Phase II Field Demonstration at Plant Smith Generating Station: Assessment of Opportunities for Optimal Reservoir Pressure Control, Plume Management and Produced Water

DE-FE0026140

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Acknowledgment and Disclaimer

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Presentation Outline

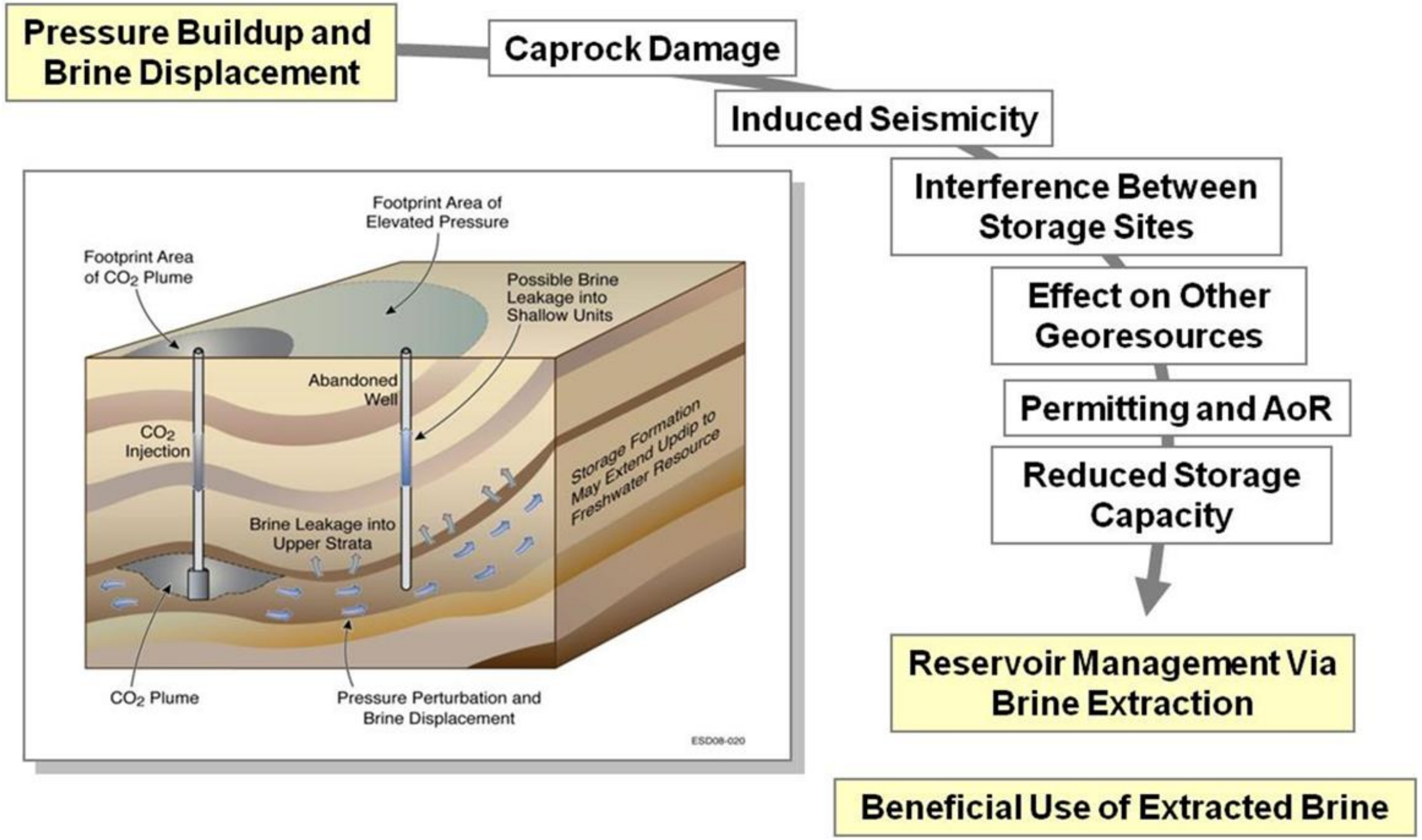
- Project Goals and Objectives
- Project Location
- Technical Objectives
- Technical Status
- Synergies
- Challenges to Date
- Project Summary

Photo showing Plant Smith in foreground and Panama City in background. Inset shows the location of Plant Smith in the Florida Panhandle (red circle).

Project Overview—Goals and Objectives

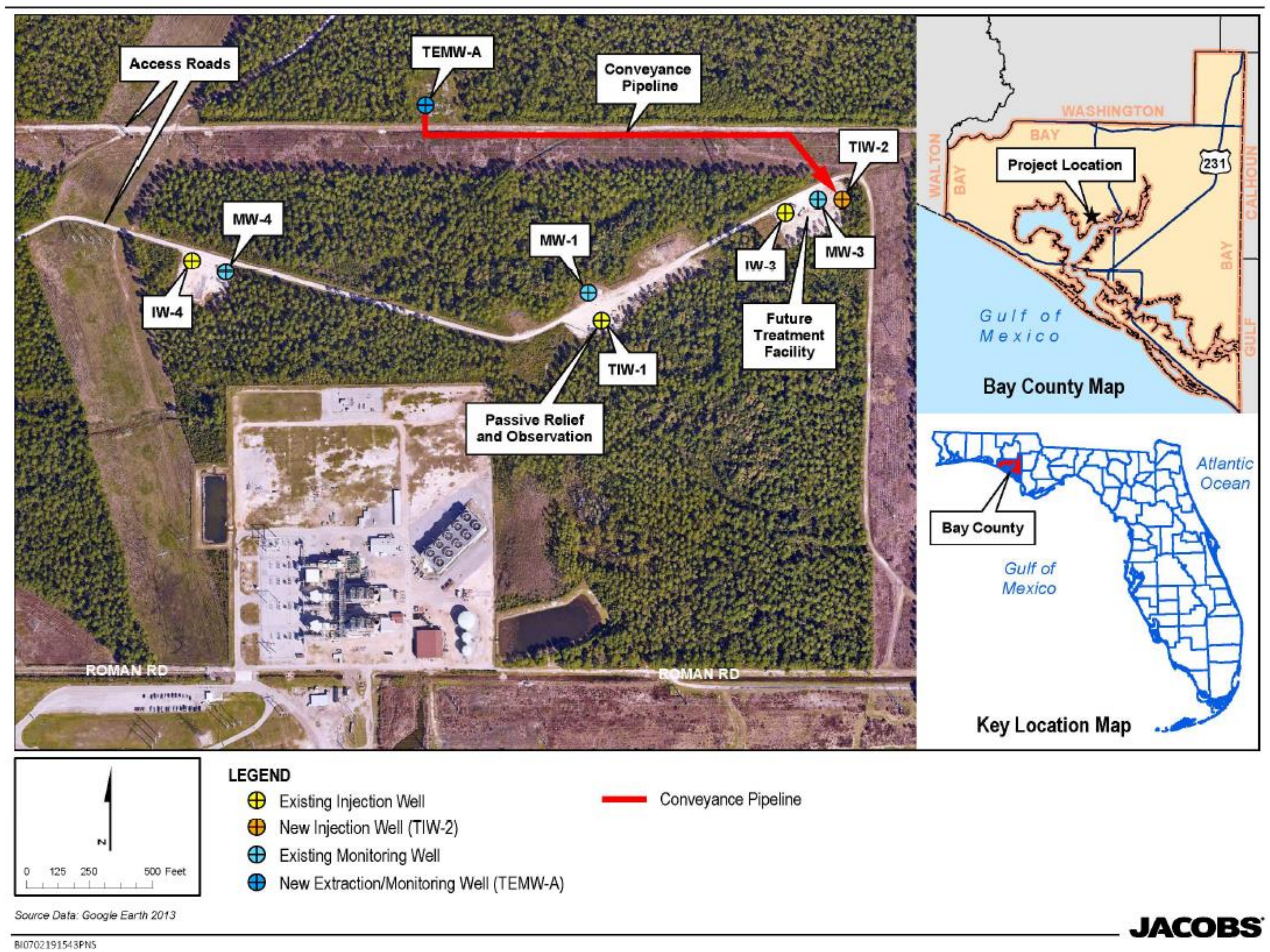
- Objective : Develop cost effective pressure control, plume management and produced water strategies for: 1) Managing subsurface pressure; 2) Validating treatment technologies for high salinity brines

Pressure management practices are needed to avoid these risks. Brine extraction is a possible remedy for reducing or mitigating risk



