Strategic Siting of Managed Aquifer Recharge

Maximizing Recharge Potential by Leveraging Geologic Heterogeneity

South American Groundwater Sub-Basin, CA

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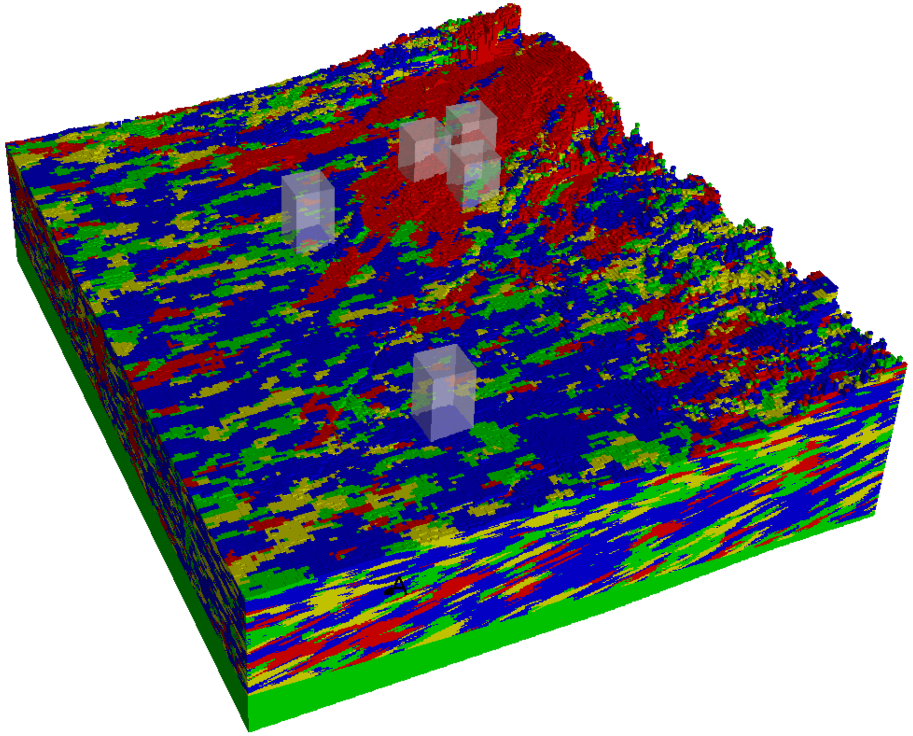
GRAC 2017



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Problem:

Geology controls recharge rates/extent …
… but regional-scale models are not detailed enough to include these details.

Conceptualization Issue

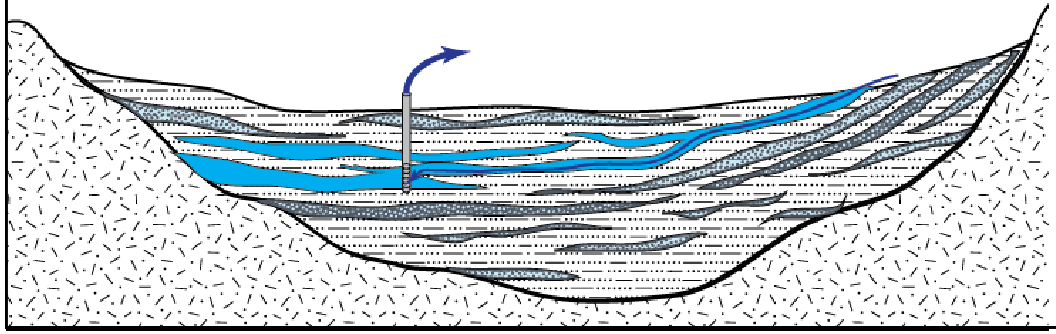
Geologic heterogeneity controls recharge …

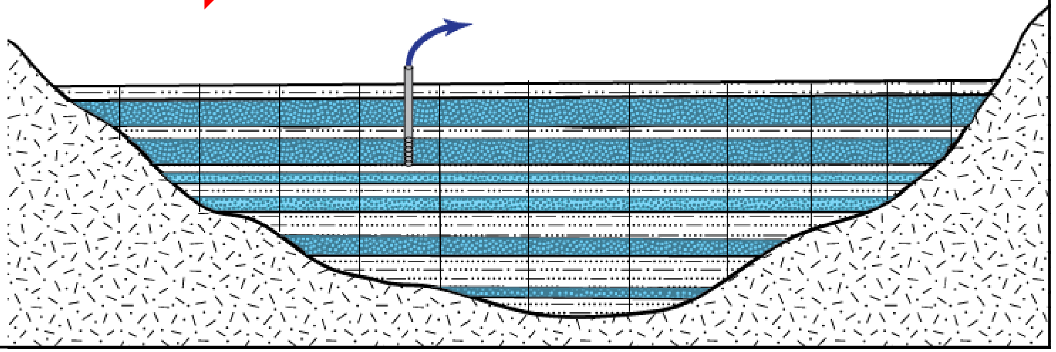
… but is often poorly understood/represented in regional coarse-resolution models

Typical Alluvial Aquifer System

aggregation & simplification

Typical GW Model





Solution:

Physically-based, complex model explicitly simulates recharge processes,
& provides reasonable ranges of recharge

Objective: Exploit preferential pathways (i.e., connected network of sand & gravel hydrofacies) for accelerated, high-volume recharge.

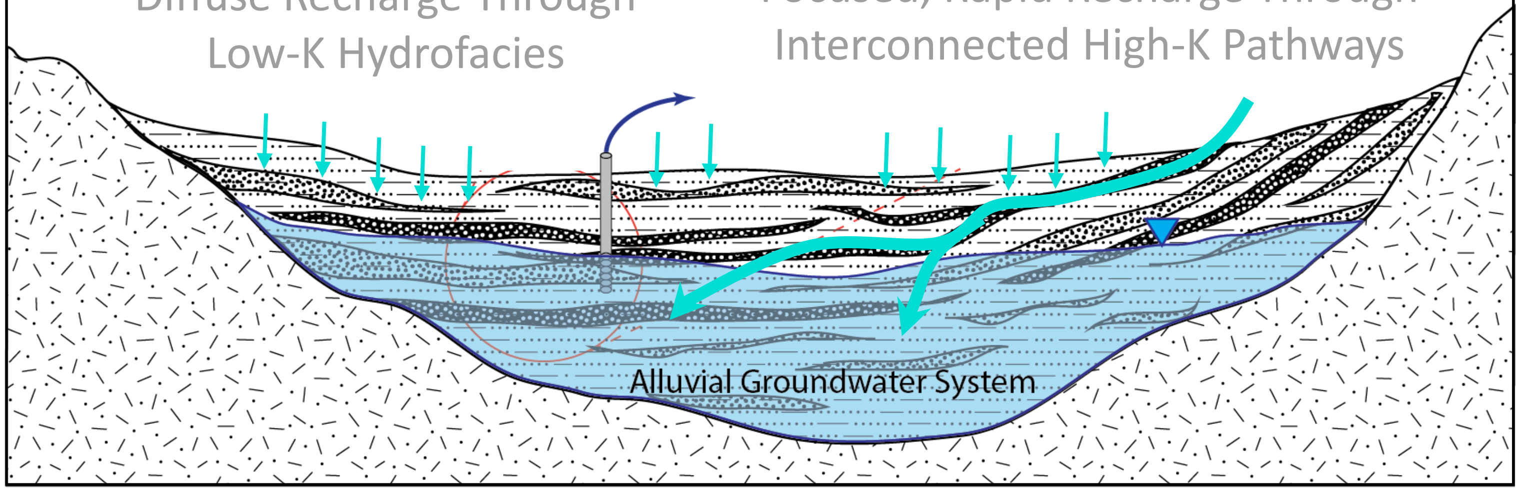
Typical Alluvial Aquifer System

Majority of Landscape

Diffuse Recharge Through Low-K Hydrofacies

Small Fraction of Landscape

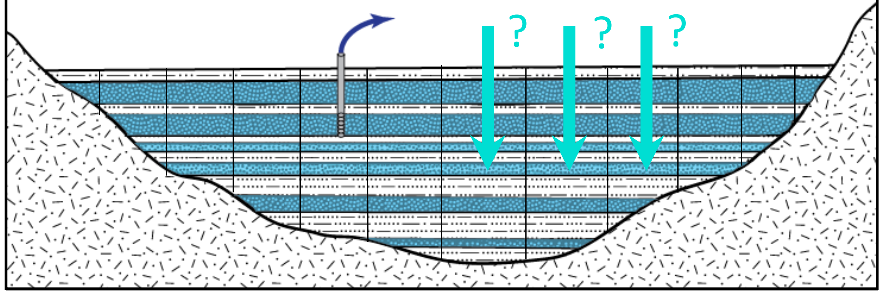
Focused, Rapid Recharge Through Interconnected High-K Pathways



