Demonstration of Proof of Concept of a Multi-Physics Approach for Near Real-Time Remote Monitoring of Dynamic Changes in Pressure and Salinity in Hydraulically Fractured Networks ©

DE-FE0031785

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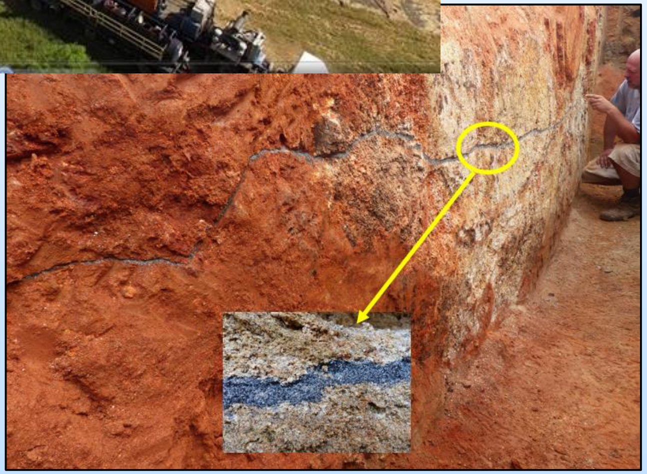
UT Austin – Bureau of Economic Geology

Subcontractors: UNC and Duke University

U.S. Department of Energy
National Energy Technology Laboratory
Oct, 14, 2020
Virtual Annual Review Meeting

Research Challenges and Project Objectives



UT/BEG's DFTS North of Eagle Ford

<u>Problem Statement:</u> Current geophysical methods are weakly sensitive to identifying stimulated reservoir volume (SRV) and dynamic changes that occurs in SRV during life time of a hydraulically-fractured (HF) reservoir.

<u>Project Objectives:</u>

1. To demonstrate Electromagnetic (EM) and Acoustic Contrast Agent (CA)-based method for <u>direct</u> *in situ* monitoring of relative physio-chemical changes that are commonly encountered during HF production <u>remotely</u>
2. Advance utility of high sampling rate, surface-deployable tools to achieve objective #1 in near real time at the UT/BEG's Devine Field Test Site (DFTS)

Persistence Pays Off

- Current project was first proposed to DOE/NETL in May 2016:

Project Narrative - Area of Interest 2

AOI2: Demonstration of Proof of Concept of Coupled Geophysical Methods for High Resolution Illumination of Fracture Networks

