Frio Brine Pilot: Lessons Learned and Questions Restated

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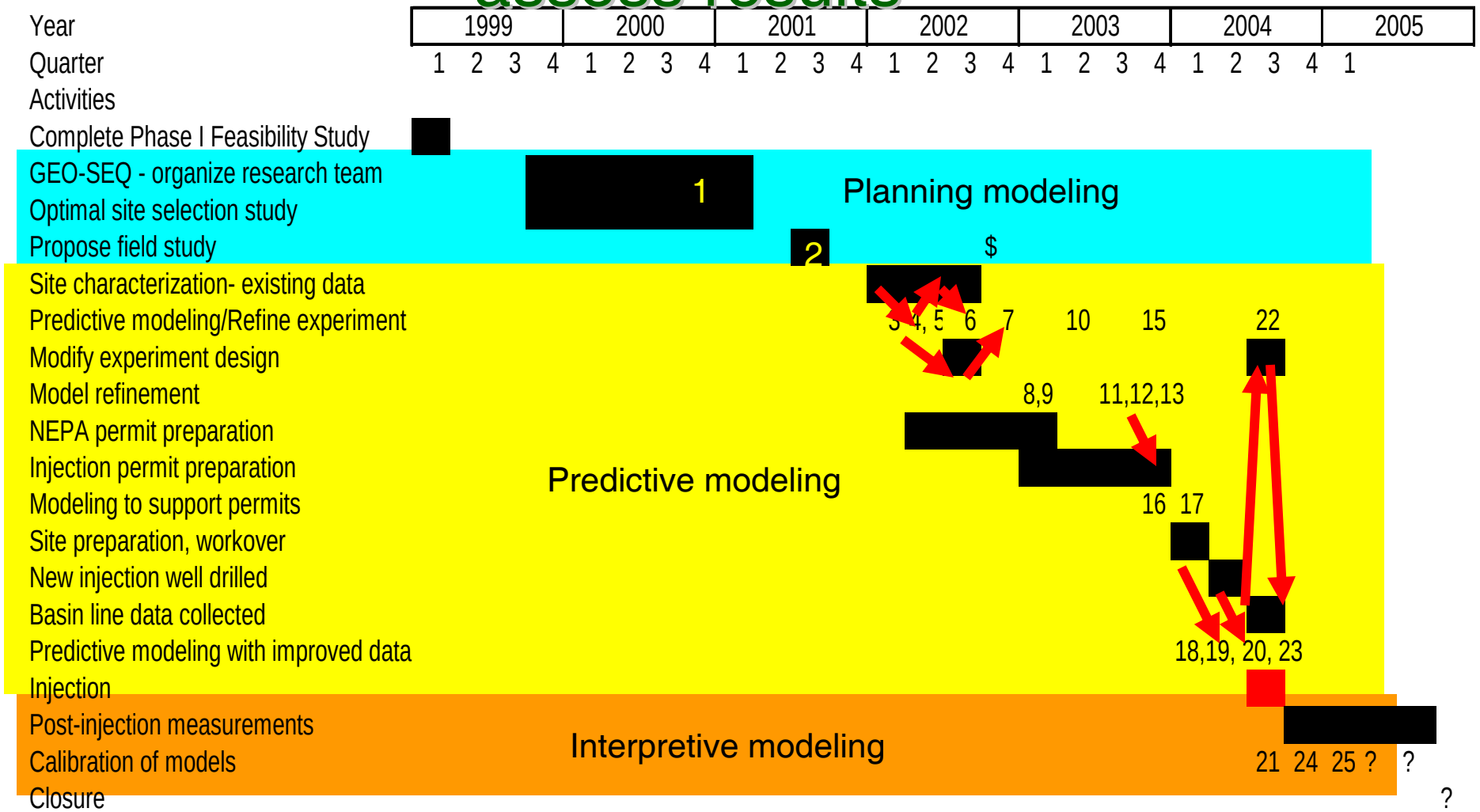
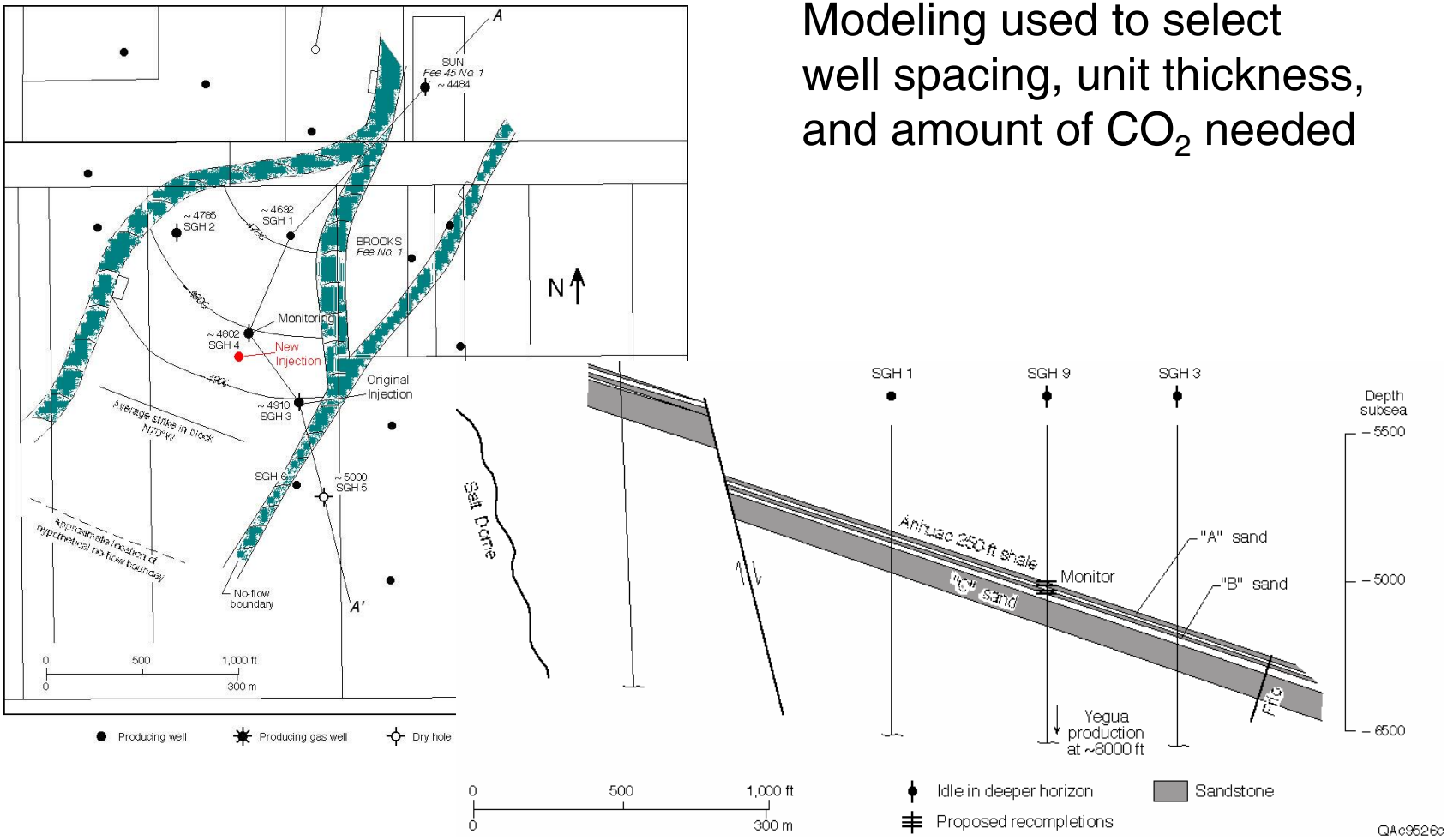
Modeling for proposal, during design, and to assess results