Plant Smith Overview

- Multiple confining units
- Thick, permeable saline aquifers
  - Eocene Series (870-2,360 ft)
  - Tuscaloosa Group (4,920-7,050 ft)
- Represent significant CO_2 storage targets in the southeast US
- Large Gulf Power Co. waste-water injection project provides infrastructure
- Water injection pressures will be managed as a proxy for CO_2 injection (~500k-1,000 gal/day)



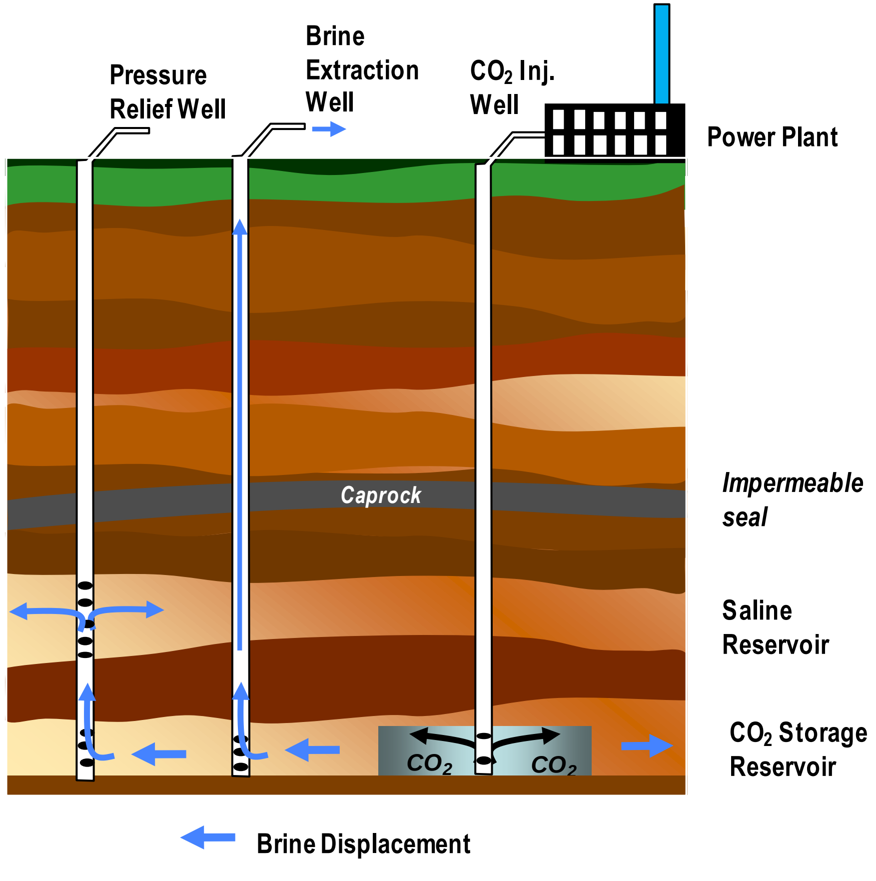
BEST project infrastructure layout showing the proposed location of the extraction well (TEMW-A), injection well (TIW-2) and flowline, and the existing passive-relief well (TIW-1)

No CO_2 injection will take place at Plant Smith

Phase II Field Demonstration Experimental Design—Passive and Active Pressure Management

- Passive pressure relief in conjunction with active pumping can reduce pressure buildup, pumping costs and extraction volume
- Existing "pressure relief well" and "new" extraction well will be used to validate passive and active pressure management strategies

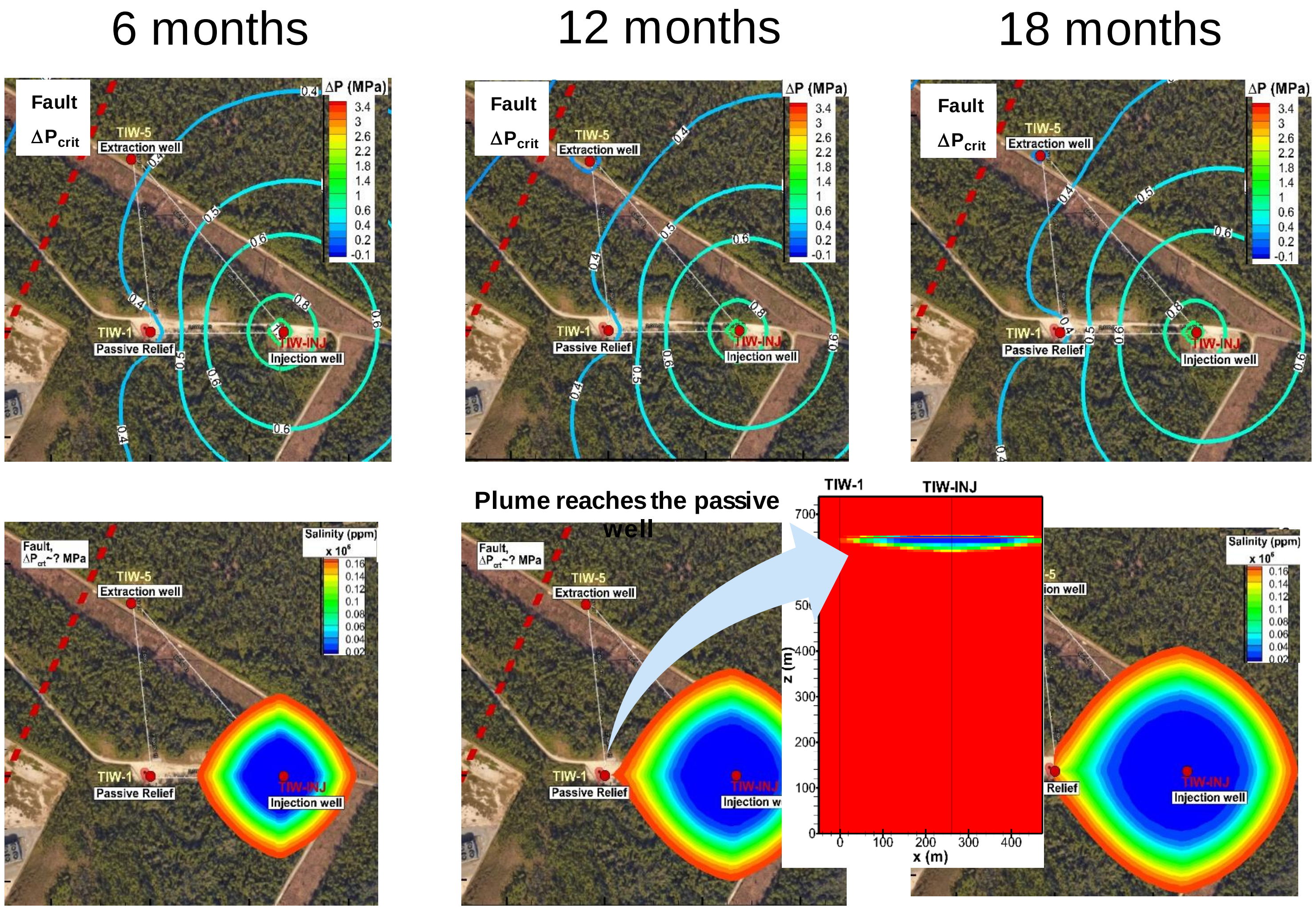
Pressure relief well has the potential to reduce extraction volume by 40%



Hypothetical CO_2 storage project showing "active" extraction and "passive" pressure relief well

Goals of Subsurface Pressure Management Via Passive + Active Brine Extraction at Plant Smith

- Scenario—Minimize risks for injection-induced seismic events and leakage along hypothetical faults by controlling
  - Pressure buildup
  - Plume migration
- Limit the size of the Area of Review
- Limit the volume extracted
- Develop and test effectiveness of adaptive optimization methods and tools to manage overall reservoir system response



