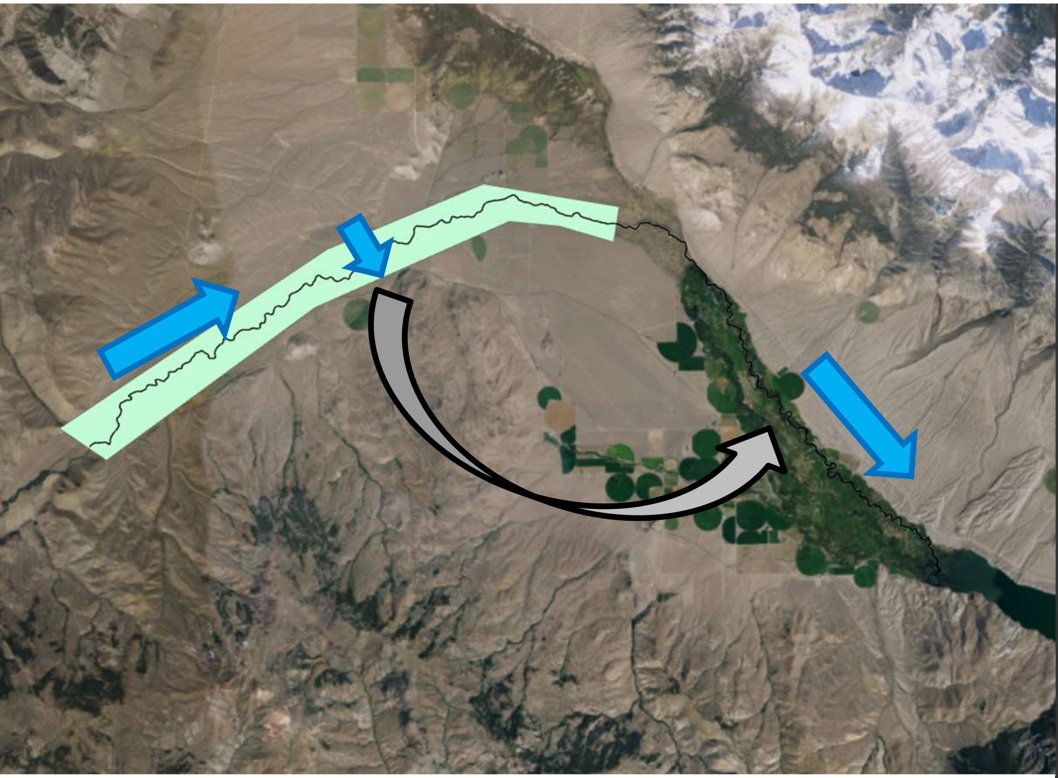

Upper Basin Updates

Summary

- Specifying Flows from Mackay Dam improves model fit to observed downstream flows and allows simulated canal diversions to occur in early/late irrigation season
- Simulating Mackay Reservoir inflow and storage was necessary to preserve the water budget in conjunction with the specified dam releases
- Improvements to the model in the upper basin were needed to provide the right volume and timing of inflows to Mackay reservoir to be available for releases to lower basin

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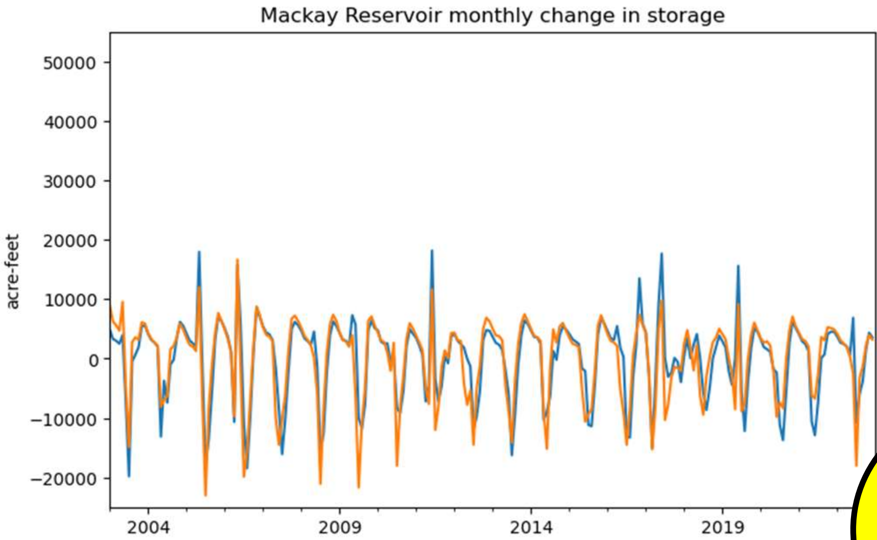

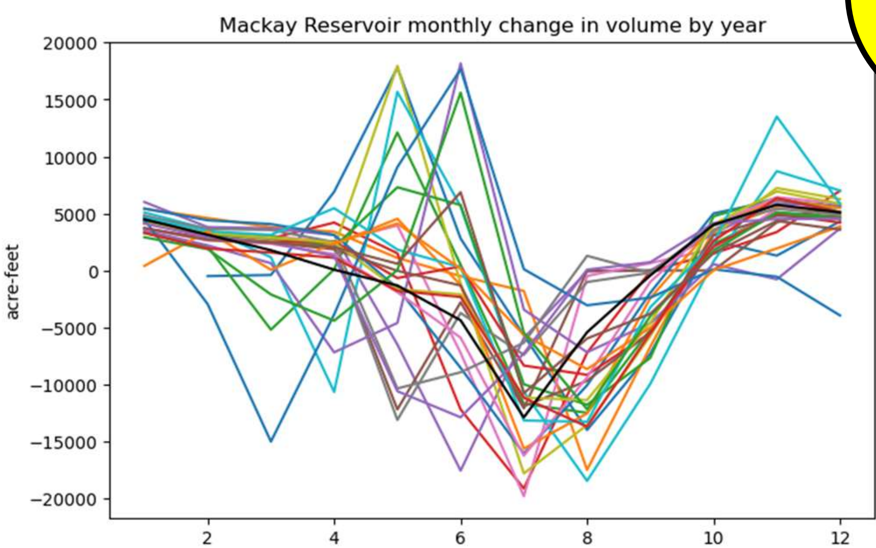

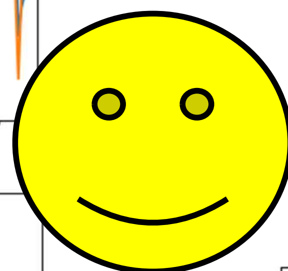

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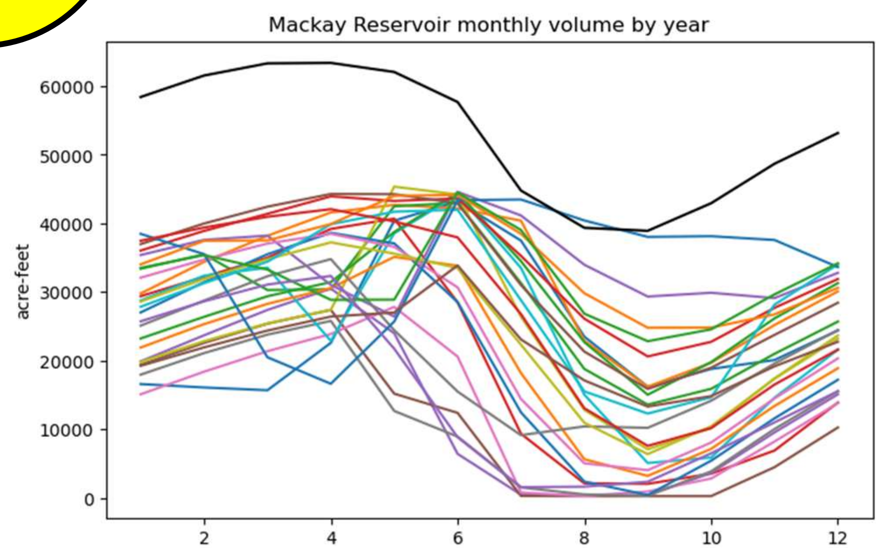
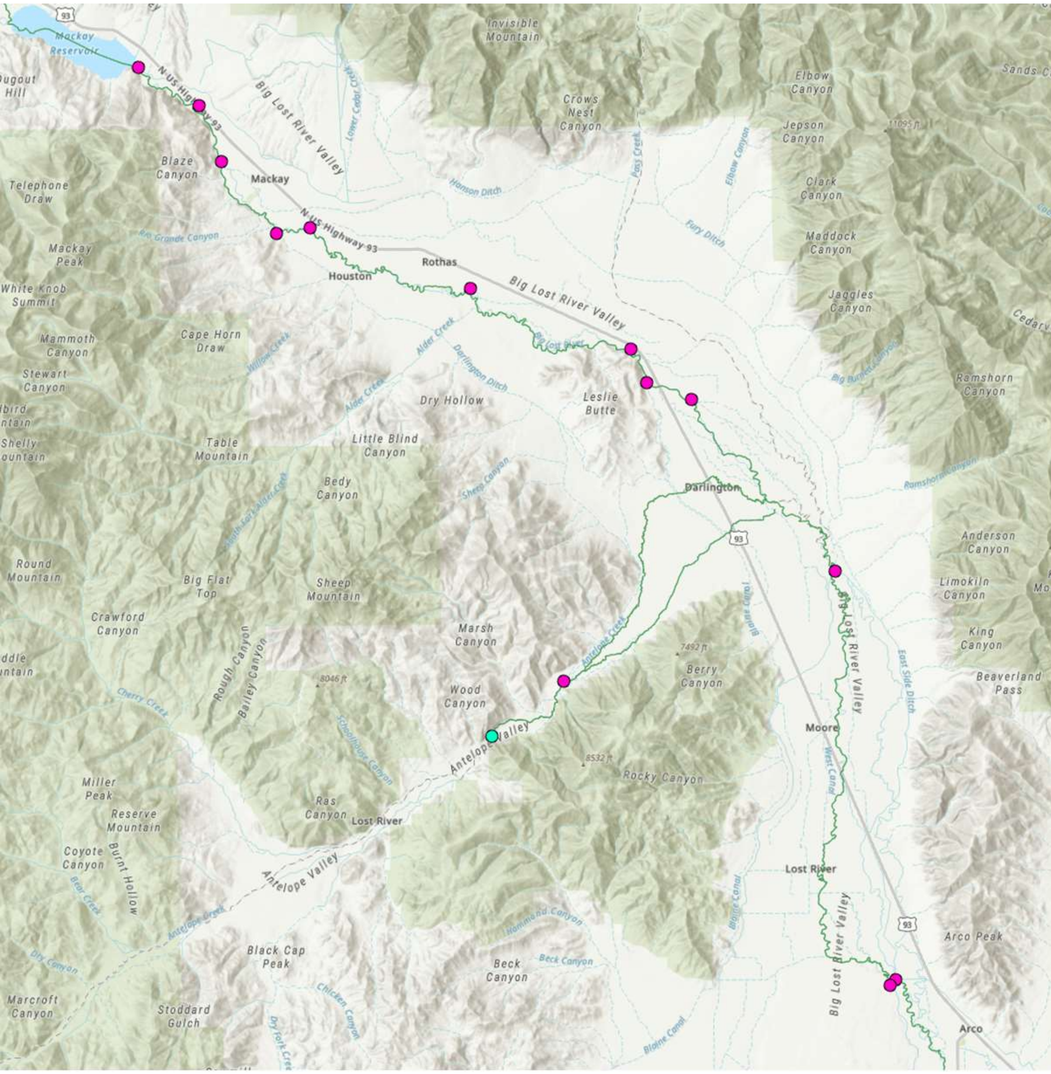




Streamflow Routing (update)

Inflows, Outflows, and Storage

Model status - streamflow routing

Inflows

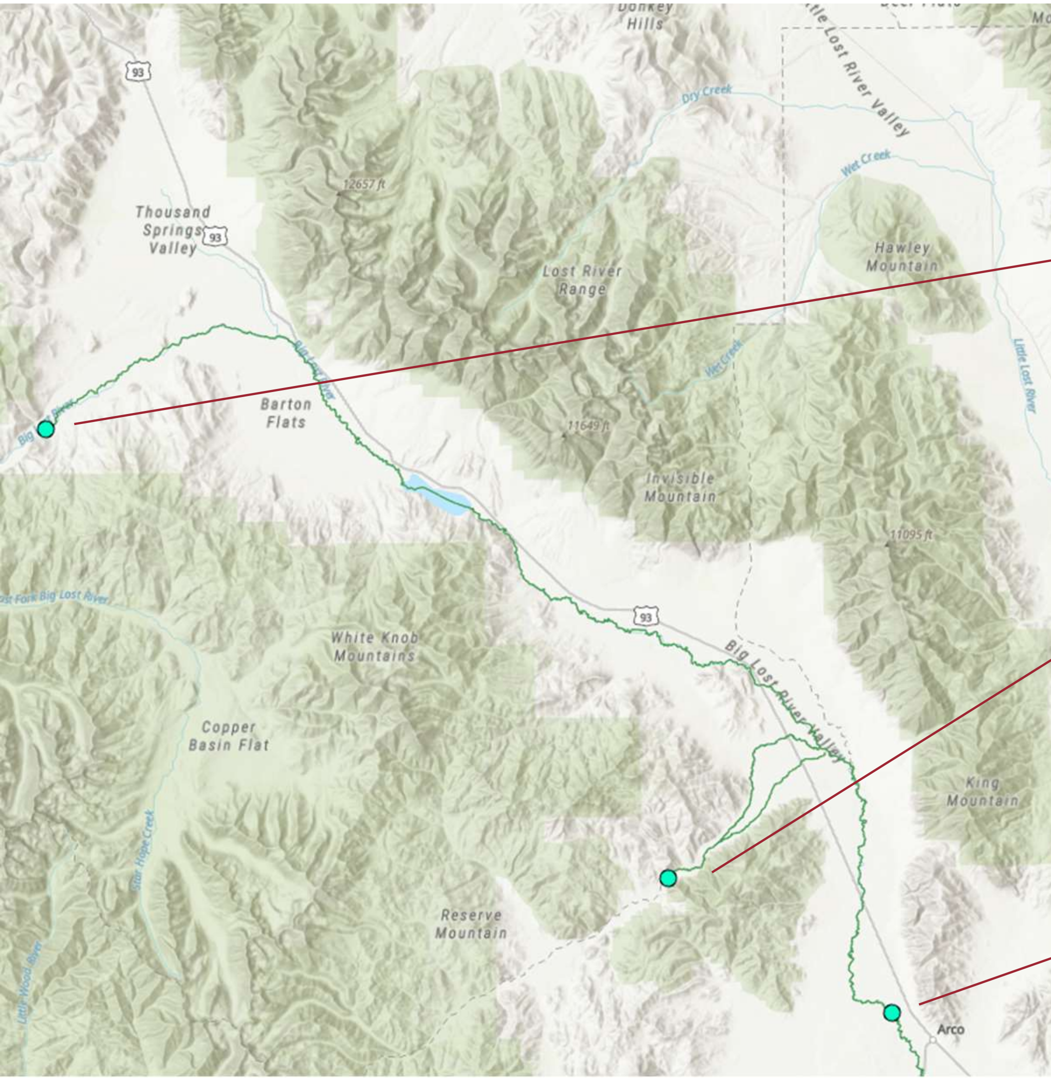
Howell gage measured flows, Antelope gage measured and estimated flows

Outflows

Non-routed diversions. Surface water removed from stream at POD locations, up to a priori defined-volumes used in farm service area calculator

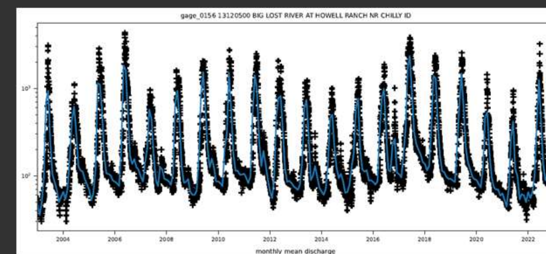
Storage

DONE – simulate storage and release of Mackay reservoir with LAK package and connect to SFR package with MVR package

