Monitoring needs: Well surveillance and plume stabilization

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Austin, Texas

Remaining problems for monitoring

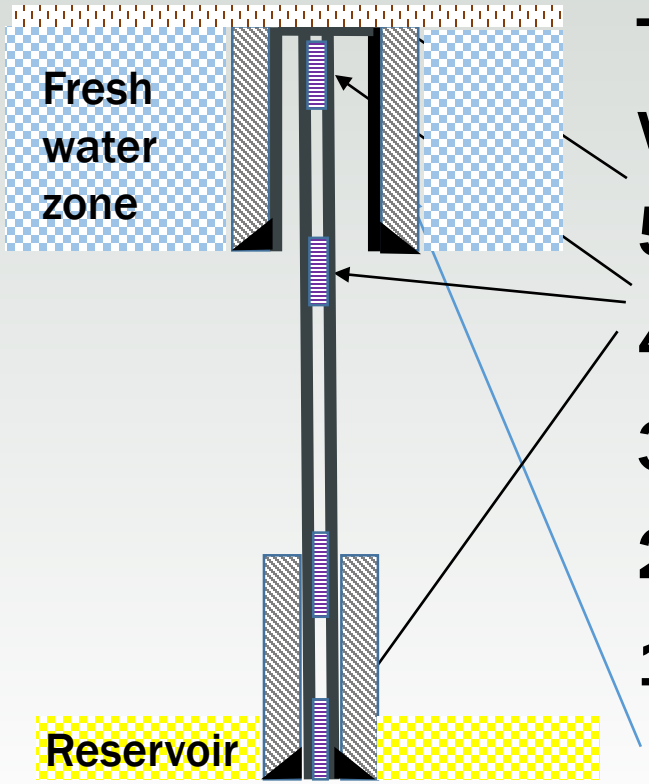
- Extensive previous work (GCCC and global):
  - Plume tracking
  - Above-zone leakage surveillance
  - Groundwater/soil gas assurance monitoring
- What key things are still missing?

1) Plugged wells – *completed & plugged per documentation*?

2) Long-term plume stabilization – *how long to monitor*?

Wells – designed to isolate

Well regulation focus – must document for UIC

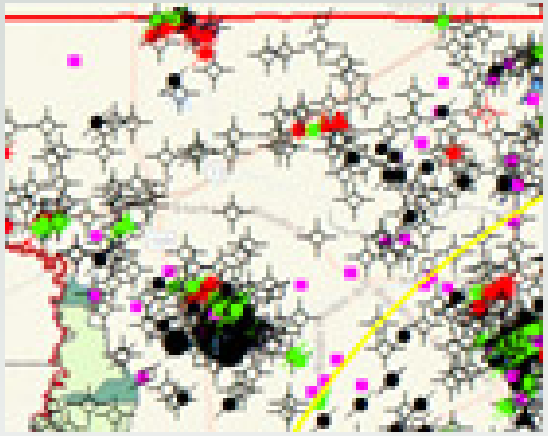


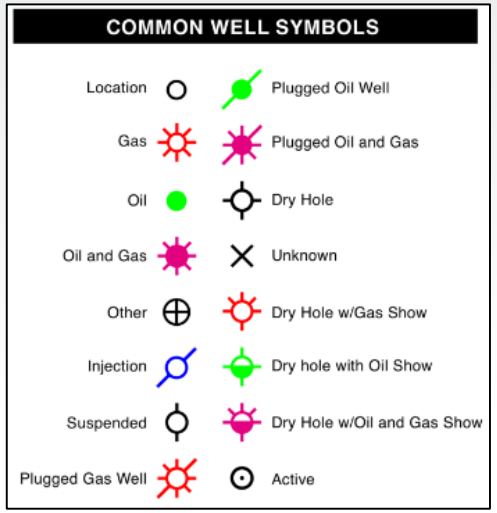
Typical barriers in plugged and abandoned (P&A) wells

5. Casing cut off below ground surface
4. Cement plugs; block perforations & long string
3. Mechanical integrity testing
2. Long string casing – isolate active zone
1. Surface casing – isolate fresh water zone