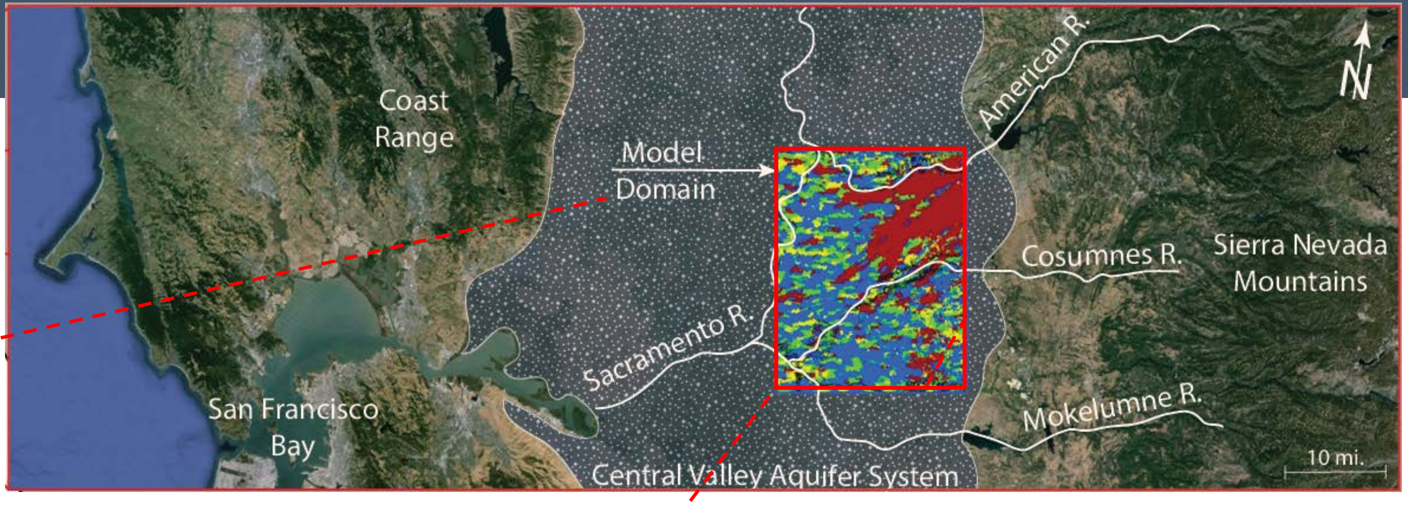
Typical GW Model

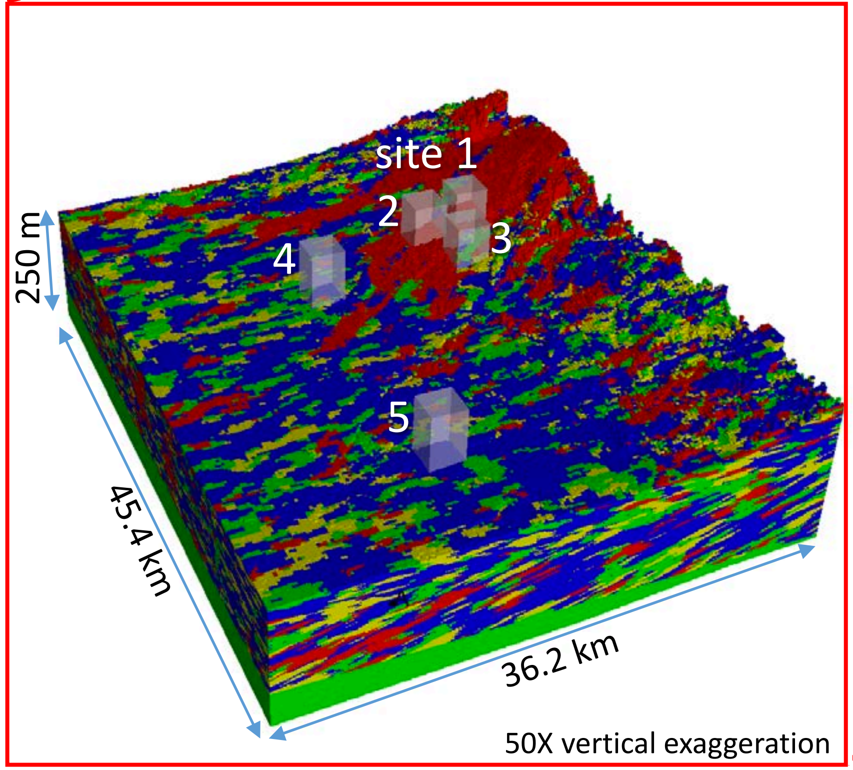
Recharge in Most Models: Integrated in Space & Time

Is Recharge Accurately Represented?



ParFlow Model
American-Cosumnes Basin





Highly-Detailed Representation of Geologic Heterogeneity

- Stochastic geostatistical model (TPROGS) informed by ~1200 well logs
- 4 hydrofacies Gravel, Sand, Muddy Sand, Mud
- ~10 million cells (200m X 200m X 1m)

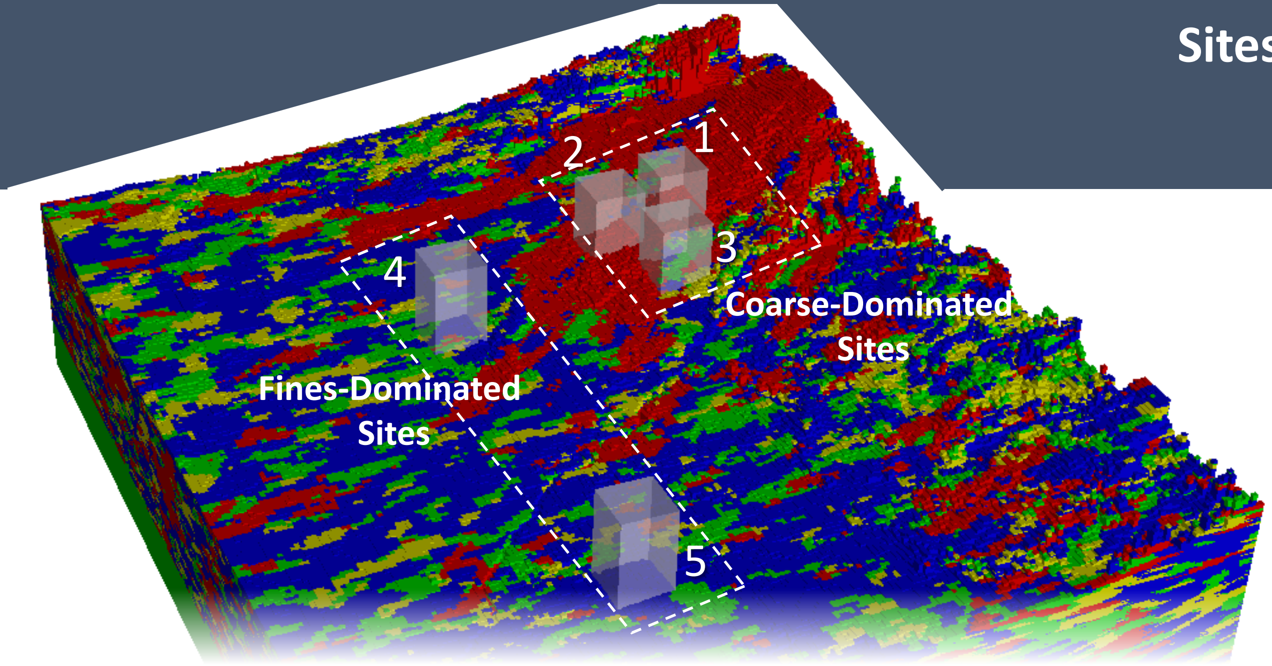
Managed Aquifer Recharge Simulations

- 3D, variably-saturated, integrated flow model
- Parallelized on 120–180 supercomputer cores (~6000–17,000 CPU hours/run)
- 5 recharge sites
- 180-day simulations
- 10-cm ponded water over 1420 acres

Goal:

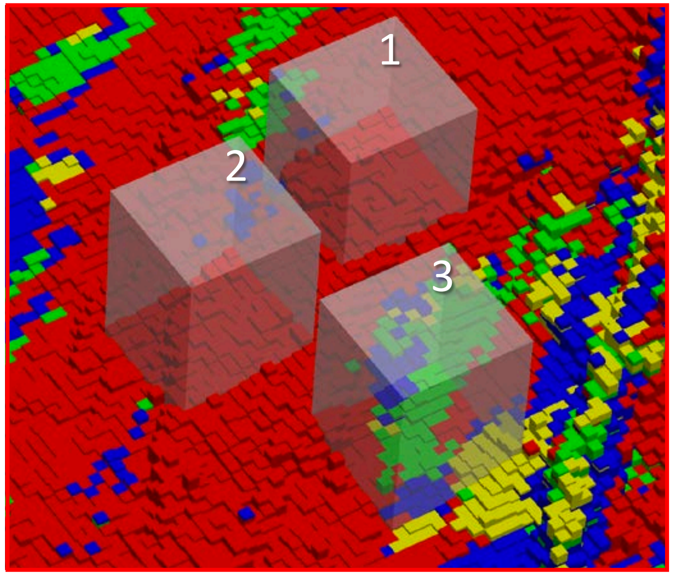
- Sophisticated representation of physics & geology (1) simulates realistic recharge rates & (2) identifies potential for accelerated recharge.