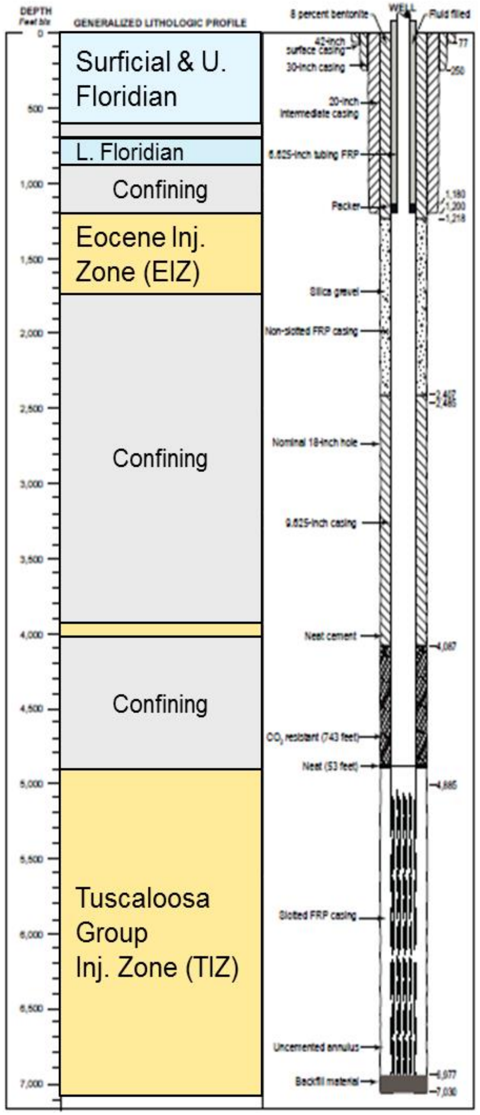
Progress and Current Status

Completed Injection and Extraction Wells

Electric rig drilling injection well TIW-2

Diesel rig drilling extraction/observation well TEMW-A

TIW-1



Core Samples from ~5,000 ft (~1,524 m)

Core barrel containing continuous side-wall cores

Close-up view of side-wall cores
Clay (left) and sandstone (Right)

Lower Tuscaloosa Sidewall Core Samples

- Interpreted to be fluvial sands
- Weakly consolidated to unconsolidated; interbedded with clay
- Total porosity ranges from 27 – 34 %
- Permeability ranges from 3.86E-13 to 1.52E-12 m/s (392 – 1,538 mD)

TIW-2 sidewall core sample 38; Depth 4,842 ft.

TIW-2 sidewall core sample 30; Depth 4,914 ft.

TIW-2 sidewall core sample 28; Depth 4,926 ft.

TIW-2 sidewall core sample 27; Depth 4,932 ft.

Some pebble conglomerate may be present. Some calcareous cement present.

Samples are poorly sorted to moderately well-sorted; fine to coarse grain sands

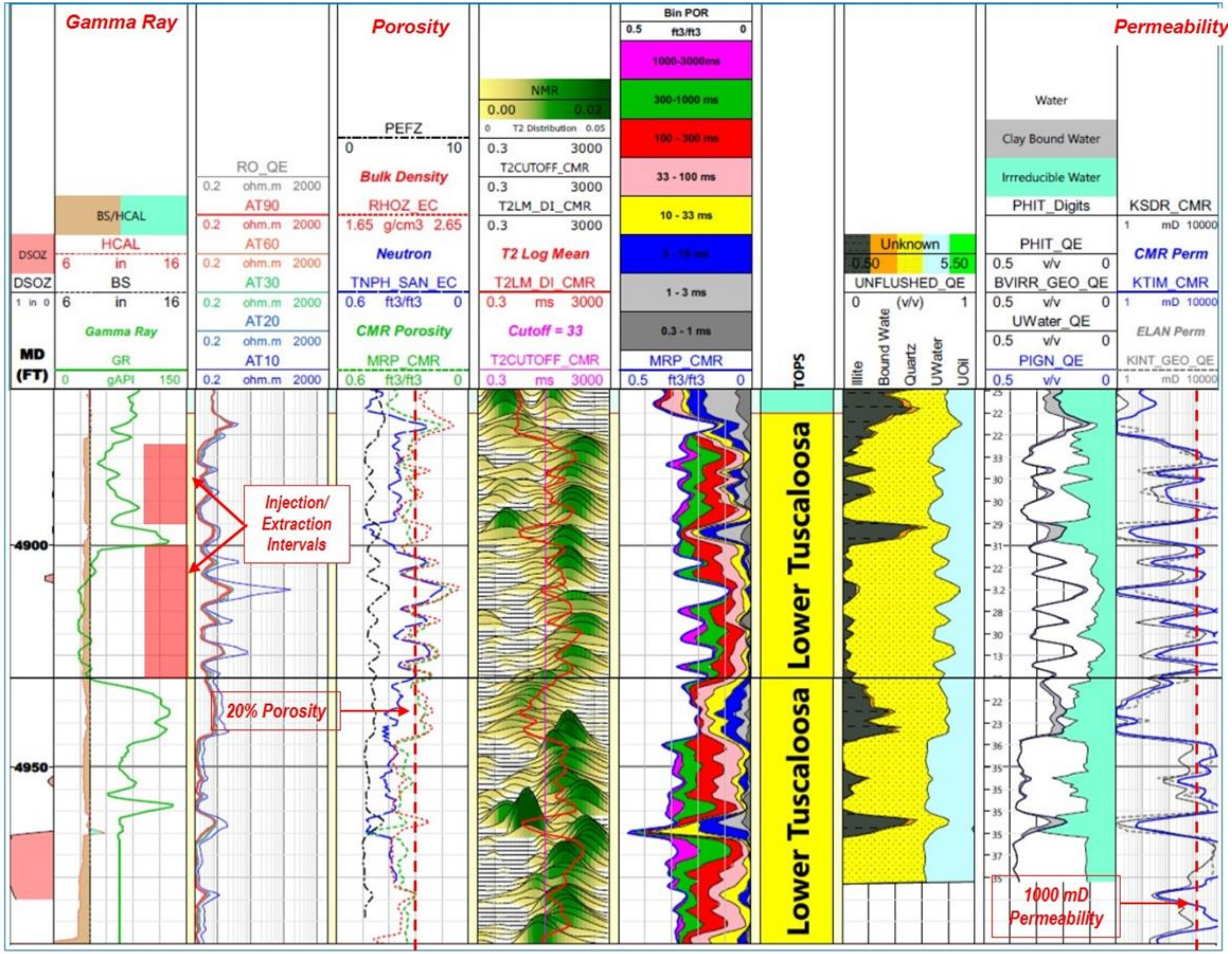
High K-feldspar content (high gamma-ray)

Correlations were used to derive layer properties because of highly unconsolidated sands

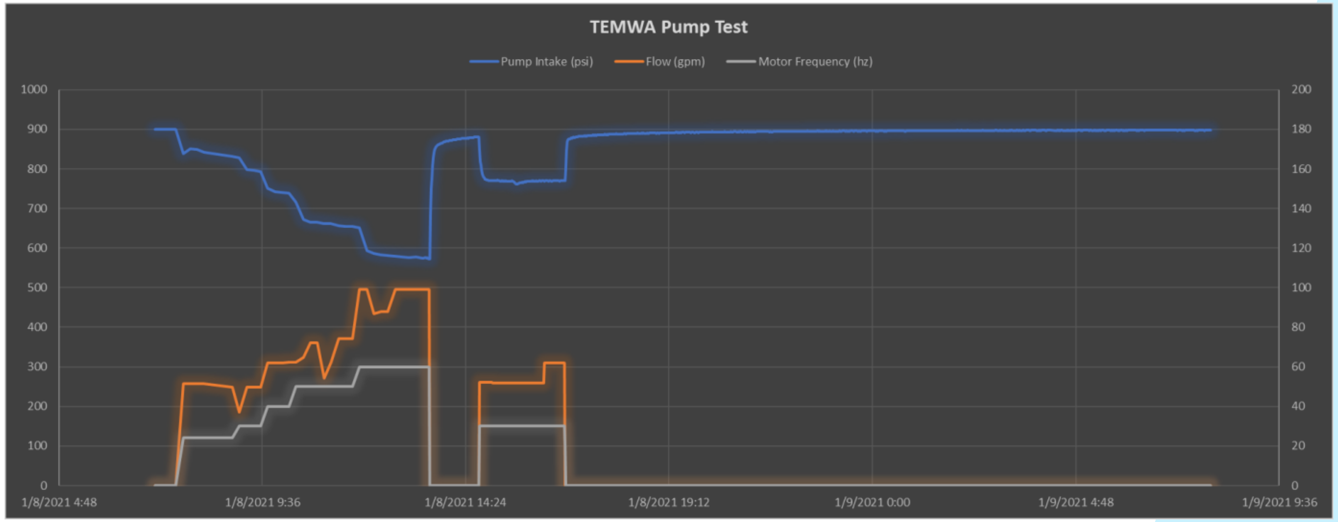
Collected and Interpreted Geophysical Well Logs

