Anticipating the Long Haul: Exploring Threshold Boundaries With Basin-wide Stream Depletion Mapping

Sustaining Colorado Watersheds Conference 2015: In it for the Long Haul
Wednesday October 6th – Thursday October 8th, 2015
The Westin Riverfront Resort, Avon, Colorao

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Water Resource and Environmental Consultants

Outline

- Stream-Depletion Products
- Scott River Valley Introduction
- Groundwater model of the Scott River Valley
- Creating Stream Depletion Simulations (SDS)
- SDS Results
  - Trends with time
  - Seasonal fluctuations
  - Spatial variability
  - Connection/disconnection, **thresholds or trouble spots**

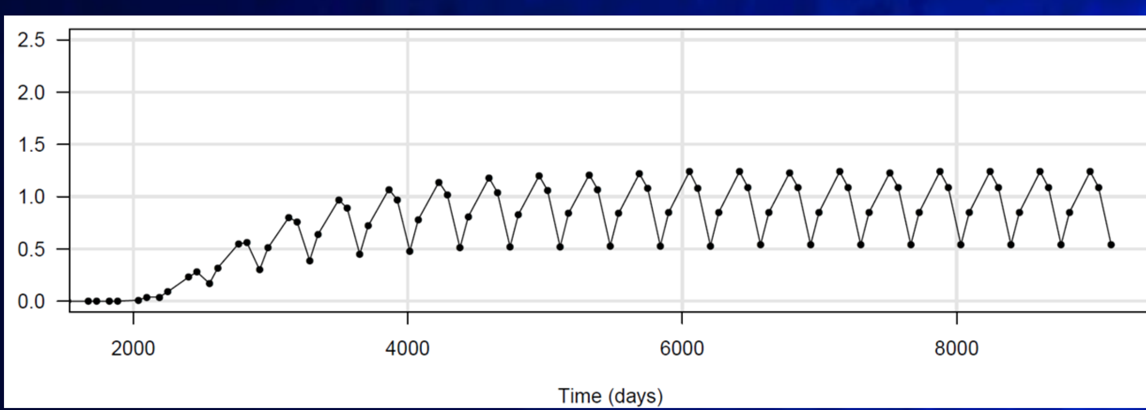
Conceptual presentation

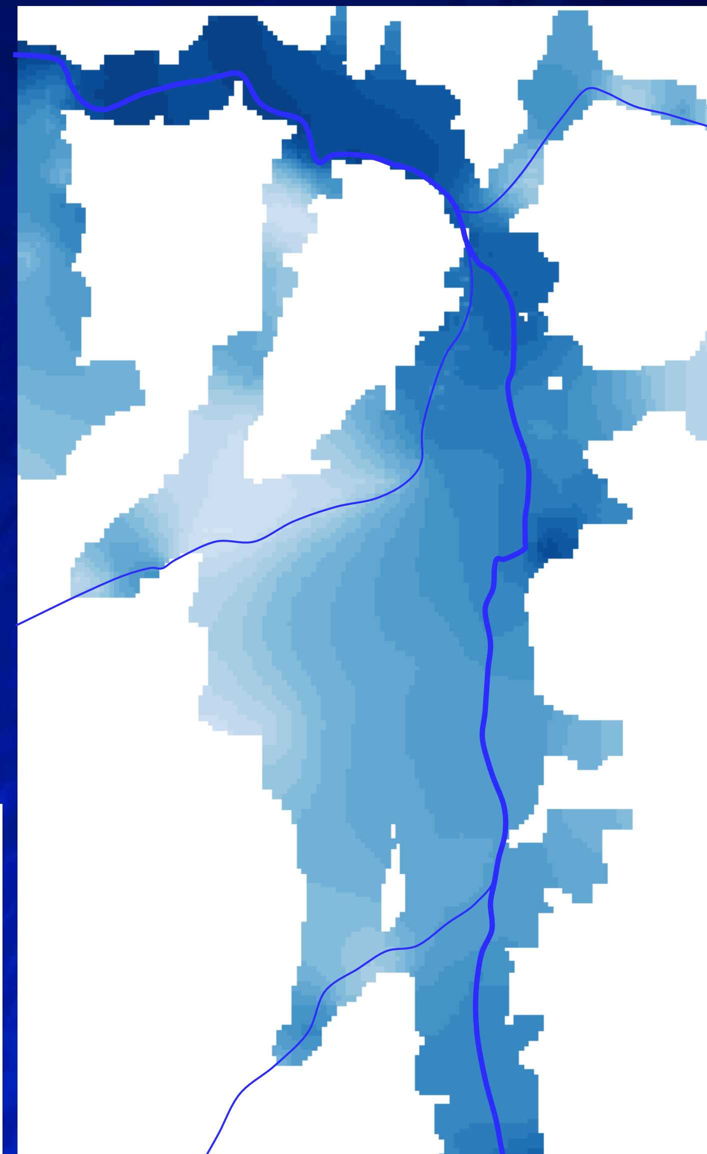
- *Results are preliminary*
- *Additional work will be required to quantify results for the particular system*

Slide 3

Quantifying Stream Depletion

- Stream Depletion Maps
  - Snapshot in time
  - How does pumping (or injection) affect the river
  - Proportion of pumping/recharge from/to stream
- Response Functions
  - At a specific location
  - Changes with time
    - Trends
    - Seasonality