Sites are chosen to represent wide range of geologic heterogeneity

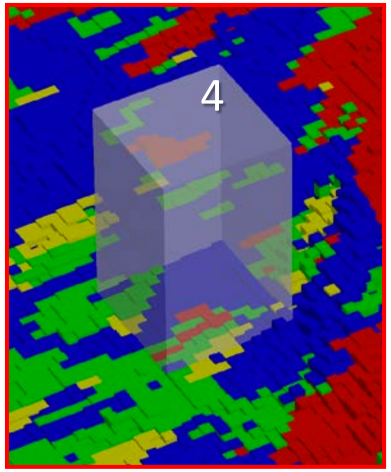


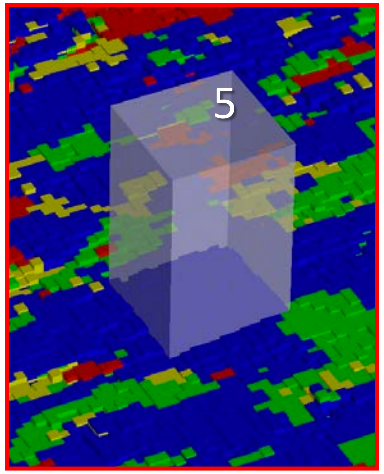
Hydrofacies:
Gravel Sand
Muddy Sand Mud

Sites 1–3: Dominated by Interconnected Sand & Gravels



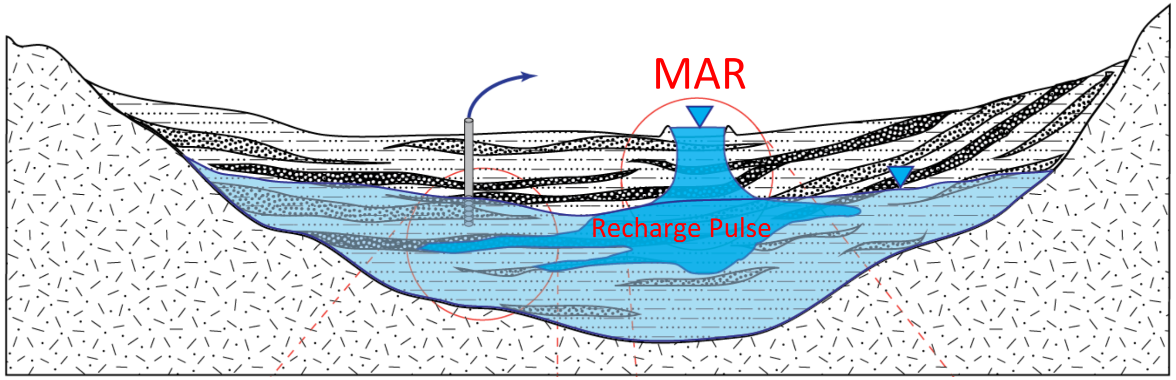
Sites 4 & 5: Dominated by Muddy Sand and Mud





Model Post-Processing

(1) Isolate pressure and change-in-storage response for each simulation.
(2) Isolate responses by to hydrofacies.



Main Benefits of Recharge:

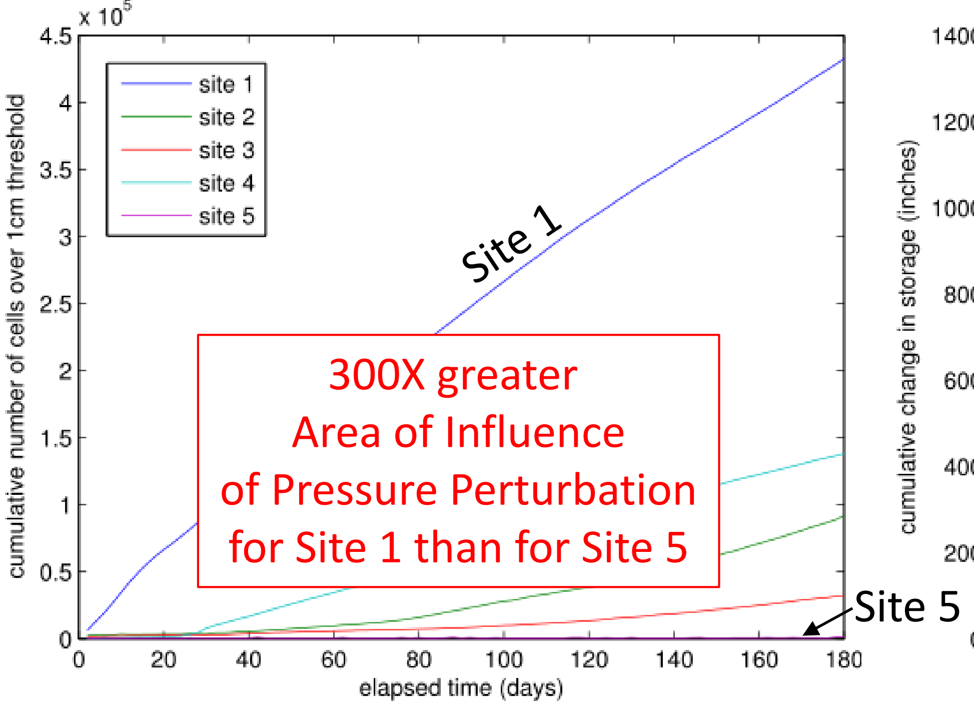
1. Increase in Pressure (i.e., Piezometric Head)
2. Increase in Groundwater Storage

Model Results

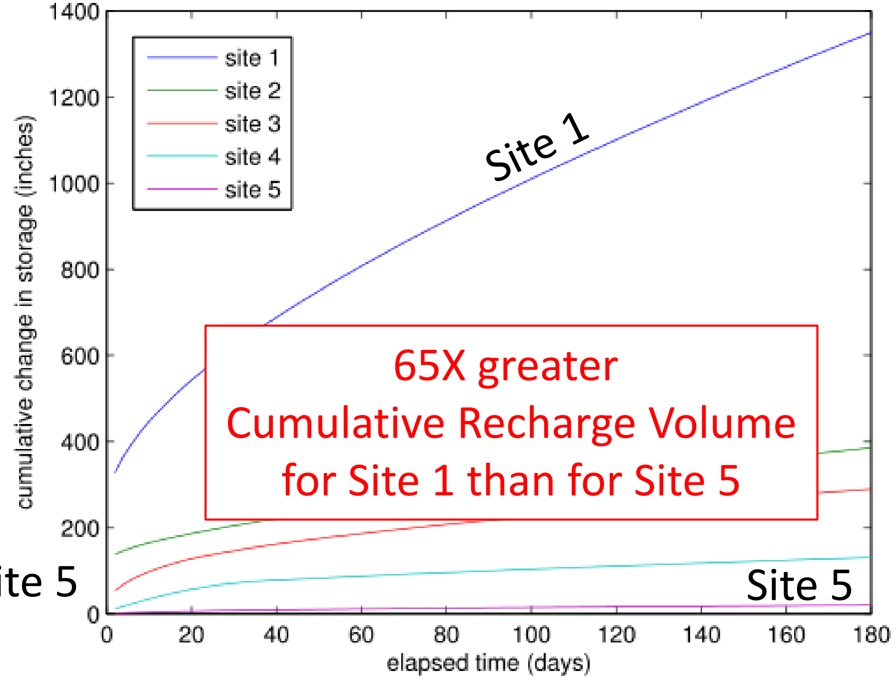
Domain-Wide Pressure and Change-in-Storage Response for Each MAR Simulation

