Example Predictive Uncertainty Analysis

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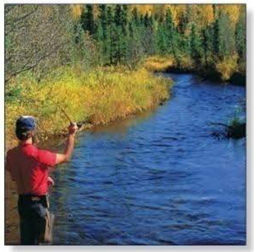
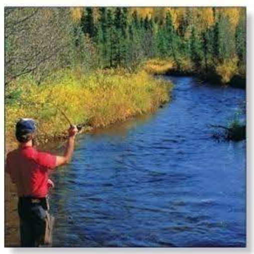
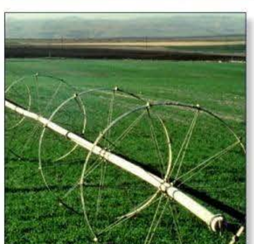
Date December 3, 2015

Outline

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

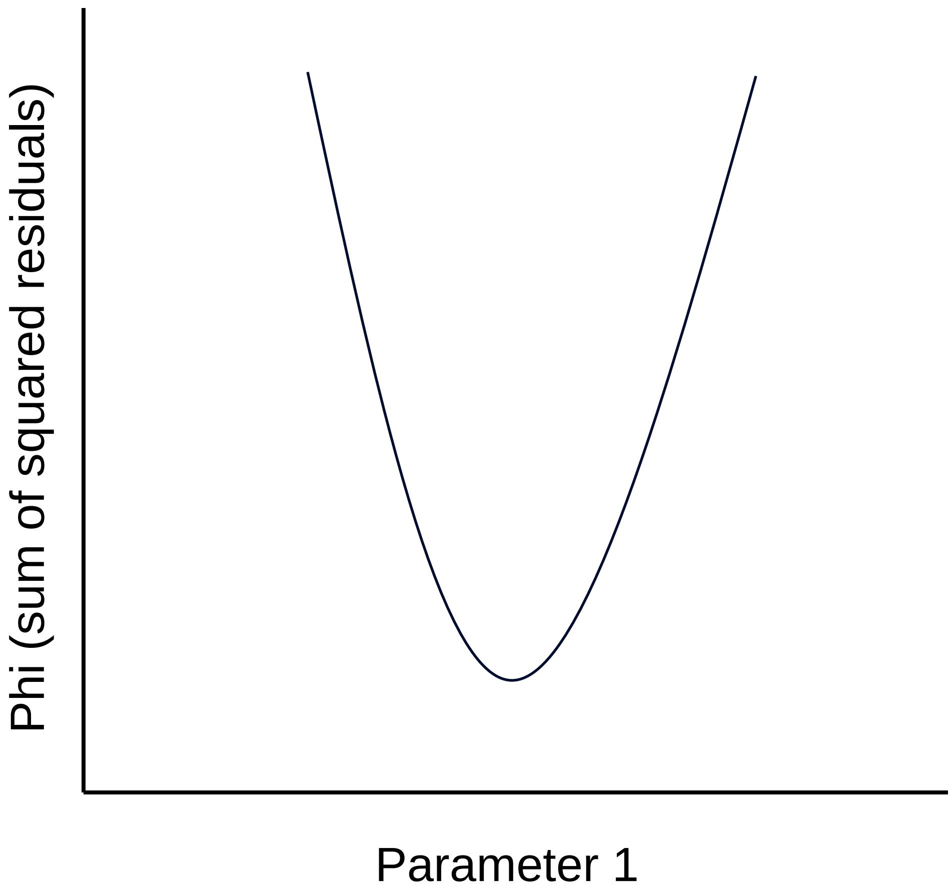





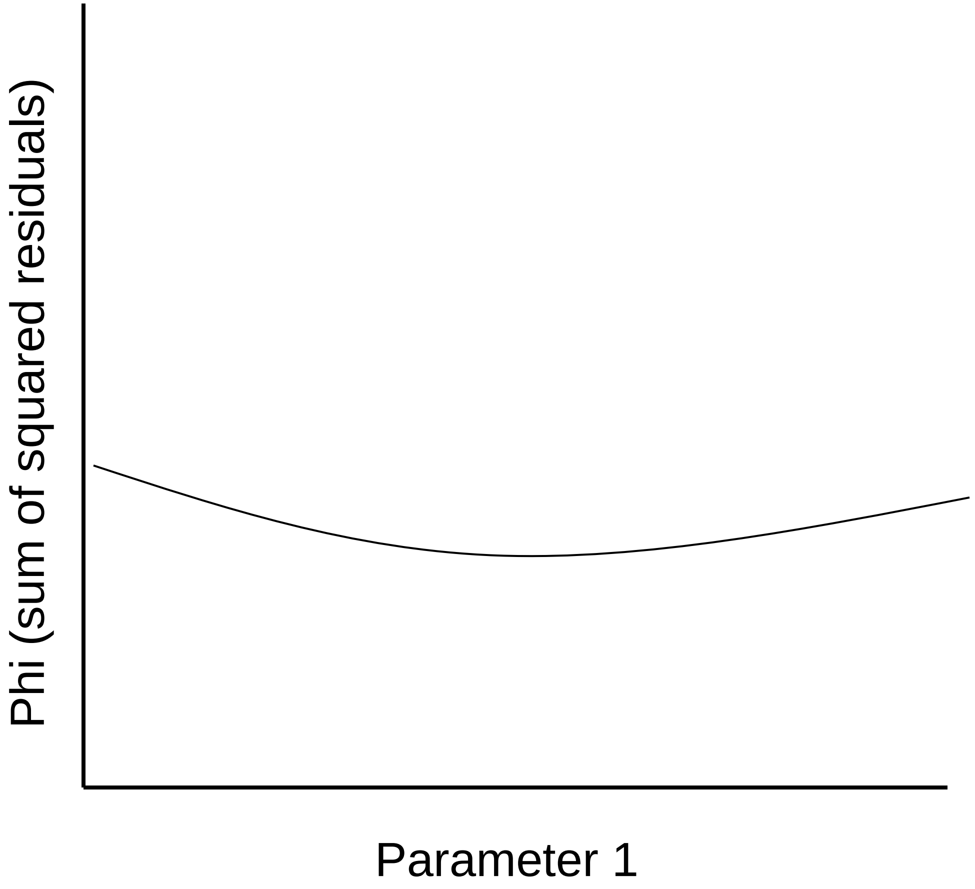
Assumptions

- 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

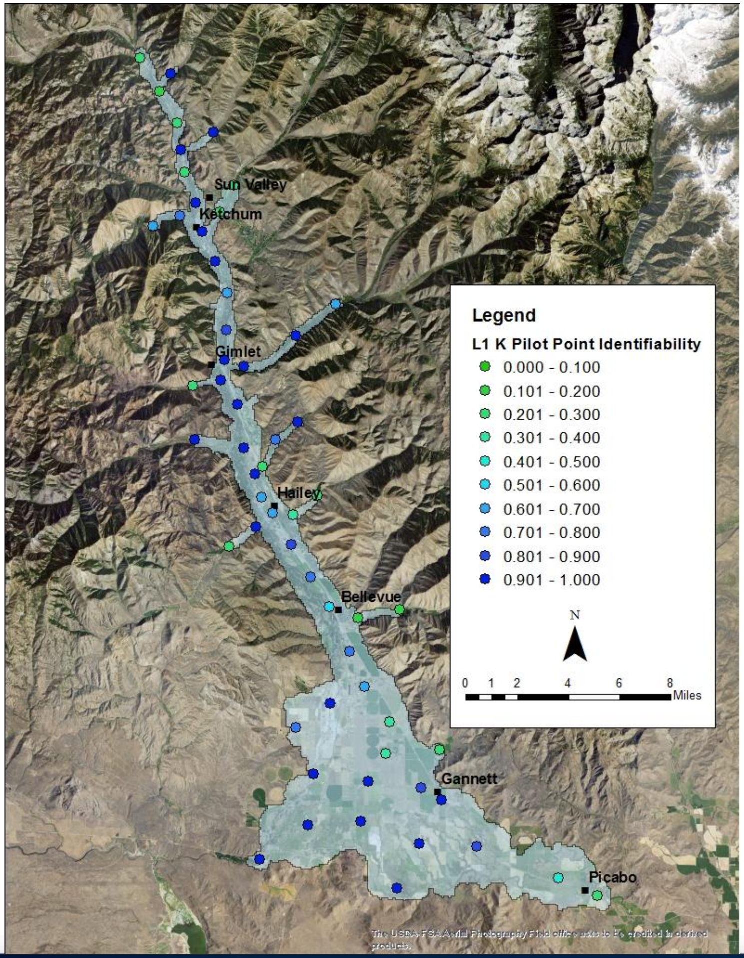
Parameter Identifiability Definition



Parameter Identifiability Definition

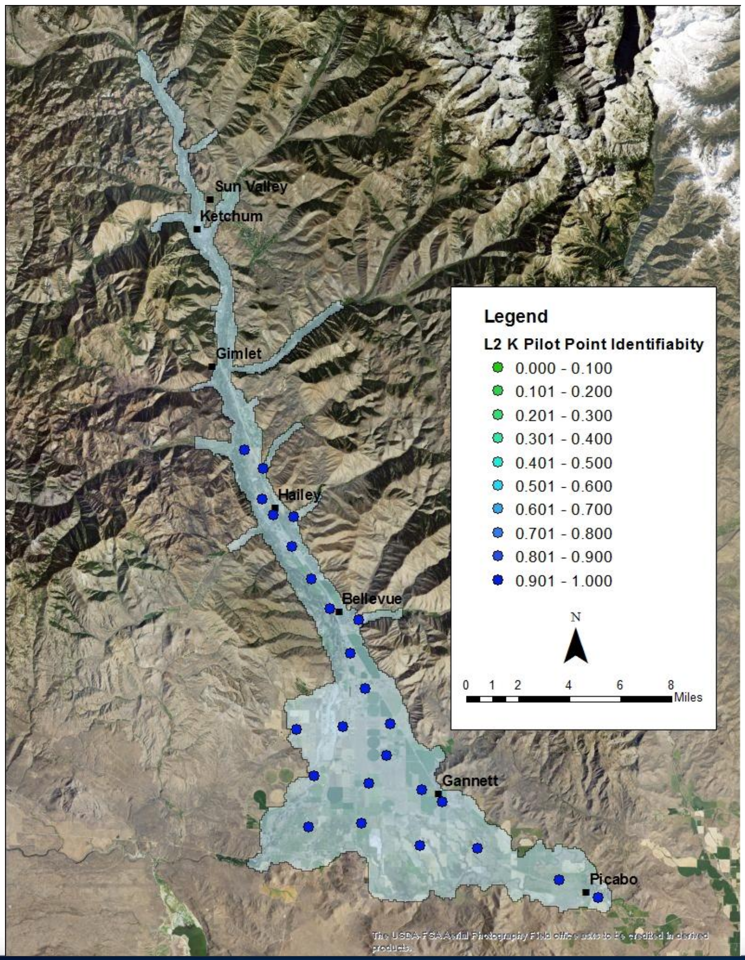