Never-the-less wells are the most likely failure point in storage system

- ~ Dozen or so reported CO_2 leakage incidents
- Non-compliance rate – ~1/1000/per yr failure (*CO_2 frequency seems similar*) *
- Well management focus of UIC regulation (*including Class VI*)
- Industry best practice during CO_2 EOR –
  - invest in well prep
  - avoid need to shut in (for repair)
- Numerous mature monitoring approaches – open & accessible
- **Worst problem: Wells P&A prior to project start** (***Must rely on records or do high-cost and high-risk repair***)

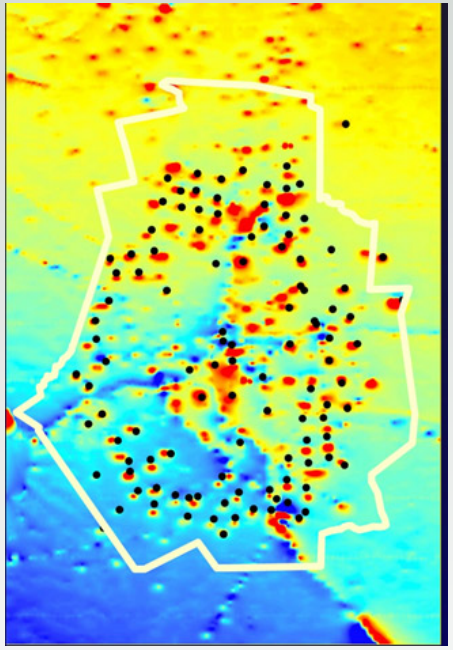




Porse, Wade and Hovorka, 2014

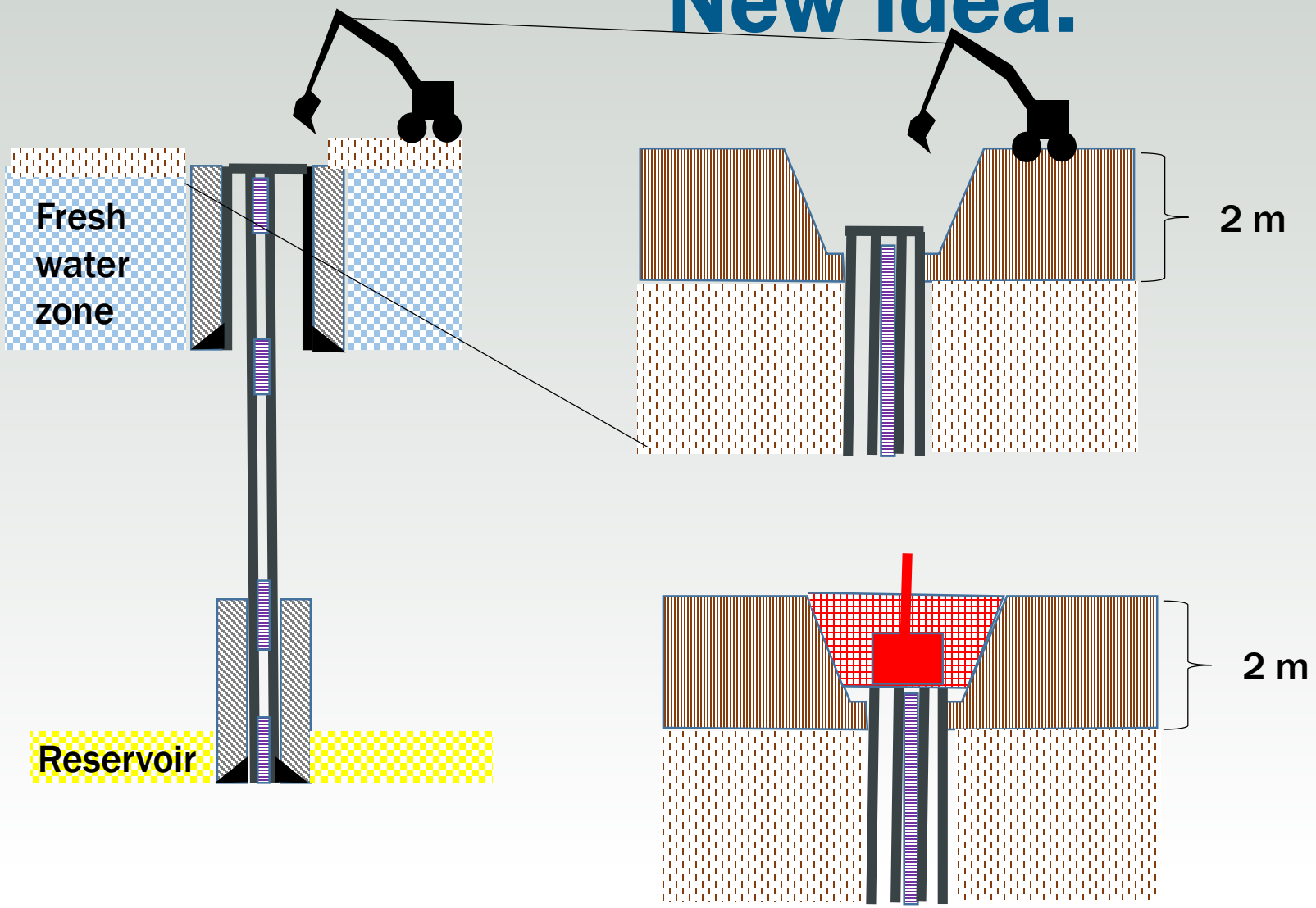
What can be done?

