Errors Resulting From Assuming Unconfined Aquifers Are Constant Thickness

Gary Johnson, Bryce Contor, Rob VanKirk

University of Idaho

Humbolt State University

Please Understand

- Not yet published – preliminary
- Don’t blame you if you are skeptical

The Problem

Common thinking is that if changes in aquifer thickness are a small proportion of total thickness (maybe 10%) then effects of assuming constant thickness are small

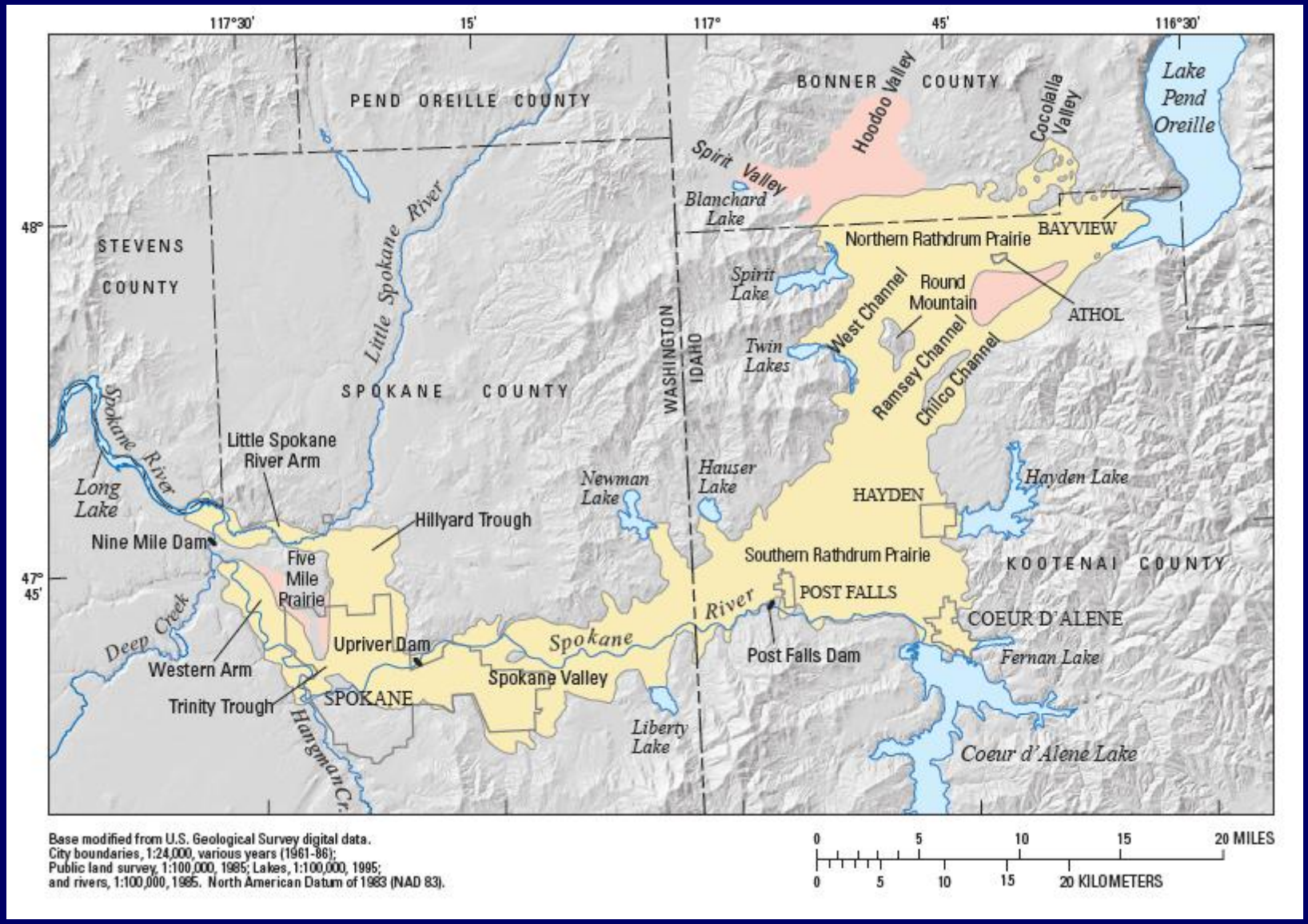
Not necessarily true when evaluating responses of surface water gains and losses relative to magnitude of imposed stress

STEP 1: Attempt to convince you that the second statement is true

- **SVRP model runs**
- **Idealized model runs (not presented)**
- **Analytical solutions (not presented)**

STEP 2: What does it mean for SRPA

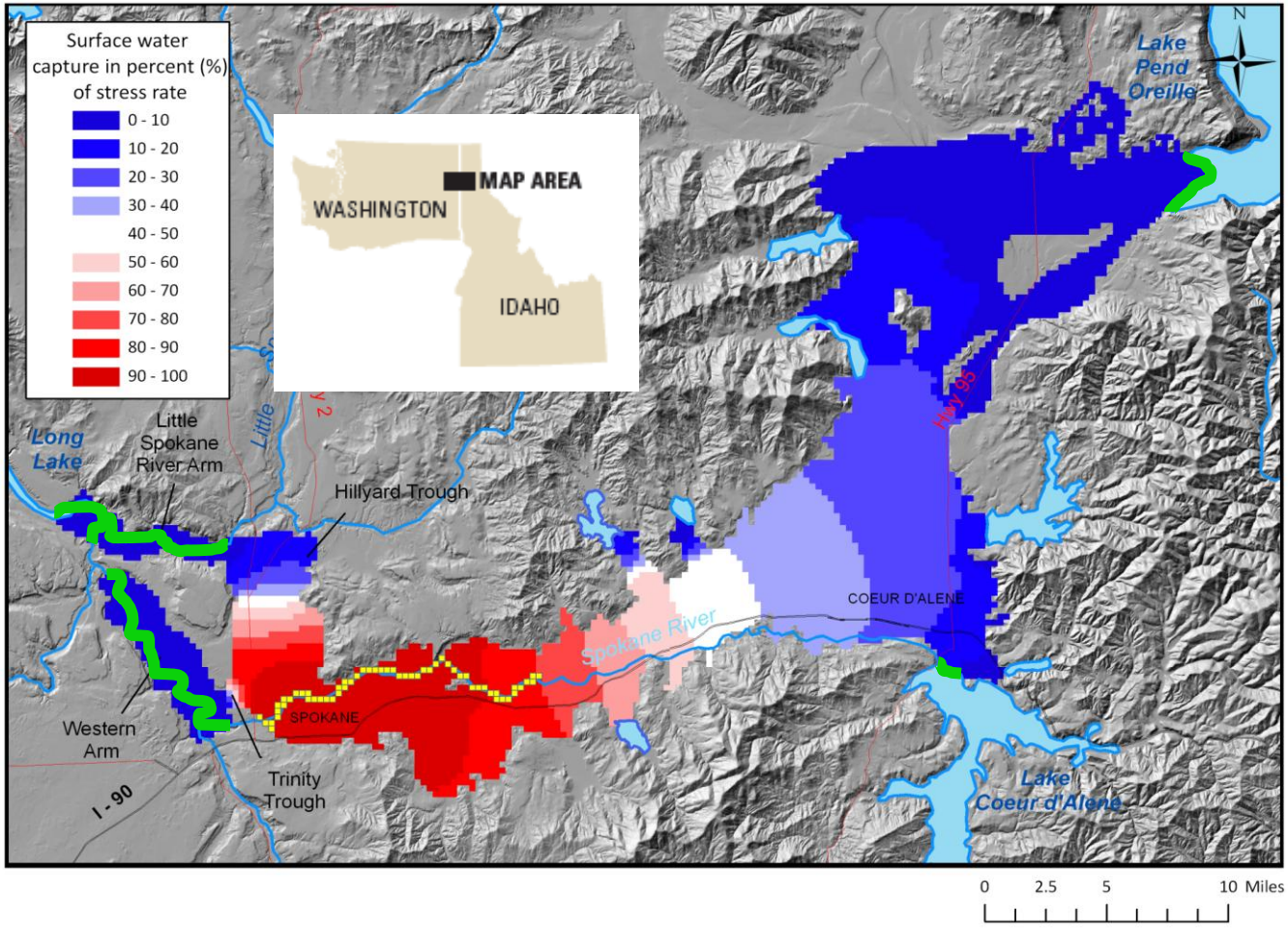
SVRP Model Runs



SVRP

- Unconfined except Hillyard Trough has deeper confined layer
- Calibrated as constant thickness then changed to unconfined representation
- Attempted response function generation with constant thickness and variable thickness representations – results showed areas of substantial difference
- Differences much greater than anticipated based on aquifer thickness

Reponses of Middle Segment of Spokane River

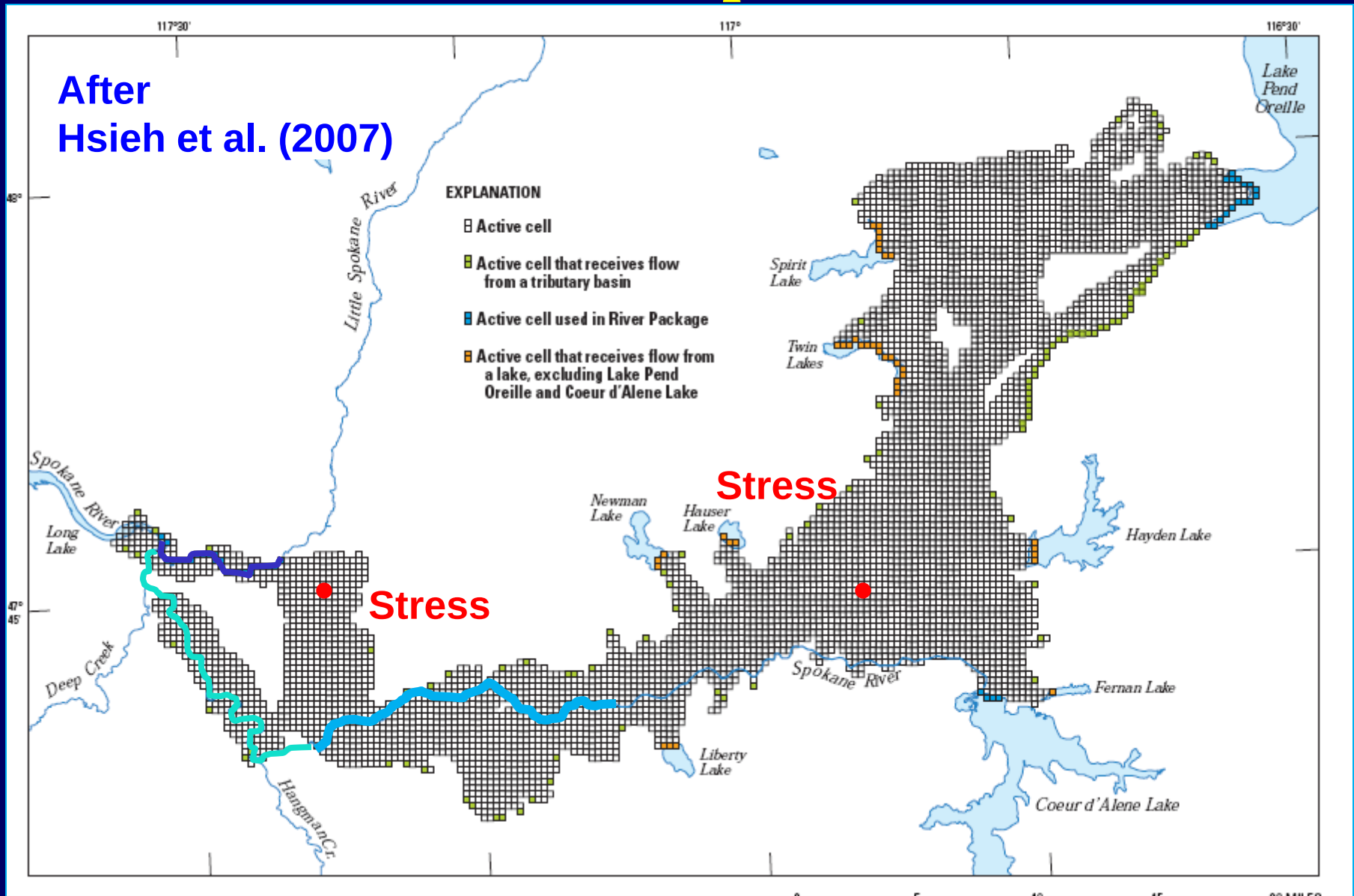


Linearity Evaluation

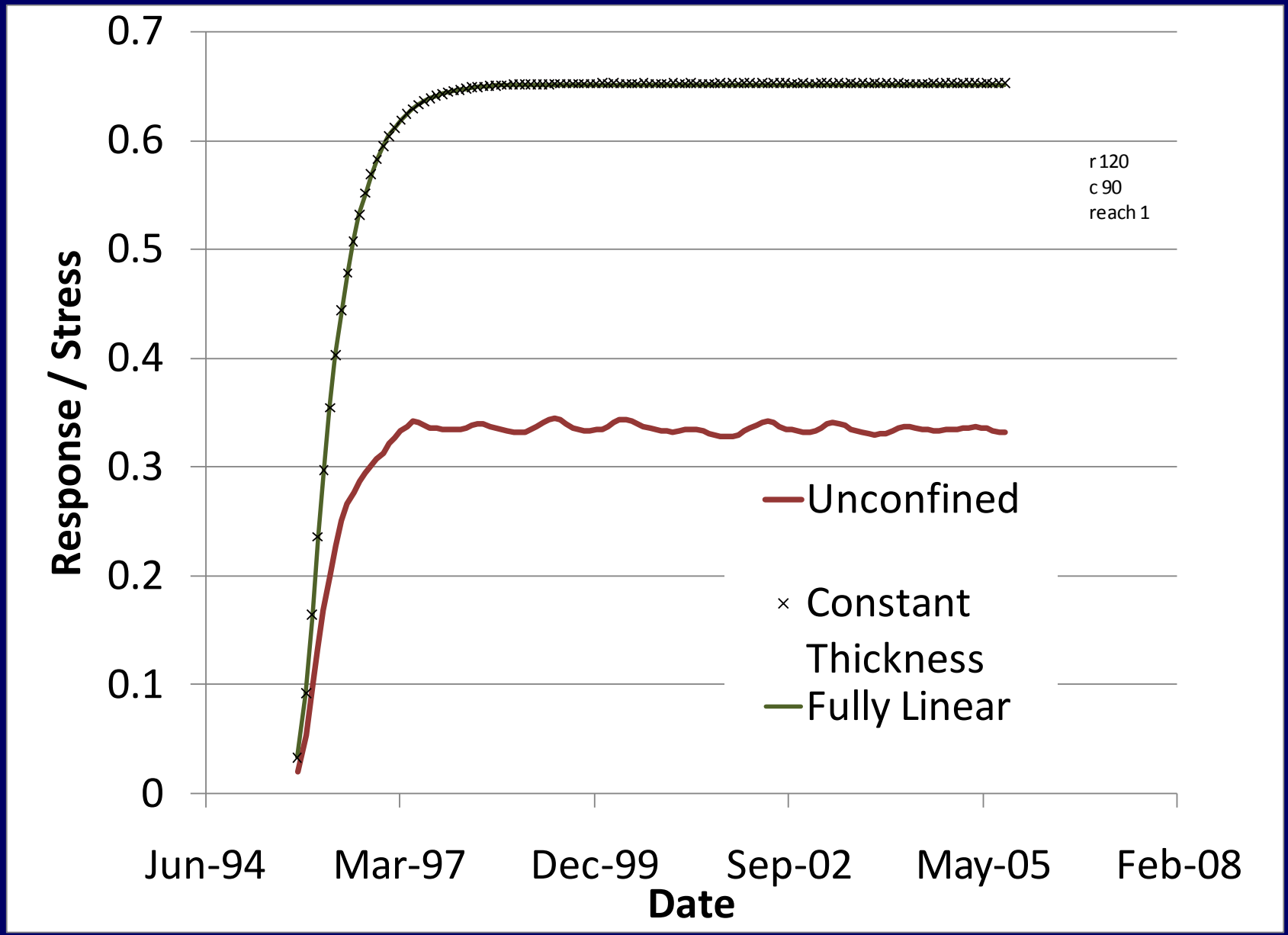
Error = (Unconfined Response (% of stress)) — (Confined Response (% of stress))

