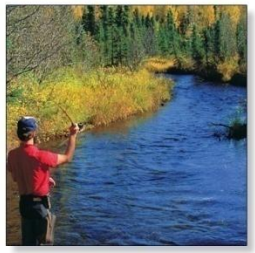
Example Predictive Uncertainty for the Wood River Valley Aquifer Model

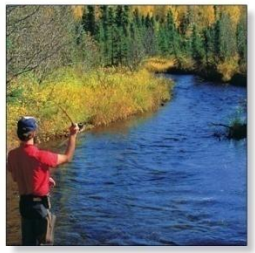
Presented by Allan Wylie, IDWR

Date October 1, 2015

Outline

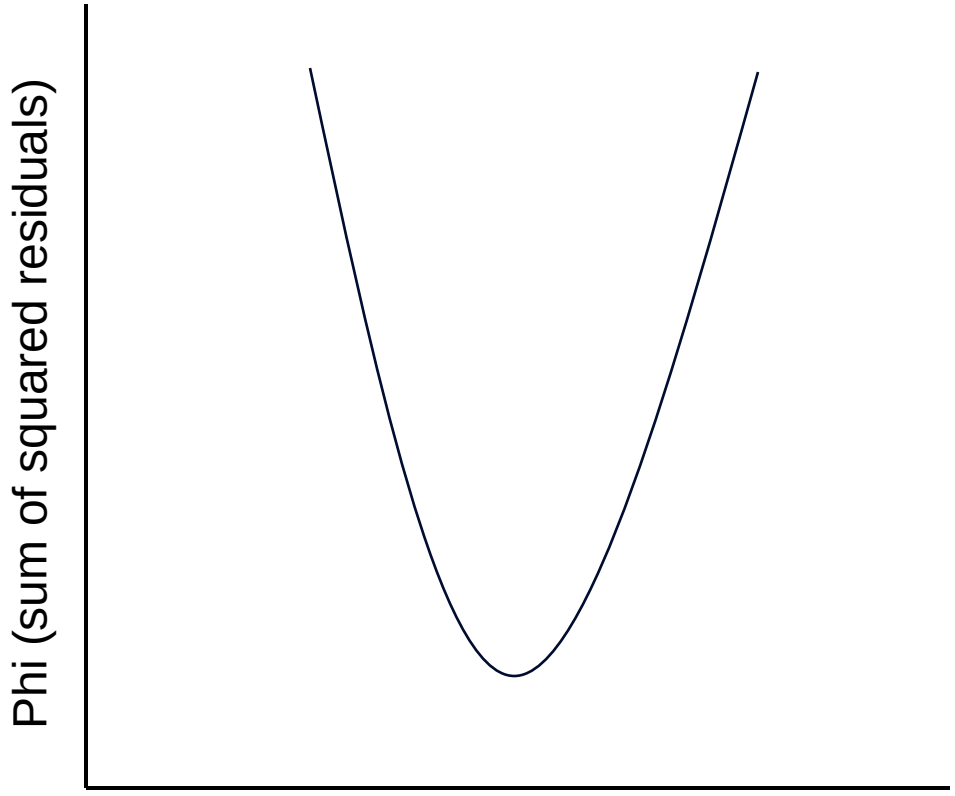
- How well does our data and calibration process define adjustable parameters
  - Hydraulic conductivity
  - Specific yield/storage
  - Riverbed/drain conductance
  - Entity irrigation efficiency
  - Tributary underflow
- Example Uncertainty Analysis

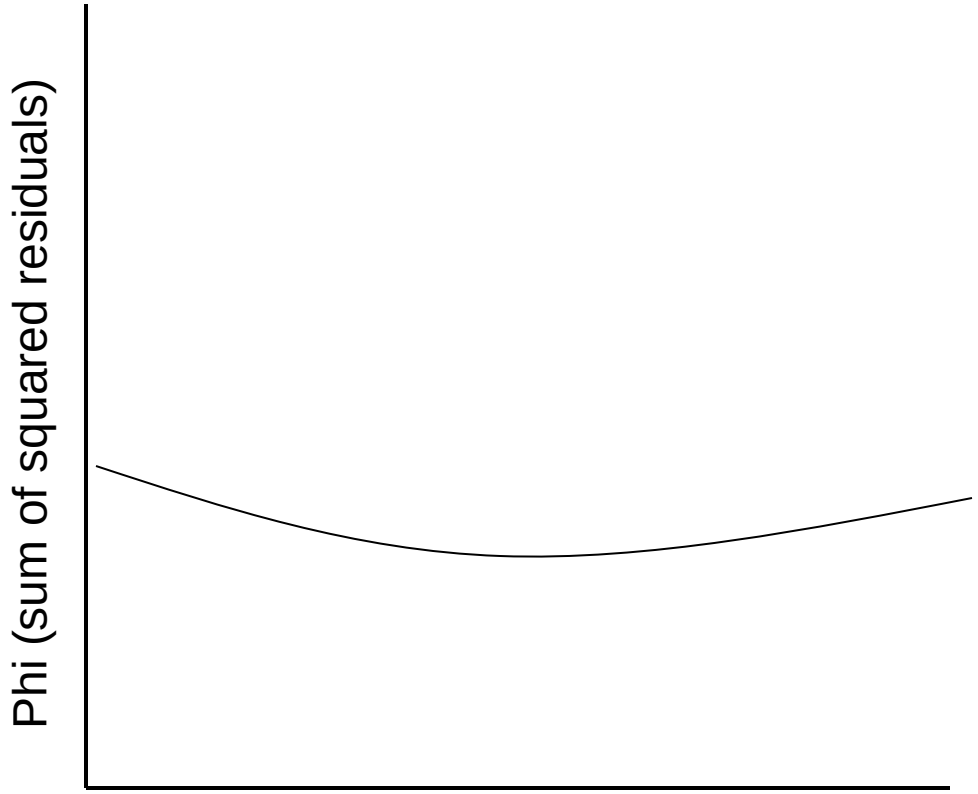
Assumptions

- Analysis assumes that model is linear
  - Neither the natural system nor the model is linear
- Analysis assumes that uncertainty is normally distributed
  - Uncertainty is not normally distributed
- Analysis assumes observations weights are inversely proportional to uncertainty
  - Sometimes true, sometimes not true
- Analysis is still informative
  - Identifies the parameters and predictions that are tightly constrained by the calibration and those that are loosely constrained by the calibration