- Find all wells –
  - record search
  - historic photos
  - magnetic surveys etc.
- Reenter, repair, and re-plug questionable wells
  - expensive & risky
  - not sure what is down there
- Conduct surveillance of remaining uncertain wells
  - How?
  - When?



Residual magnetic intensity, Cranfield, MS –
Note: known wells match magnetic signal well
(J. Paine/ Fugro)

New idea:



- Excavate many P&A well stubs @ 6 ft.
- Install instrument pack
  - Temperature
  - Conductivity
  - Moisture
  - pH
  - *etc.*
- Backfill with engineered materials
- Report out via cell phone

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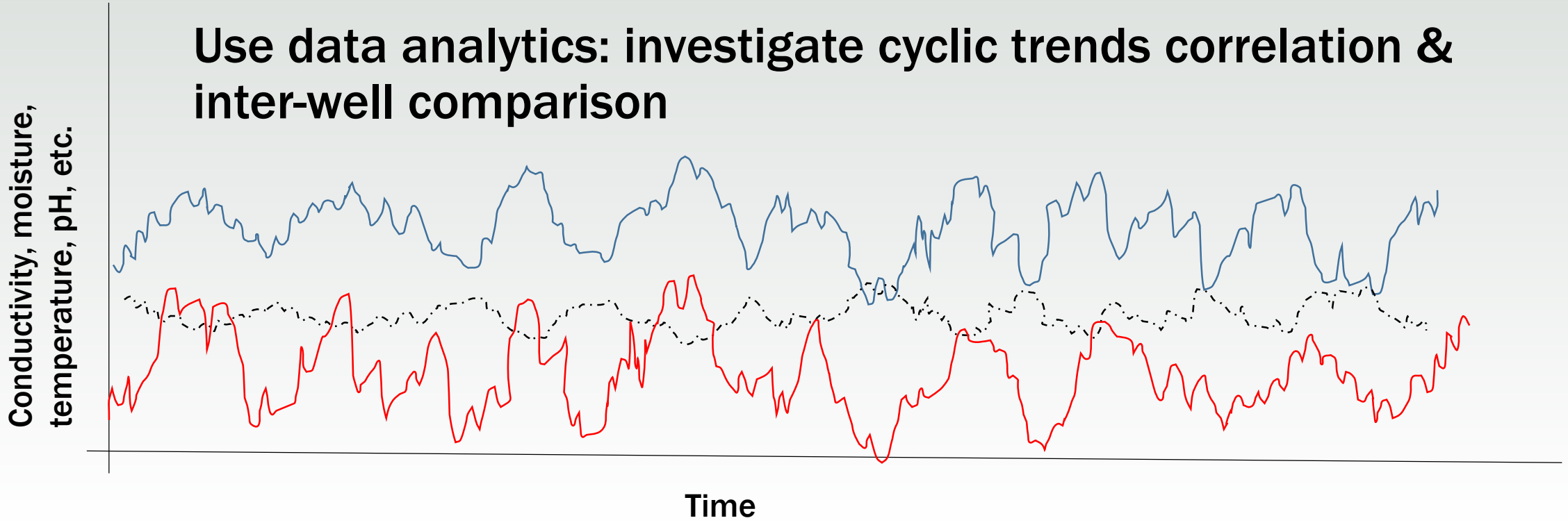
Data Reduction – High-noise/Complex system