Parameter Identifiability, L1 K



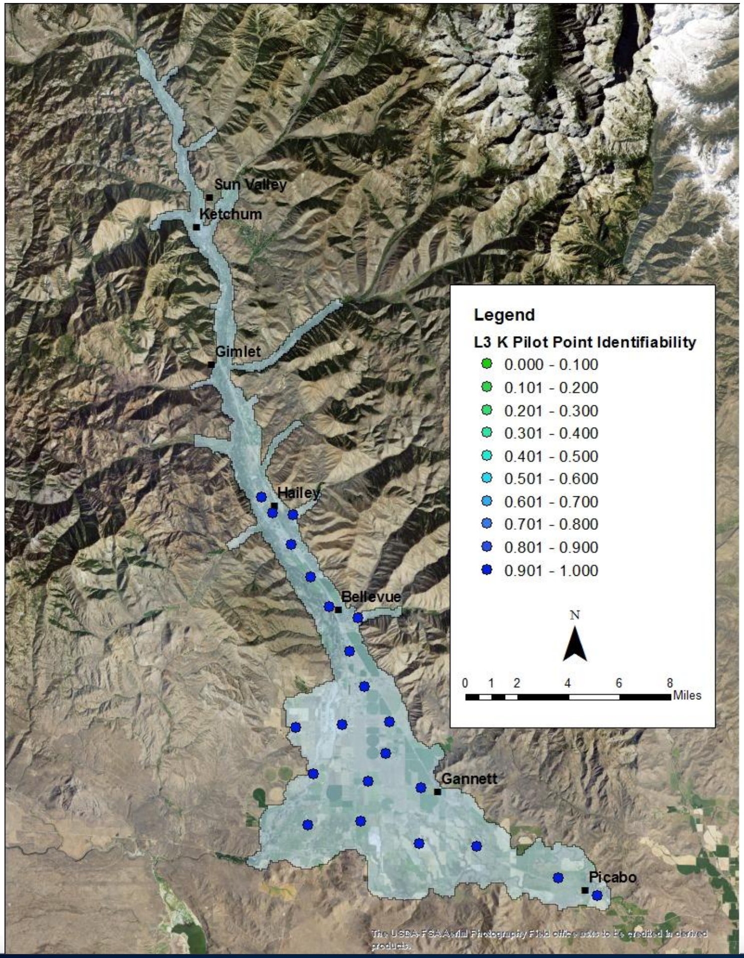
- Layer 1 K
  - Defined by 568 wells with 2,524 observations
    - ~6 observations per well
    - 1,575 in 8 wells during last year of calibration period
  - Constrained by the calibration

Parameter Identifiability, L2 K



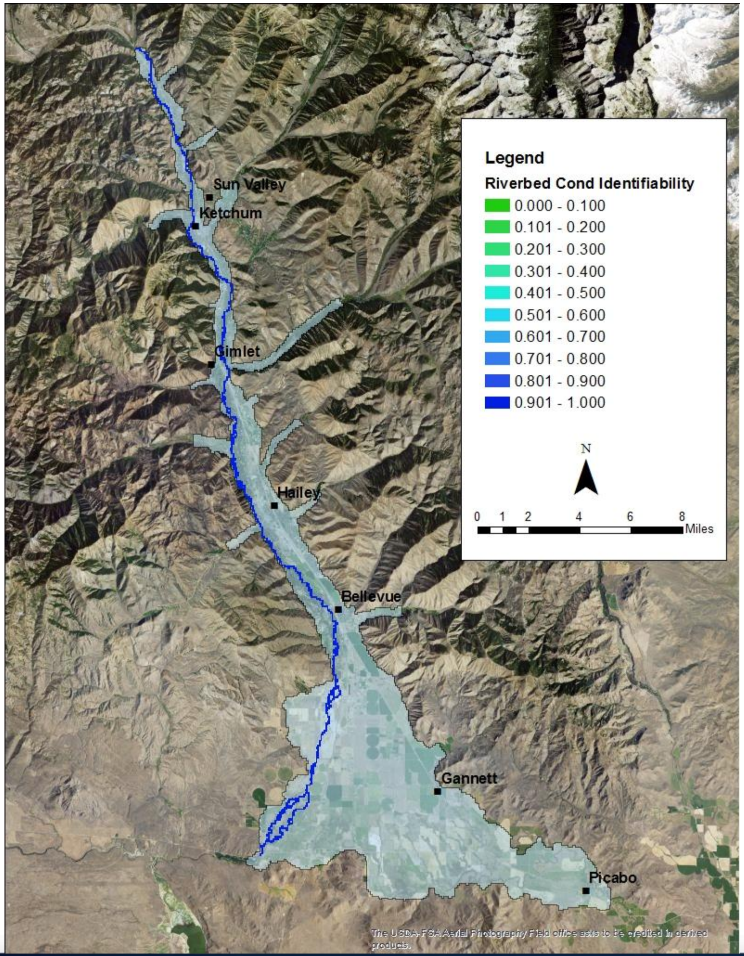
- Layer 2 K
  - Defined by 16 wells with 263 observations
    - 251 observations in one well

Parameter Identifiability, L3 K



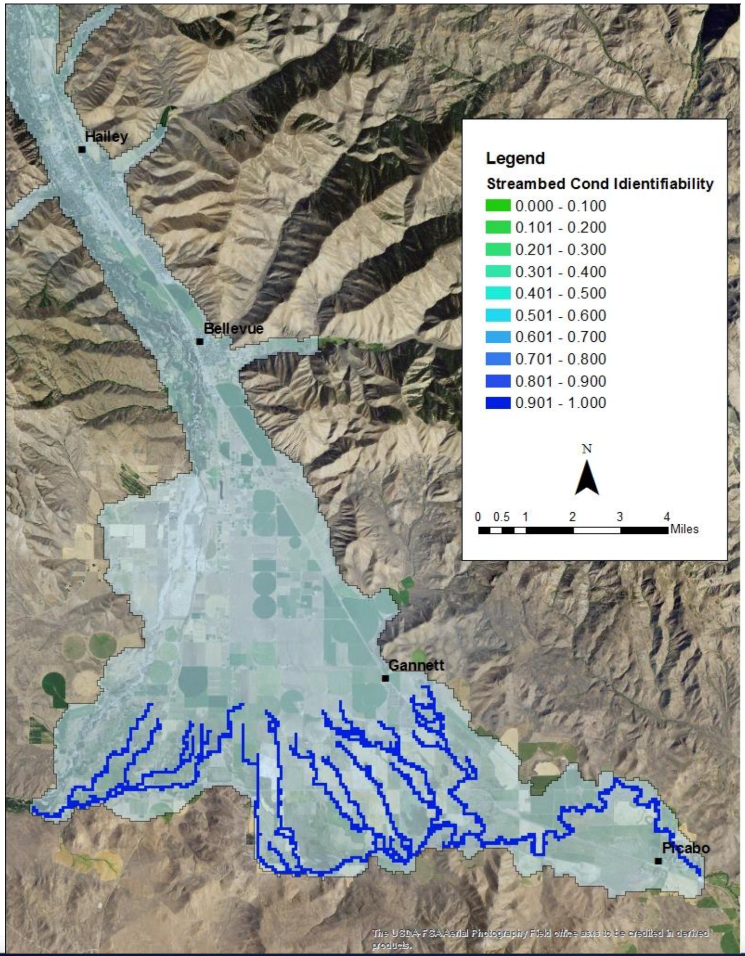
- Layer 3 K
  - Defined by 196 wells with 422 observations
    - 201 observations in one well