Confined response:
constant thickness = average thickness from same time period

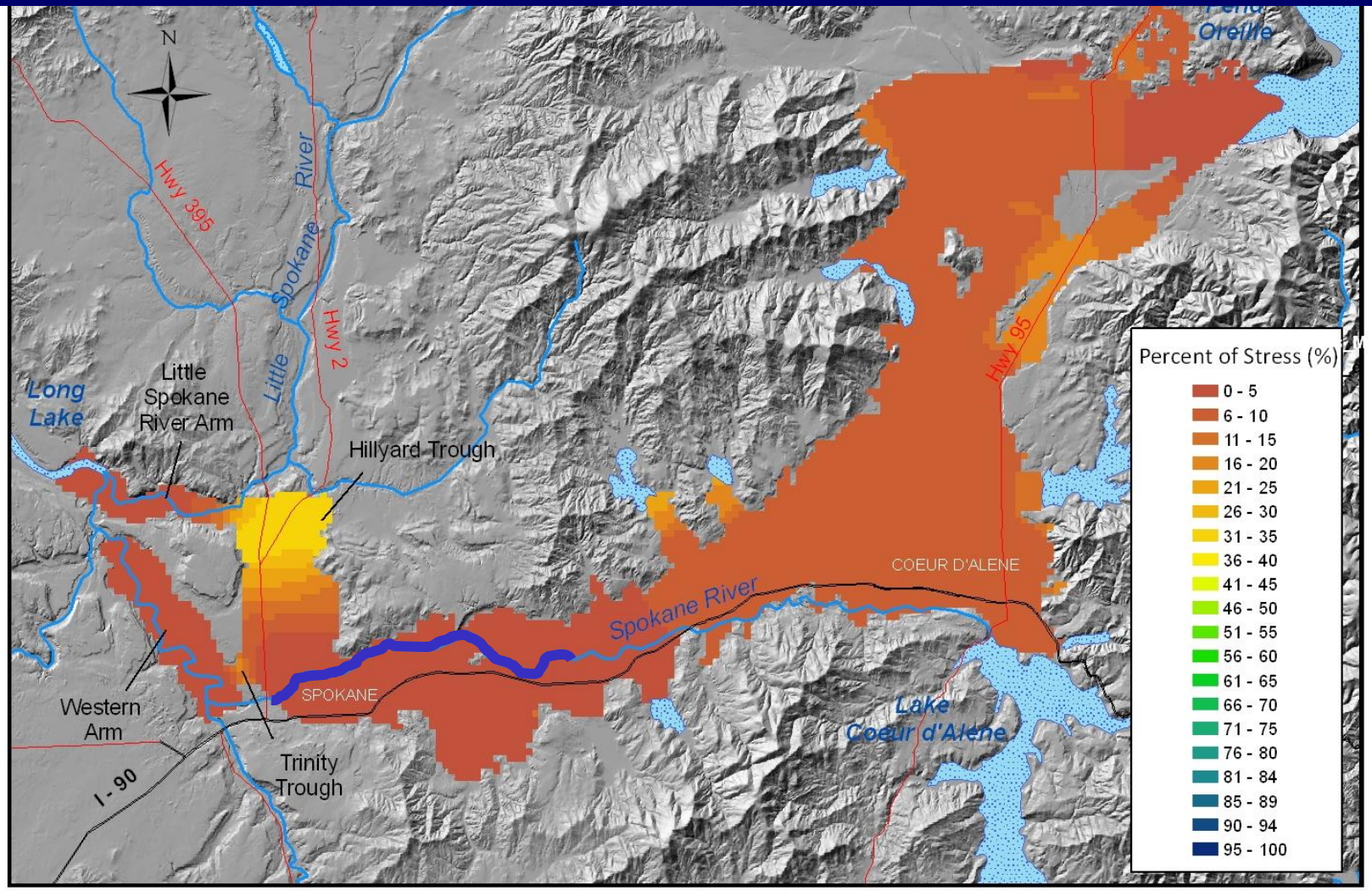
Spokane Valley Rathdrum Prairie Example



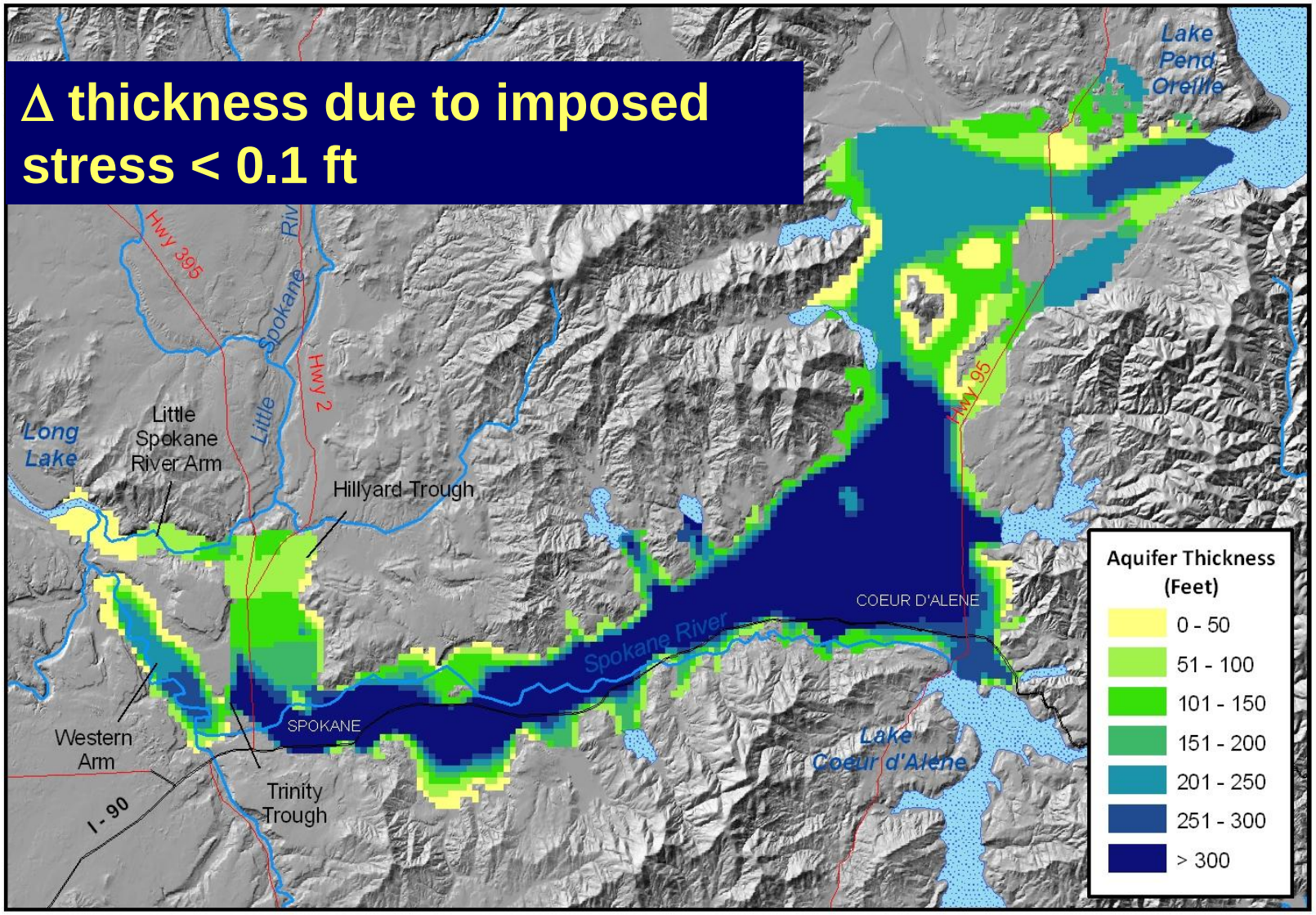
Example Response Differences



Map of Relative Error
(percent of stress)



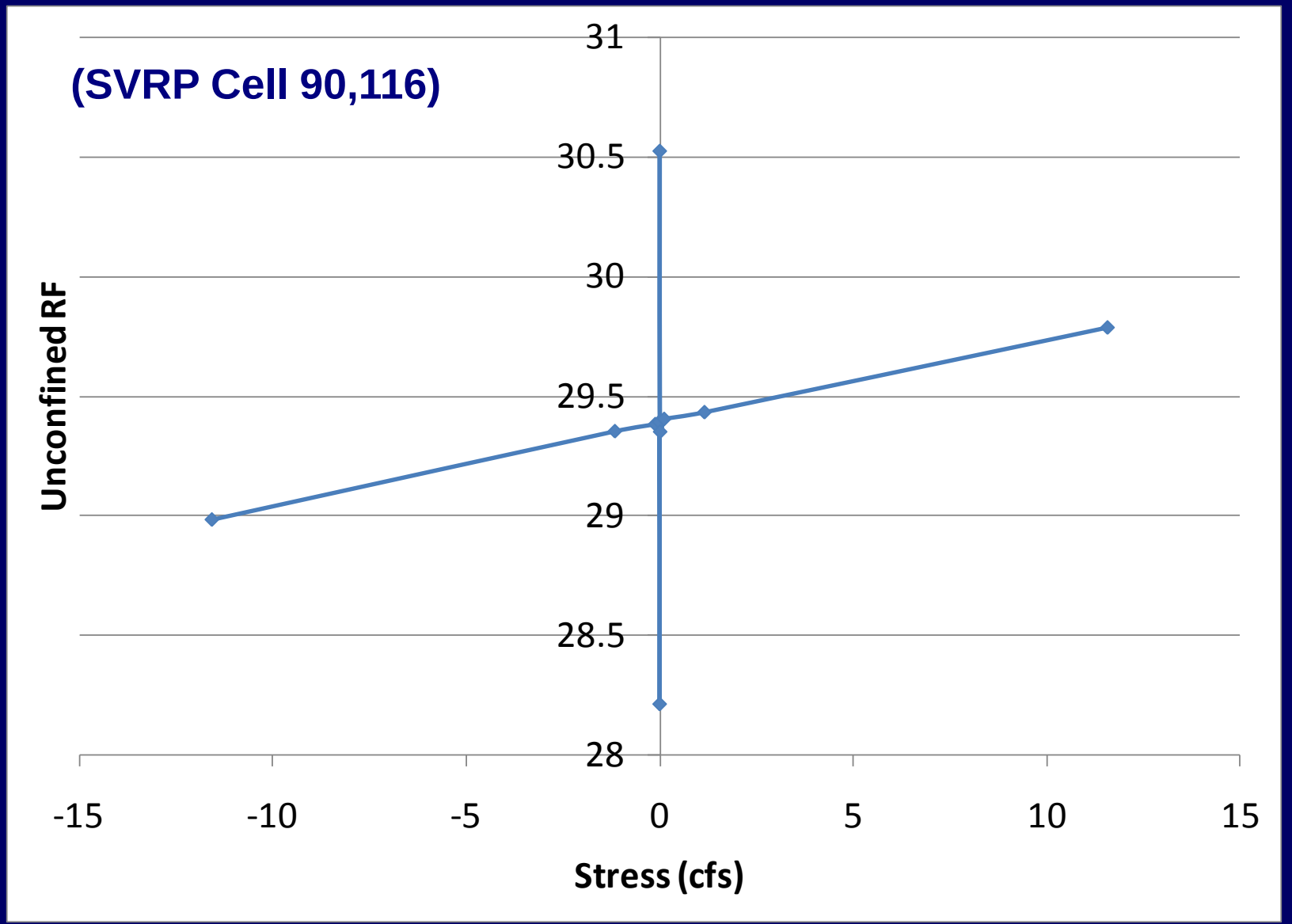
Aquifer Thickness Map



SVRP Summary

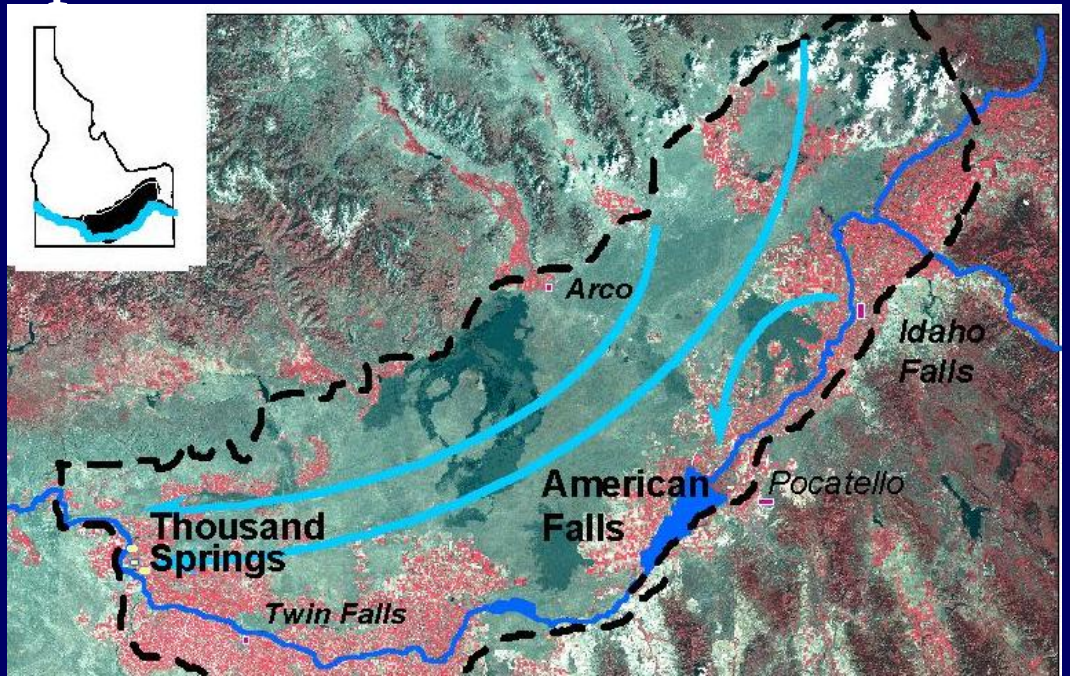
- Unexpectedly large errors from using constant thickness representation in some locations
- Change in thickness less than 1% of total thickness
- Variable thickness representation produces consistent responses regardless of stress magnitude (within limits) or sign
- Response function maps generated with variable thickness representation
- Also some (but more limited) errors due to treating boundaries as linear condition