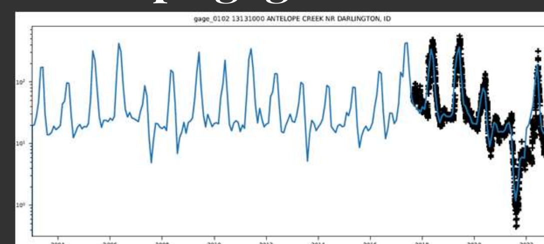


BLRM surface water inflows

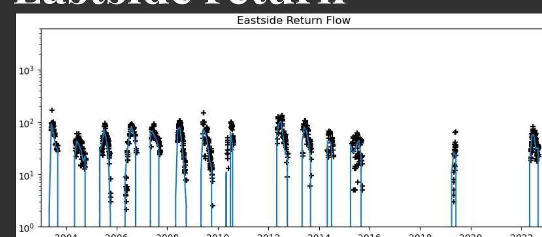
Howell gage



Antelope gage



Eastside return



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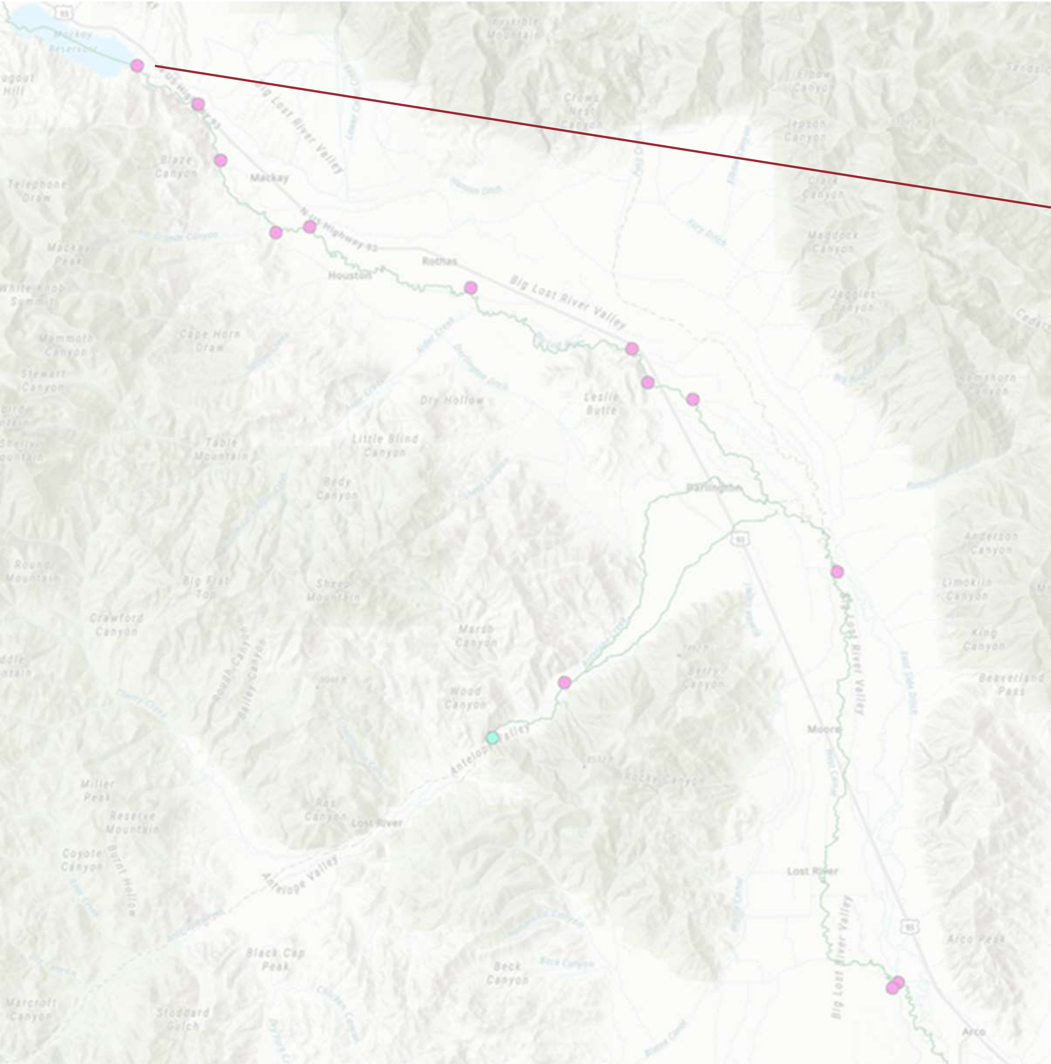
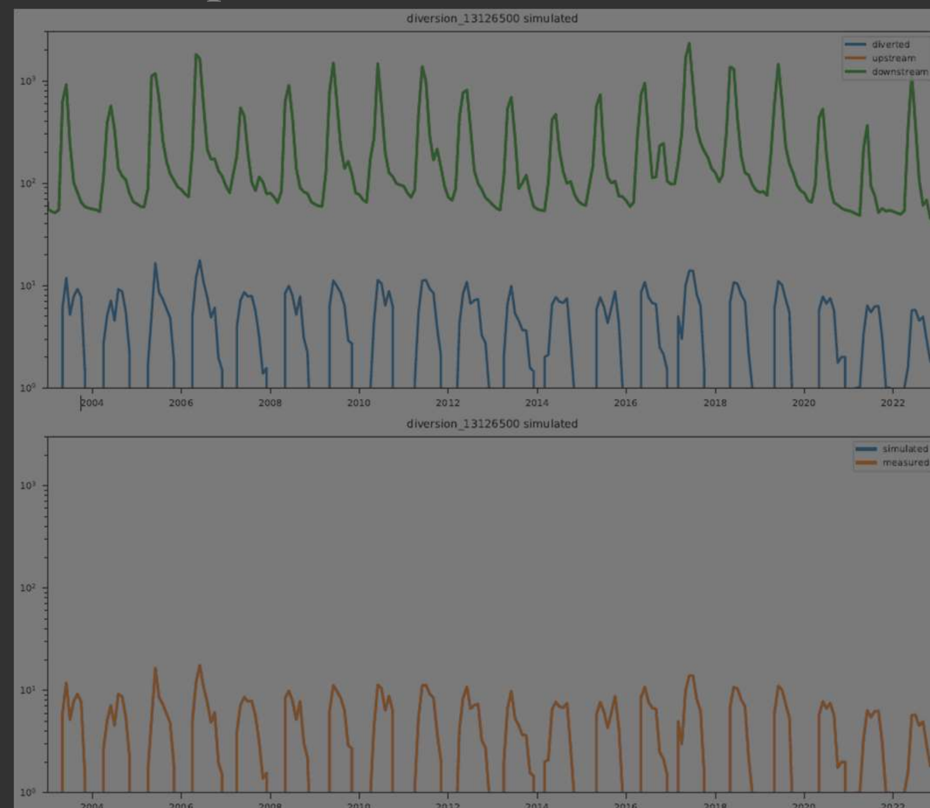


BLRM surface water diversions

Sharp Diversion



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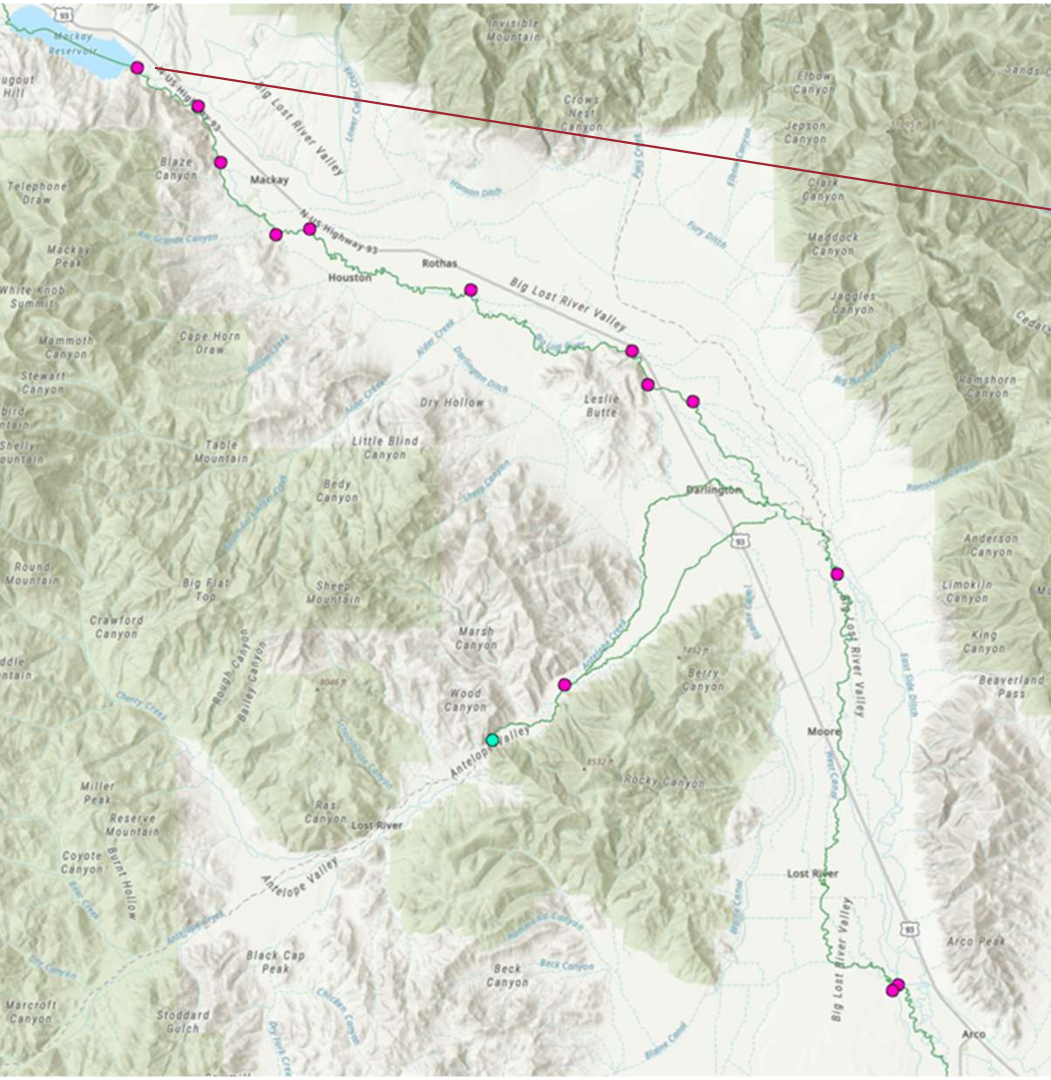
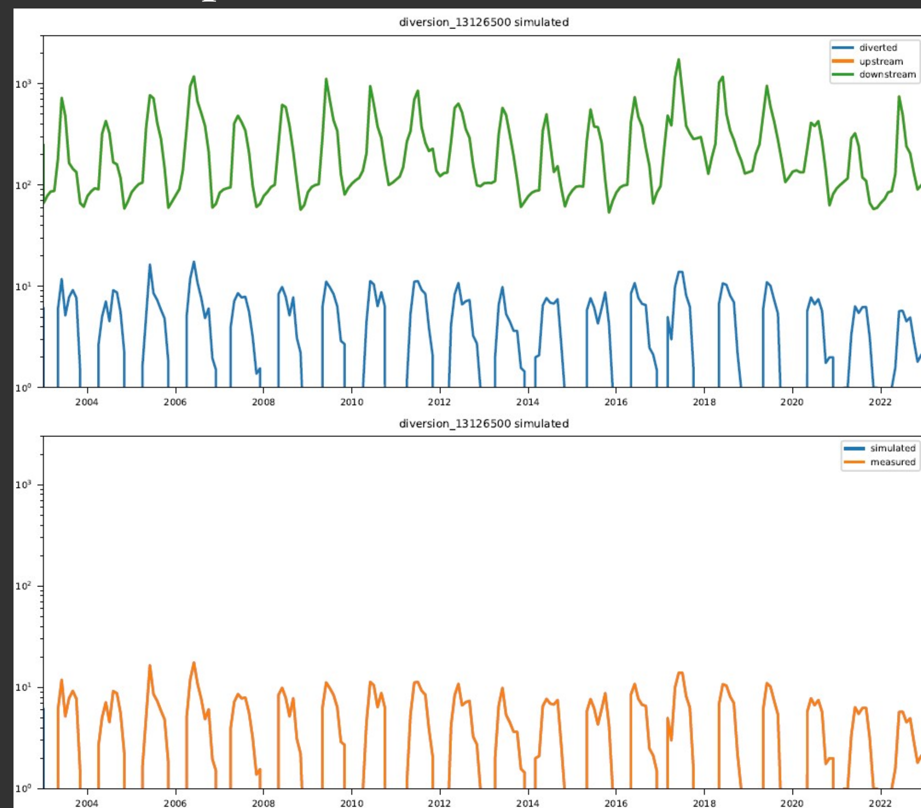
BLRM surface water diversions



Sharp Diversion



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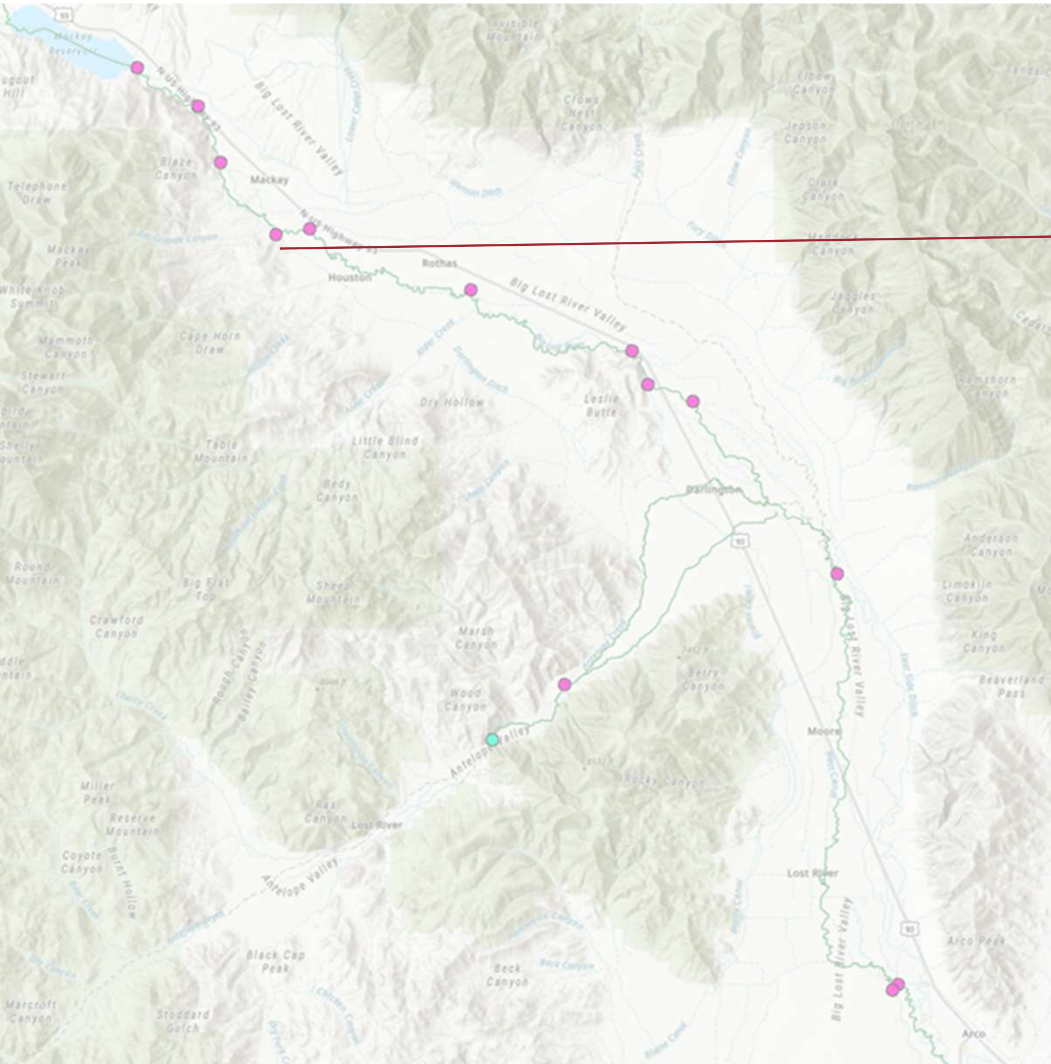
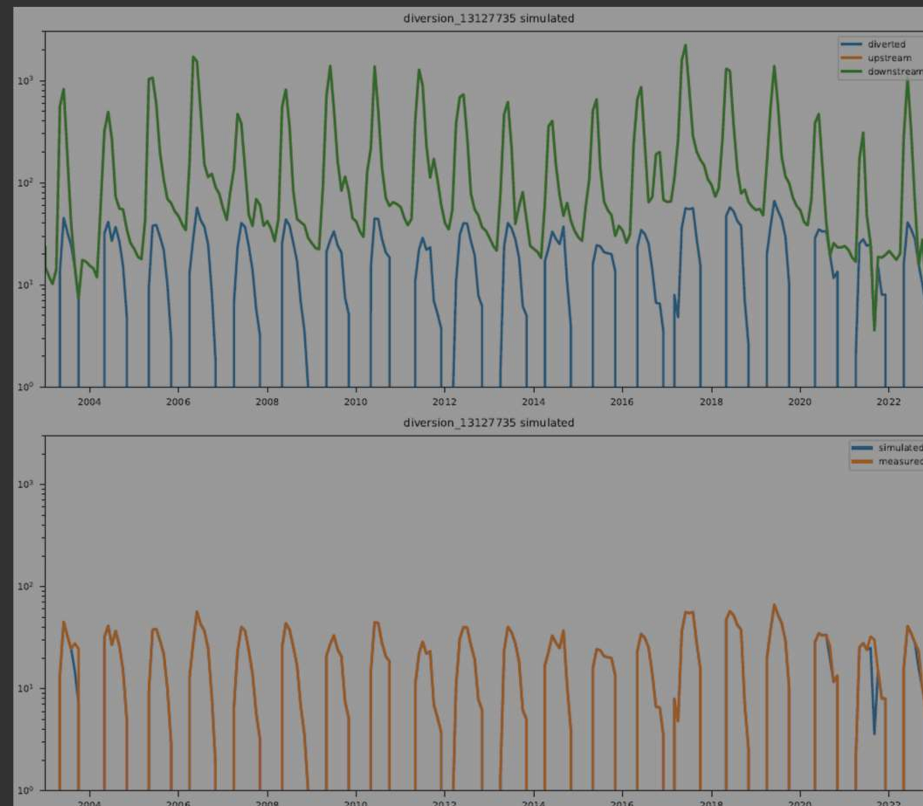