Parameter Identifiability, Wood R



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

Parameter Identifiability, Stream



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

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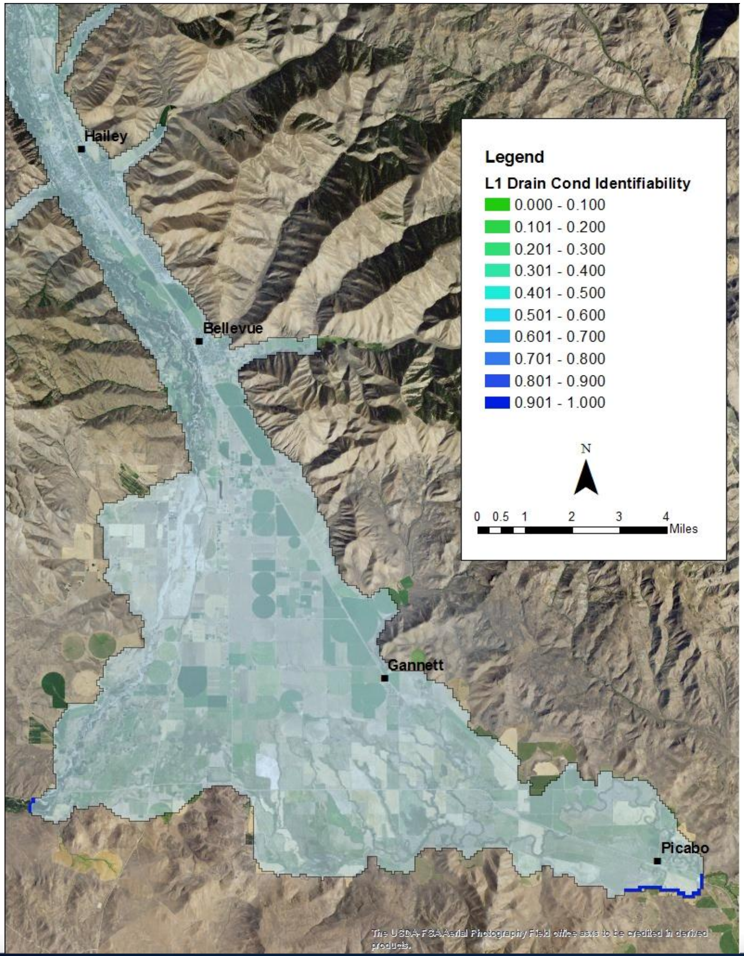
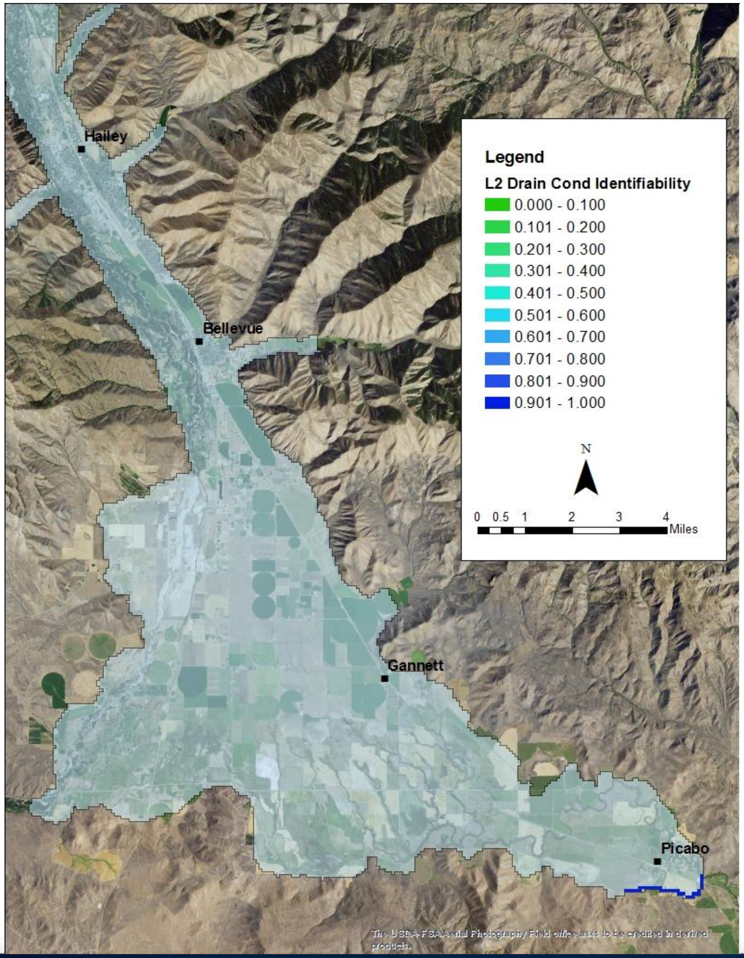
Parameter Identifiability, Drain



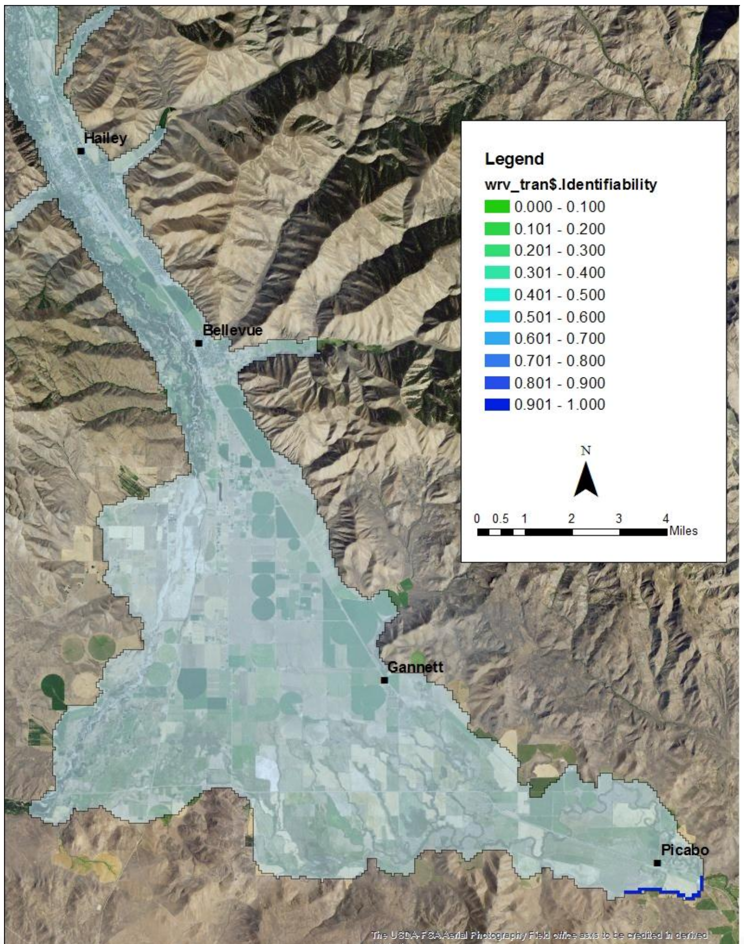
- Layer 1 drain conductance
  - Defined by two estimated observations

Parameter Identifiability, Drain



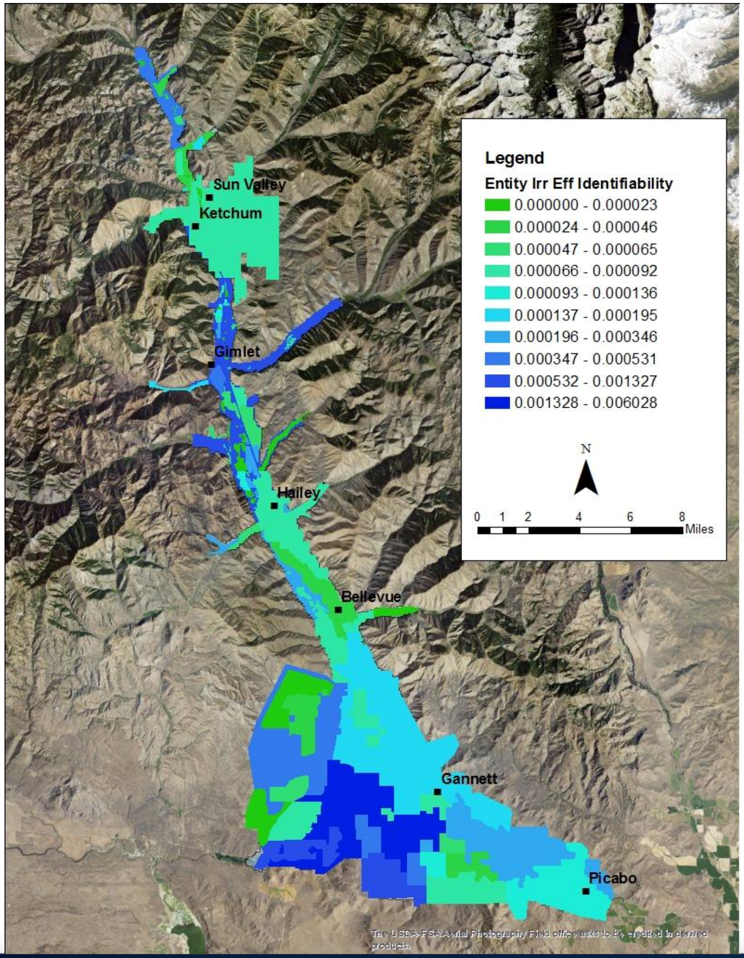
- Layer 2 drain conductance
  - Defined by estimated observation

Parameter Identifiability, Drain



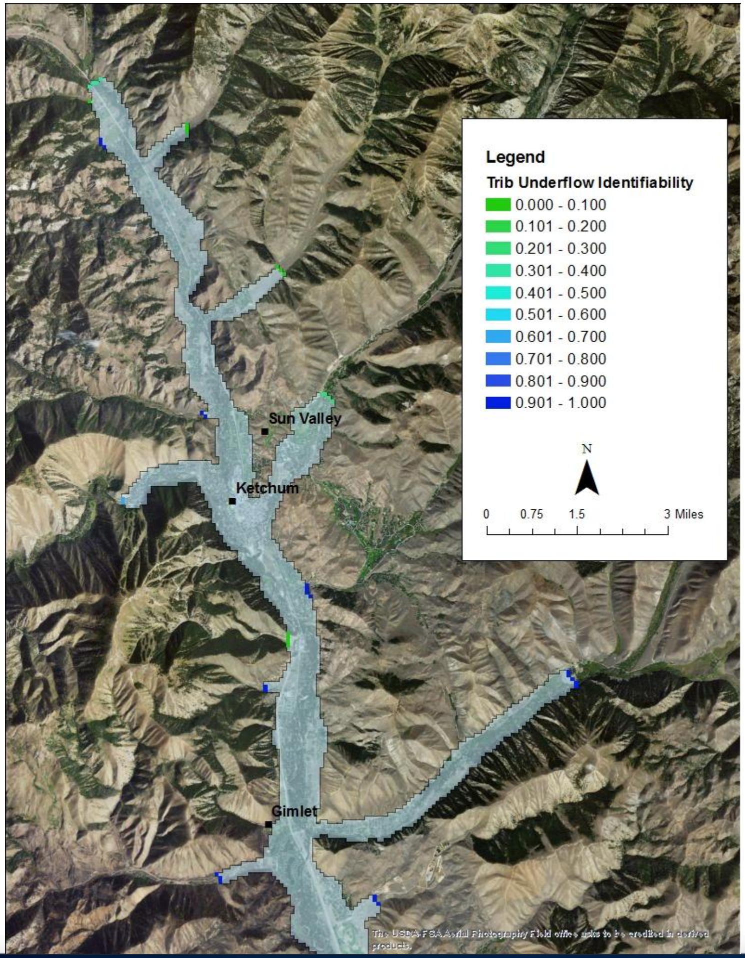
- Layer 3 drain conductance
  - Defined by estimated observation