Stress Magnitude Has Little Impact on RF

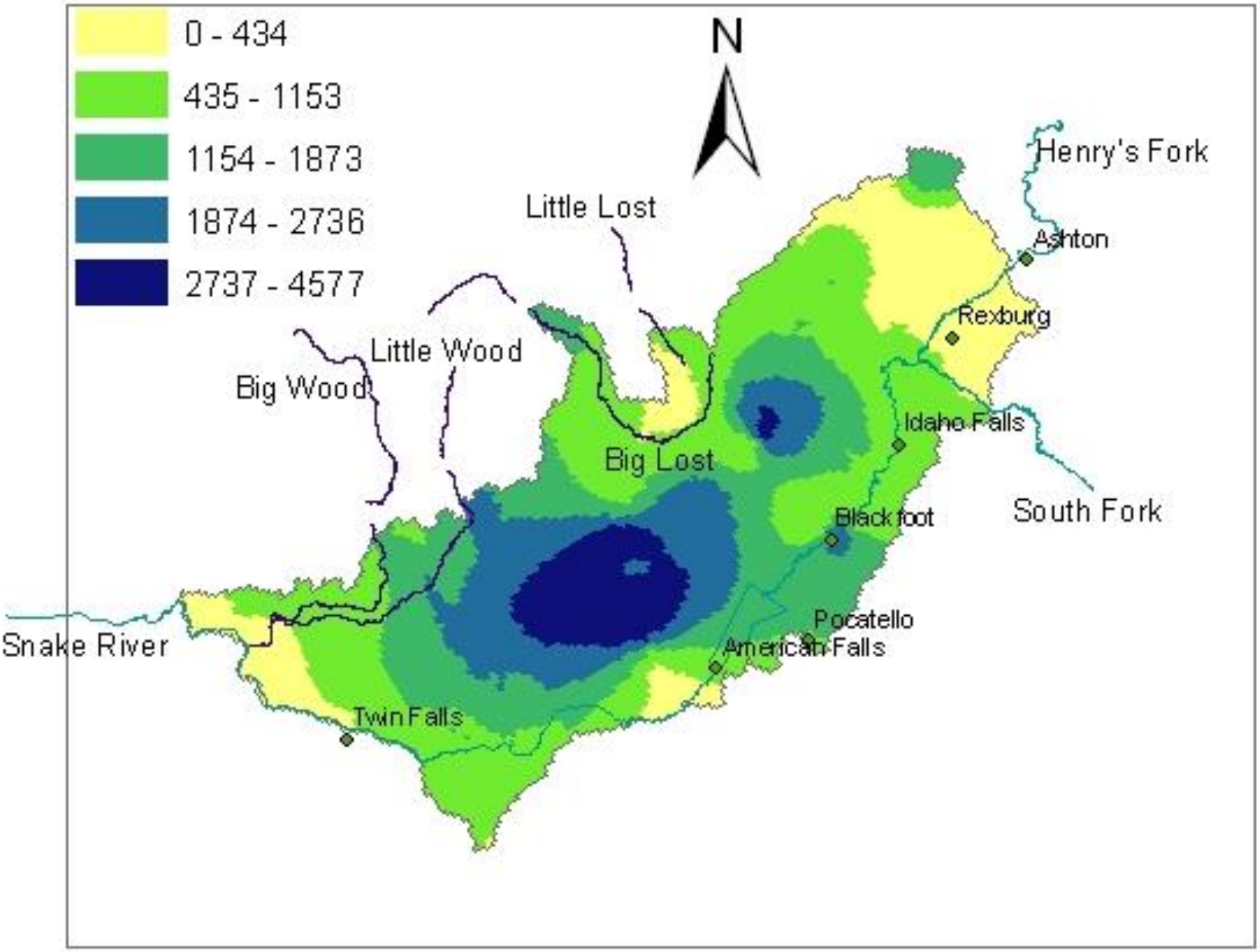


Implications: Snake River Plain

- Treated as constant thickness
- May be used for management simulations that examine effect of ground water pumping on surface water
- Need to evaluate impact of constant thickness assumption



Thickness in feet



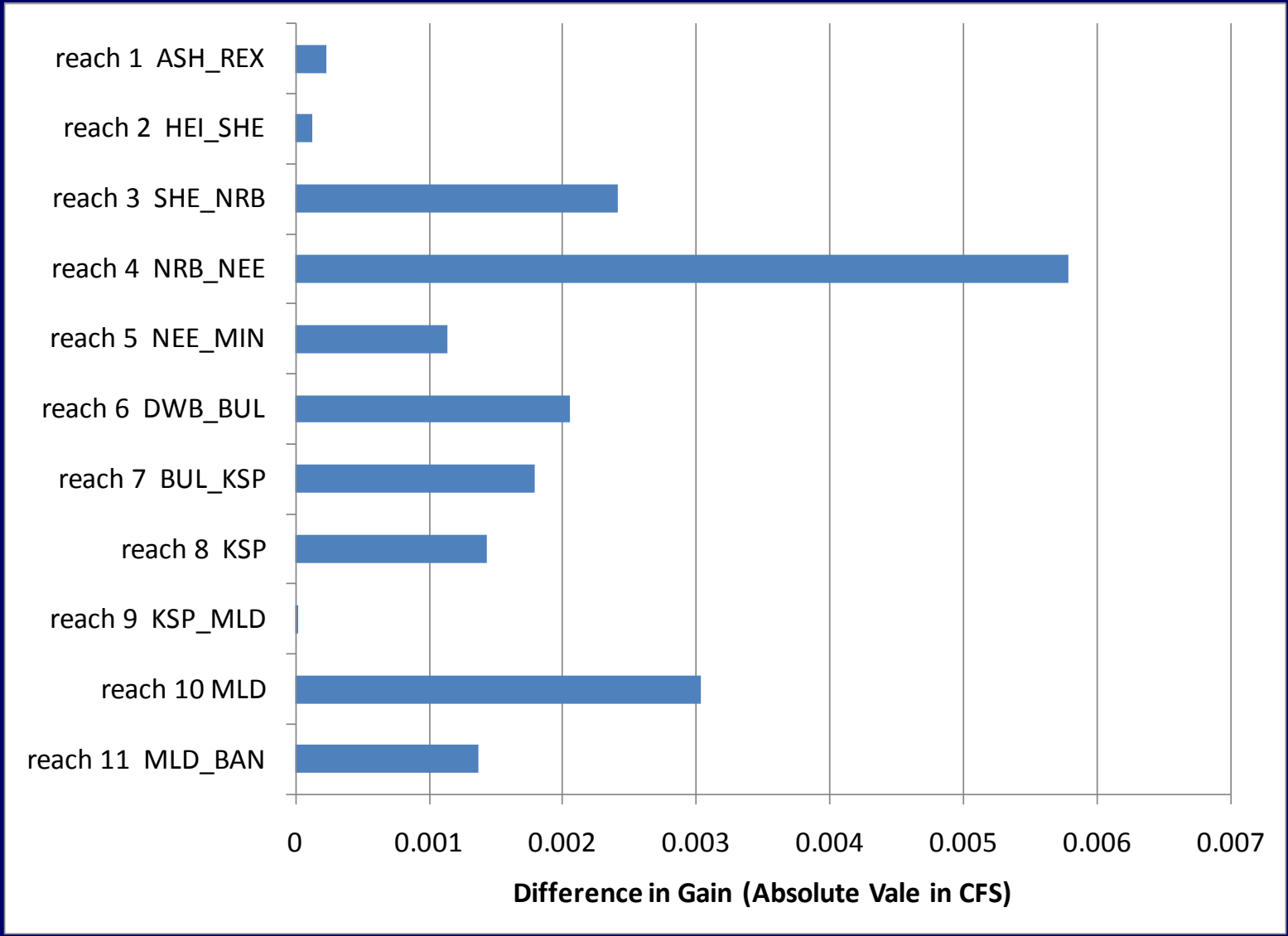
Snake Plain SS Constant Thickness (Confined) and Unconfined Simulations

- Used files from IDWR ftp site for SS SRPAM1.1
- Double precision MODFLOW version used
  - Required change to PCG solver
  - Required new post processing programs
  - Reduced mass balance error by over 2 orders of magnitude (less than 8 cfd for all simulations)

Procedure

- Original SS Confined simulation (DP)
- Determine thickness and calculate K = T/b at each cell
- Data file changes as necessary (K for T)
- Unconfined SS simulation (DP)
  - Reach gains match confined pretty well (next slide)
- Stress each model cell at 11.57 cfs and difference reach gains from respective unstressed (confined or unconfined) and express as ratio to stress
- Difference unconfined and confined response ratios

Difference in Reach Gains Confined and Unconfined SS

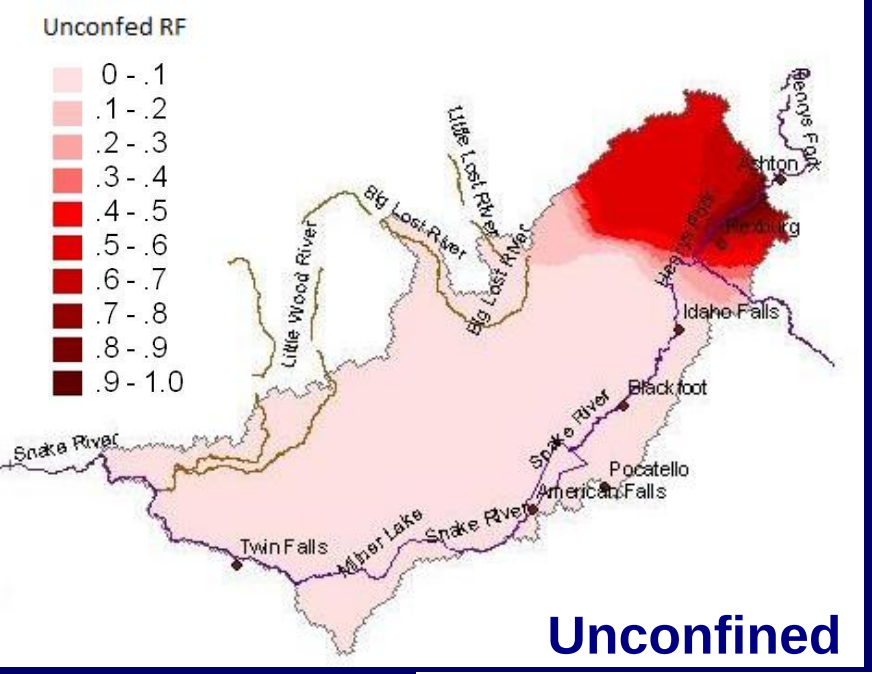


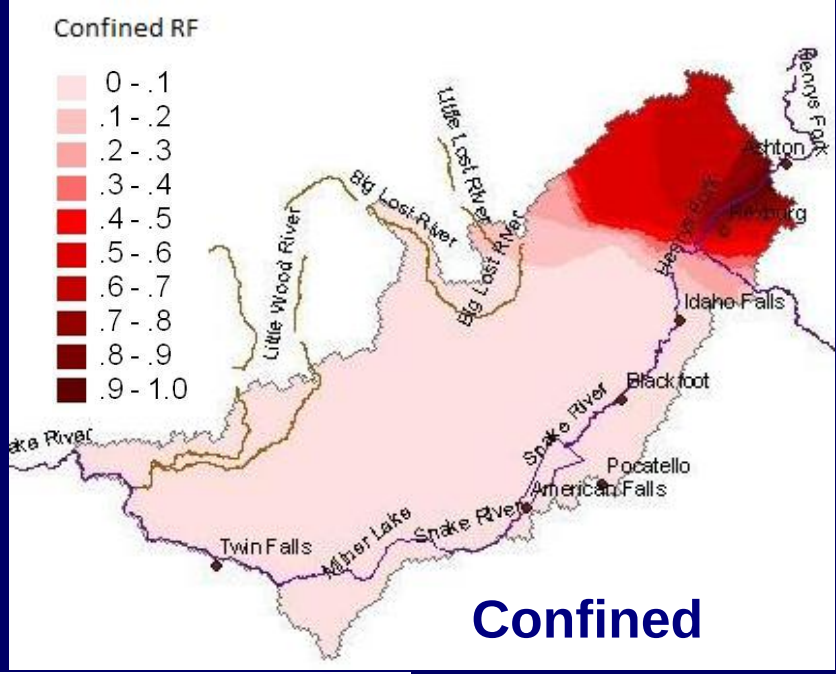
Difference Maps

$$RF(unconf) = \frac{\text{Stressed Unconfined Reach Gain} - \text{UnStressed Unconfined Reach Gain}}{1000000}$$

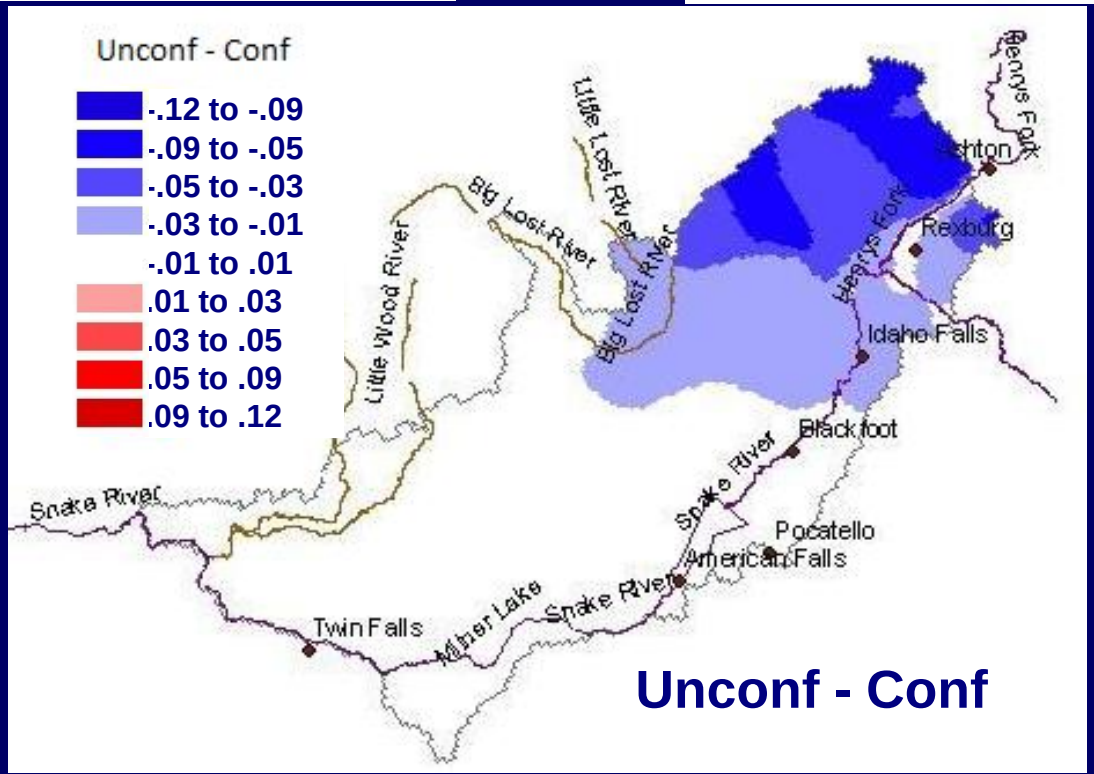
$$RF(conf) = \frac{\text{Stressed Confined Reach Gain} - \text{UnStressed Confined Reach Gain}}{1000000}$$