1-25 TOUGH2 model sets, Christine Doughty, LBNL

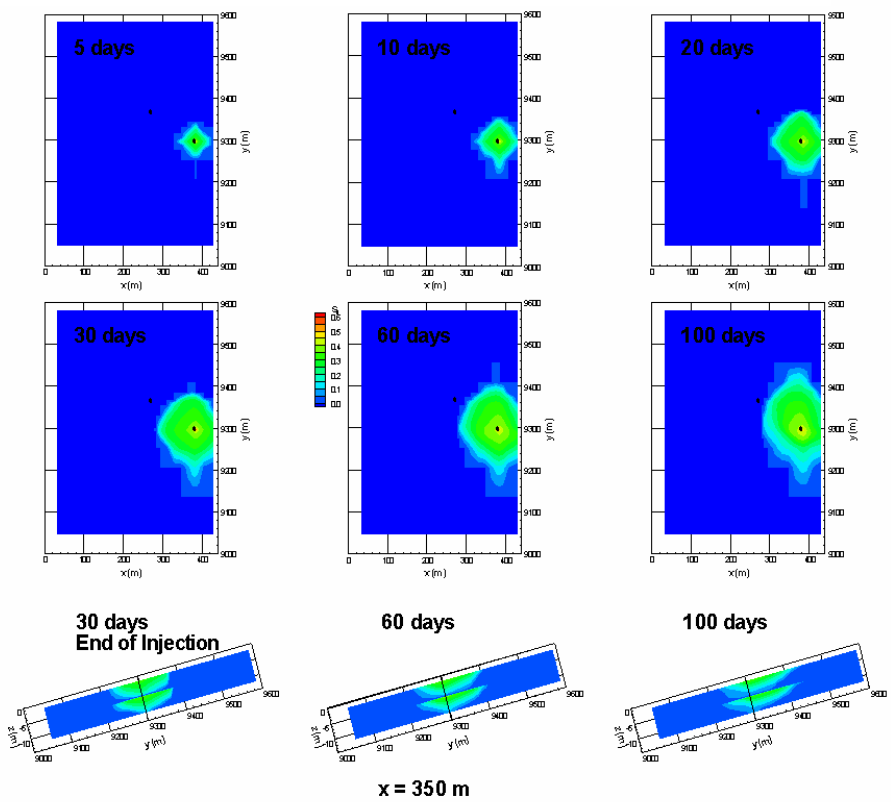
Simple Characterization for Proposal

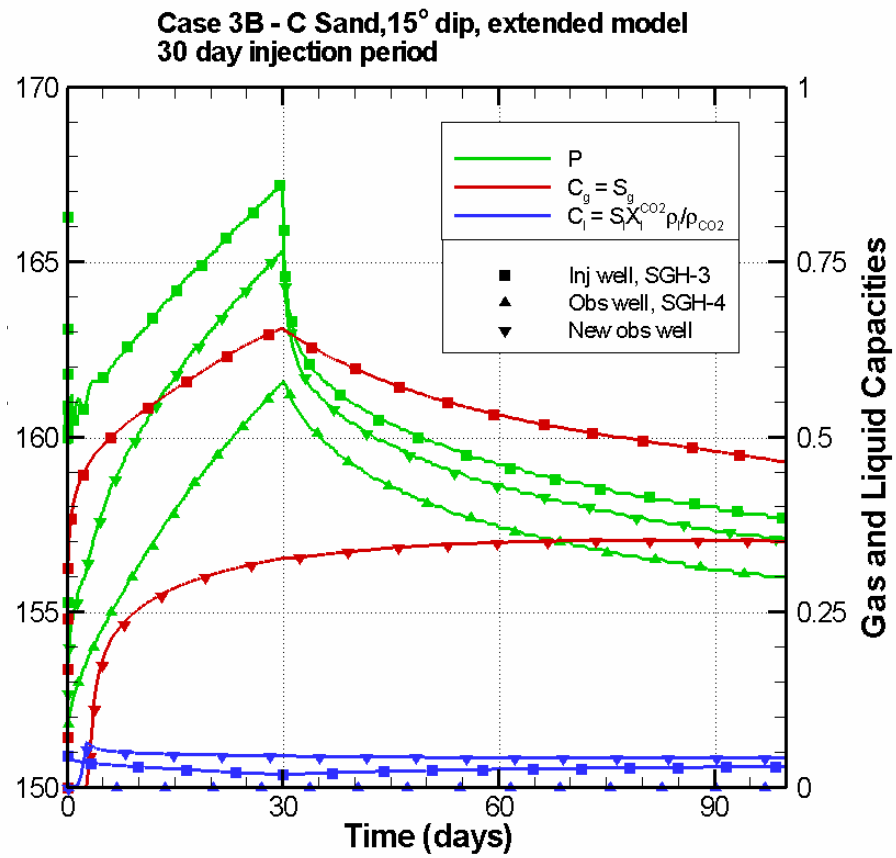
Modeling used to select well spacing, unit thickness, and amount of CO_2 needed



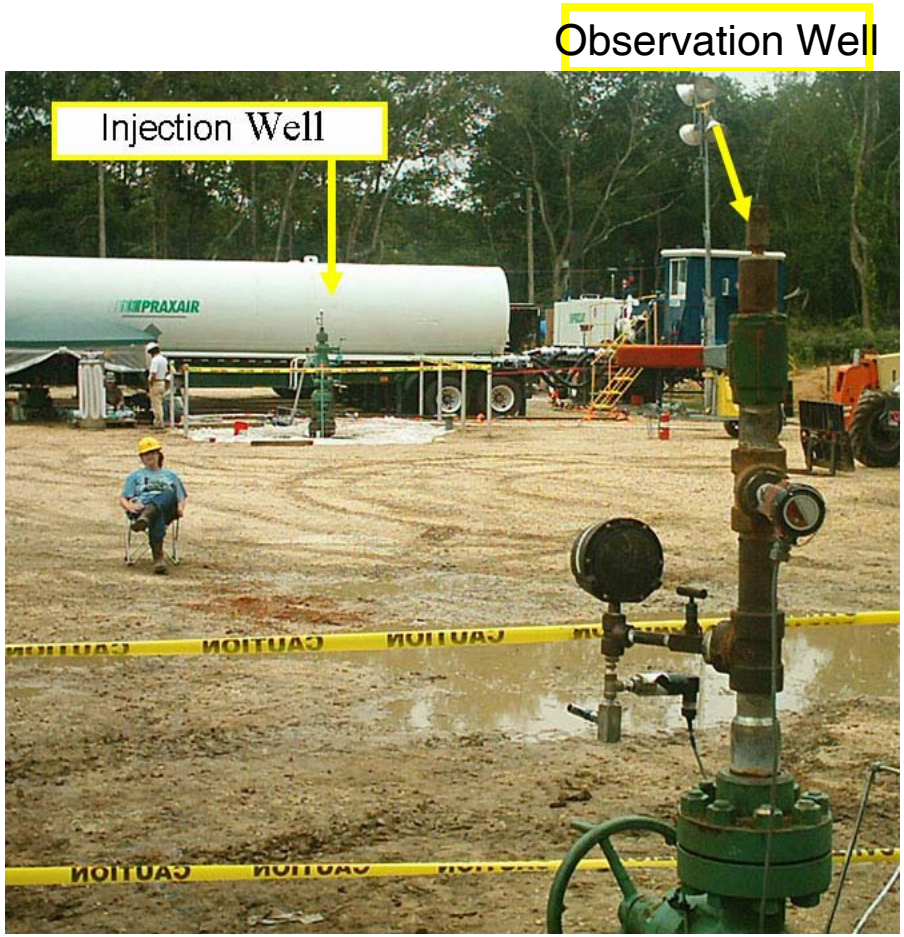
Will CO2 arrive?