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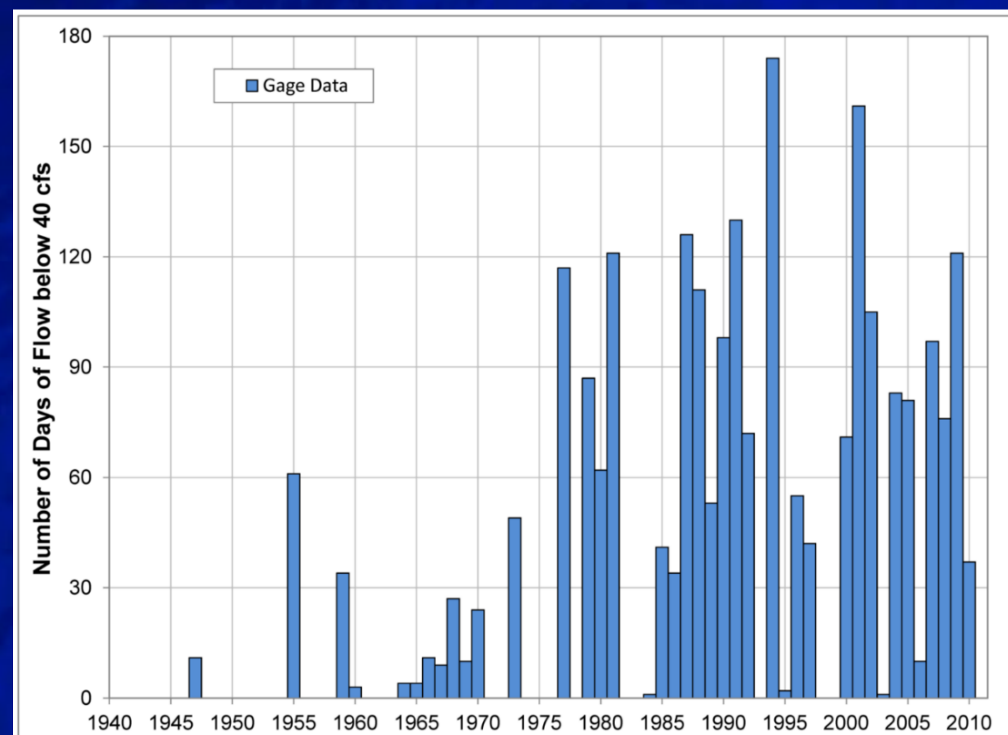
Estimating Stream Depletion : Scott River Valley

- Northern California
- Alluvial Valley
- 70 square miles
- Snowmelt driven
- Primarily agriculture

Scott River Flows

- Low flows in the Scott River and its tributaries
- Potential causes
  - Supply changes
  - Demand changes

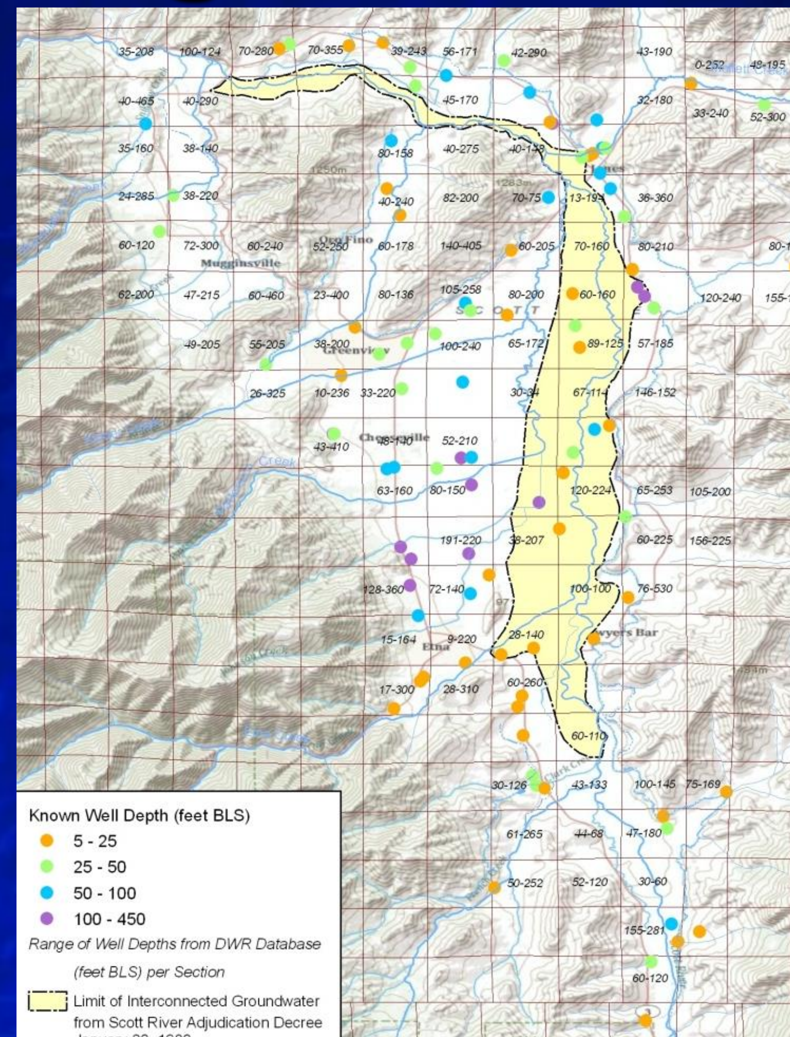


Long-Term Change in Basin Yield

- Van Kirk & Naman, JAWRA, August 2008
  - Analysis of Basin Yield from Snow Water Data
    - Historical period: ~ 1940s to 1976
    - Modern period: 1977 - 2005
  - Average historical declines in late summer flow are:
    - 39% due to climate,
    - 61% due to watershed factors