May, 4, 2016

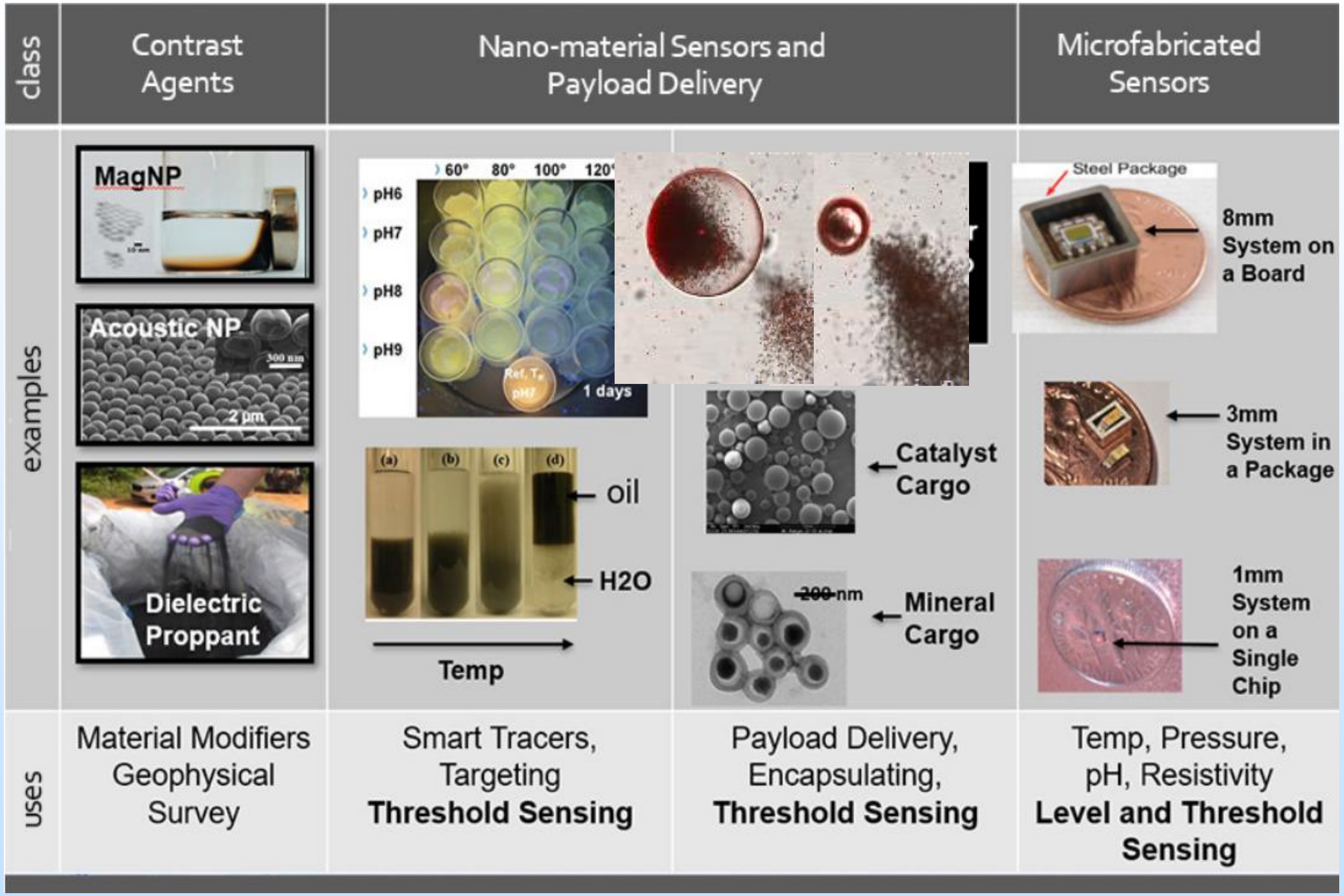
SUBMITTED UNDER FUNDING OPPORTUNITY ANNOUNCEMENT

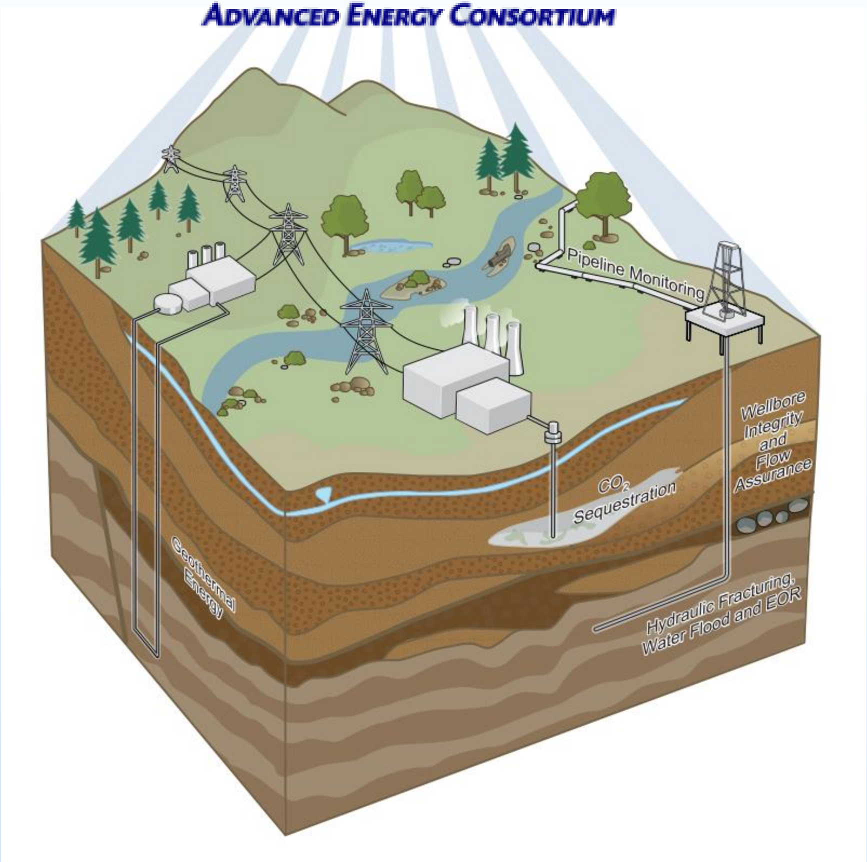
DE-FOA-0001445

Unique Aspects of Current Work

- It leverages the AEC's previous investment in contrast agents for fracture and water flood mapping, payload delivery and micro-sensor research programs, as well as a well-characterized testbed at the UT's DFTS
- The scale of the proposed demonstration is large enough to be representative of the reservoir scale but still allow us to perform verification of the proposal economically
- It combines multiple geophysical techniques, configurations, and models
- It lays the foundation for future consideration in an actual HF field