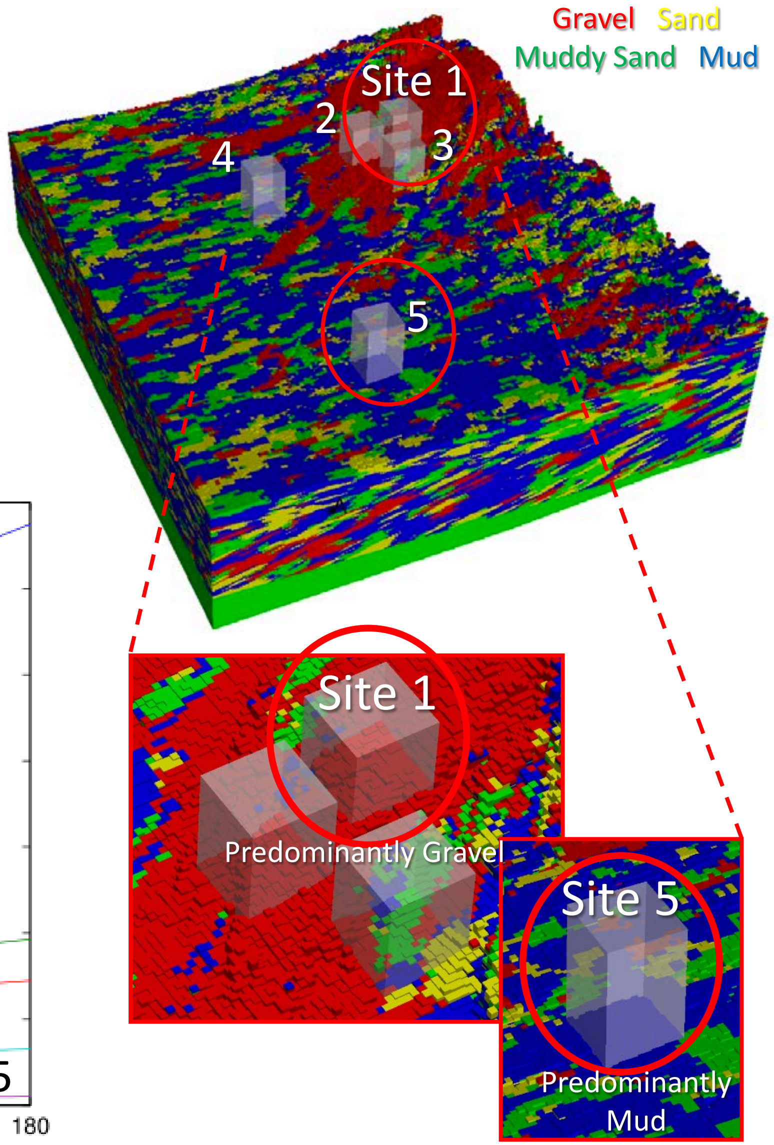
Large Range of Responses Across Sites

Pressure Perturbation Area of Influence



Cumulative Change in Groundwater Storage

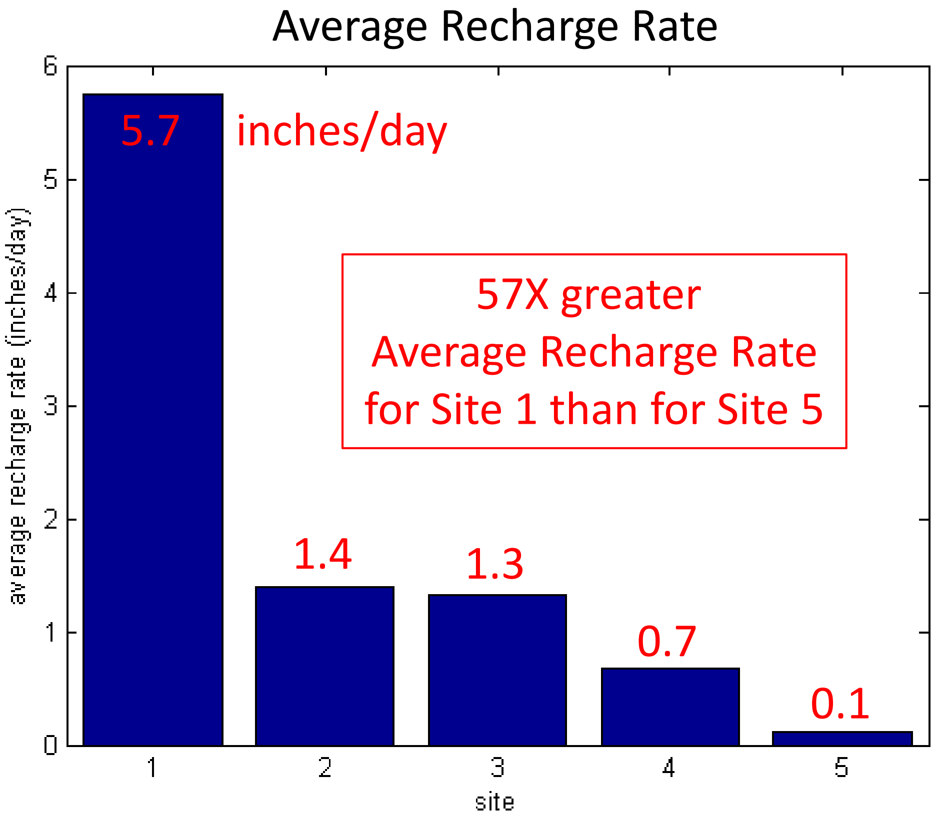


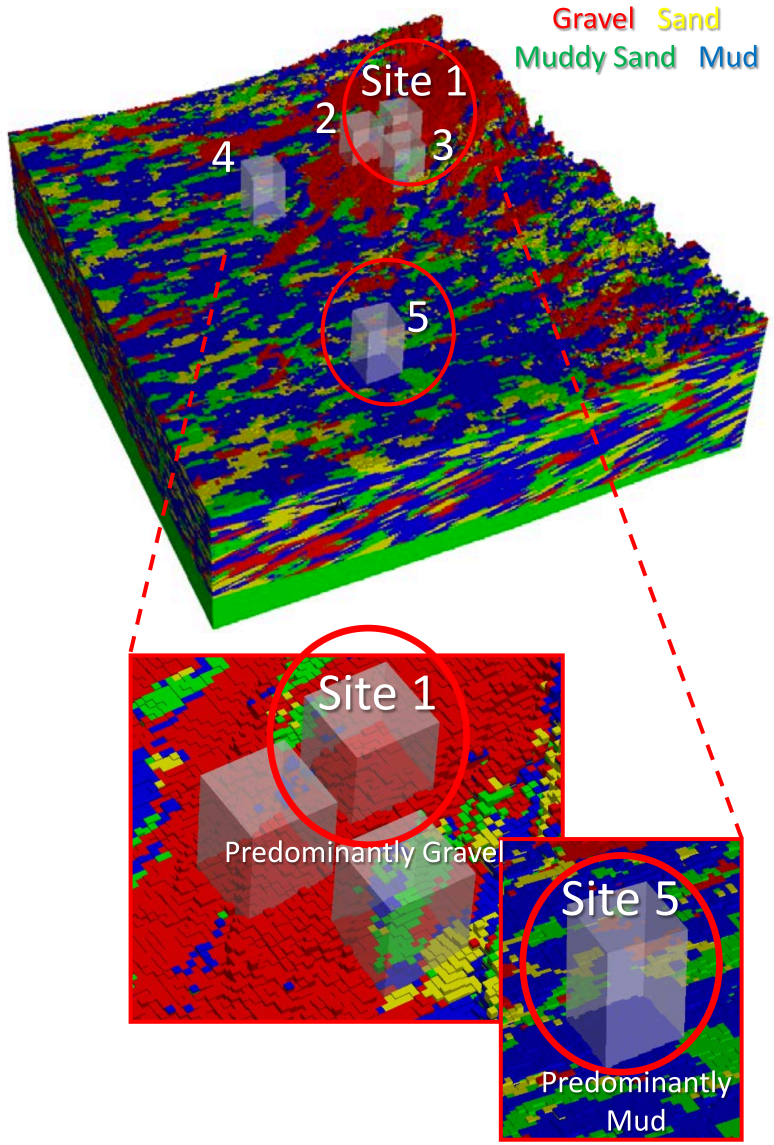


Model Results

Domain-Wide Pressure and Change-in-Storage Response for Each MAR Simulation

Large Range of Responses Across Sites