Parameter Identifiability, Irrigation Entity Efficiency



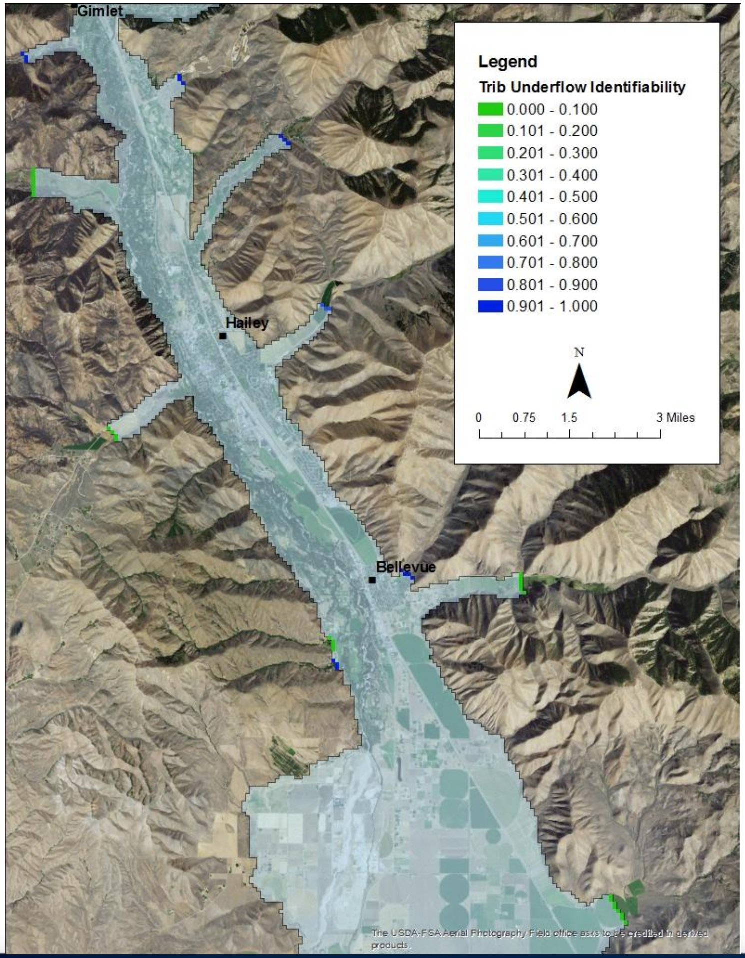
- Irrigation entity efficiency
  - Only applied to entities with groundwater irrigation

Parameter Identifiability, Tributary Underflow



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

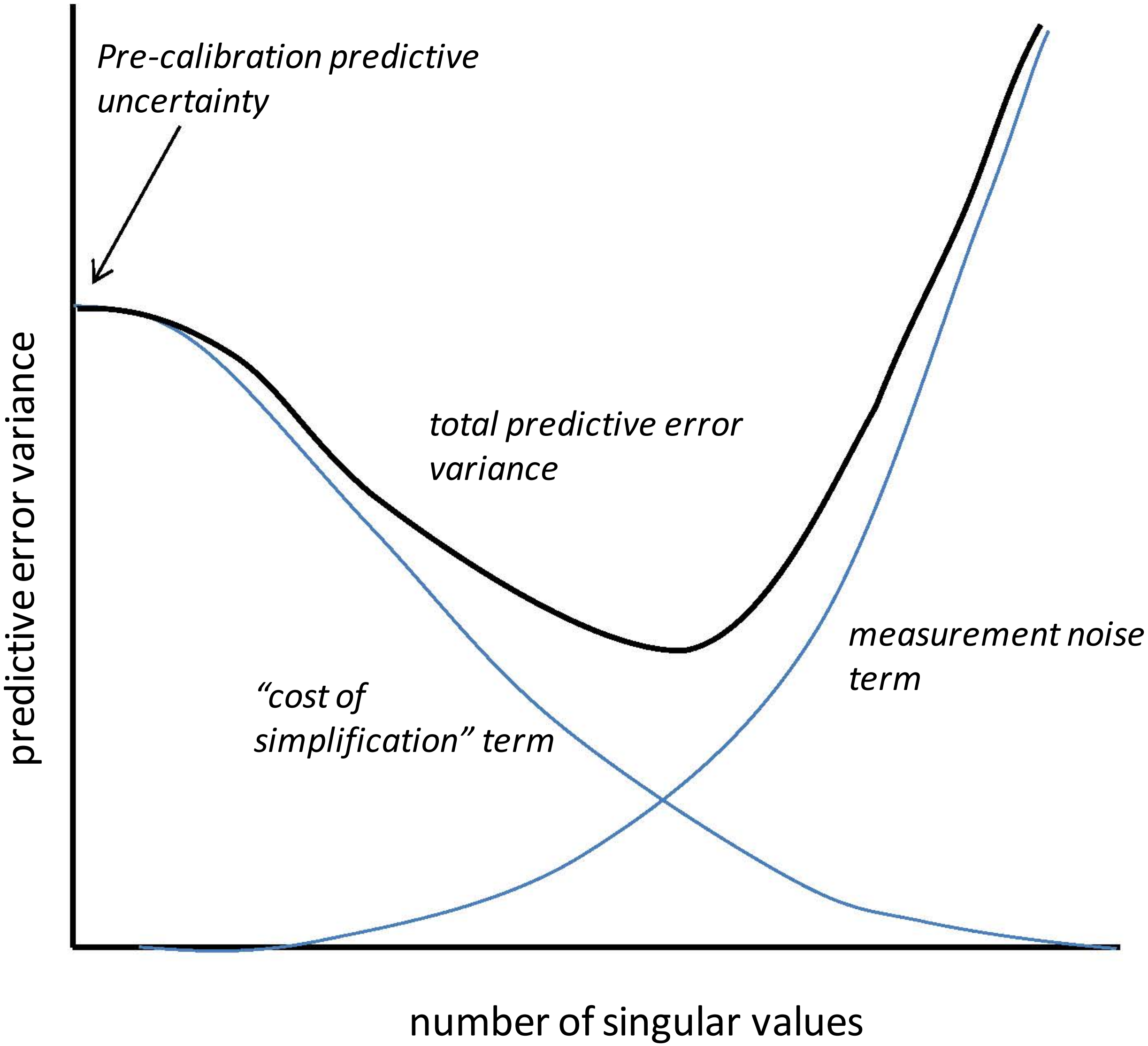
Parameter Identifiability, Tributary Underflow (2)



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

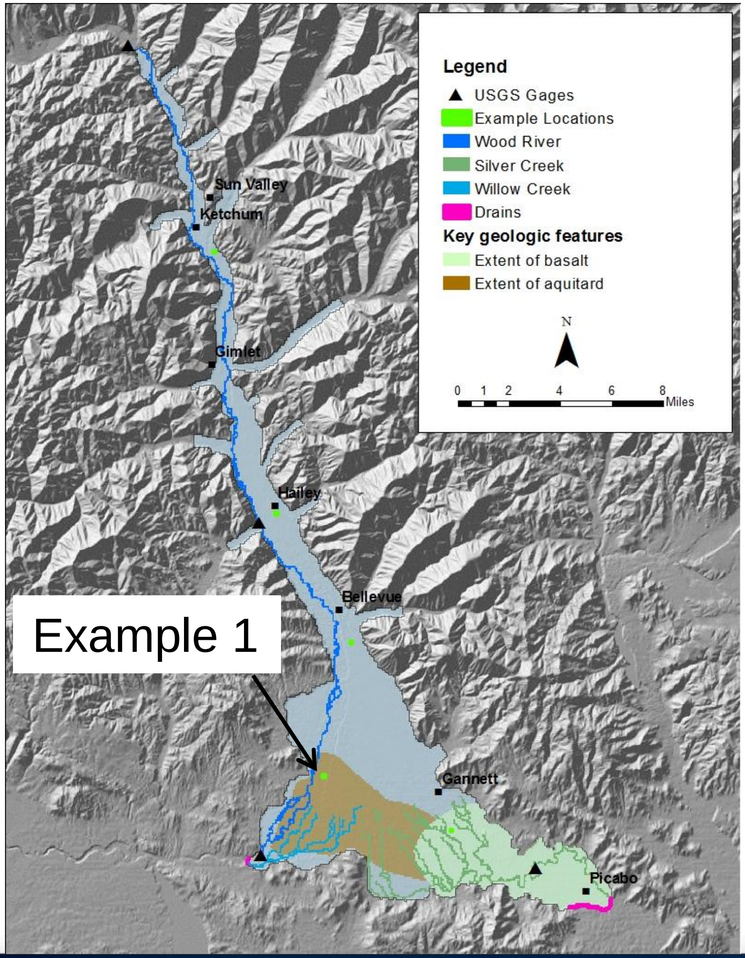
Nonadjustable Parameters

- Storage fixed for this analysis
- 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



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

Example 1



- Full model
- Steadystate
- Pumping well in layer 3 beneath confining layer
- Predict impact on Silver Creek above Sportsman Access

Analysis

- Example 1
  - Impact of injecting in layer 3 beneath confining layer
- Analysis for predicted impact on Silver Creek
  - Without calibration
    - Total uncertainty standard deviation = 2163%
  - After calibration
    - Total uncertainty standard deviation = 16.5%
      - 68, 95, 99.7 rule
      - 95% confidence ~ 61% +/- 33%

Reach	Steady state impact
nr Ketchum-Hailey	0.09%
Hailey-Stanton Crossing	25.44%
Silver Abv Sportsman Access	61.02%
Willow Creek	13.47%
Silver Blw Sportsman Access	0.00%
Total Impact	100.01%