Potential Watershed Demand Changes

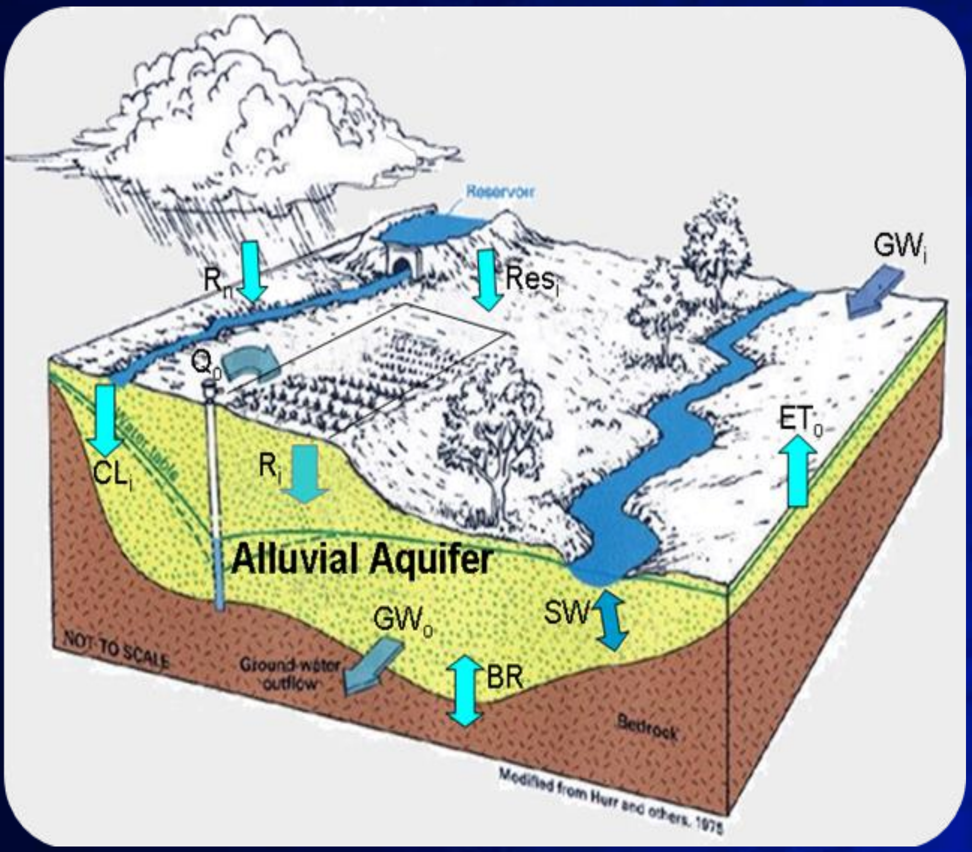
- Numbers of irrigation wells:
  - 99 irrigation wells in 1979
  - 130 irrigation wells in 1999
  - 172 irrigation wells in 2010
- Groundwater
  - Offset late-season surface water shortage
  - Extend growing season during dry years



Can We Increase/Restore Flows?

- What changes would improve impacted flows?
- Can we provide information to help develop a set of proposed changes?

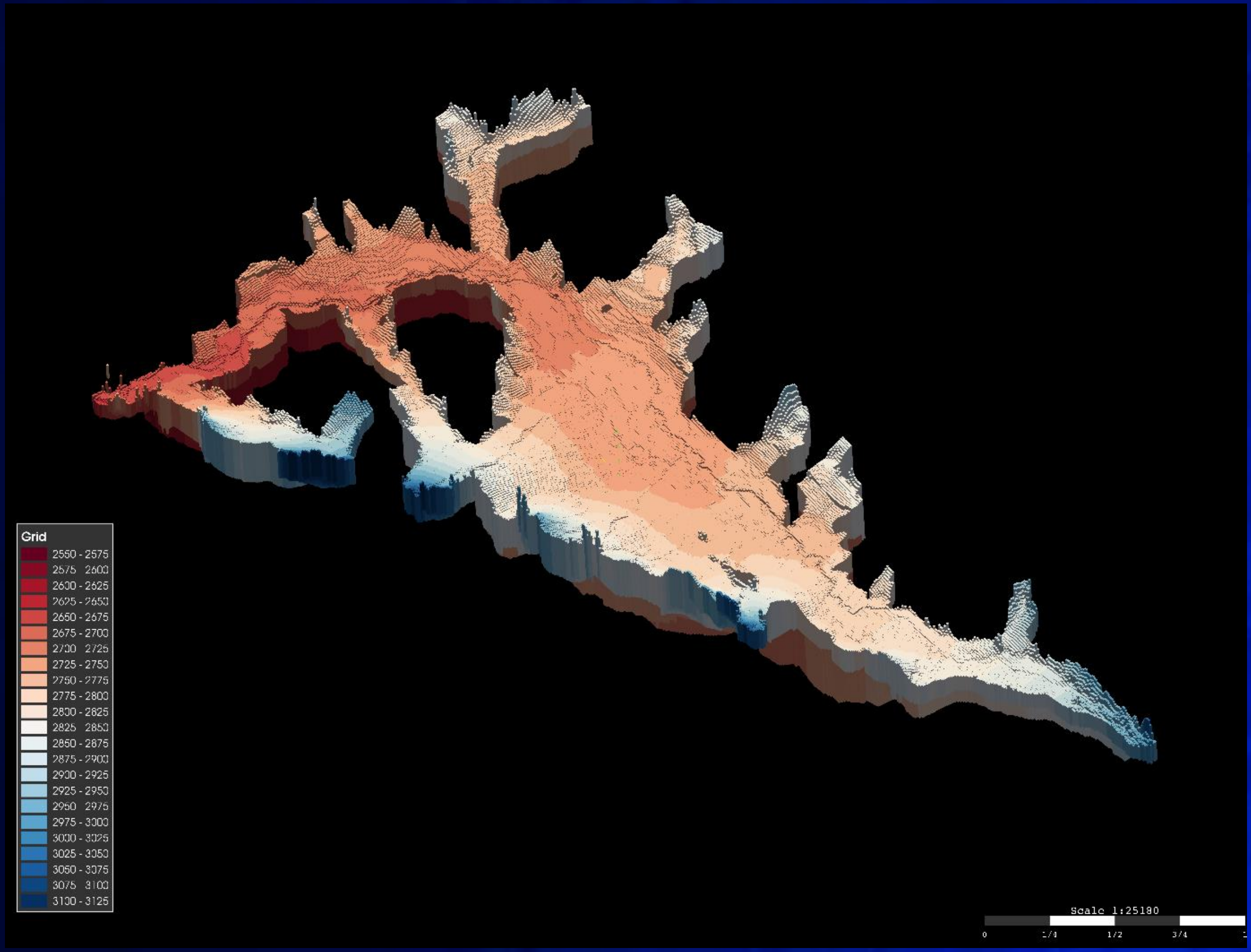
Improving Streamflow in Groundwater- Connected Systems