Data noisy because of variability & trend in environment

Use data analytics: investigate cyclic trends correlation & inter-well comparison



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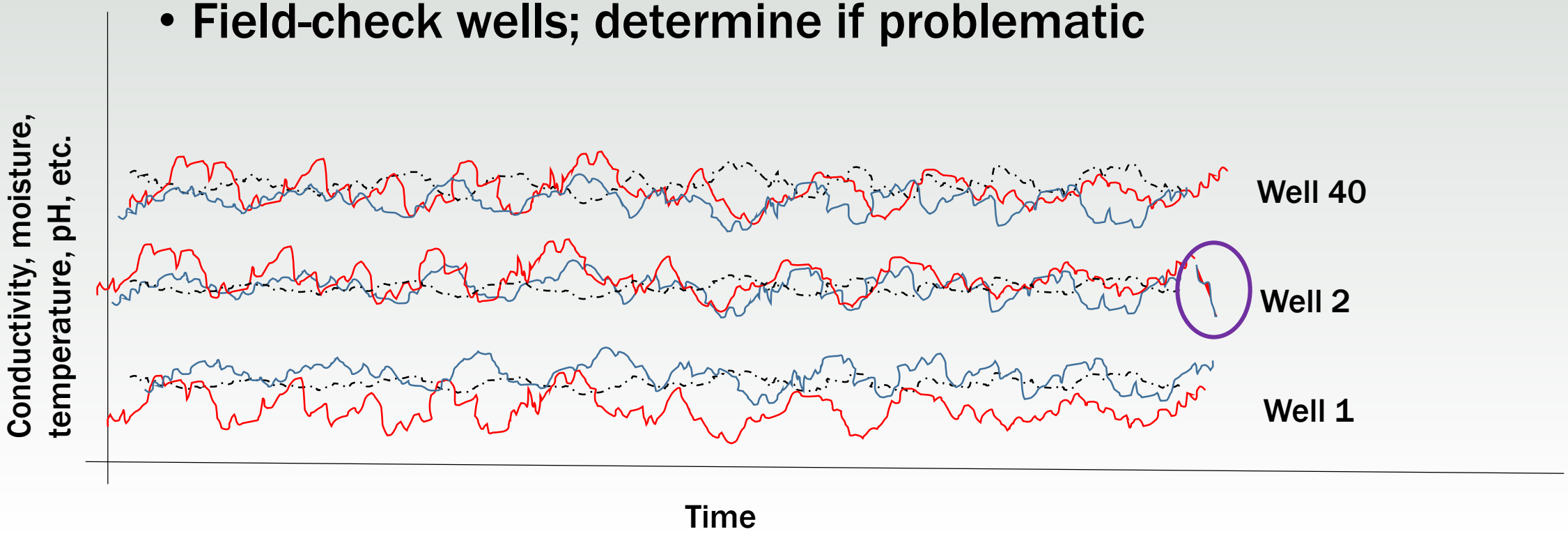
Data reduction
Compare Wells, Find Anomalies Early