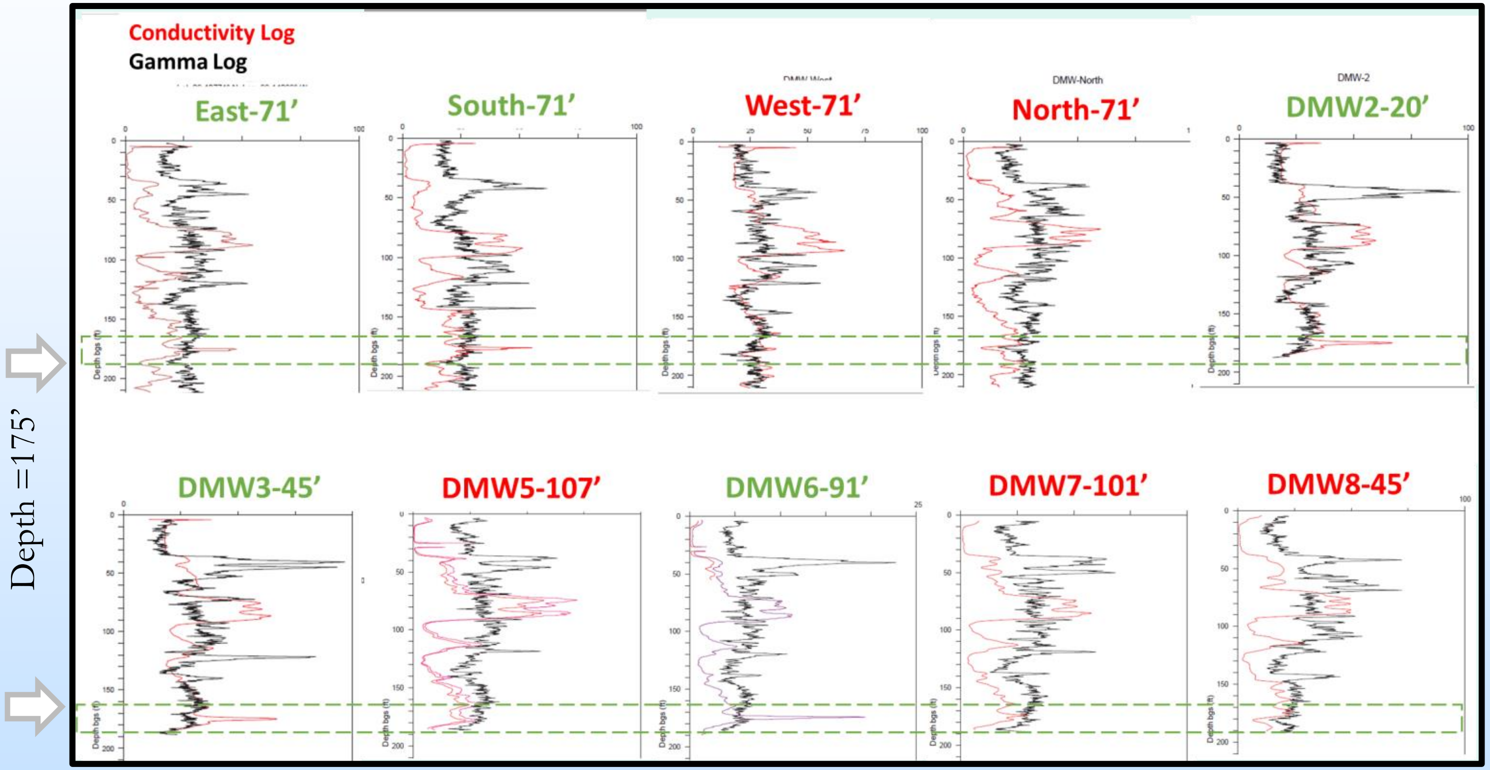
AEC Prototypes and Applications

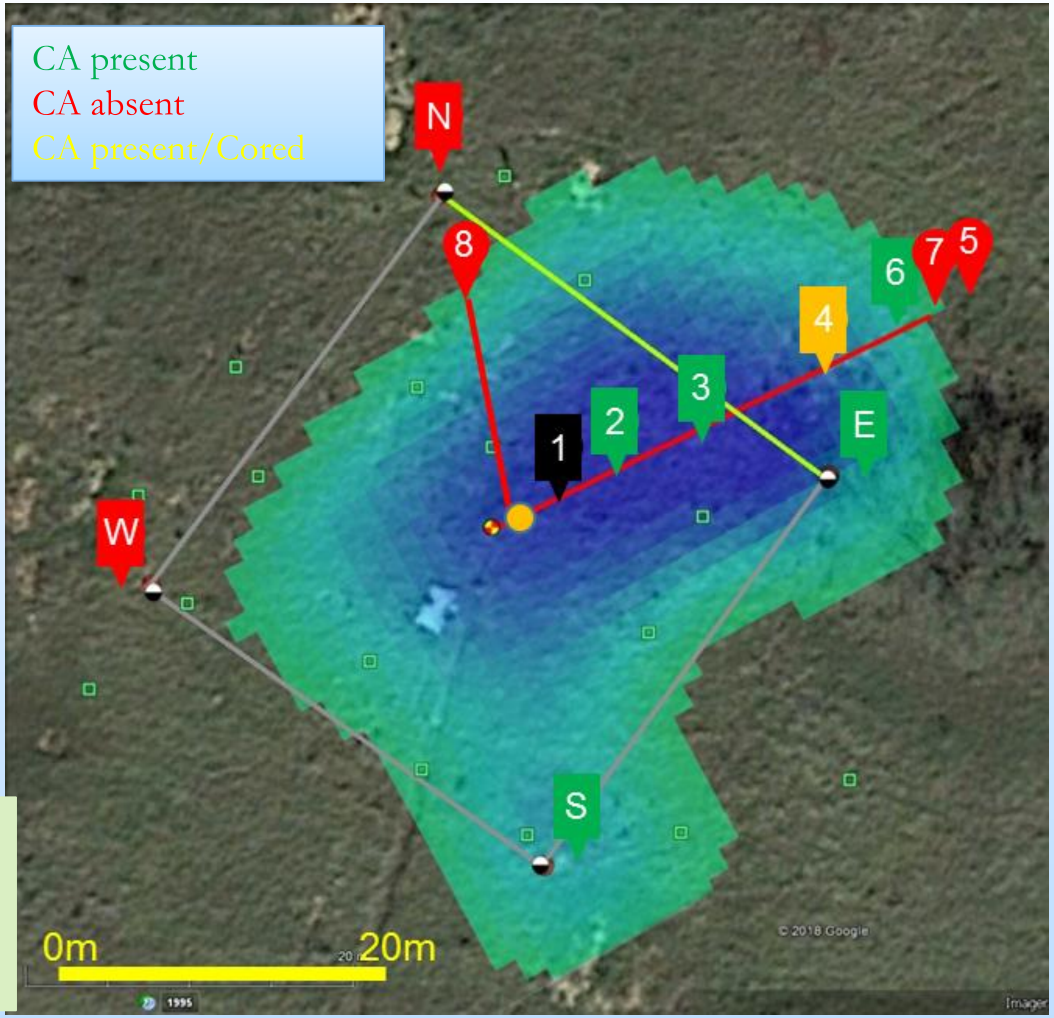




- Sensors and materials will be used individually or combined to interrogate the subsurface and other inaccessible environments
- Size can range from nano to milli scale and for small to meso applications: (e.g. CCUS, EGS, Hydrology, Environmental, Pipes, Cement, etc..)

Leveraging Prior Work by UT's/AEC/BEG Developed Validated Methods to Accurately Map SRV at DFTS





6 Verification and 4 Existing OB Wells Logged, Plus 2 Cored, Excellent agreement between logs and inversion results at the predicted depth and locations- **~5ft Lateral Precision!**

Ahmadian et. al. SPE 2018 **SPE-189858-MS**
Ahmadian et. al. SPE 2019 **SPE-*196140*-MS**

Project Partners

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OFFICE OF OIL & NATURAL GAS

NATIONAL ENERGY TECHNOLOGY LABORATORY

BUREAU OF ECONOMIC GEOLOGY

TEXAS
The University of Texas at Austin

AEC
ADVANCED ENERGY CONSORTIUM

Duke UNIVERSITY

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

ExxonMobil

REPSOL

Sandia National Laboratories

TOTAL

Funding (DOE and Cost Share)

	FY 2019		FY 2020		Total	
	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share
Applicant-UT Includes Services for Field Work	$ 414,841.00	$ 105,030.78	$ 535,551.00	$ 149,629.90	$ 950,392.00	$ 254,660.68
Sub-recipient A-UNC	$ 99,999.00	$ 20,075.00	$ 100,000.00	$ 20,075.00	$ 199,999.00	$ 40,150.00
Sub-recipient B-Duke	$ 172,485.00	$ 43,121.00	$ 177,122.00	$ 44,281.00	$ 349,607.00	$ 87,402.00
Total ($)	$ 687,325.00	$ 168,226.78	$ 812,673.00	$ 213,985.90	$ 1,499,998.00	$ 382,212.68
Total Cost Share %		20%		21%		20%