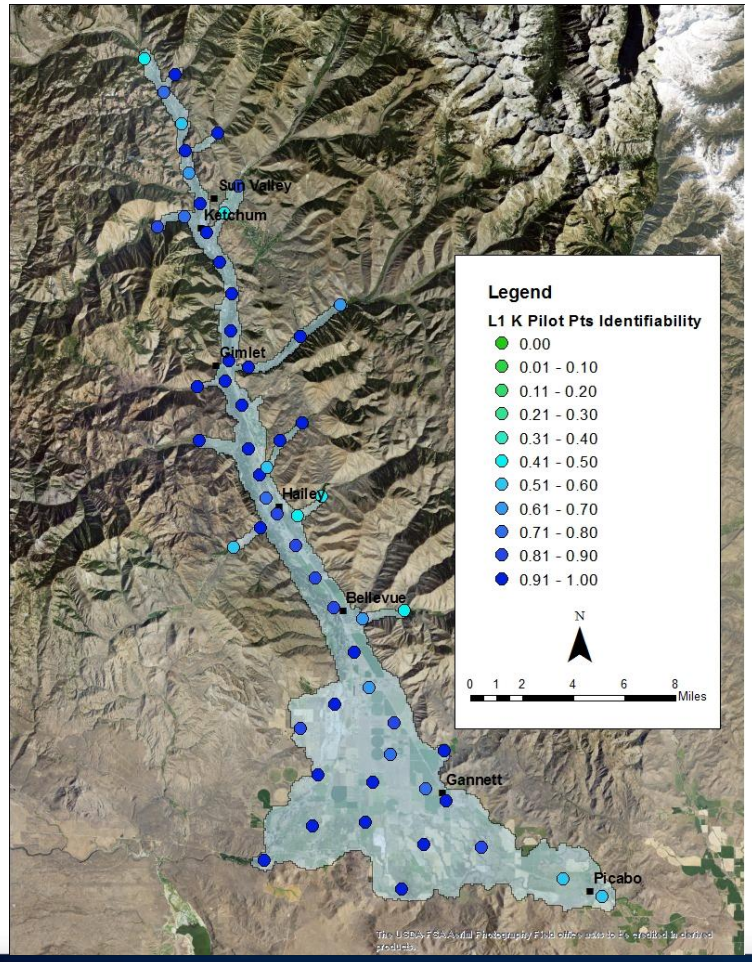
Parameter Identifiability Definition



Parameter Identifiability Definition

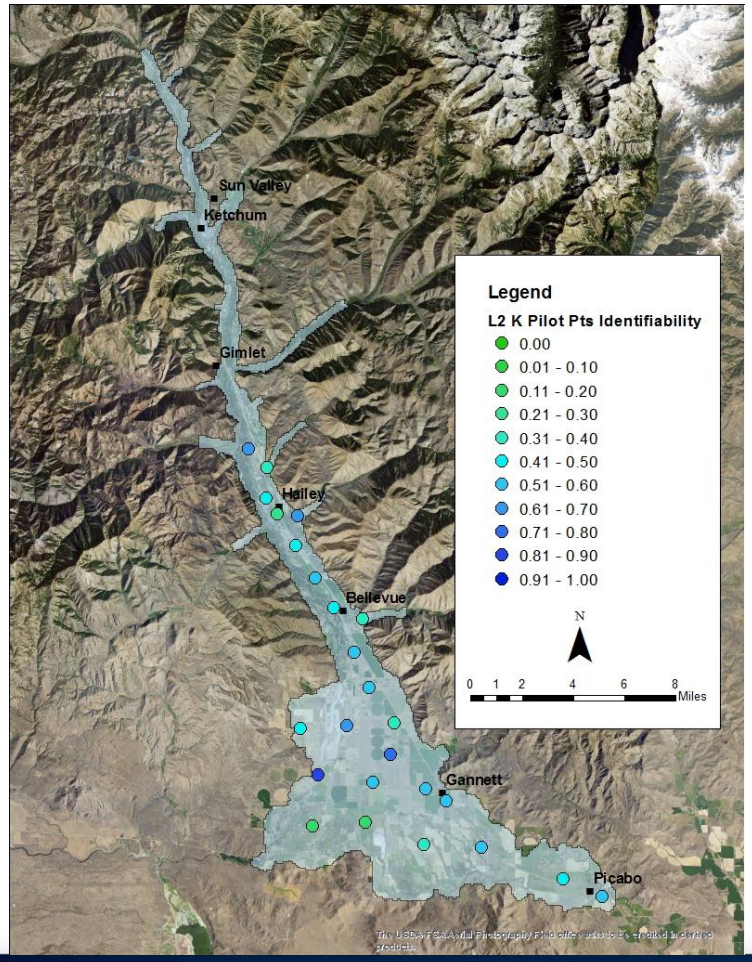


Parameter Uncertainty, L1 K



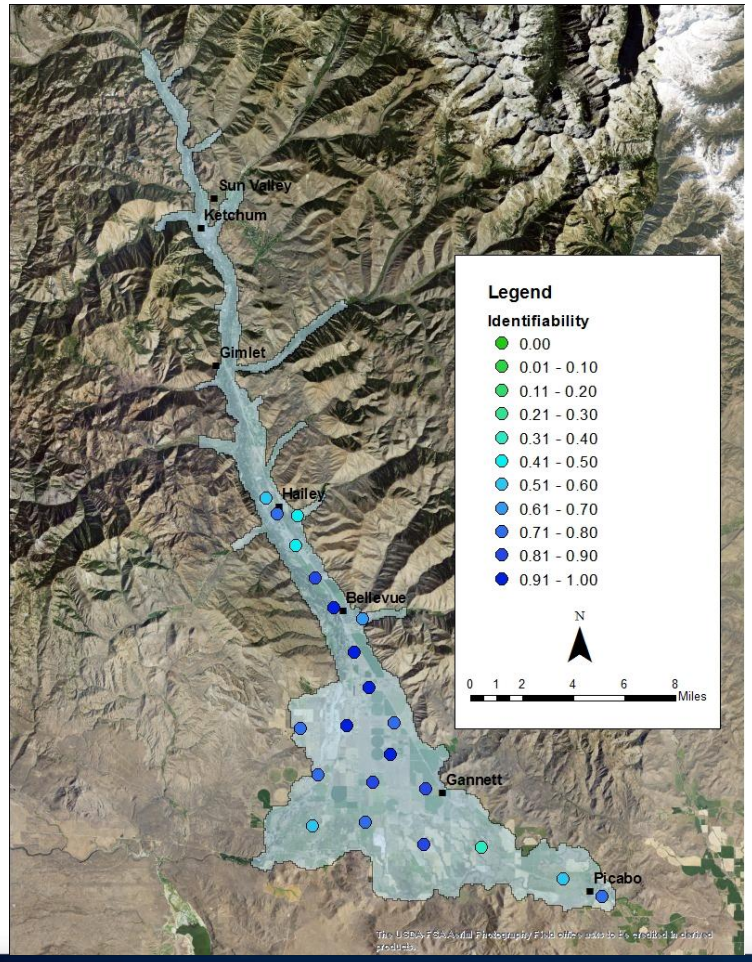
- Layer 1 K
  - Defined by 568 wells with 2,524 observations
    - ~6 observations per well
    - 1,575 in 8 wells during last year of calibration period
  - Constrained by the calibration

Parameter Uncertainty, L2 K



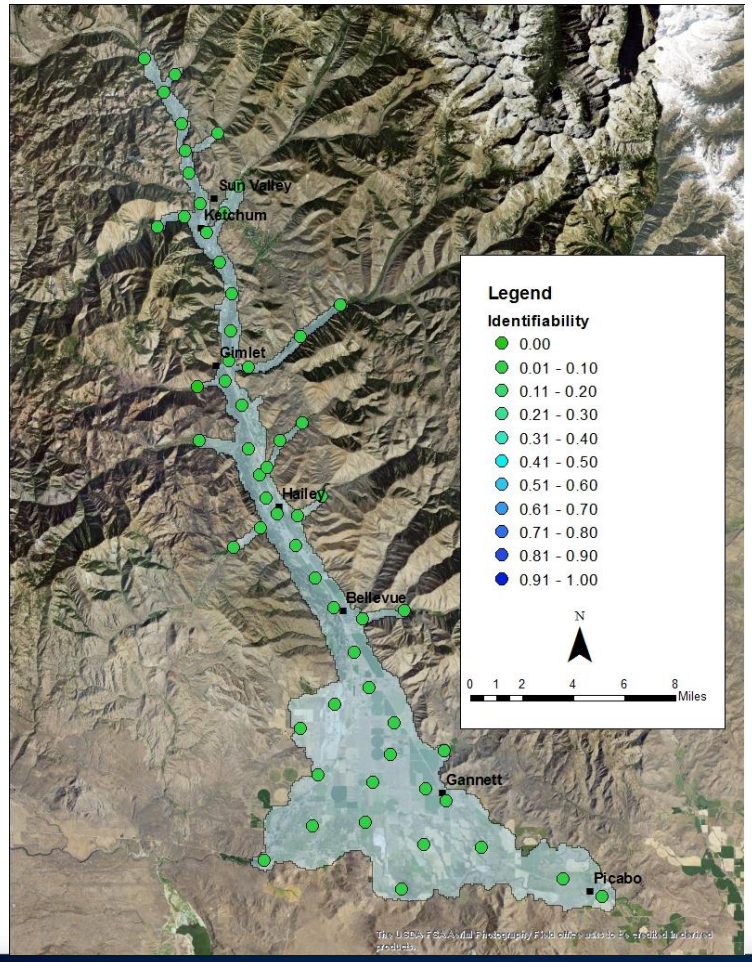
- Layer 2 K
  - Defined by 16 wells with 263 observations
    - 251 observations in one well

Parameter Uncertainty, L3 K



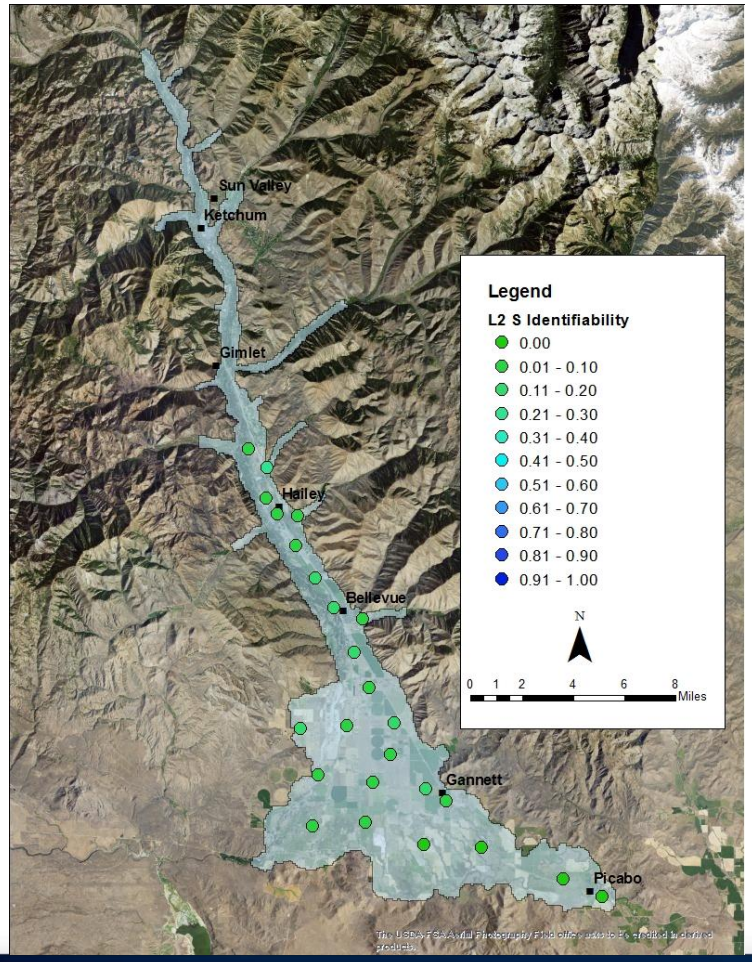
- Layer 3 K
  - Defined by 196 wells with 422 observations
    - 201 observations in one well