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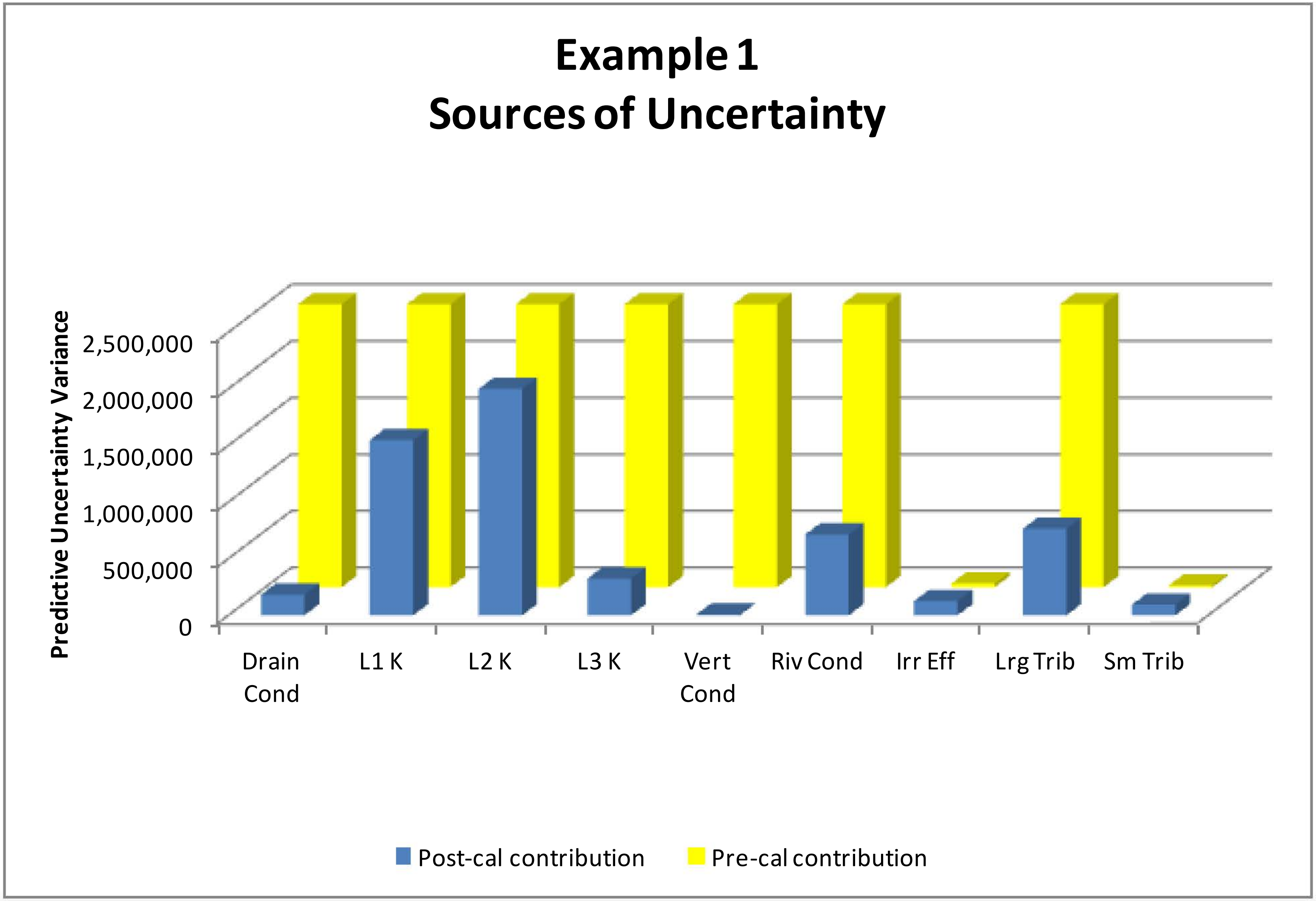
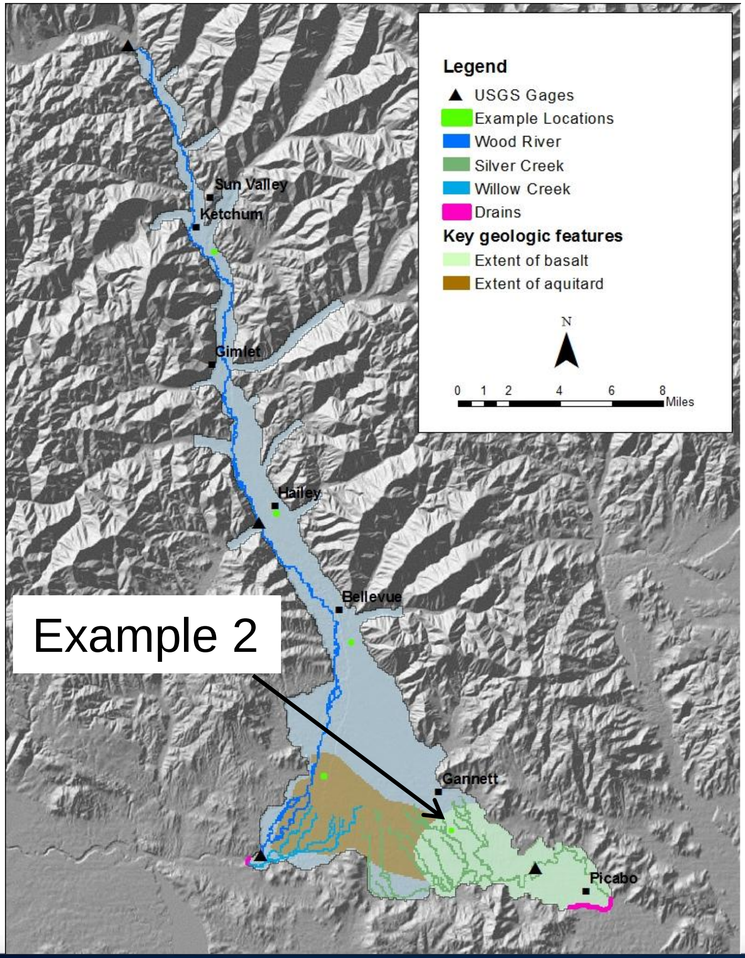


Example 2



- Full model
- Steadystate
- Pumping well in basalt in layer 3
- Predict impact on Silver Creek above Sportsman Access

Analysis

- Example 2
  - Impact of injecting in layer 3 beneath confining layer
- Analysis for predicted impact on Silver Creek
  - Without calibration
    - Total uncertainty standard deviation = 191%
  - After calibration
    - Total uncertainty standard deviation = 19.3%
      - 68, 95, 99.7 rule
      - 95% confidence ~ 98% +/- 39%

Reach	Steady state impact
nr Ketchum-Hailey	0.00%
Hailey-Stanton Crossing	1.04%
Silver Abv Sportsman Access	97.99%
Willow Creek	0.97%
Silver Blw Sportsman Access	0.00%
Total Impact	100.00%

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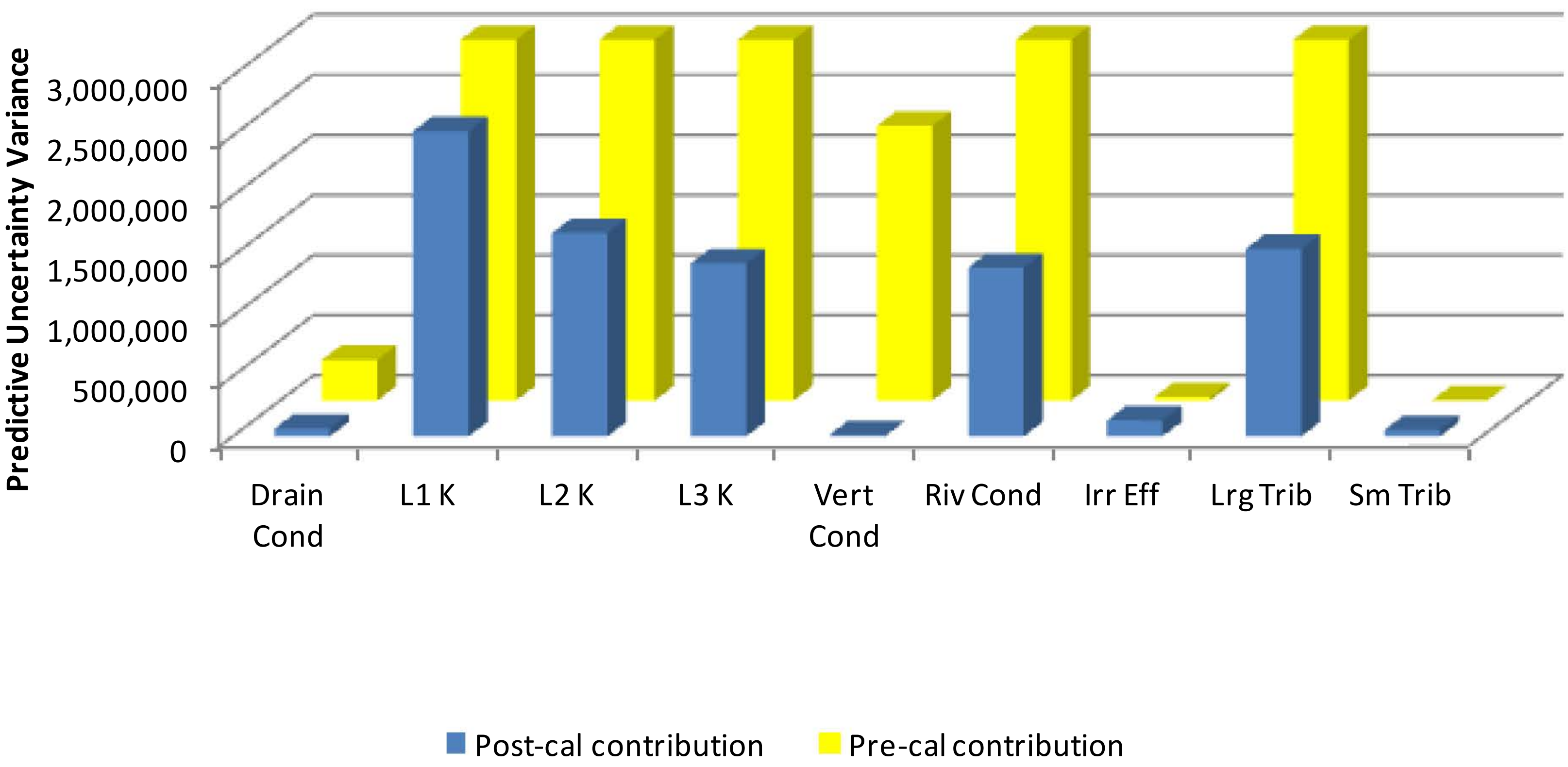
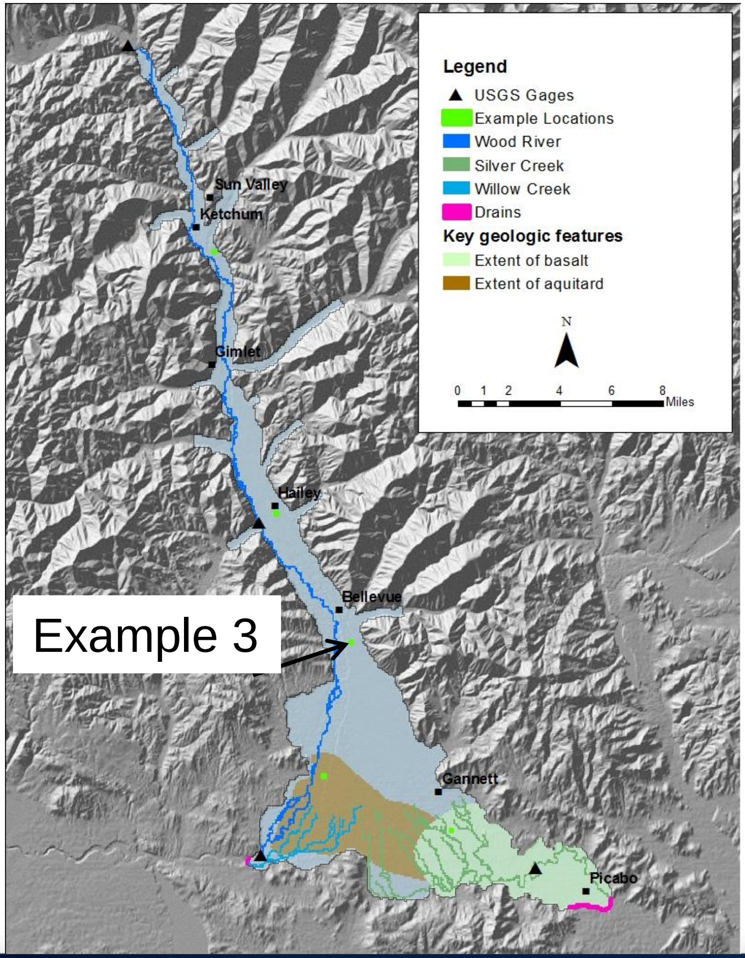
Example 2
Sources of Uncertainty