Extraction Well TEMW-A well logs for the extraction interval

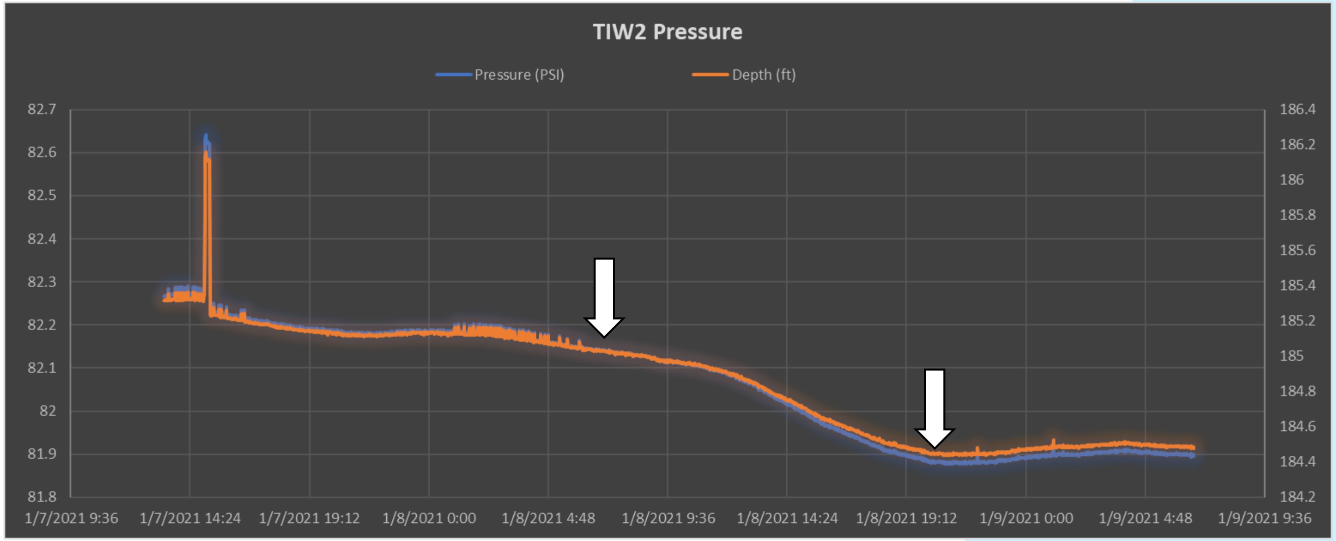
- Gamma Ray
- Induction Resistivity
- Density log
- Neutron porosity log
- Combinable Magnetic Resonance (CMR) porosity
- CMR permeability



Hydraulic Characterization of Injection Zone



Drawdown (left scale, psi) and flow rate (right scale, gpm) recorded during pump test



Drawdown (right scale, ft) at passive relief well TIW-2 recorded before, during and after pump test

← Sustained yield of 54 gpm with injectivity of 0.38 gpm/psi

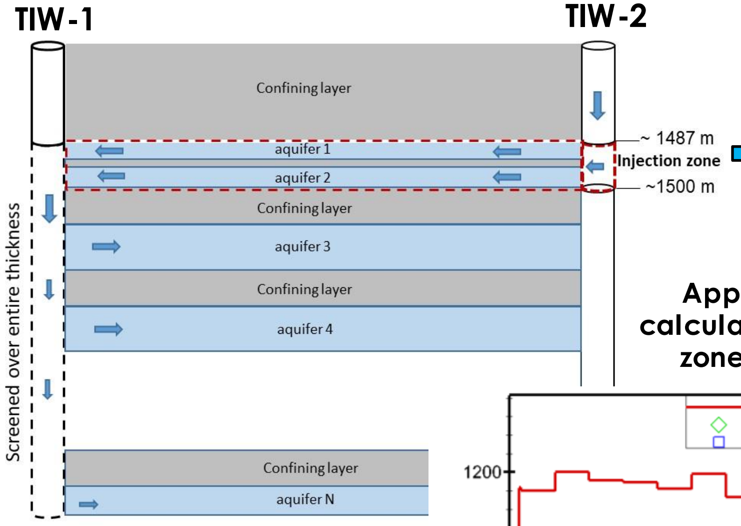
← Observed drawdown of 0.5 ft at TIW-2 located ~1,600 ft away

Running and setting electric submersible pump in TEMW-A at 2,022 ft below pad level

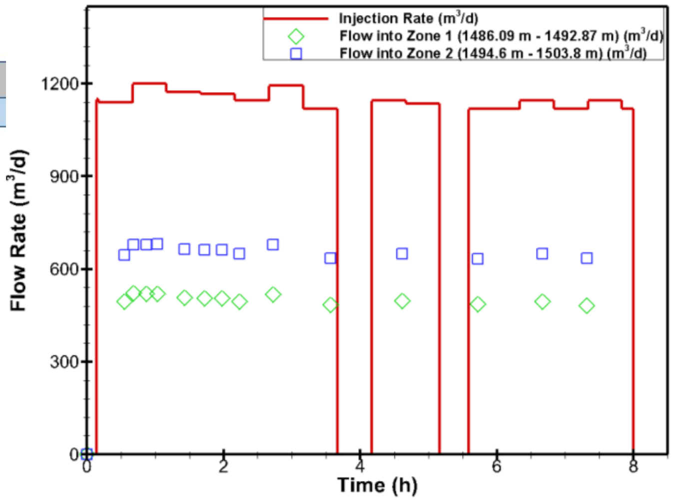
Updated Reservoir Model Properties From Analysis of Brine Injection Test in TIW-2 (*New Well*)

- Injected stored and filtered Tuscaloosa brine water into TIW-2 at an average rate of about 200 gpm for 8 hours and monitored pressure changes in TIW-1 (observation and passive relief well). No injectivity issues were detected.
  - Permeability values of the confining layers (underlying and in between the injection layers) are found to be significantly greater (~ 28 times) than the initially estimated values based on the well logs → affects the effectiveness of the passive relief well (i.e., TIW-1).

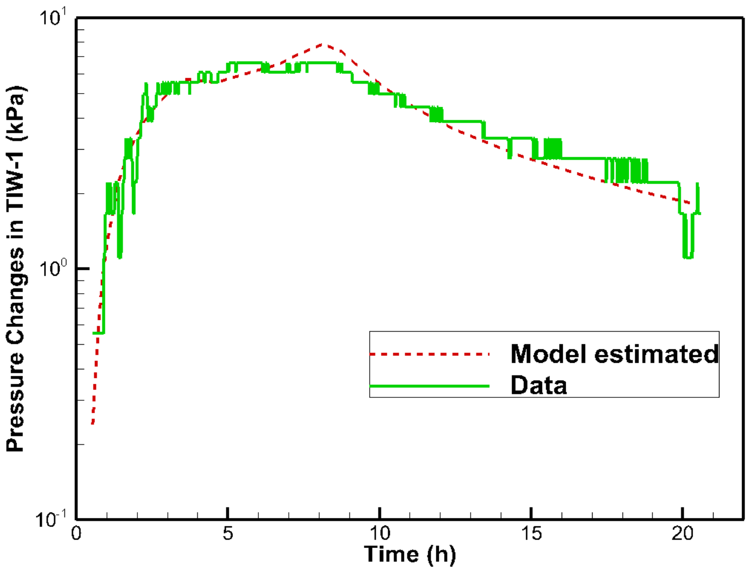
Passive relief well providing a hydraulic communication from the injection zone layers to the underlying aquifer layers



Applied injection rate and calculated flow into two different zones as a function of time



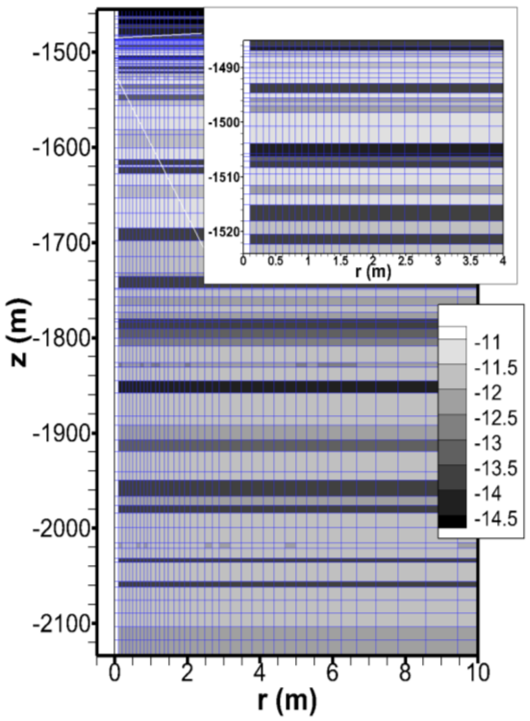
Model fitting to injection test data



Estimated mean values of the model parameters

Permeability for aquifers (m^2)	Mean=7.6×10^{-13} (stdev=5.6×10^{-13})
Permeability for aquitards or confining layers (m^2)	Mean=1.7×10^{-14} (stdev=1.5×10^{-14})
Pore compressibility for aquifers (Pa^{-1})	1.06×10^{-10}
Pore compressibility for aquitards or confining layers (Pa^{-1})	1.00×10^{-9}
Effective conductivity of the leaky well (m/d)	18709.84