- Identify anomalous signal
- Field-check wells; determine if problematic



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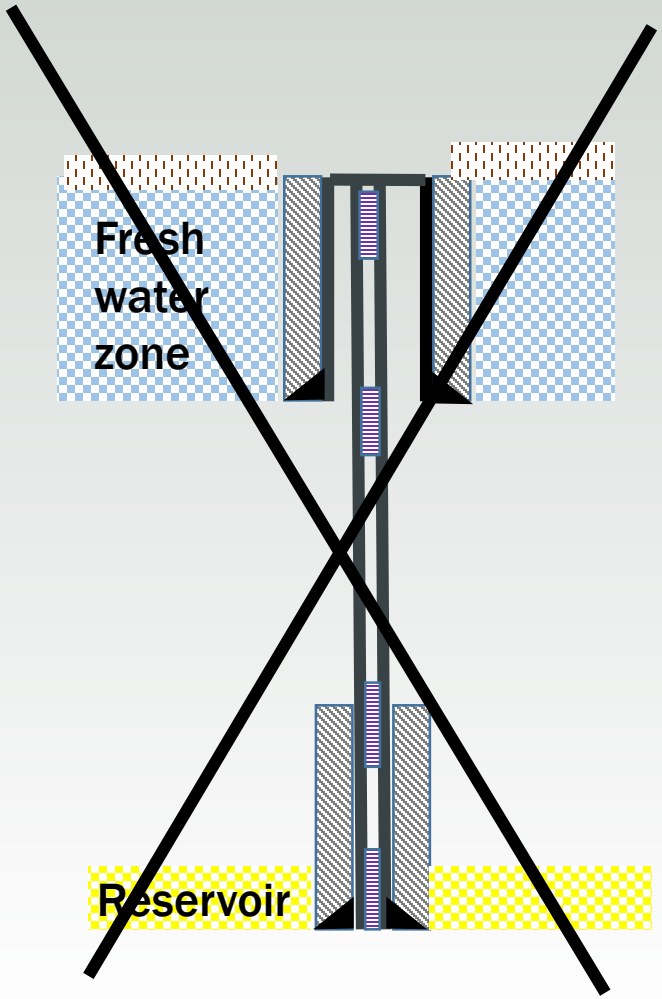
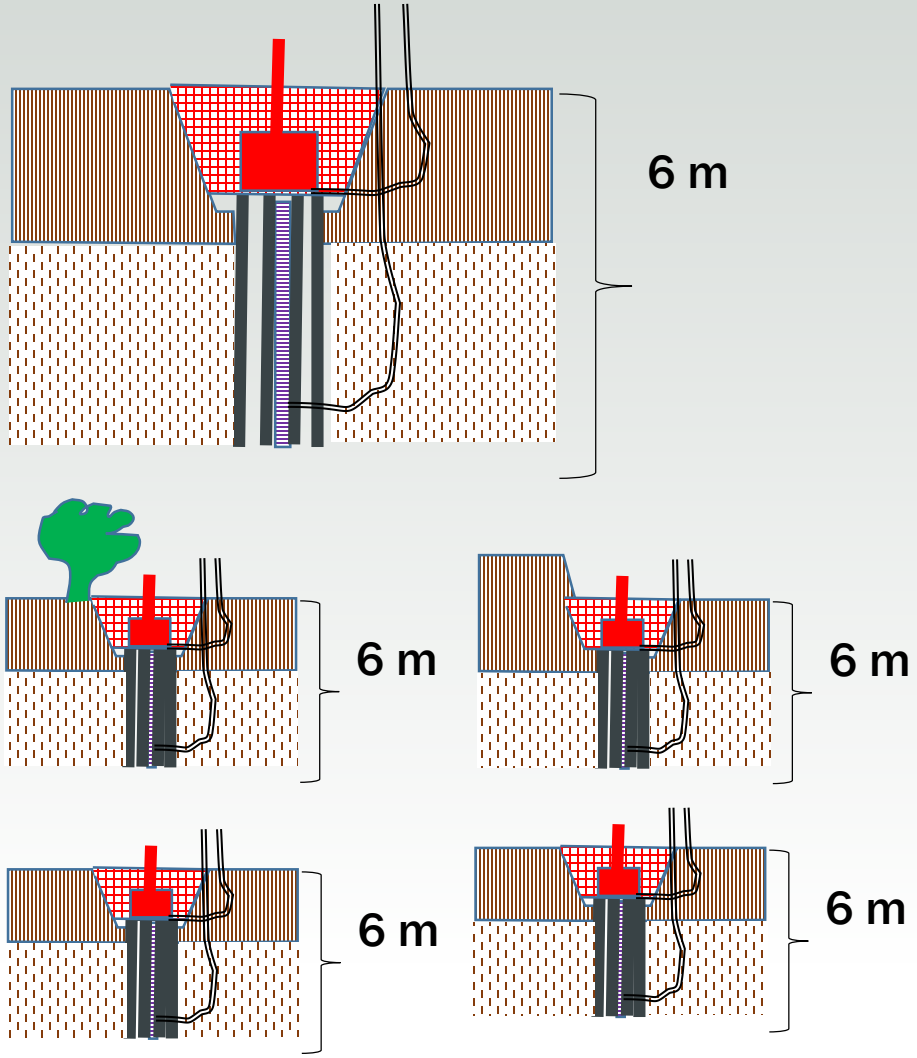
Test campaign