Example 3



- Full model
- Steadystate
- Pumping well in basalt in layer 3
- Predict impact on Hailey to Stanton Crossing

Analysis

- Example 3
  - Impact of injecting in layer 3 beneath confining layer
- Analysis for predicted impact on Hailey-Stanton Crossing reach of Wood River
  - Without calibration
    - Total uncertainty standard deviation = 173%
  - After calibration
    - Total uncertainty standard deviation = 5.67%
      - 68, 95, 99.7 rule
      - 95% confidence ~ 86% +/- 11%

Reach	Steady state impact
nr Ketchum-Hailey	1.30%
Hailey-Stanton Crossing	86.12%
Silver Abv Sportsman Access	10.18%
Willow Creek	2.40%
Silver Blw Sportsman Access	0.00%
Total Impact	100.00%

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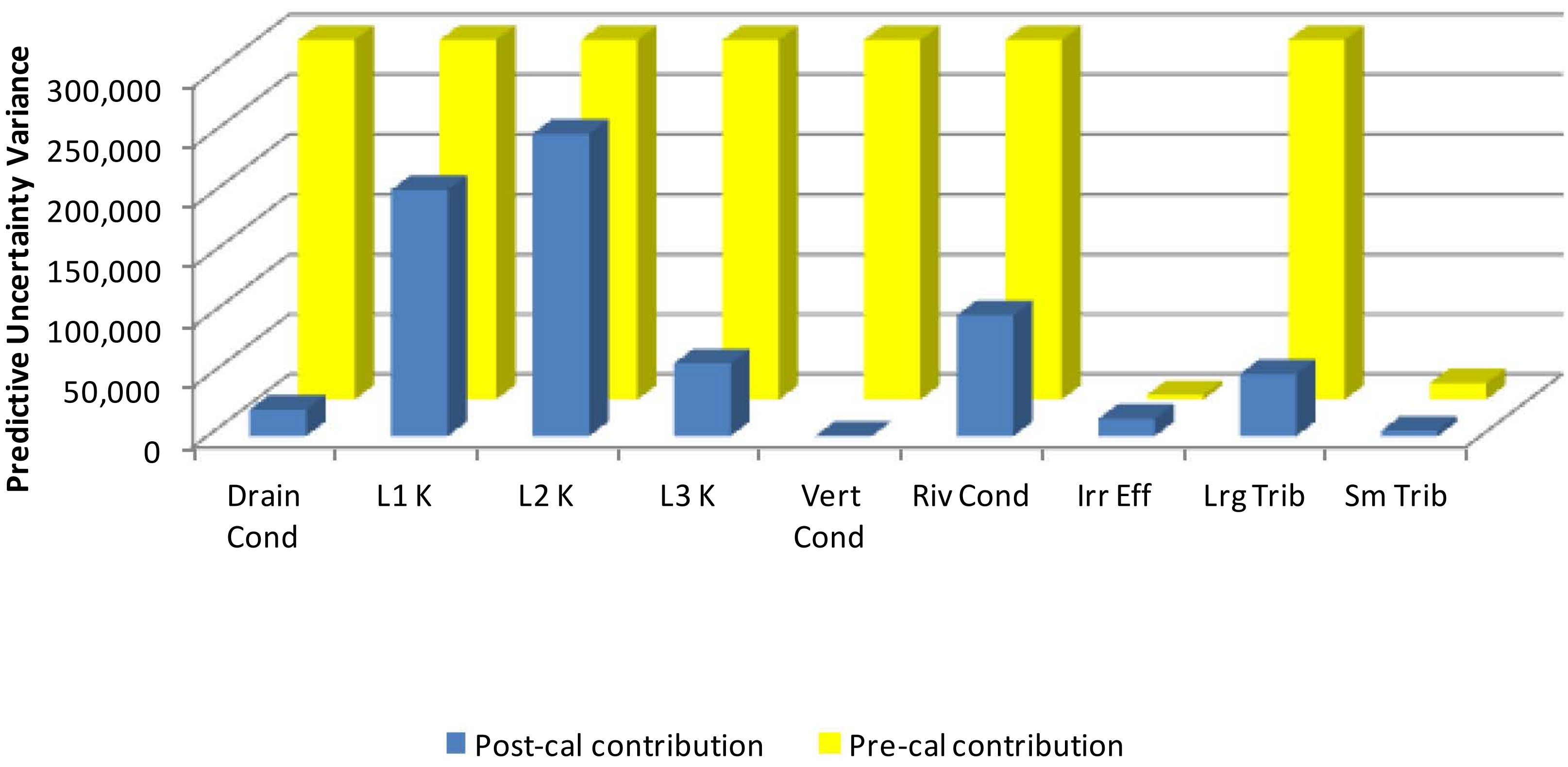
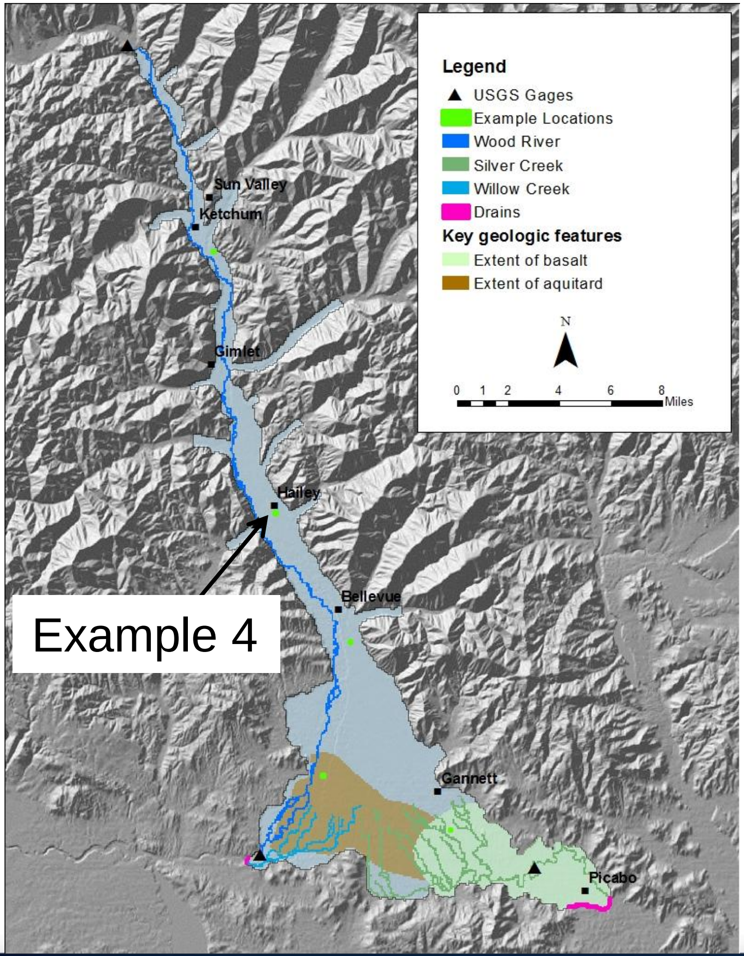
Example 3
Sources of Uncertainty



Example 4



- Full model
- Steadystate
- Pumping well in layer 1
- Predict impact on Hailey to Stanton Crossing