- Management options, e.g.,
  - Artificial recharge using excess winter flows
  - Floodplain connectivity for infiltration
  - Timing and location of pumping
  - Augmentation wells
- Evaluate dynamics
  - Distance/layout impacts
  - Aquifer material properties
  - **Temporal/spatial redistribution of available resources**

Groundwater Model

- Literature: USGS, DWR, CA Water Resource Control Board, UC-Davis (Prof. Harter), other
- Field Visits: 3/20, 8/17-18, and 9/26-27, 2011 and a Basin flyover, 9/29, 2011

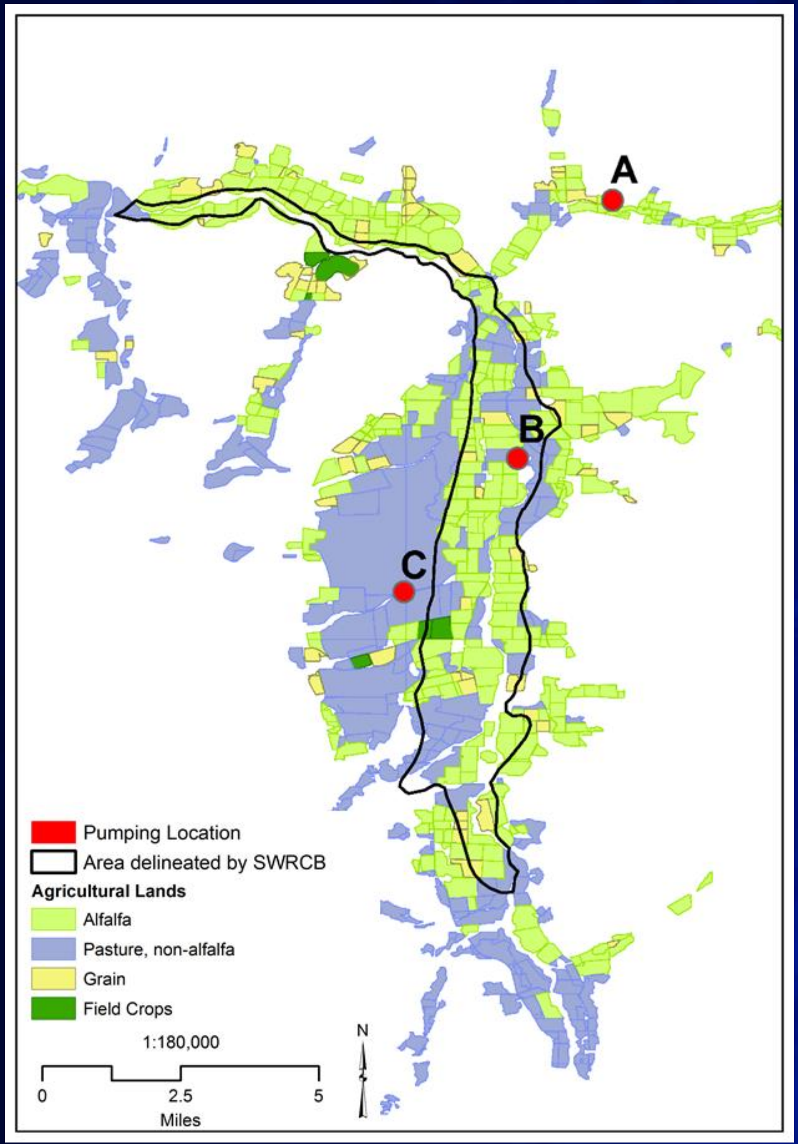


- Data
  - Groundwater Elevations (USGS, DWR)
  - Surface Water Gaged Flow (USGS, DWR)
  - Irrigation Water Use (DWR)
  - Topography (LiDAR, USGS DEMs)
  - Watershed Yield, Climate (PRISM)
  - Aquifer Response (short-term and long-term)
  - Soils, Geology (>1,000 logs reviewed)
  - Scott Valley Decree

Groundwater Study Conclusions

- With simulated post-1980 pumping increases
  - Simulated groundwater levels **decline**
  - Declines are on the order of **a couple feet**;
- Stream depletion quantities are **consistent** with the observed non-climate-related Scott River flow decreases (61% of change)