- Install test facilities
- ***Don't need real wells***
- Install fluid access to simulate well leakage
- An array to create variability

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Ultimate goal

- Low-cost, real-time, automated, easily replicable, long-term surveillance (of a population of P&A wells)
- Flag wells that deviate from trend for risk consideration (*possible reentry & repair*)
- Value:
  - Avoid blowouts – early intervention
  - Gain license to operate & close site
- Cost per installation: depends on value

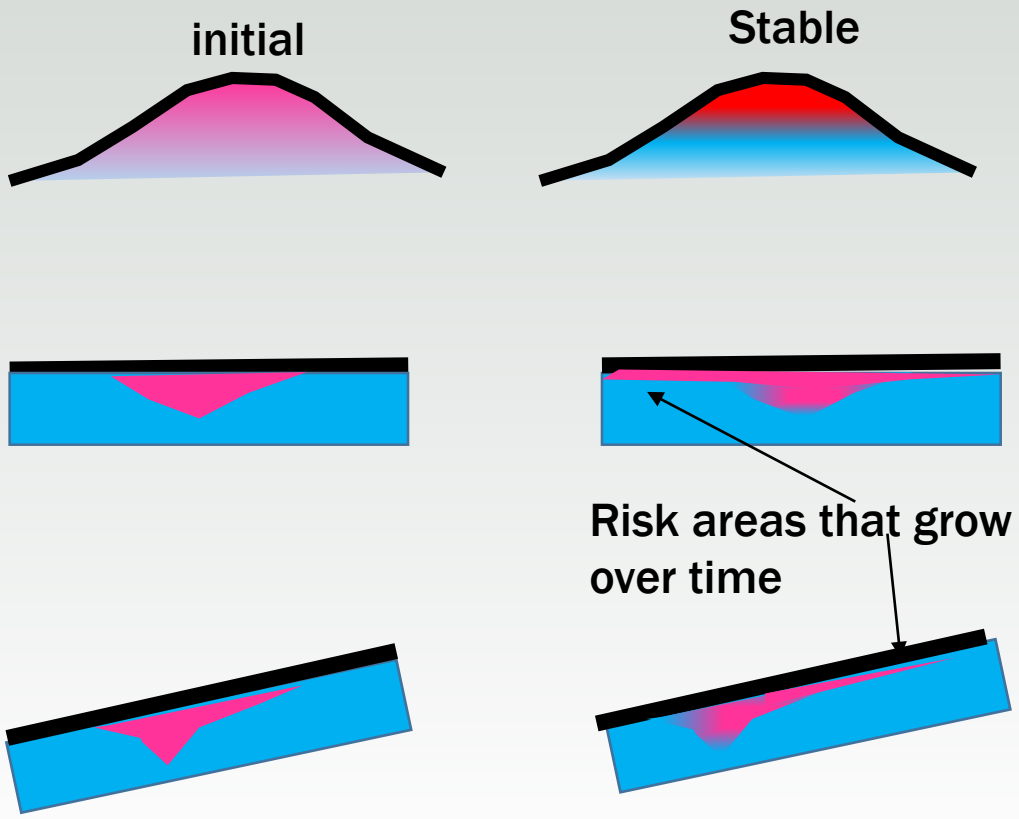
Project status

- An idea in search of funding

Long-term plume stabilization

- Problem: How long do we monitor? (*assurance of planned, acceptable long-term stabilization*)
- What metrics indicate reduced risk of lateral migration? (i.e., acceptable levels)