BLRM surface water diversions

Darlington Diversion



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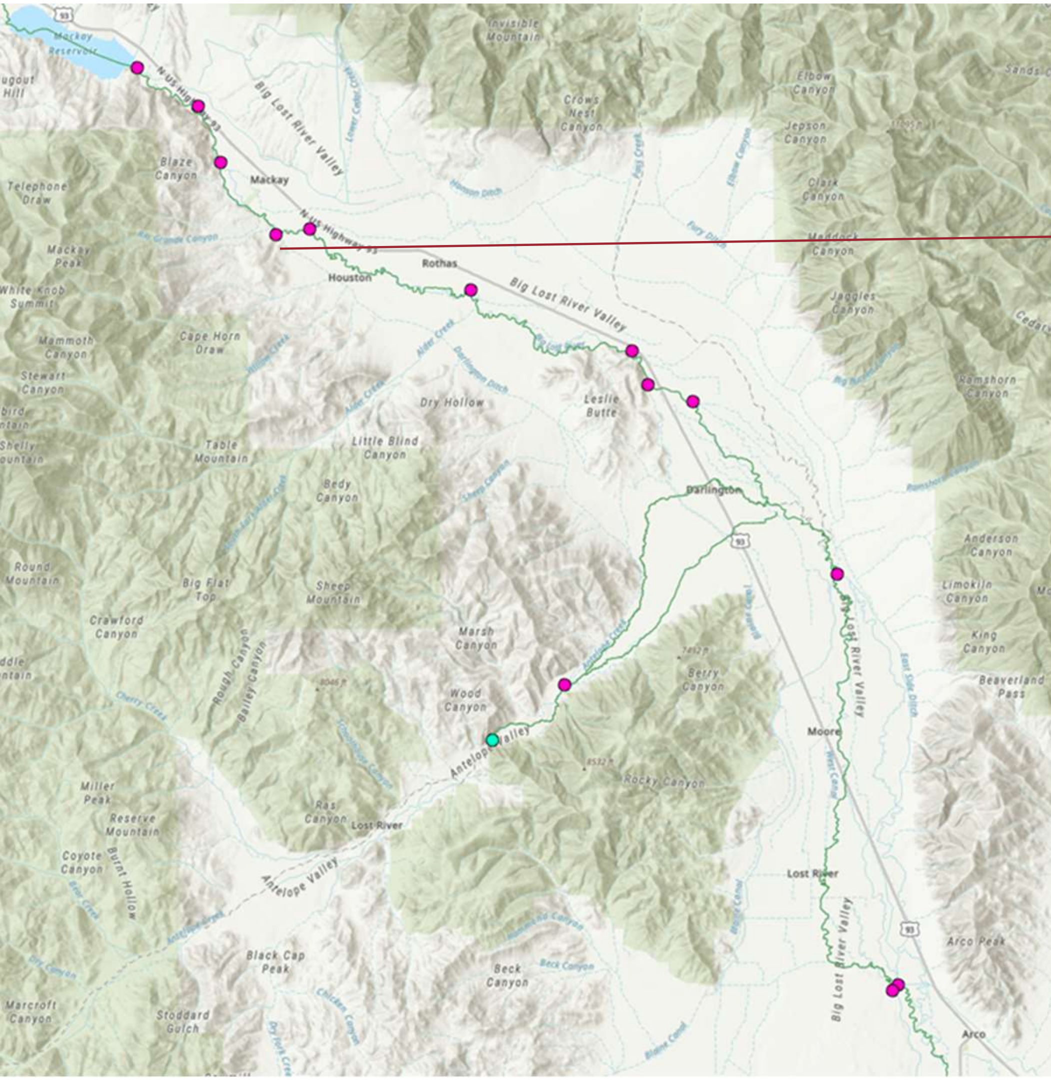
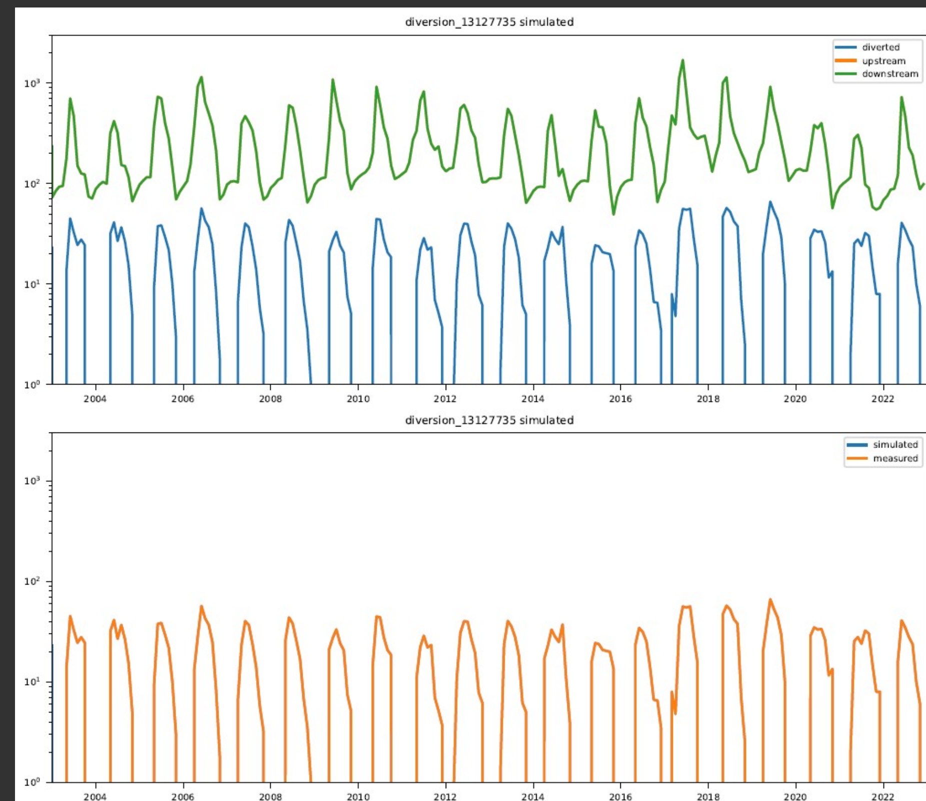
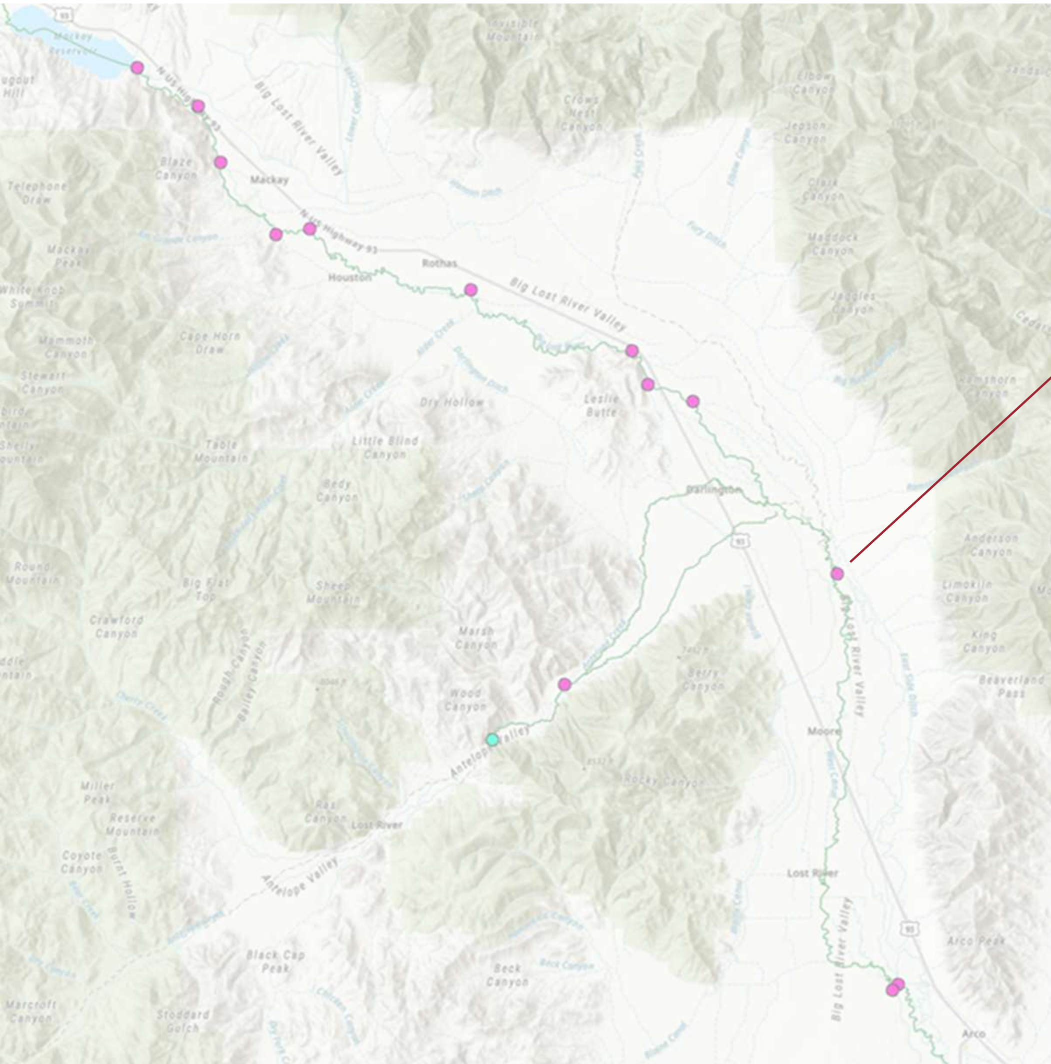


BLRM surface water diversions

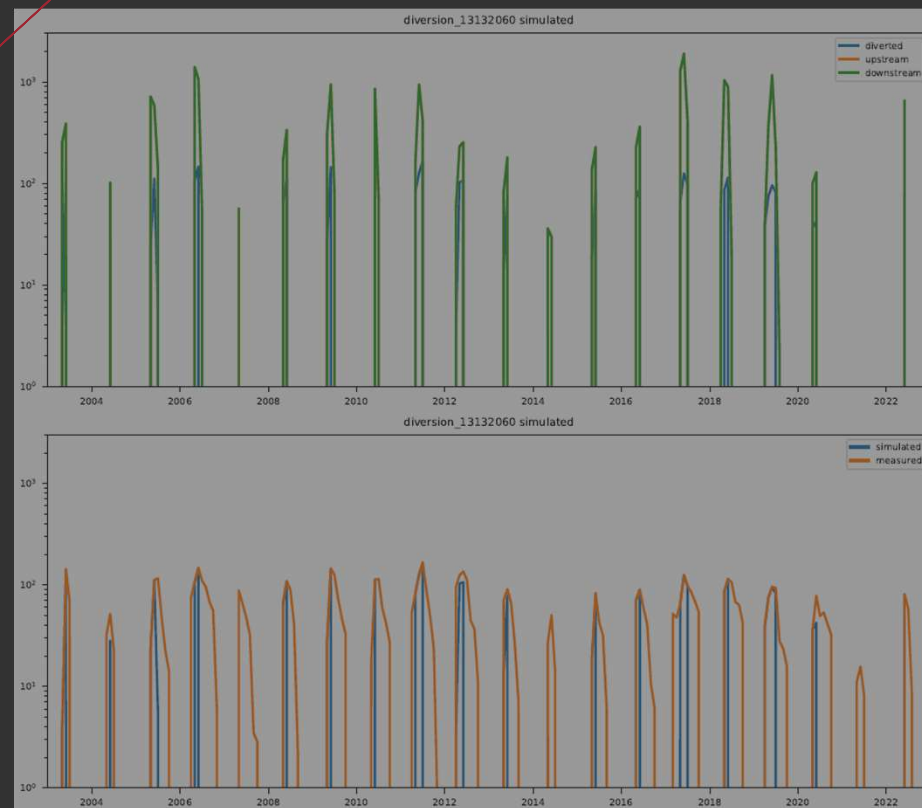
Darlington Diversion

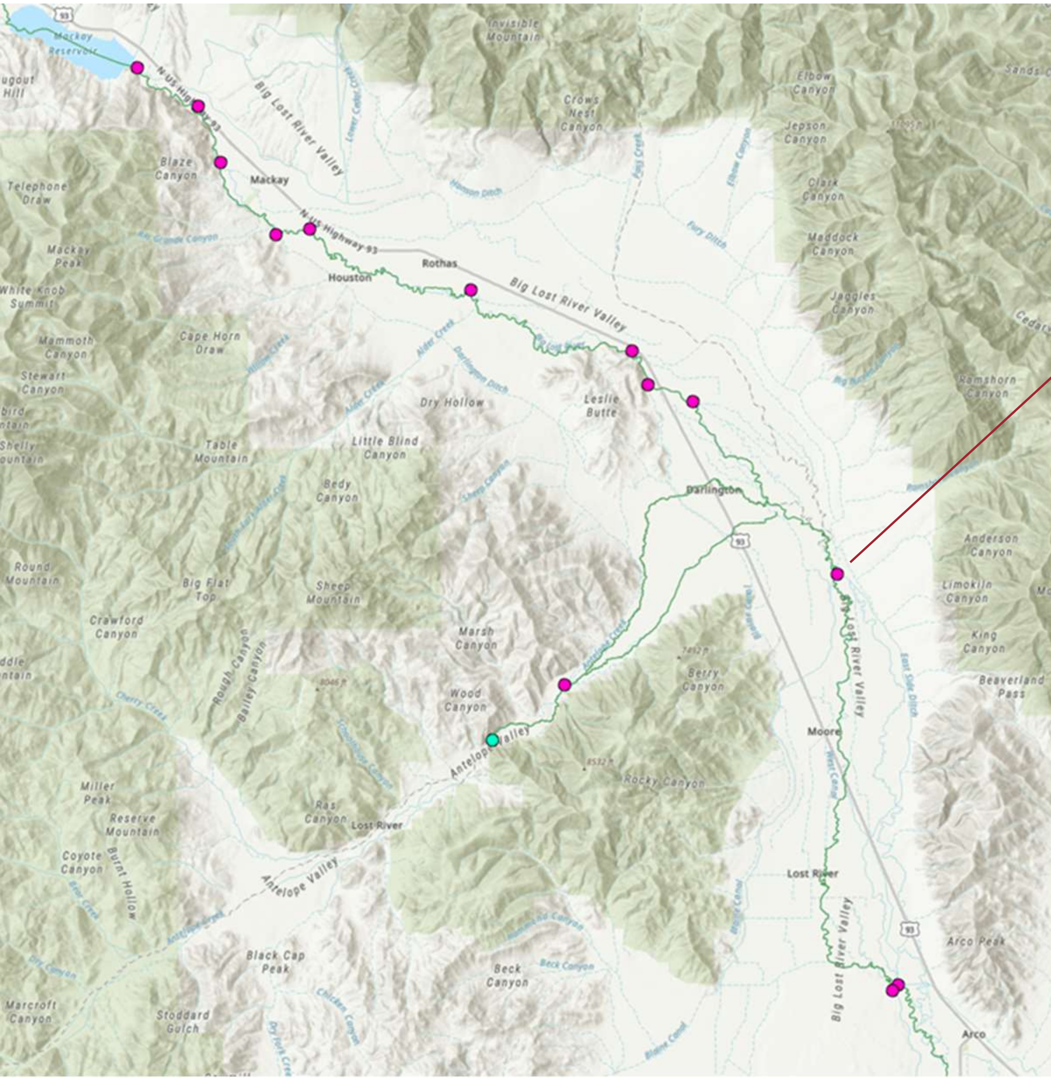




BLRM surface water diversions

Eastside Diversion





BLRM surface water diversions

Eastside Diversion

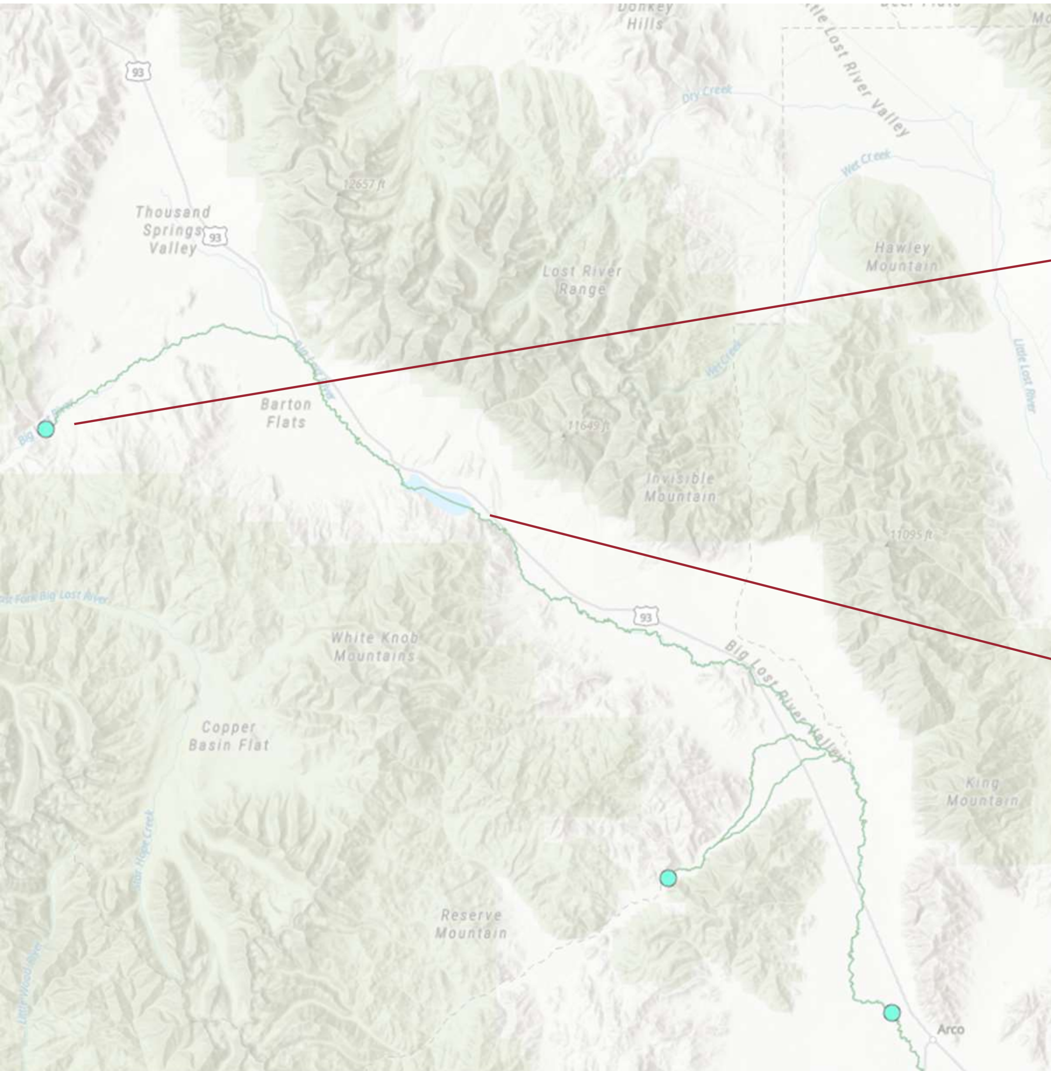
Model status – streamflow routing

Stream-Aquifer Exchange

Gains and losses are simulated via head-dependent boundary condition between stream stage and aquifer head. Overall volumes are reasonable but not yet matching to reach-scale observations (e.g. seepage study findings)