Parameter Uncertainty, L1 Sy



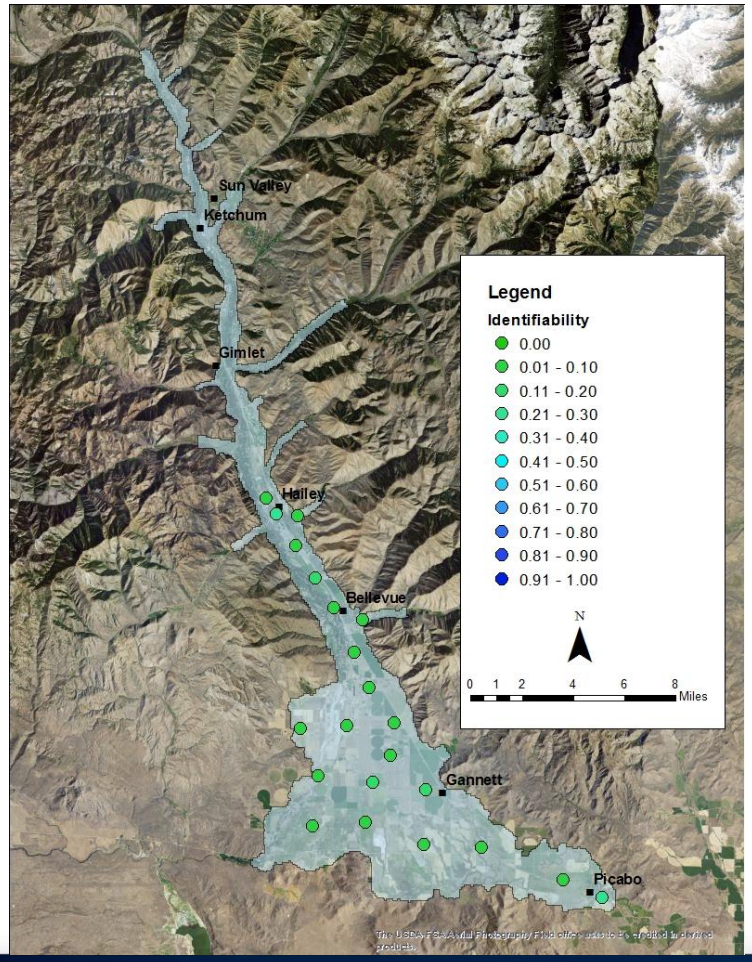
- Layer 1 Sy
  - Defined by 568 wells with 2,524 observations
    - ~6 observations per well
    - 1,575 in 8 wells in last year of calibration period
  - Most wells don't have regularly repeated observations

Parameter Uncertainty, L2 S



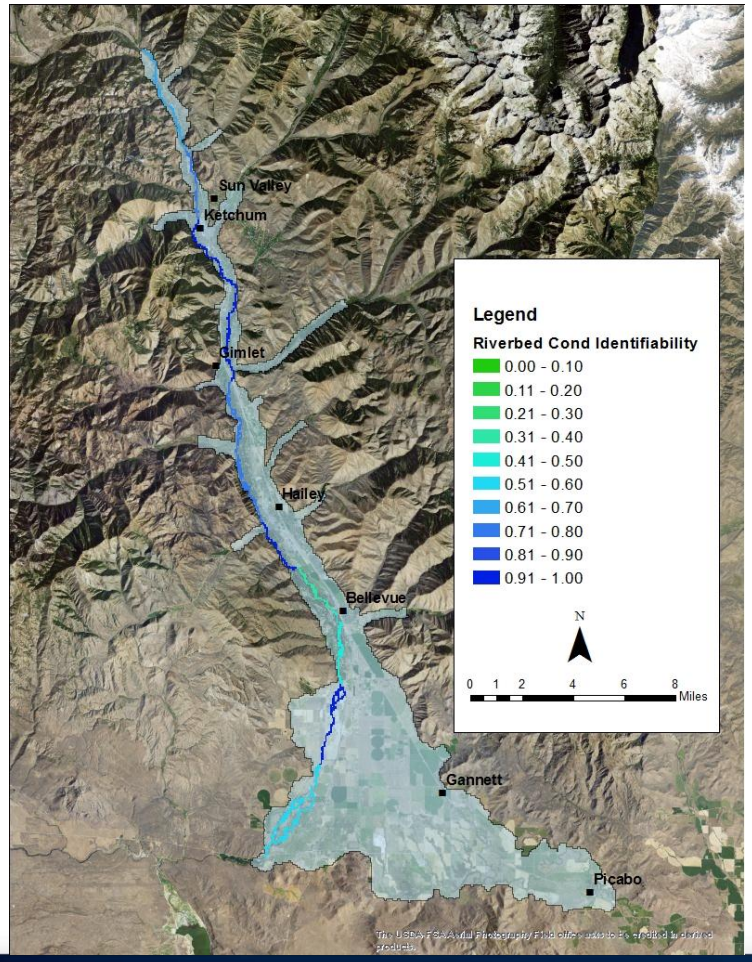
- Layer 2 S
  - Defined by 16 wells with 263 observations
    - 251 observations in one well
  - Most wells don't have regularly repeated observations

Parameter Uncertainty, L3 S



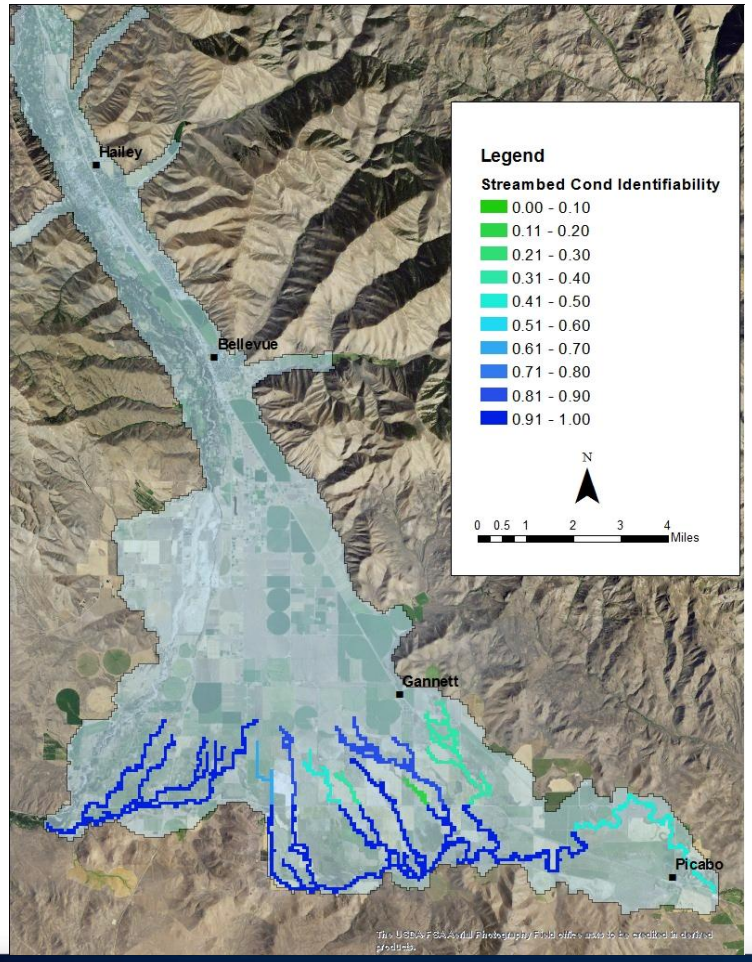
- Layer 3 S
  - Defined by 196 wells with 422 observations
    - 201 observations in one well
  - Most wells don't have regularly repeated observations

Parameter Uncertainty, Wood R



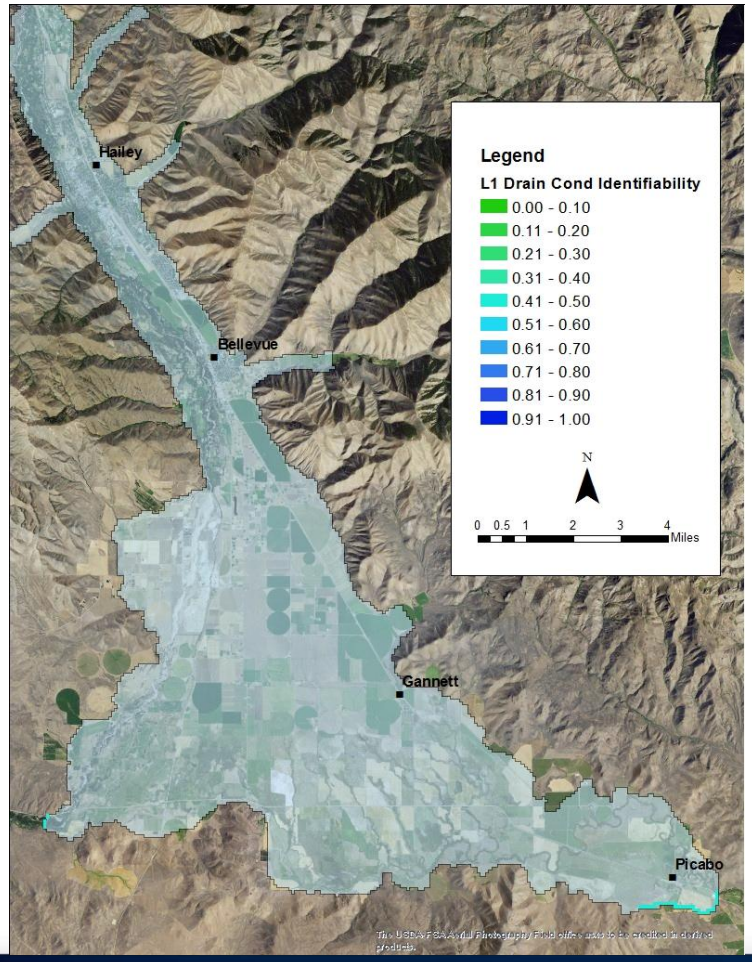
- Wood River riverbed conductance
  - Defined by 284 reach gain observations
  - Riverbed conductance includes length, width, and hydraulic conductivity
  - Average for reach