Analysis

- Example 4
  - Impact of injecting in layer 1
- Analysis for predicted impact on Hailey-Stanton Crossing reach of Wood River
  - Without calibration
    - Total uncertainty standard deviation = 261%
  - After calibration
    - Total uncertainty standard deviation = 9.62%
      - 68, 95, 99.7 rule
      - 95% confidence ~ 57% +/- 19%

Reach	Steady state impact
nr Ketchum-Hailey	38.33%
Hailey-Stanton Crossing	57.34%
Silver Abv Sportsman Access	3.51%
Willow Creek	0.82%
Silver Blw Sportsman Access	0.00%
Total Impact	100.00%

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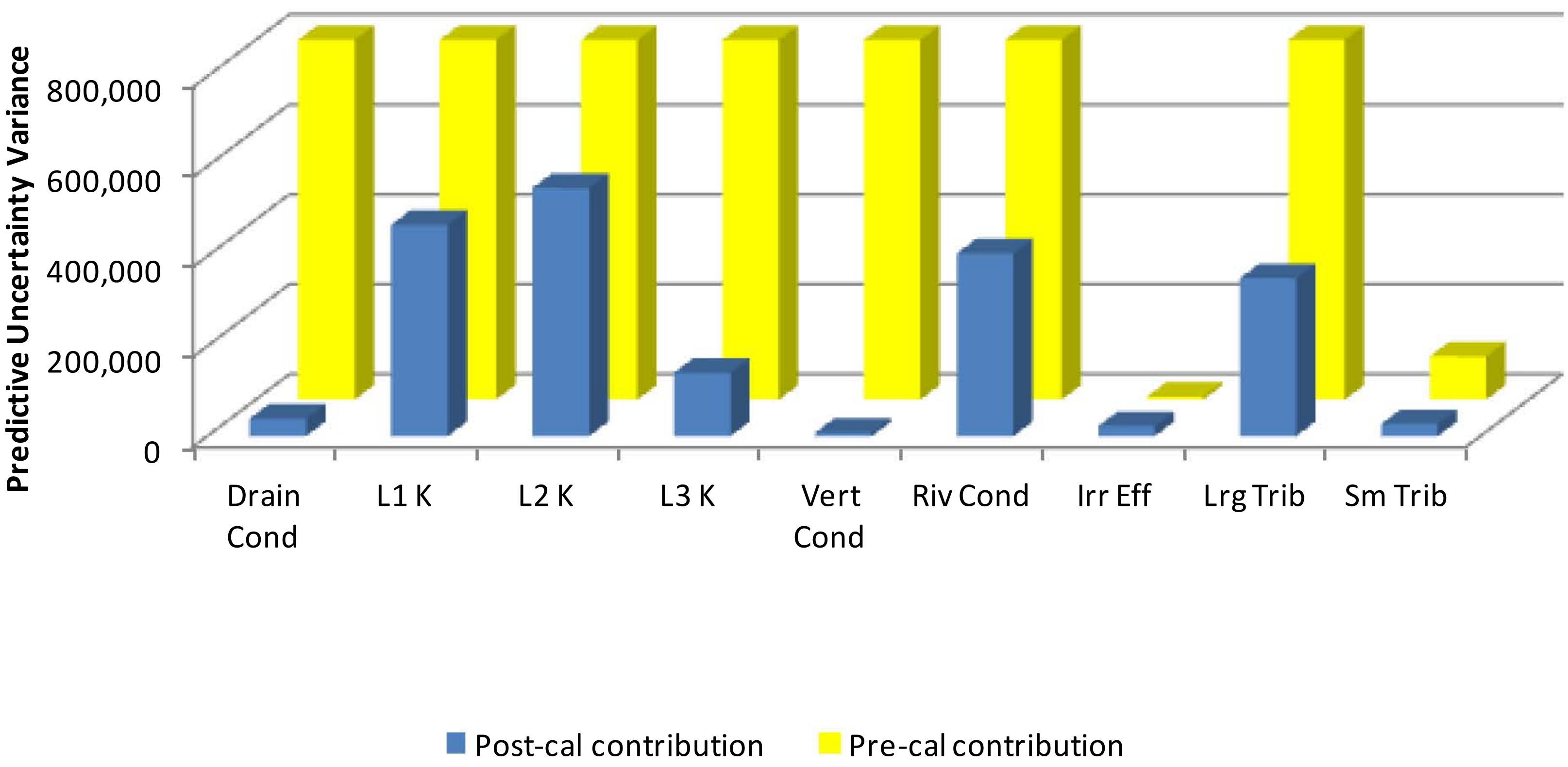
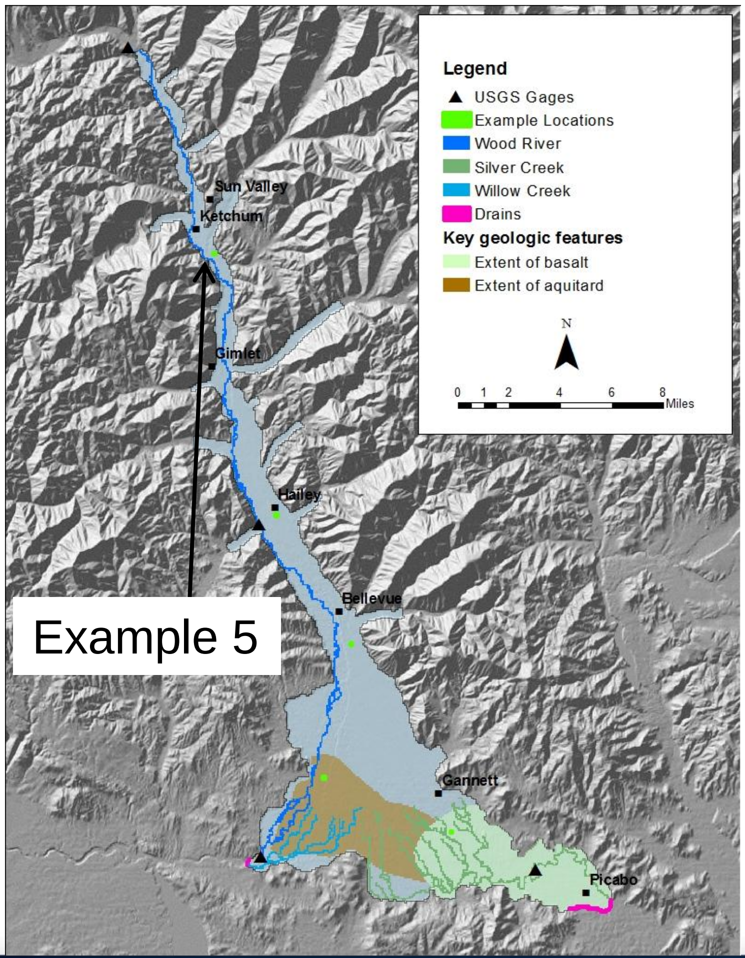
Example 4
Sources of Uncertainty



Example 5



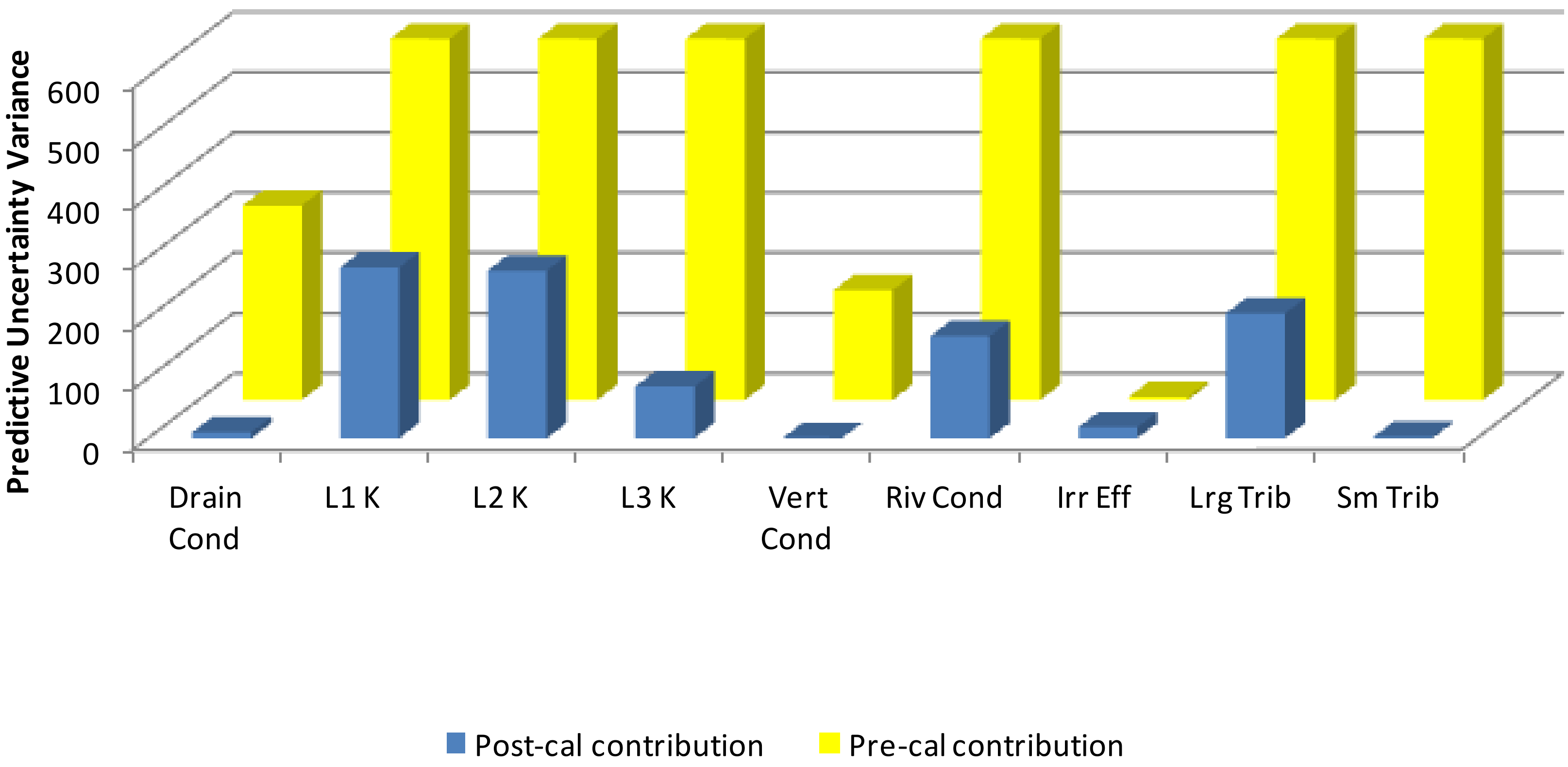
- Full model
- Steadystate
- Pumping well in layer 1
- Predict impact on nr Ketchum-Hailey