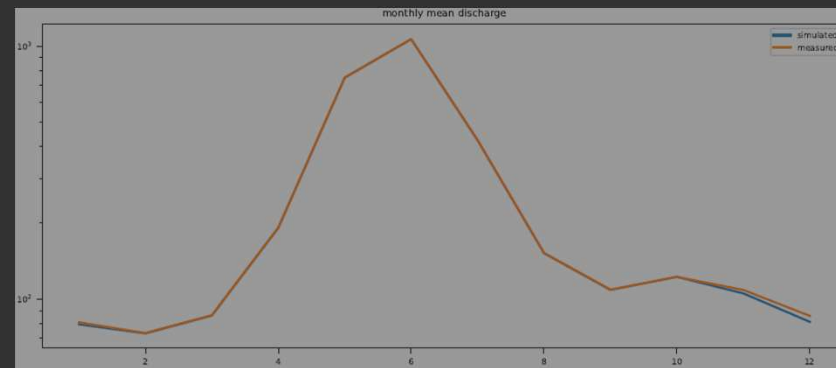
Monthly Flows

Simulating specified releases from Mackay Reservoir greatly improved fit to monthly mean in middle and lower basin

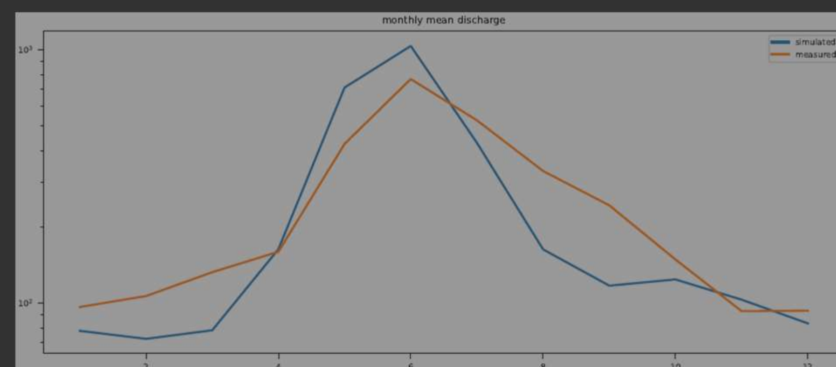


Importance of simulating storage and release

Howell gage



Below Mackay gage



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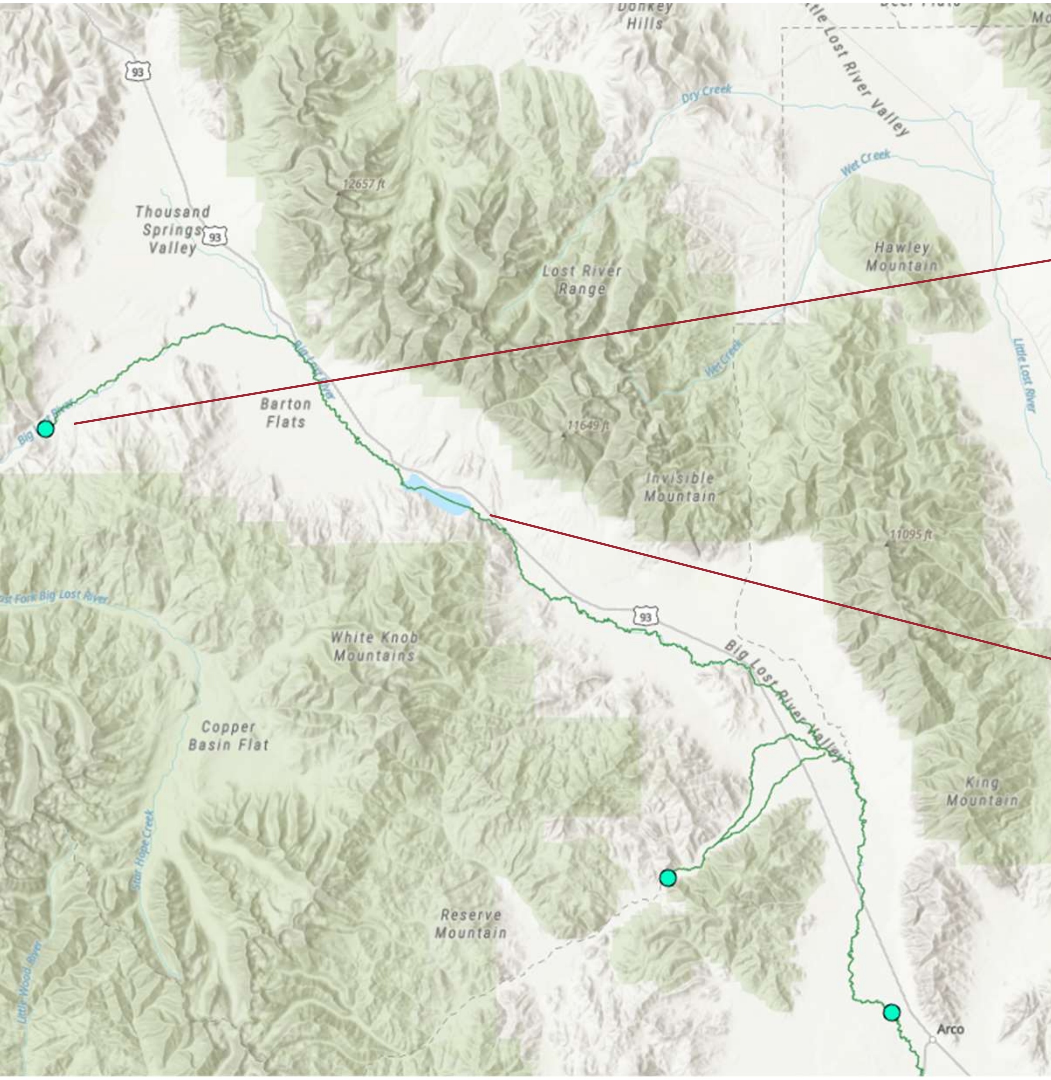

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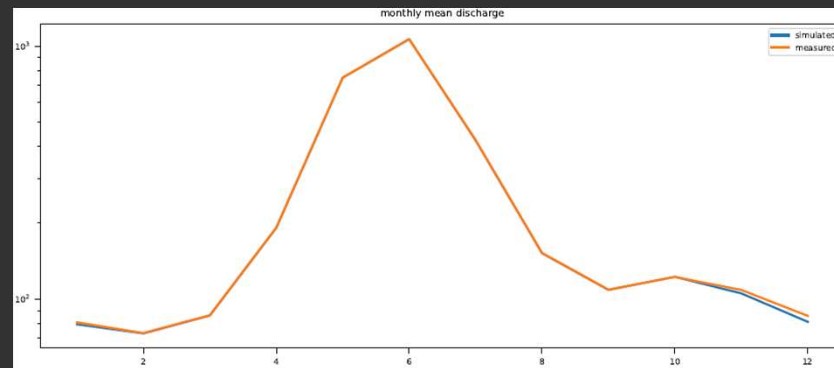
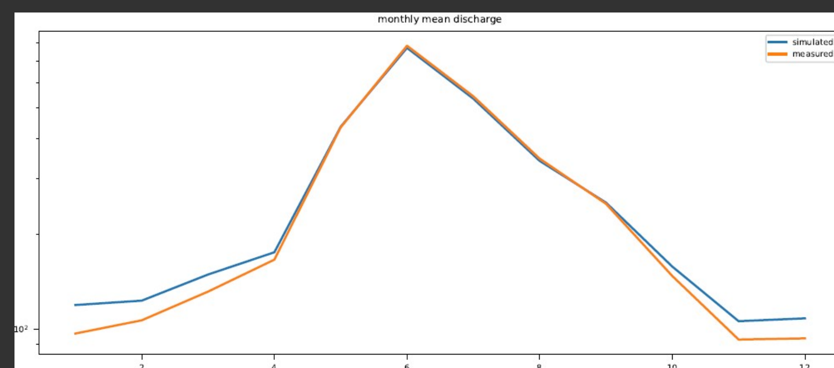
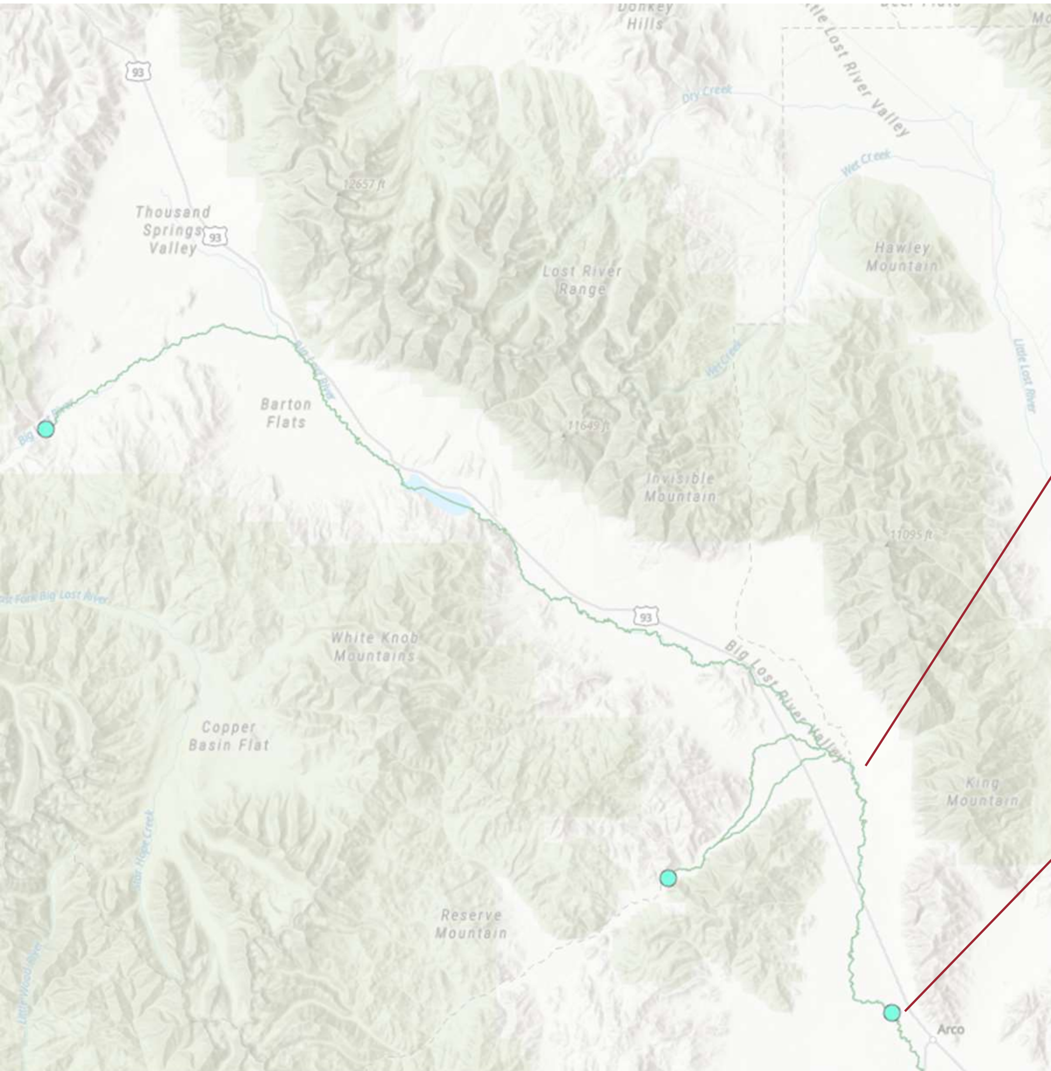


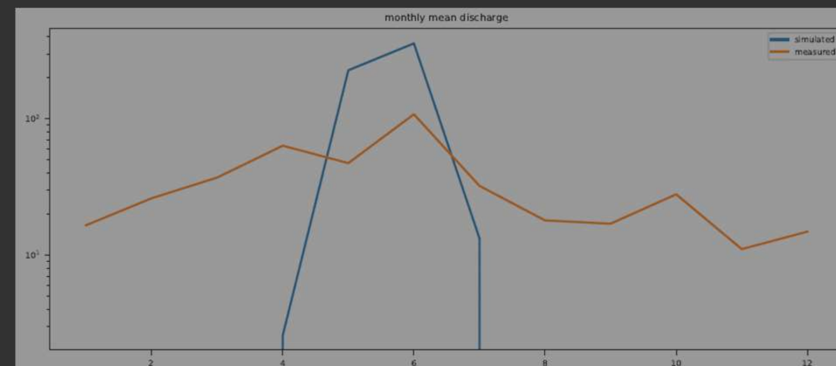
Below Mackay gage



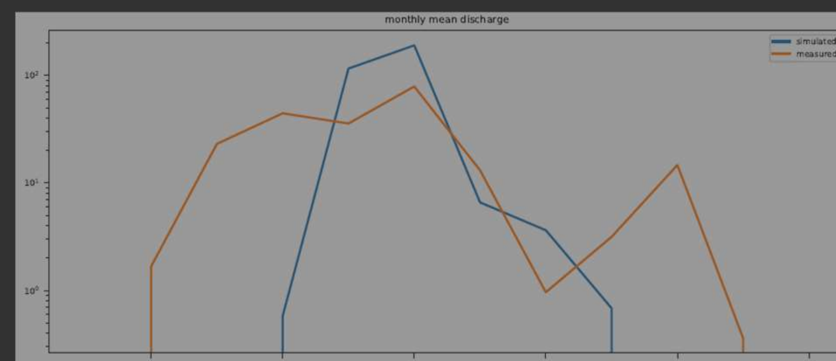


Importance of simulating storage and release

Below Moore gage



Arco gage



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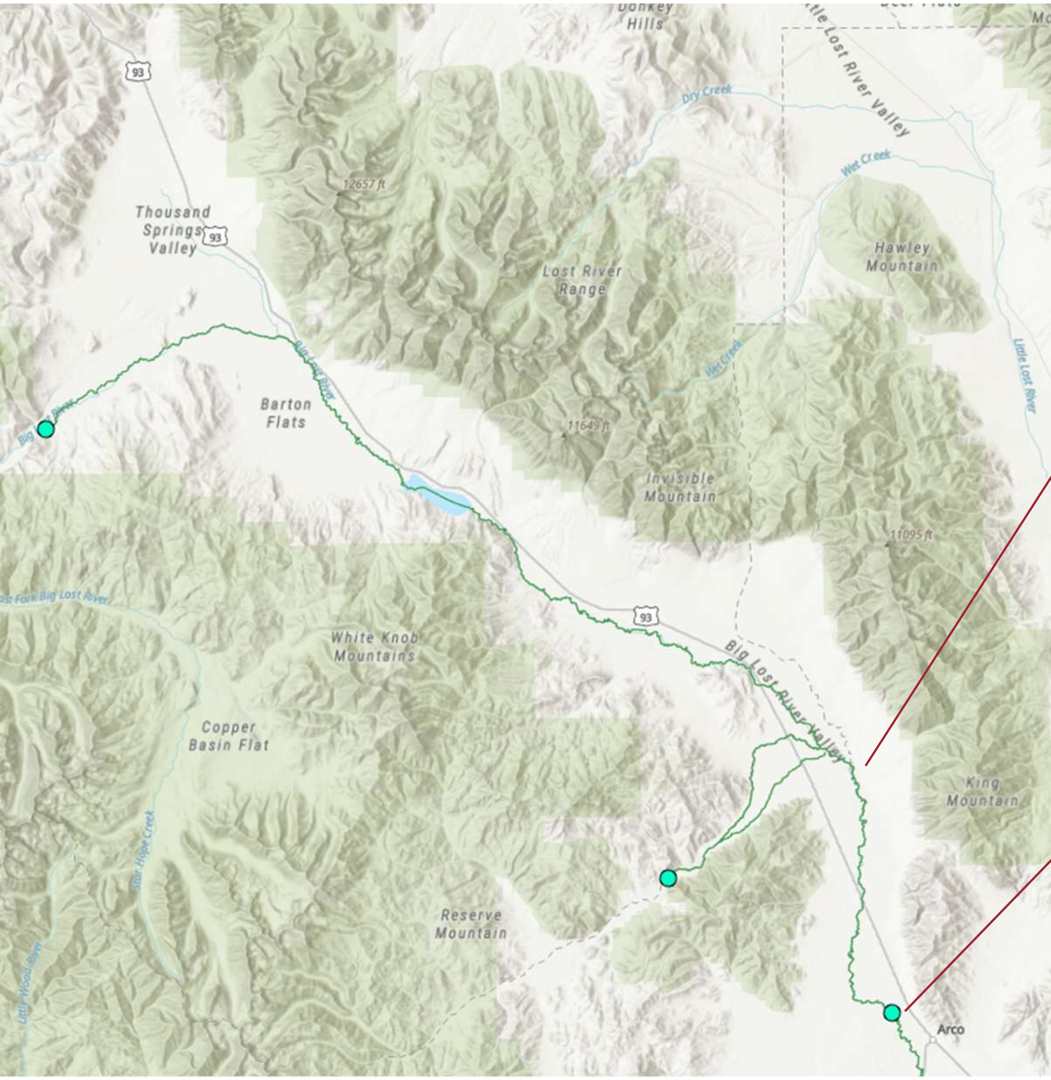