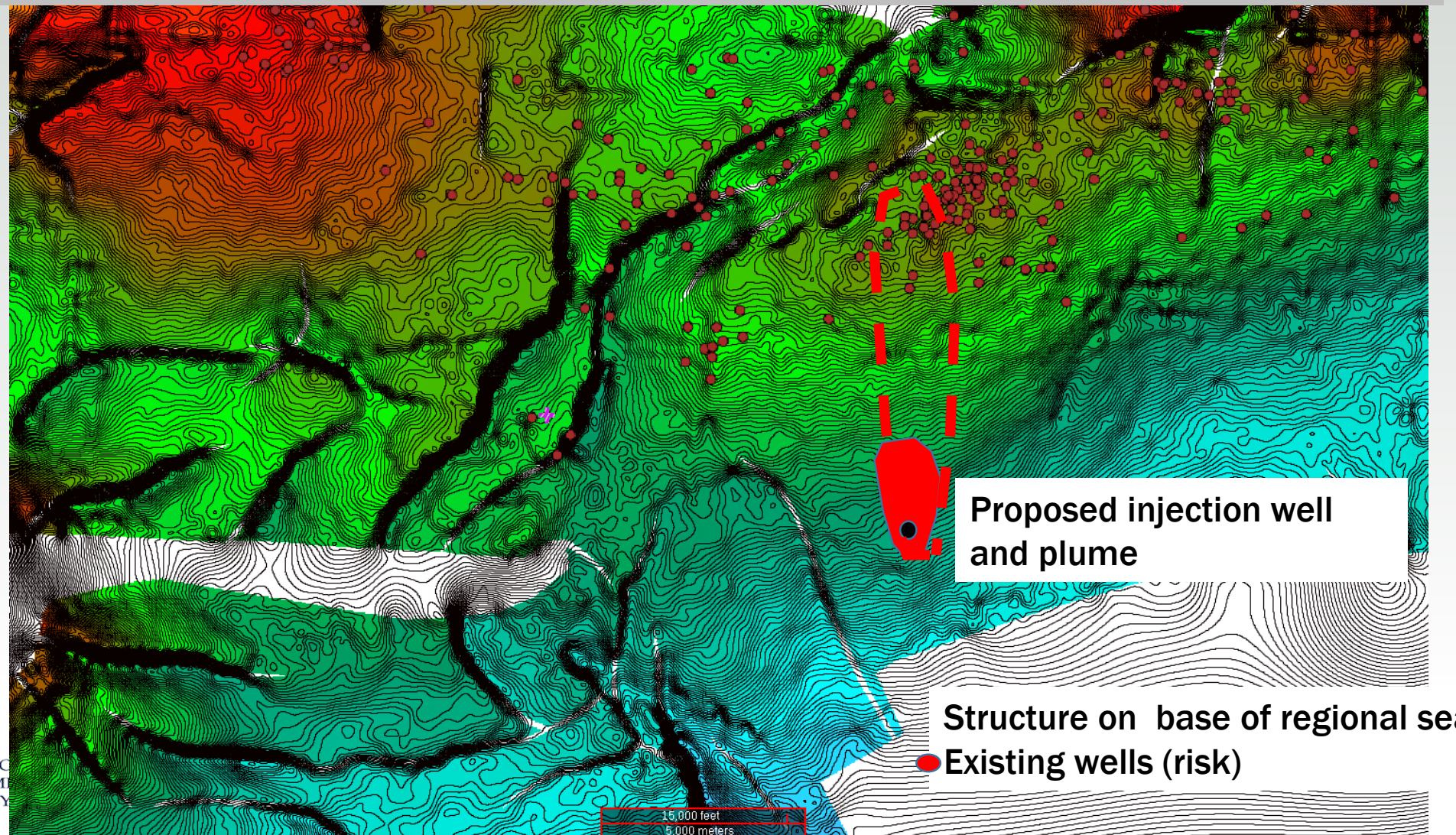
Stabilization Risk is Geometry-Dependent



- **Structural closure:**
  - CO_2 saturation at crest increases over time;
  - approaches limit defined by residual water saturation
  - Risk = column height? ***maybe***
- Dipping or flat strata:
  - plume migration *lateral*,
  - accesses new portions of seal

    Flaws?