Parameter Uncertainty, Stream



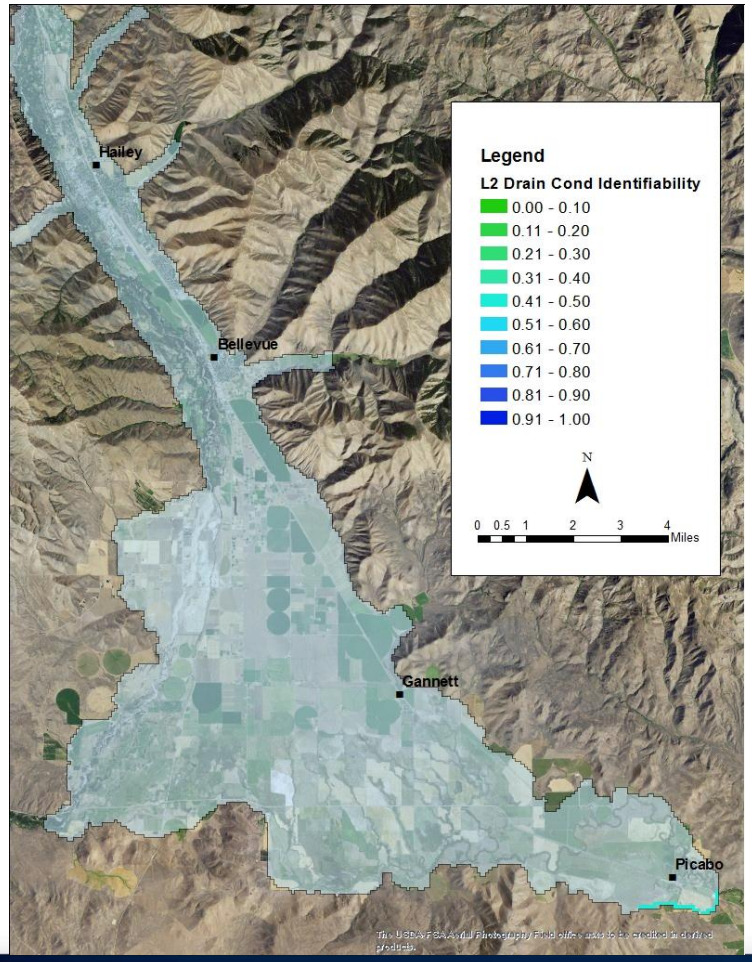
- Willow and Silver Cr conductance
  - Defined by 509 reach gain observations

Parameter Uncertainty, Drain



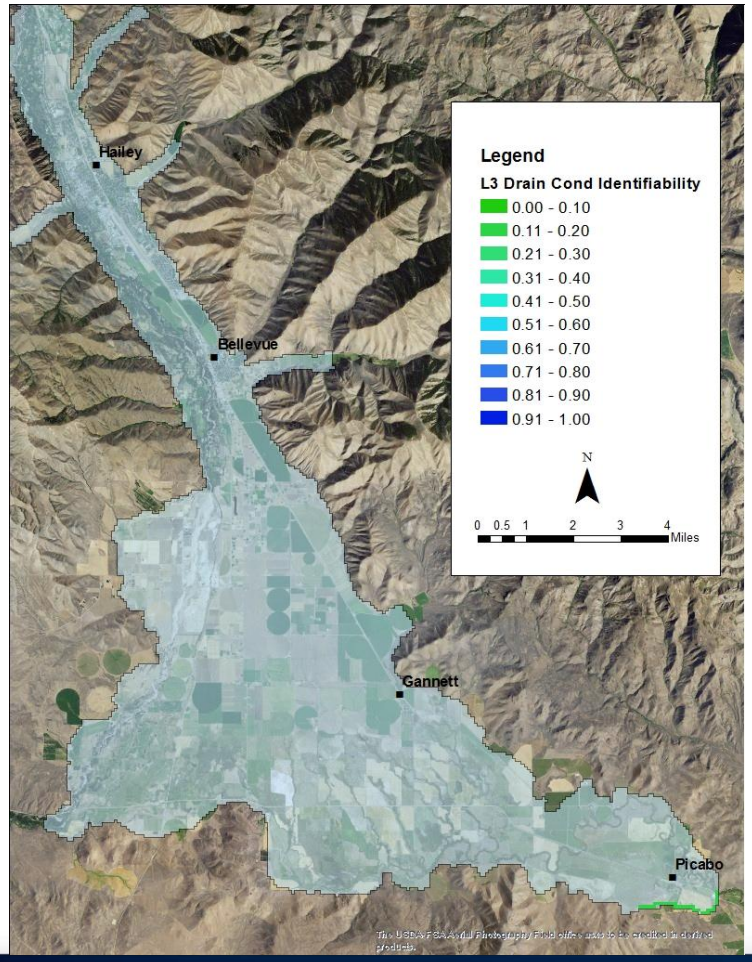
- Layer 1 drain conductance
  - Defined by two estimated observations

Parameter Uncertainty, Drain



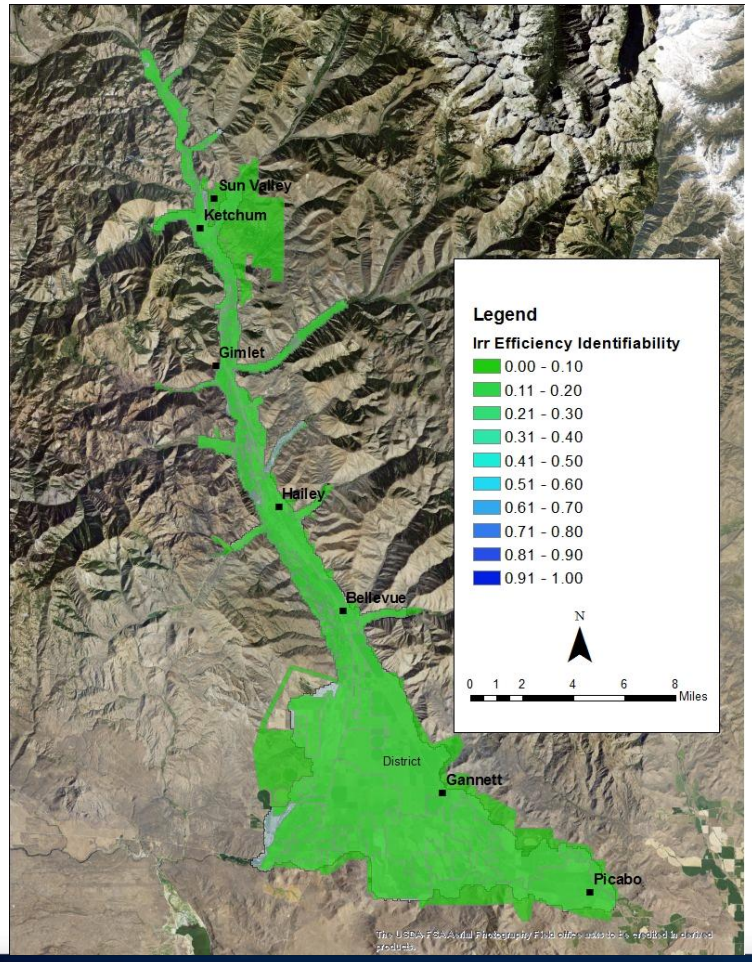
- Layer 2 drain conductance
  - Defined by estimated observation