Experimental design interaction with geologic uncertainties



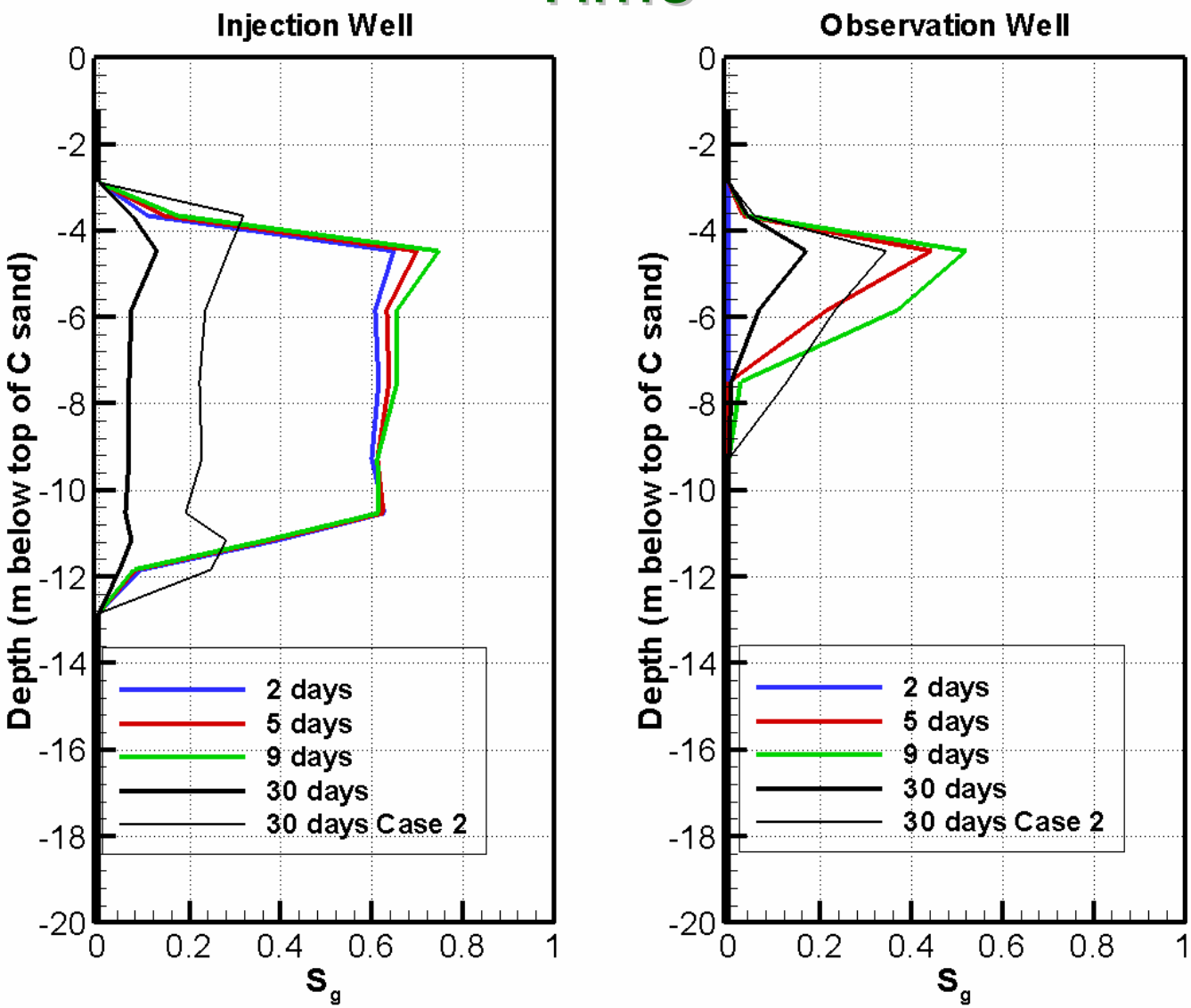


Small is Beautiful



- Closely spaced measurements in time and space
- Emphasis on post-injection period
- High science, low risk