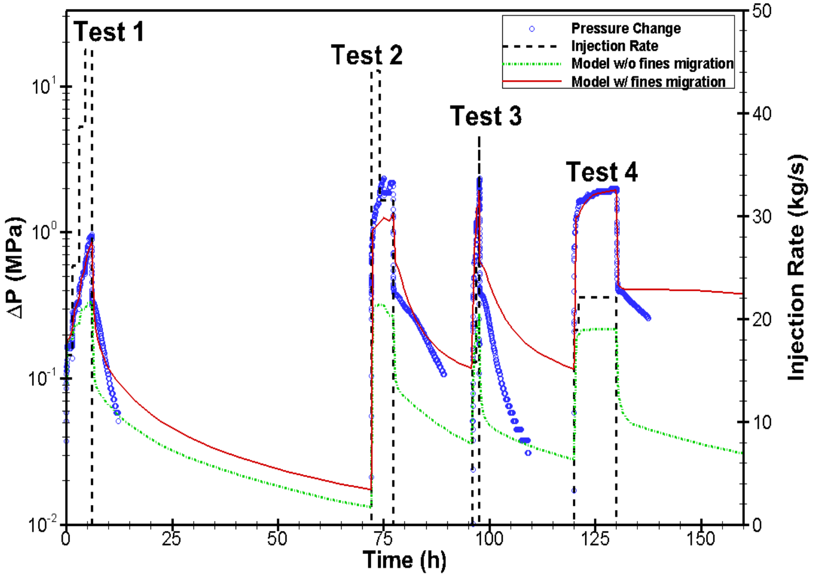
Calibrated cross-sectional view of the layer $\log_{10}$permeability (in m^2)



Analyses of the Previous Injection Tests in TIW-1 (*Injecting low-salinity water*)

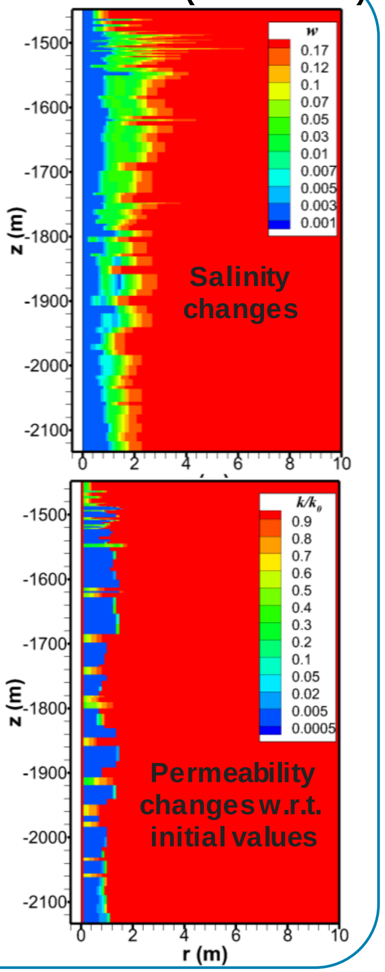
- Involved injection of low-salinity water (< 1000 ppm) into TIW-1 along its entire screened interval. The injectivity of the well consistently decreased from Test 1 to Test 4. As the reservoir layers contain significant amounts of clays (10-26% by weight), clay particle detachment and pore clogging could have contributed to the injectivity decline.
- Developed and applied field-scale and pore-scale numerical models to assess the degree of permeability decline caused by fines migration
- Our analysis suggests that the detachment of clay fines can be avoided by increasing the salinity of the injected water above the critical salt concentration (~4000-9000 ppm)

Field-scale numerical model results



- **Model results indicate that clay fines detachment causes a rapid decline of near-well permeability and this may be partly reversible by brine backflow**

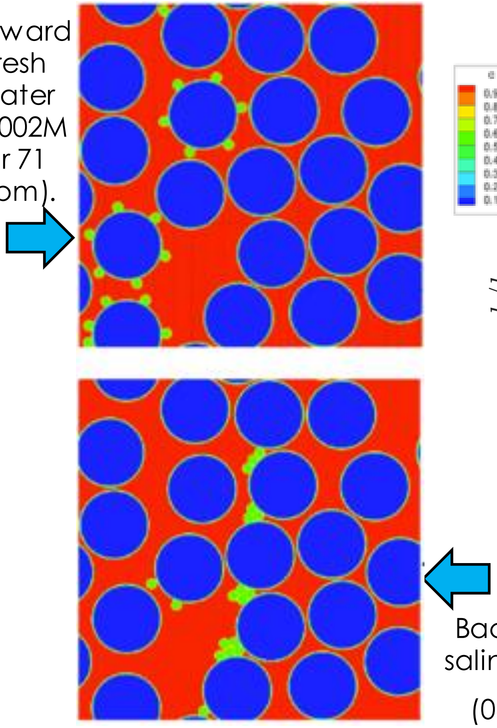
t = 130 h (End of Test 4)



Pore-scale numerical model results (Reversibility of permeability damage)

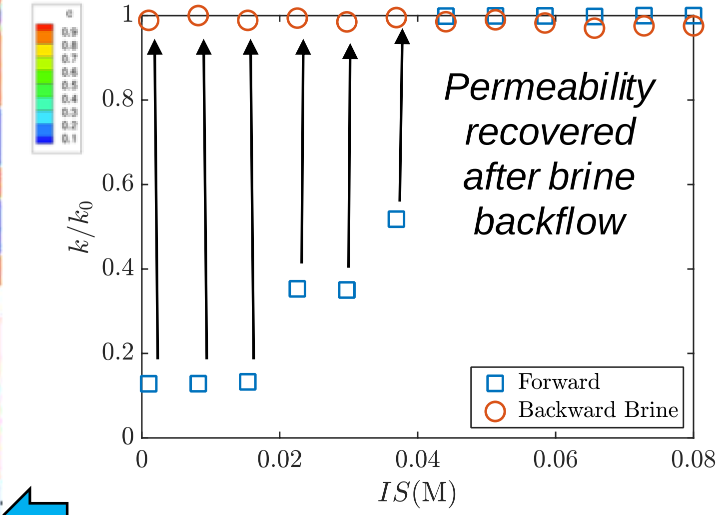
- Based on Navier-Stokes equation + immersed boundary method to simulate the motion of particles subject to hydrodynamic, van der Waals and electric double layer forces

Forward fresh water (0.002M or 71 ppm).



Backward high-salinity water flow

(0.2 M or 7100 ppm)



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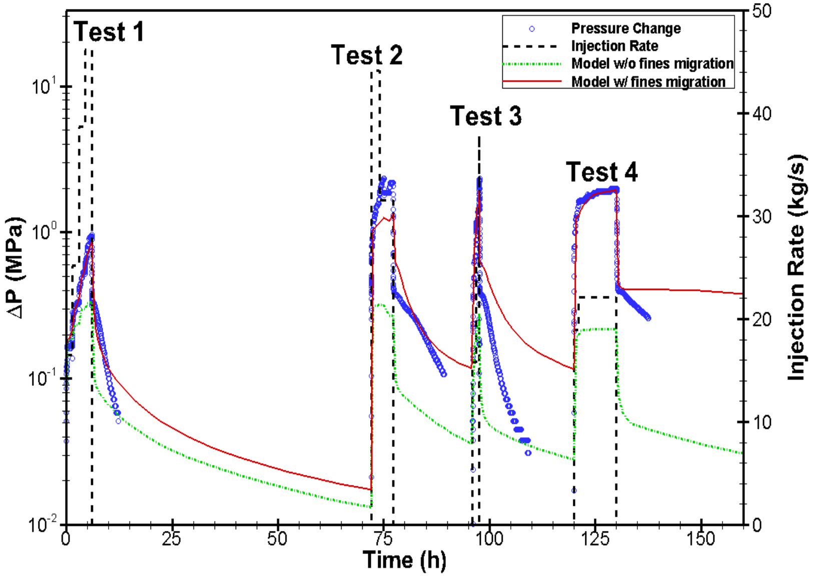