Parameter Uncertainty, Drain



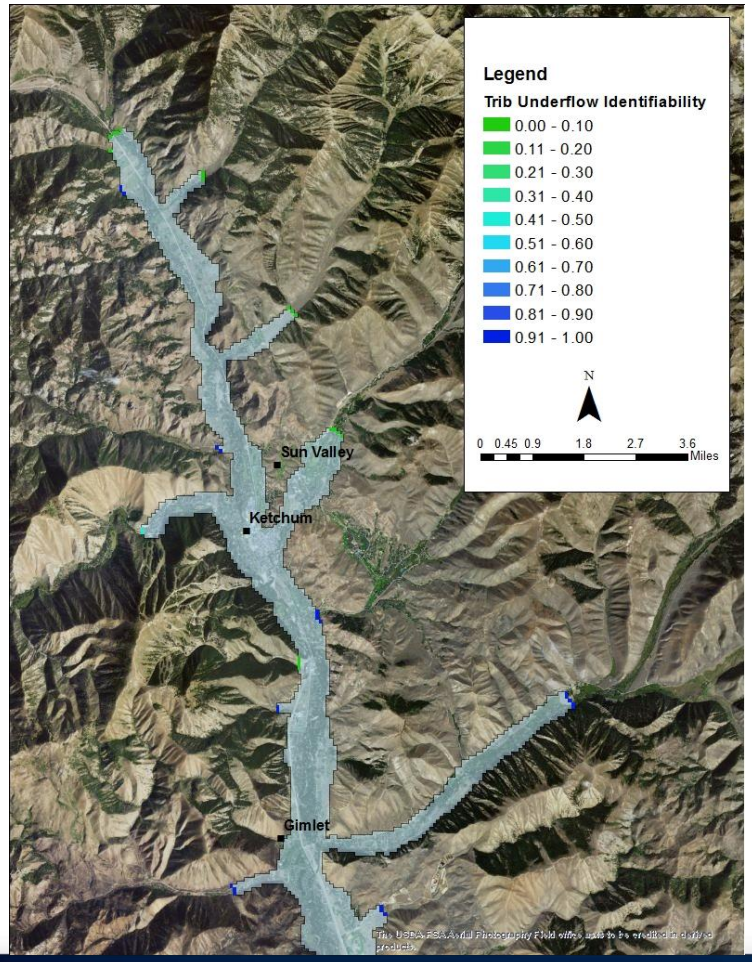
- Layer 3 drain conductance
  - Defined by estimated observation

Parameter Uncertainty, Irrigation Entity Efficiency



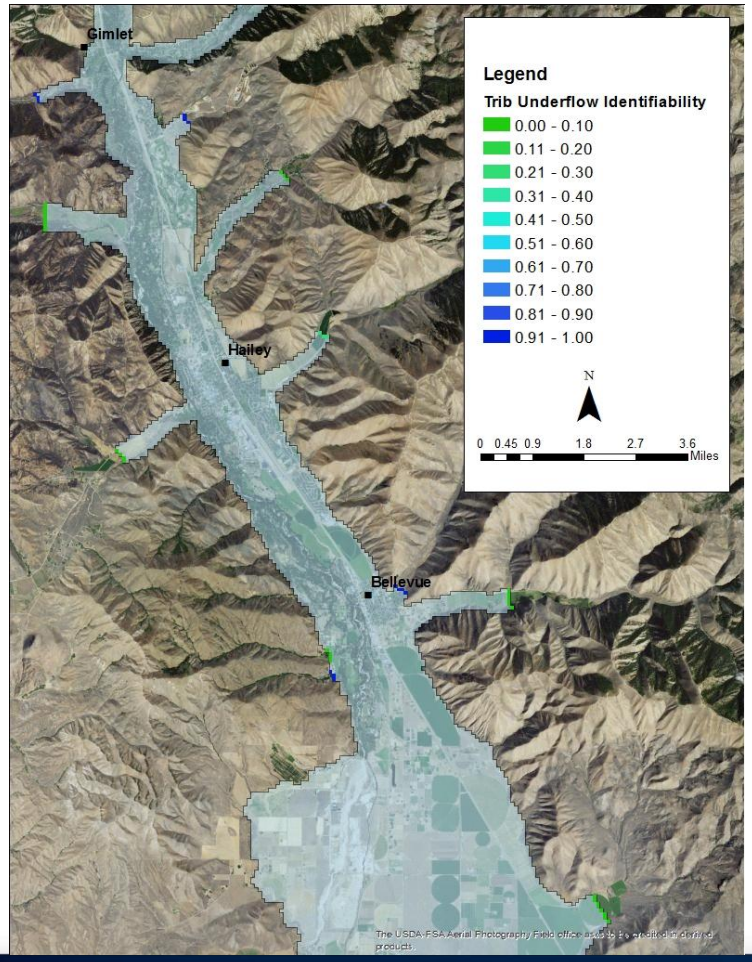
- Irrigation entity efficiency
  - Only applied to entities with groundwater irrigation

Parameter Uncertainty, Tributary Underflow



- Tributary underflow scalar
  - Used to adjust the average annual tributary underflow

Parameter Uncertainty, Tributary Underflow (2)

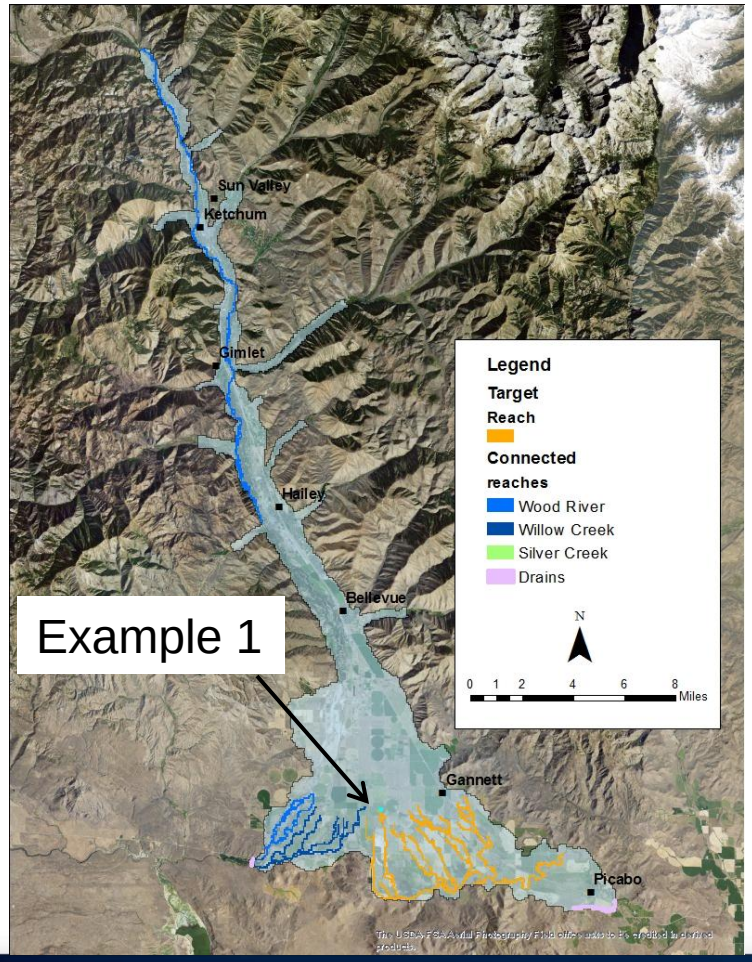


- Tributary underflow scalar
  - Used to adjust the average annual tributary underflow

