

# Big Lost River Model

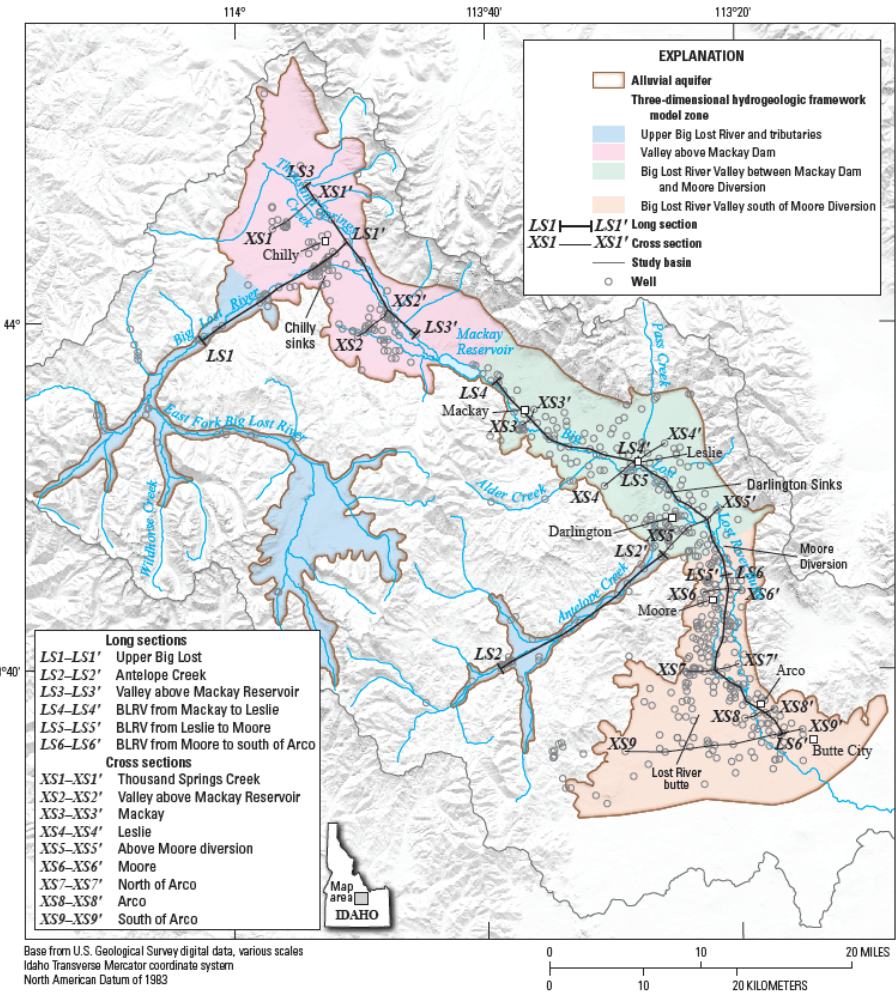
MTAC #8 Status Update  
2024.11.13

# Model status

- Implementation of conceptual model complete
- Looping through parameter estimation workflow with PEST++ IES
  - **Inner loop: adjusting observation weights by group, adding parameters to represent variability at different spatiotemporal scales**
  - **Outer loop: revisiting conceptual model, adjusting initial property values of underlying base model**
- Very soon: deploy posterior parameter ensemble on forecasts of interest:
  - hypothetical lining of all canals
  - hypothetical curtailment of all GW irrigation

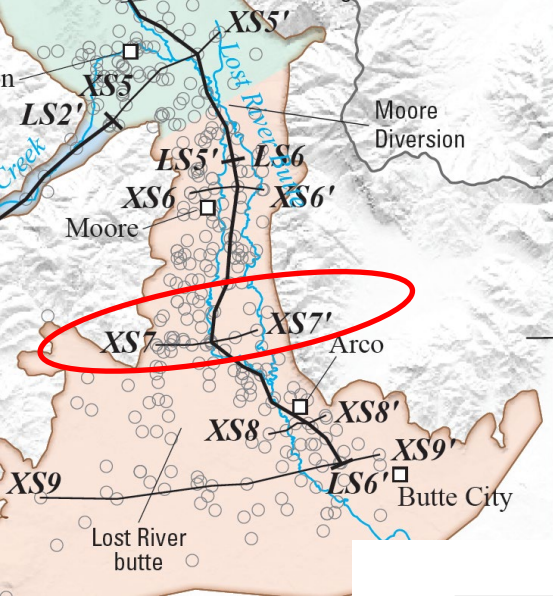
# Model changes

- Model layering adjustments to align with hydrogeologic framework
- Reconfigured General Head Boundary condition in lower valley
- Filled missing EVT data in months with incomplete coverage
  
- Iterative adjustments to initial estimates of aquifer and boundary condition properties based on results of ensemble evaluations



# Model Layering

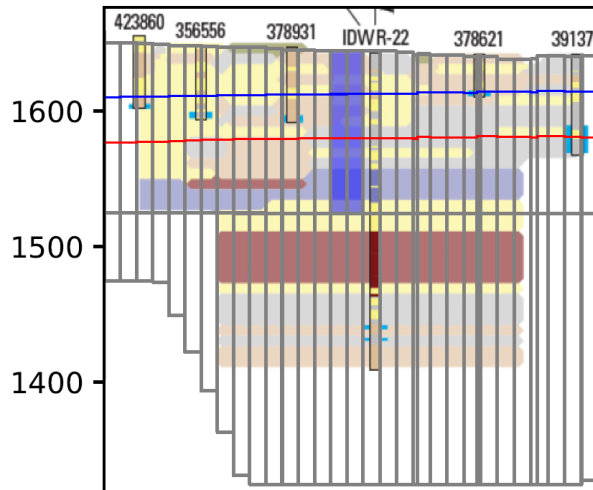
Figure 4. Overview of hydrogeologic framework model zone boundaries, wells, and geologic section lines, Big Lost River Basin, south-central Idaho. See figures 6–12 for long sections and cross sections identified in this figure.

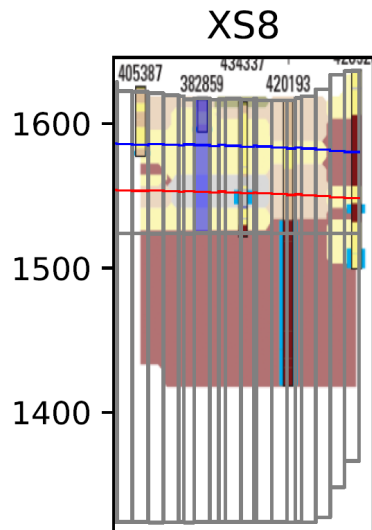
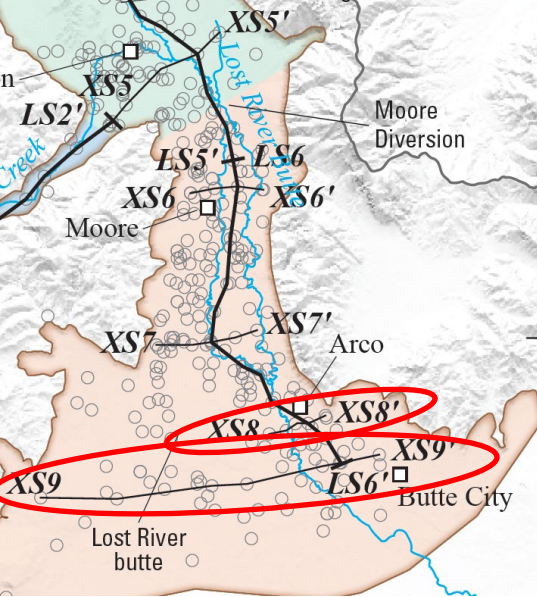


# Motivation

- Accurately represent change in aquifer property values with depth where basalt underlies alluvial basin fill
- Zone 4 (Moore to Arco):
  - Shallow layer: Alluvial basin fill
  - Deep layer: Allv/Basalt mix

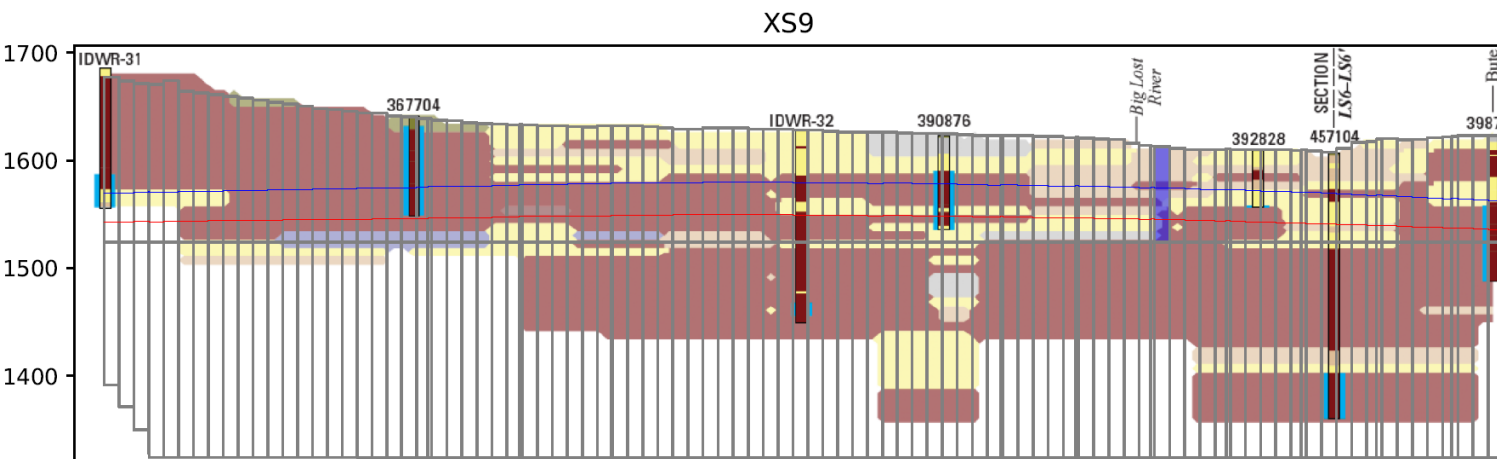
XS7

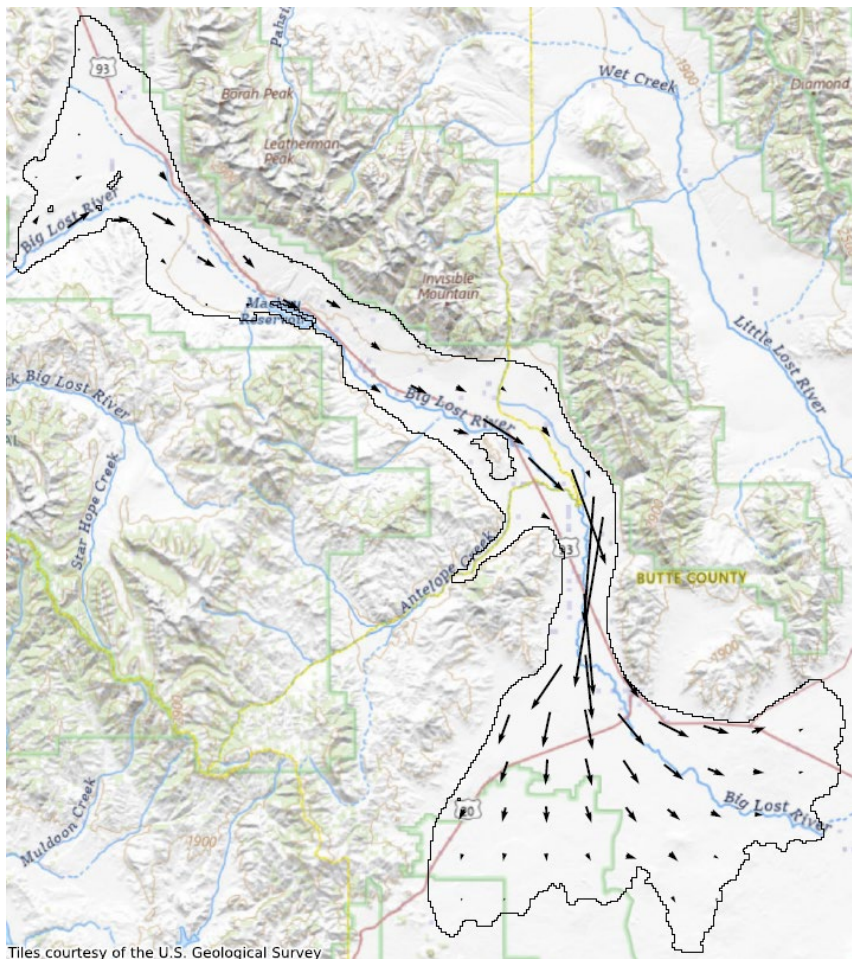




# Motivation

- Accurately represent change in aquifer property values with depth where basalt underlies alluvial basin fill
- Zone 5 (below Arco):
  - Shallow layer: Allv/Basalt mix
  - Deep layer: mostly Basalt

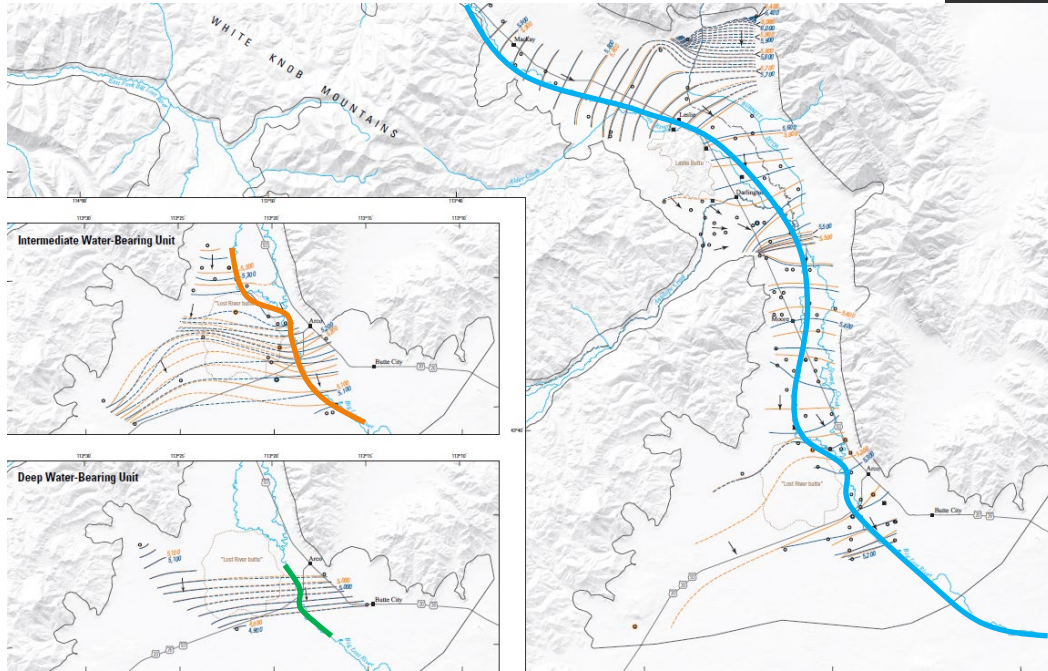


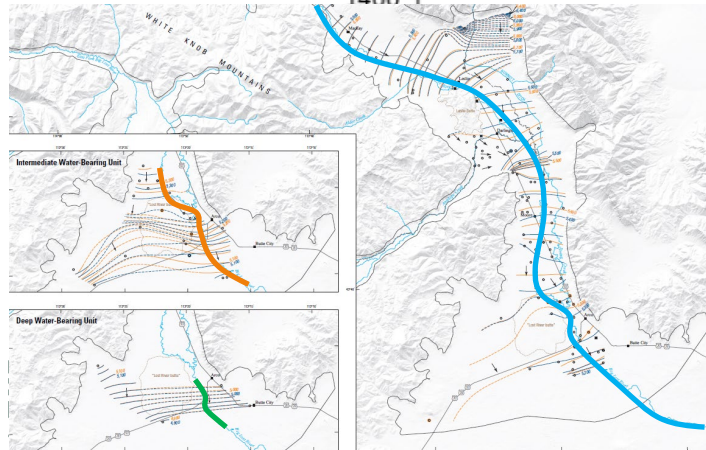
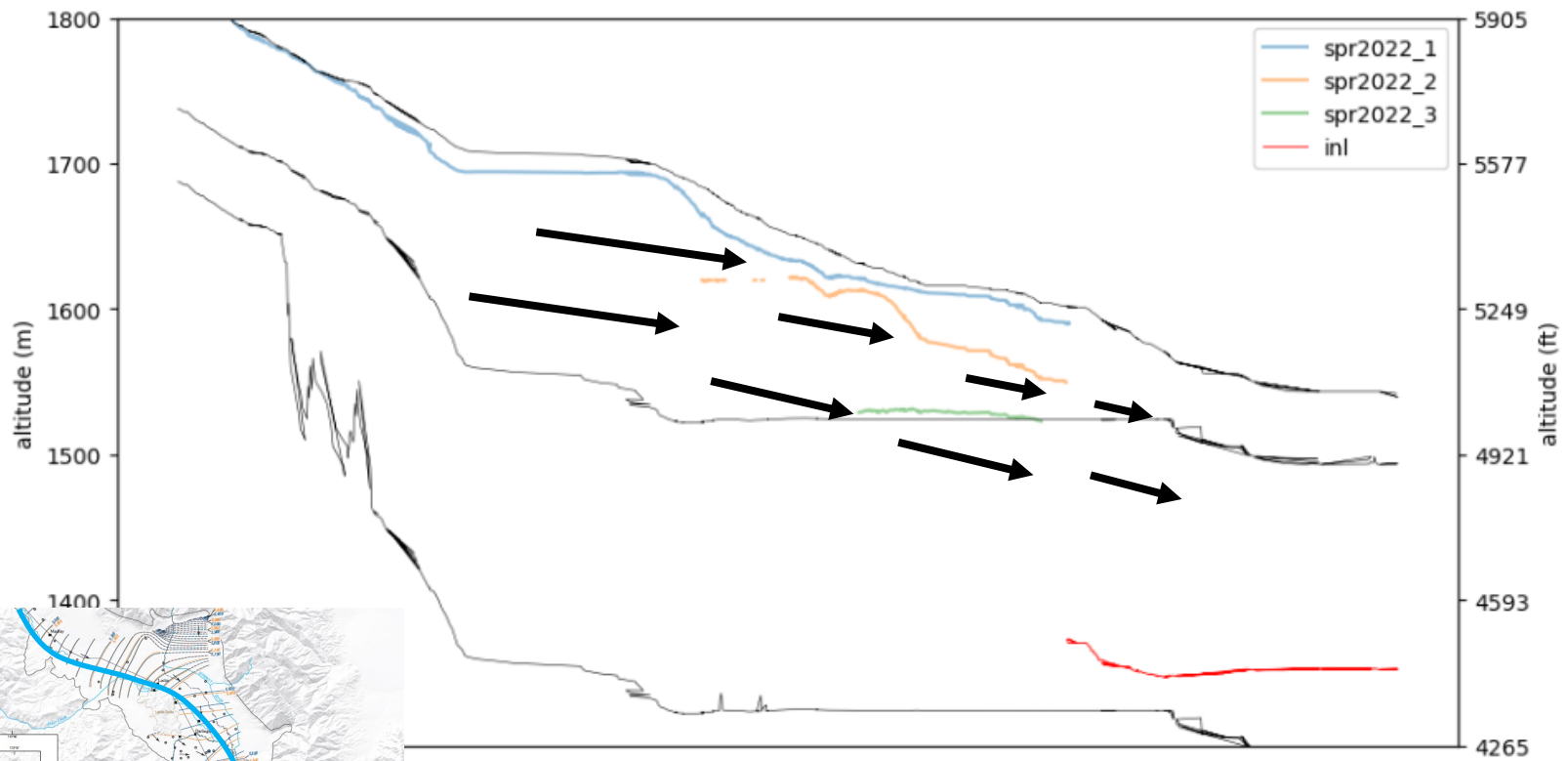


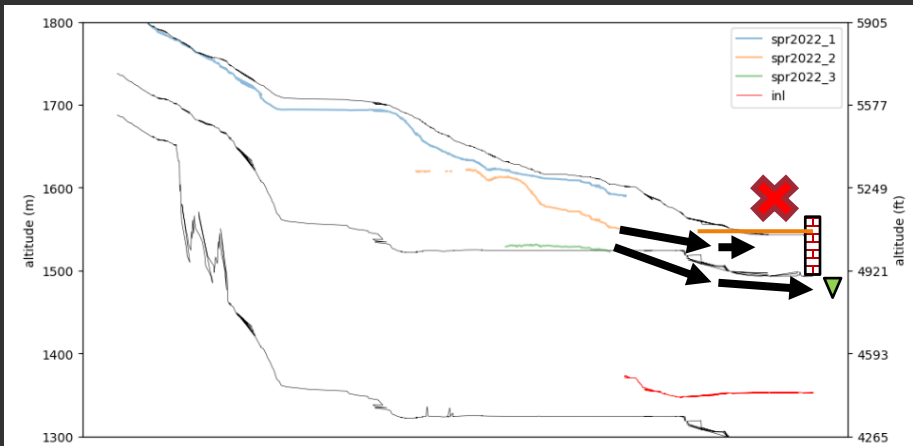
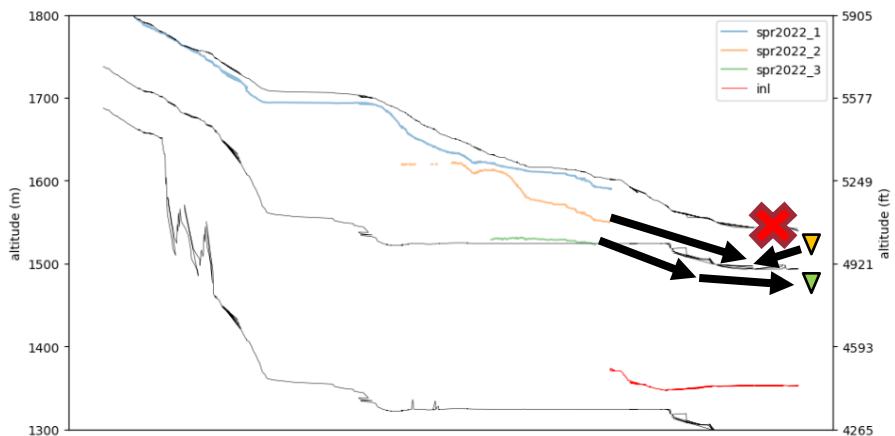
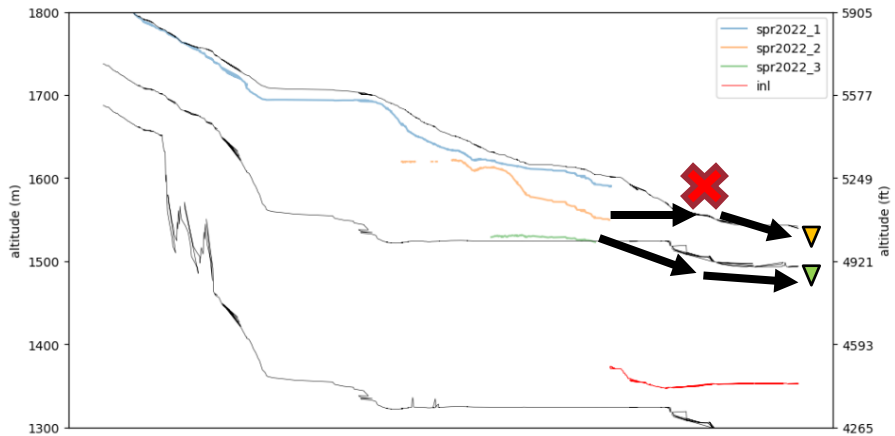
# General Head Boundary Condition