Importance of simulating storage and release

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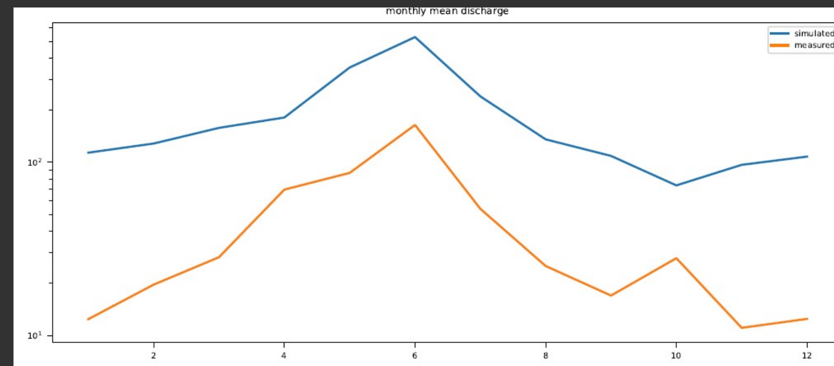
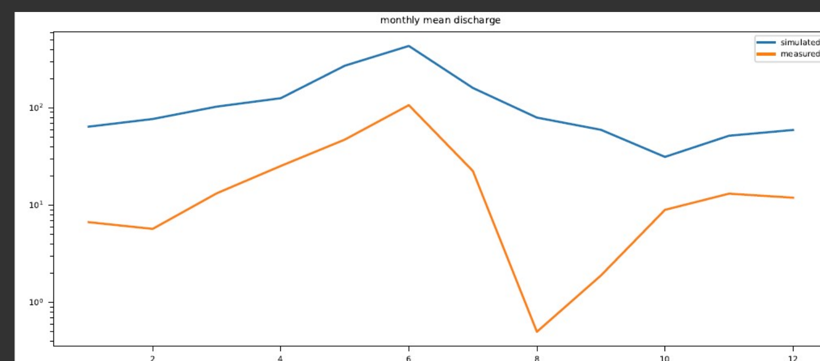


Arco gage



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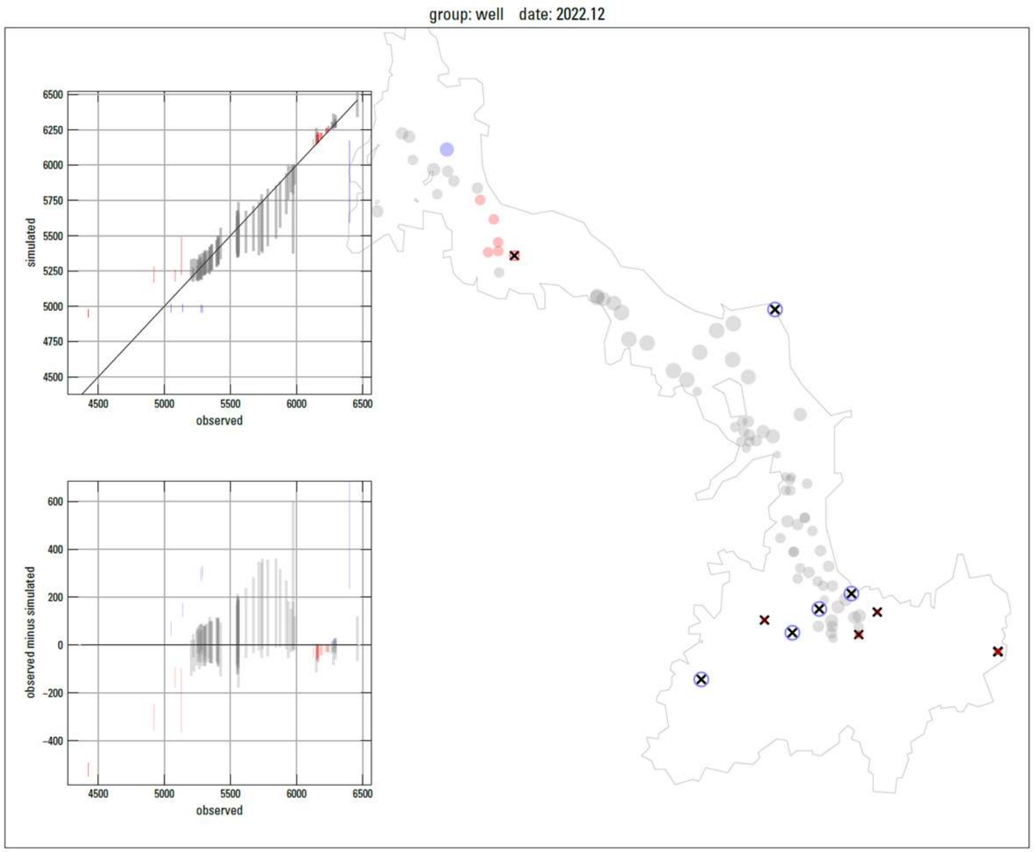
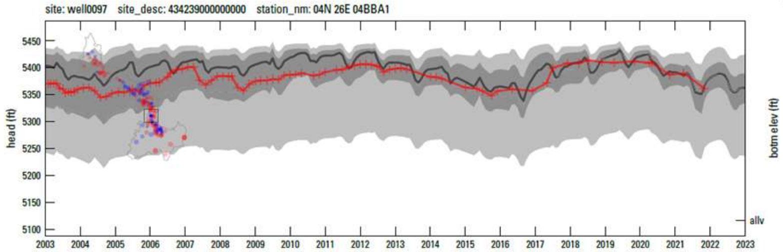




Parameter Estimation

Continued investigation with the Prior Parameter Ensemble

Two necessary conditions for decision-support modeling

(Knowling and others, 2019)

High-dimensional	Stochastic
Avoid erroneous decision based on model forecast bias	Express reliability in simulated outcomes

Ensemble modeling with PESTPP-IES

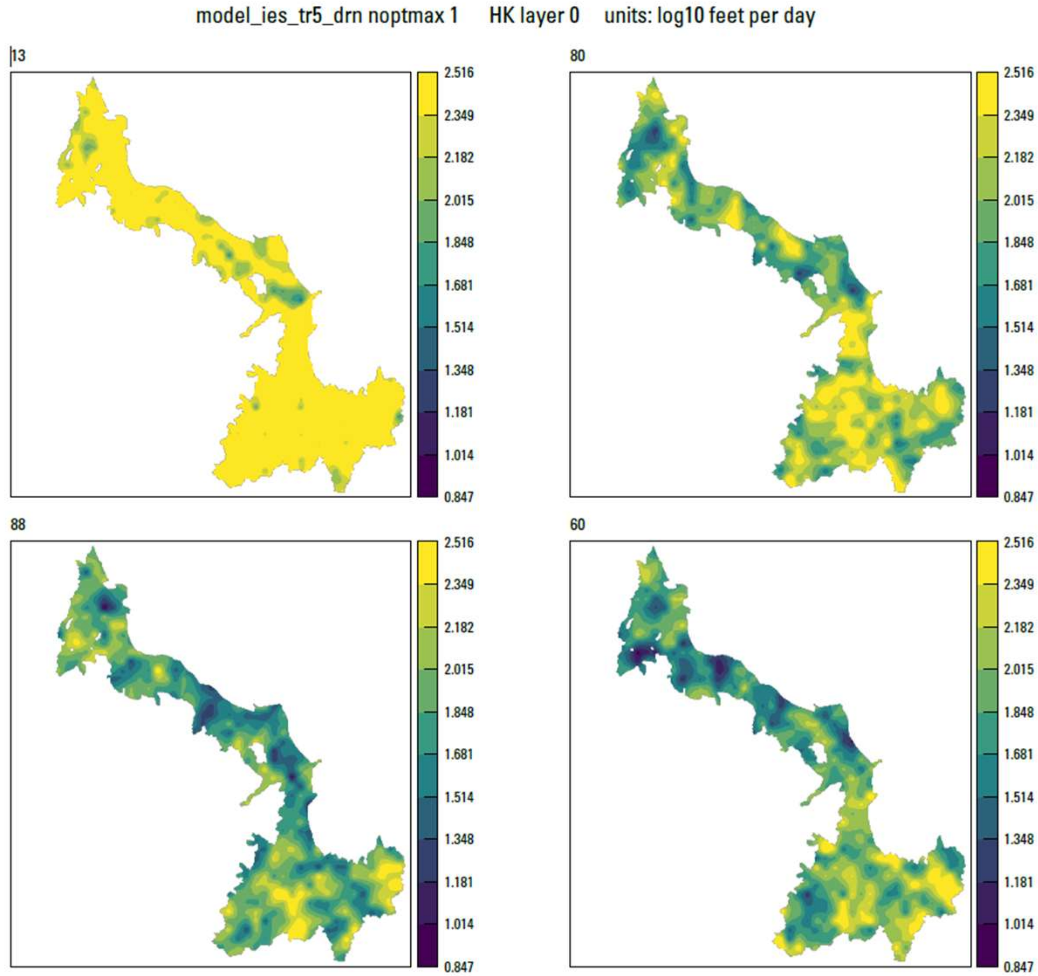
High-dimensional

Make use of many thousands of parameters (or even millions) to better simulate natural variability on multiple spatio-temporal scales

(with fewer total model runs, less CPU time)

Stochastic

Upgraded parameter ensemble provides multiple model realizations that fit historical observations equally well, retaining a level of uncertainy in parameter values that will give a range of equally likely forecast results.



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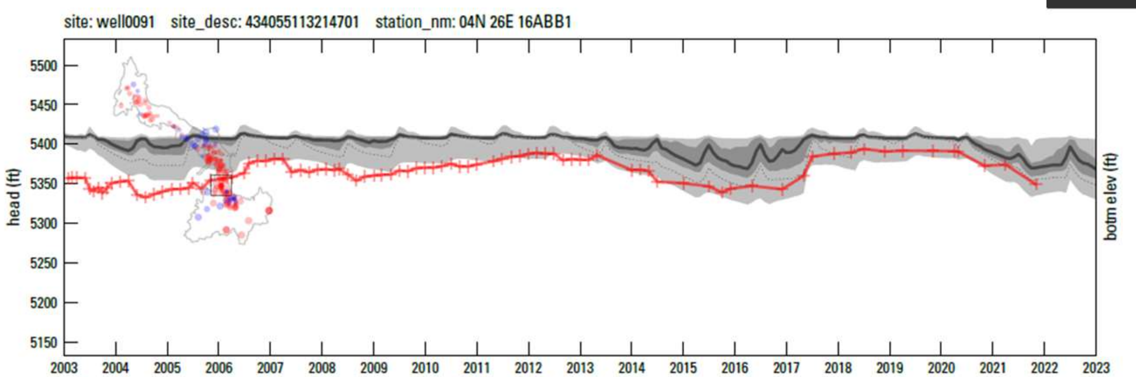
In general, for BLRM we aim to OVER-parameterize and UNDER-fit

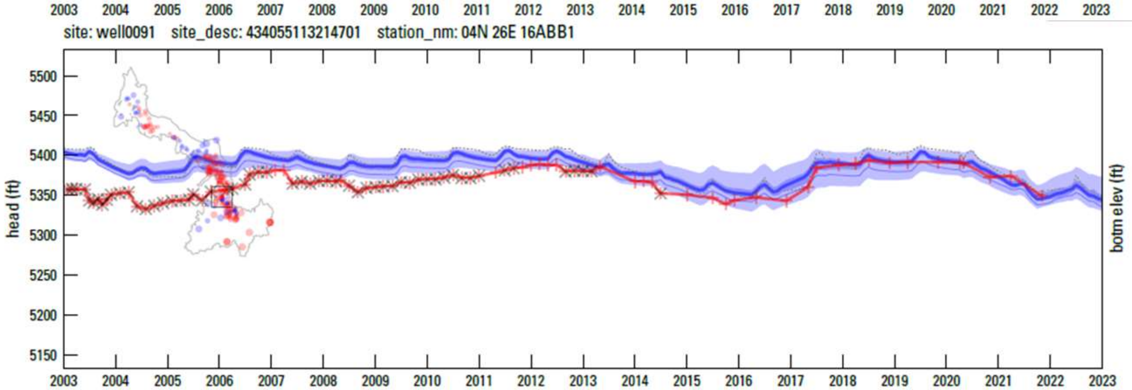
Define parameters as overlapping multipliers at Coarse, Intermediate, and Fine scales

Providing many "receptacles" (pars) to assimilate information from observation data prevents bias incurred from parameter compensation

Some parameters are assigned a fixed range of values and not allowed to adjust to match observations. This formalizes our ignorance of certain inputs and retains appropriate unceraintanty

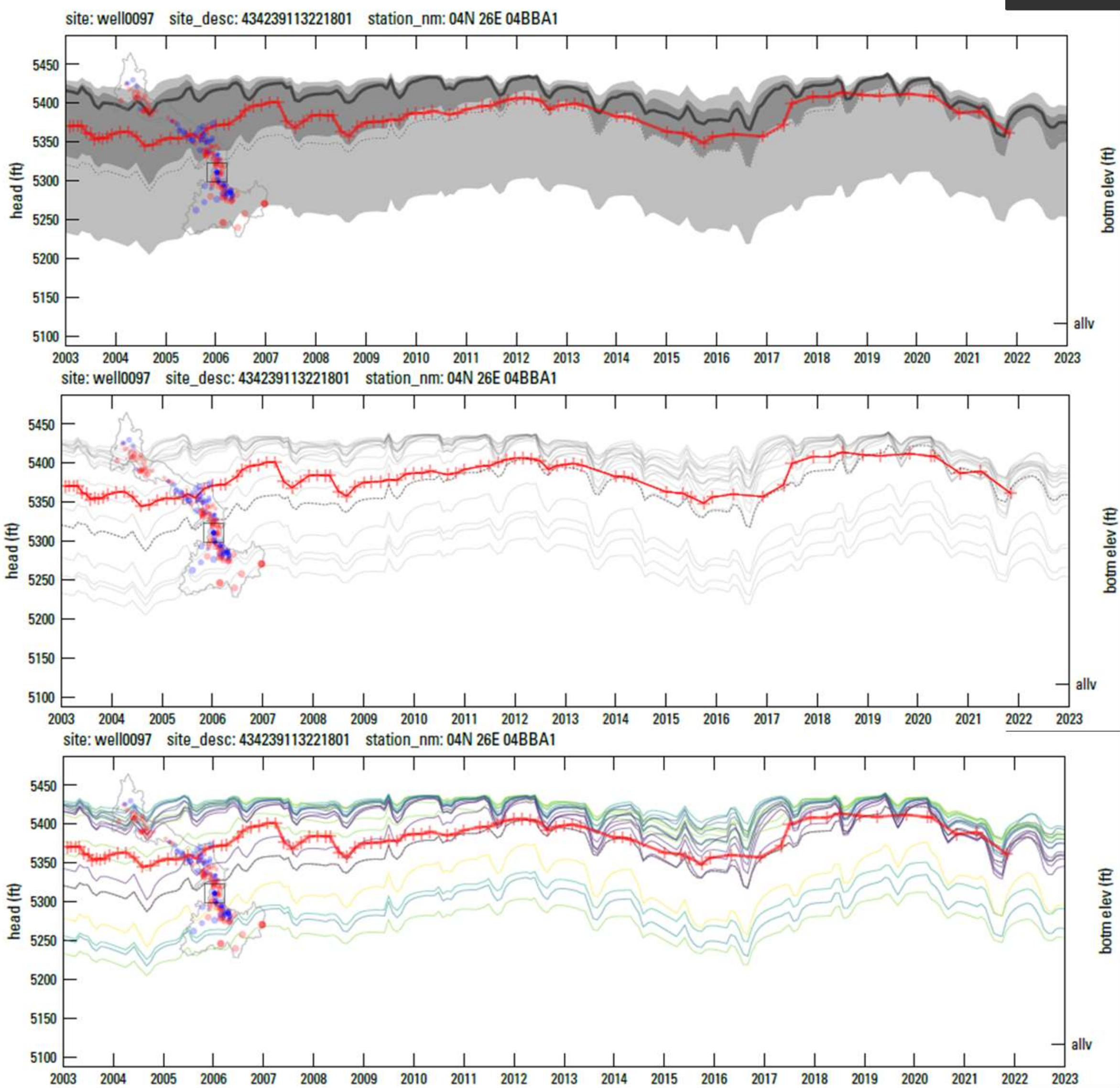
In general, for BLRM we aim to OVER-parameterize and UNDER-fit





Overfitting parameters to historical observations leads to bias in forecast, and too-low variance (false certainty) that ignores the importance of what we don't know or can't simulate

Some outlier measurements are far outside the range of the prior ensemble results (prior data conflict) and automatically removed from the objective function to avoid parameter compensation