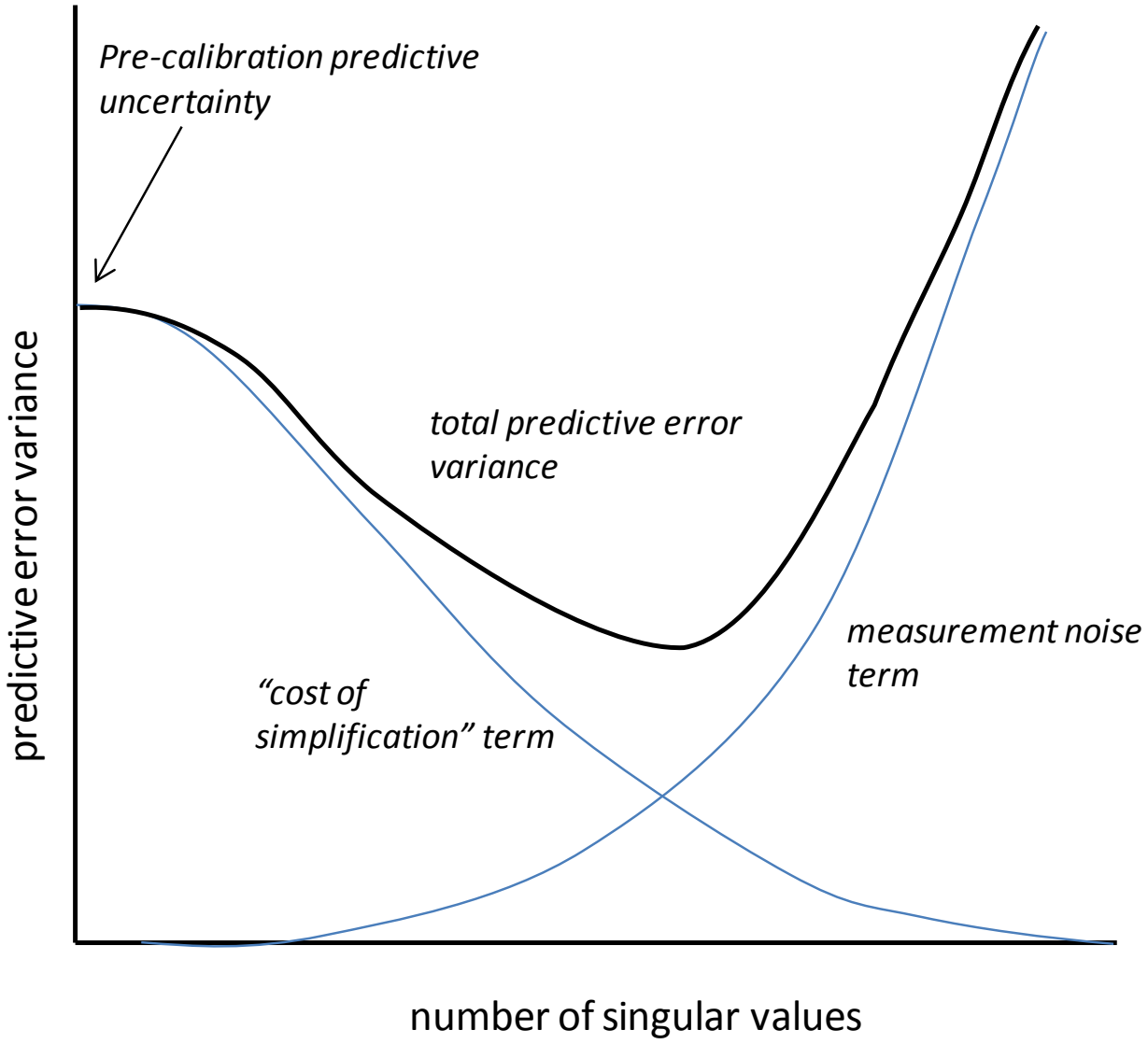
Nonadjustable Parameters

- Correlated, data too sparse, too complex, etc
- Reasonable assumptions
- Doesn't mean they don't impact the model
  - Canal seepage
  - Extent of the confining layer
  - Extent of basalt
  - Non-irrigated recharge
  - River stage
  - Etc

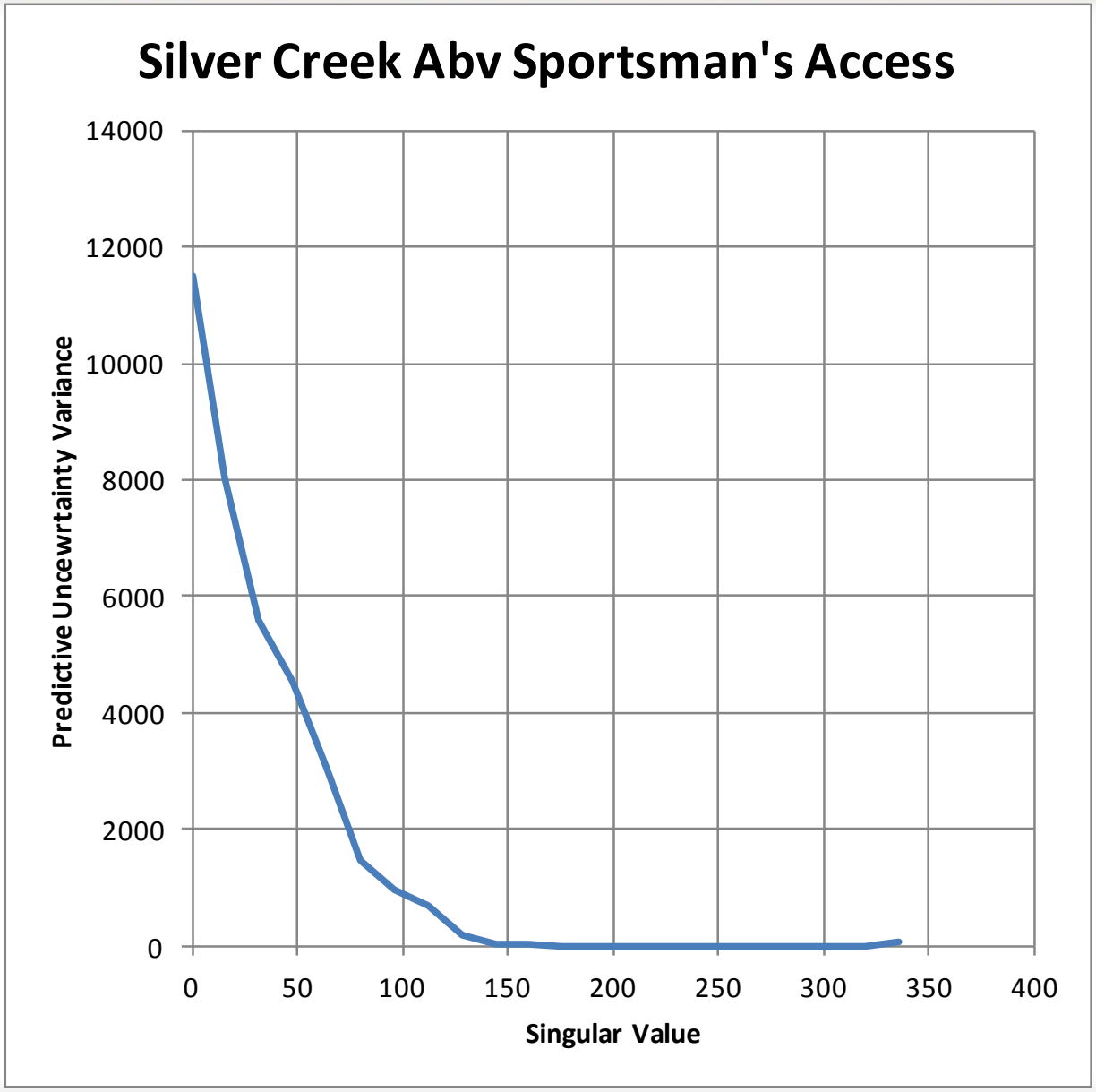
Example 1



- Superposition
- Steadystate
- Pumping well in layer 3 beneath confining layer
- Predict impact on Silver Creek



From "PEST-Based Model Predictive Uncertainty Analysis" by John Doherty, 2010

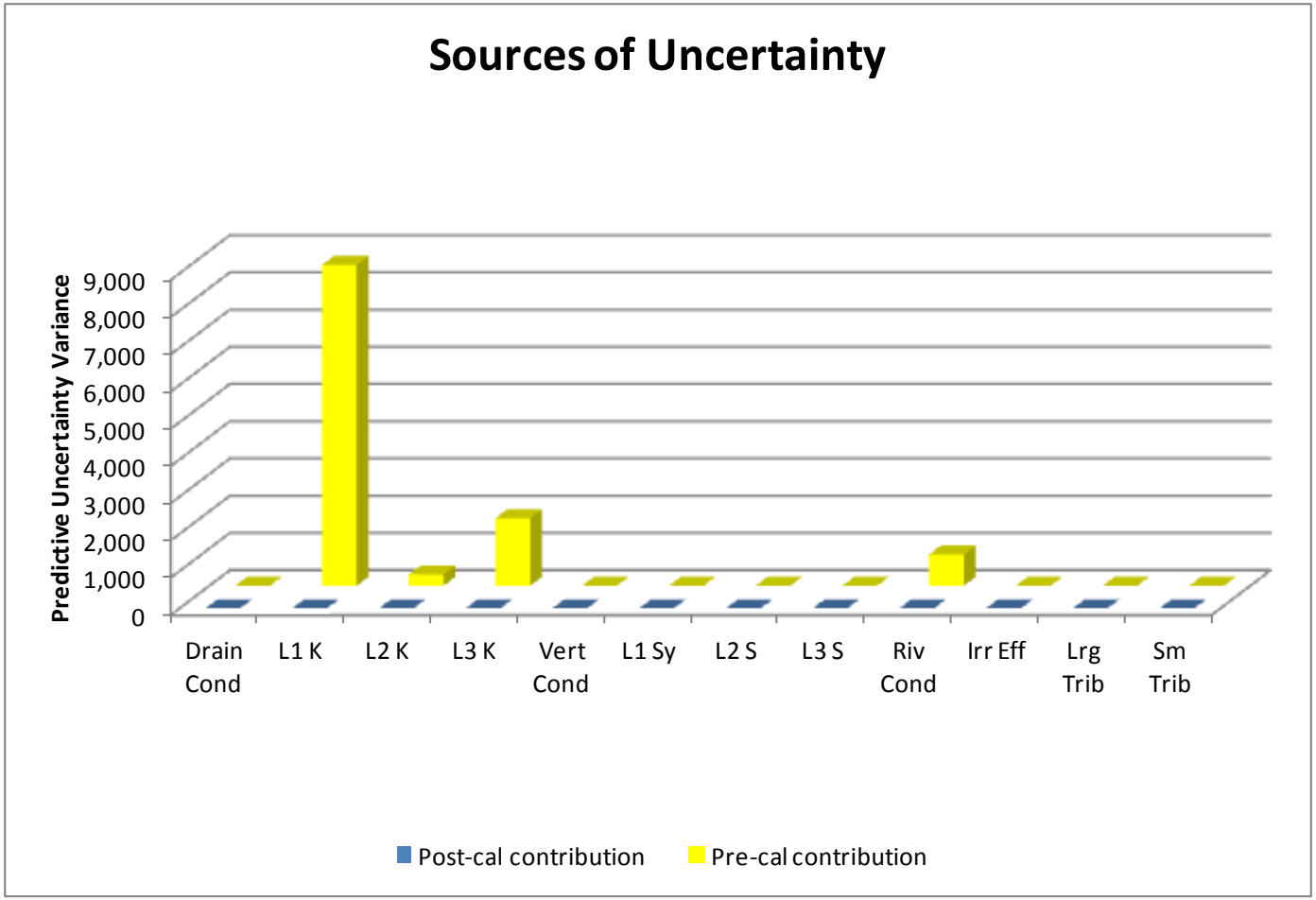

Silver Creek Abv Sportsman's Access
Predictive Uncewrtainty Variance
14000
12000
10000
8000
6000
4000
2000
0
0
50
100
150
200
250
300
350
400
Singular Value