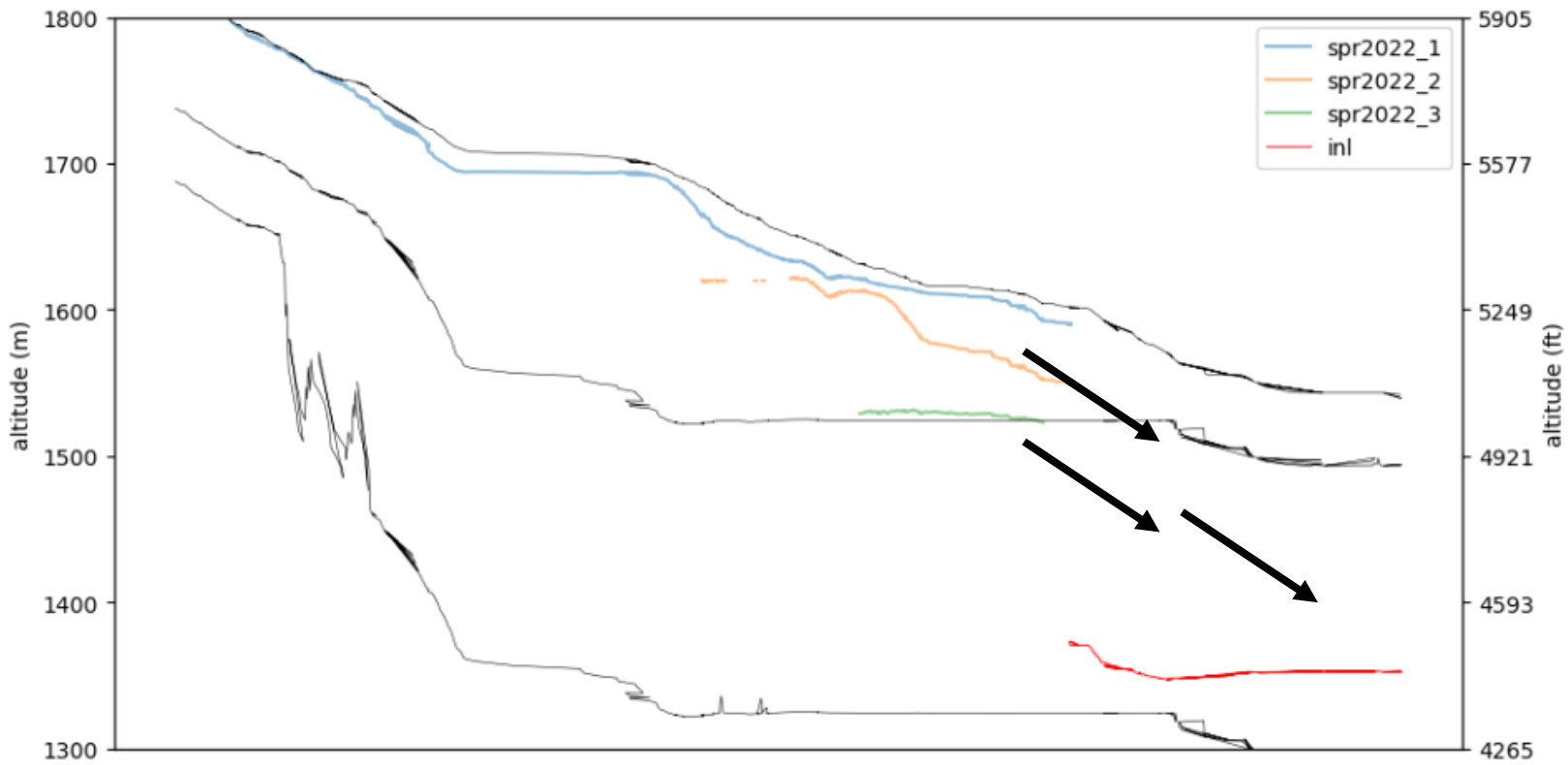
# Motivation

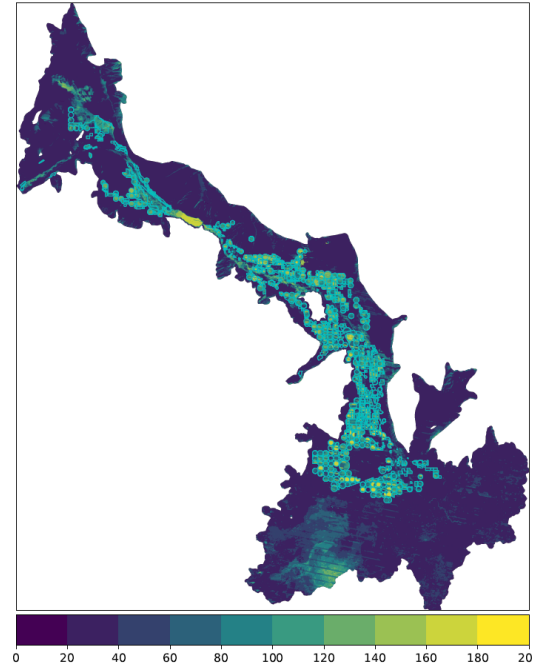
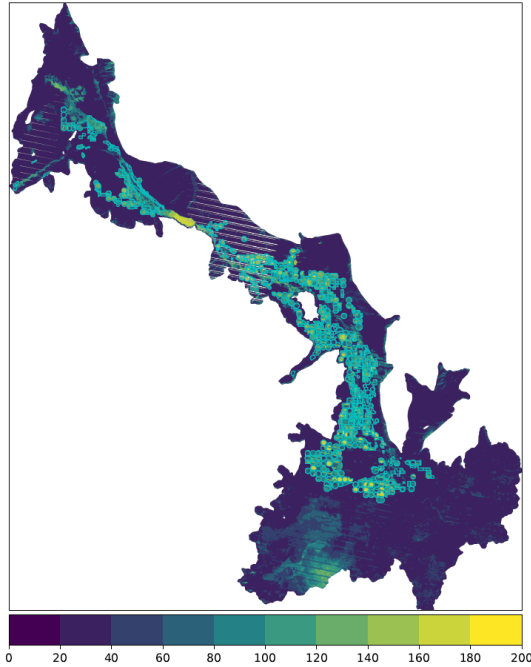
- Simulate GW discharge toward EPA as increasingly vertical toward model boundary
- Avoid adding additional deeper layers
- Avoid unrealistic simulations in ensemble of near-surface water table and GW discharge to stream below Arco











**Fill Missing  
EVT values**



## Motivation

- Fill missing remote sensing data with reasonable values before calculating average fluxes of irrigated lands in each service area

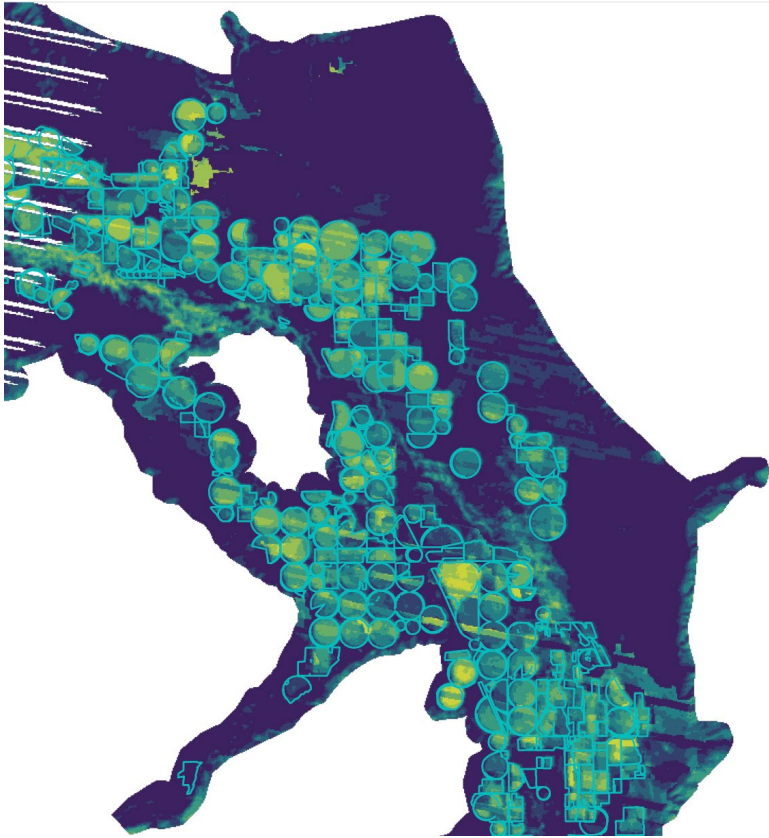
## Solution

- First pass: use mean of previous and following month values in each cell where those values are not null
- Second pass: fill remaining null values with mean monthly value of that cell

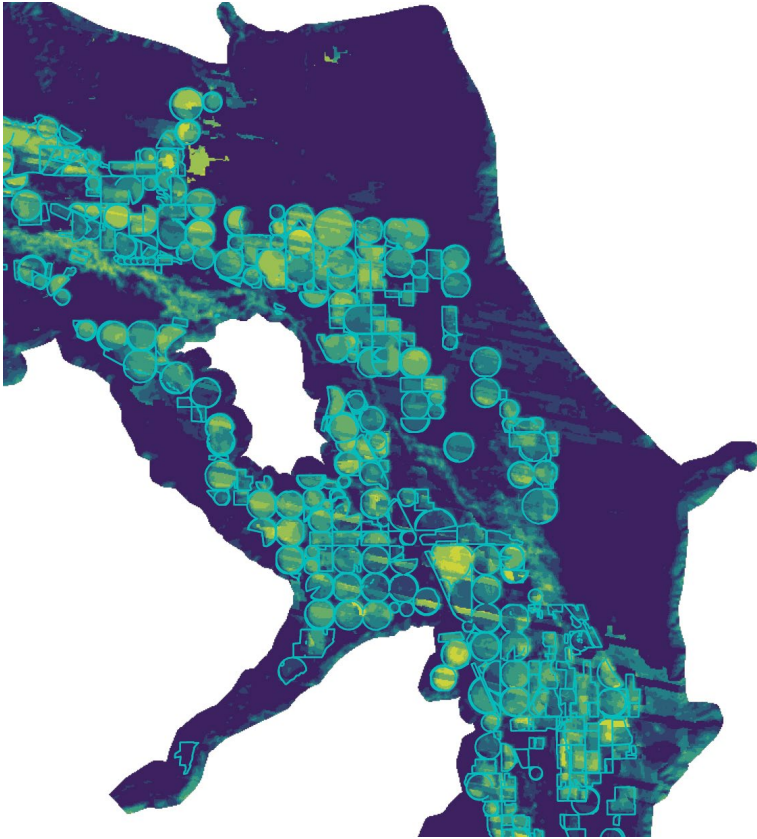
# Example: Sept. 2012

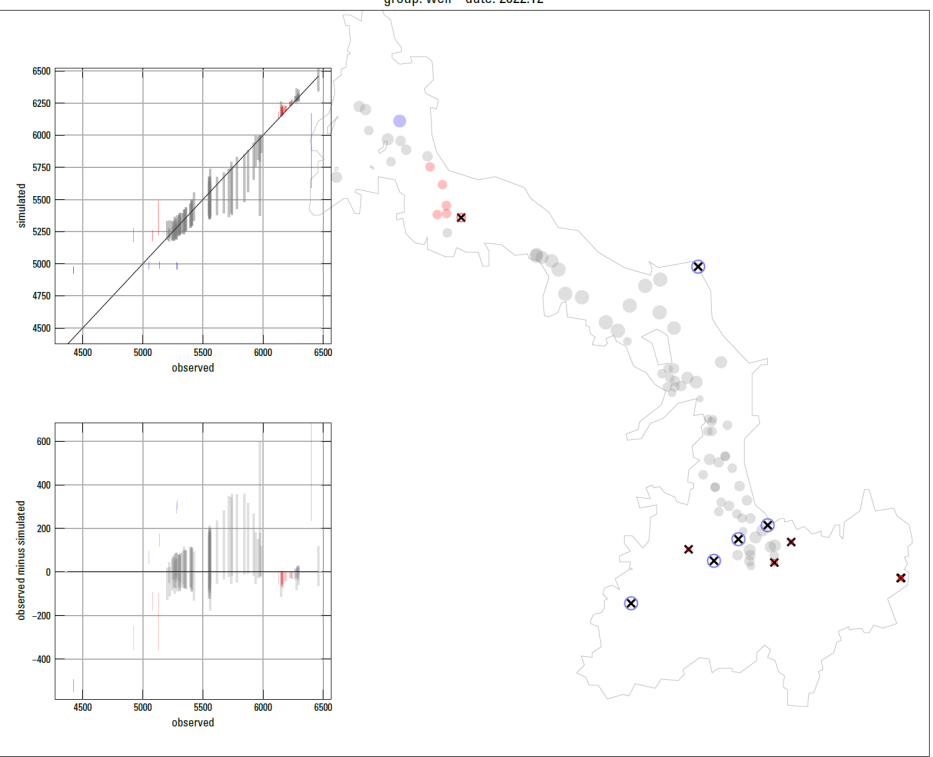


## Example: Sept. 2012



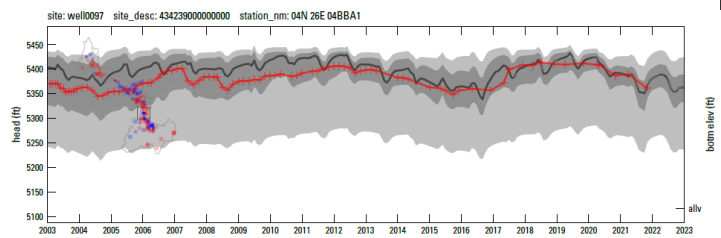
# Example: Sept 2012





# Parameter Estimation

History Matching with PEST++  
Iterative Ensemble Smoother



# Quick review

# Two necessary conditions for decision-support modeling

(Knowling and others, 2019)

High-dimensional



Avoid erroneous decision  
based on model forecast bias

Stochastic



Express reliability in simulated  
outcomes

# Ensemble modeling with PESTPP-IES

## High-dimensional

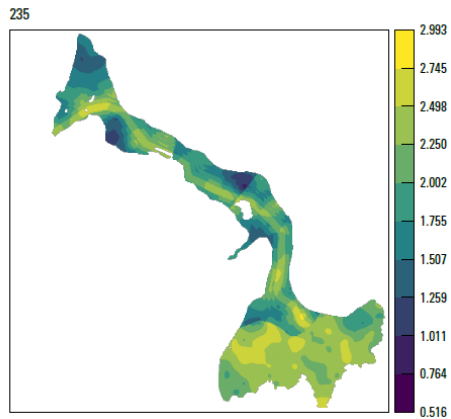
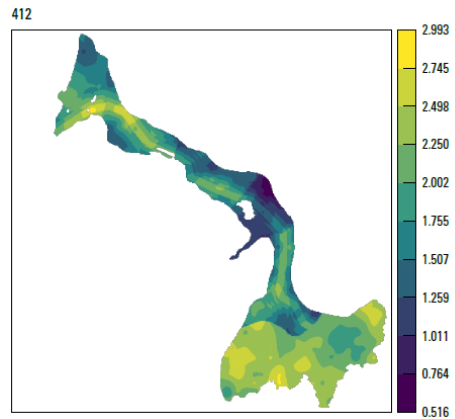
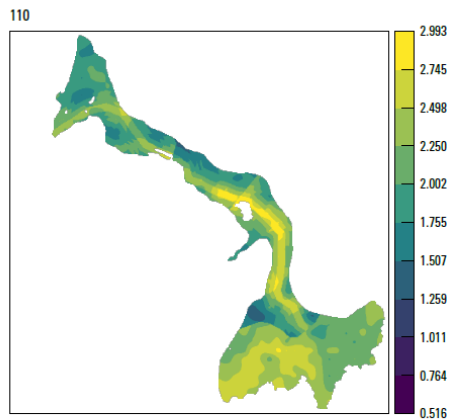
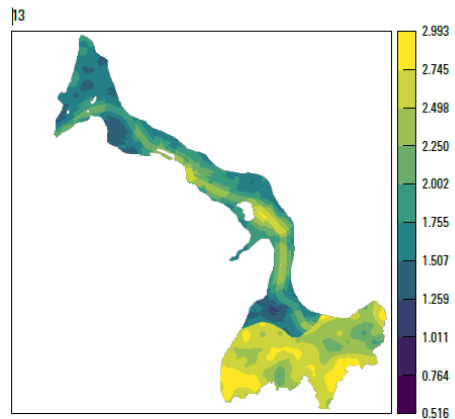
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Make use of many thousands of parameters (or even millions) to better simulate natural variability on multiple spatio-temporal scales  
**(with fewer total model runs, less CPU time)**

## Stochastic

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



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

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

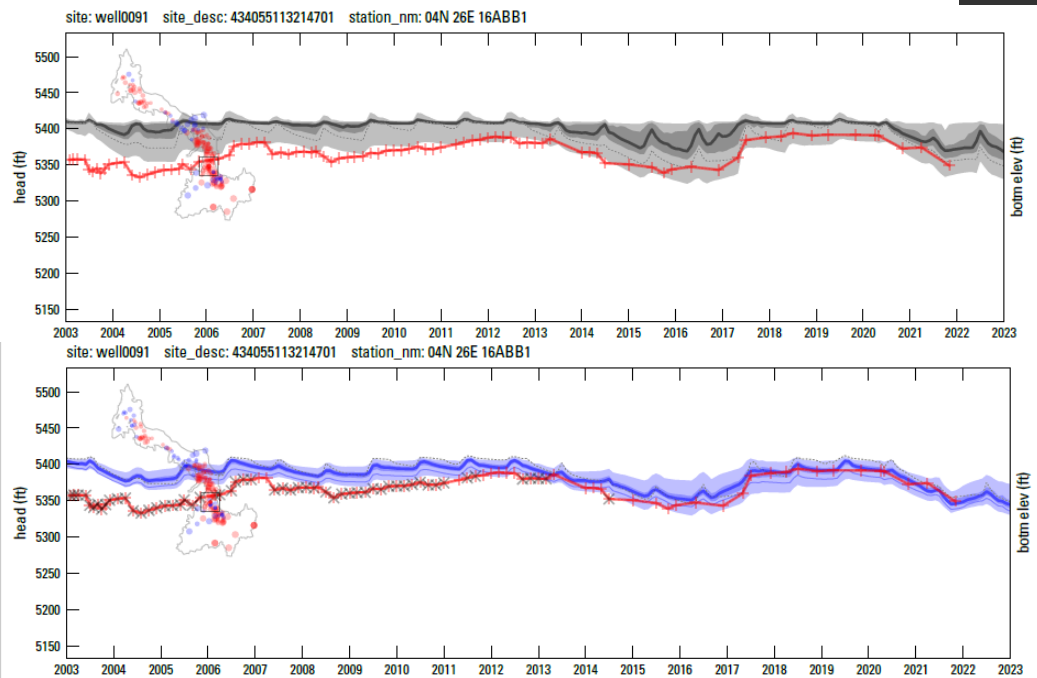
Providing many “receptacles” (pars) to assimilate information from observation data prevents bias incurred from parameter compensation