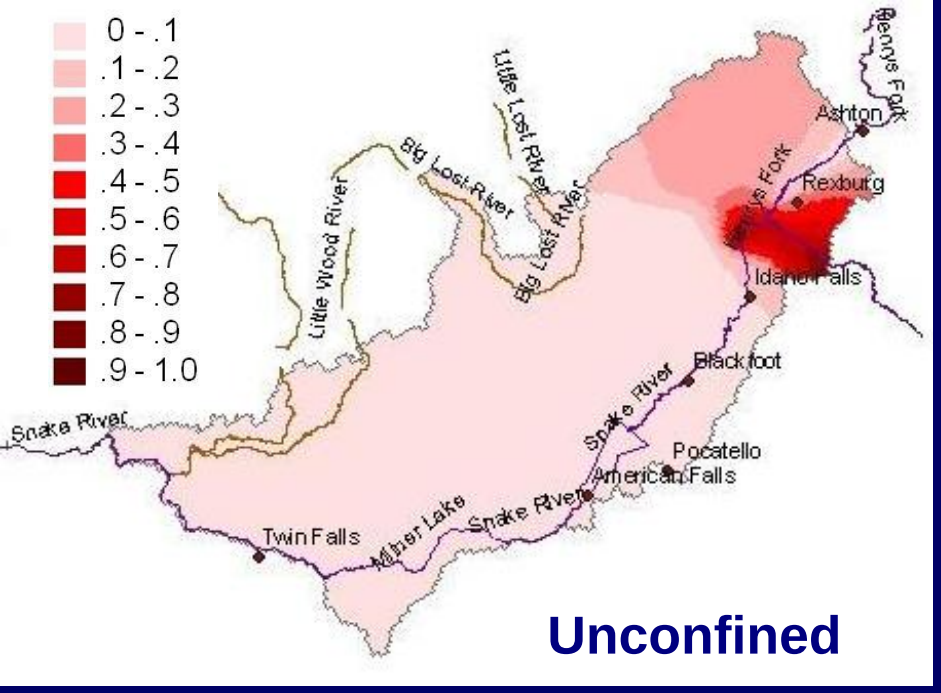
Difference = RF(unconf) – RF(conf)