Technical Approach/Project Scope

BP1

1. Project Management and Planning
2. Workforce Readiness for Technology Deployment

3. Calibration of CA Response in Laboratory Fracture Models *BP1-Go-no-Go

4. Model Development and Validation with Synthetic Data
5. Sensitivity Analysis *BP1-Go-no-Go

BP2

6. Design of Field Experiments
Formation Well Testing
Field Construction/Work
Surveys

7. Data Processing/Interpretation

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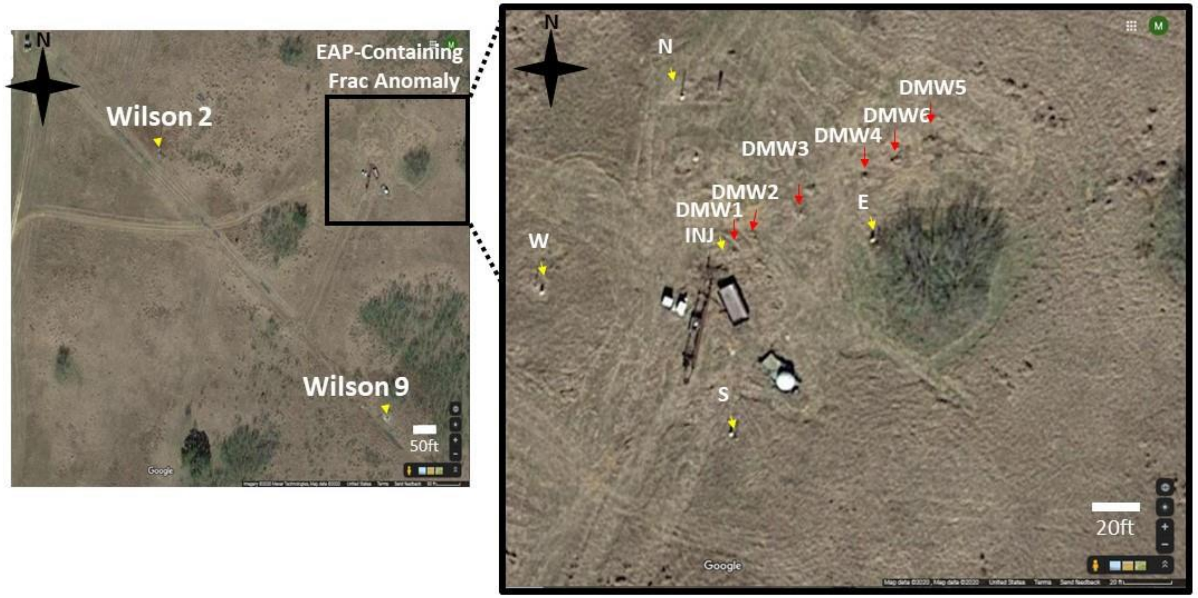
Progress and Current Status of Project