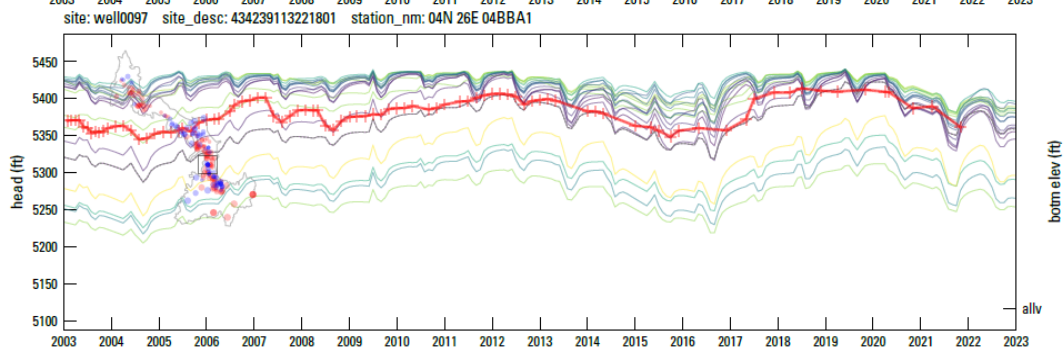
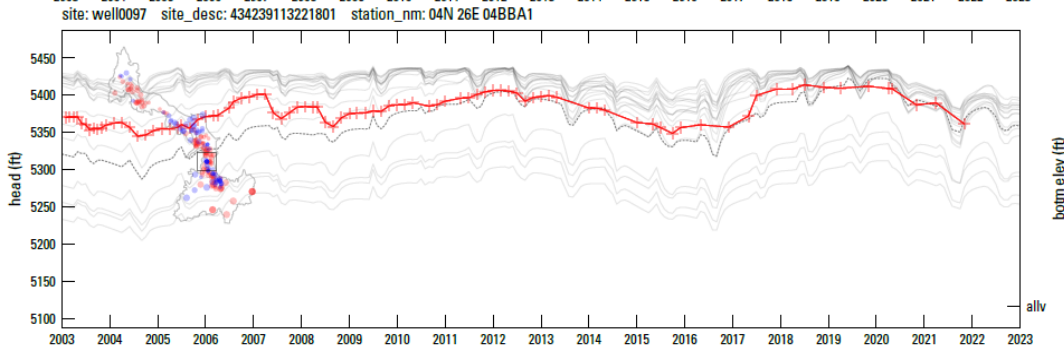
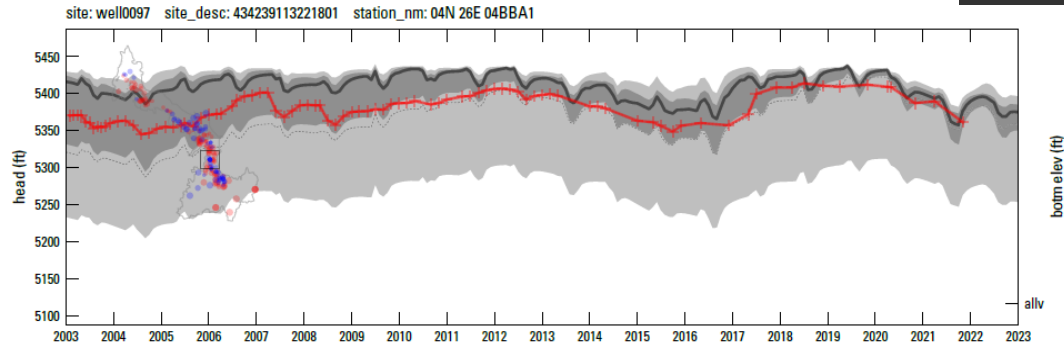
Some parameters are assigned a fixed range of values and not allowed to adjust to match observations. This formalizes our ignorance of certain inputs and retains appropriate uncertainty

# 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

# Latest Results

# Latest Results

## Observations

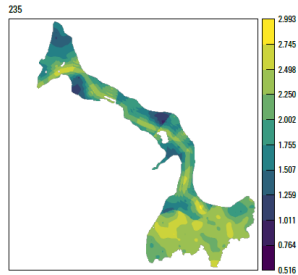
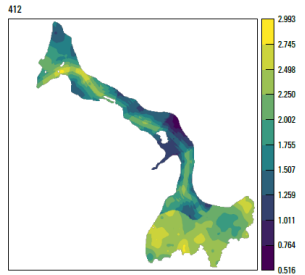
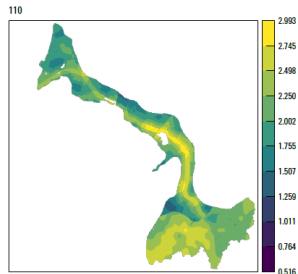
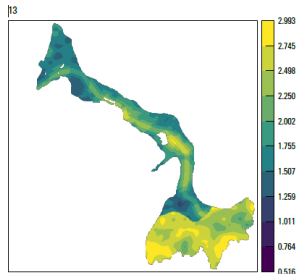
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- Groundwater levels
- Groundwater contours
- Lake stage
- Stream gages
- Stream reach gain/loss
- Irrigation diversions
- GW budget estimates

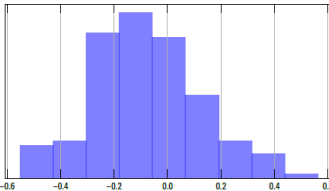
## Parameters

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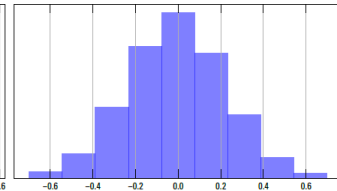
- Aquifer Properties
- Boundary Condition Properties
- Model Input Forcings



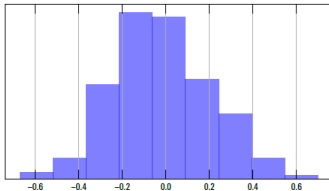
C) npf\_k\_layer1\_cn, count:1  
min:-5.5E-01, max:5.6E-01



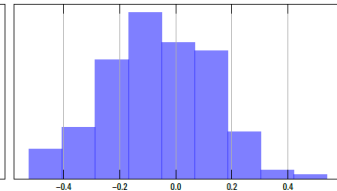
D) npf\_k\_layer1\_po, count:330  
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E) npf\_k\_layer1\_zn, count:5  
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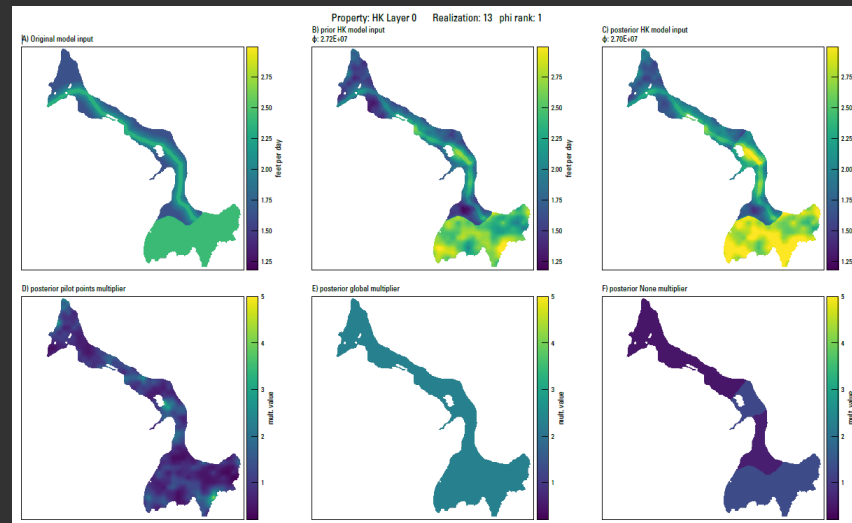


F) npf\_k\_layer2\_cn, count:1  
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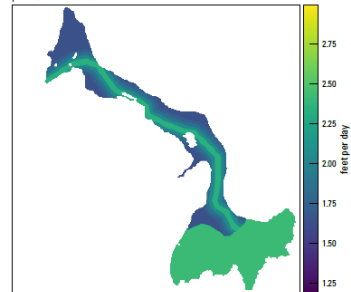
# Model Parameters

- Aquifer Properties
- Boundary Condition Properties
- Model input forcings

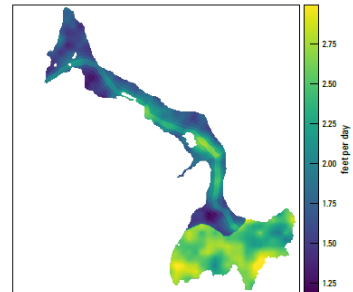


Property: HK Layer 0 Realization: 13 phi rank: 1

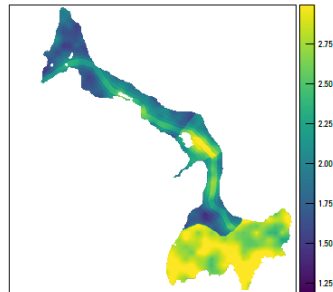
A) Original model input



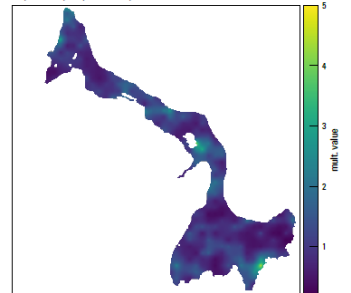
B) prior HK model input  
 $\phi: 2.72E+07$



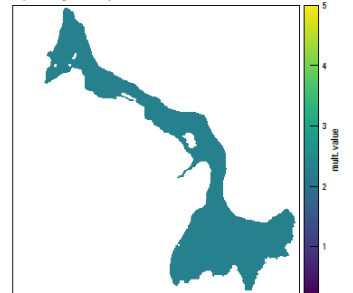
C) posterior HK model input  
 $\phi: 2.70E+07$



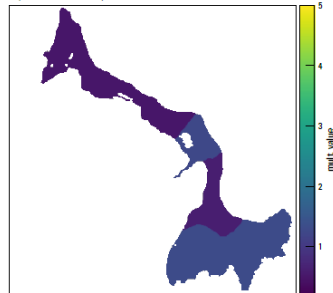
D) posterior pilot points multiplier



E) posterior global multiplier



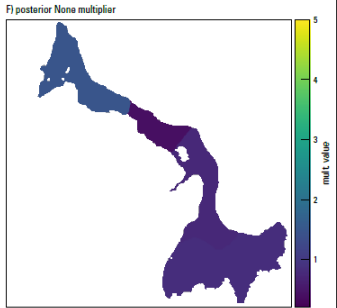
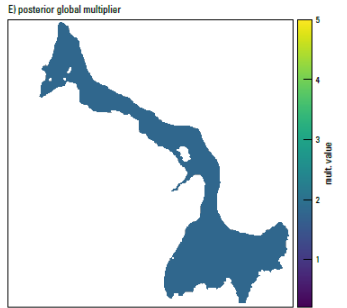
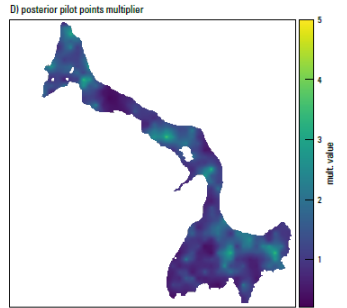
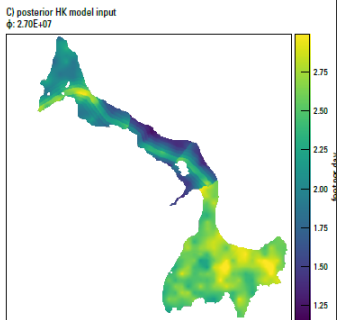
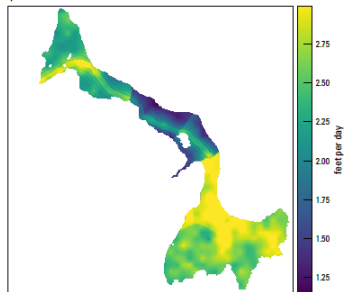
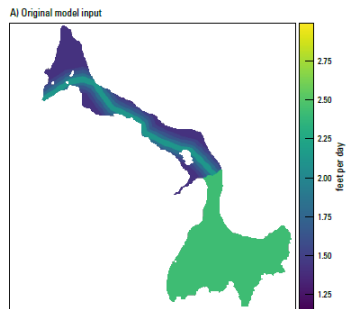
F) posterior None multiplier



## Horizontal K

- Multipliers applied at 3 scales:
  - global
  - zone
  - pilot point
- Multiplier range = 0.2 – 5.0
- Initial model values = 8 – 80 m/d

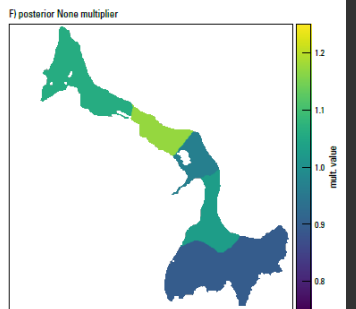
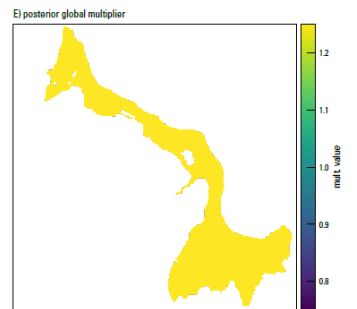
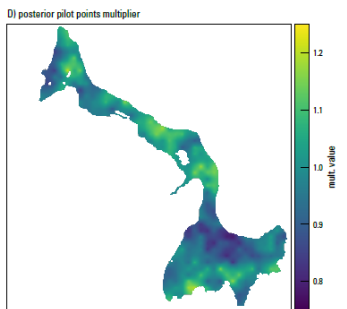
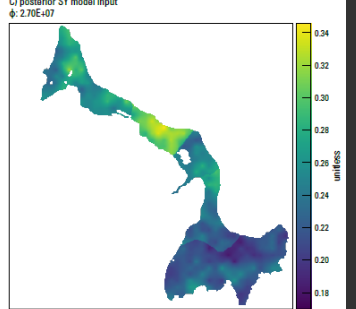
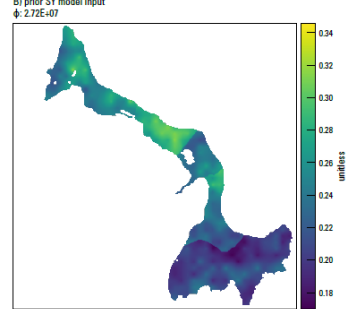
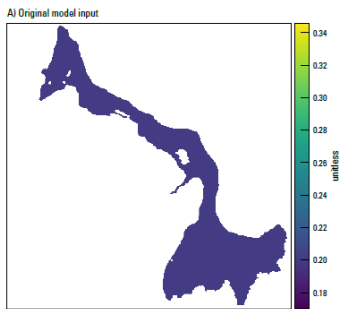
Property: HK Layer 1 Realization: 13 phi rank: 1  
B) prior HK model input  
φ: 2.72E+07



# Vertical K anisotropy

- Multipliers applied at 3 scales:
  - global
  - zone
  - pilot point
- Multiplier range = 0.2 – 5.0
- Initial model values = 0.0001 – 0.1

Property: SY Layer 0 Realization: 13 phi rank: 1

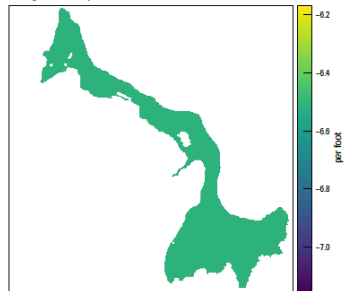


## Specific Yield

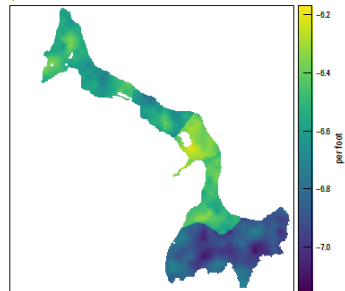
- Multipliers applied at 3 scales:
  - global
  - zone
  - pilot point
- Multiplier range = 0.75 – 1.25
- Initial model values = 0.2

Property: SS Layer 0 Realization: 13 phi rank: 1

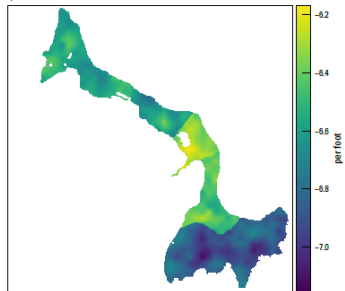
A) Original model input



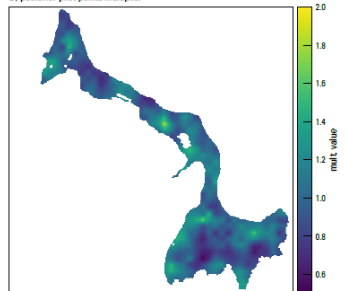
B) prior SS model input  
#: 2.72E+07



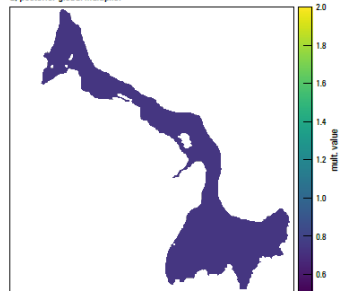
C) posterior SS model input  
#: 2.70E+07



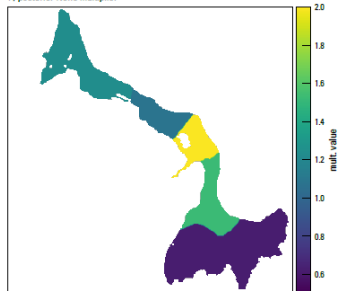
D) posterior pilot points multiplier



E) posterior global multiplier



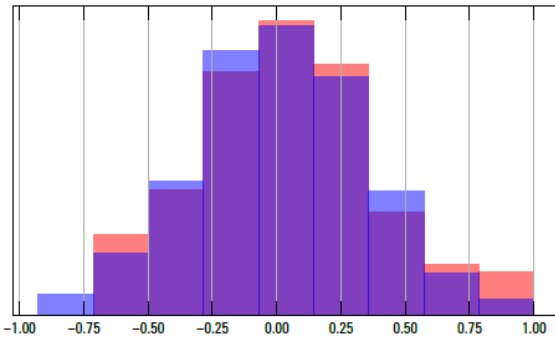
F) posterior None multiplier



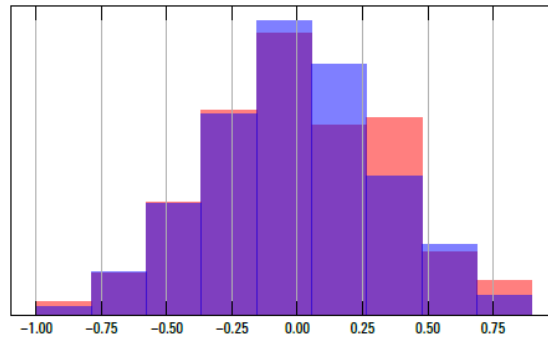
## Specific Storage Multipliers applied at 3 scales:

- global
- zone
- pilot point
- Multiplier range = 0.5 – 2.0
- Initial model values = 1e-6

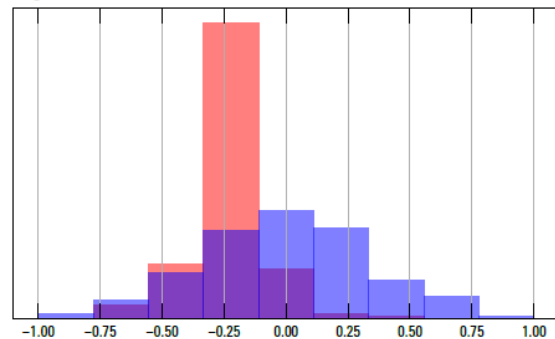
A) drmts\_cond, count: 1



B) drnws\_cond, count: 1



C) ghb\_cond, count: 1

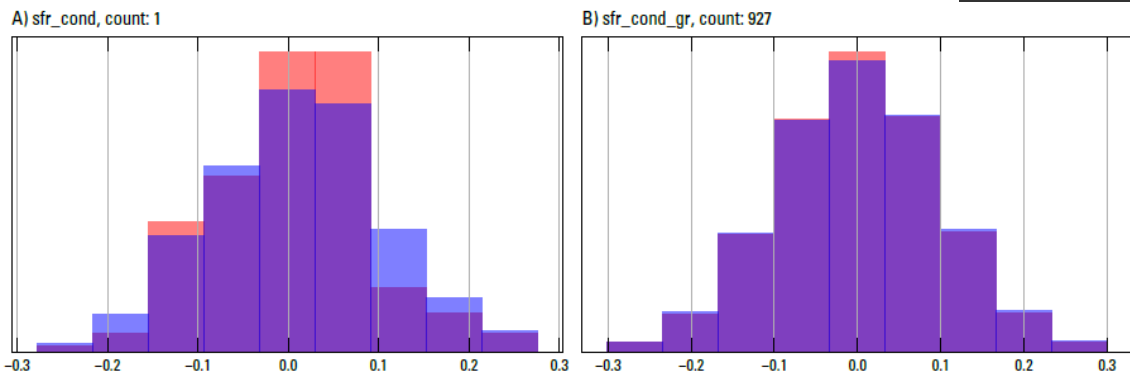


## Boundary Conditions

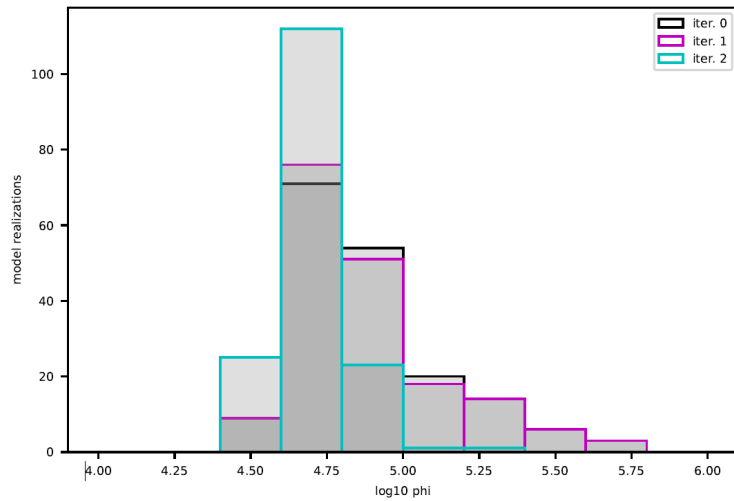
- DRN package conductance
- global
- range = 0.1 – 10.0
- init. Value = 4 – 8 m<sup>2</sup>/d
- GHB package conductance
- global
- range = 0.1 – 10.0
- init. Value = 0.5 m<sup>2</sup>/d

## Boundary Conditions

- SFR package streambed K
- global
- grid
- range = 0.5 – 2.0
- init. Value = 0.5 – 1.0 m/d



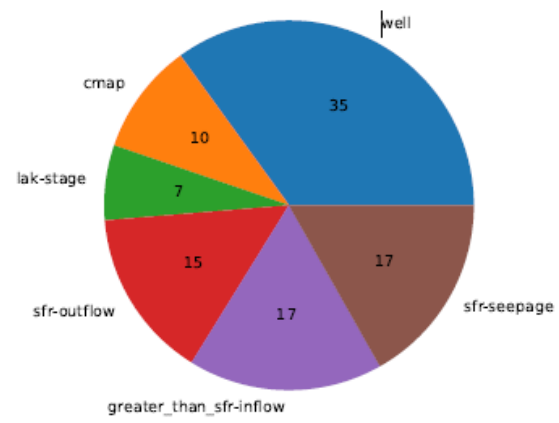
objective function by upgrade iteration



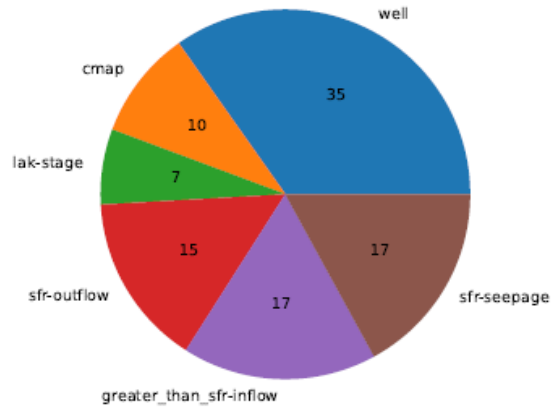
# Objective Function

- Sum of squared weighted residuals
- Weights are assigned by observation type so that each group has a proportional representation in the objective function