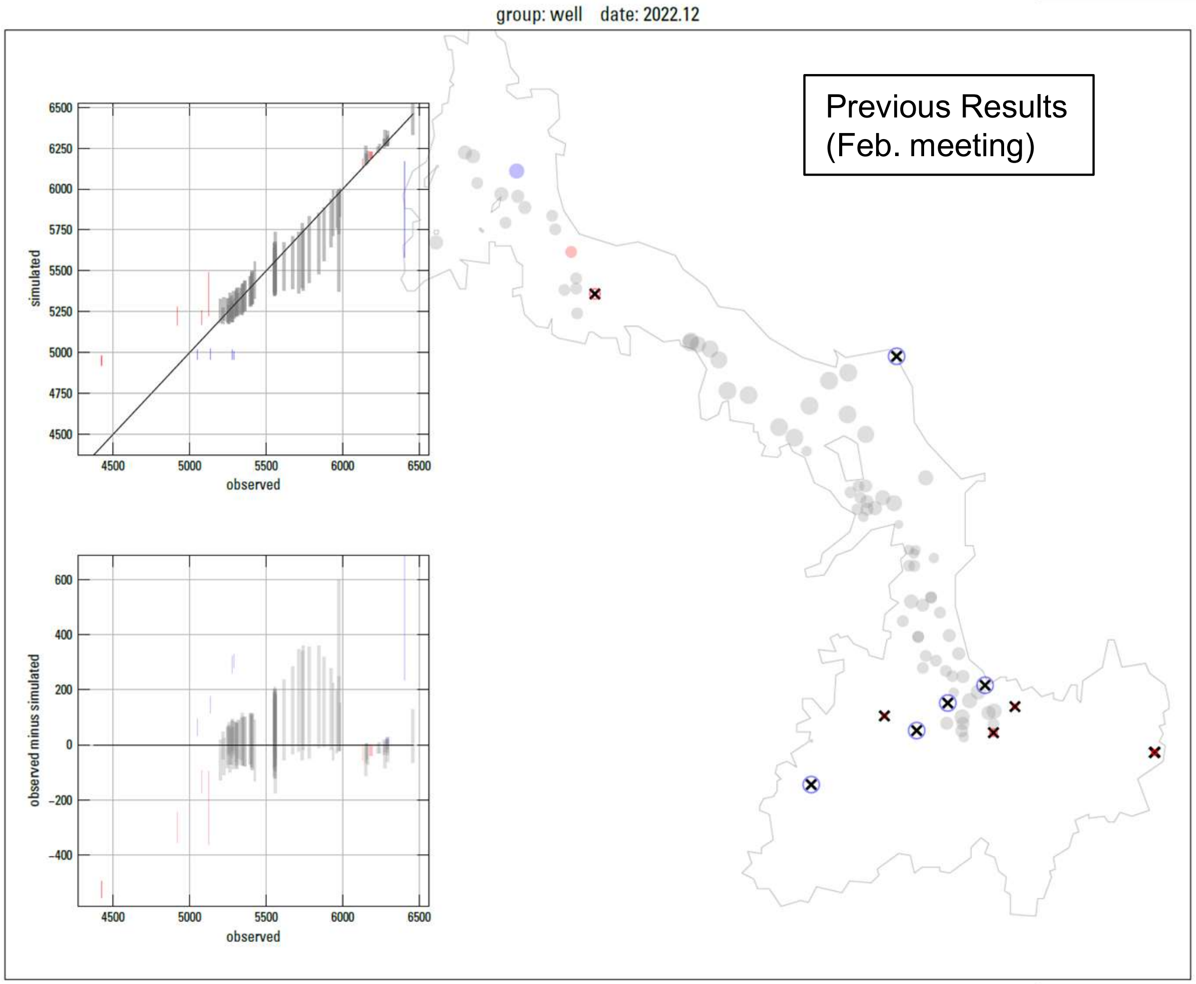


Example to get familiar with ensemble results

Filled plots show max/min range, interquartile range, and median simulated value at each time step

Time series of individual model realizations can look more chaotic

Each realization has different parameter values, randomly drawn from the defined prior distribution



Example to get familiar with ensemble results

Residual maps show spatial variability of fit to observations and range of simulated values for a given time step

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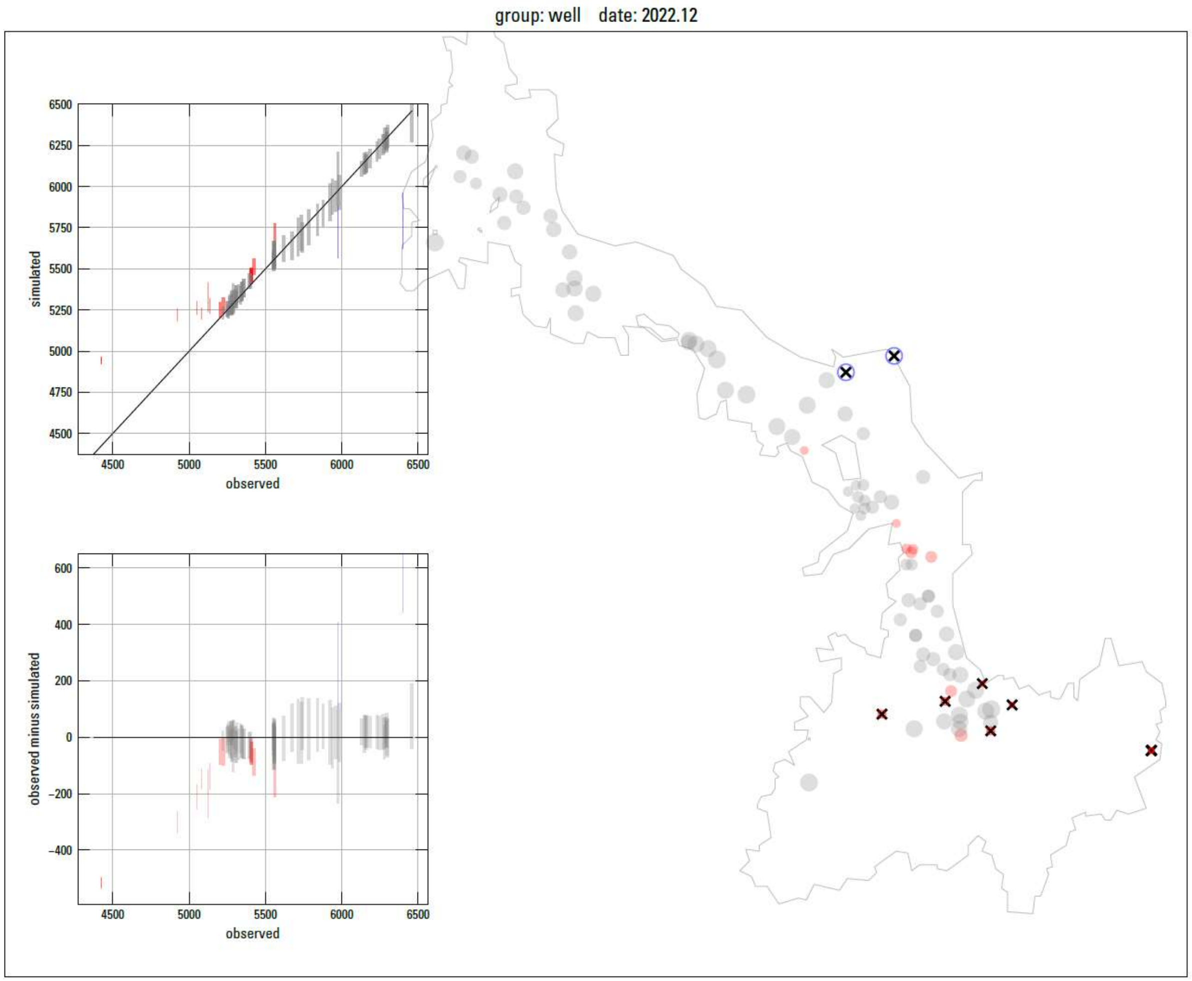
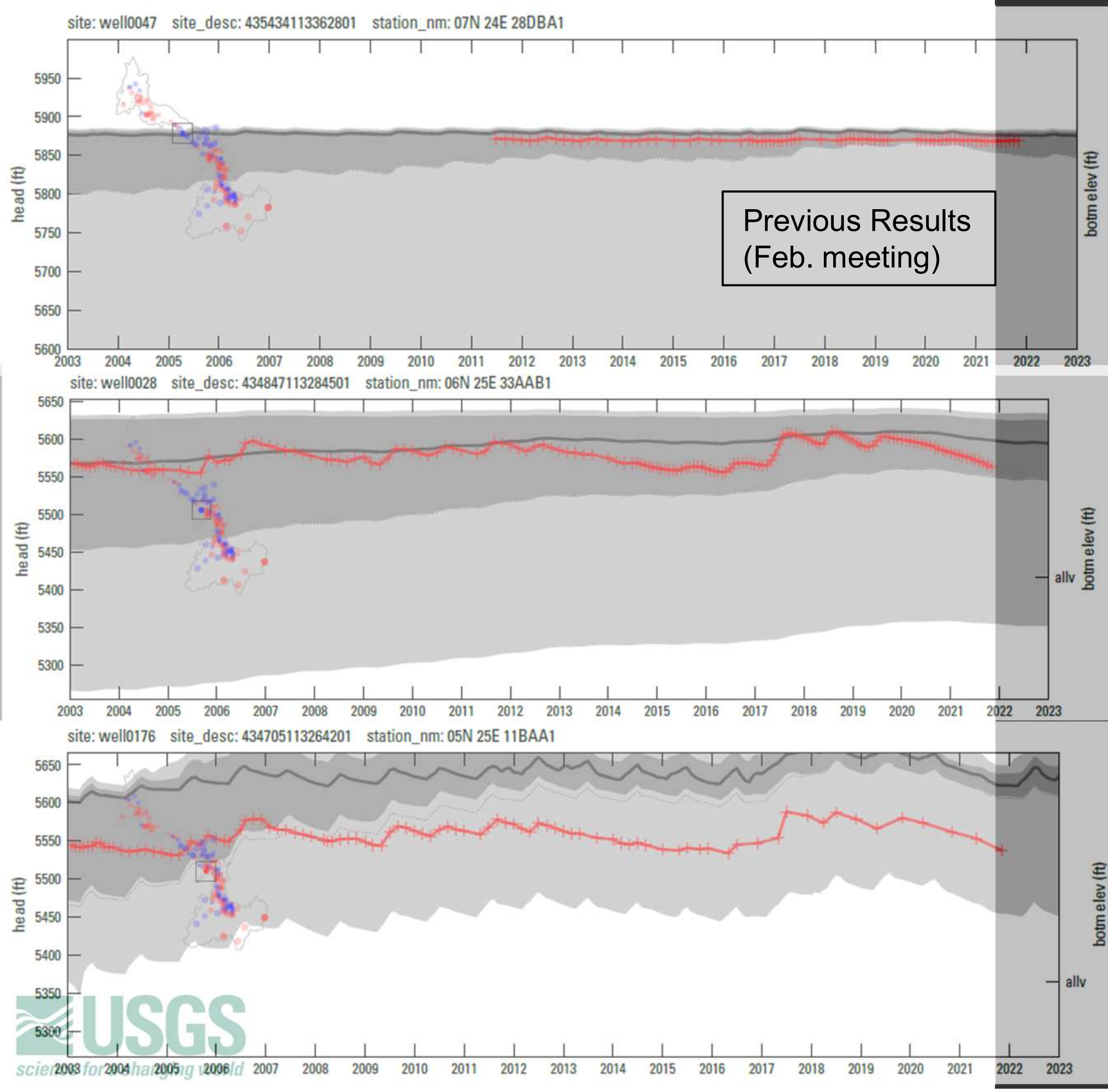


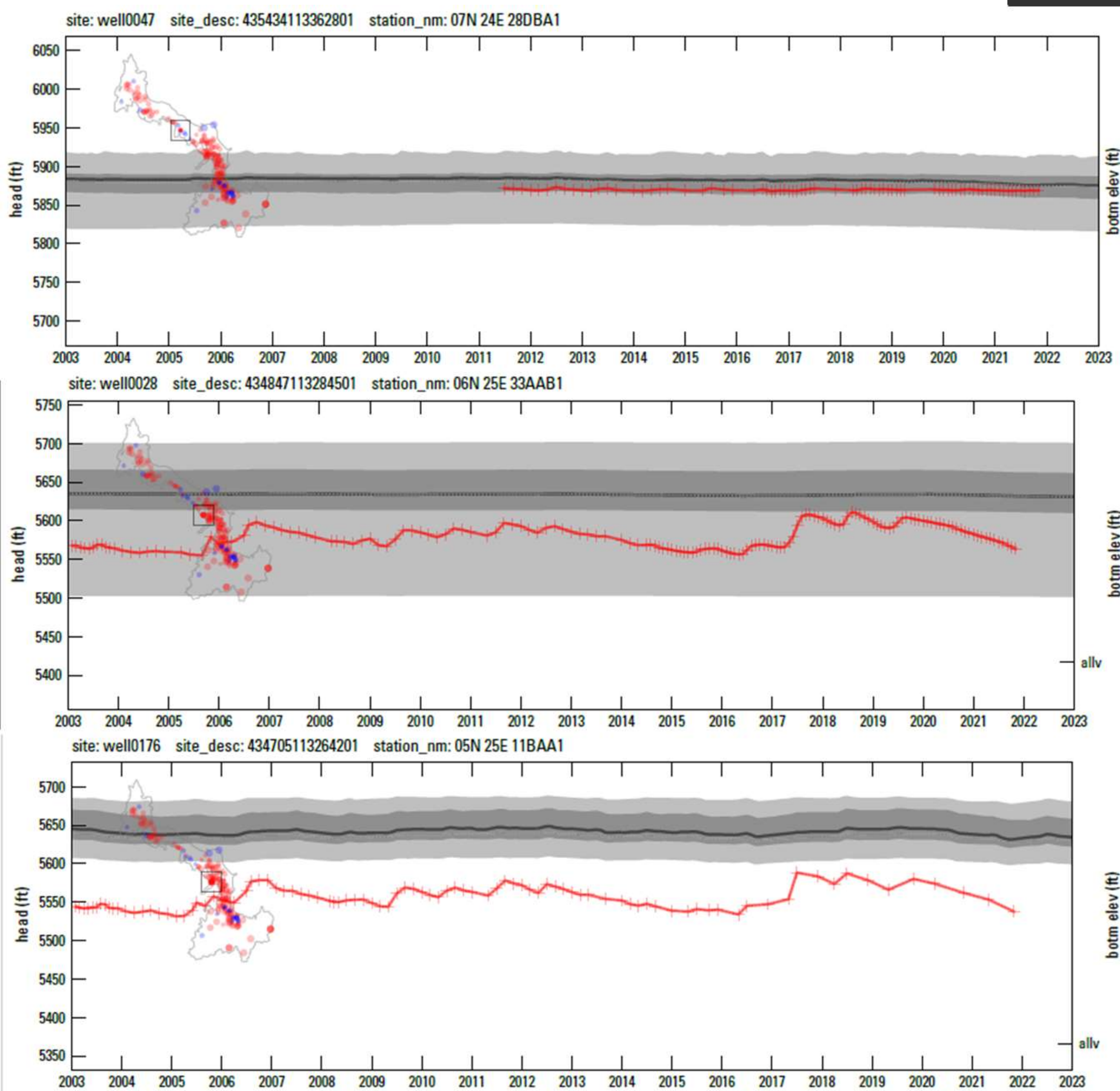
Overall summary of changes in model fit-to-data: Better flows, worse heads

It's an iterative process: Improving one aspect of the model often degrades another. Strive for balance.



Decent coverage of GW level observations in most areas

“coverage” : observed value is bounded by max/min values simulated by the ensemble of model realizations