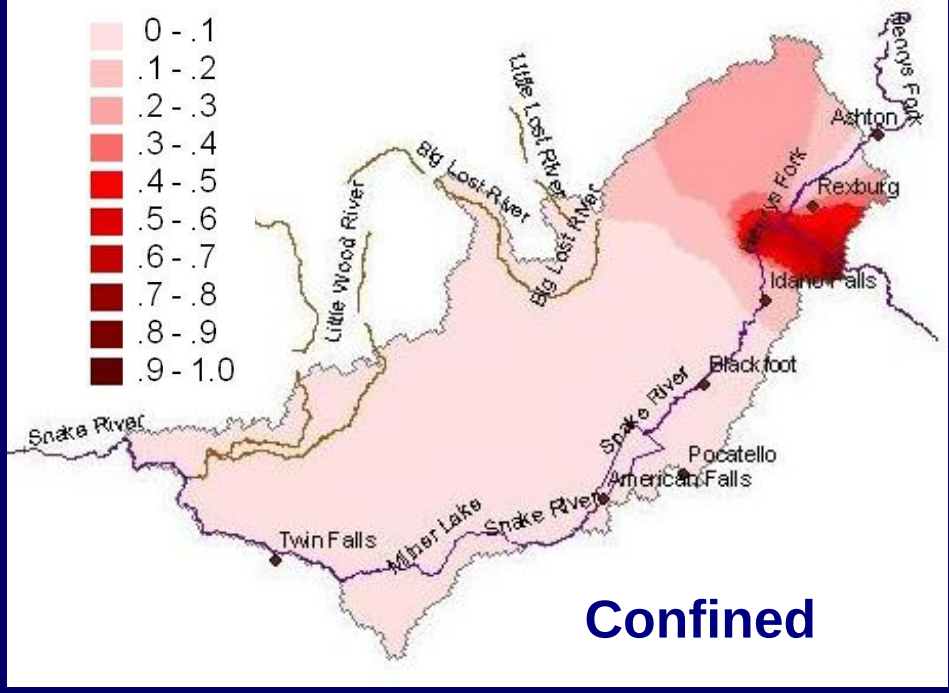




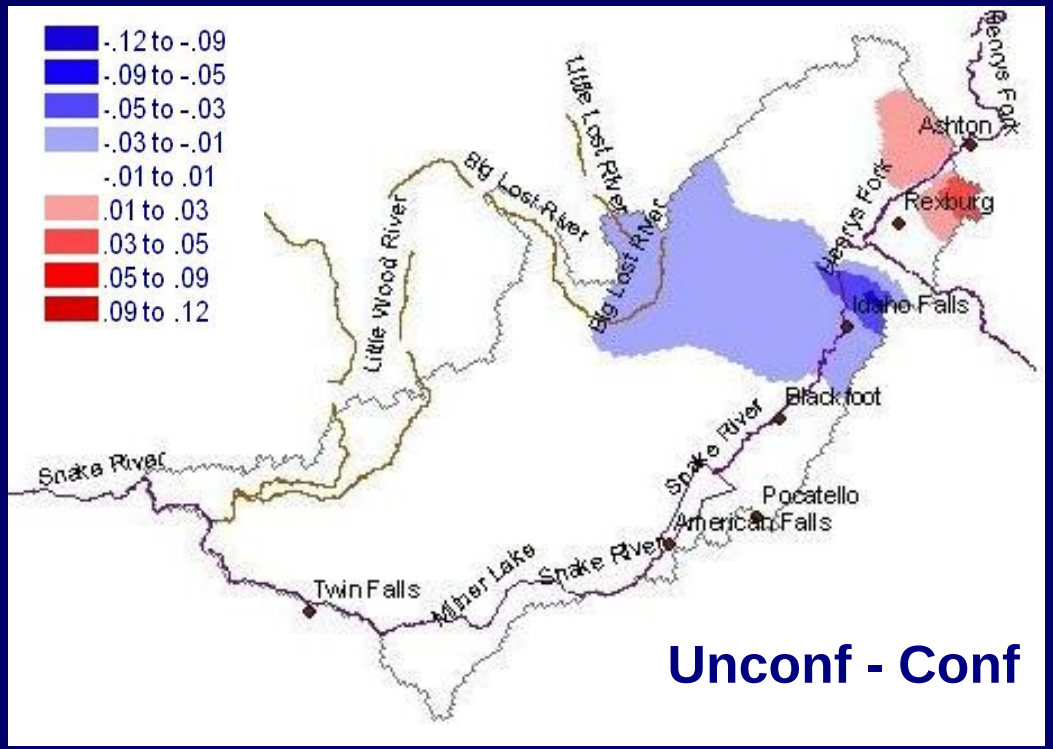
Ashton To Rexburg

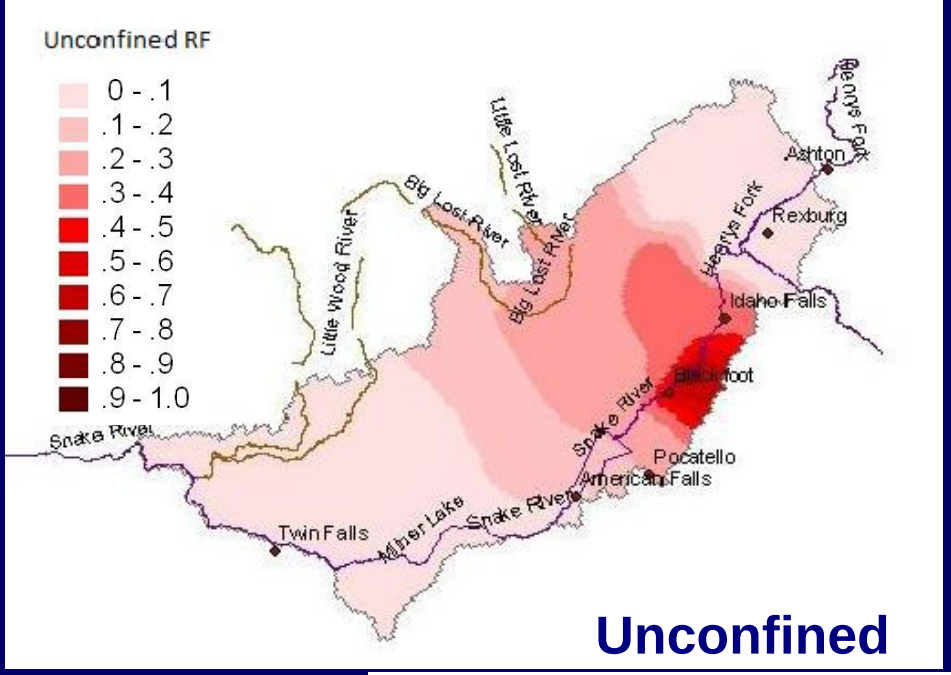


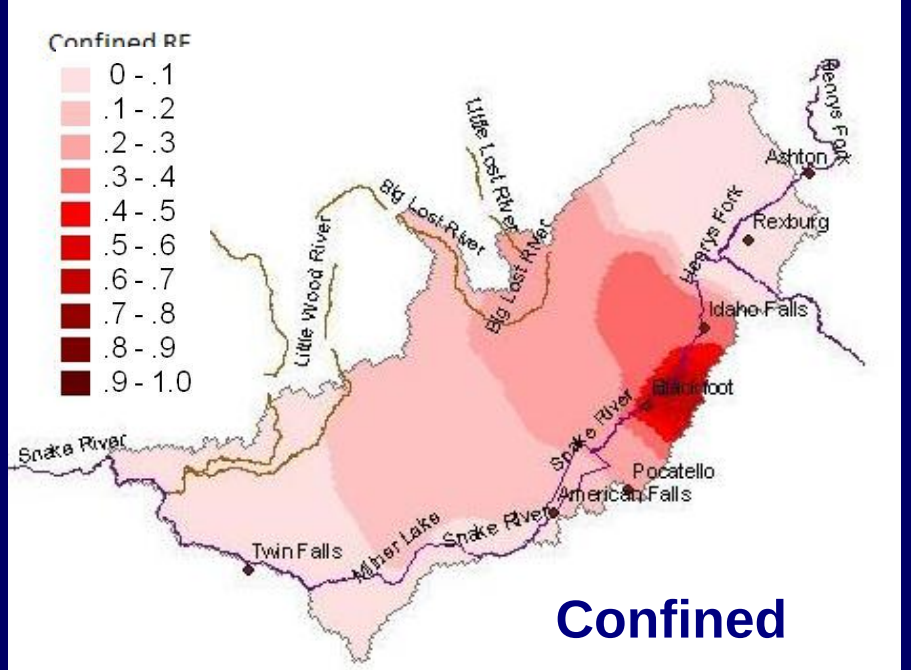




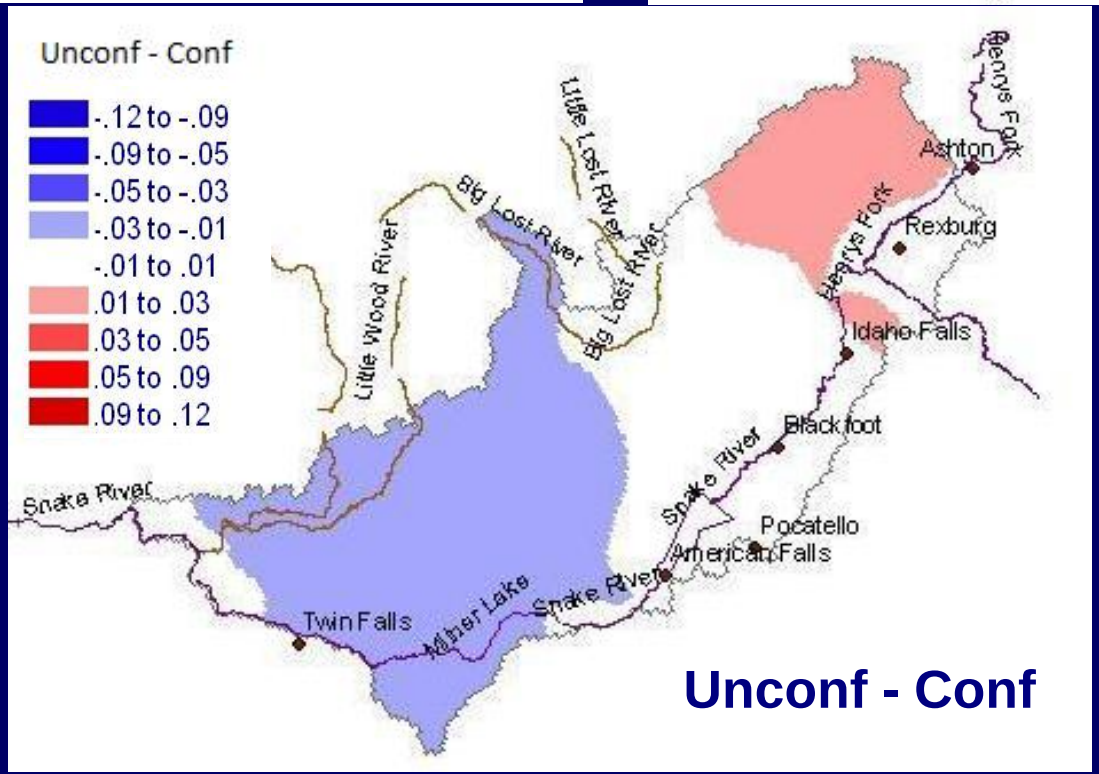
Heise To Shelley

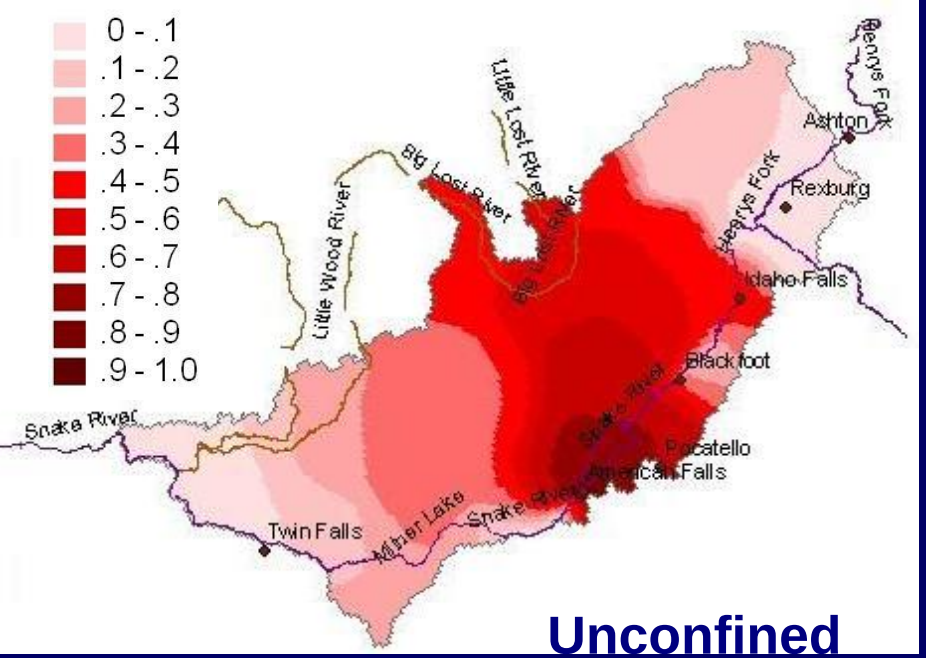




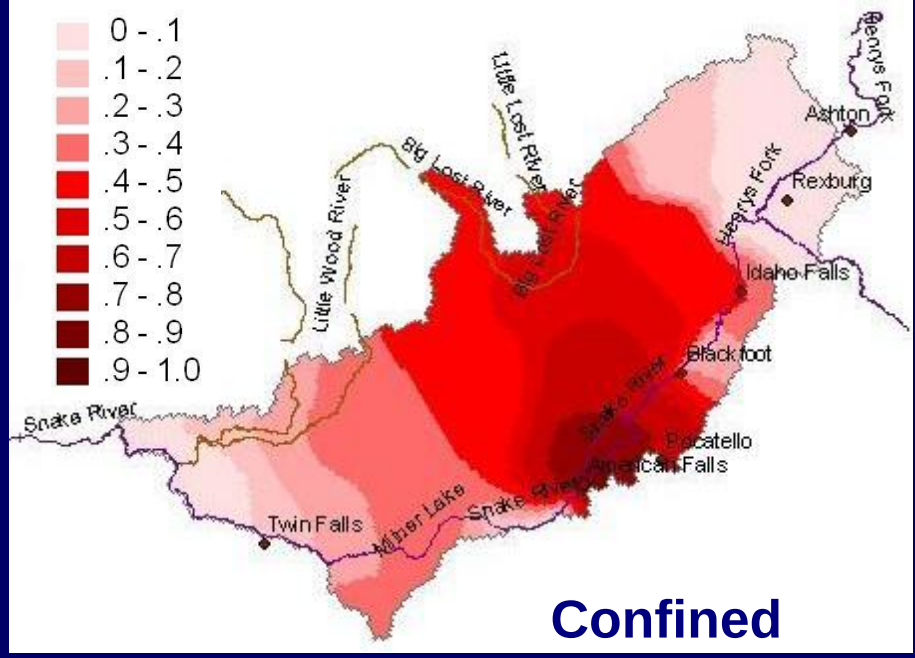


Shelley To Blackfoot



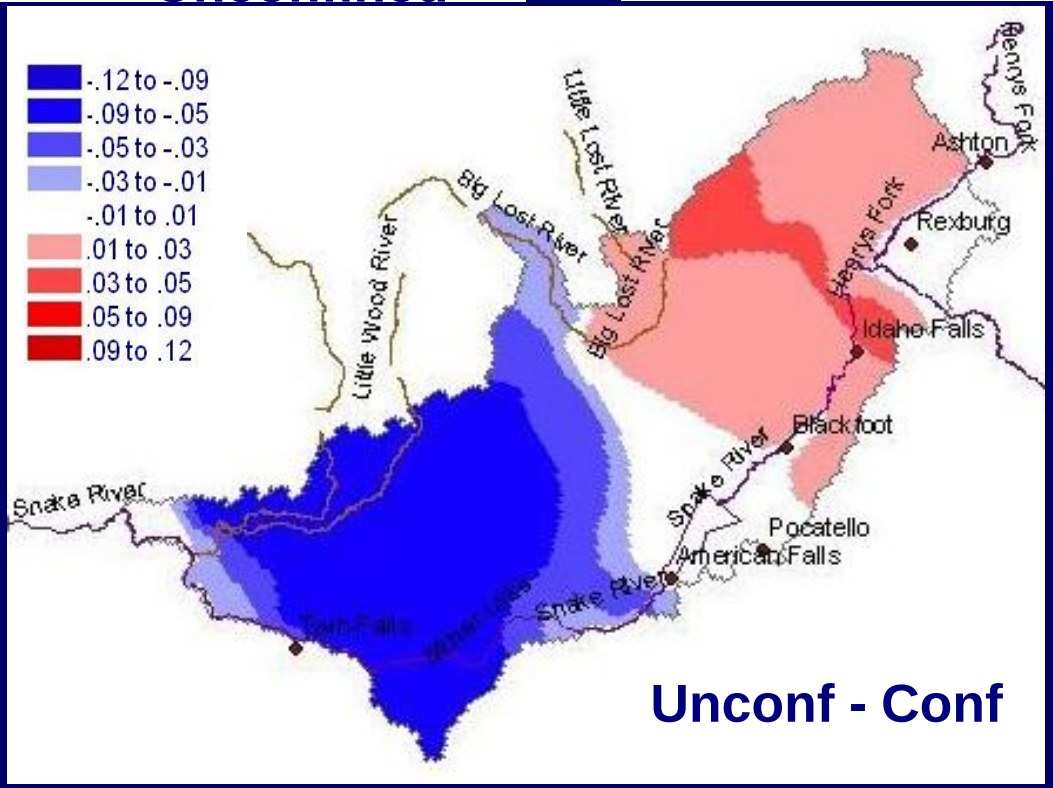


Unconfined

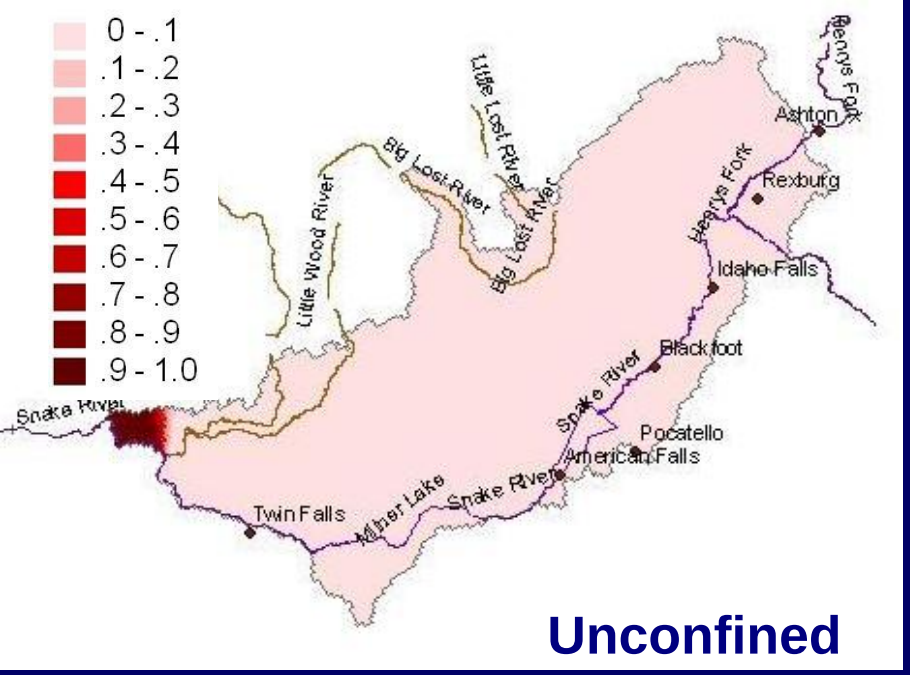


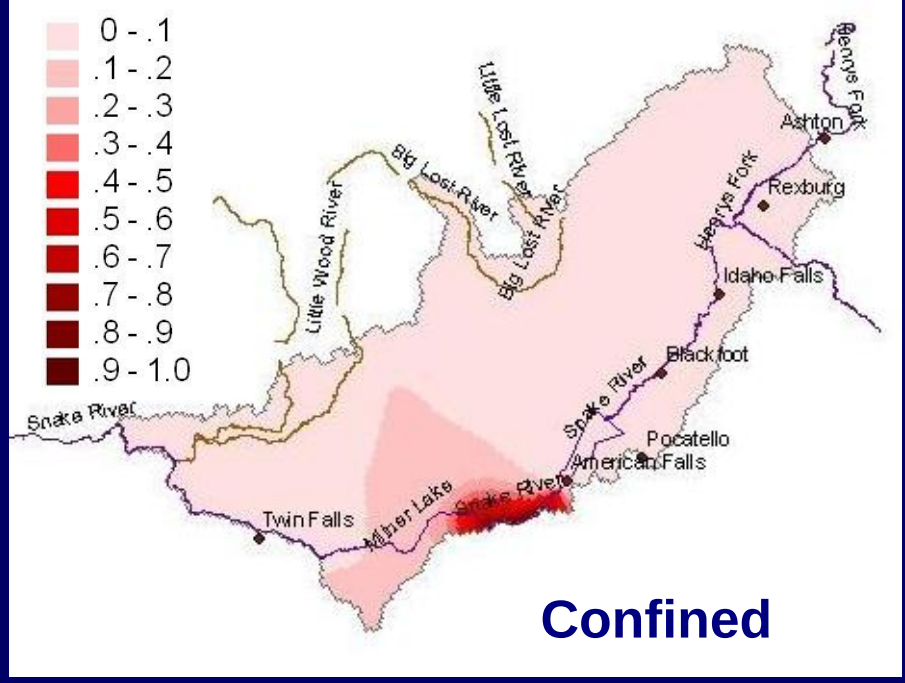
Confined

Blackfoot To Neeley

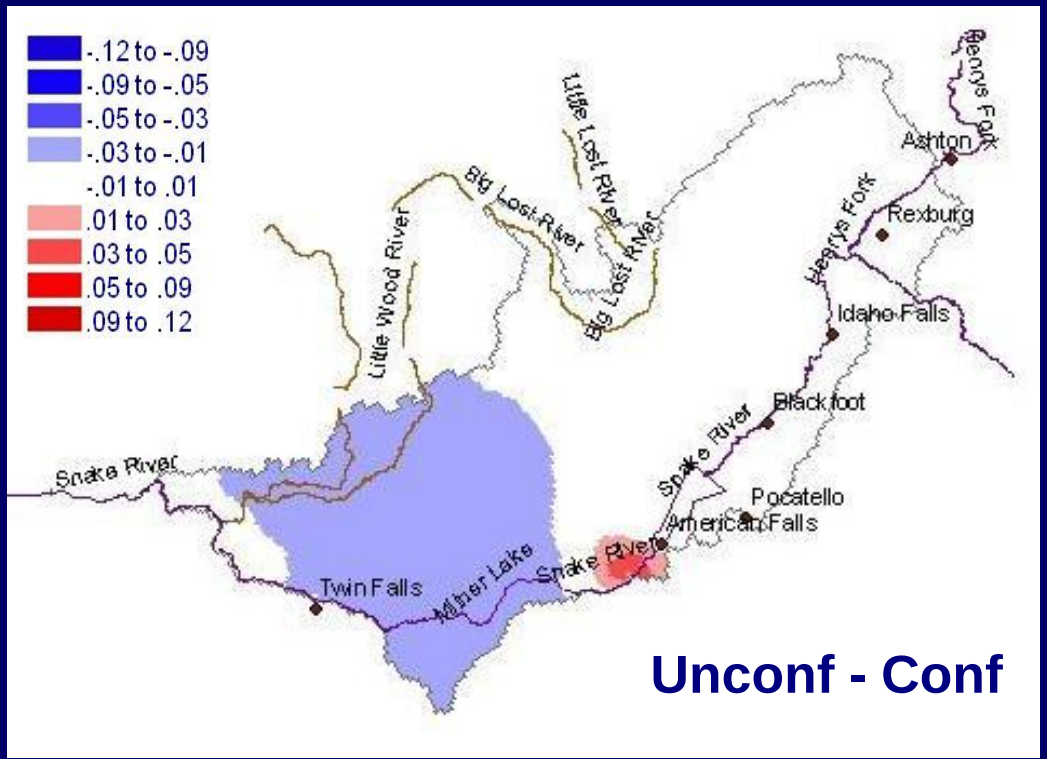


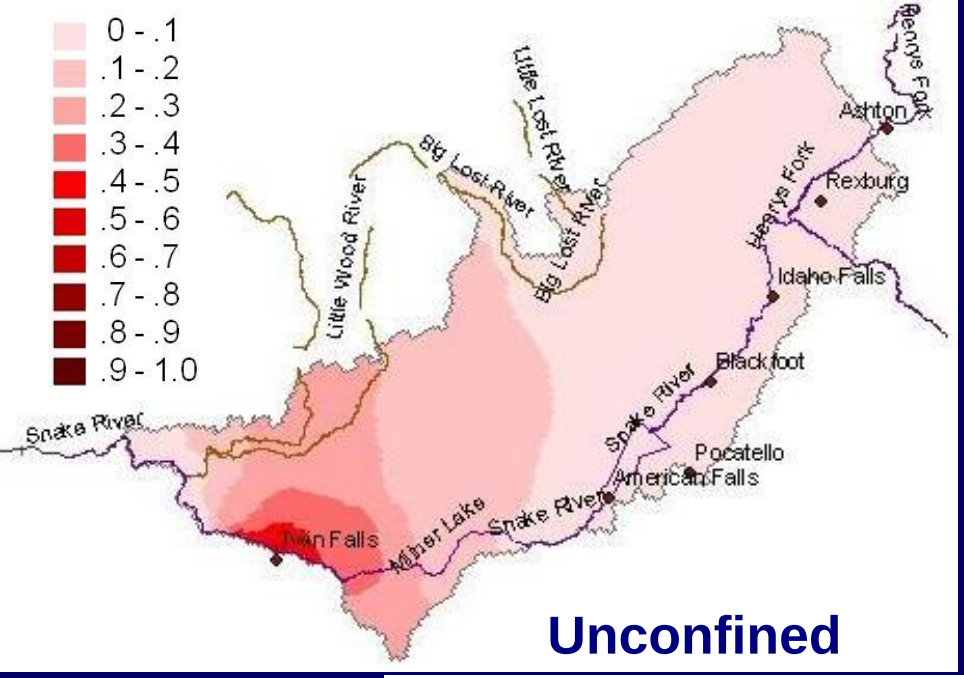
Unconf - Conf



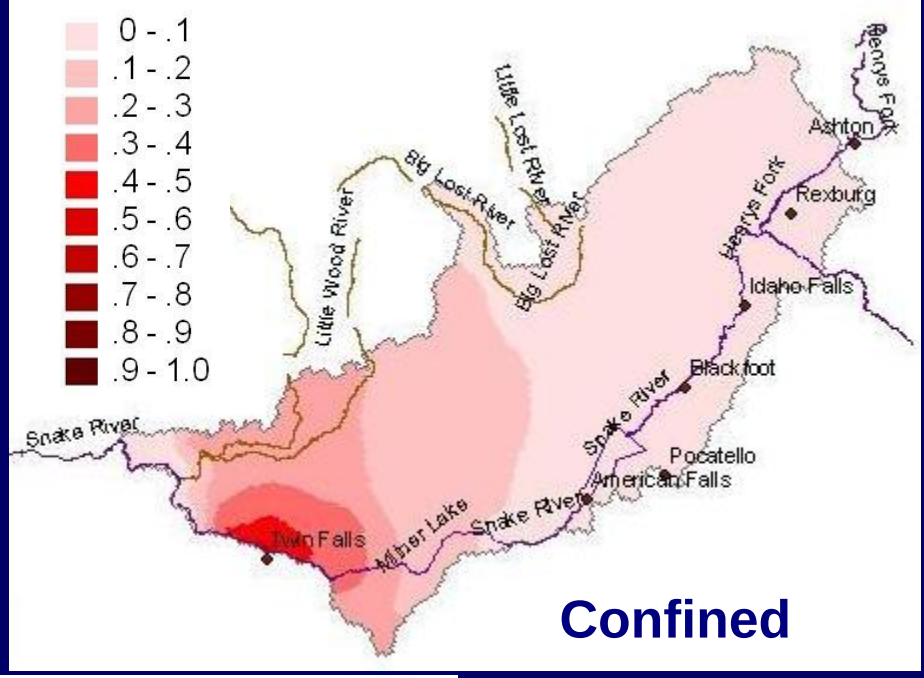


Neeley To Minidoka