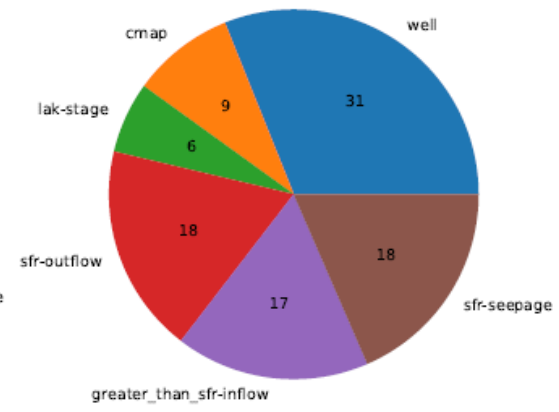
iter. 0



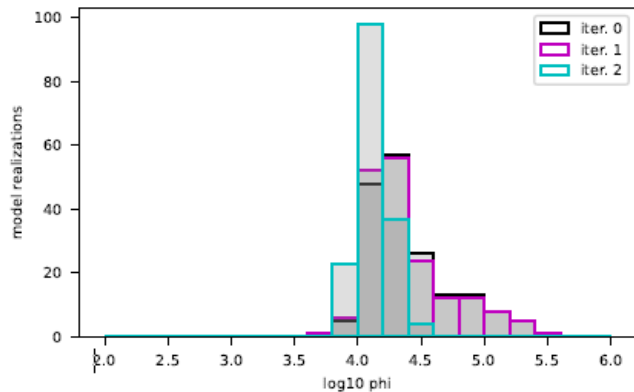
iter. 1



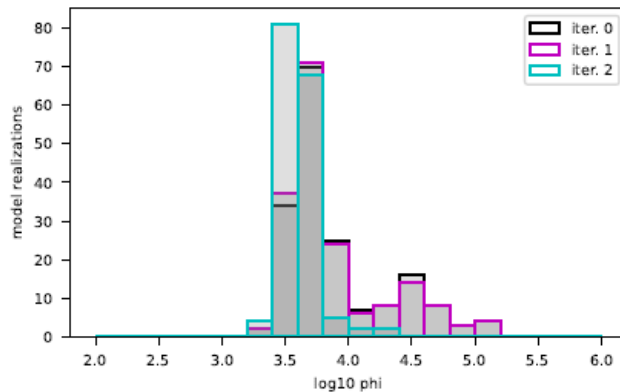
iter. 2



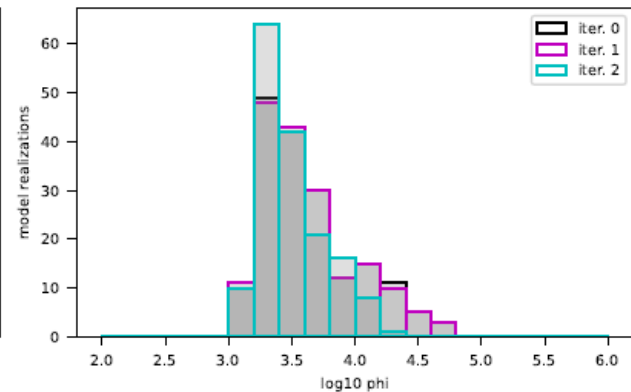
well phi by upgrade iteration



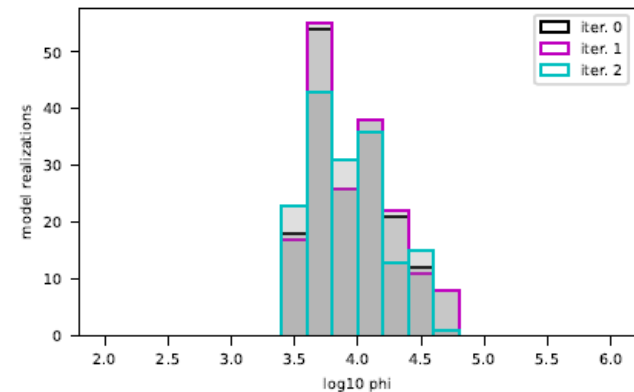
cmap phi by upgrade iteration



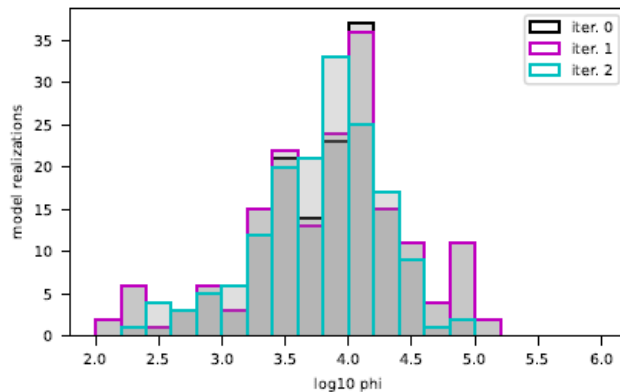
lak-stage phi by upgrade iteration



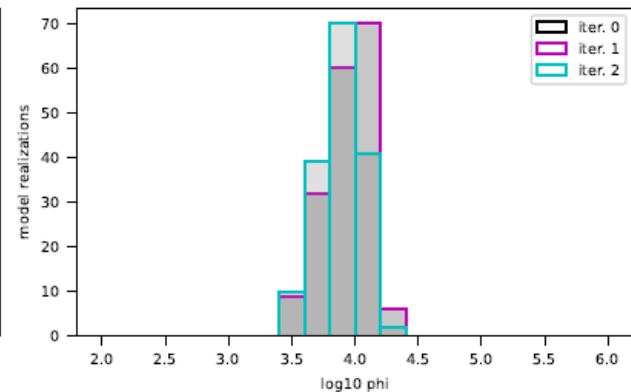
sfr-outflow phi by upgrade iteration

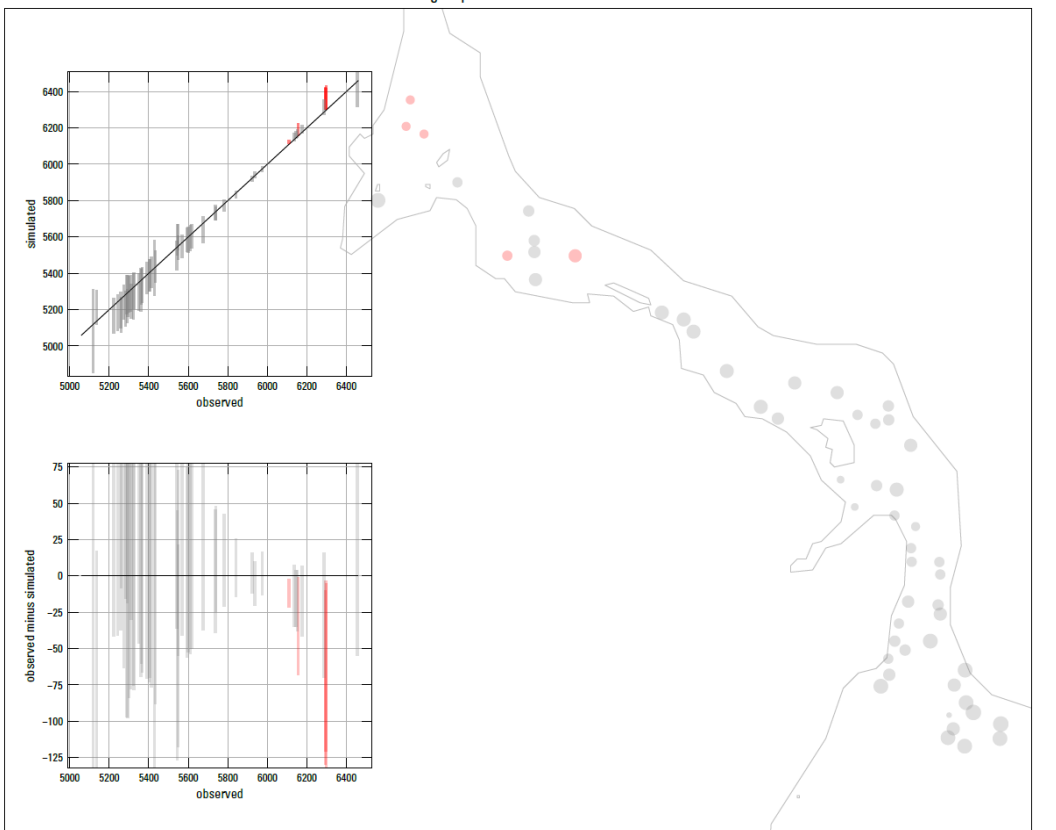


greater\_than\_sfr-inflow phi by upgrade iteration



sfr-seepage phi by upgrade iteration

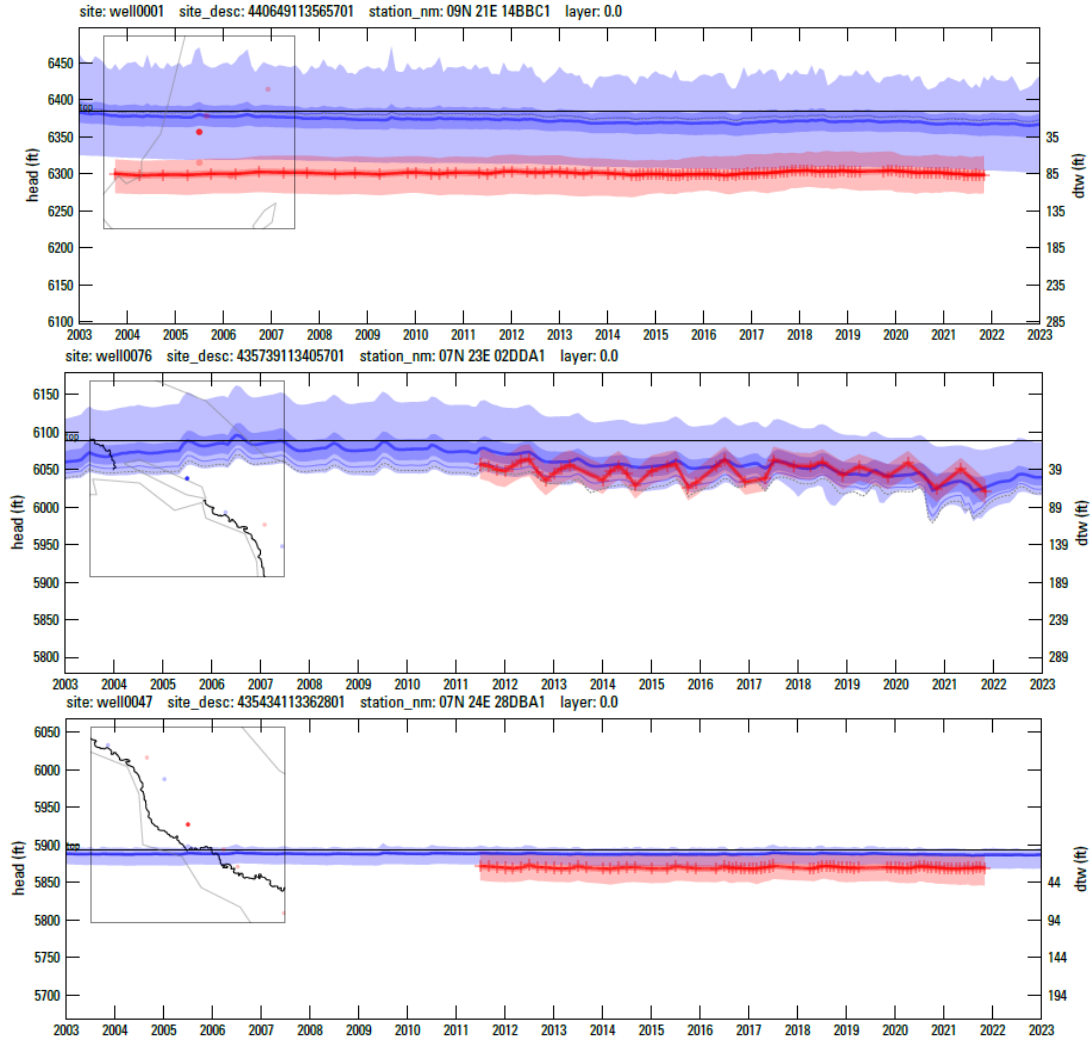




## Groundwater Levels

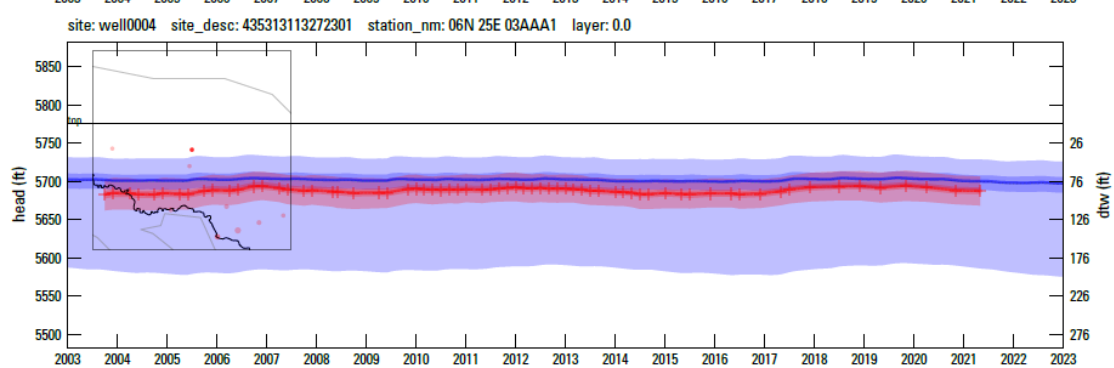
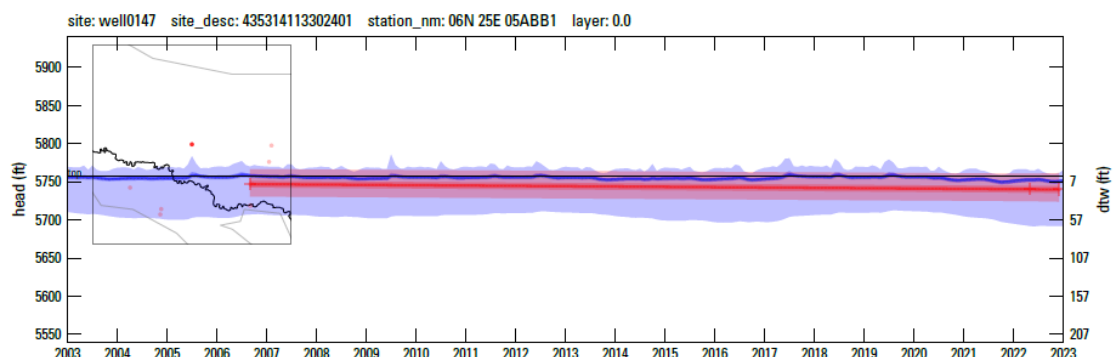
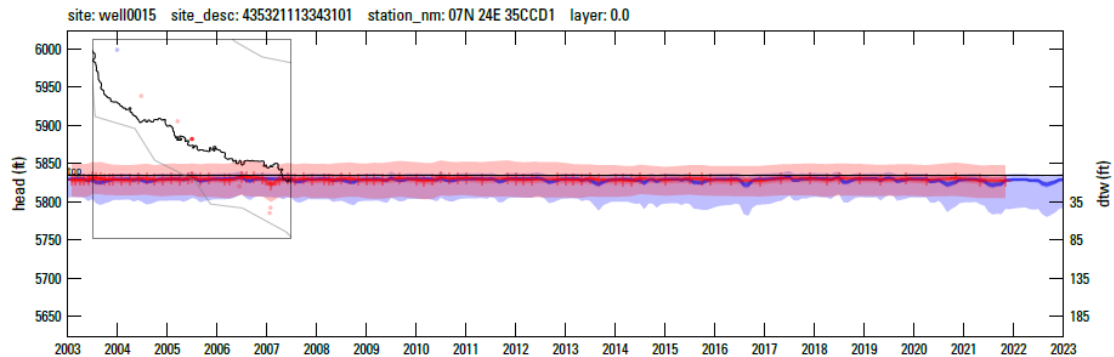
Residual maps show spatial variability of fit to observations and range of simulated values for a given time step

- Spatial pattern of fit to data is consistent throughout simulation period
- Heads are generally too high in Thousand Springs area
- Ensemble range of values could be tightened up in lower basin (low end of simulated range is too low)



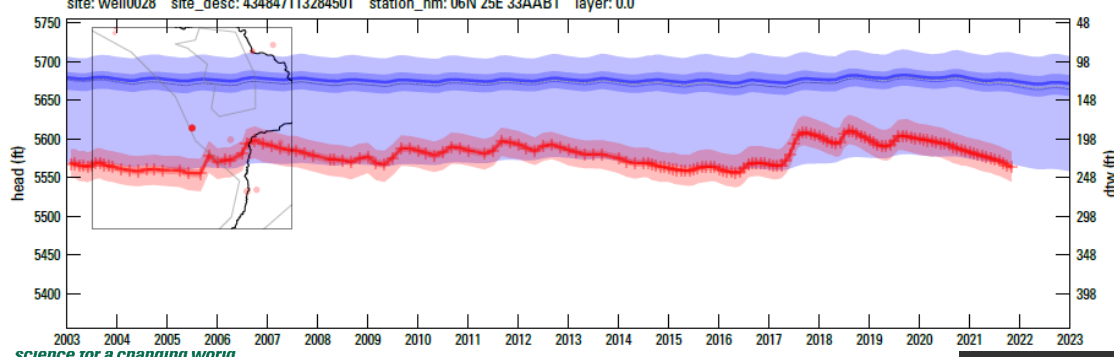
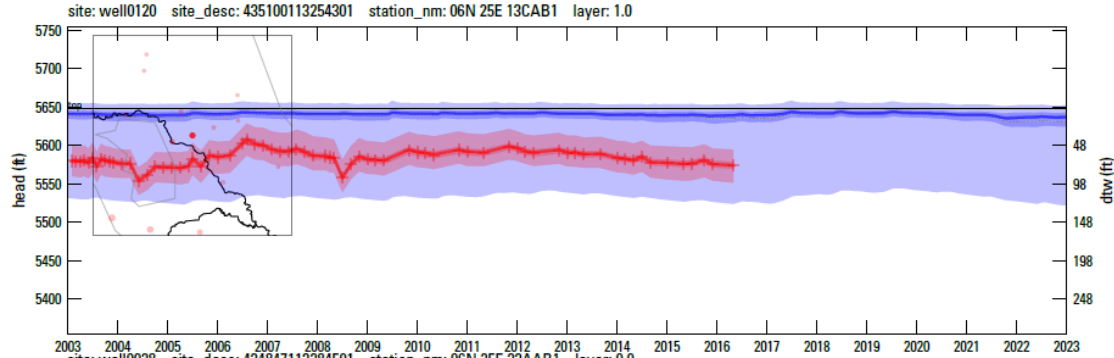
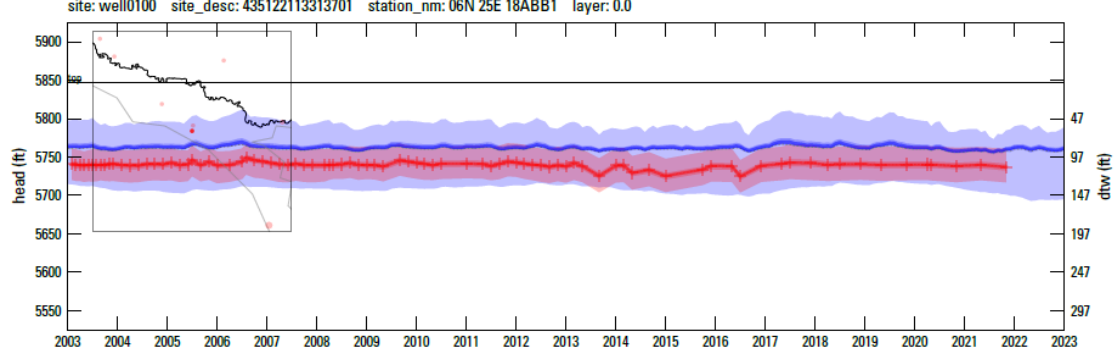
## Groundwater Levels

Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)



## Groundwater Levels

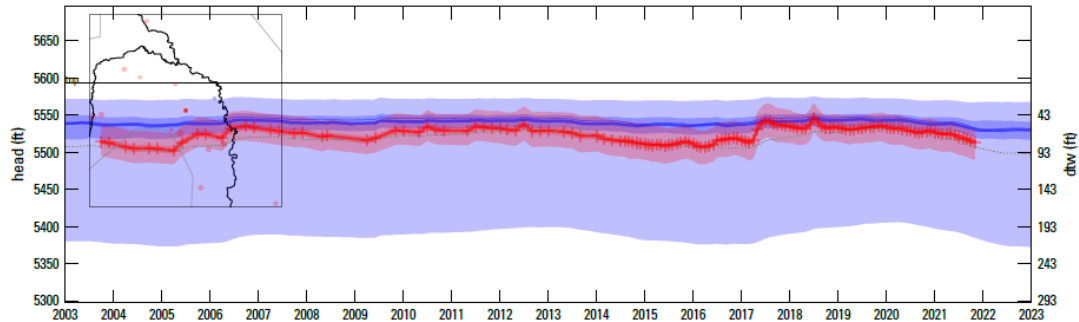
Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)