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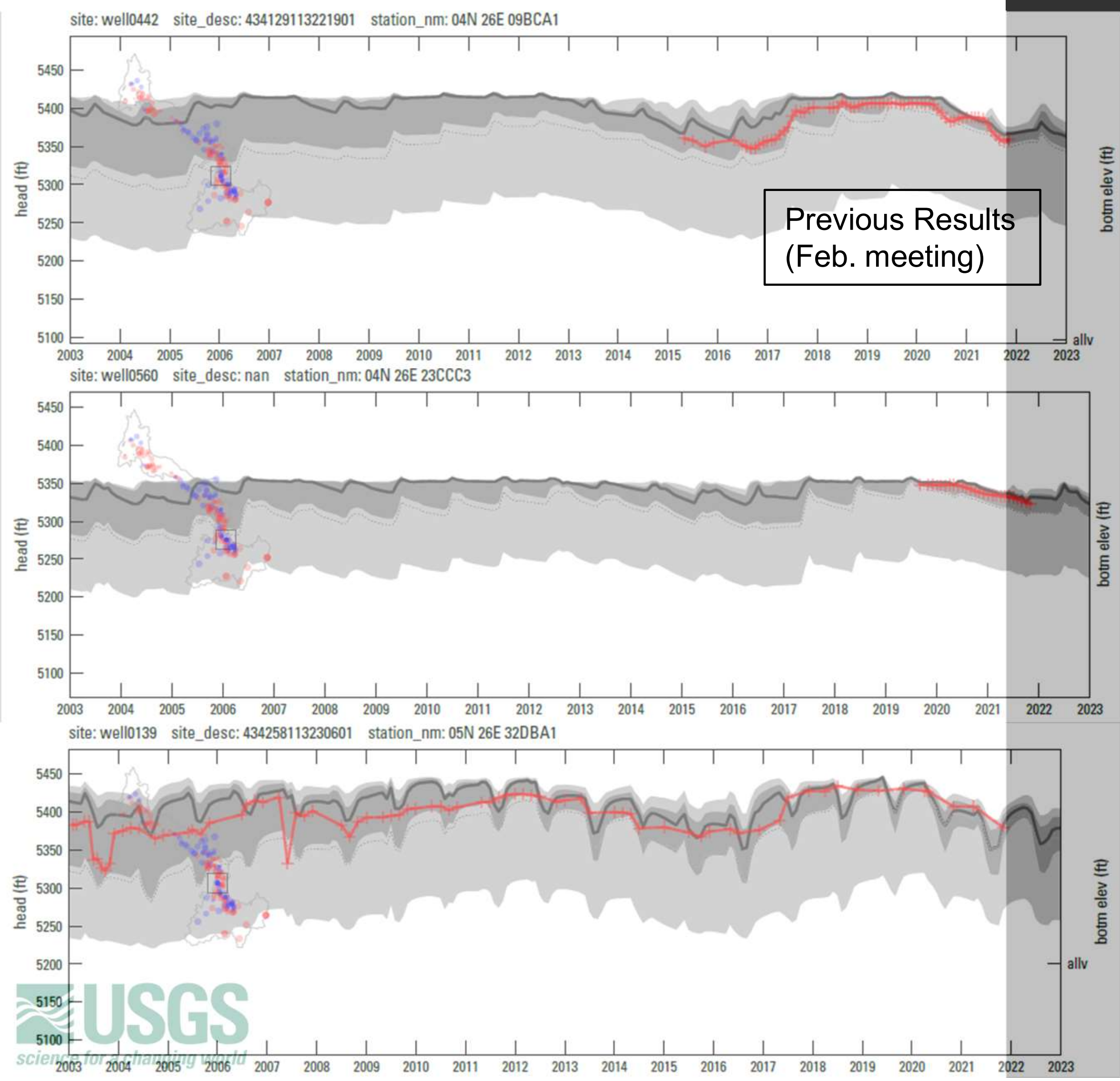
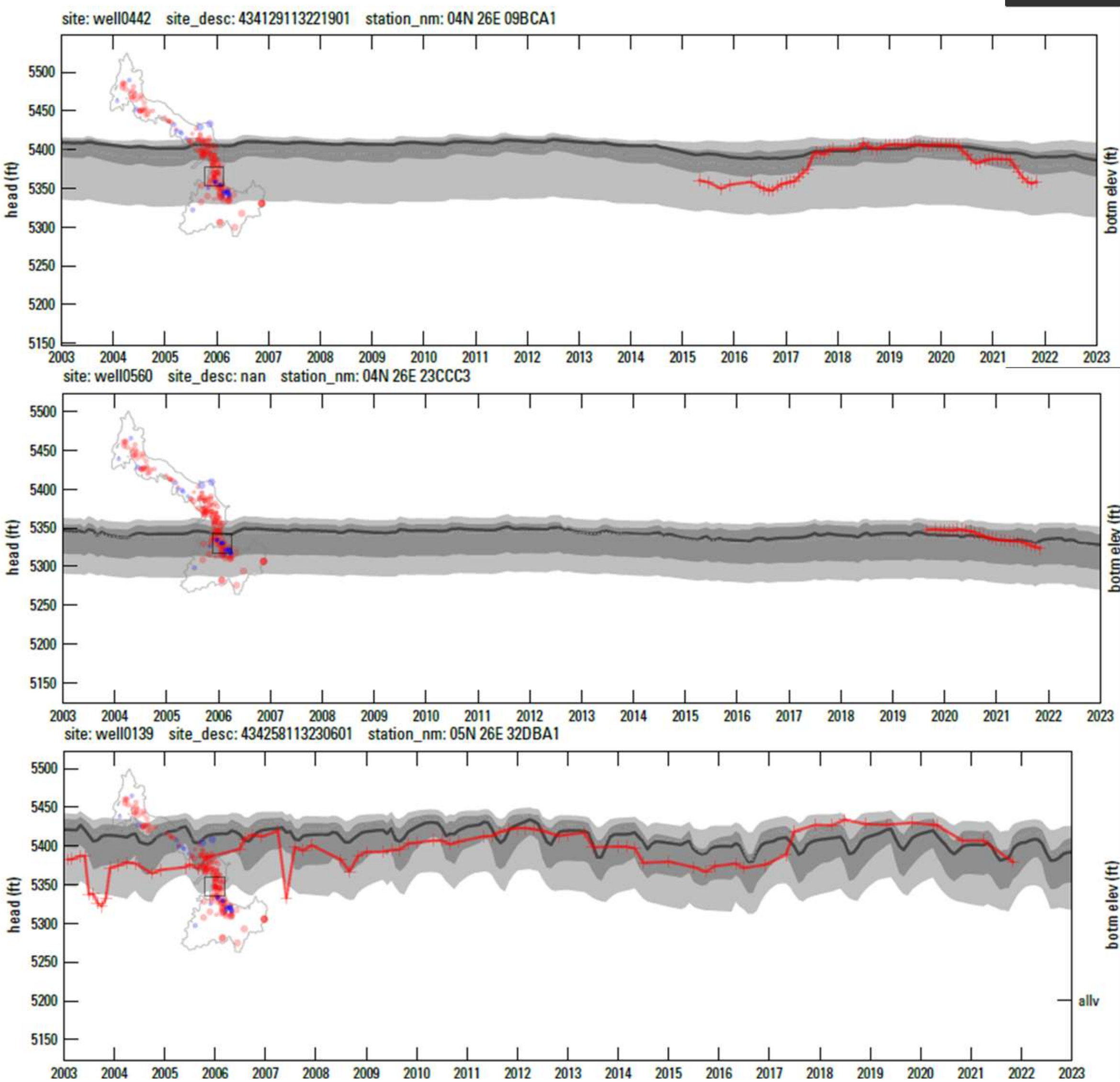
Best matches in lower valley between Moore and Arco





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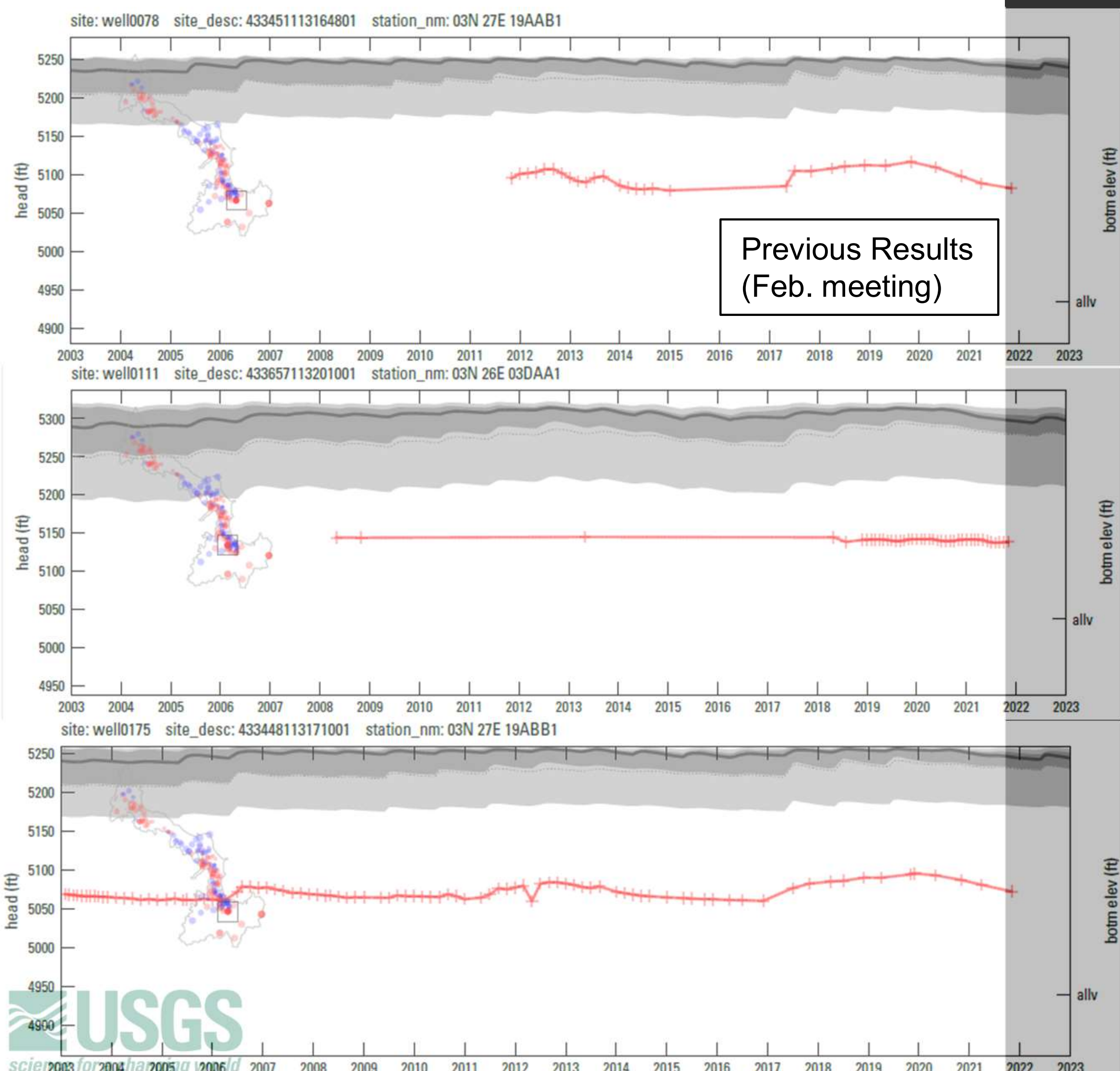

Poor performance south of Arco (more work to do on layering scheme)

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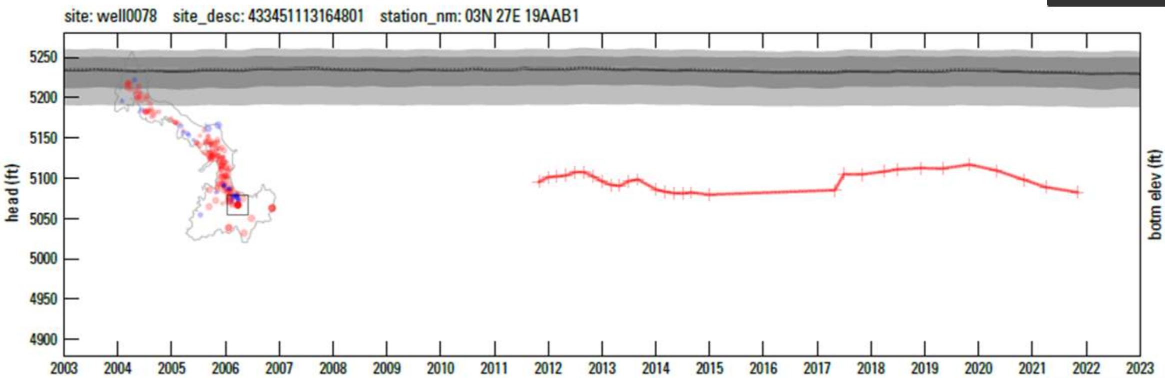
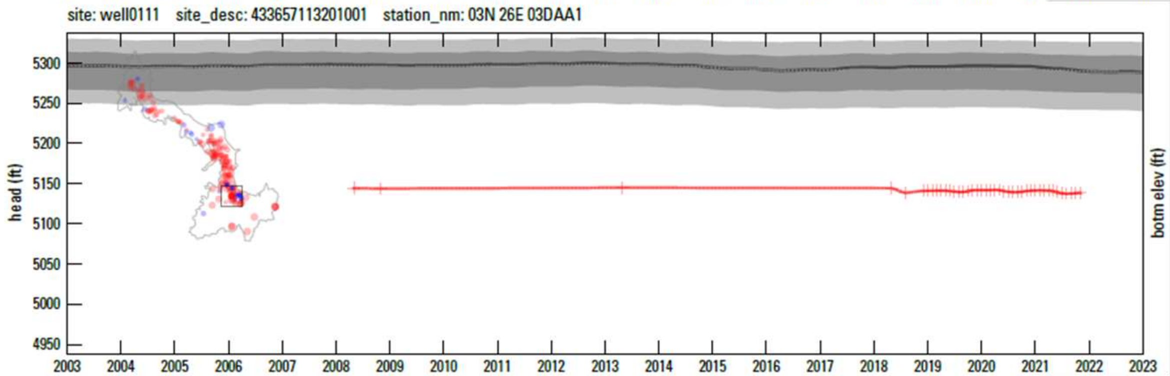
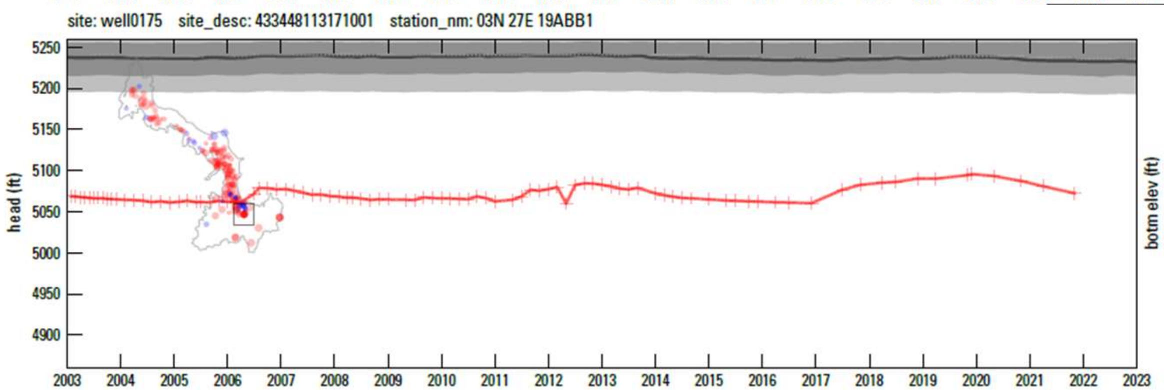
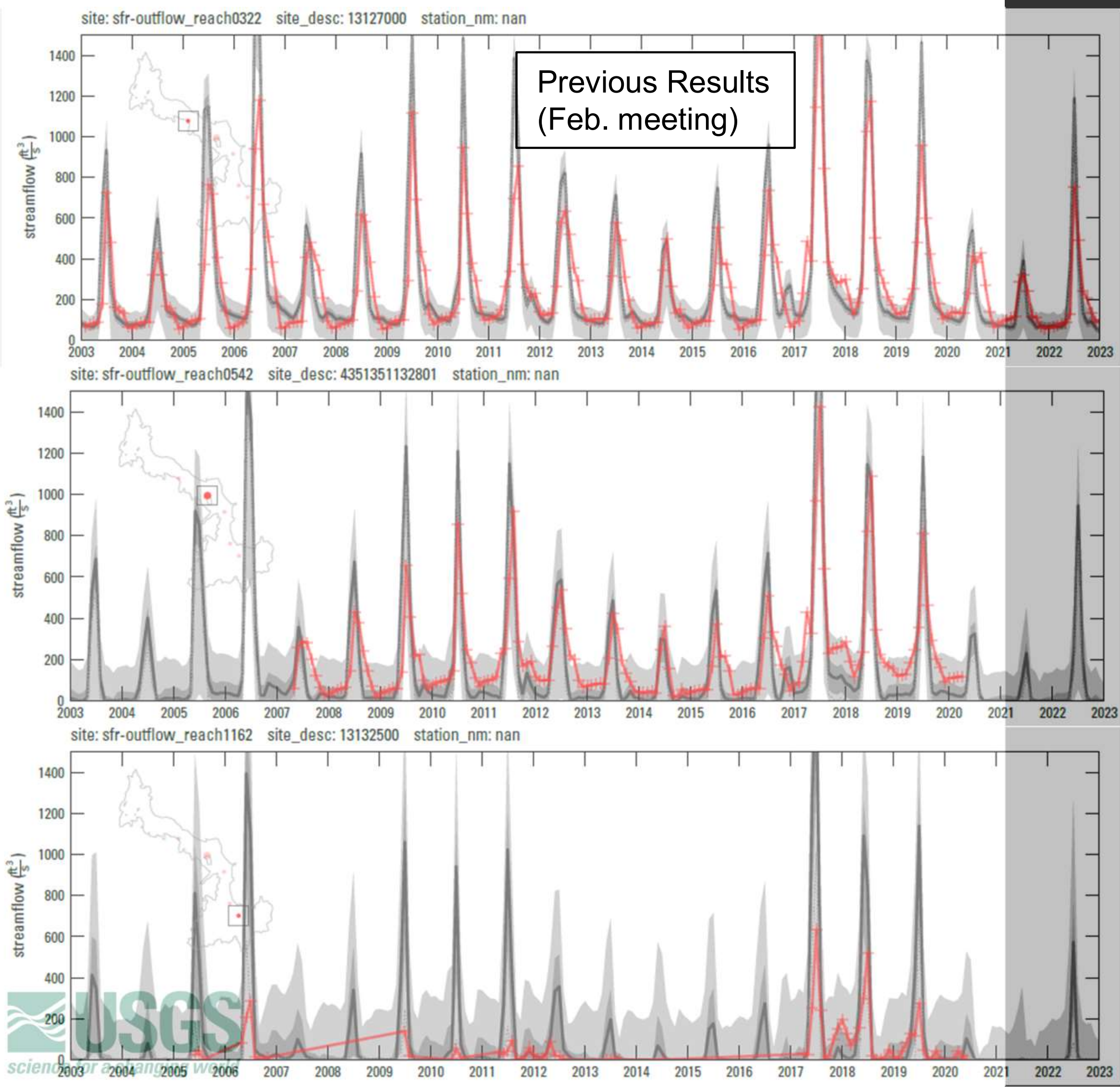
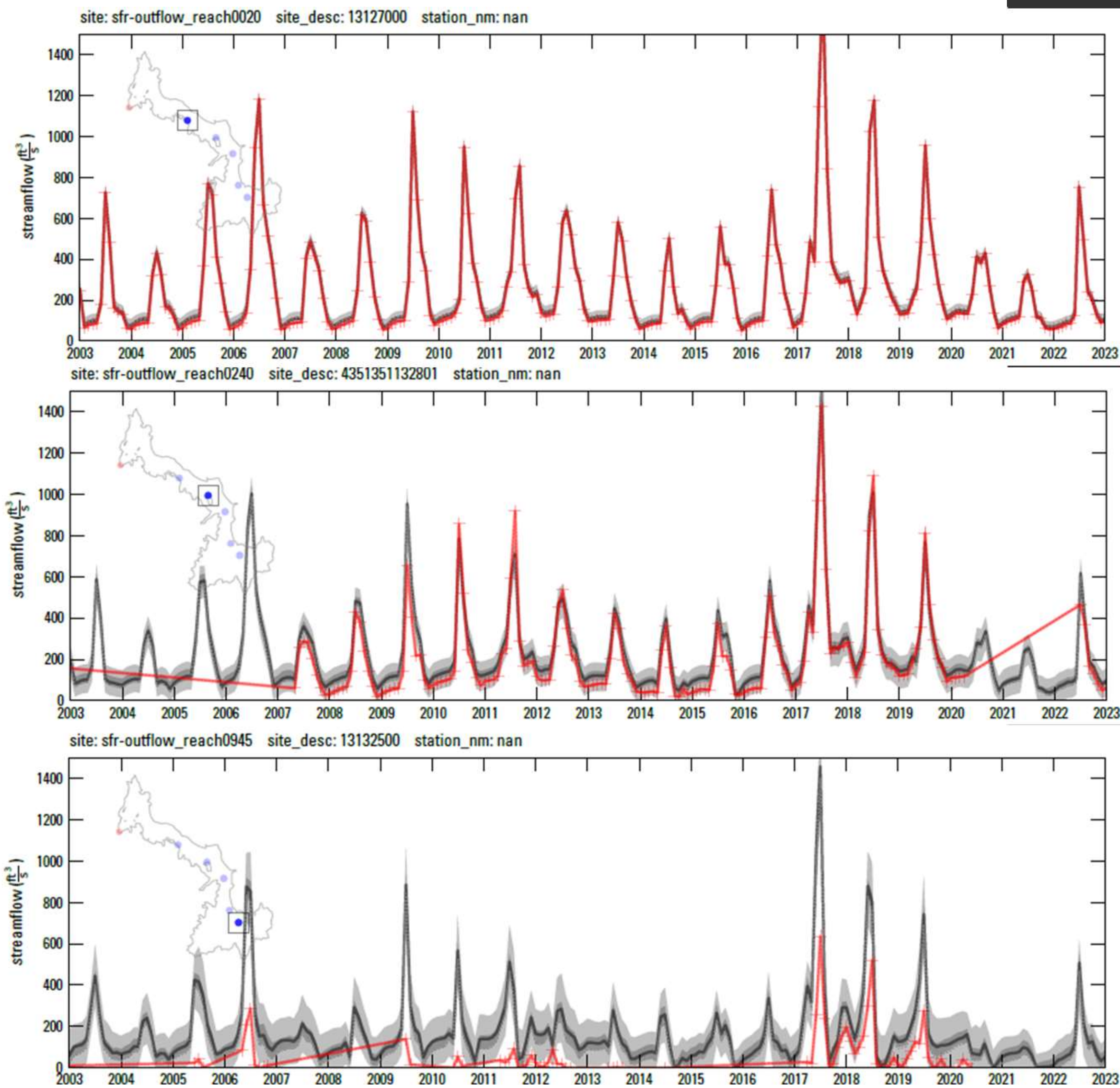