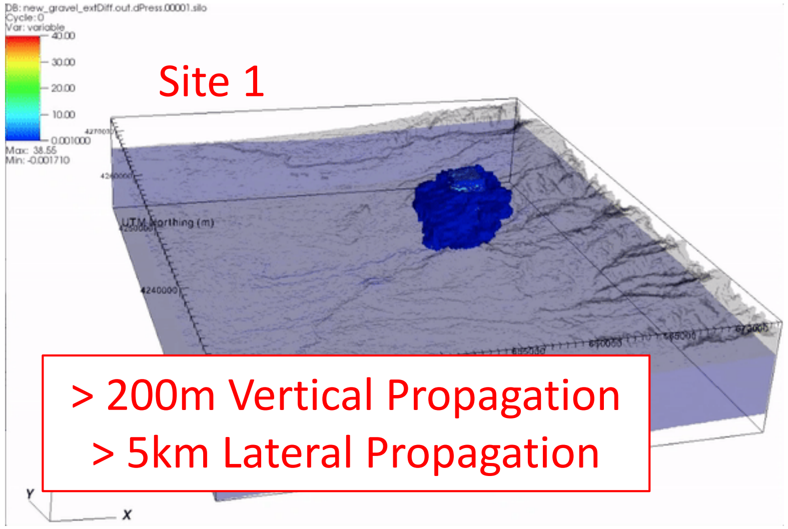


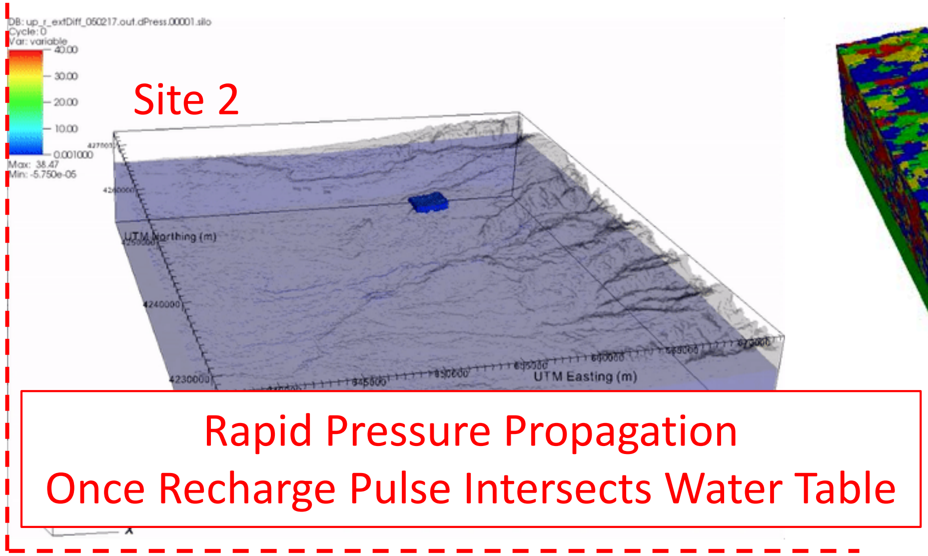


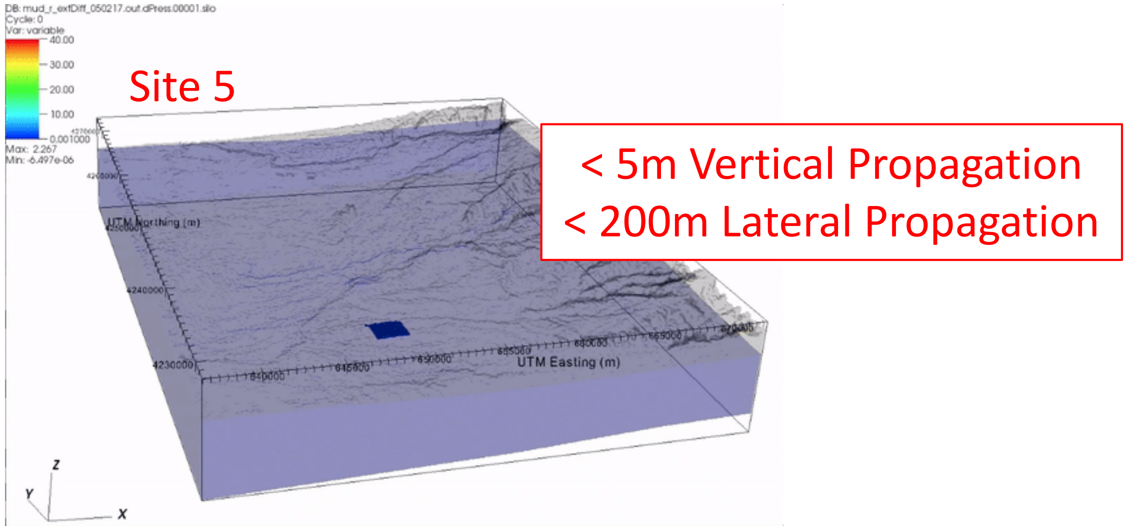
Model Results

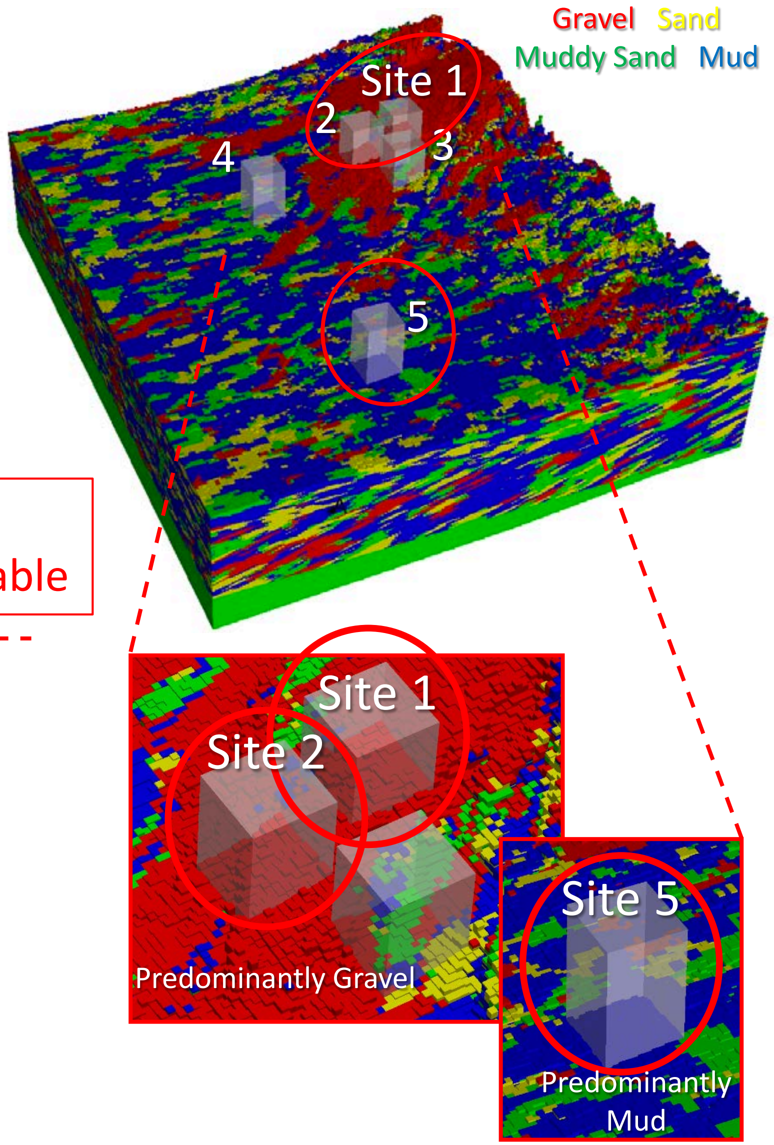
Domain-Wide Pressure Response for Each MAR Simulation

Pressure Perturbation Animations (0–180 days)









Model Results

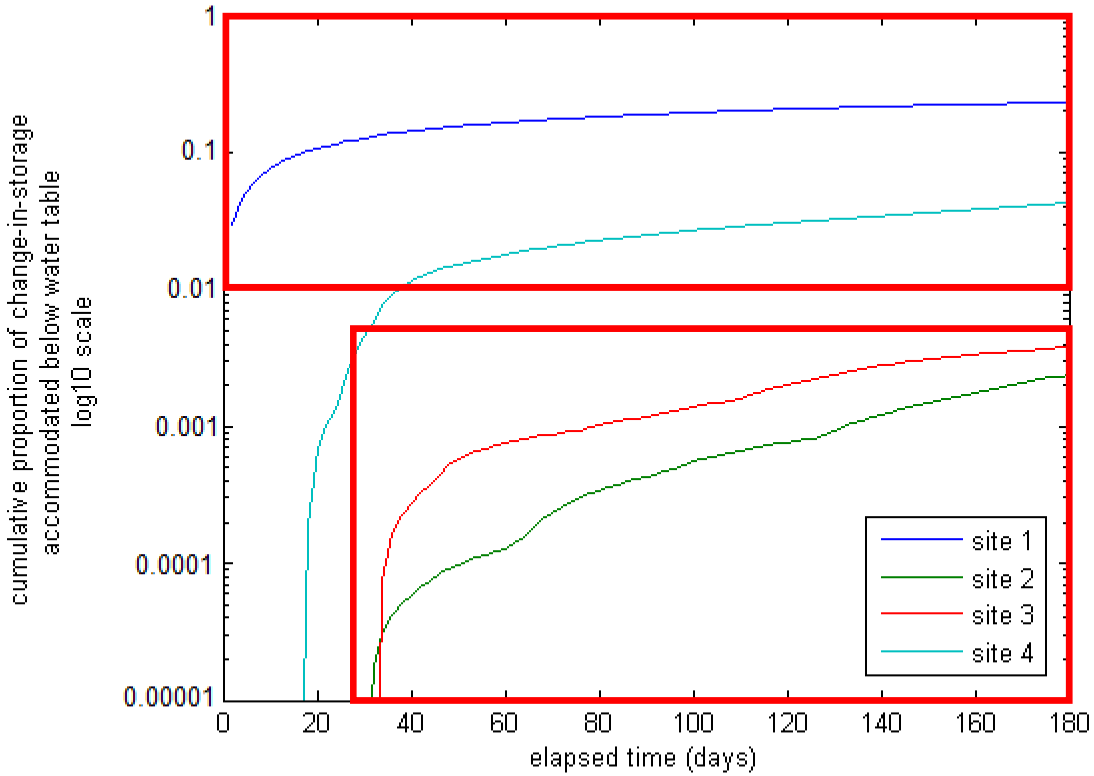
Pressure & Change-in-Storage Response
Above & Below Initial Water Table