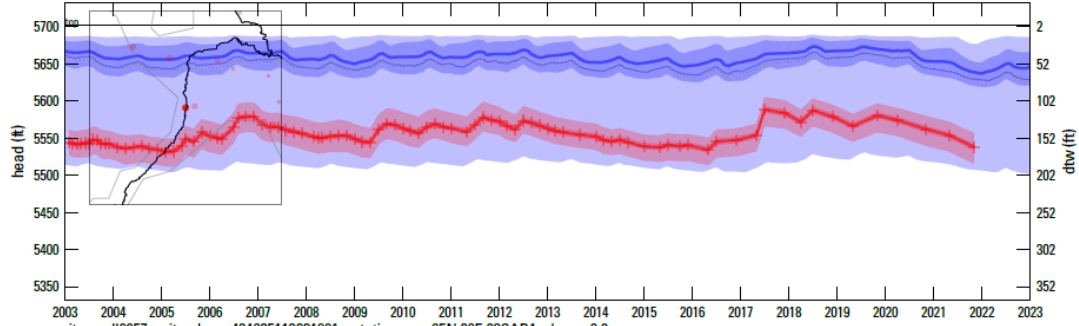
## Groundwater Levels

Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)

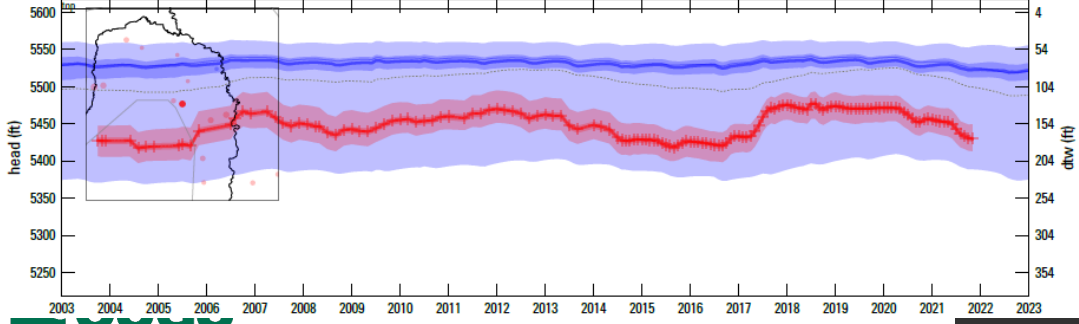
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site: well0176 site\_desc: 434705113264201 station\_nm: 05N 25E 11BAA1 layer: 0.0

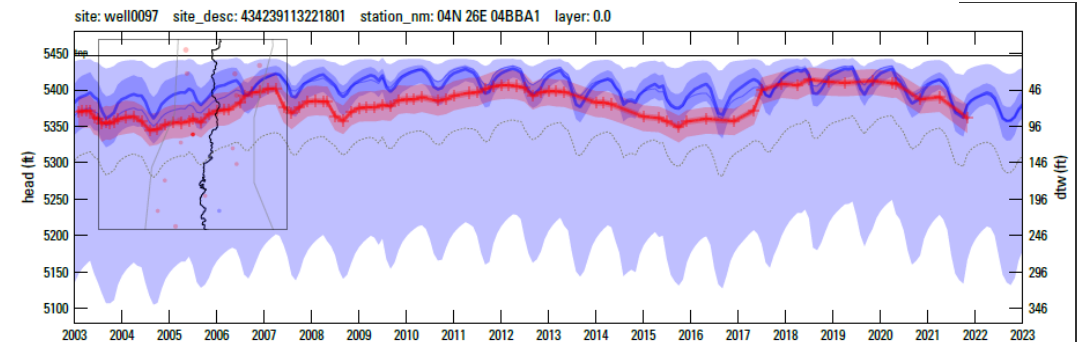
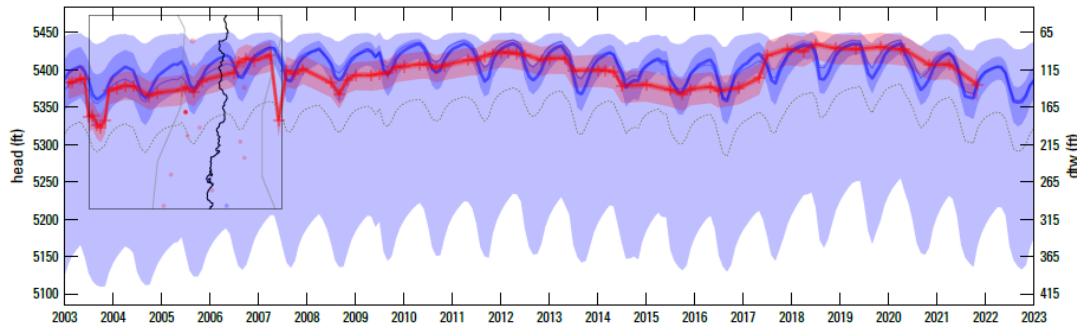
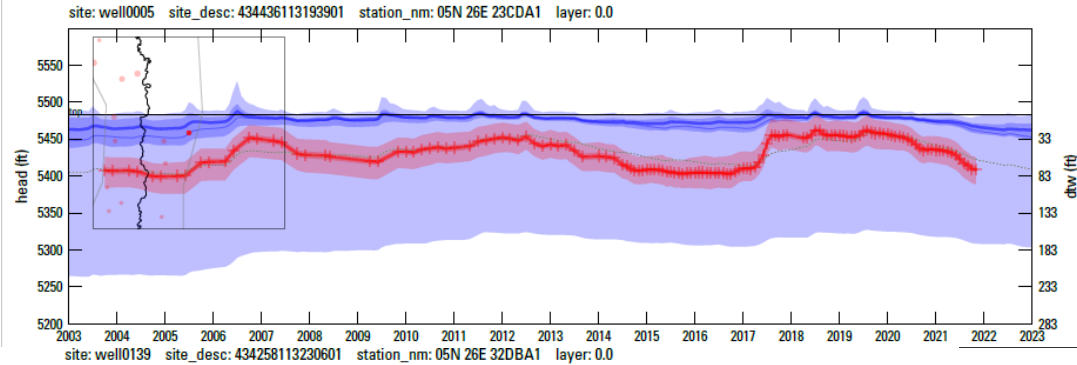


site: well0057 site\_desc: 434635113231901 station\_nm: 05N 26E 08CAB1 layer: 0.0



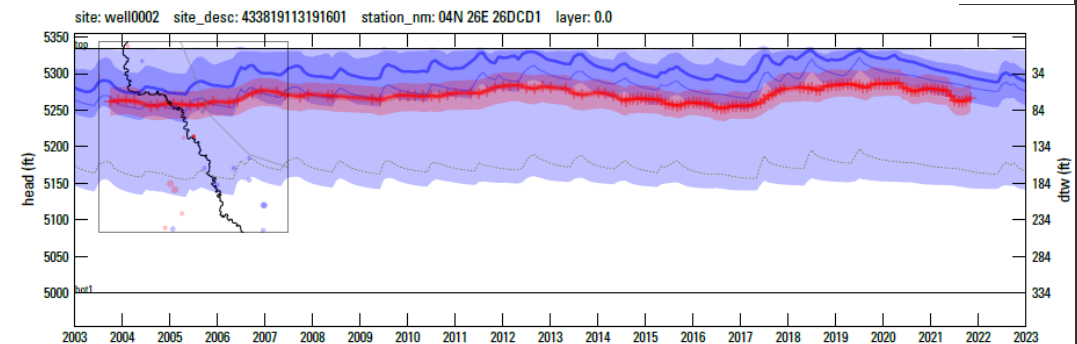
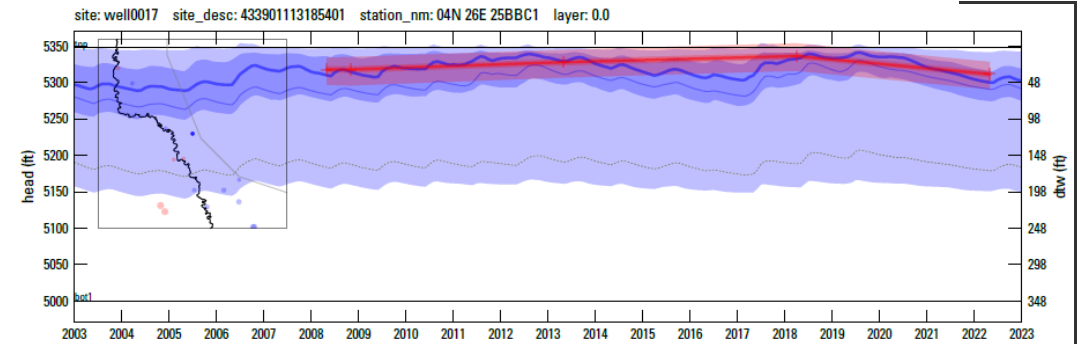
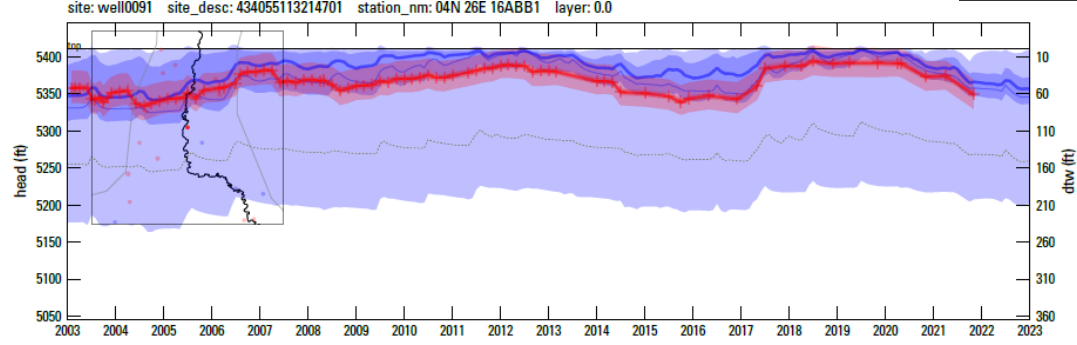
## Groundwater Levels

Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)



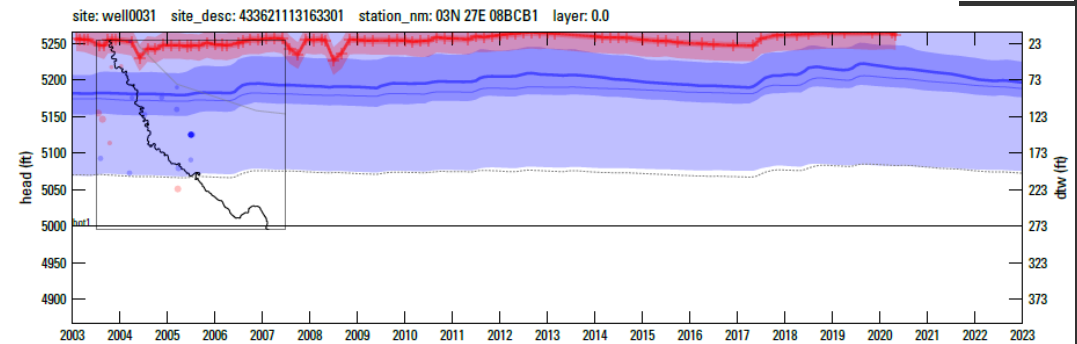
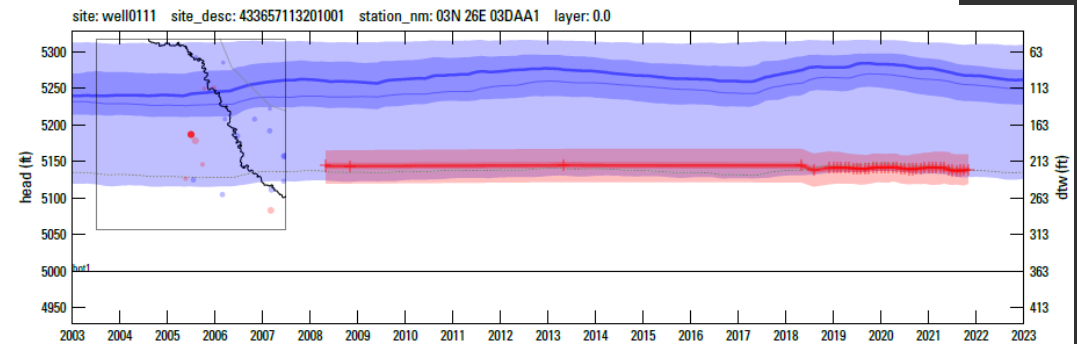
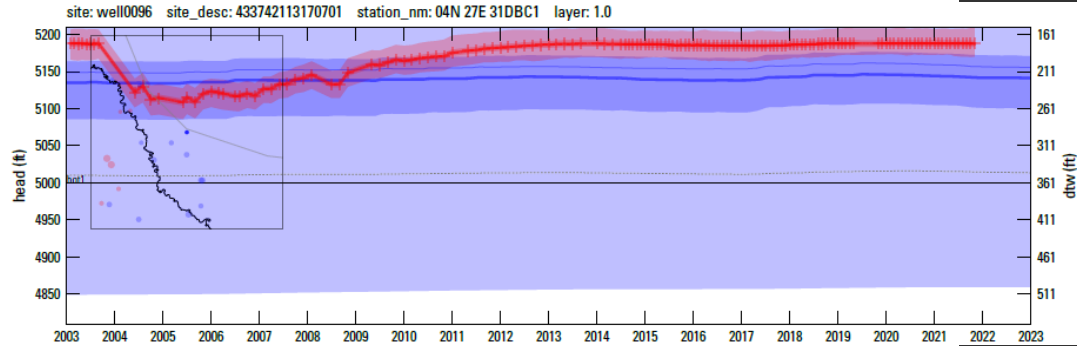
## Groundwater Levels

Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)



## Groundwater Levels

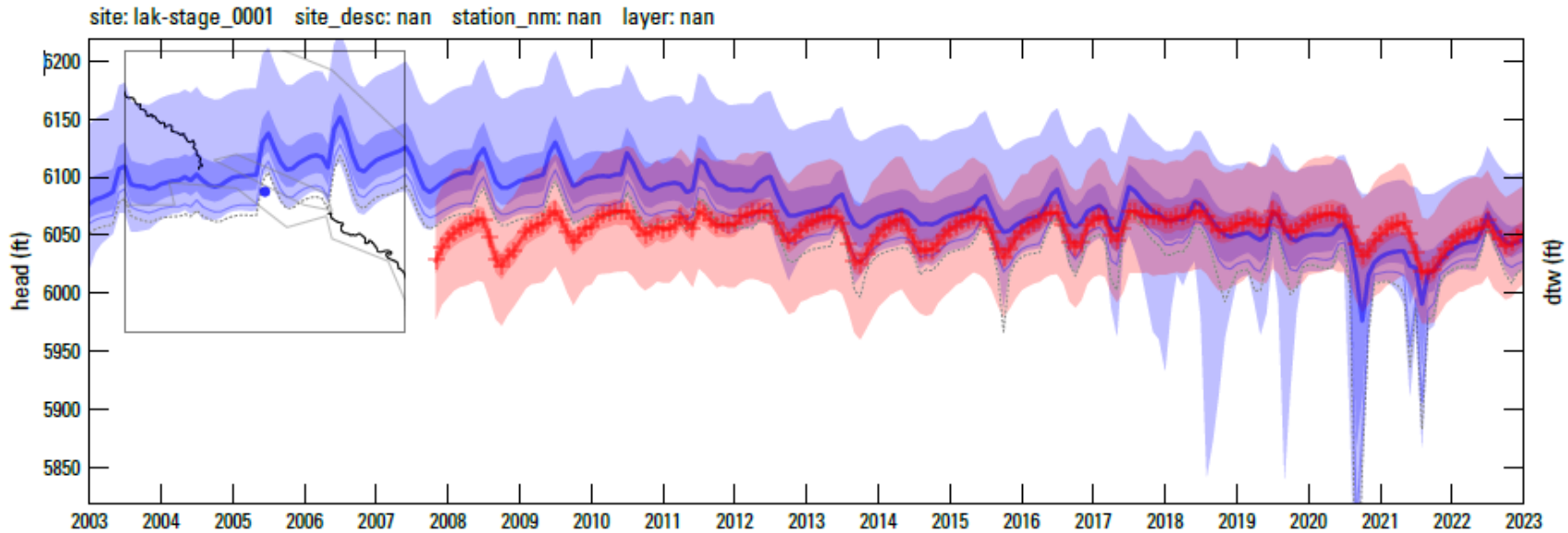
Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)

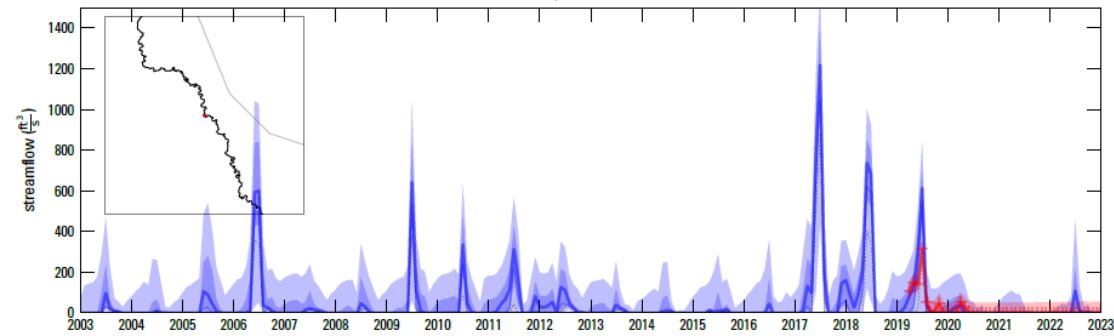
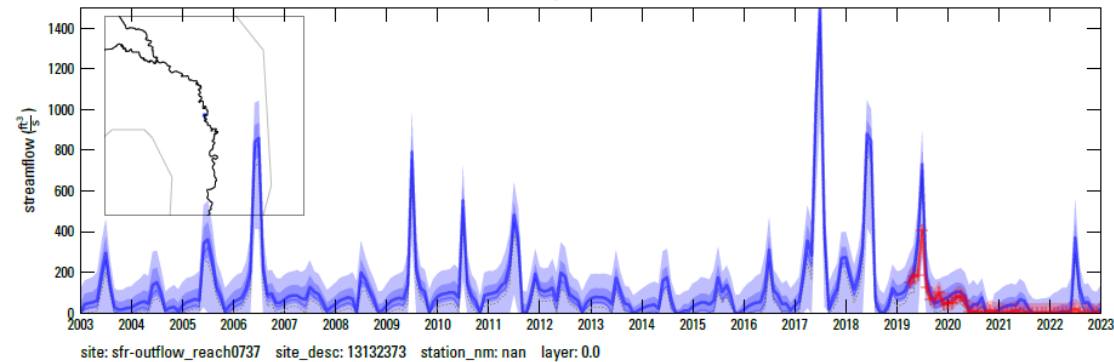
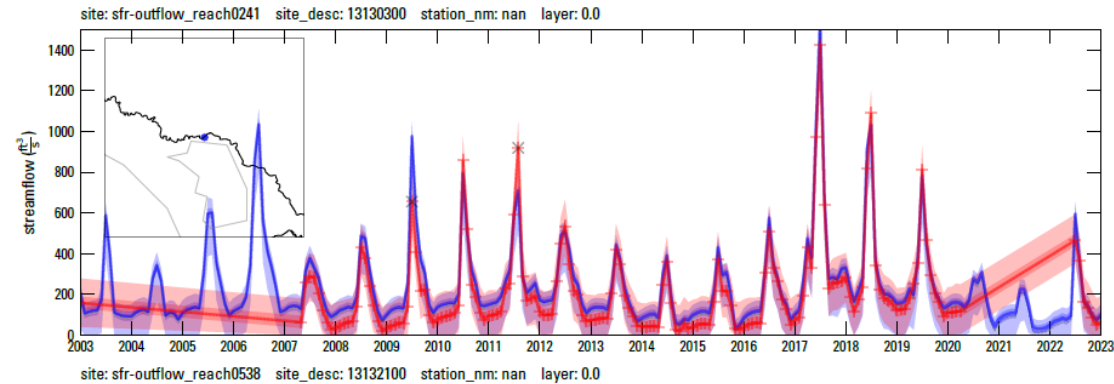


## Groundwater Levels

Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)