Analysis

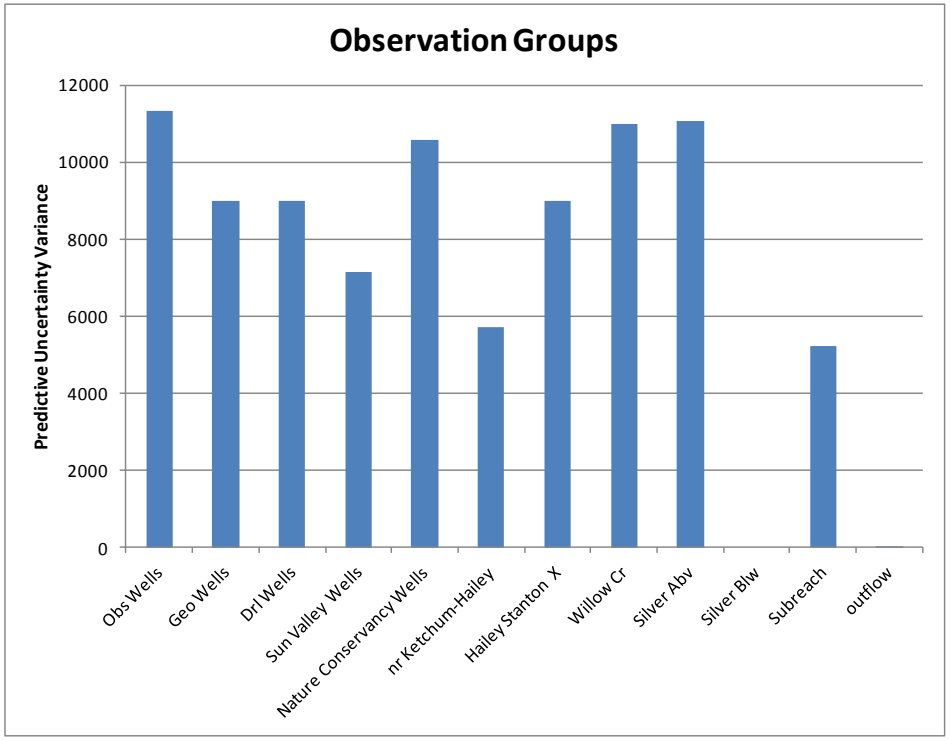
- Example 1
  - Impact of injecting in layer 3 beneath confining layer
- Analysis for predicted impact on Silver Creek
  - Without calibration
    - Total error standard deviation = 107
  - After calibration
    - Total error standard deviation = 9.5
      - 68, 95, 99.7 rule
      - 95% confidence ~ 75% +/- 19%

Reach	Impact at steady state
nr Ketchum-Hailey	0.79%
Hailey-Stanton Crossing, Willow Cr + Subsurface Discharge	24.52%
Silver Creek	74.69%
Silver Cr Blw Sportsman's Access + Subsurface Discharge	0.00004%
Total	100.00%

Sources of Uncertainty

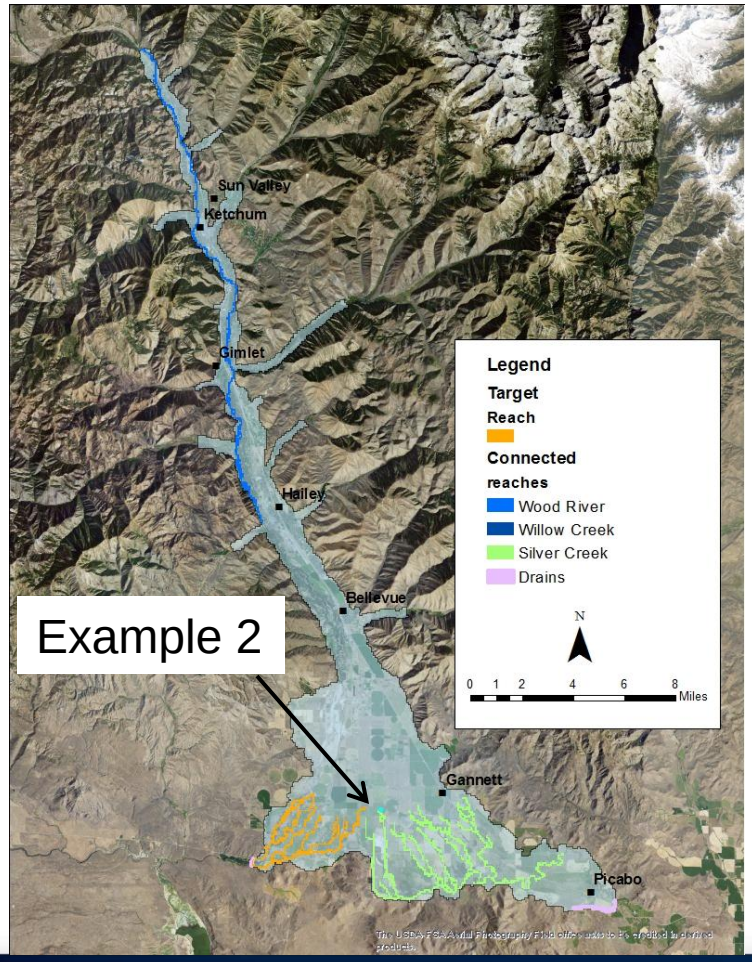


Reductions in Uncertainty

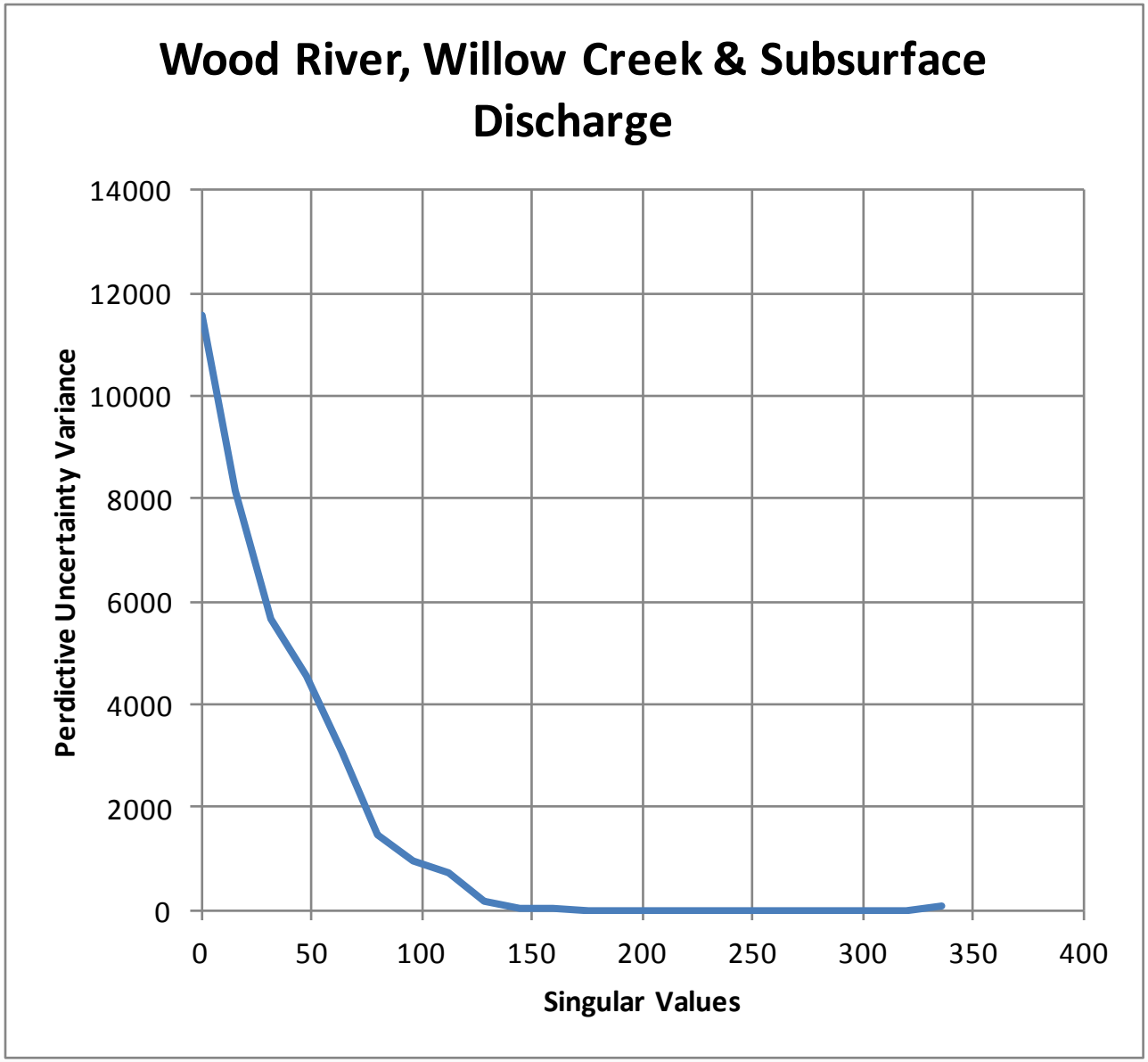


- Determined by subtraction
  - Remove dataset and recheck analysis

Example 2



- Superposition
- Steadystate
- Pumping well in layer 3 beneath confining layer
- Predict impact on Wood River below Hailey, Willow Cr, and subsurface discharge at Stanton Crossing