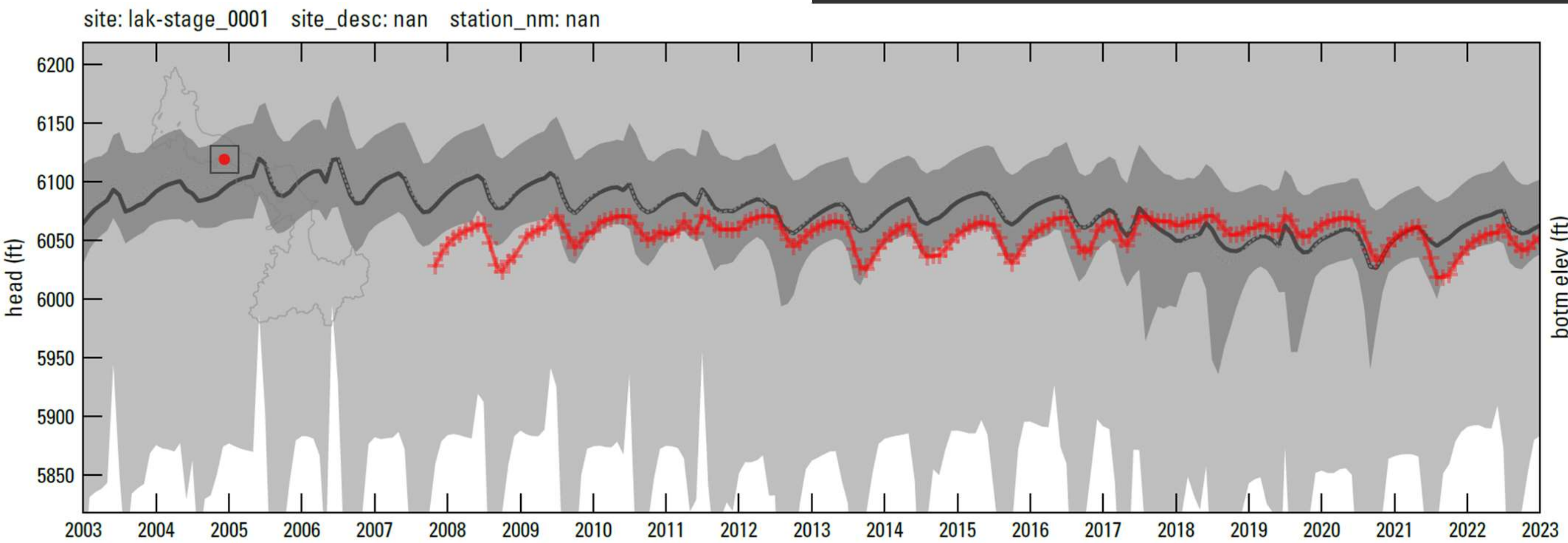


Storage and release simulation needed to better match stream hydrographs.



Storage and release simulation needed to better match stream hydrographs.

Lake Stage generally simulated too high but matches annual pattern very well



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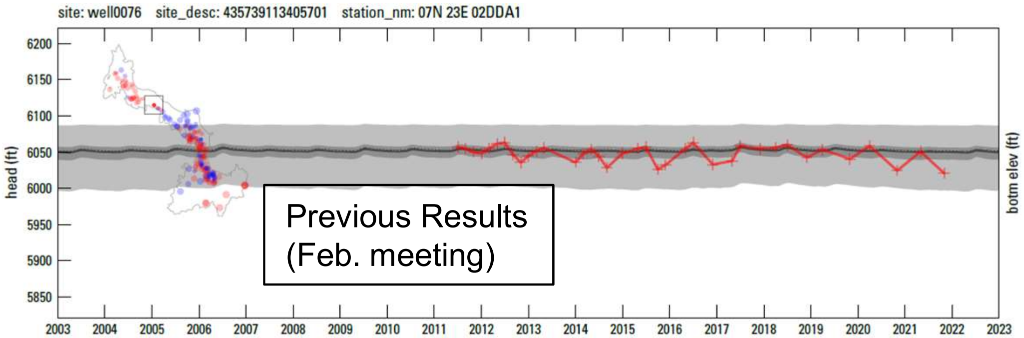
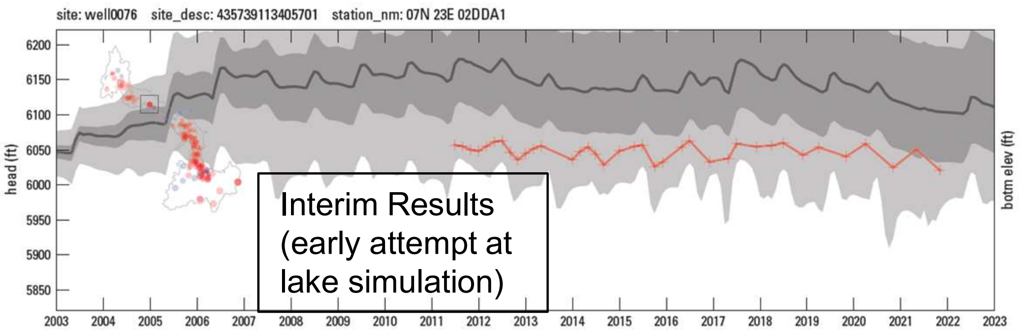
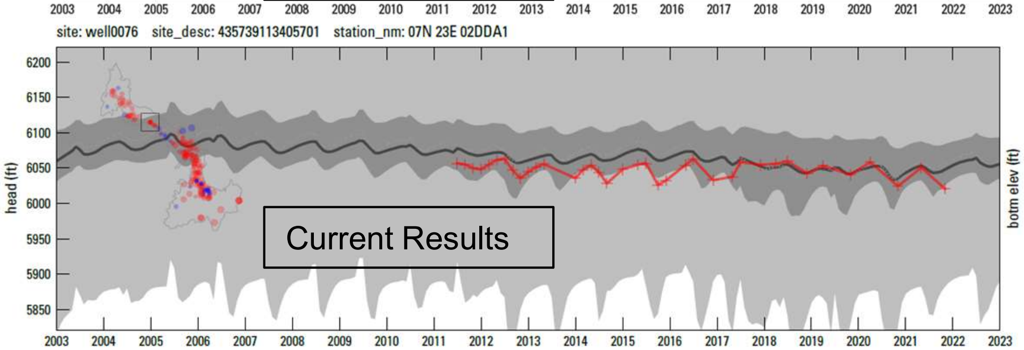
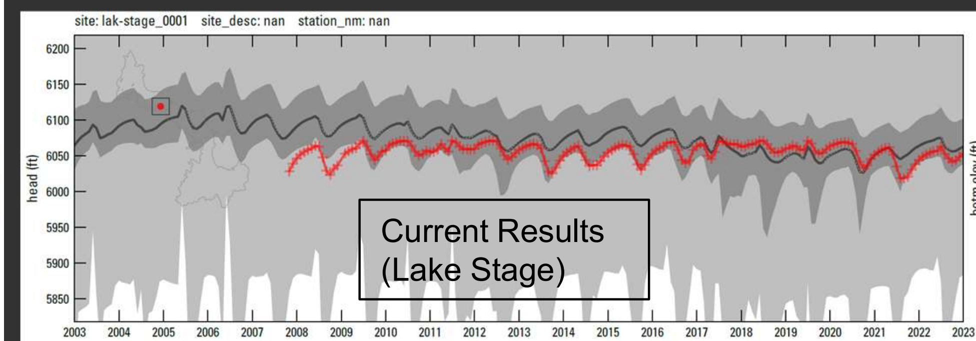
Effect of simulating lake on nearby well









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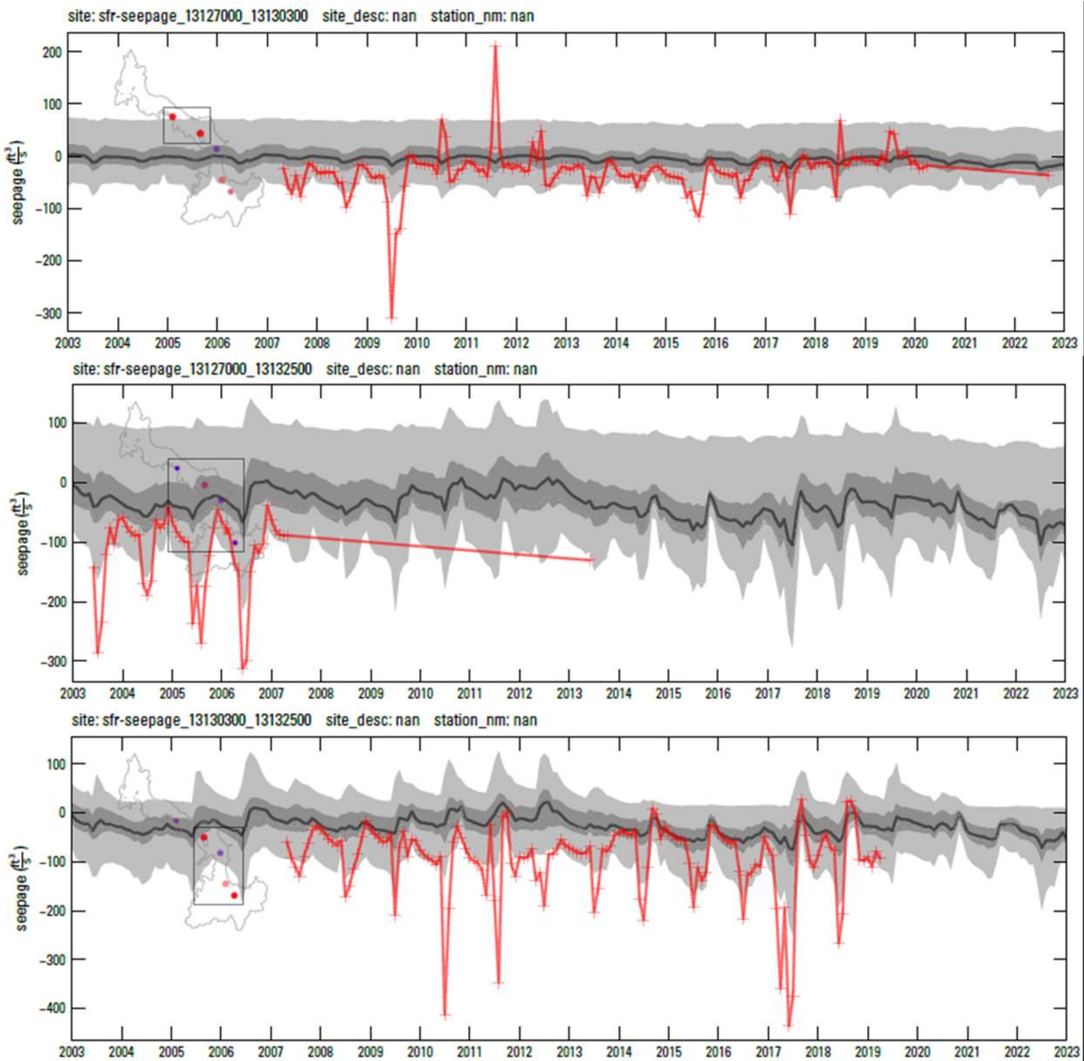

Next steps:

- **Improve fit to stream gains/losses**
- **Re-evaluate model layer scheme and general head boundary condition in lower basin**
- **Automated parameter estimation runs (!)**

Thanks!

jknight@usgs.gov

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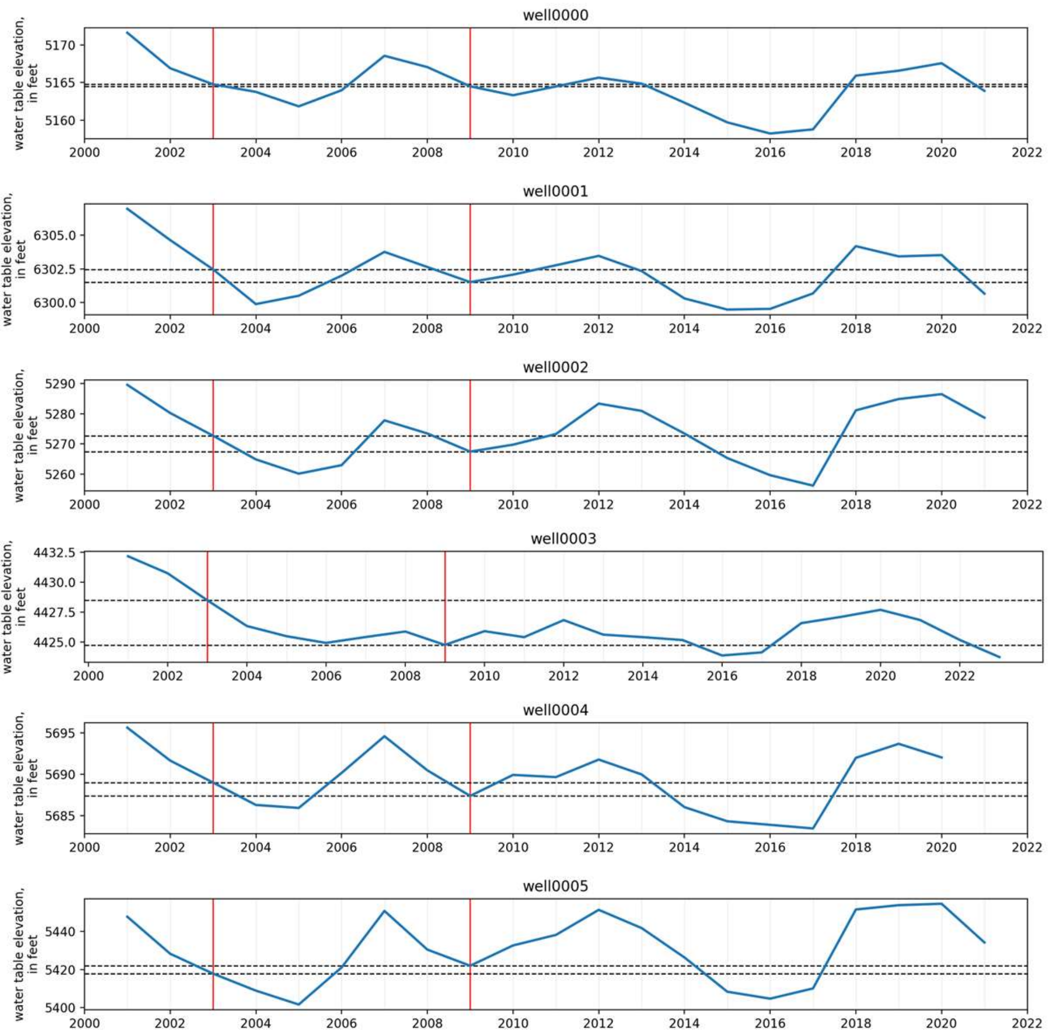

Steady-state period selection

- Identified range of years where most GW levels started and ended at similar elevations
- Data availability is greater during our historical simulation period (2003-2022). Selecting a period within that range gives us more confidence in our time-averaged inputs for SS period