Analysis

- Example 5
  - Impact of injecting in layer 1
- Analysis for predicted impact on nr Ketchum-Hailey reach of Wood River
  - Without calibration
    - Total uncertainty standard deviation = 15.3%
  - After calibration
    - Total uncertainty standard deviation = 0.21%
      - 68, 95, 99.7 rule
      - 95% confidence ~ 100% +/- 0.42%

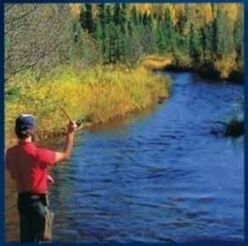
Reach	Steady state impact
nr Ketchum-Hailey	100.00%
Hailey-Stanton Crossing	0.01%
Silver Abv Sportsman Access	0.00%
Willow Creek	0.61%
Silver Blw Sportsman Access	0.00%
Total Impact	100.61%

Example 5
Sources of Uncertainty



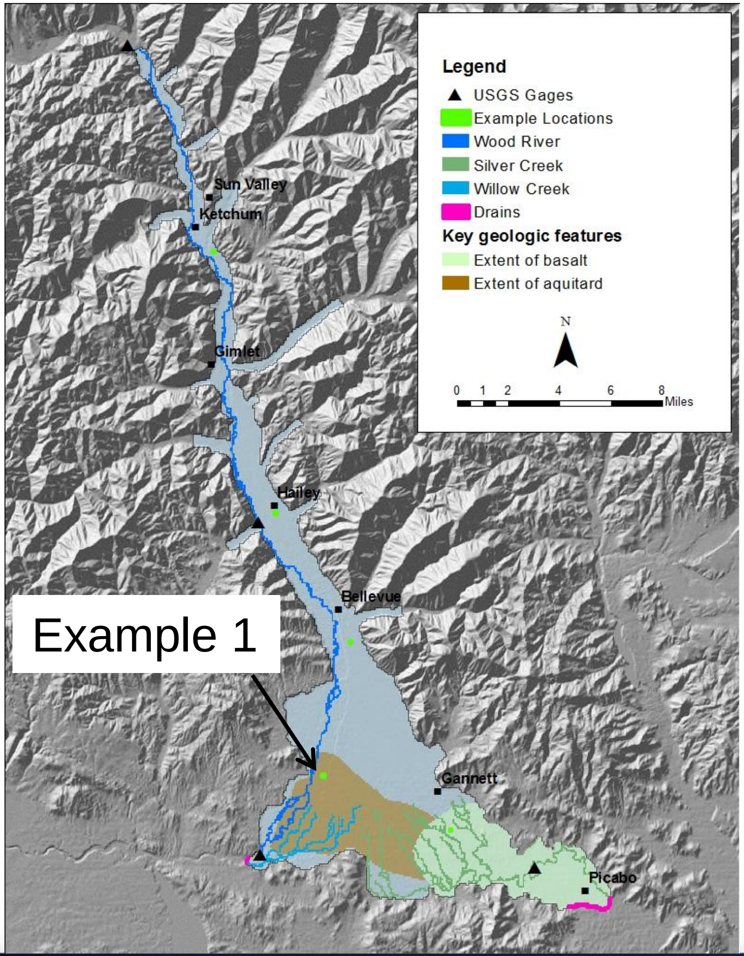
Conclusions

- The hydraulic conductivity distribution is constrained by the calibration
- Riverbed conductance is constrained by the calibration
- Steady-state analysis, storage coefficient not involved
- Drain conductance is 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



End

Example 1



- Full model
- Steadystate
- Pumping well in layer 3 beneath confining layer
- Predict impact on Silver Creek above Sportsman Access

Single cell analysis

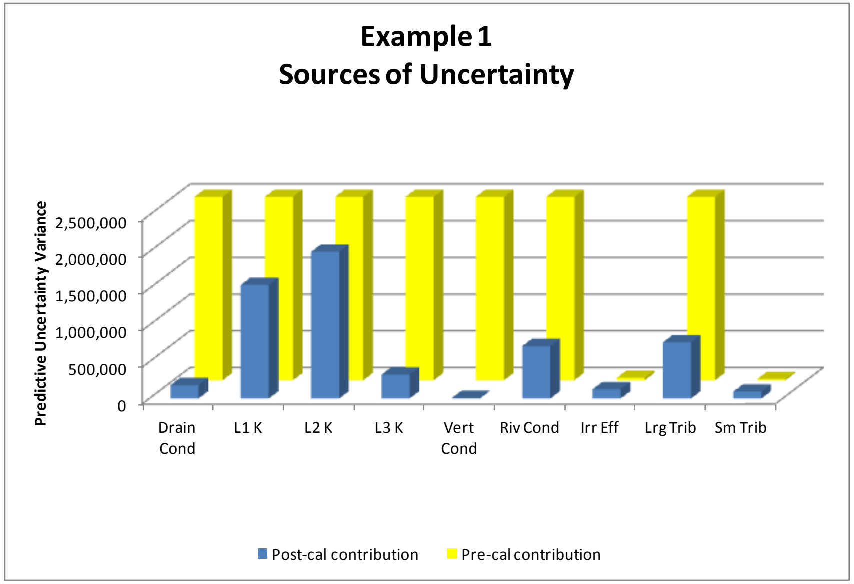
Analysis	Target Reach	Prediction	C.I. 95
Example 1	Silver Creek	61.02%	32.99%
Example 2	Silver Creek	97.99%	38.61%
Example 3	Wood R Hai-StanX	86.12%	11.34%
Example 4	Wood R Hai-StanX	57.34%	19.24%
Example 5	Wood R Nr Ket-Hai	100.00%	0.42%

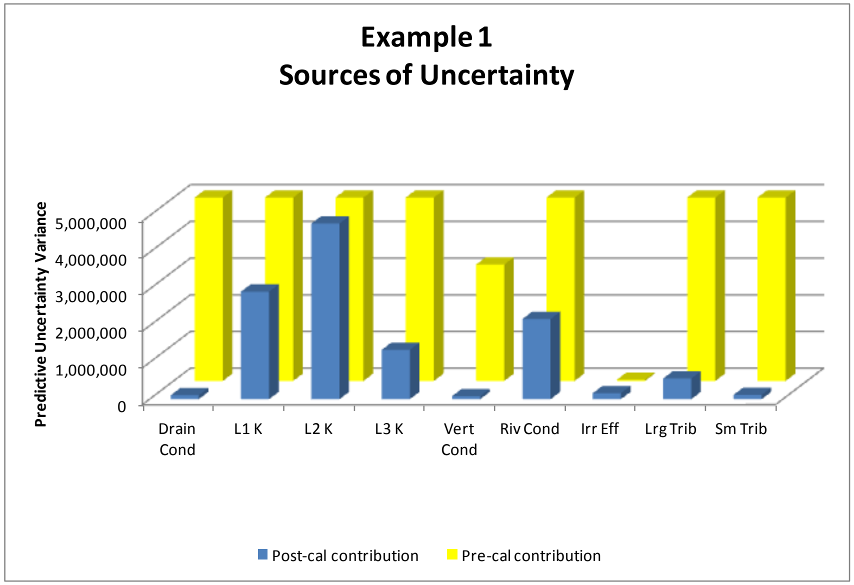
5X5 cell analysis

Analysis	Target Reach	Prediction	C.I. 95
Example 1	Silver Creek	61.02%	46.47%
Example 2	Silver Creek	97.99%	21.69%
Example 3	Wood R Hai-StanX	86.12%	11.13%
Example 4	Wood R Hai-StanX	57.34%	16.68%
Example 5	Wood R Nr Ket-Hai	100.00%	0.42%

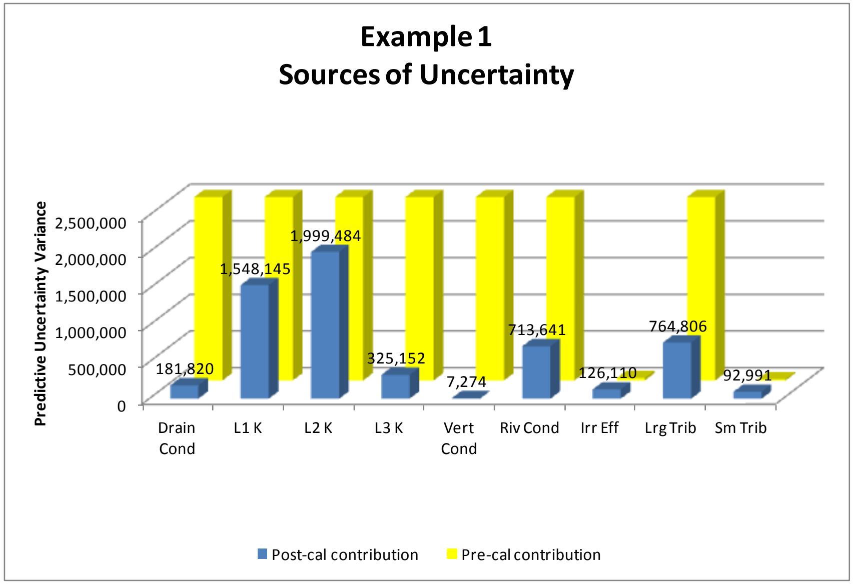
Single cell analysis

5X5 cell analysis





Single cell analysis



5X5 cell analysis