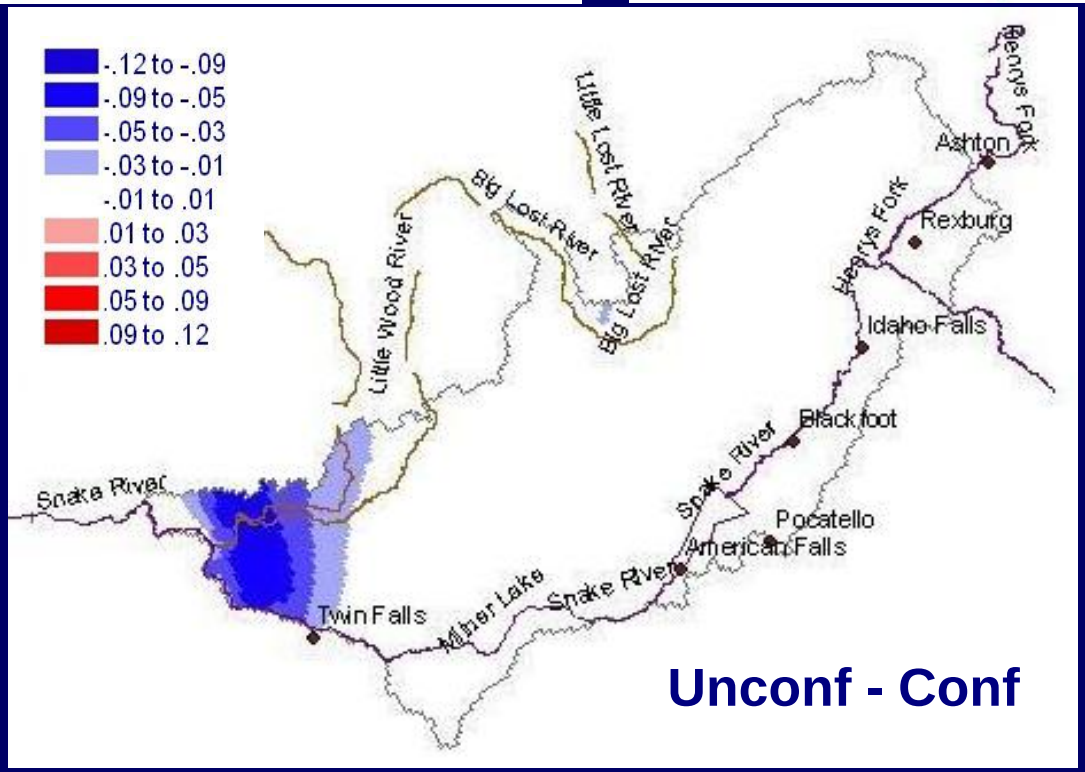


Unconfined

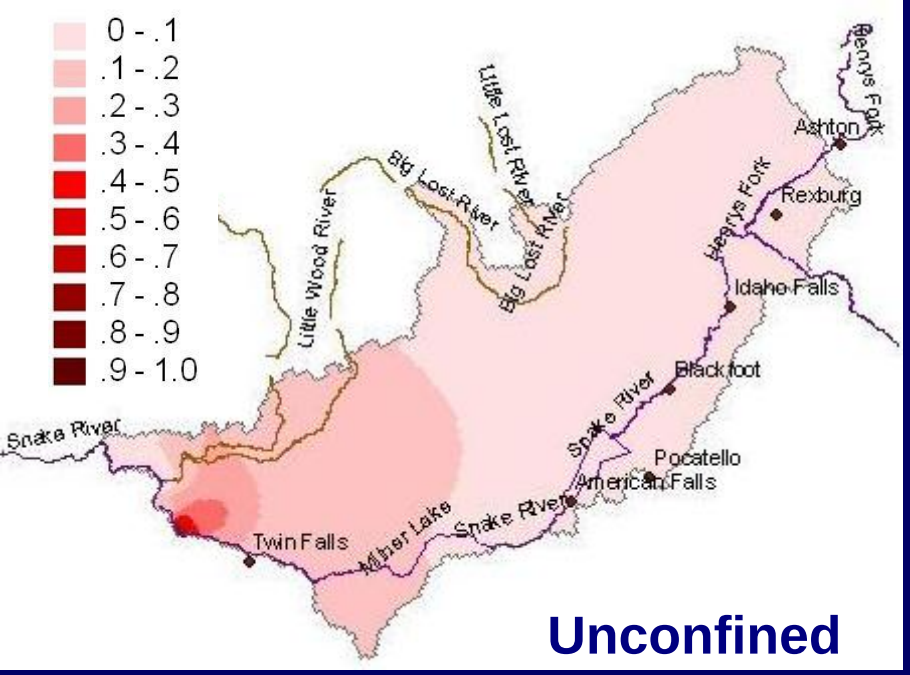


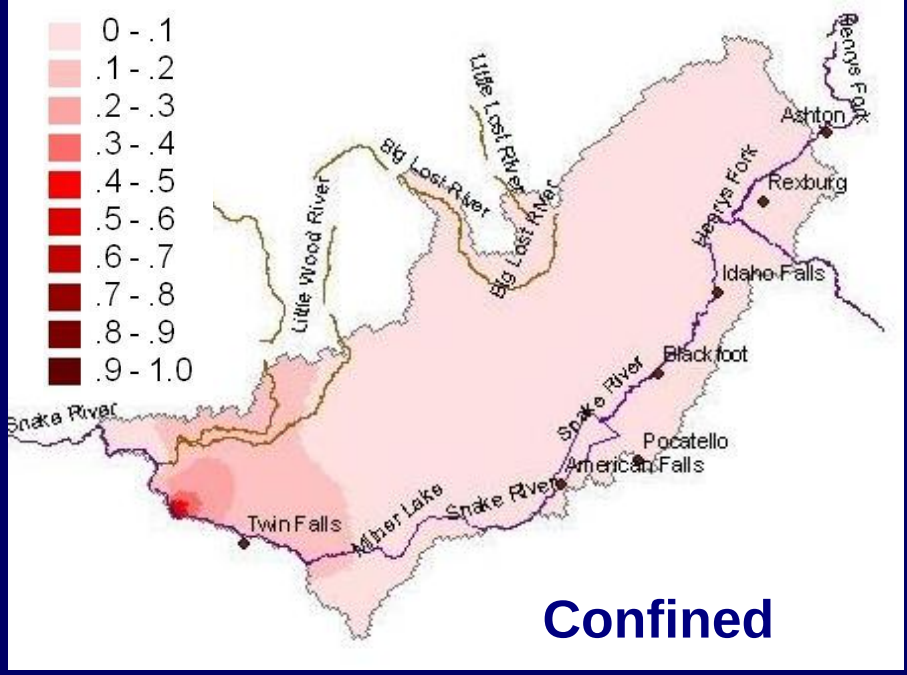
Confined

Devils Washbowl To Buhl

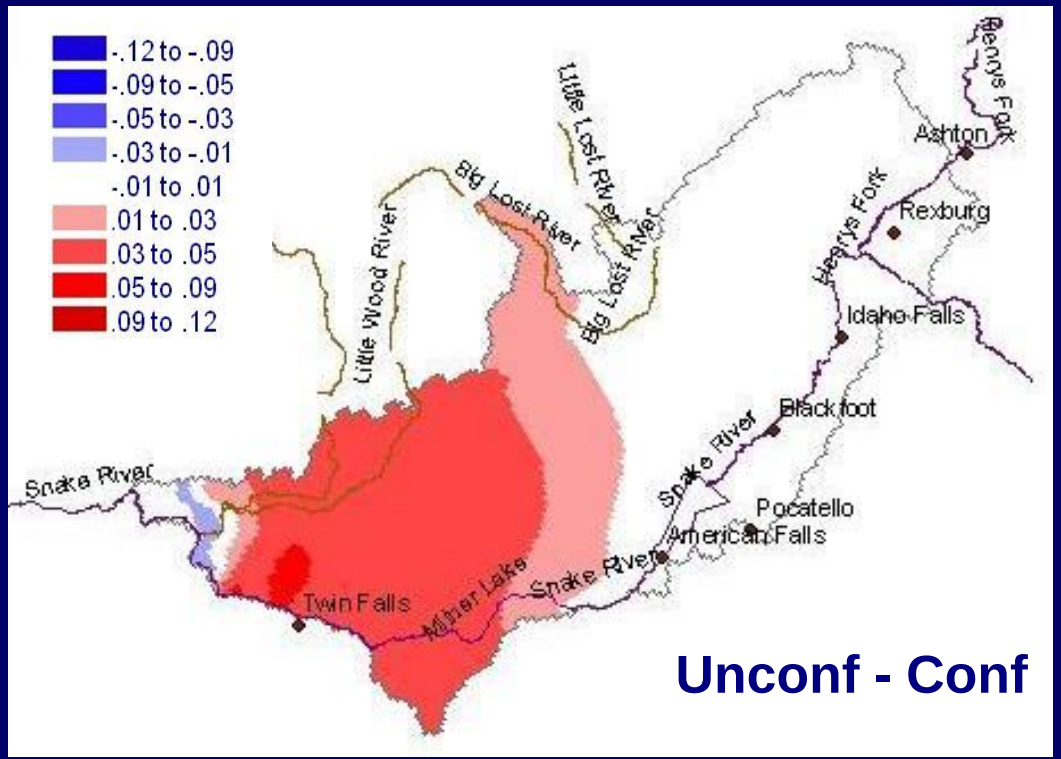


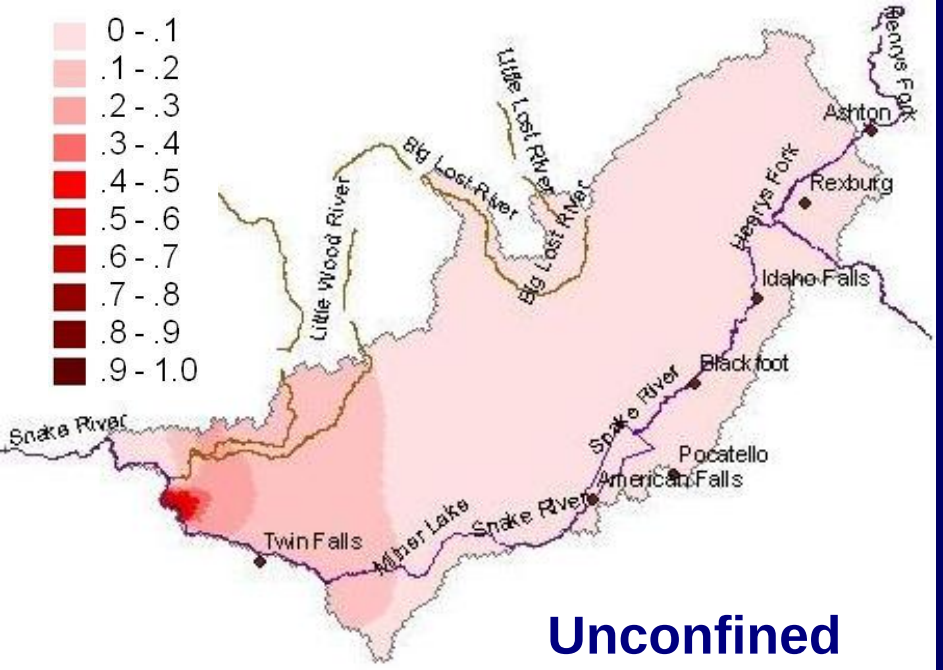
Unconf - Conf



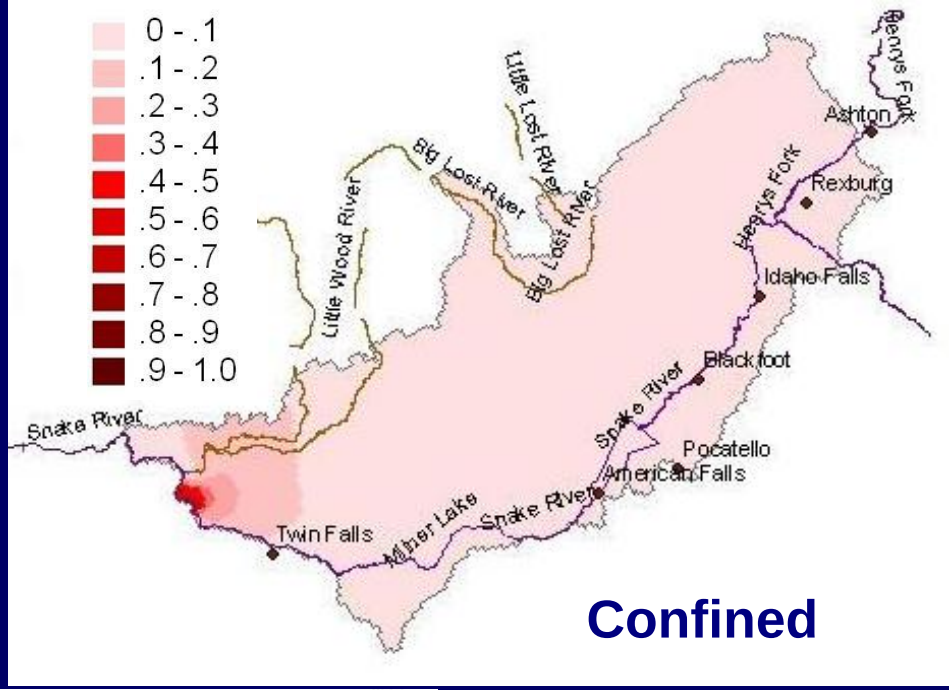


Buhl to K Springs



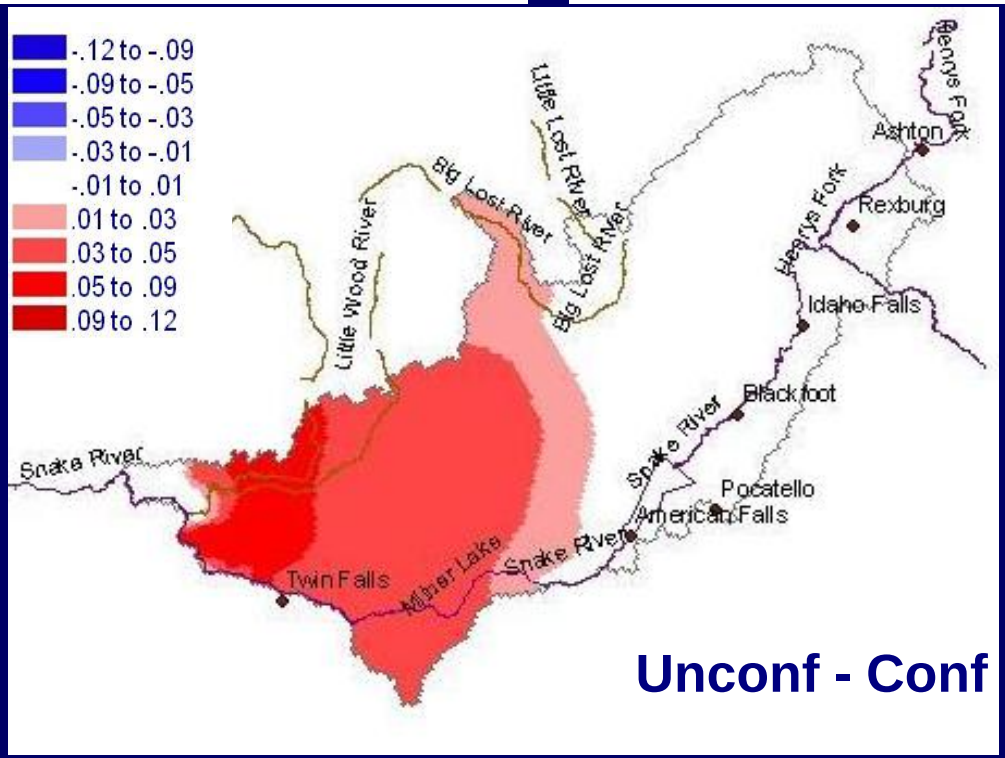


Unconfined

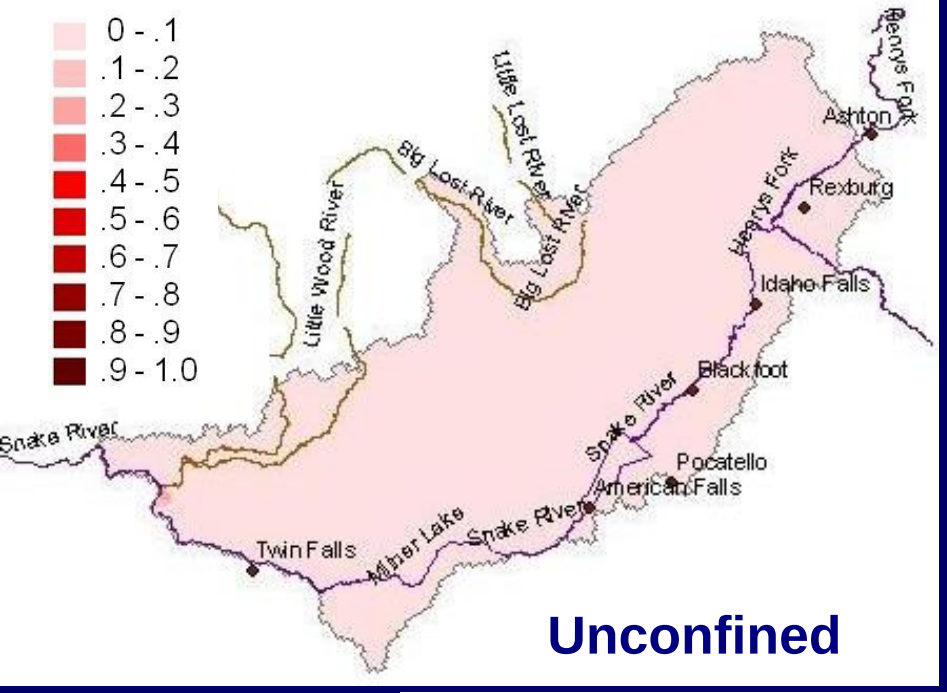


Confined

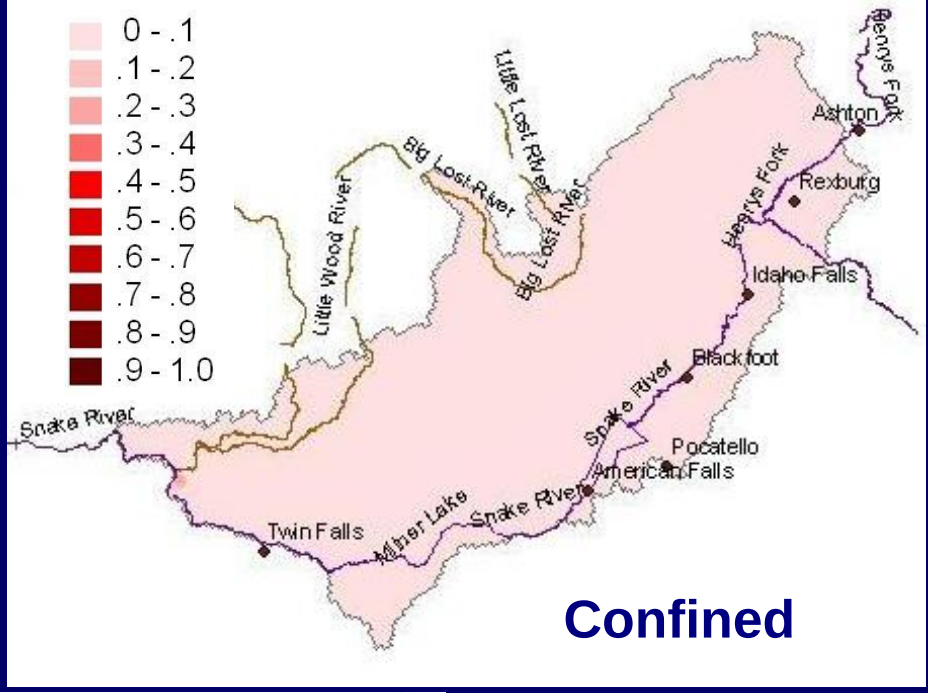
Thousand Springs



Unconf - Conf

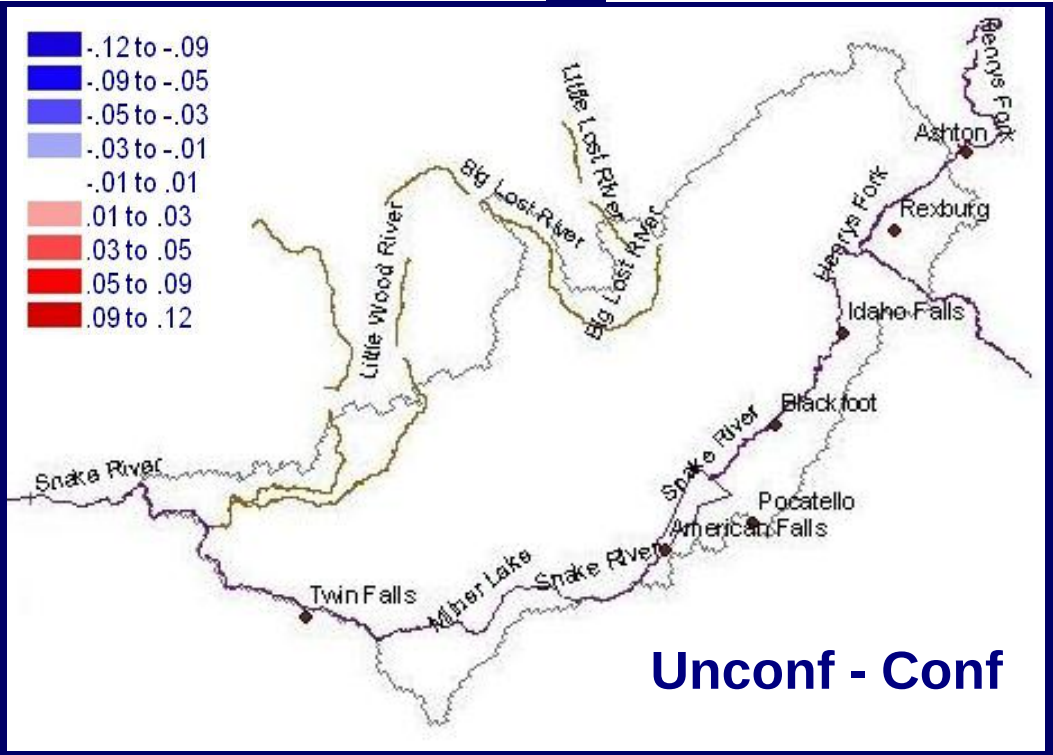


Unconfined

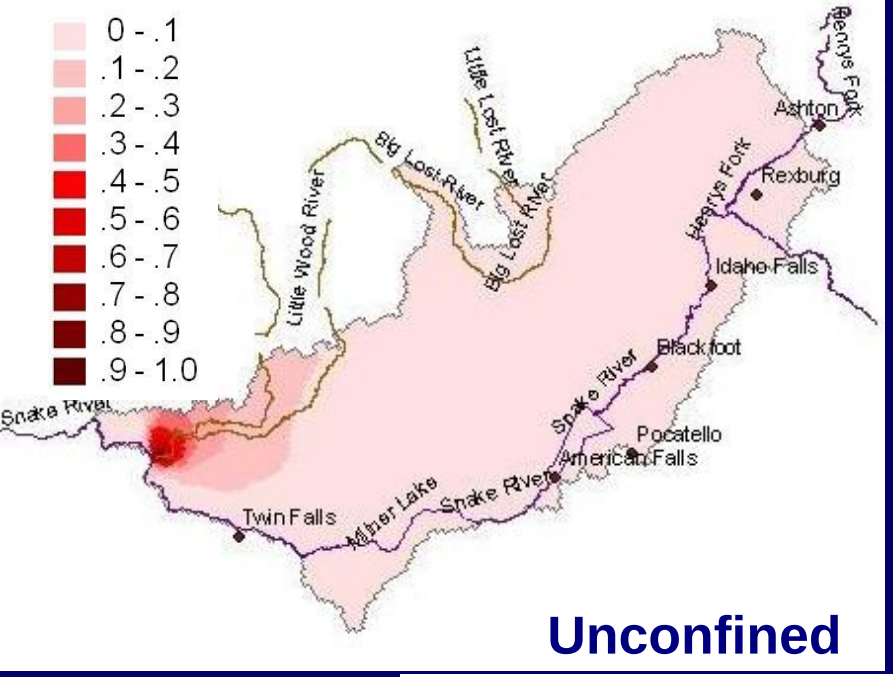


Confined

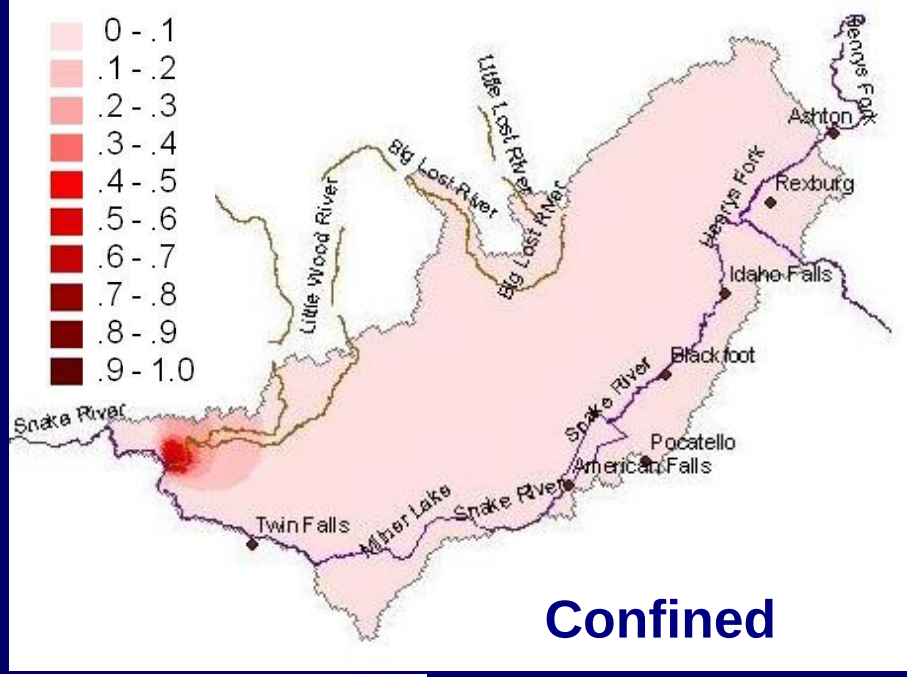
Thousand Springs To Malad



Unconf - Conf