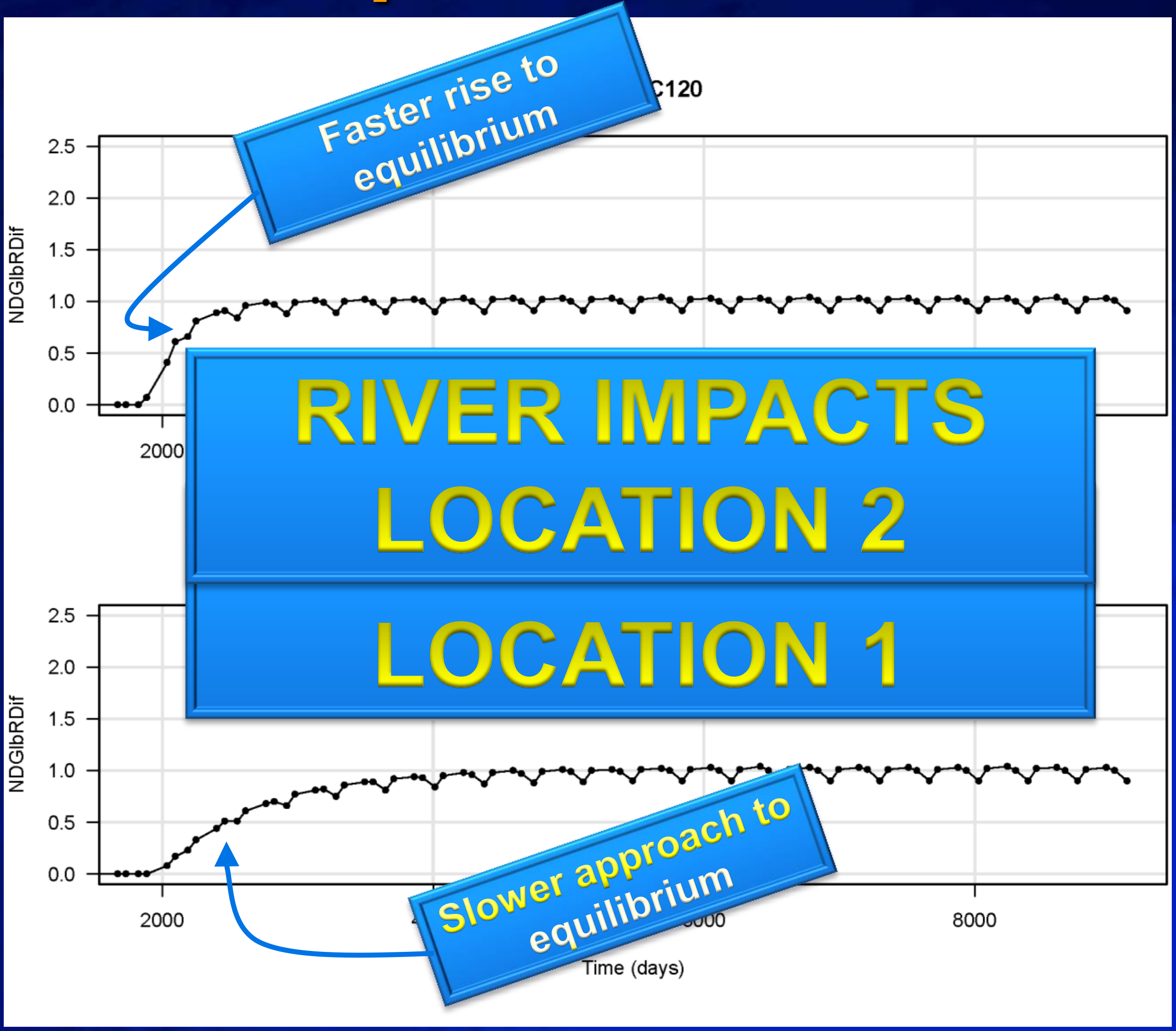
Can We Make a Screening Tool?



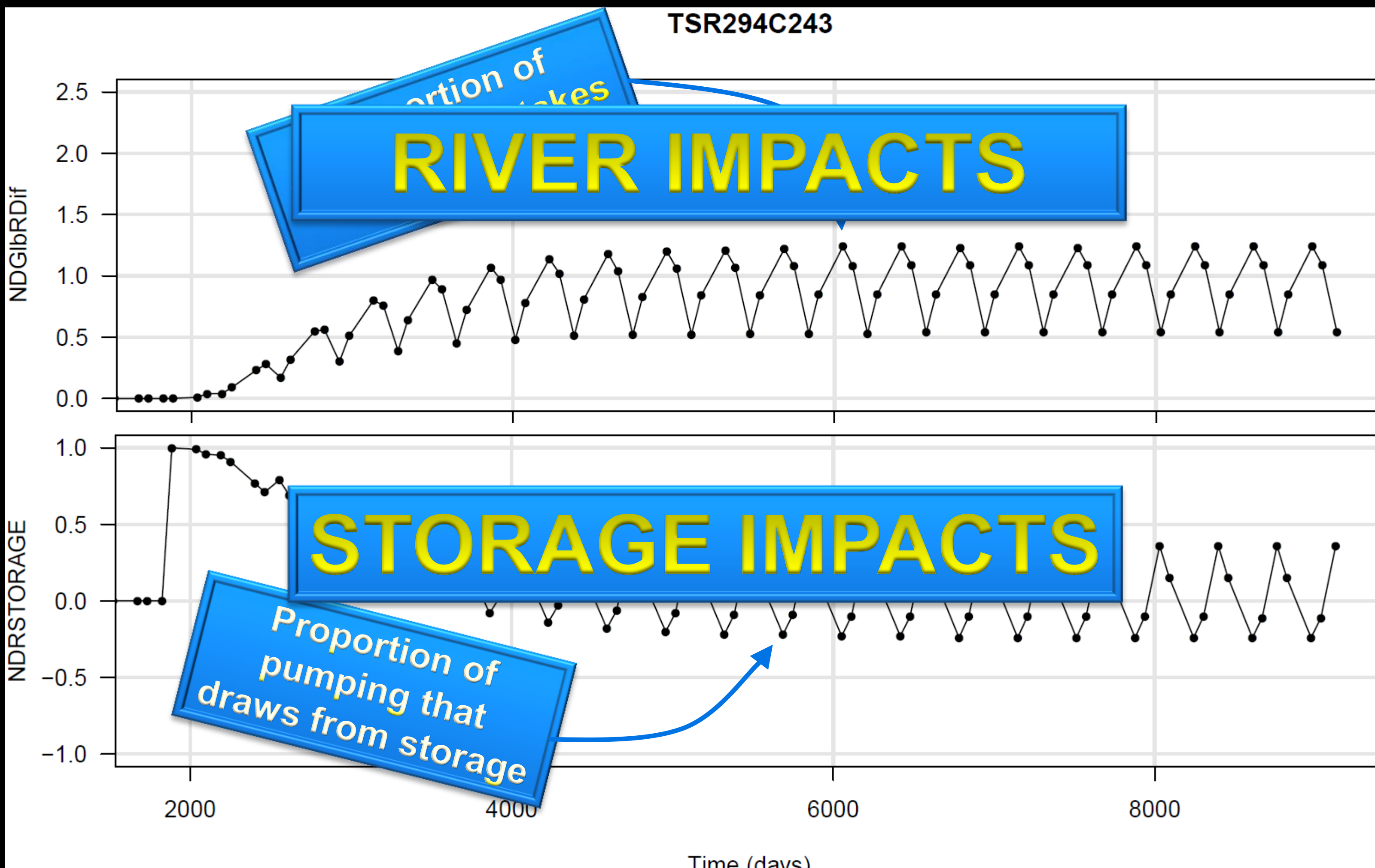
- **Stream Depletion Simulations (SDS)**
  - "baseline"
  - "baseline + change"
  - "change": pumping/recharge at A, B or C
- Compare flow to/from
  - Stream reaches
  - Other features
- Graphs and maps to assess
  - Critical timing
  - Sensitive locations