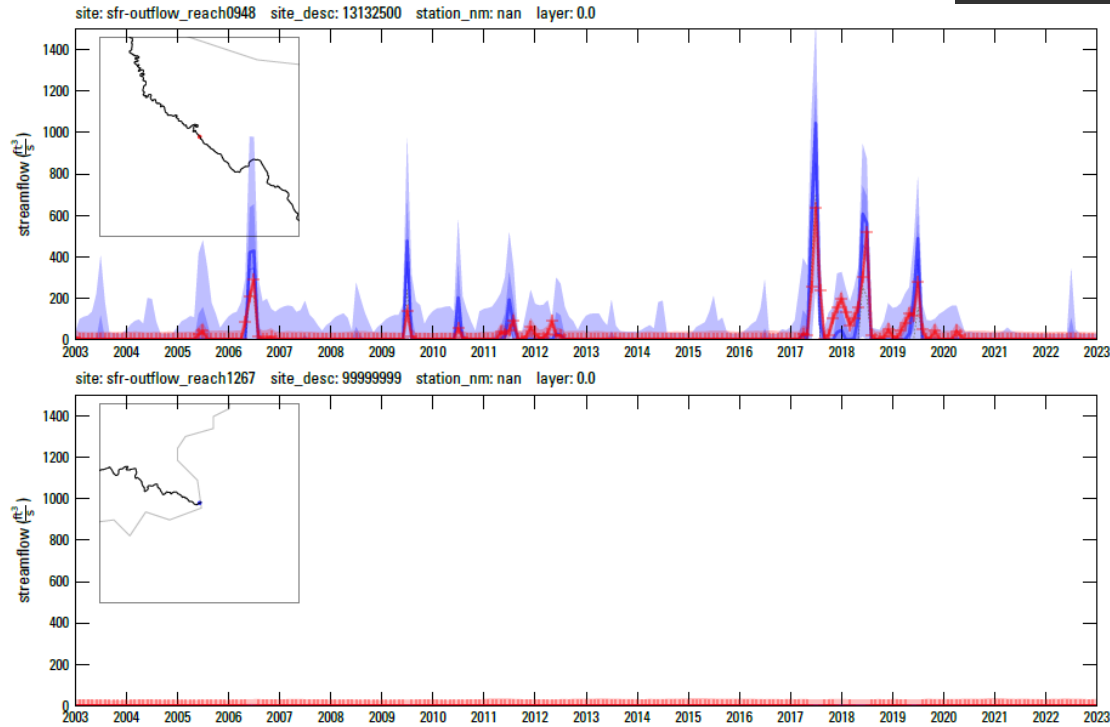
# Lake Stage





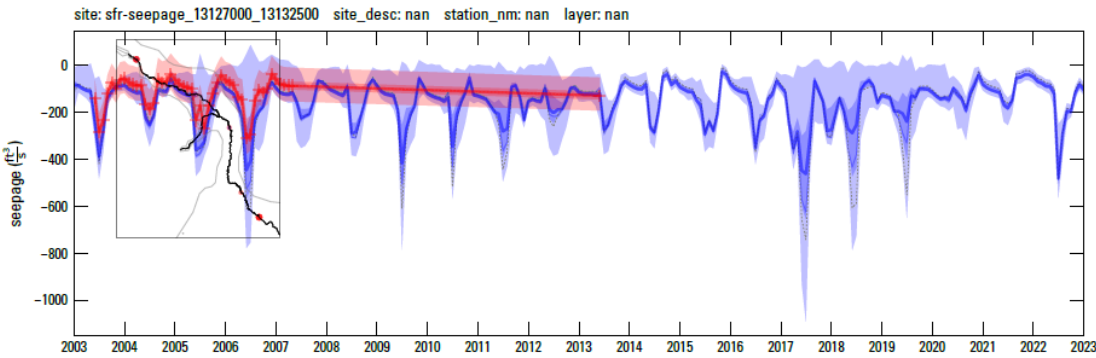
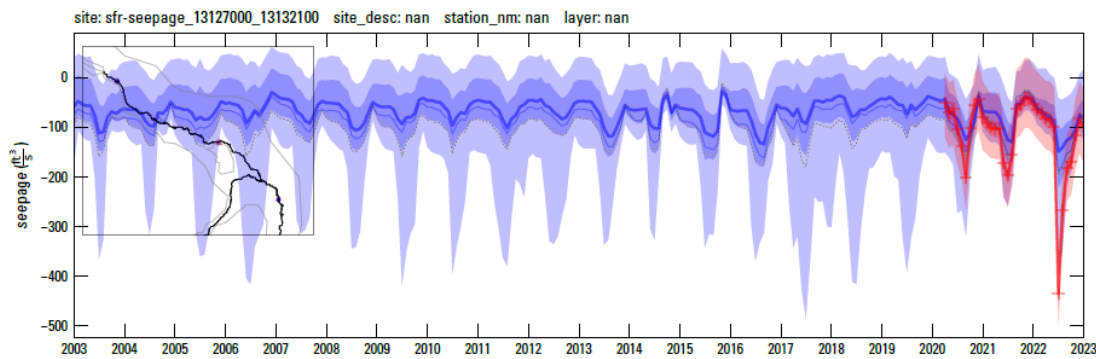
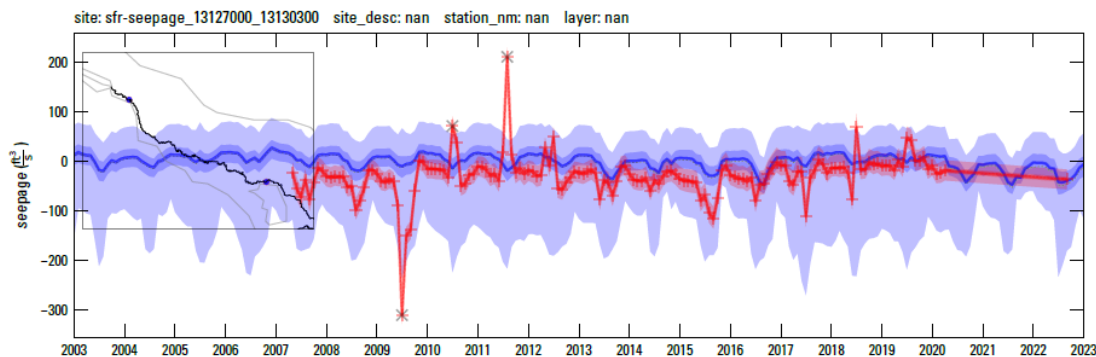
## Stream Gage Measurements

Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)



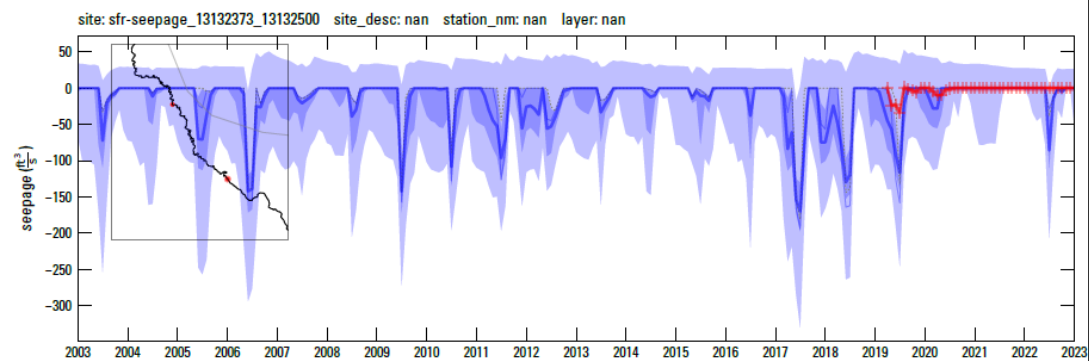
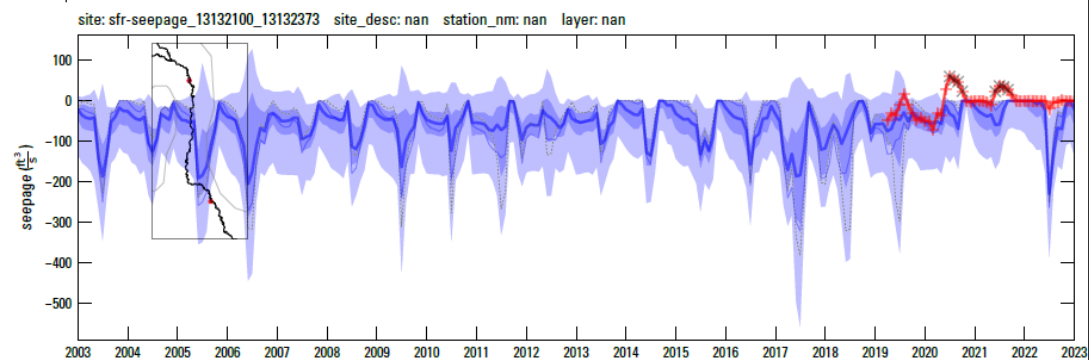
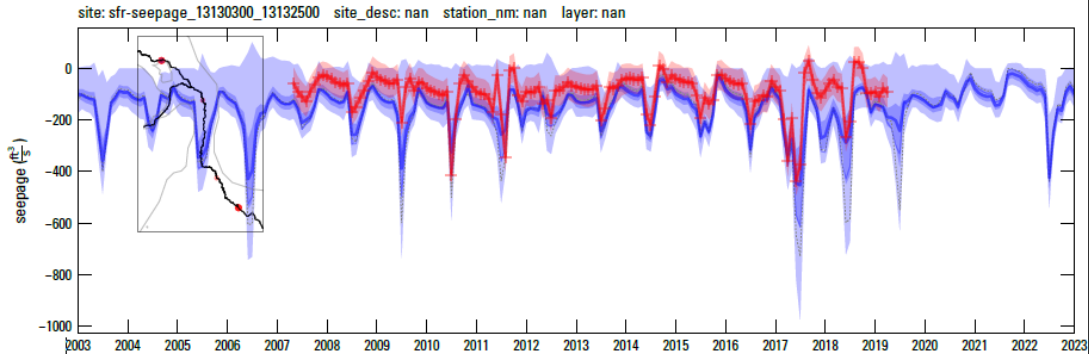
## Stream Gage Measurements

Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)



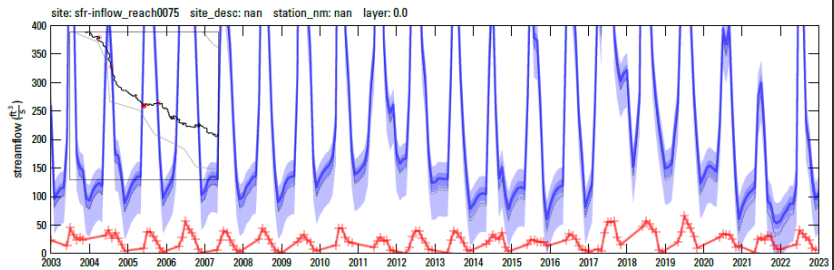
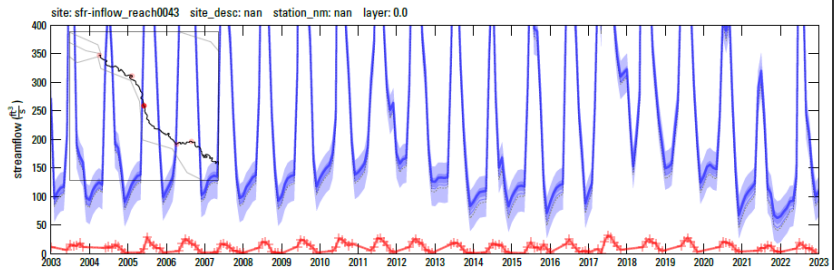
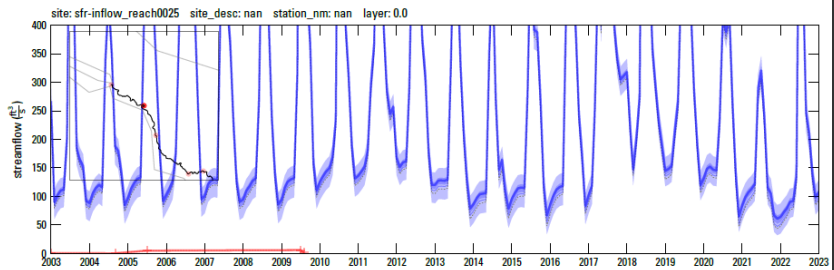
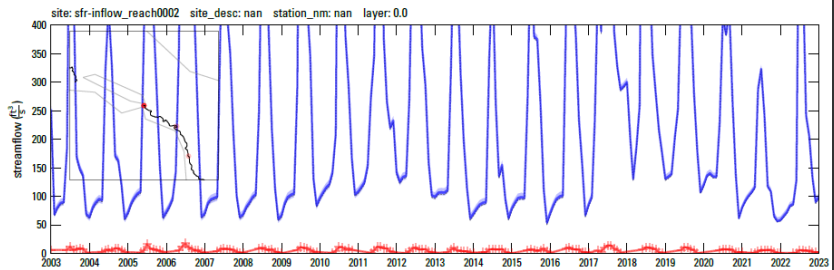
## Stream Reach Gain/Loss

Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)



## Stream Reach Gain/Loss

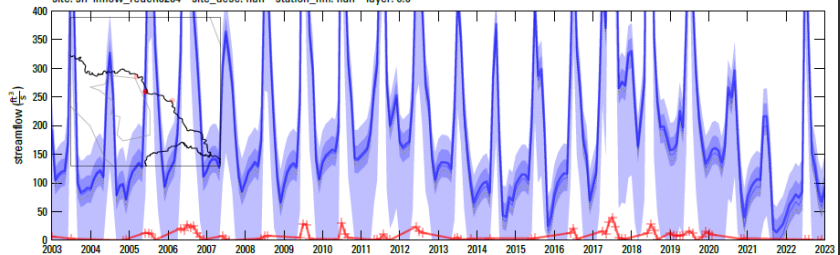
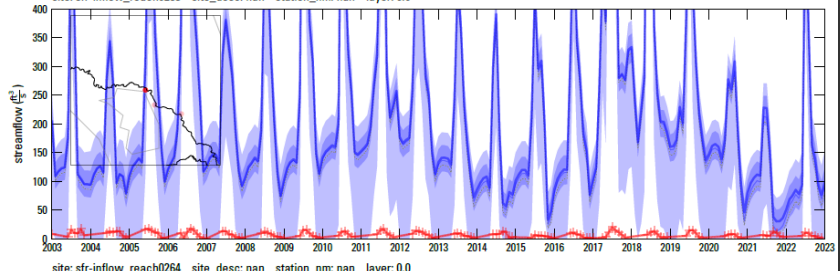
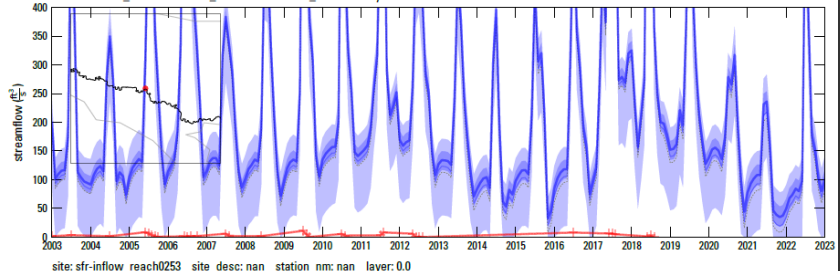
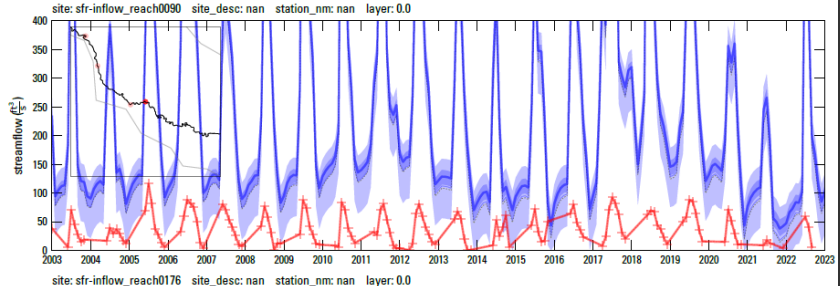
Time series hydrographs show measured value and acceptable range (red) vs simulated range (blue)



**Minimum upstream flow required to simulate SW diversions**

**Observation targets deployed as “greater than” targets**

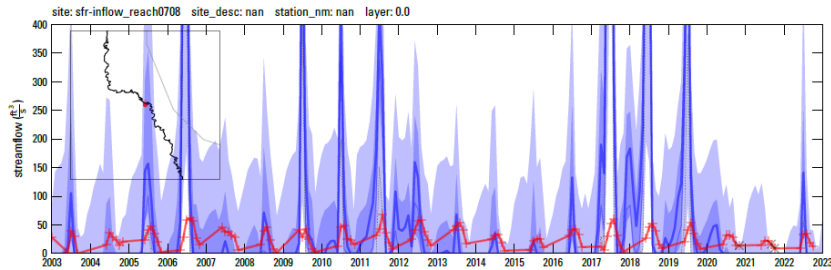
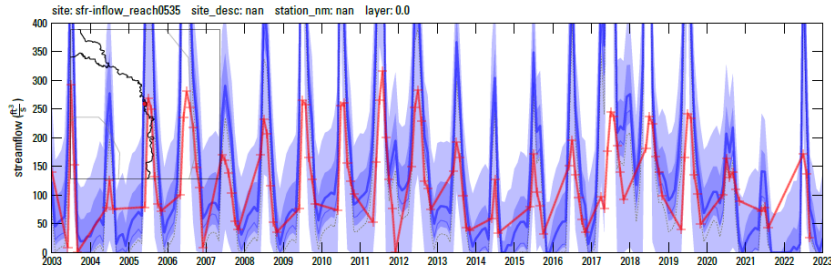
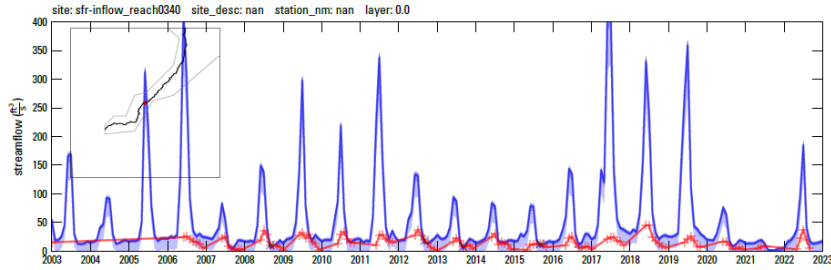
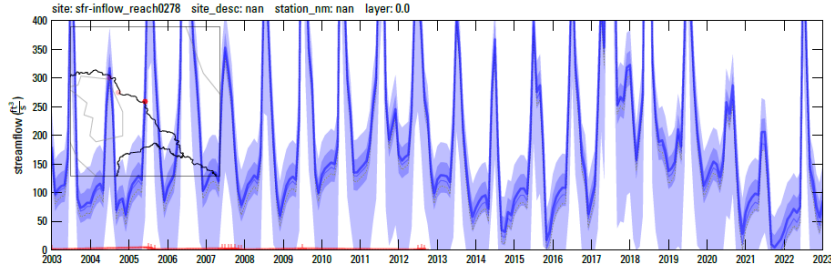
**Penalty is only incurred when flow is less than defined diversion**



**Minimum upstream flow required to simulate SW diversions**

**Observation targets deployed as “greater than” targets**

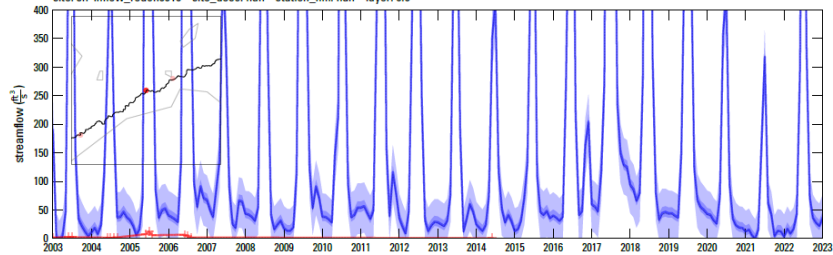
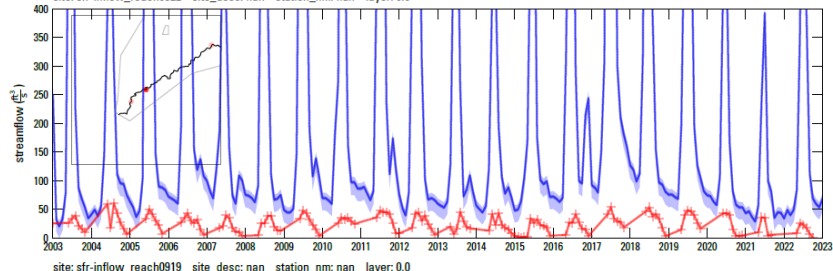
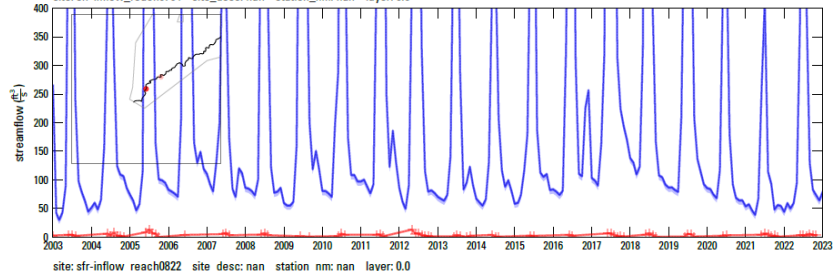
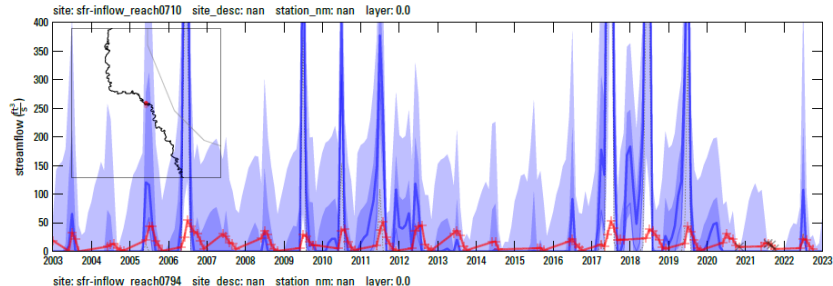
**Penalty is only incurred when flow is less than defined diversion**



**Minimum upstream flow required to simulate SW diversions**

**Observation targets deployed as “greater than” targets**

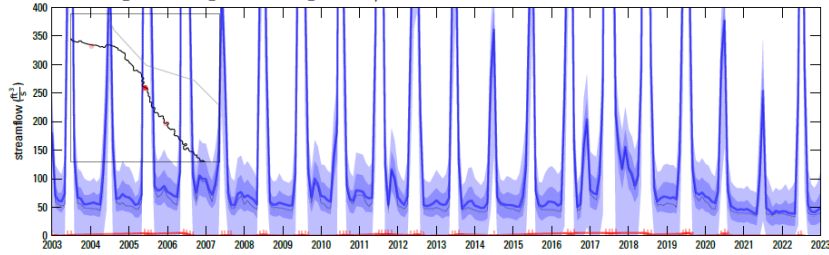
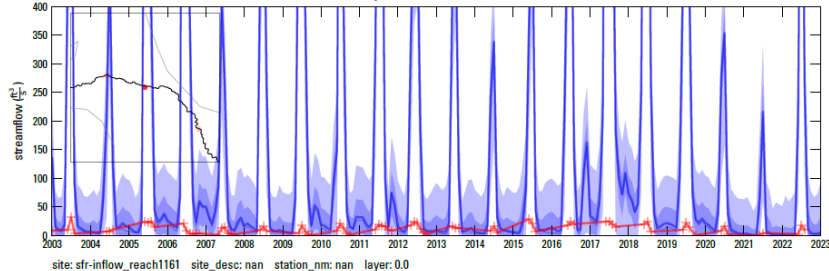
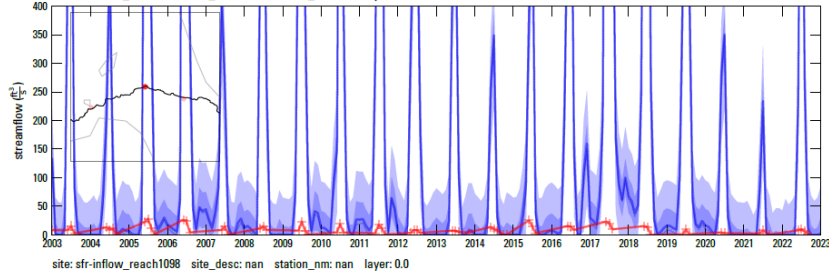
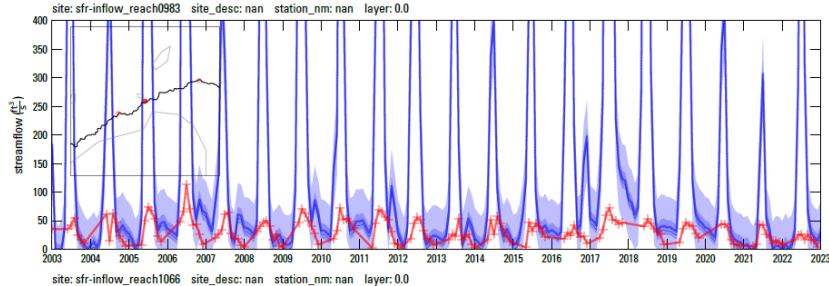
**Penalty is only incurred when flow is less than defined diversion**