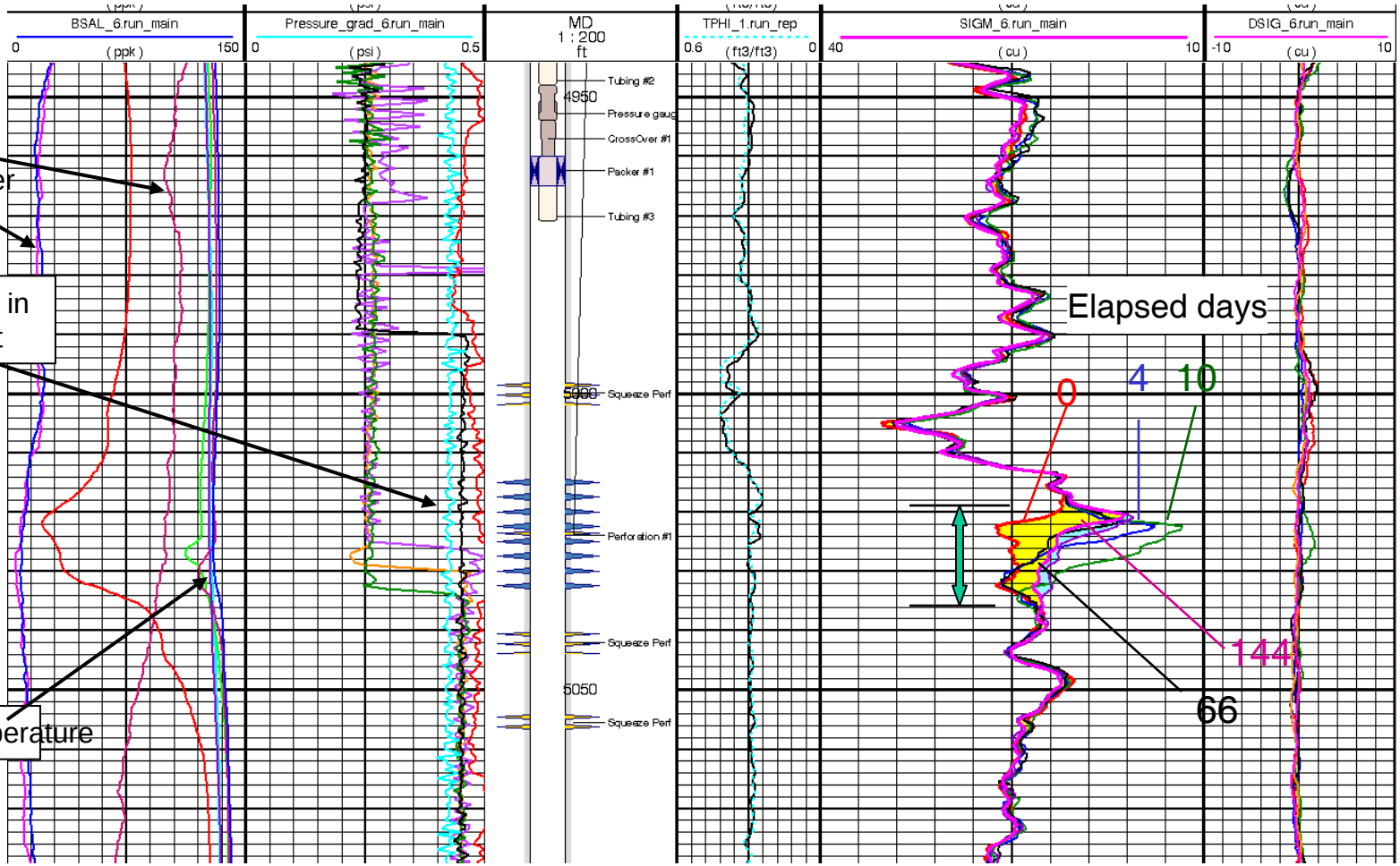
Predicted Saturation Distribution Through Time