Stream Depletion

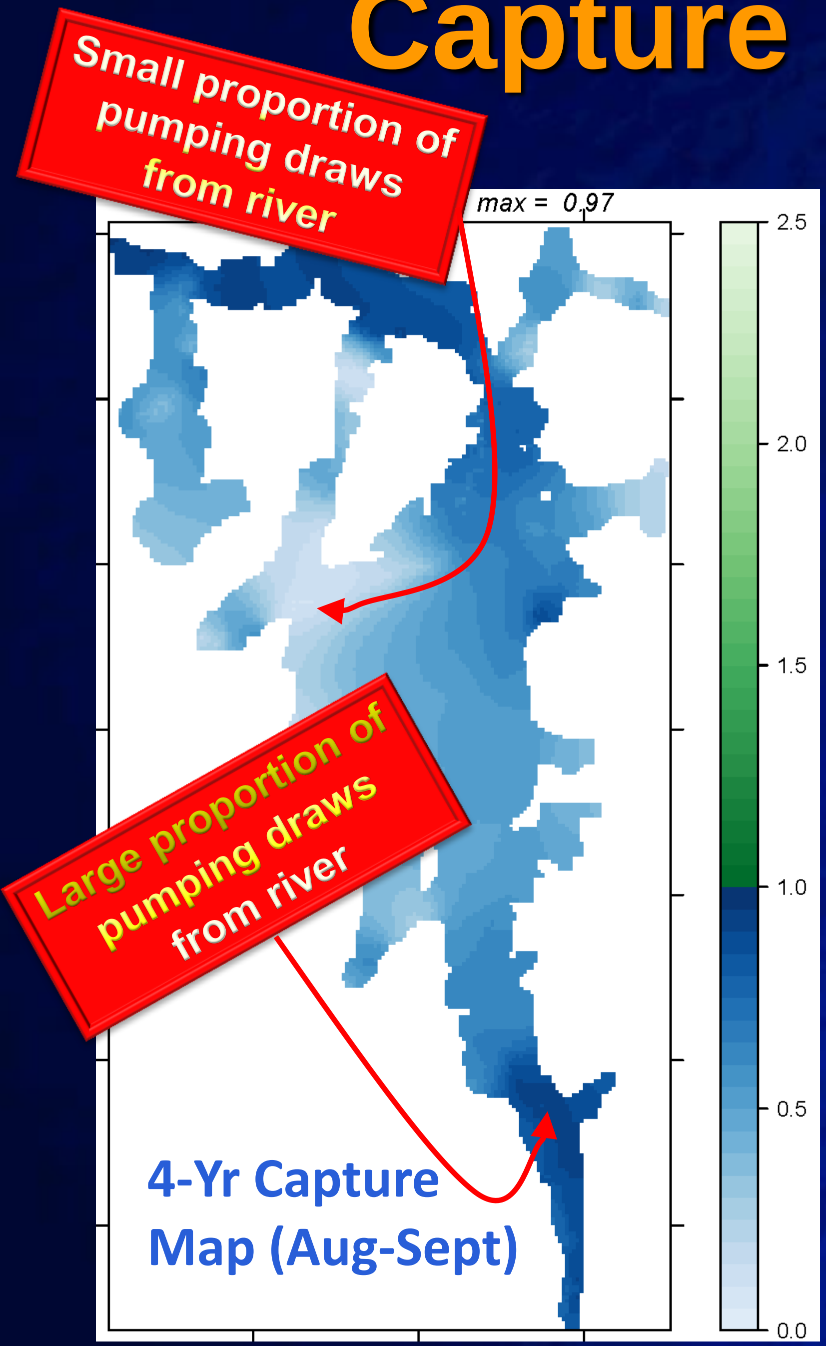
- Response Functions
- Net Impact on rivers
- Fraction captured with time
- Impact attenuated with distance