**Minimum upstream flow required to simulate SW diversions**

**Observation targets deployed as “greater than” targets**

**Penalty is only incurred when flow is less than defined diversion**

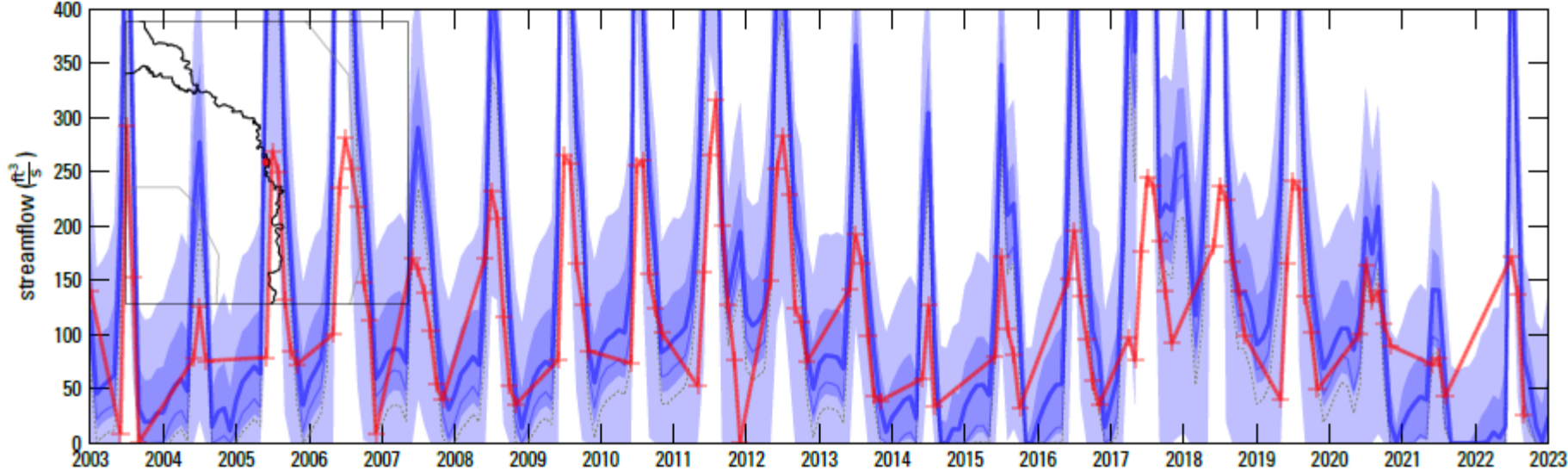


**Minimum upstream flow required to simulate SW diversions**

**Observation targets deployed as “greater than” targets**

**Penalty is only incurred when flow is less than defined diversion**

site: sfr-inflow\_reach0535 site\_desc: nan station\_nm: nan layer: 0.0



**Stream reach containing Moore and Eastside diversions is most susceptible to GW budget error.**

Prepared in cooperation with the Idaho Department of Water Resources

## Groundwater Budgets for the Big Lost River Basin, South-Central Idaho, 2000–19

Chapter C of  
Characterization of Water Resources in the Big Lost River Basin,  
South-Central Idaho



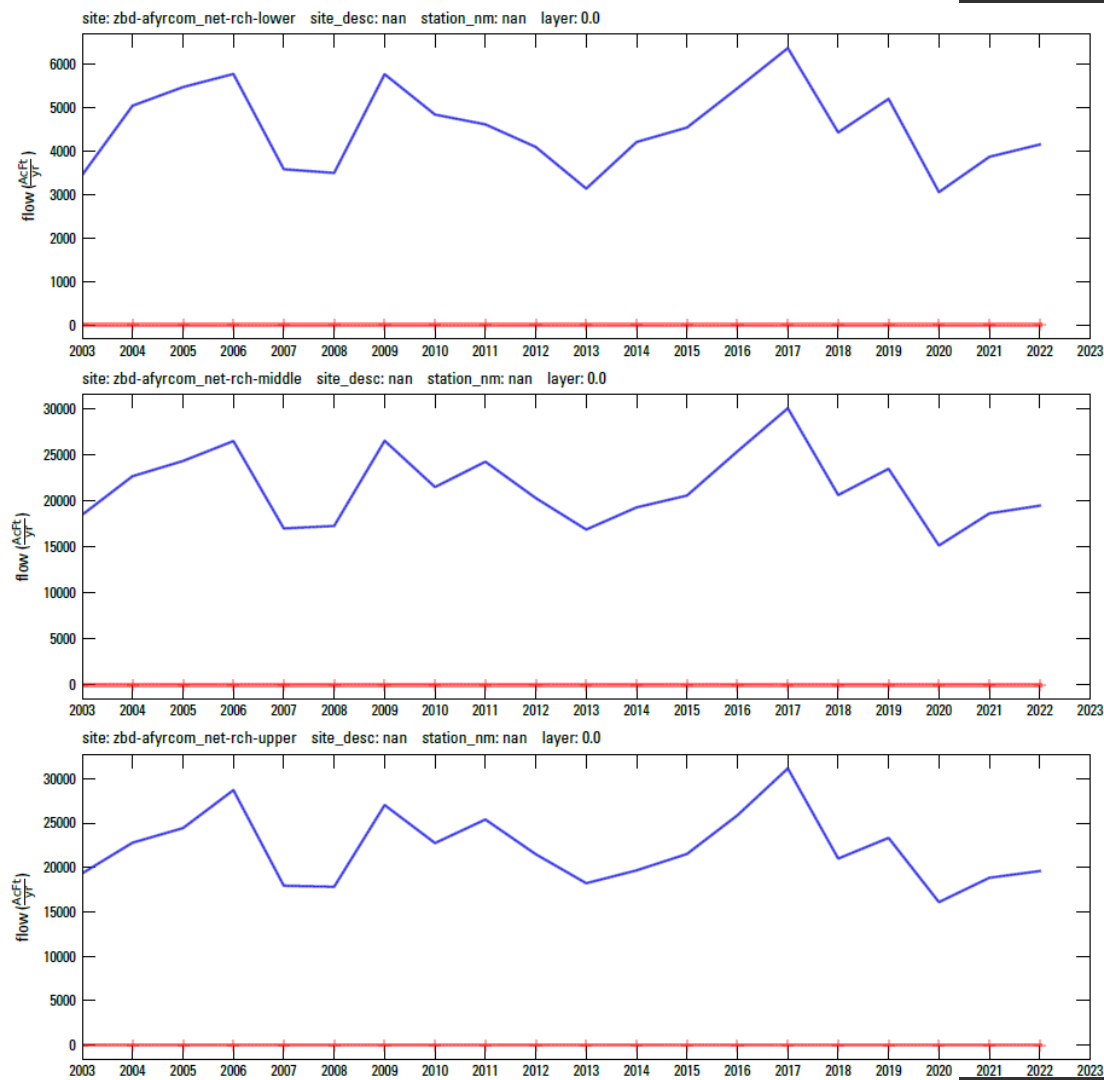
Scientific Investigations Report 2021–5078–C

## GW Budget estimates

- Annual 2003–19 groundwater inflows and outflows derived from Clark (2021).
- Unweighted “soft” targets used to evaluate model behavior and ensure simulated forcings match our intentions.
- Some differences between the published budget and model-simulated budget are expected and necessary due to different assumptions made in the modeling process.

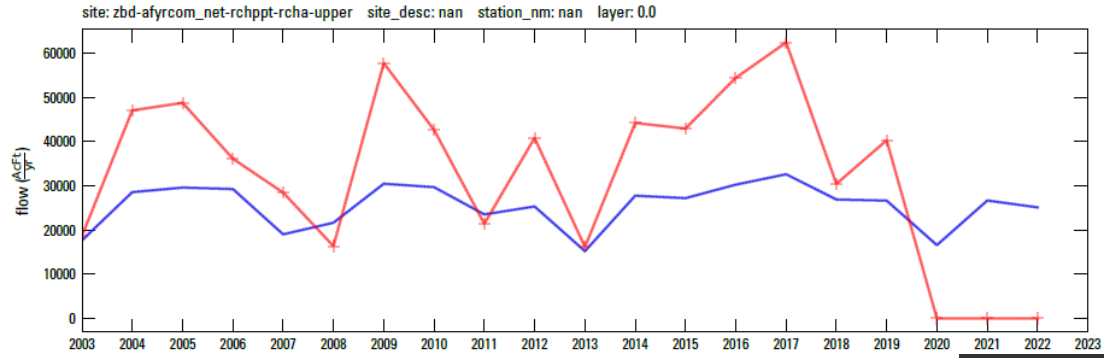
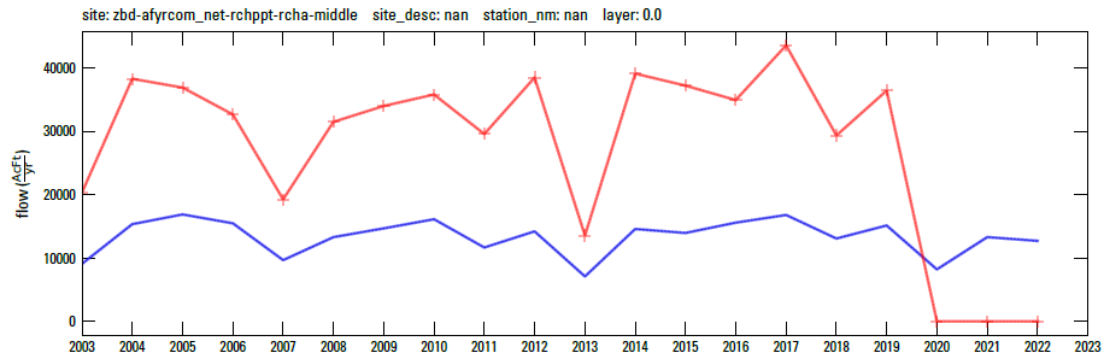
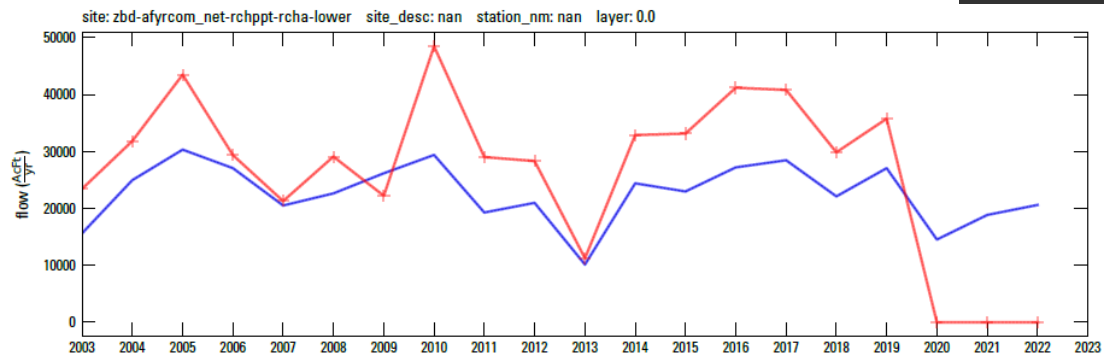
# GW Budget estimates

- Tributary Underflow



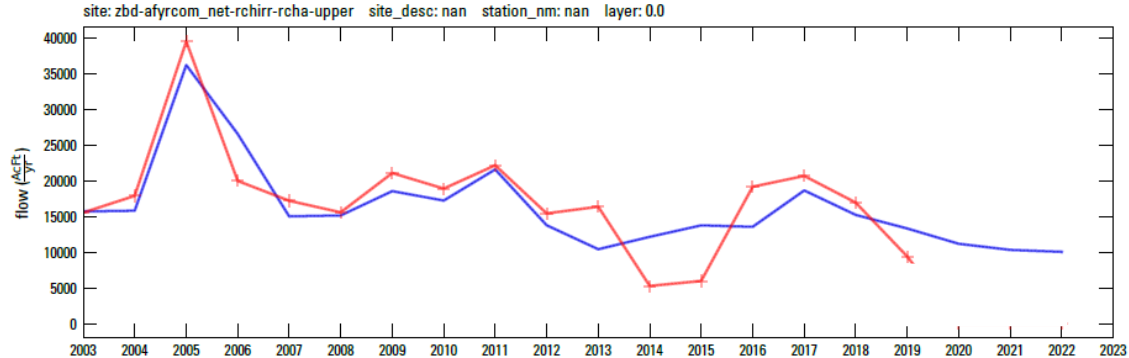
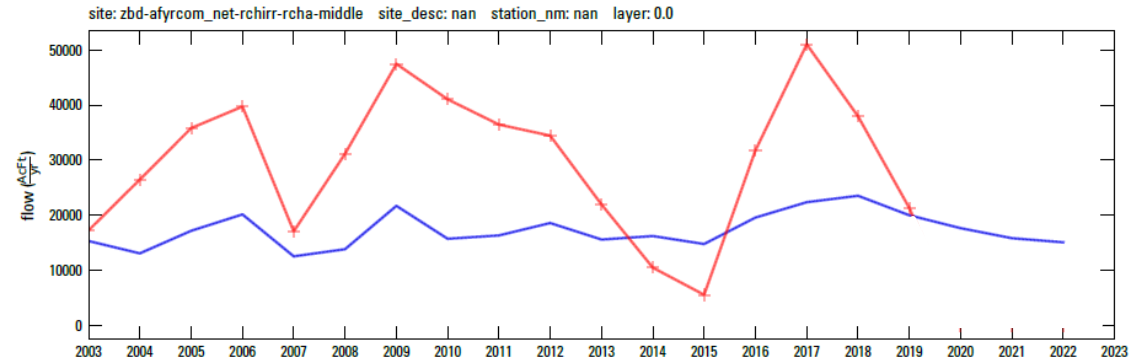
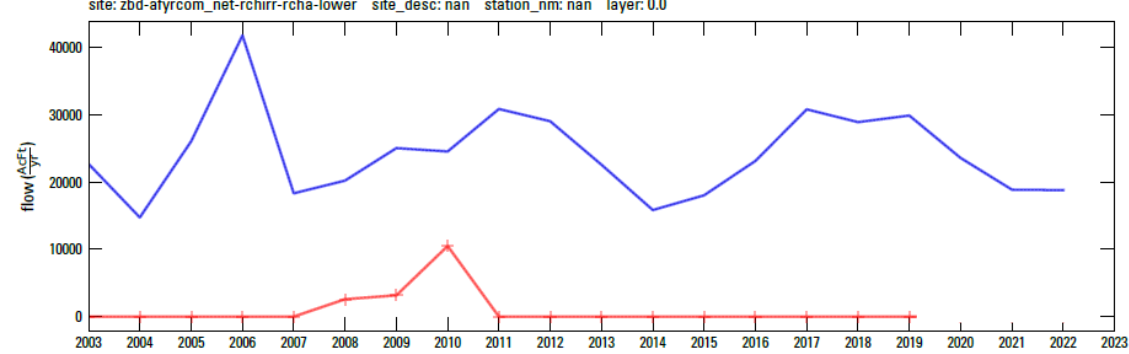
# GW Budget estimates

- Areal Recharge (non-irrigation)



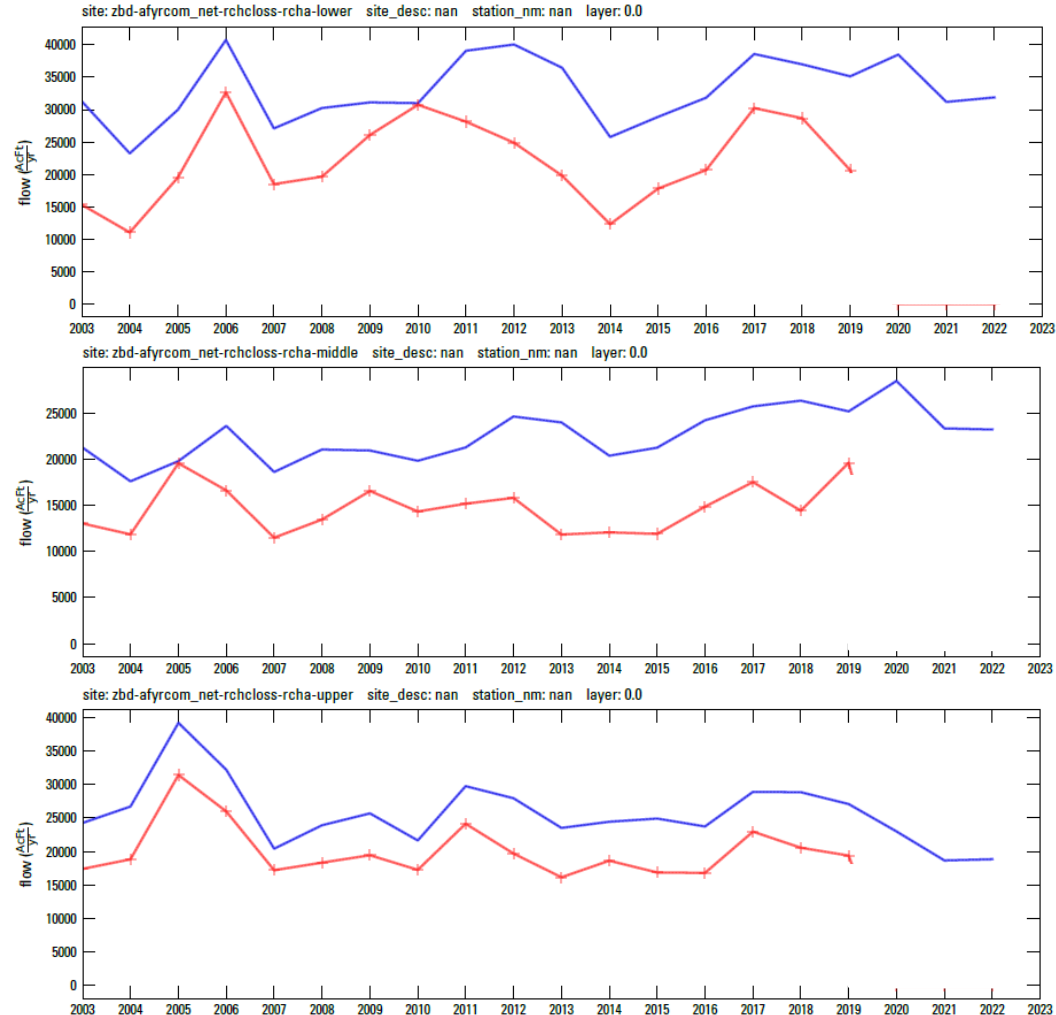
# GW Budget estimates

- On-farm incidental recharge



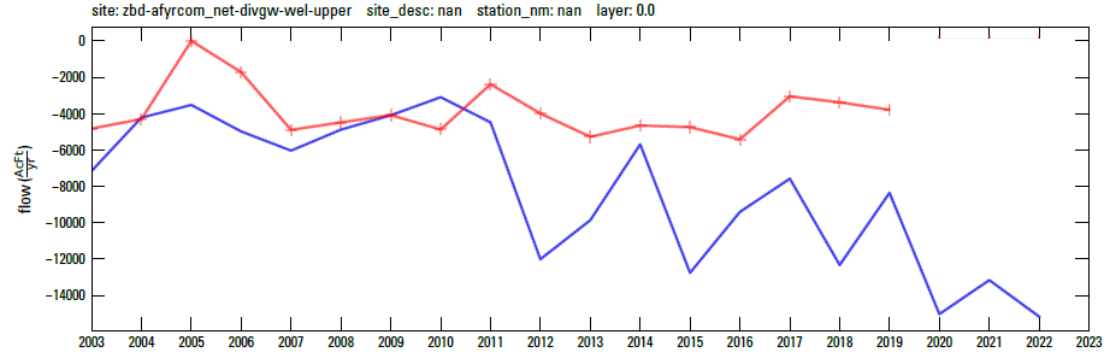
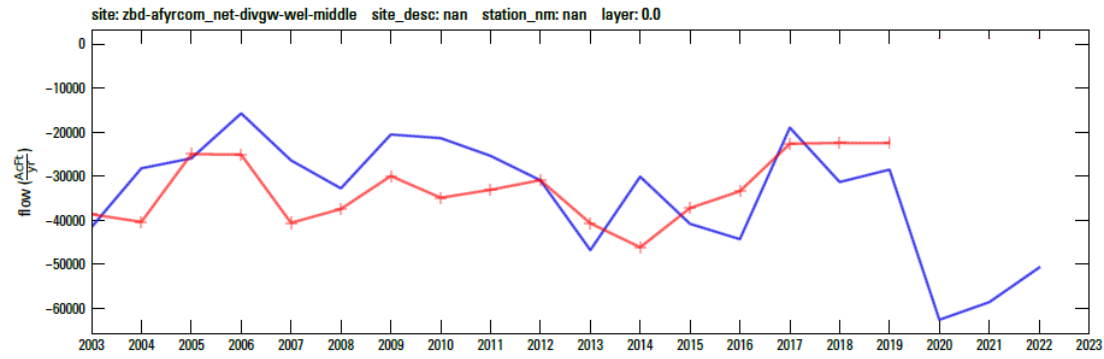
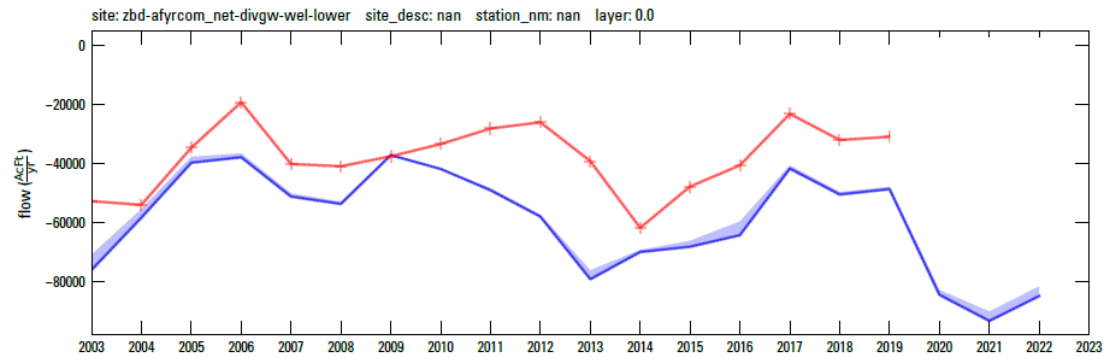
# GW Budget estimates