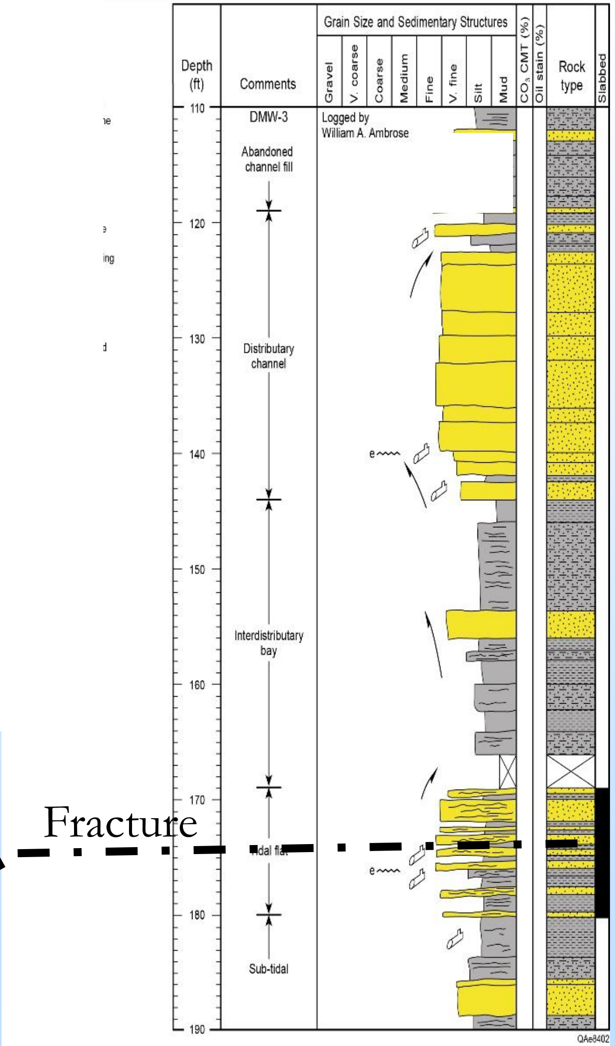
3.0: Core and Material Characterization

DFTS Site



Representative Cores Showing the Existing Fracture and CA

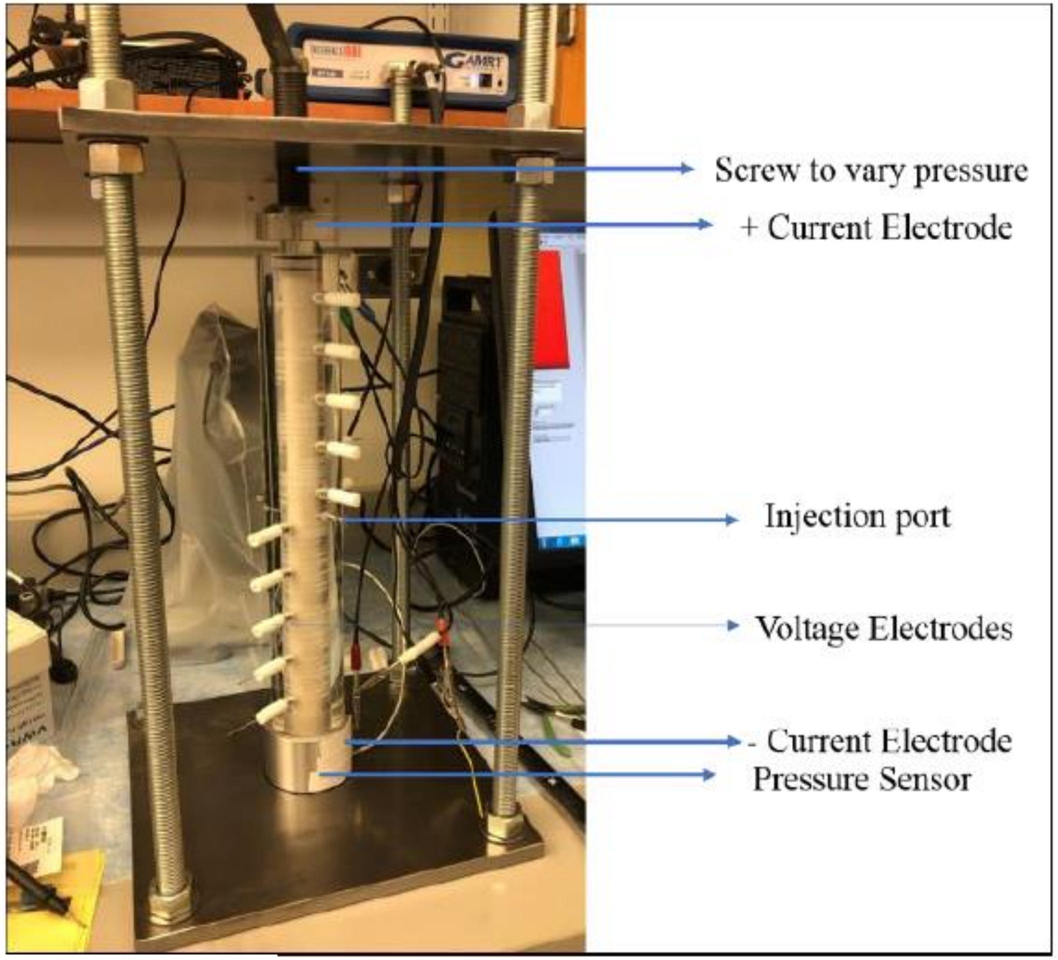
Stratigraphy



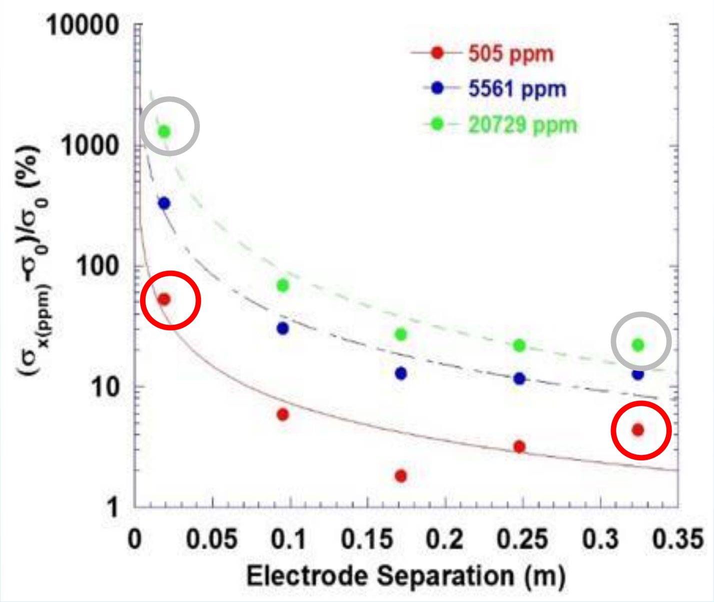
- Described 249 ft (76 meters) of core for DFTS
- Selected intervals from the DMW1 and DMW3 cores were slabbed and photographed to document lithology and stratification
- Facies and depositional-systems interpretations have been made
- Based on stratification and vertical facies relationships, a tidally influenced deltaic interpretation has been proposed.

3.0: Electrical Measurements in the Lab*- Salinity

Measurement models built to mimic scale down version of the Devine test site



% Relative Change in Conductivity vs. Salinity as a Function of Electrode Separation

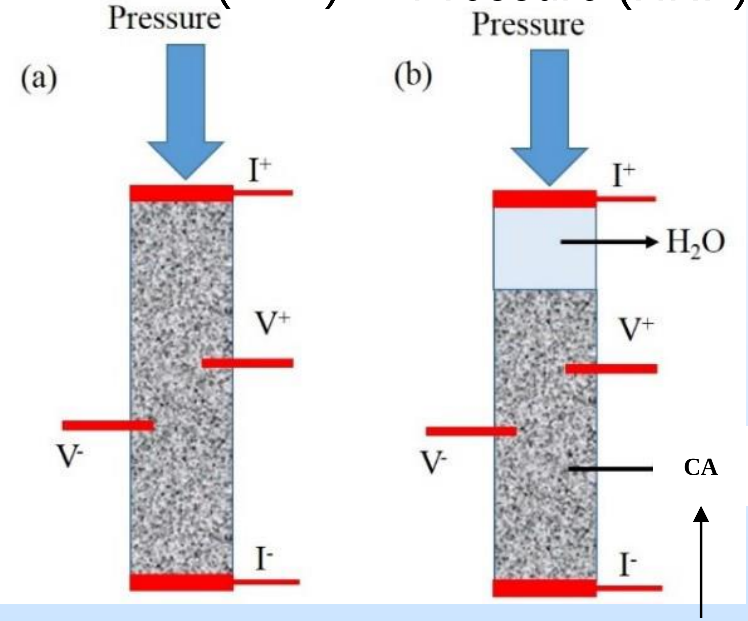


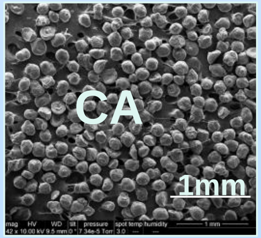
- Relative change in conductivity is large for all electrode configurations probed when salinity is changed:
- <u>All passes the Go-No-Go criteria for BP1</u>