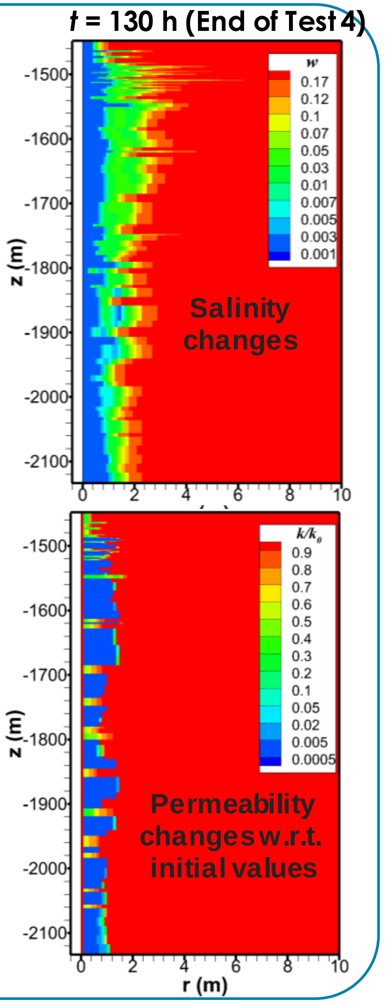

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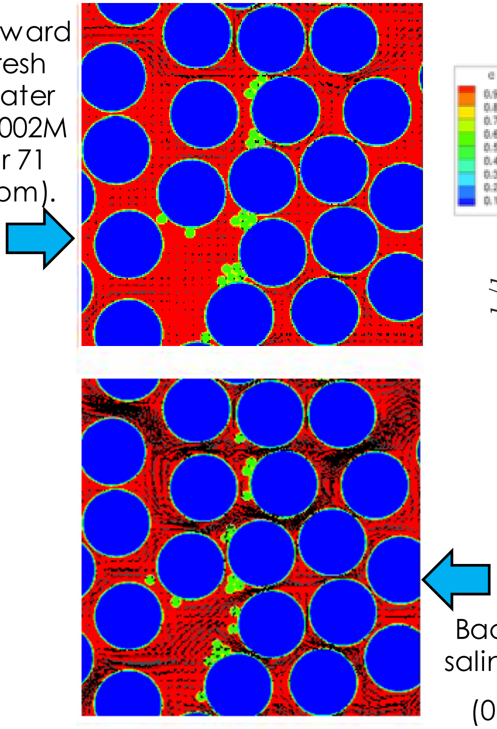

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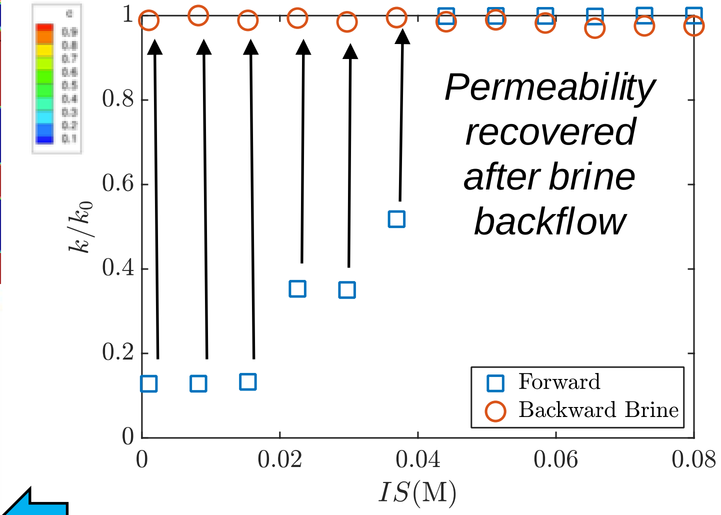


Reservoir Simulation for Test/Well Design

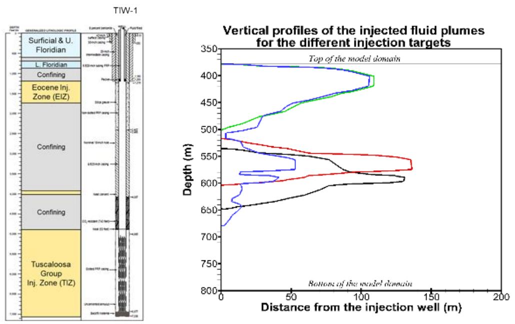
	Thickness (m)	Top depth (m)	Porosity	Perm (mD)
Confining Zone: Tuscaloosa Marine Shale	46.3296	1403.2992	0.24	0.2
Confining	15.5448	1449.6288	0.2	0.1
Lower Tuscaloosa - Sandstone ("Pilot Sand") - Confining	11.8872	1465.1736	0.2	12
Confining	11.2776	1477.0608	0.2	0.5
Potential Injection Zone 1	3.3528 2.1336	1488.3384 1491.6912	0.26 0.31	**190** **800**
Confining	2.4384	1493.8248	0.15	0.5
Potential Injection Zone 2	7.3152	1496.2632	0.32	**1300**
Confining	5.7912	1503.5784	0.27	7
Potential Injection Zone 3	7.9248	1509.3696	0.325	**2625**
Confining	7.0104	1517.2944	0.27	10
Potential Injection Zone 4	4.572 2.1336 5.7912	1524.3048 1528.8768 1531.0104	0.3 0.29 0.32	**600** **550** **1060**
Confining	3.6576	1536.8016	0.12	0.5

- Assessed four individual injection zone options:

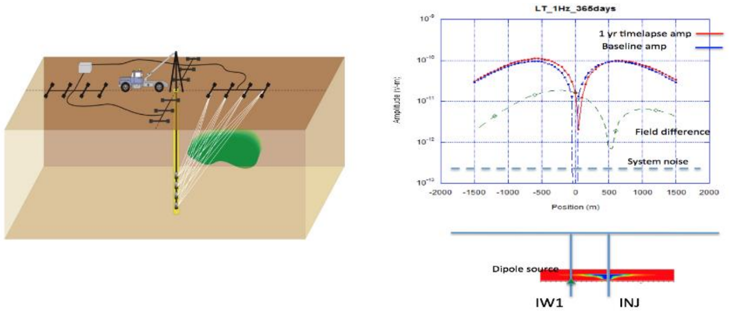
1. Base case geological model for 100 gpm and 200 gpm injection rates
2. Reduced confining layer permeability values by a factor of 10 for 100 gpm injection rate
3. Reduced injection layer permeability values by a factor of 10 for 100 gpm injection rate
4. Combination of iz1 and iz2

Monitoring – Inversion for Pressure & Salinity

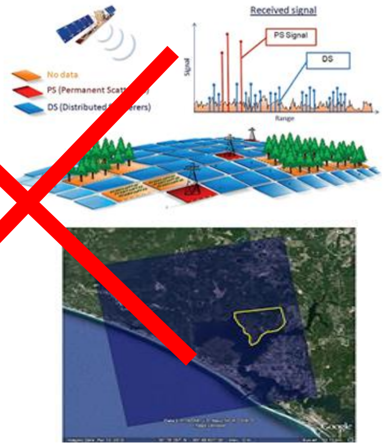
- **Borehole -** Continuous and time-lapse (discrete) borehole measurements of fluid pressure, flow rate, temperature, and electrical conductivity will be used to provide high-resolution, ground-truth, direct measurements at discrete locations (1D).



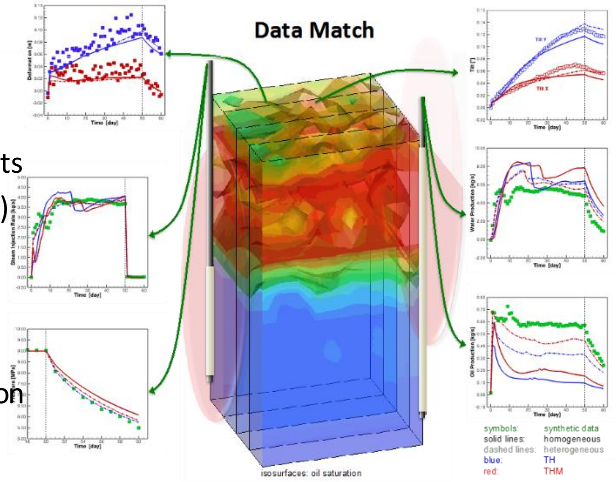
- **EM** - Time-lapse crosswell and borehole-to-surface EM will provide indirect measurements of the higher resistivity injected ash pond water with spatial resolutions in 2D and 3D approaching several meters to tens of meters, respectively.