Observed Saturation Distribution Through Time-Injection Well

Borehole correction

Sigma



Borehole salinity: run 1 high, run 5&6 fresh water

6 run: pressure gradient in borehole: water gradient

Run 5&6: constant temperature

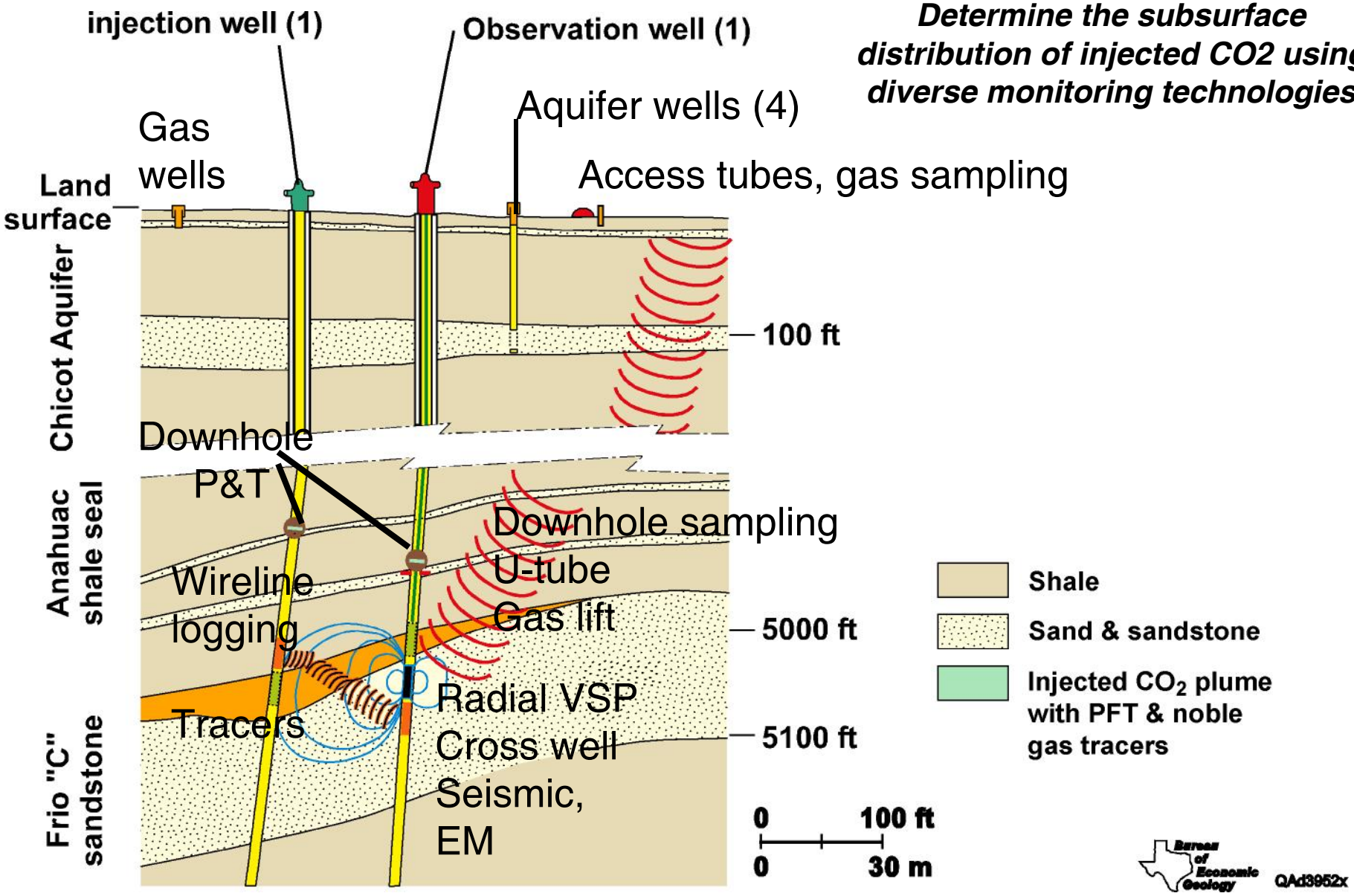
Schlumberger

Tool Selection Appropriate for Goals and Subsurface Environment

- No one tool is “Best”
  - Case specific
    - what is needed?
    - What is possible?
- Interference among tools
  - Geophysics vs. sampling
  - Surface monitoring vs. subsurface sampling