3.0: Electrical Measurements in the Lab*- Pressure

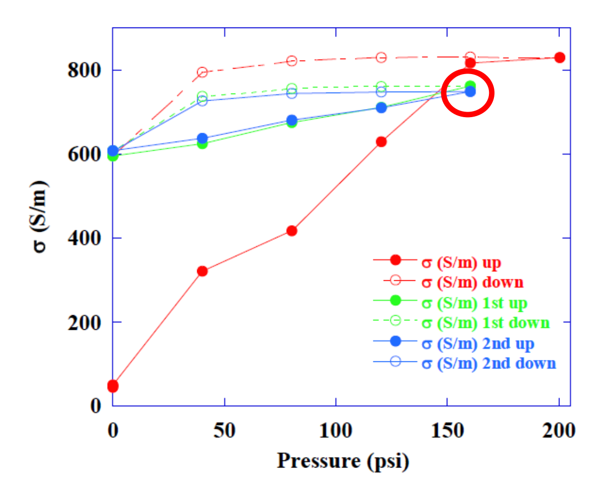
Two pressure dependent properties of CA probed

High Lithostatic Pressure (HLP) | High Hydrostatic Pressure (HHP)

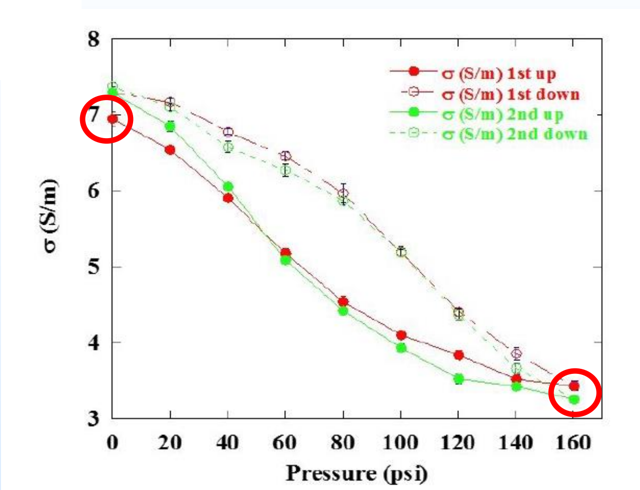




Lithostatic/HLP



Hydrostatic/HHP



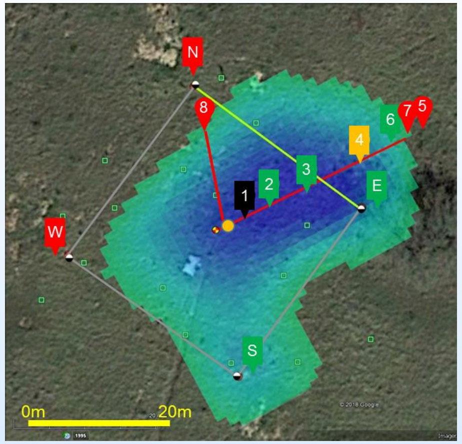
- Relative change in conductivity is large when either lithostatic or hydrostatic pressure is applied to the CA in a confined space
- Hypothesis:
  - a) Lithostatic Pressure causes CA grain to compact,
  - b) Hydrostatic Pressure caused CA grain separation

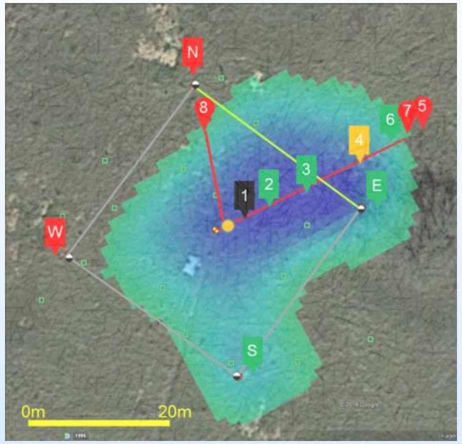
  All passes the Go-No-Go criteria for BP1

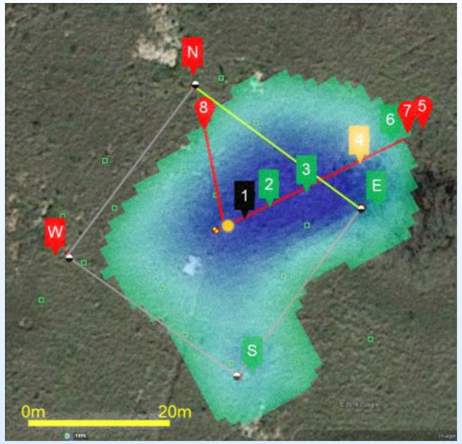
Field Study Plan-Expected Results

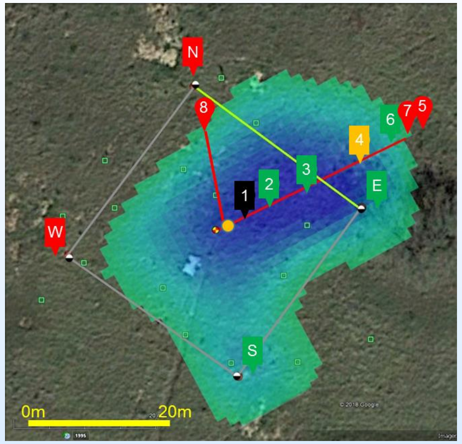
Work Plan: Baseline Packed CA Low salinity/HLP → Inject with fresh H2O HHP → Inject with HS brine HHP → Rest Period / Extraction / leak-off Low Salinity/HLP

Expected Outcome:









High e- conductivity → Decrease e- conductivity → Increase e- conductivity → Increase e- conductivity

e- conductivity of undisturbed CA under HLP >

e- conductivity of CA in fresh H2O <

e- conductivity of CA in high salinity (HS) + HHP (assumed -TBD)