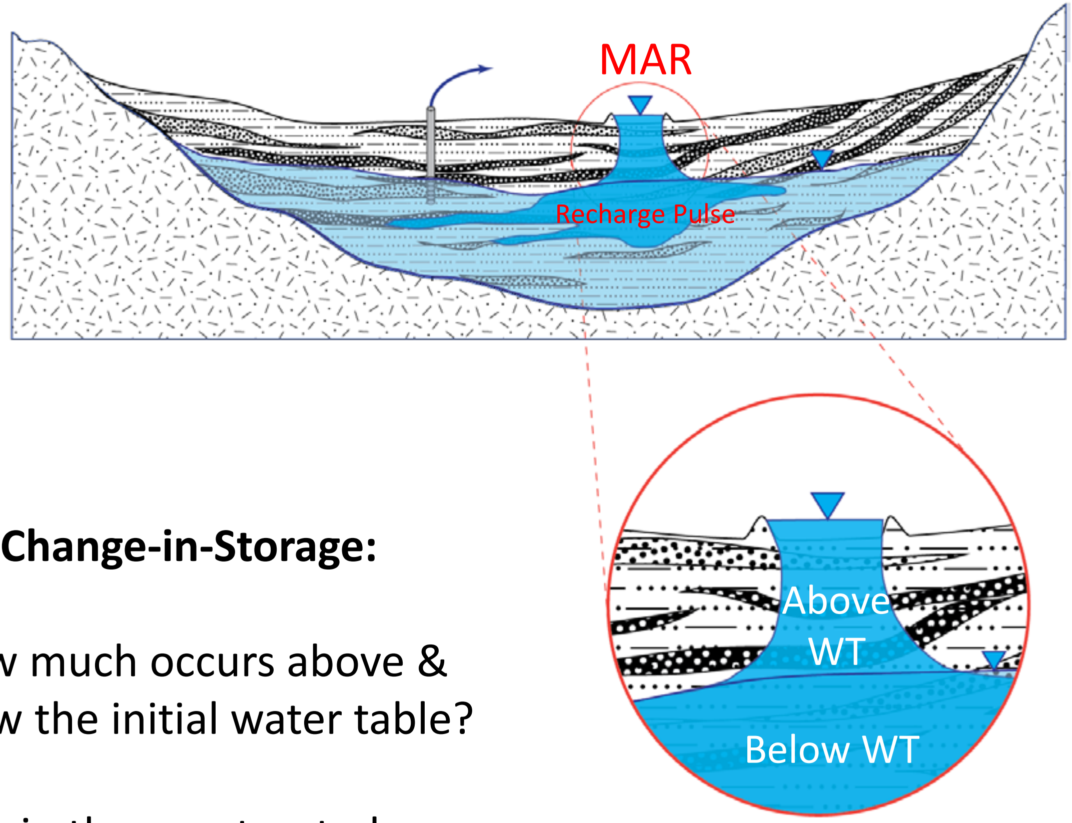
Majority of change-in-storage occurs in the unsaturated zone

Proportion of Change-in-Storage Accommodated Below Initial Water Table

Sites 1 & 4:
Sites 2 & 3:

4-12% of recharge accommodated in semi-confined aquifer system





Change-in-Storage:

How much occurs above & below the initial water table?

… i.e., in the unsaturated zone vs. the semi-confined aquifer system

Model Results

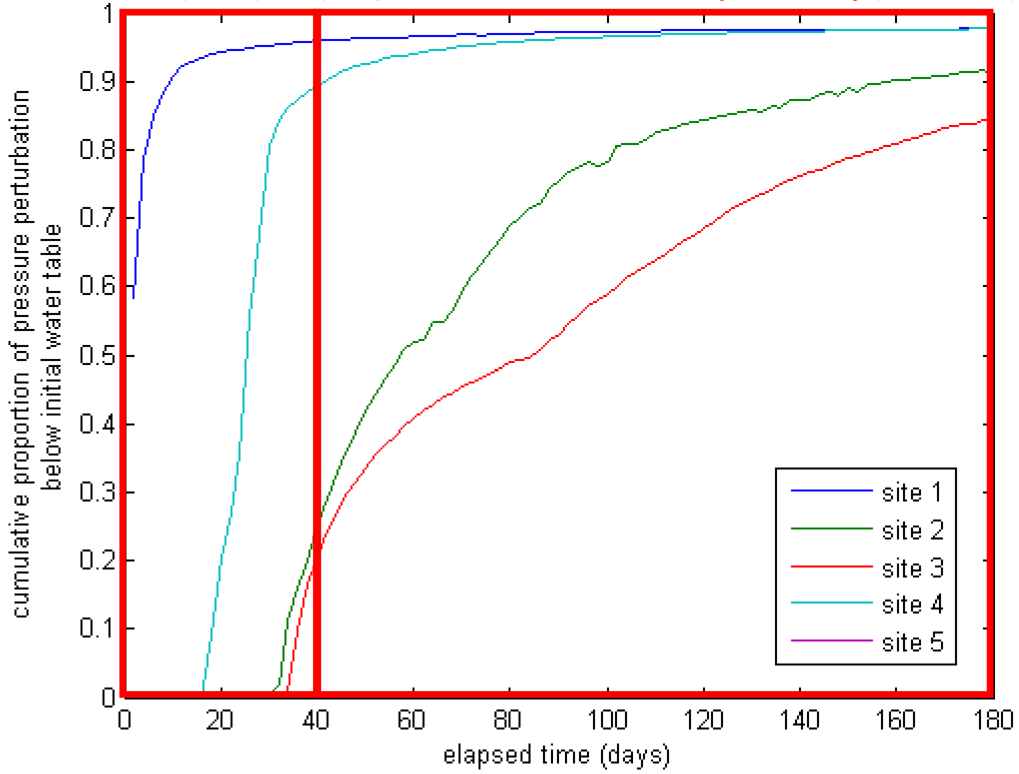
Pressure & Change-in-Storage Response Above & Below Initial Water Table

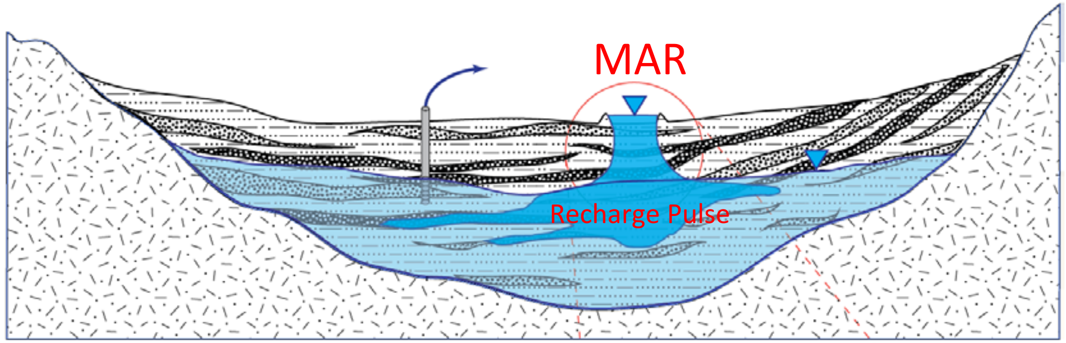
Majority of pressure response occurs in the semi-confined aquifer system

Early Time (0–40 days):
Pressure response in UZ until wetting front reaches WT
… then rapid propagation in semi-confined aquifer system

Late Time (40–180 days):
Vast majority of response is in semi-confined aquifer system

Proportion of Pressure Response
Above & Below Initial Water Table

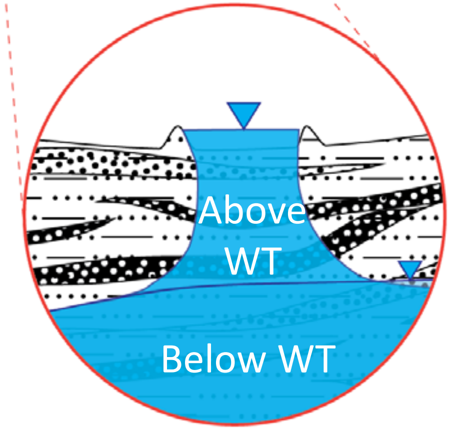




Pressure Response:

How much occurs above & below the initial water table?