Monitoring at Frio Pilot

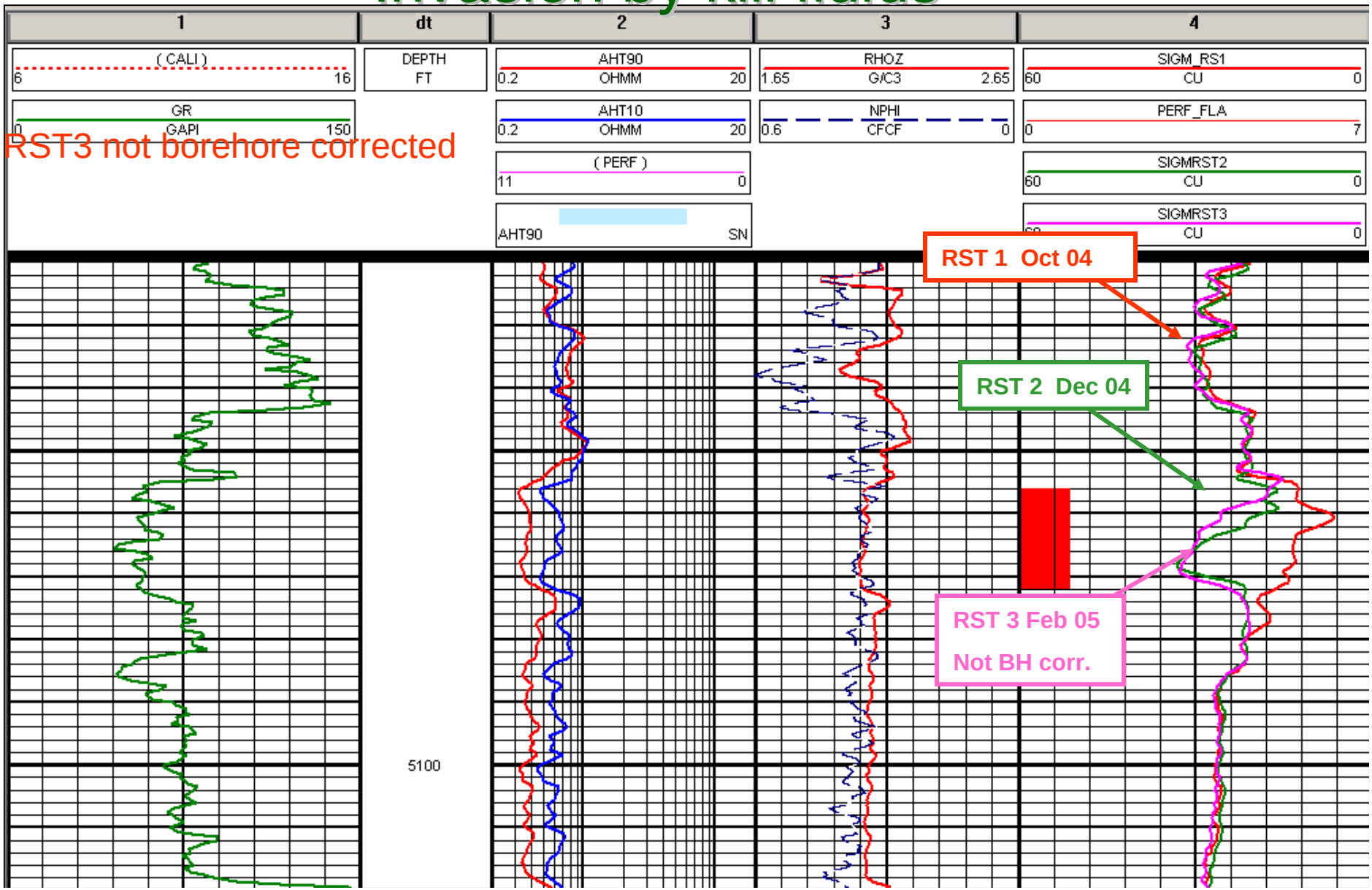
Determine the subsurface distribution of injected CO2 using diverse monitoring technologies