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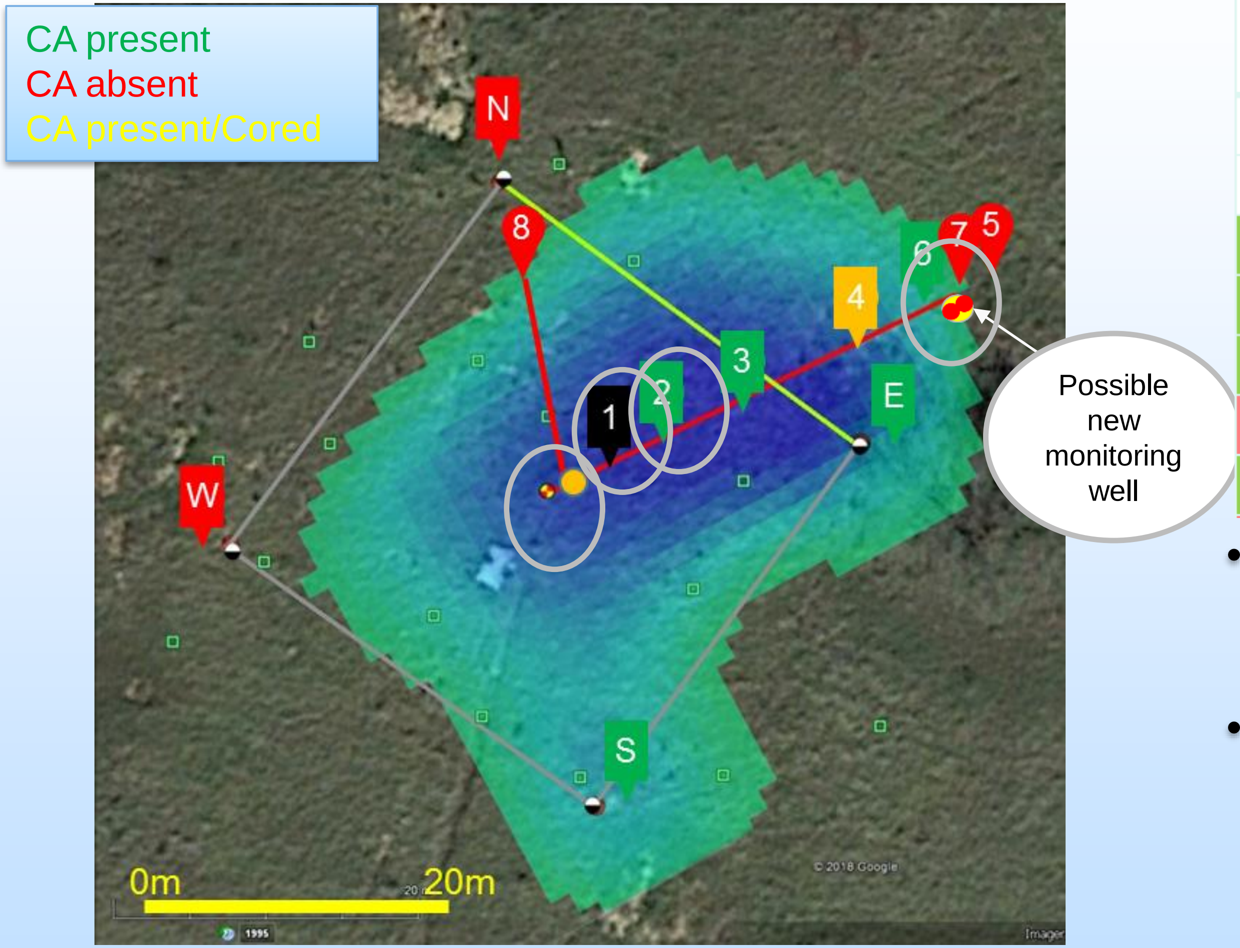
Proposed Study Leverages the Existing Infrastructure at the UT/BEG's Devine Test Site



Well ID	Distance to Inj well (ft)	Total Depth (ft)	Screen /Perf Depth (ft)	Completion Type-Equipment
Inj well	0	267	175	Steel/4"/Perf
DMW1	10	267	170-77	PVC/2"-ERT
DMW2	20	190	170-180	PVC/2"
DMW3	45	190	130-135	PVC/2"
DMW4	75	190	130-135	PVC/2"
DMW5	107	190	NA	PVC/2"
DMW6	91	190	NA	PVC/2"

- Injection via Huff-n-Puff from existing injection well

- Fluid migration and pressure will be validated by downhole Pressure/Salinity gauges in DMW1-2 and possibility in a new monitoring well at distal end of the HF

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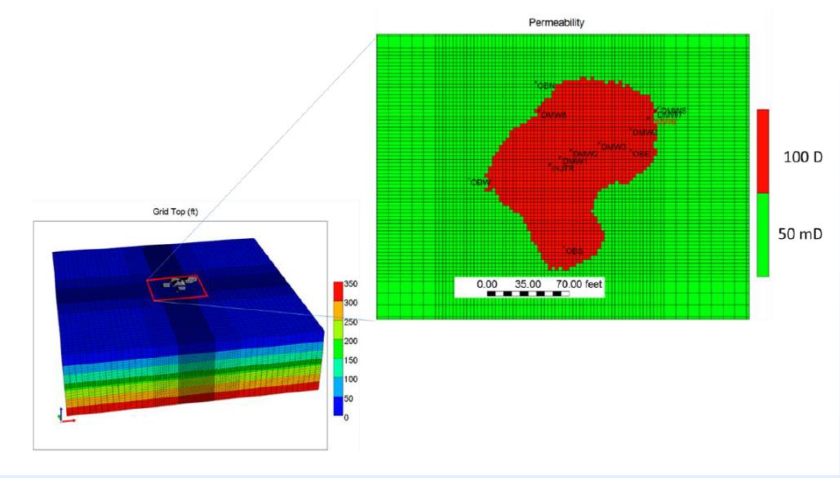
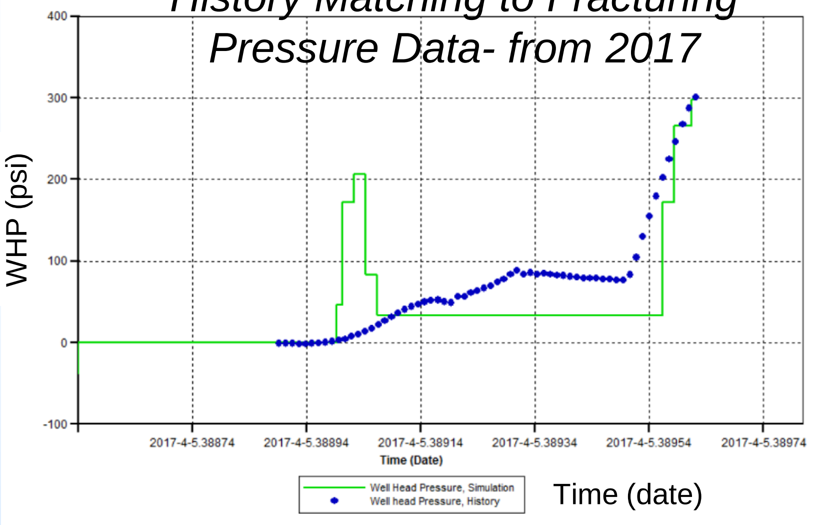
5.1: Fluid Flow Modeling-Field Test Plan