Seasonal Variations Multiple Features

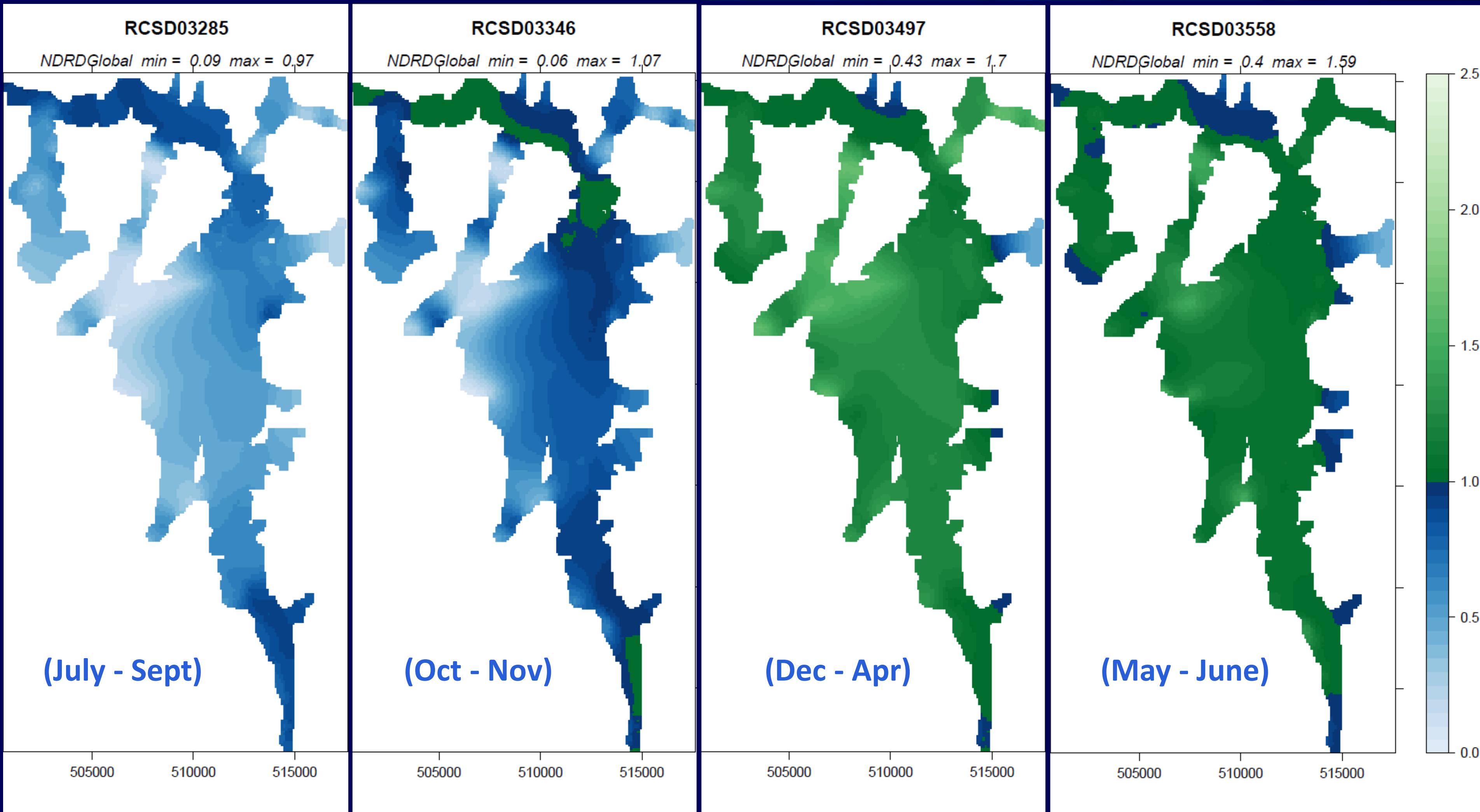


Capture Map Example



- Snapshot in time
- Color fill indicates fraction of pumping impact on feature for pumping at that location
- Accretion map: fraction of recharge impacting feature
- Example
  - After 4 years of pumping
  - End of Aug-Sept stress period
  - Features: Scott River and tributaries