- Canal Loss recharge



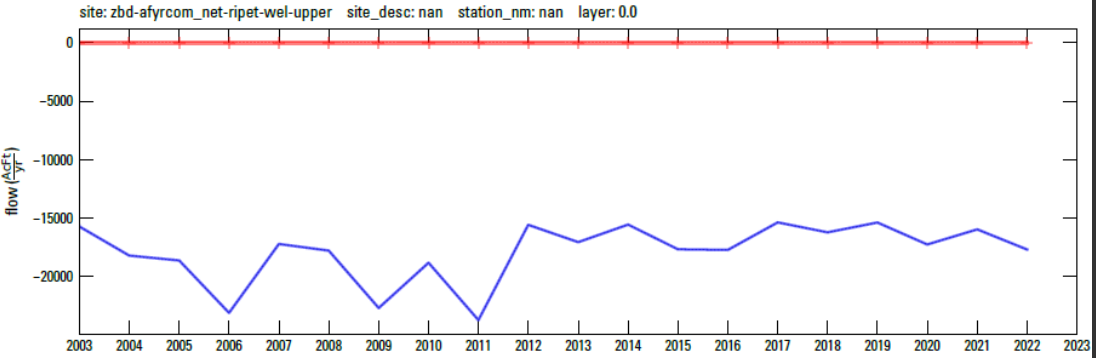
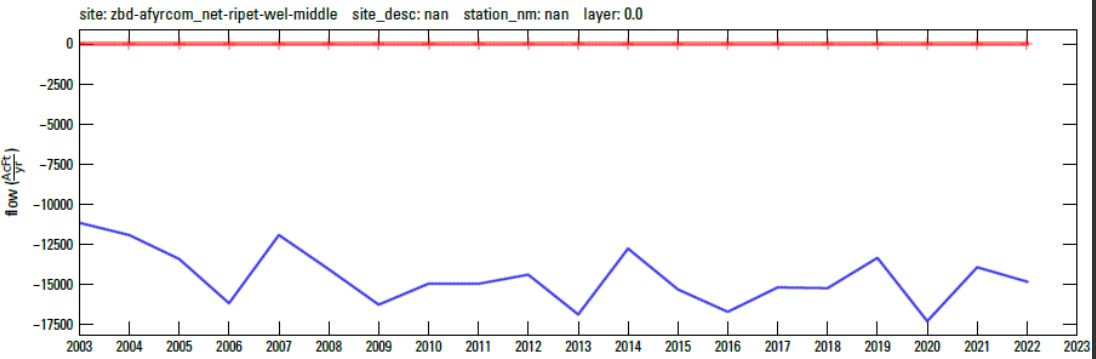
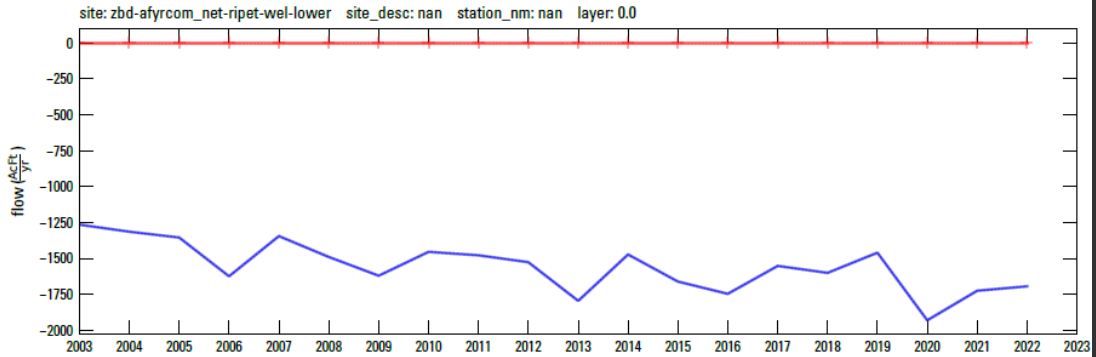
# GW Budget estimates

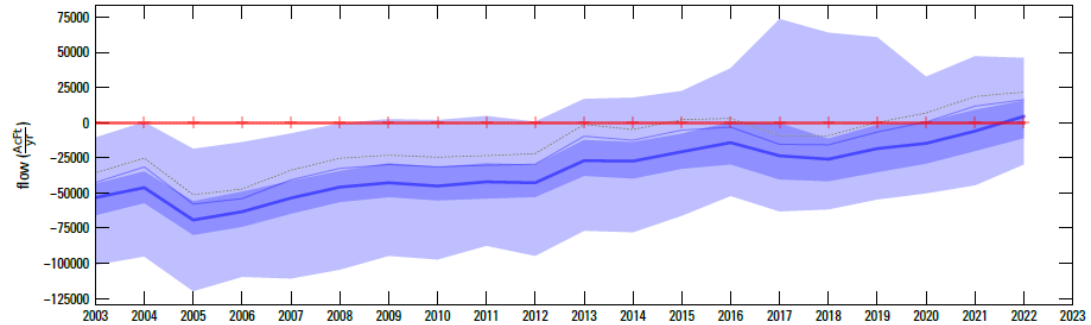
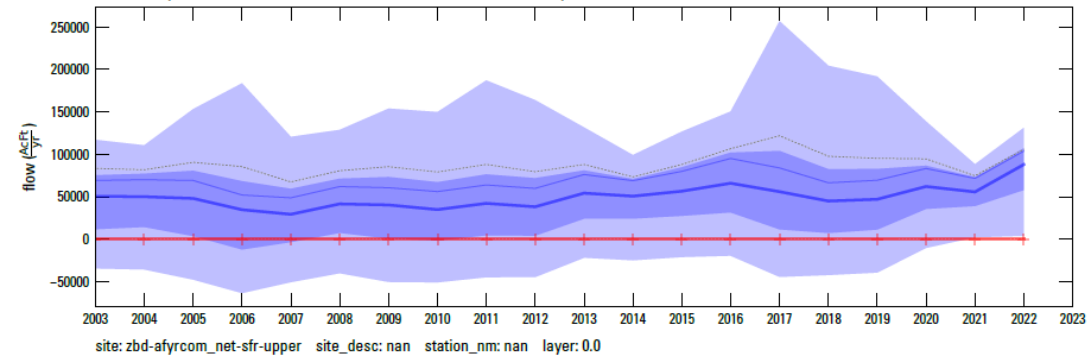
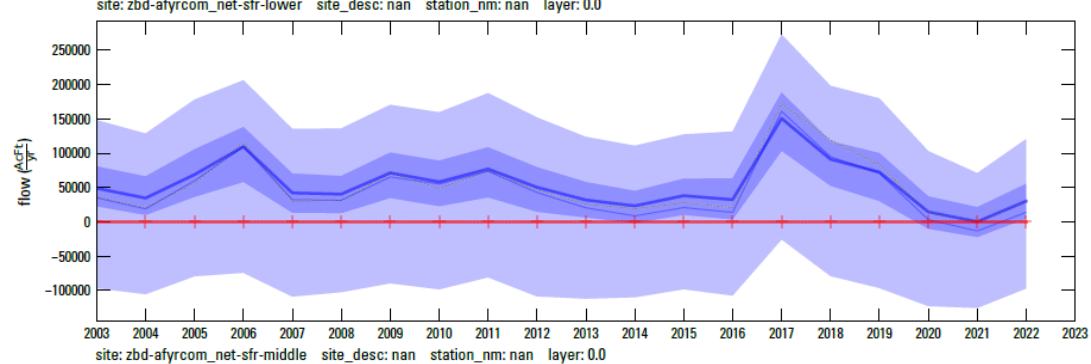
- Groundwater Irrigation  
NOTE: inverted y-scale



# GW Budget estimates

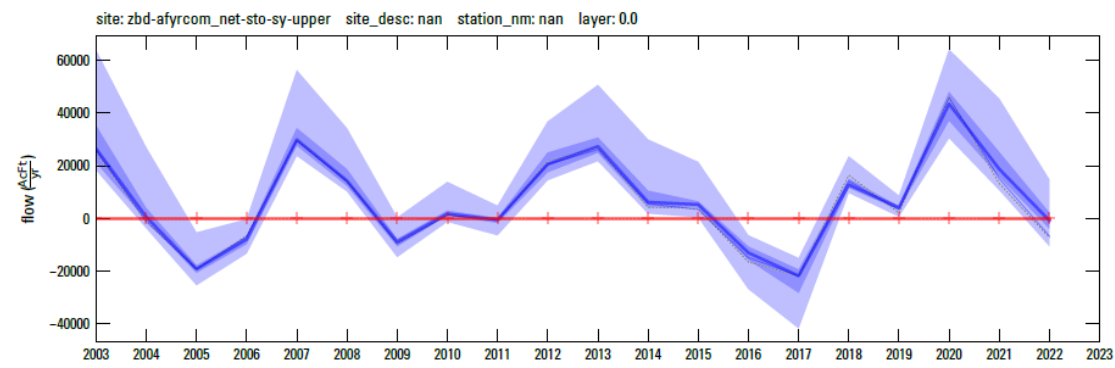
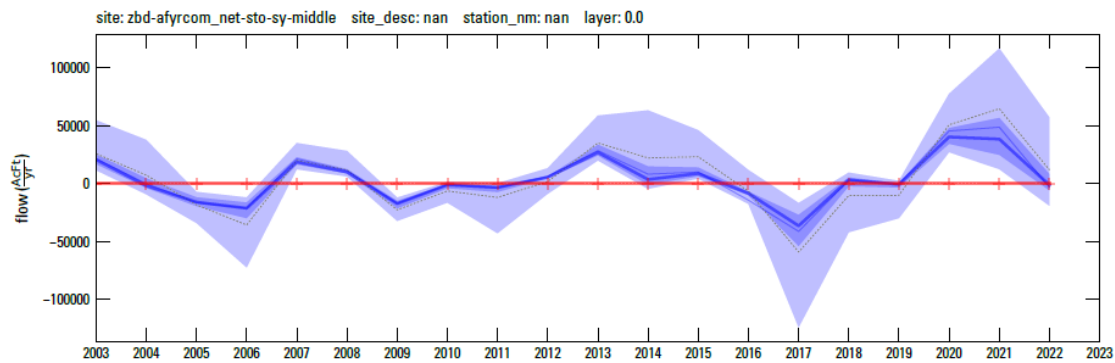
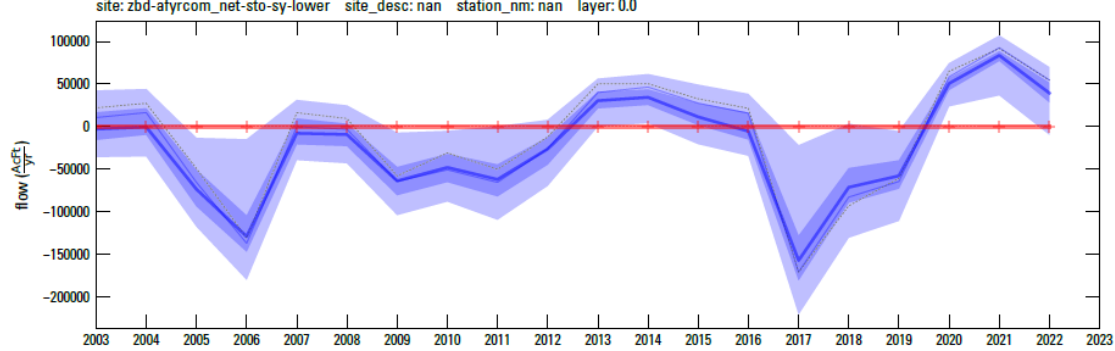
- Riparian EVT
- NOTE: inverted y-scale**





## GW Budget estimates

- Stream-aquifer exchange
- NOTE: positive=flow into aquifer**

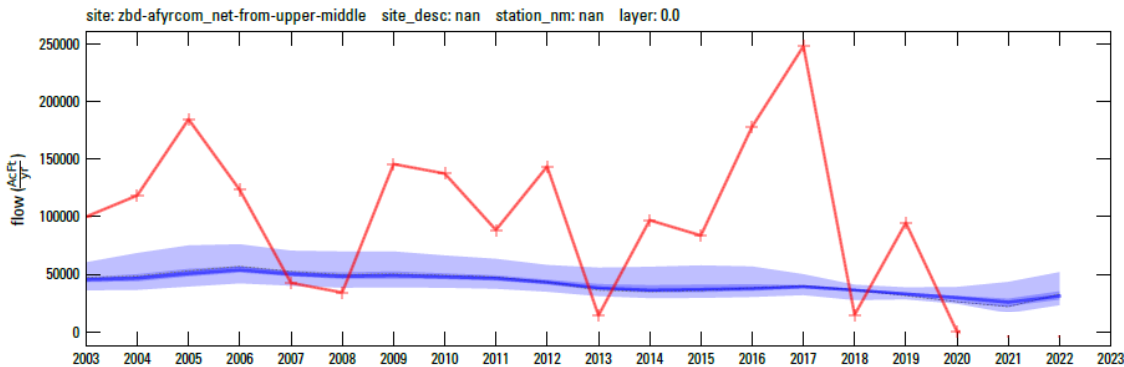


# GW Budget estimates

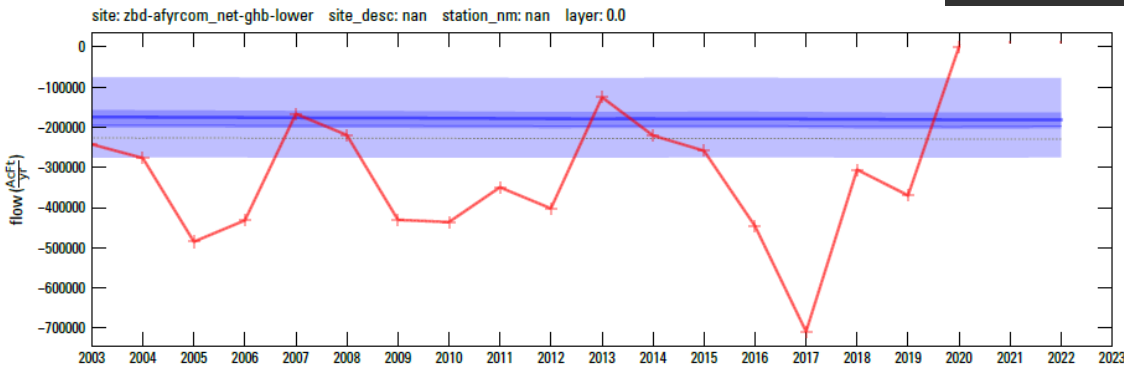
- Storage Change
- NOTE: positive=reduction in storage contributing to GW flow**

## GW Budget estimates

- Groundwater flow from upper to middle basin



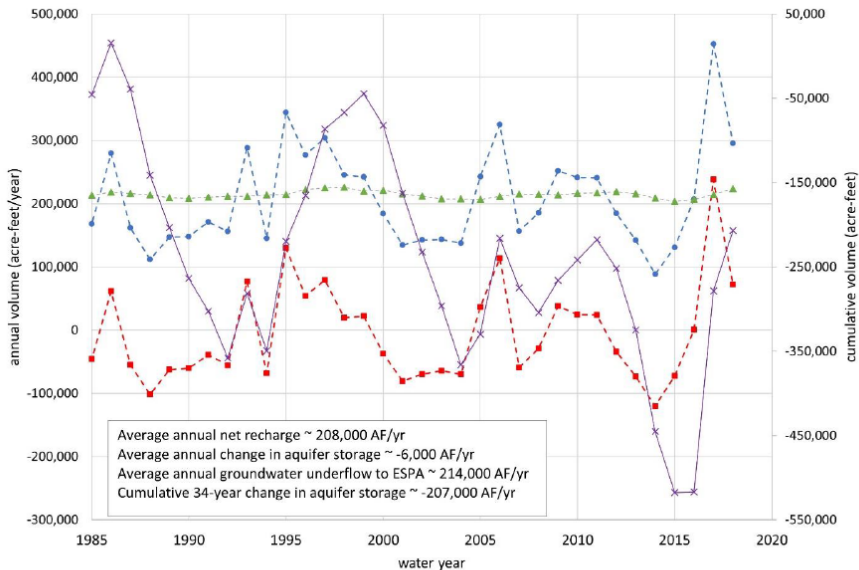
- Groundwater flow out of lower basin toward ESPA



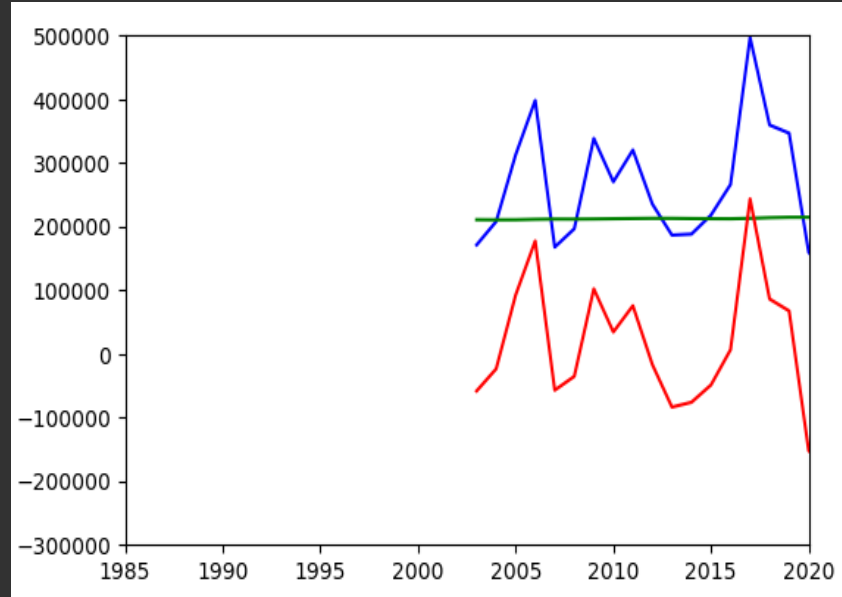
**NOTE: comparing model outflow to the budget's GW residual which includes effects of storage change**

# GW Budget estimates

- Comparing to ESPAM2.2

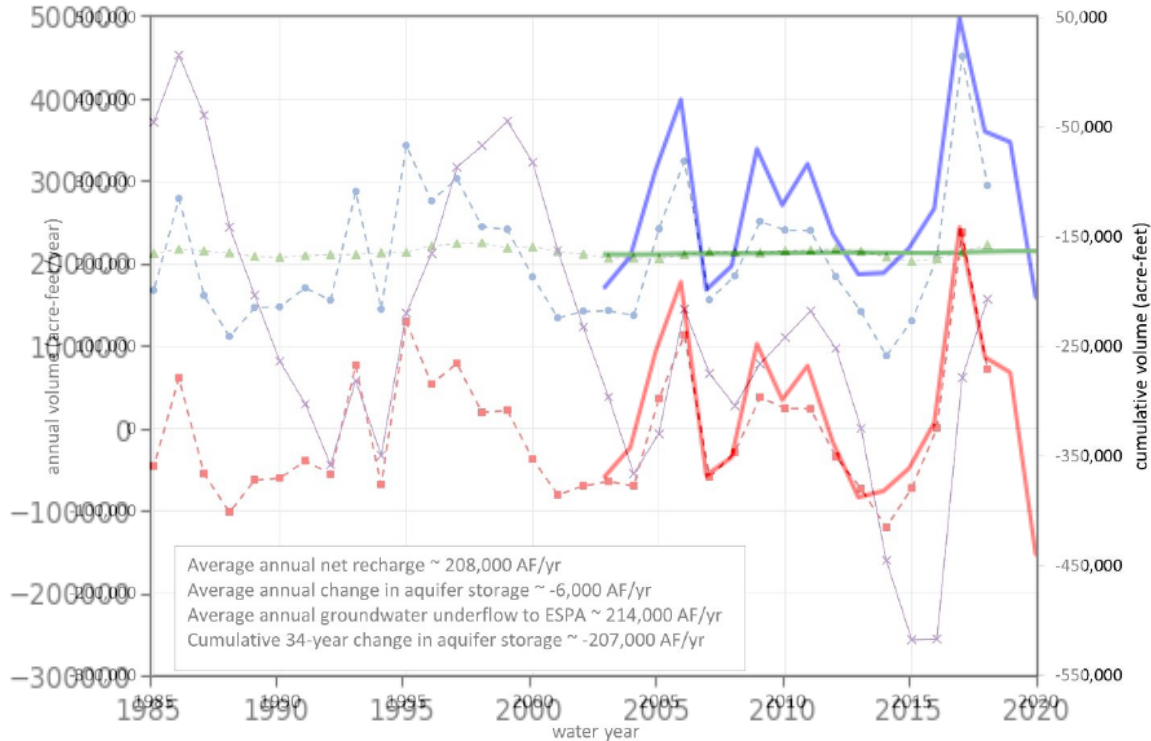


- - annual net recharge (recharge less groundwater withdrawal) - - annual change in aquifer storage within Big Lost valley  
 - - annual groundwater underflow at mouth of Big Lost valley - - cumulative change in aquifer storage within Big Lost valley



# GW Budget estimates

- Comparing to ESPAM2.2



# Thanks!

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