- **InSAR** - InSAR will be used to map surface deformations resulting from subsurface pressure increases over 16 day intervals



Joint Inversion - We will use LBNL's powerful inverse modeling and parameter estimation tool iTOUGH (in its parallel version MPiTOUGH2) for the automated joint inversion of hydrological, large-scale geophysical (EM) data, and surface deformation data.



EPRI

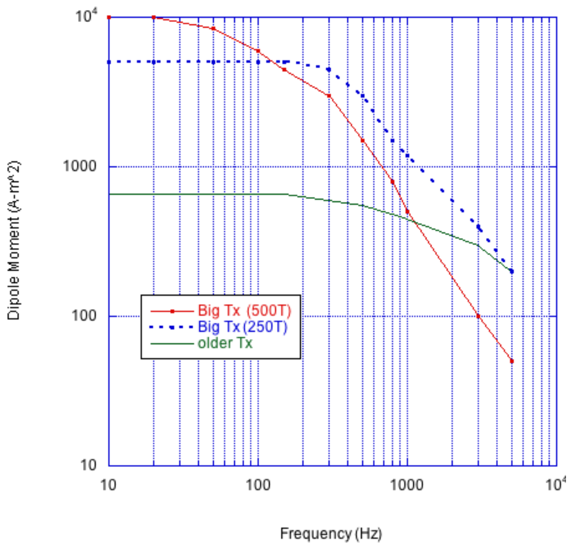
Crosswell EM System Update New Transmitter (TX) built for BEST Project

New Crosswell EM TX

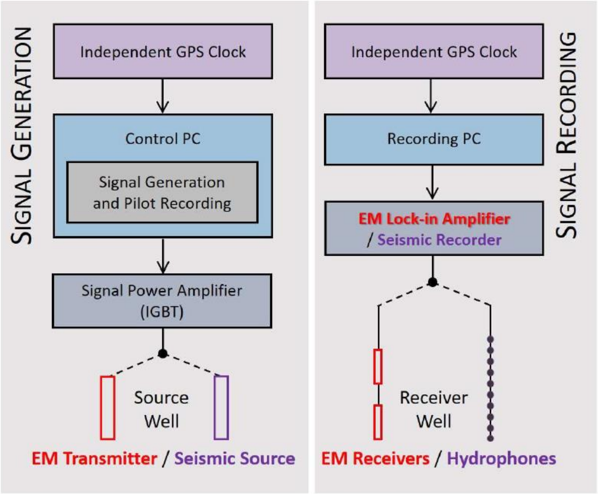
- Housing: fiberglass pipe
- Diameter: 3.5”
- Length: 12 ft
- Weight: ~150 lbs
- Tool head GH-7
    - Gerhardt-Owen 7 conductor
- Send amplified signal from the surface
    - Maximum 300 V
    - Maximum 2 amp/ wire

Picture of TX on the ground

Moment of ‘BEST’ source versus older TX



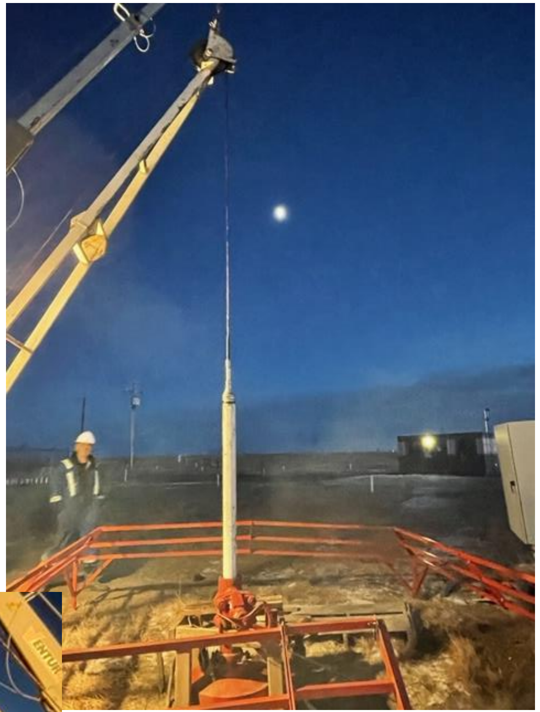
Integrated Seismic/ EM Acquisition System



Crosswell EM System Update New TX built for BEST Project

Testing of System

- Tested several time in spring / summer of 2021
  - Local Richmond Field Station test site
  - Well depths of 70m
  - Successful collection of several data sets
- Field Data Acquisition at CaMI Site in December 2021
  - TX failed after an hour's operation at ranging from 315m to 200m depth
  - Took top off and found water had shorted out capacitor bank
  - Replaced capacitor bank and filled top section with mineral oil
  - Tool failed after 1 hour operation at 300 m depth



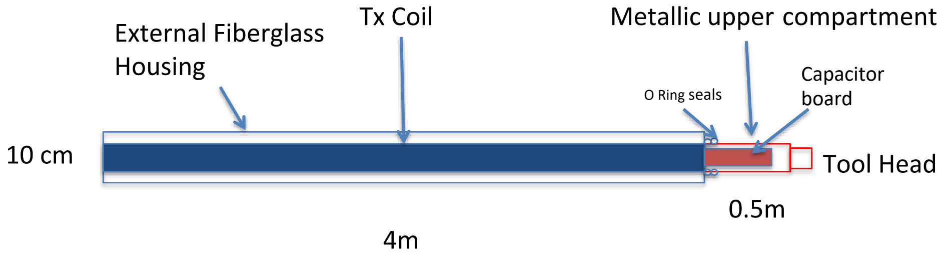
Testing the new transmitter in a well at the CAMI field site Alberta CN

EPRI

Crosswell EM System Update New TX built for BEST Project

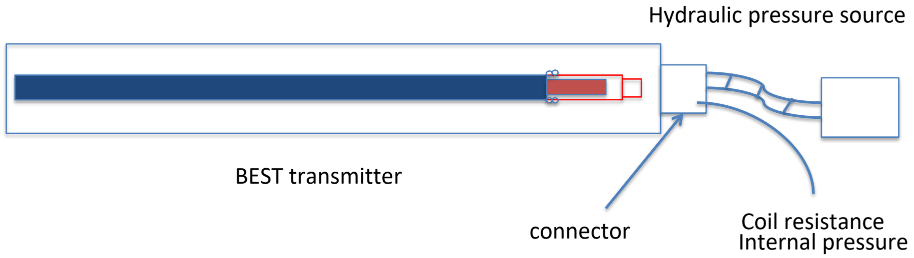
Rebuilding of Transmitter

Rebuilt with a sealed metallic box housing the capacitor board



Refurbished a pressure housing to pressure test transmitter

Sealed pipe



To date TX has been tested with no leaks to 640 psi or ~1400’ equivalent depth

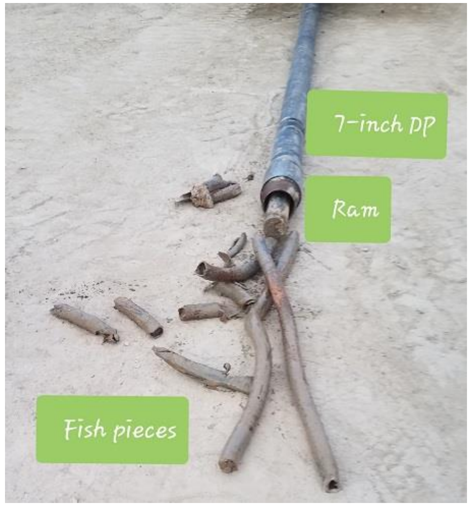
Challenges

Past Challenges

Subcontractor	Bid Amount
HAD Drilling Co.	No bid
Layne Drilling Co.	$6,859,713
Schlumberger Carbon Services	No bid
Younquist Brothers, Inc.	$10,995,000