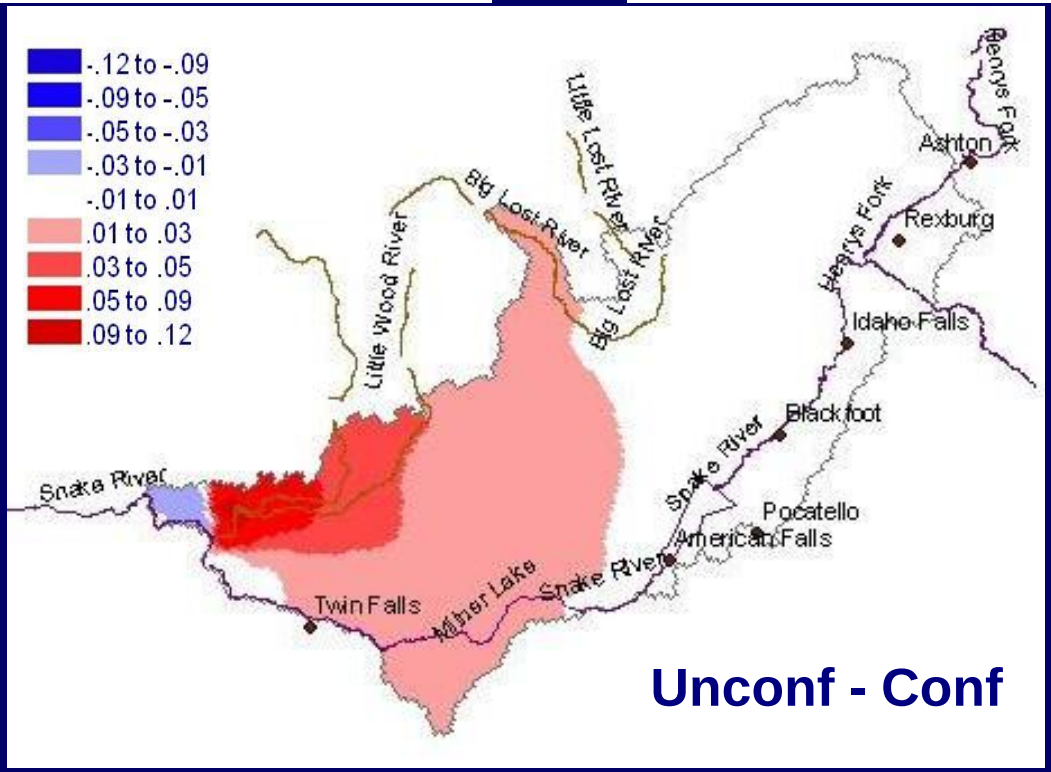


Unconfined

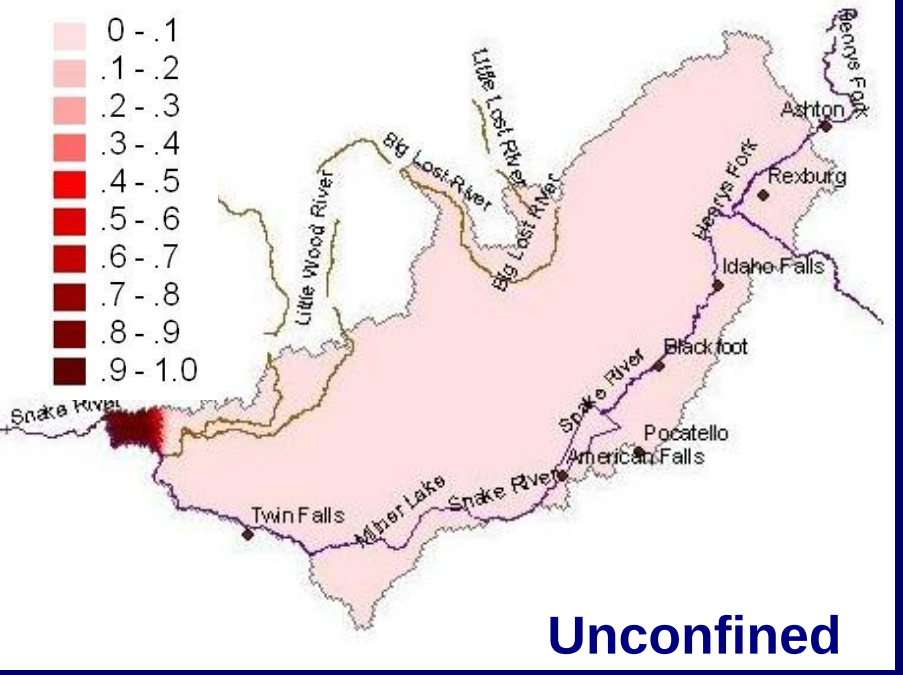


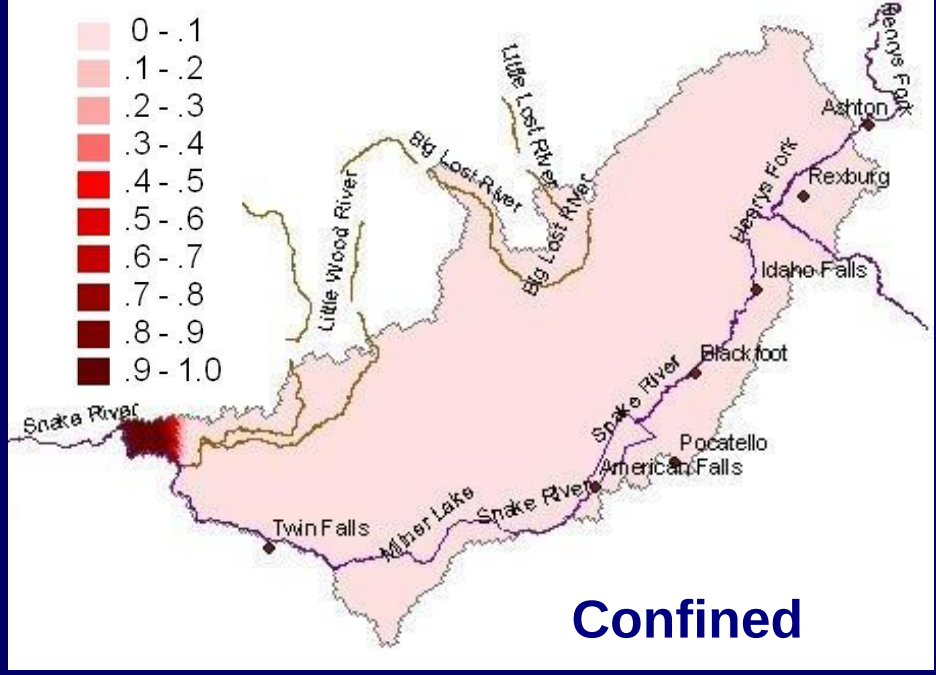
Confined

Malad

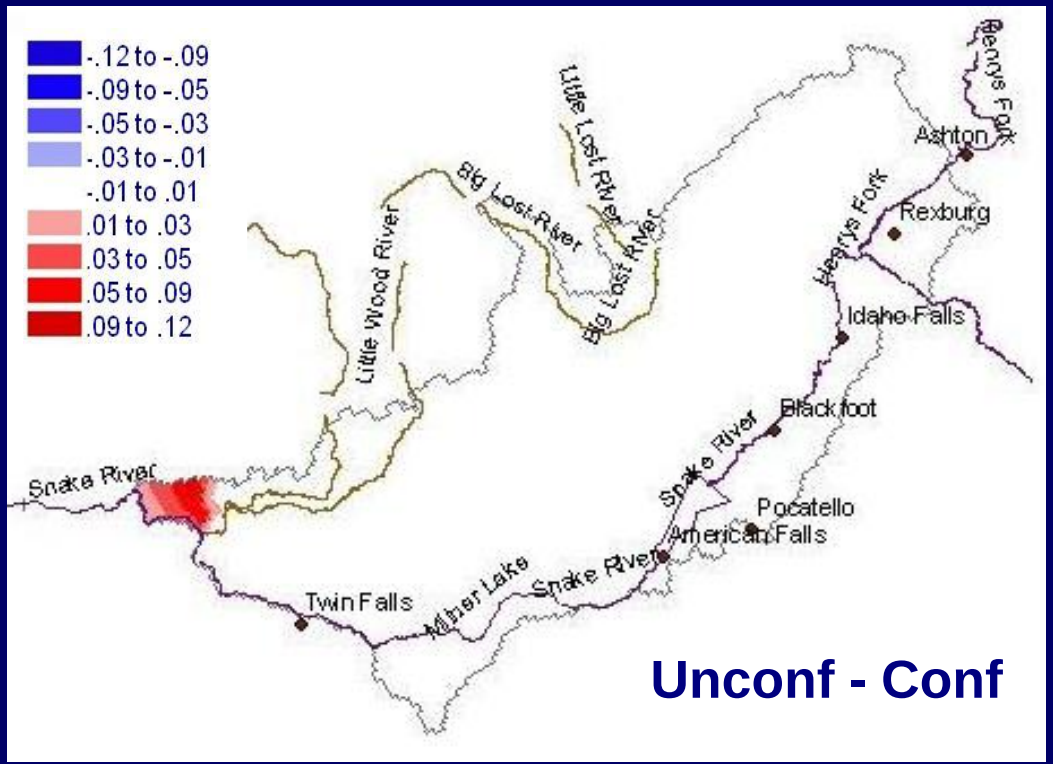


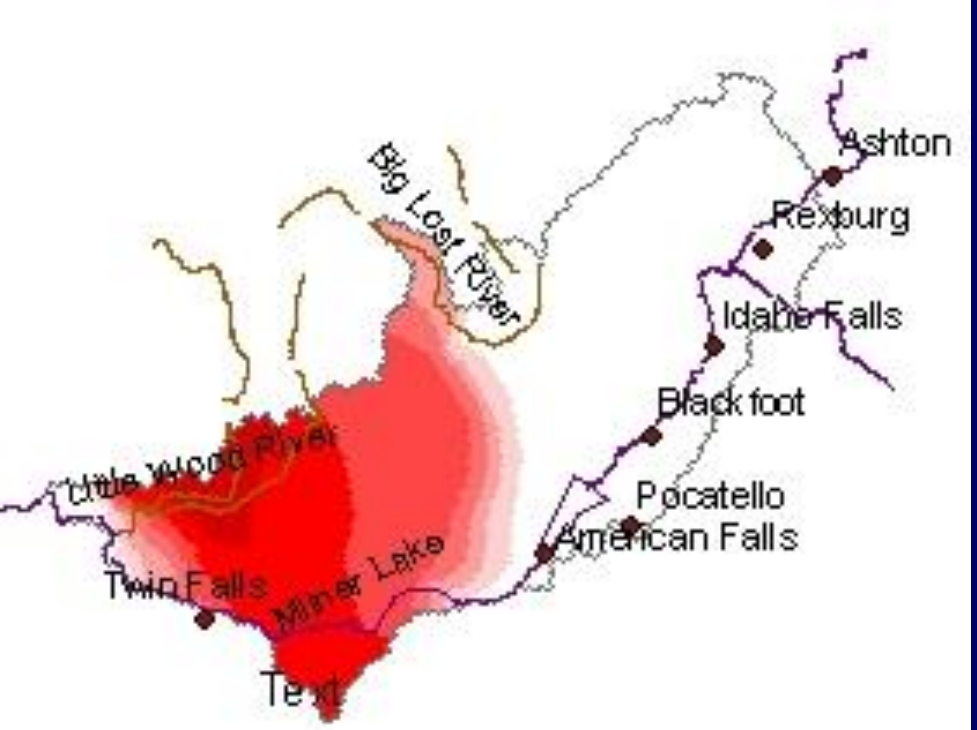
Unconf - Conf



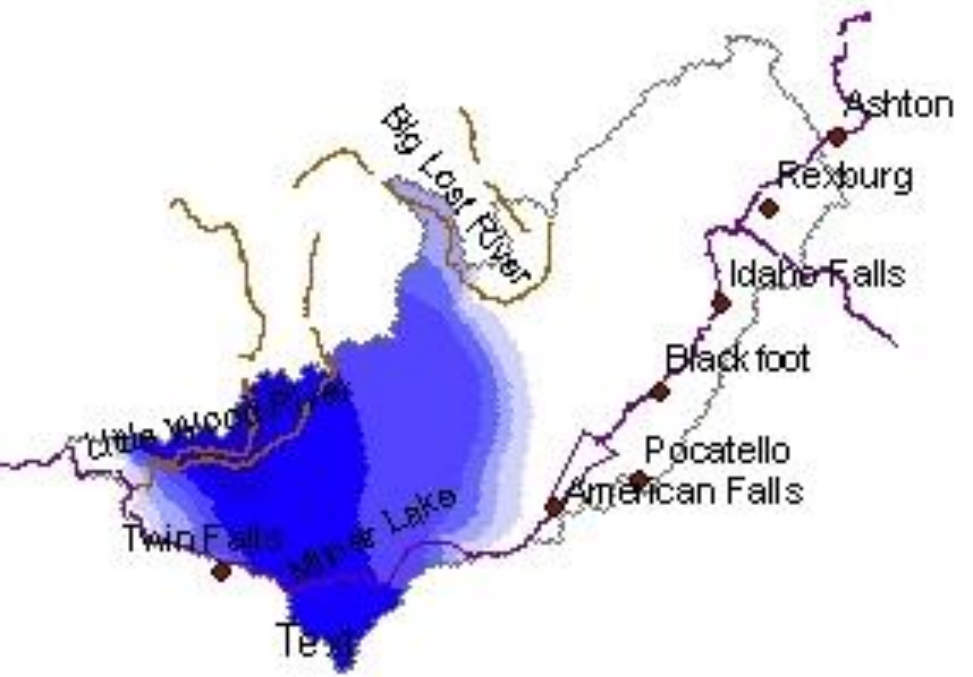


Malad To Bancroft



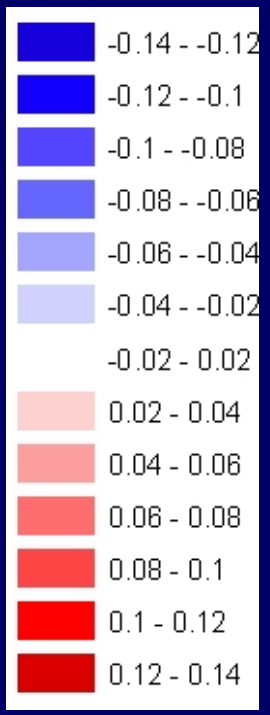


Aggregate Below Milner



Aggregate Above Milner

Unconf RF – Conf RF



Summary

- Unconfined simulations yield larger RFs than confined at down gradient reaches even in thick aquifers
- Results are nearly independent of magnitude or sign of Q
- Difference depends on many factors but can be equivalent to a ΔRF of 0.4 or more (as in Spokane-Rathdrum)
- Differences exist in both transient and SS
- In SRPA, ΔRF is less than 0.12 at all locations and reaches
- MAYBE it doesn't matter because we calibrate under the same conditions as used in applications
- This does not mean that we can't use response functions

Compensating by Calibration?

- Model calibration was as constant thickness and included reach gains
- Did model calibration create artificially large T to lower reaches, compensating for the constant thickness assumption?
  - Difficult to know, but maybe
    - Differences may be small relative to total reach gains but become significant when viewed relative to a specific stress
    - h also used as target which would possibly modify any compensating effect