… i.e., in the unsaturated zone vs. the semi-confined aquifer system

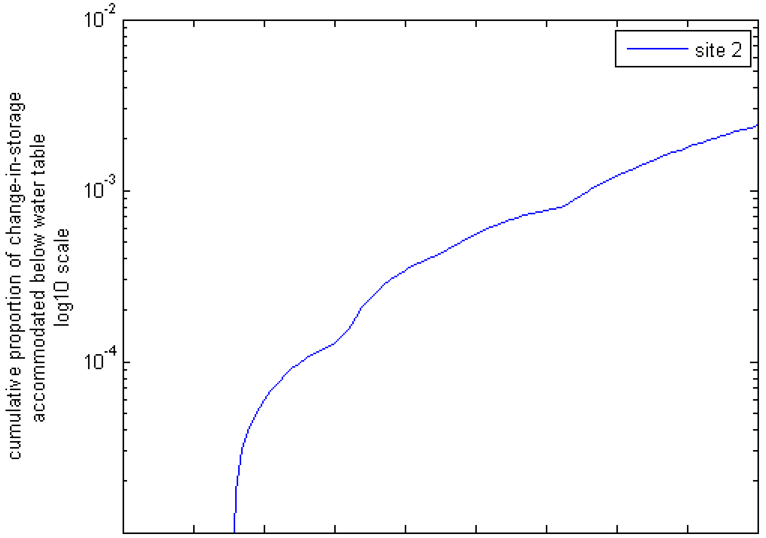


Model Results

Pressure & Change-in-Storage Response
Above & Below Initial Water Table

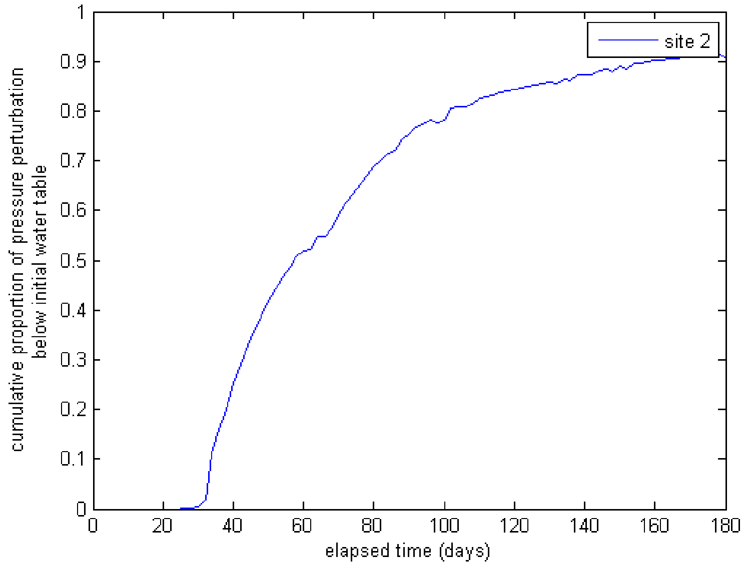
Change-in-Storage

Proportion
Below Water Table

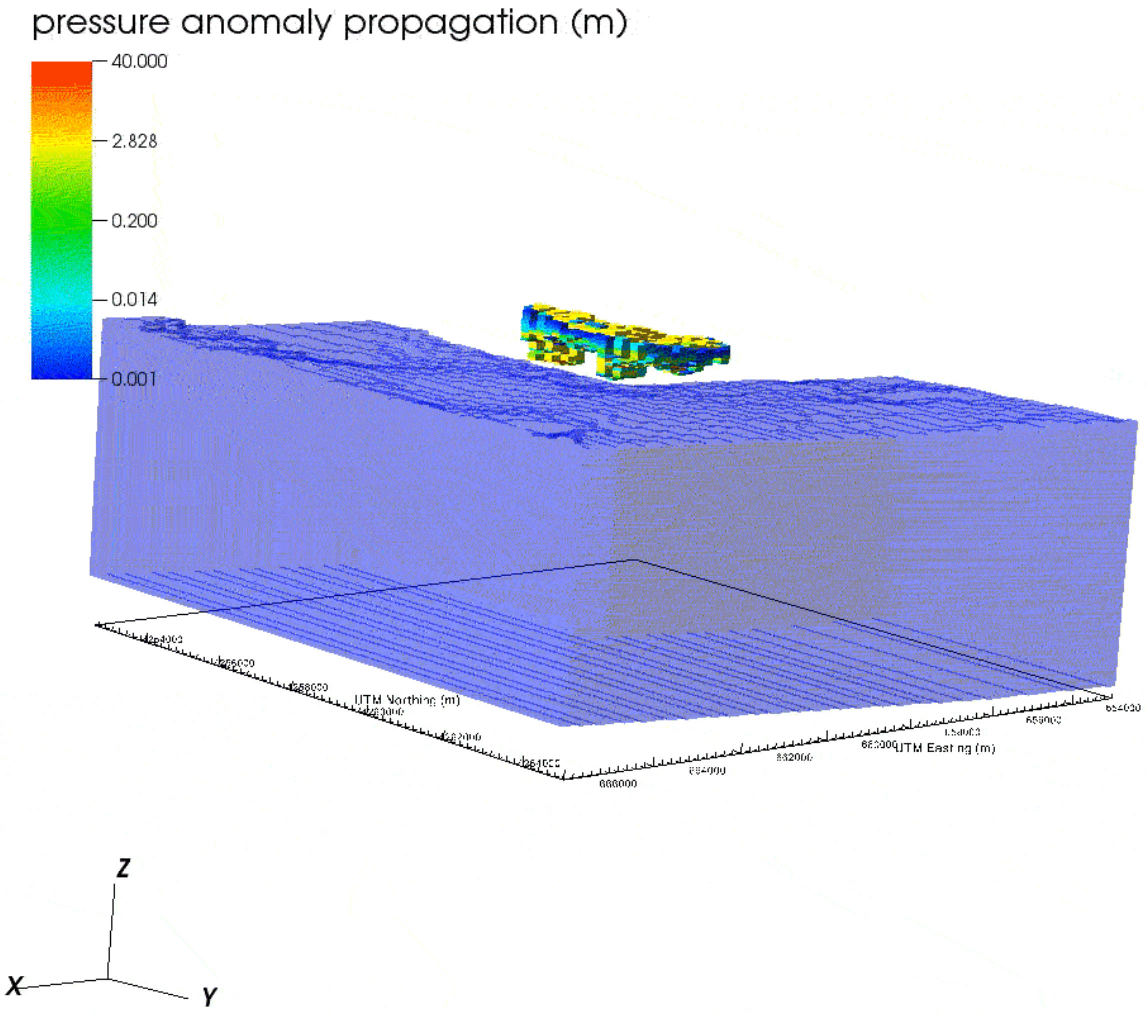


Pressure Response

Proportion
Below Water Table



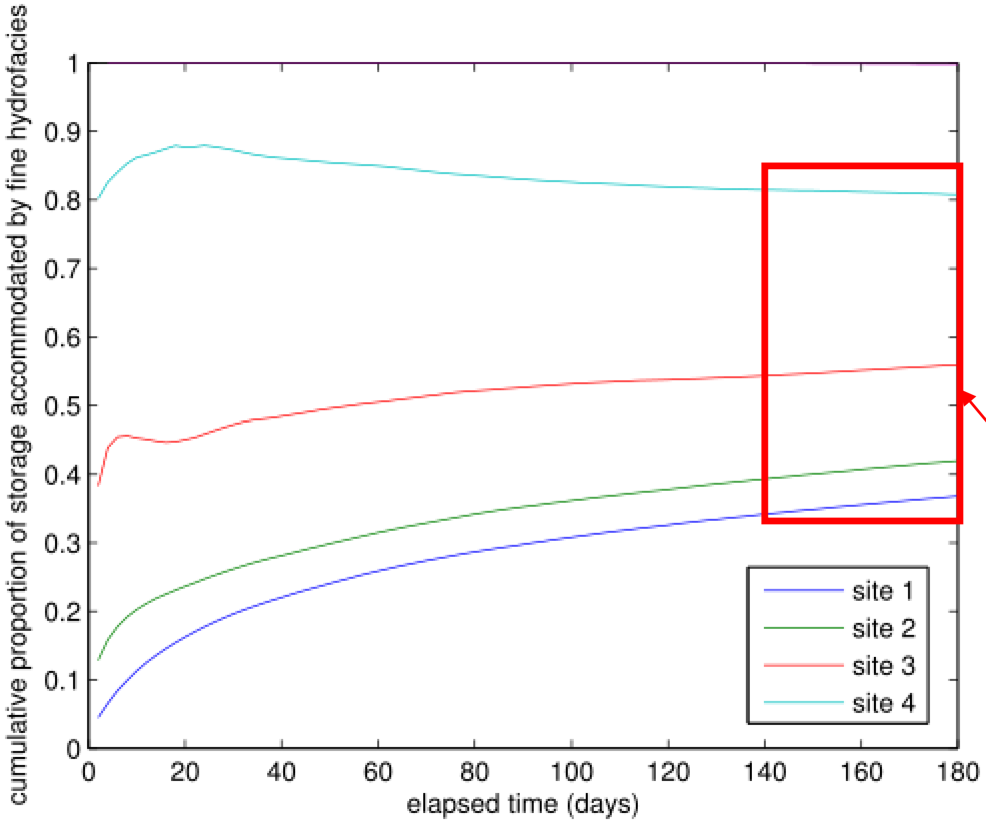
Site 2 Detail



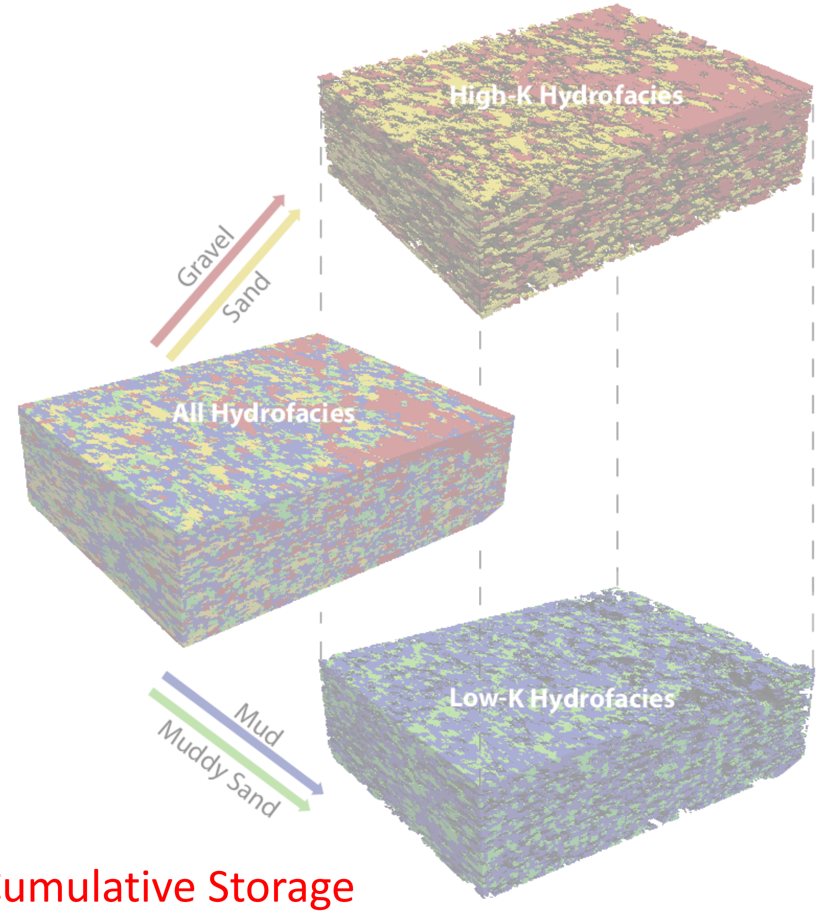
Model Results

Change-in-Storage Response
in Fine- and Coarse-Texture Hydrofacies

Cumulative
Proportion of Storage Accommodated
by Fine Hydrofacies



~35–80% of Cumulative Storage
Accommodated by Fine Hydrofacies

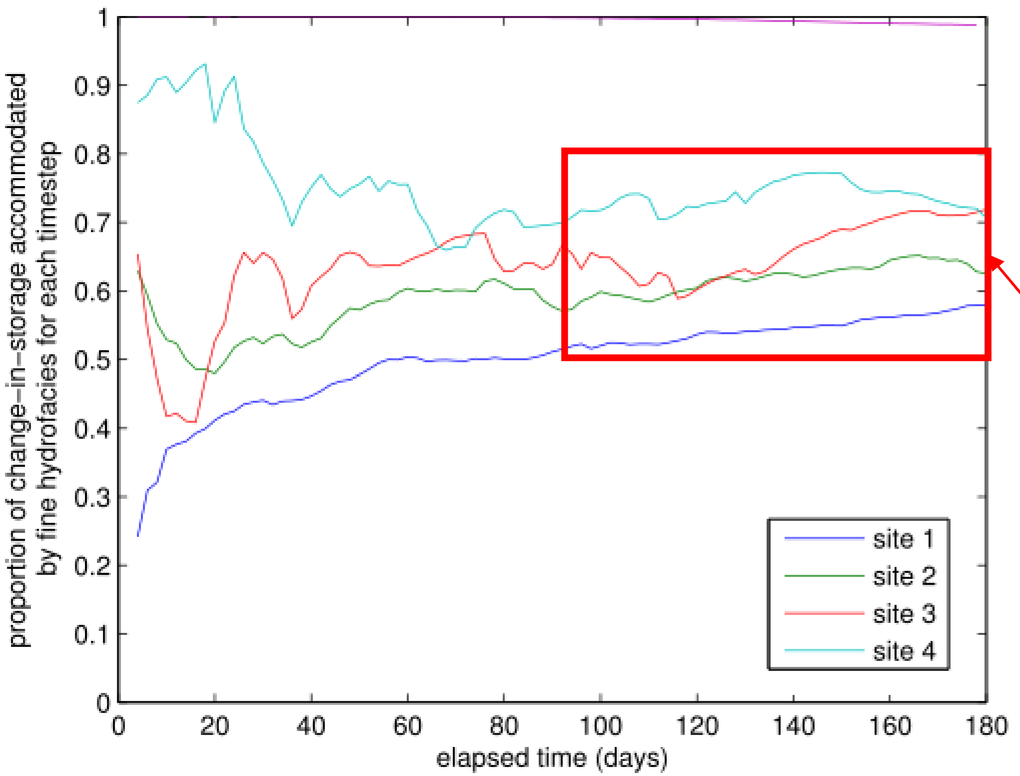


Model Results

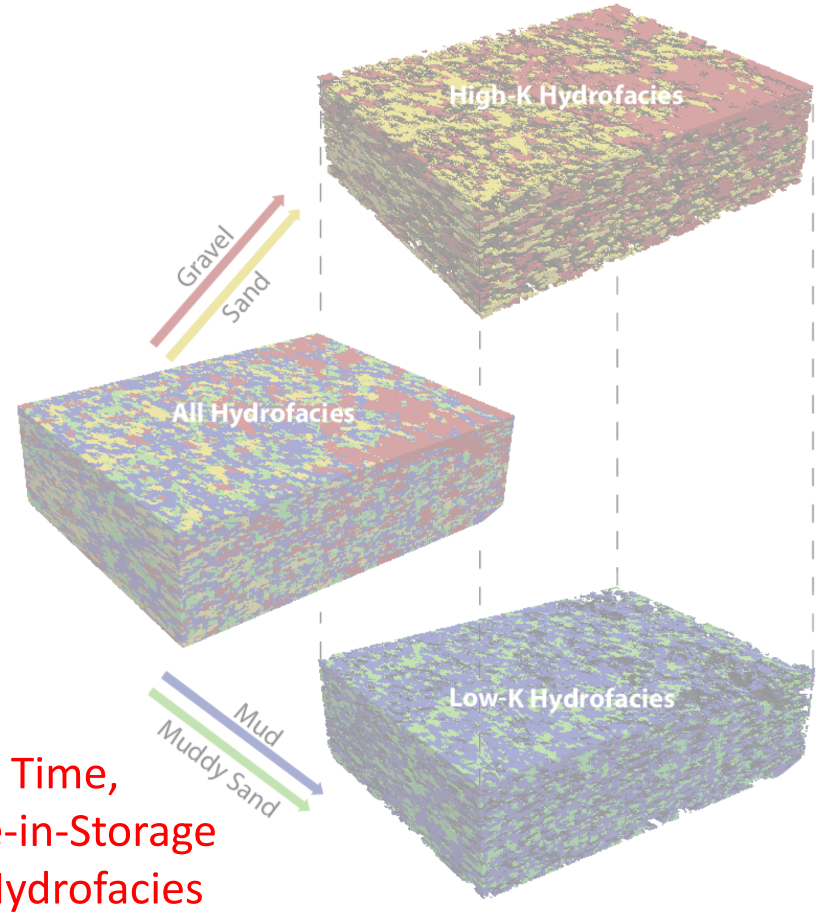
Change-in-Storage Response
in Fine- and Coarse-Texture Hydrofacies

Proportion of Storage Accommodated
by Fine Hydrofacies

… <u>At Each Time Step</u>



During Late Time,
> 50% of Change-in-Storage
Occurs in Fine Hydrofacies



Discussion

Large variation in **recharge rates**/volumes and area-of-influence of **pressure perturbation** among sites.

Subsurface geology is the primary control on this variation.

Vast majority of **pressure perturbation** occurs **below water table**.

Nearly all **recharge volume** is accommodated in the **unsaturated zone**.

Fine-textured hydrofacies (i.e., **mud & muddy sand**) accommodate a **substantial proportion of recharge** volume, especially **during late time**.

Questions?

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Funding Sources:

NSF Climate Change, Water, & Society IGERT
NSF Graduate Research Fellowship Program
UC Water Security & Sustainability Initiative

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