Example case



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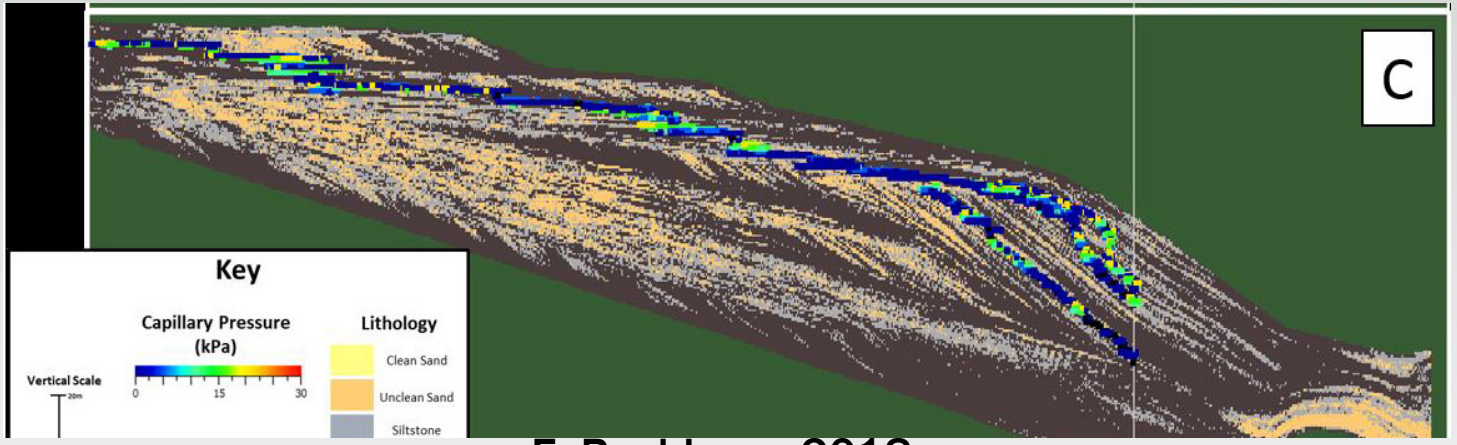
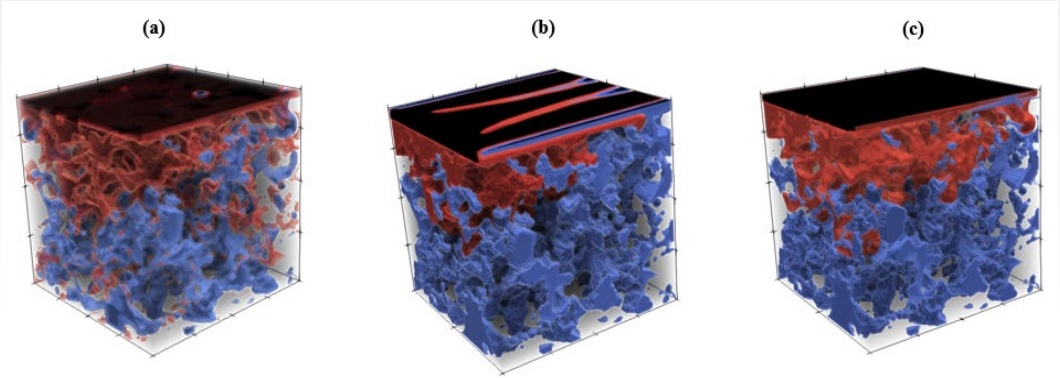
Uncertainties

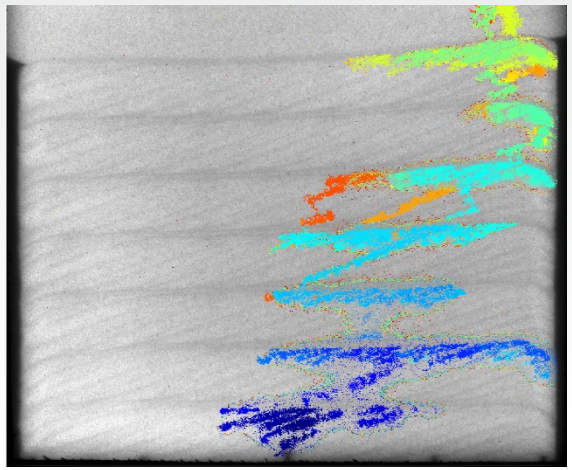
- Upscaling processes:
  - Low viscosity buoyant flow
  - Trapping in small traps
  - Trapping in bedforms
  - Residual trapping
  - Dissolution



E. Beckham, 2018



S. Bakhshian, 2019



P. Krishnamurthy, 2020

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Project status

- Collecting the information (to better understand processes)
- Need viable concept for early monitoring (to confirm correctness of late-stage stabilization)
- Don’t wait 100 years to determine if project is OK!