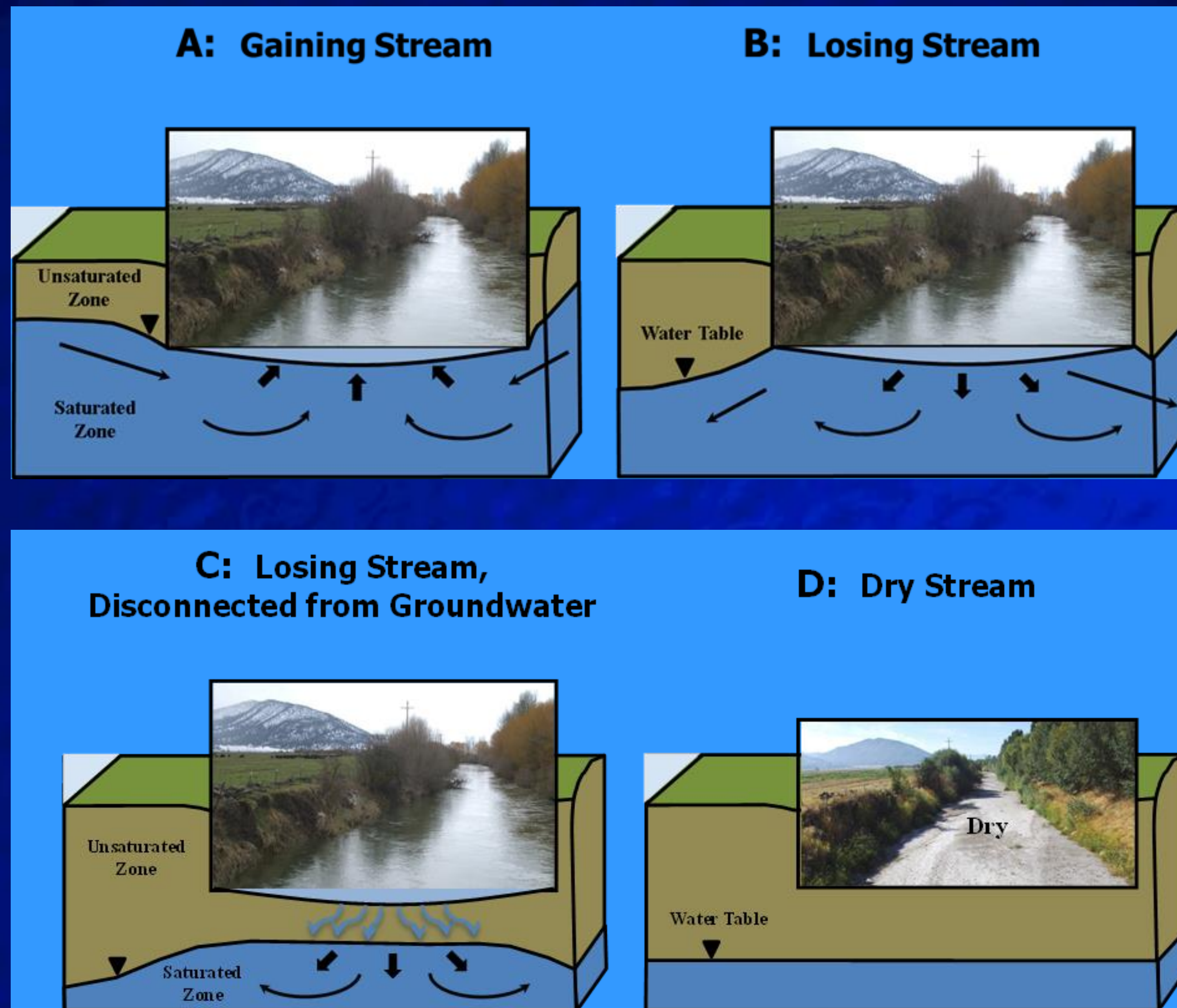
Depletion Seasonality in 4th Year



- Time and space fluctuations: chances for hitting a threshold

Stream-Aquifer Interaction

- Disconnected: Water level below the stream bed
- River will not respond until groundwater recovers



Evaluate Changes in Disconnection

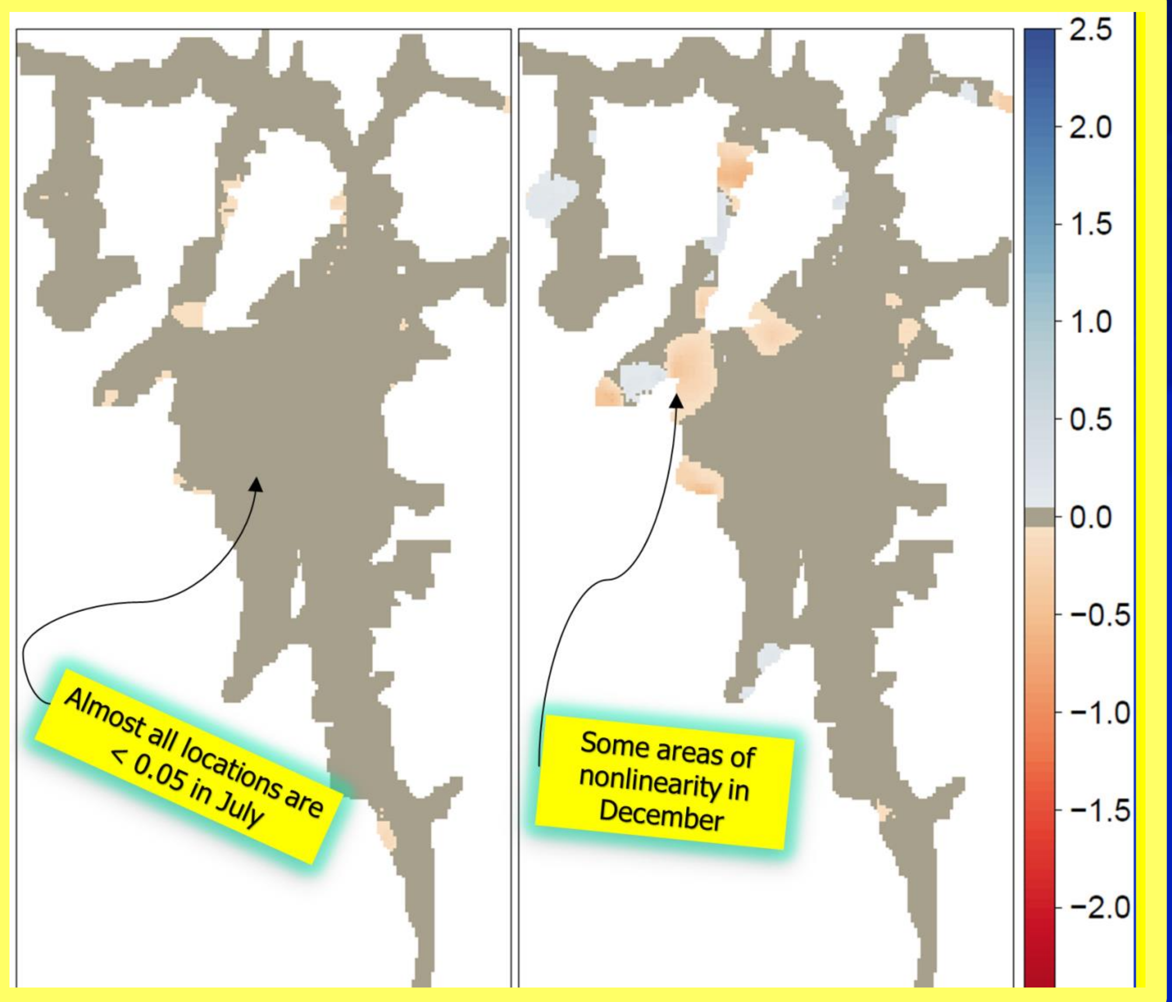
- Repeat the entire SDS process
- Simulate using a <u>different pumping rate</u>
- Compare results
- Values ≠ 0 indicate changes in disconnection

$$NLIN^{i,t} = \frac{\left(\frac{D_{250}^{i,t}}{2}\right) - D_{125}^{i,t}}{Q125}$$

- $i: feature$
- $t: time$
- $D_{250}^{i,t}$: $Depletion\ at\ feature\ i, time\ t, when\ pumping\ at\ 250$
- $D_{125}^{i,t}$: $Depletion\ at\ feature\ i, time\ t, when\ pumping\ at\ 125$

Where and When is the Connection Sensitive

- July: connection is similar
- December: reconnection is different



Conclusions

- SDS provide tools to evaluate long-haul impacts
- Select best pumping locations and times
- Explore augmentation options
  - Screen locations/rates for augmenting groundwater
  - Beaver ponds in various locations
- Identify locations and times when augmentation may not produce flows