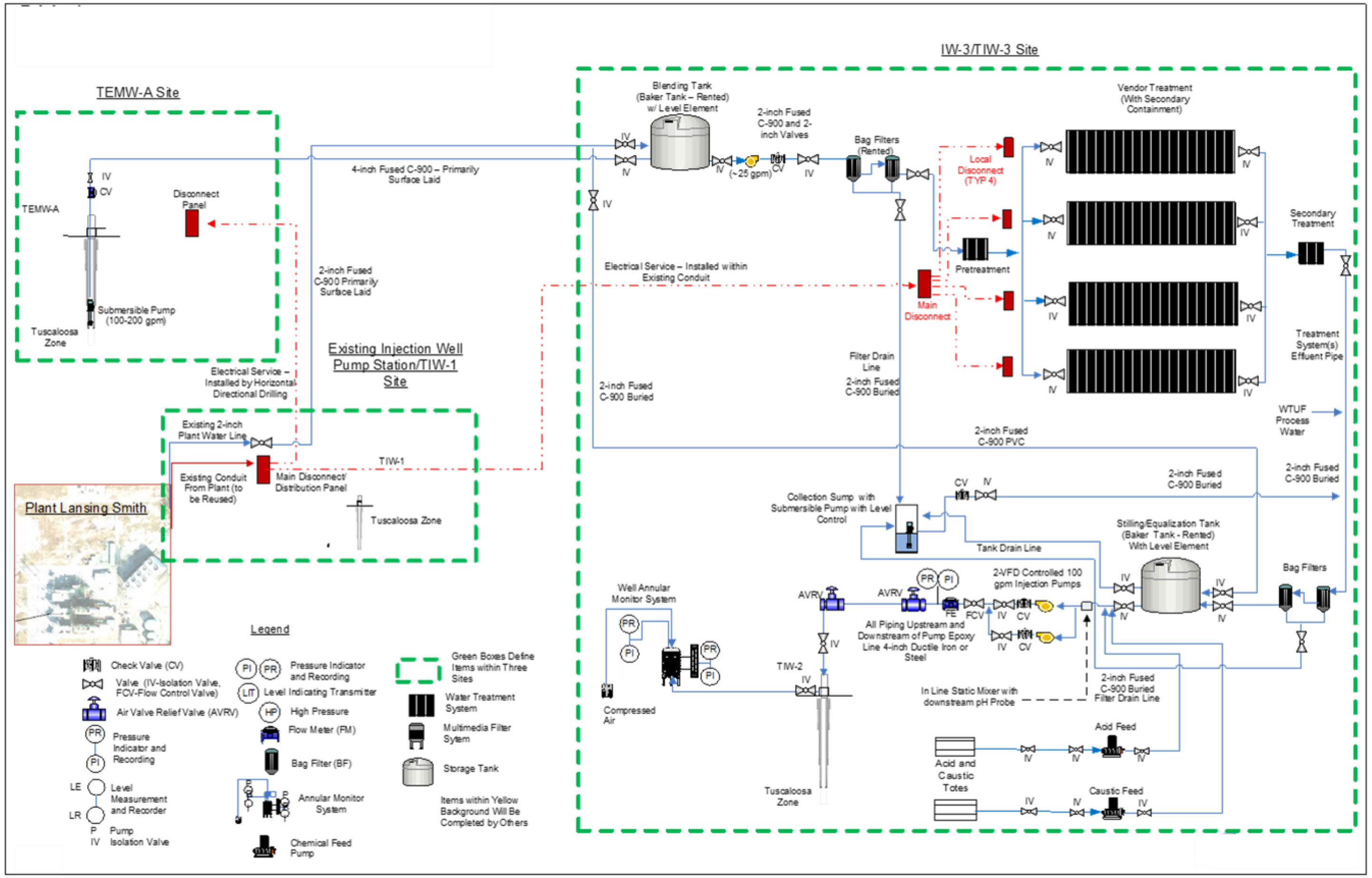
- Well costs much higher than expected in Florida (top)
- Contracting – never goes as quickly as hoped or planned
  - Unit price with cost not-to-exceed drilling contract with stipulated penalties provided important cost protection
- Weather delays – Hurricane Michael (center)
- Experienced major injection and extraction well completion problems
  - Injection well fishing (b.left) and screen clearing operations (b.right)
  - Completion challenges were mitigated
  - Resulted in 20-month project delay

Hurricane Michael landfall at Mexico Beach. https://commons.wikimedia.org/w/index.php?curid=88078359



Remaining Challenges – COVID, Inflation and Supply Chain Issues have Impacted Surface Facility Construction Costs

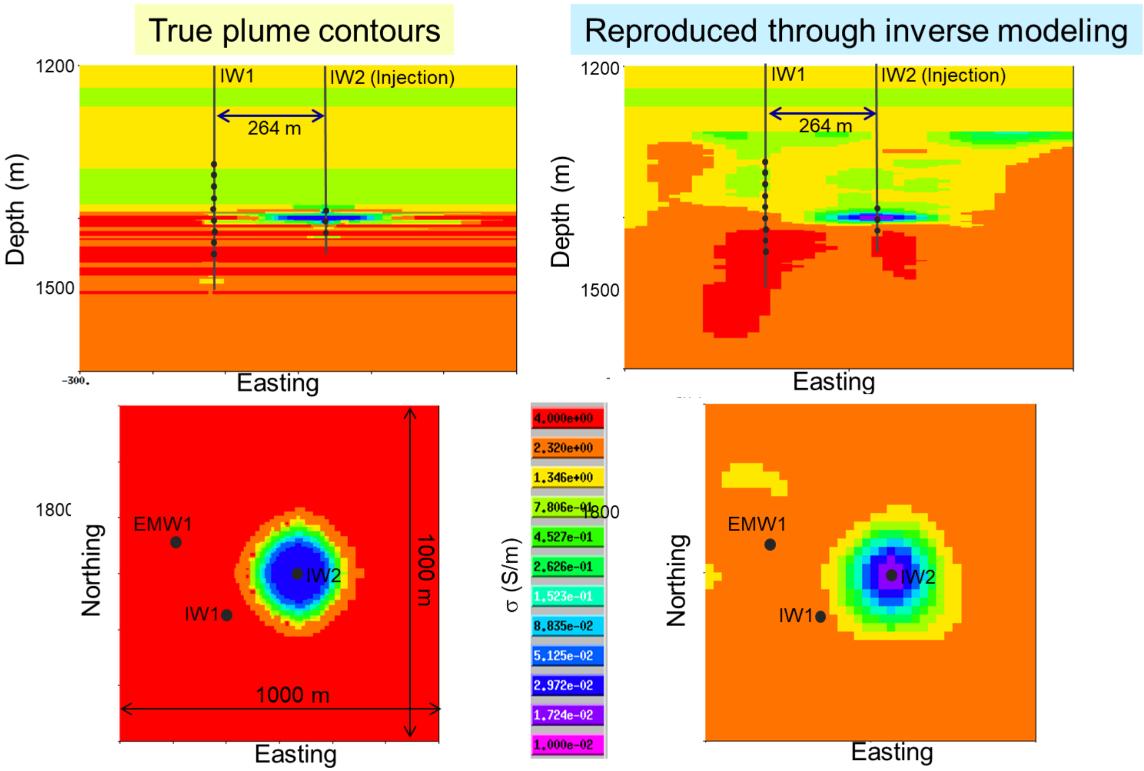
- Completed Pump station and water treatment user facility design in 2021
- Construction bids received in late 2021
  - Only 2 out of 8 companies responded with bids
  - Two bids ($3.2M and $5.0M) exceed entire construction and operations budget from 2017
- Project is preparing an alternative design that retrofits existing FPL pump station



FPL has offered the use of their pump station in 2024 subject to management approval

Summary

Summary of Accomplishments



Modeling studies show that anomalies in the magnetic field resulting from freshwater injection into the saline reservoirs can be detected using EM surveys to track plume shape and location

- The project team obtained a minor modification to the existing Gulf Power UIC permit for the project wells
- Geo-static and reservoir models were updated and used to select the final test zone and design the experiment
- Extraction well was completed and tested producing 100 gpm
- Injection well was completed and tested at >200 gpm
- 100% design complete on the water treatment user facility
- Modeling studies show that Electromagnetic (EM) surveys should have sufficient sensitivity to monitor the plume in cross-section
- Well completion problems were mitigated
- Surface infrastructure costs have escalated, requiring re-scope of the project

Project Summary

- Next Steps
- BP3 plans include:
  - Construction of the pump station and water treatment user facility in 2024
  - Equipment commissioning
  - 6 months of injection followed by 12 months of injection and extraction
- BP4 plans include:
  - Site restoration
  - Final reporting

Photographs of existing Gulf Power wellfield. Photos clockwise from upper left: Eocene Injection well EIW-4; graveled access road; pump station under construction; cleared and permitted drilling pad location for future well

Together…Shaping the Future of Energy™

Appendix

Organization Chart

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Dave Riestenberg, Geo.

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Dr. David Alumbaugh, Geophysics
Dr. Jonny Rutqvist, Geomech.

EPRI
Water Treatment
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Ashley Jansen