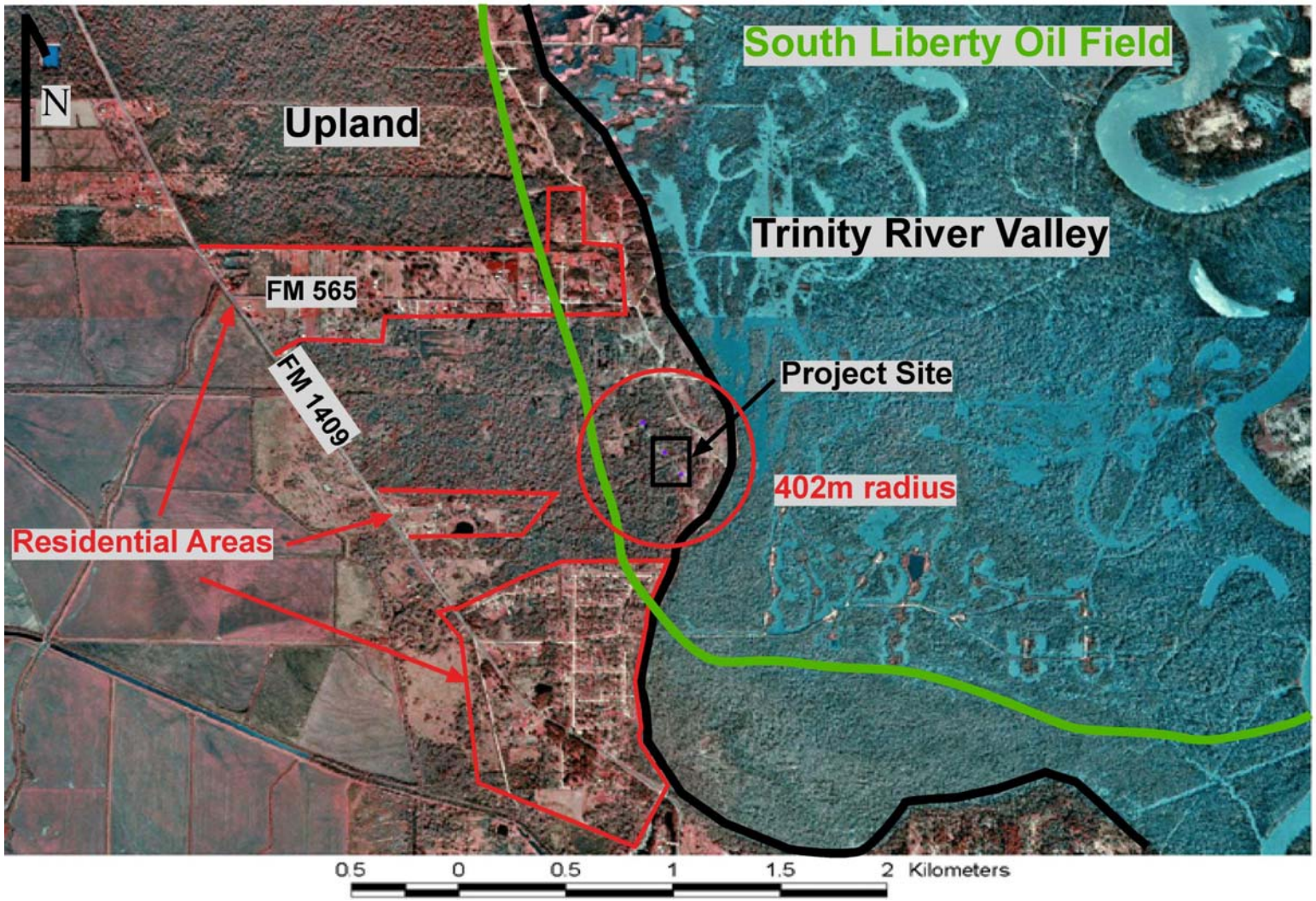
Interference among tests

- Sampling and pressure measurements require wells (open to formation, those in plume produce CO_2, and acid fluid). Geophysics require boreholes, control of wellbore fluids and pressures
- Surface monitoring should be sensitive to detect very small seepage (using tracers for example). Other operations such as surface activities and production of downhole fluids produce large perturbations).

Interference among tests
Invasion by kill fluids

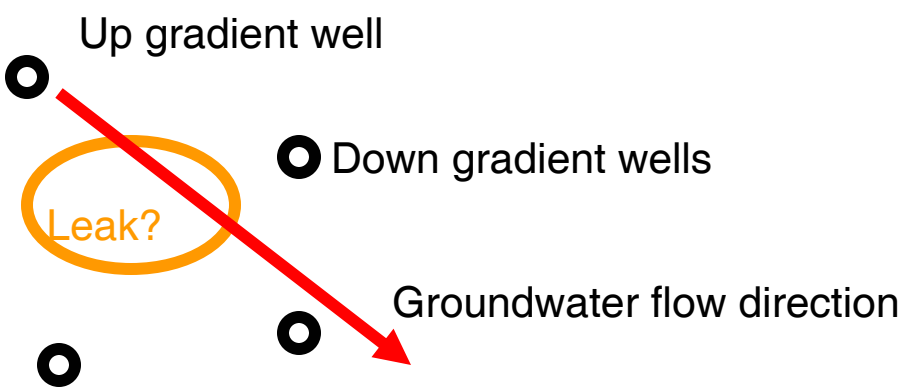


Complexity: Surface Environments



Groundwater Monitoring

- A standard test = high public assurance
- A low-cost test
- An effective test – reduced complexity, integrator of multiple leakage paths



More work needed: experiments not done at Frio

Experiment	why not done?
• Large volume of CO_2	Risk, $
• Interaction with faults	Risk, complex, premature
• 4-D survey	Problematic, $
• Observation well array in zone	$
• Tilt	Problematic, $
• Microseismic array	Problematic,$
• WAG	Interference
• EOR	interference
• EGR	interference
• Streaming potential	$
• Ecosystem impact survey	Problematic, $
• Massive pre-project PR	Problematic
• Legal/regulatory system test case	Problematic

Experiment	why not done?
• During experiment pressure monitoring in overlying brine aquifers, fresh aquifers	Interference
• Ecosystem CO2 flux towers	Problematic, $
• Surface CO2 monitoring lasers	Problematic, $
• Airborne/ satellite monitoring	Problematic
• Dealing with dissolved methane	no plan
• Exhaustive logging	Problematic, $
• Other edgy down hole monitoring (e.g. non-conductive wells)	$
• Long-term monitoring	problematic, $
• Pipeline issues	premature
• Complex gas injection	interference
• Inject low, recover high	$
• Well integrity, special cement	premature
• Long-term geochemistry	$

Problematic = estimated to be unlikely to collect useful measurements at Frio scale, duration, site specific conditions

Interference = interferes with success of another experiment

$ = cost prohibitive in total project context. Might be used in a larger budget project