Wood River, Willow Creek & Subsurface Discharge
Perdictive Uncertainty Variance
14000
12000
10000
8000
6000
4000
2000
0
0
50
100
150
200
250
300
350
400
Singular Values

Analysis

- Example 2
  - Impact of injecting in layer 3 beneath confining layer
- Analysis for predicted impact on Wood River below Hailey, Willow Creek and Subsurface discharge at Stanton Crossing
  - Without calibration
    - Total error standard deviation = 107
  - After calibration
    - Total error standard deviation = 10
      - 68, 95, 99.7 rule
      - 95% confidence ~ 24% +/- 20%

Reach	Impact at steady state
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Silver Creek	74.69%
Silver Cr Blw Sportsman's Access + Subsurface Discharge	0.00004%
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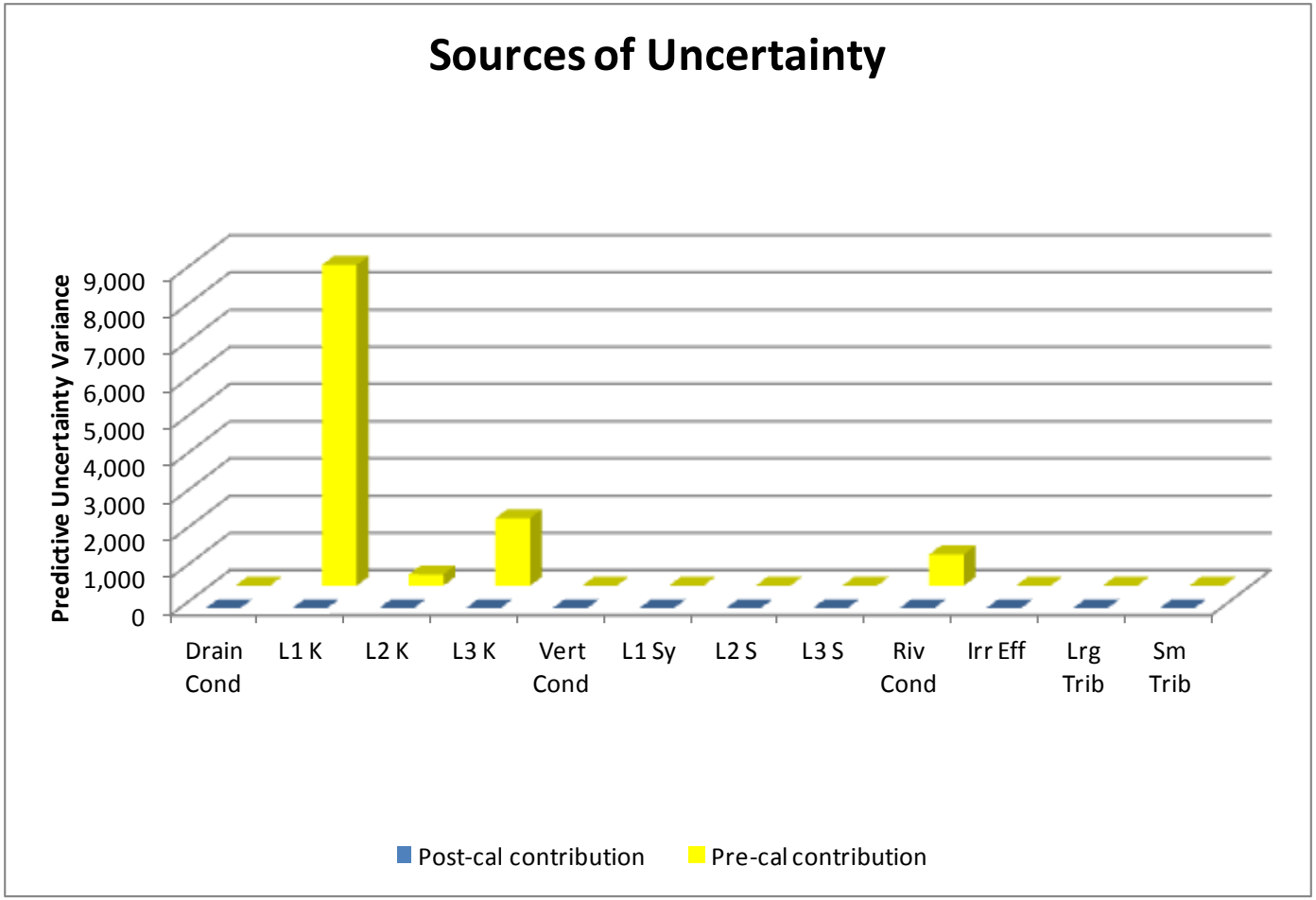
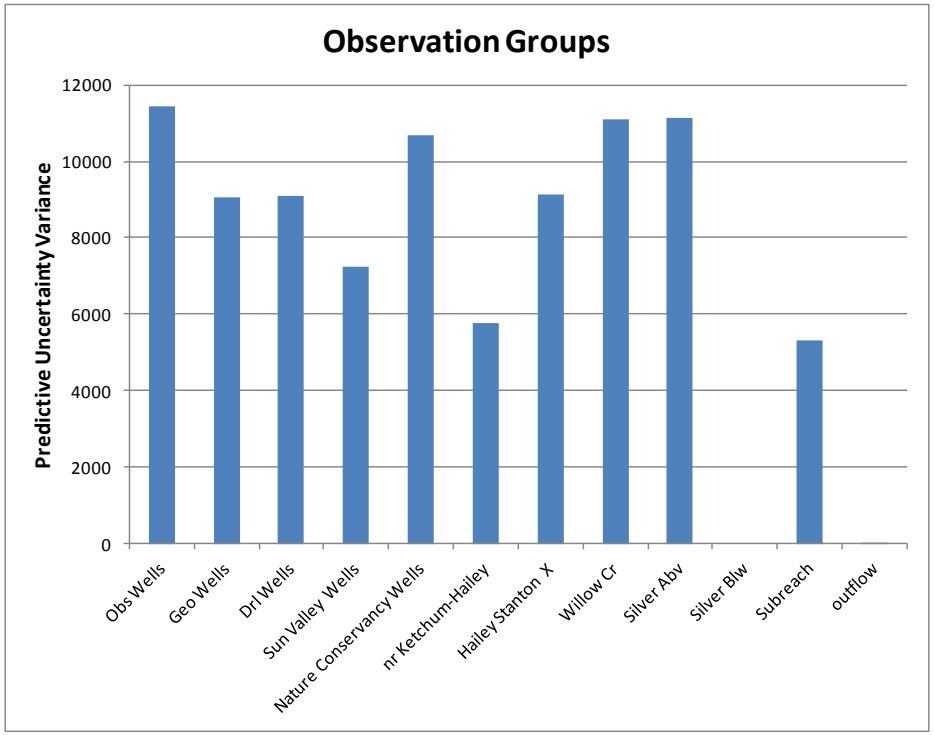


Reductions in Uncertainty



- Determined by subtraction
  - Remove dataset and recheck analysis

Summary

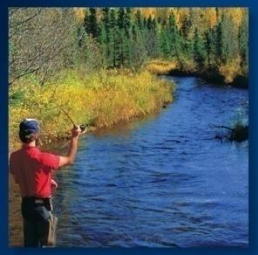
Analysis	Target Reach	Prediction	C.I. 95
Example 1	Silver Creek	74.69%	9.49%
Example 2	Willow Cr + Wood R	24.52%	10.23%

- Well injecting below the confining layer
- Observe the impact on selected surface water systems
  - Silver Creek above Sportsman's Access, subsurface outflow
  - Wood River below Hailey, Willow Cr, subsurface outflow

Conclusions

- The hydraulic conductivity distribution is constrained by the calibration
- Riverbed conductance is constrained by the calibration
- The storage coefficient distribution is loosely constrained by the calibration
- Drain conductance is loosely constrained by the calibration
- Irrigation entity efficiency is loosely constrained by the calibration
- Tributary underflow sometimes constrained sometimes loosely constrained by the calibration
- There are other parameters assigned “reasonable values” based on expert knowledge that are not adjustable
  - May or may not adversely impact predictive uncertainty
- 95% confidence interval for the selected examples did not include zero

IDAHO Department of Water Resources



End

All Wells Measured Once