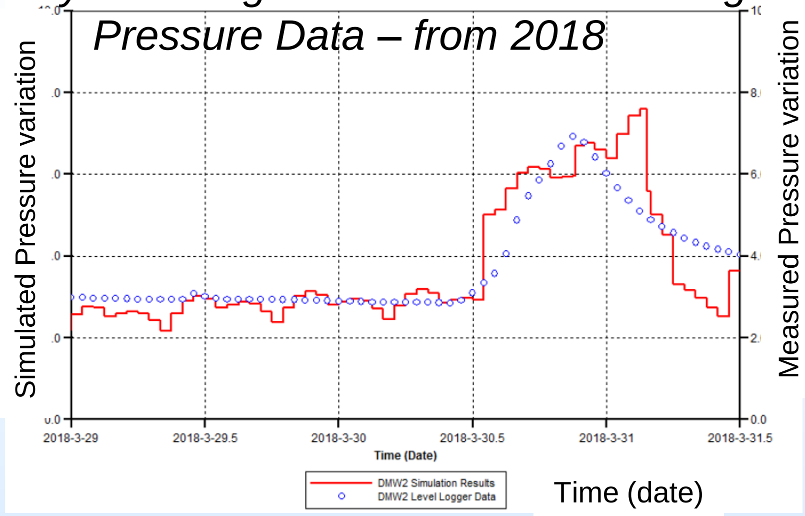
Layer Cake Model-CMG



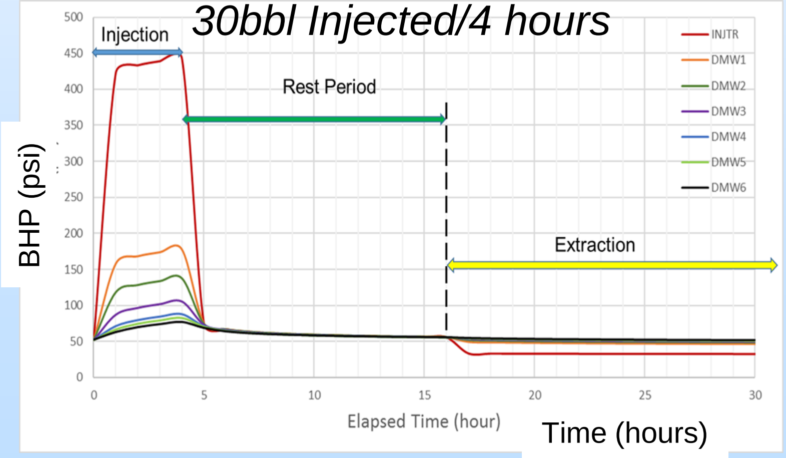
History Matching to Fracturing Pressure Data- from 2017



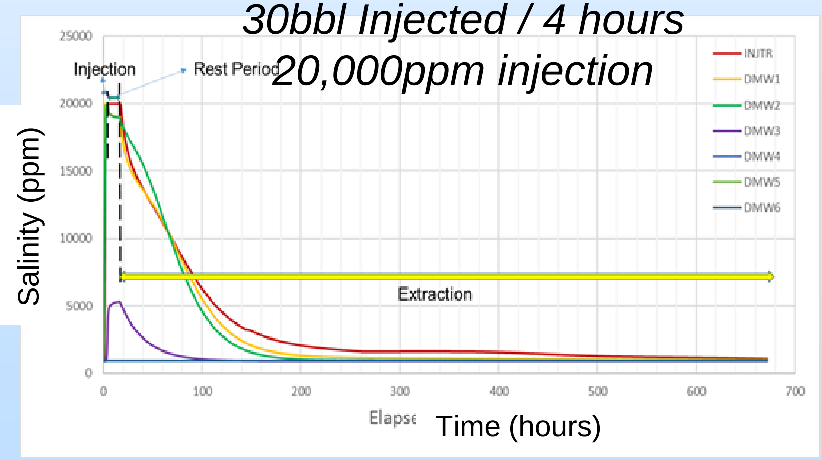
History Matching to Validation Well Drilling Pressure Data – from 2018



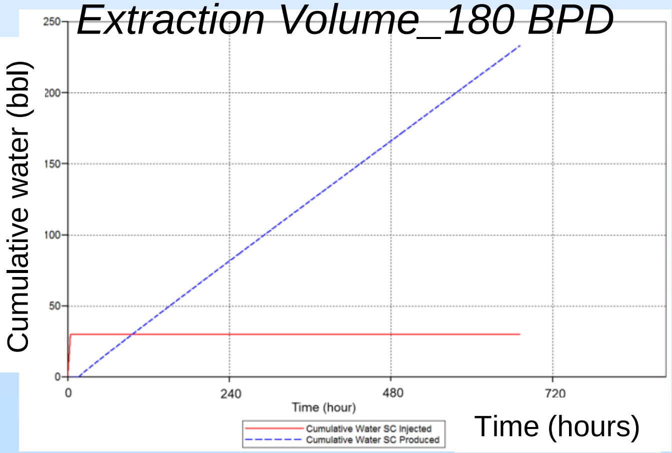
Pressure Modeling- 180BPD/ 30bbl Injected/4 hours



Salinity Modeling- 180BPD/ 30bbl Injected / 4 hours 20,000ppm injection



Cumulative Injection and Extraction Volume_180 BPD



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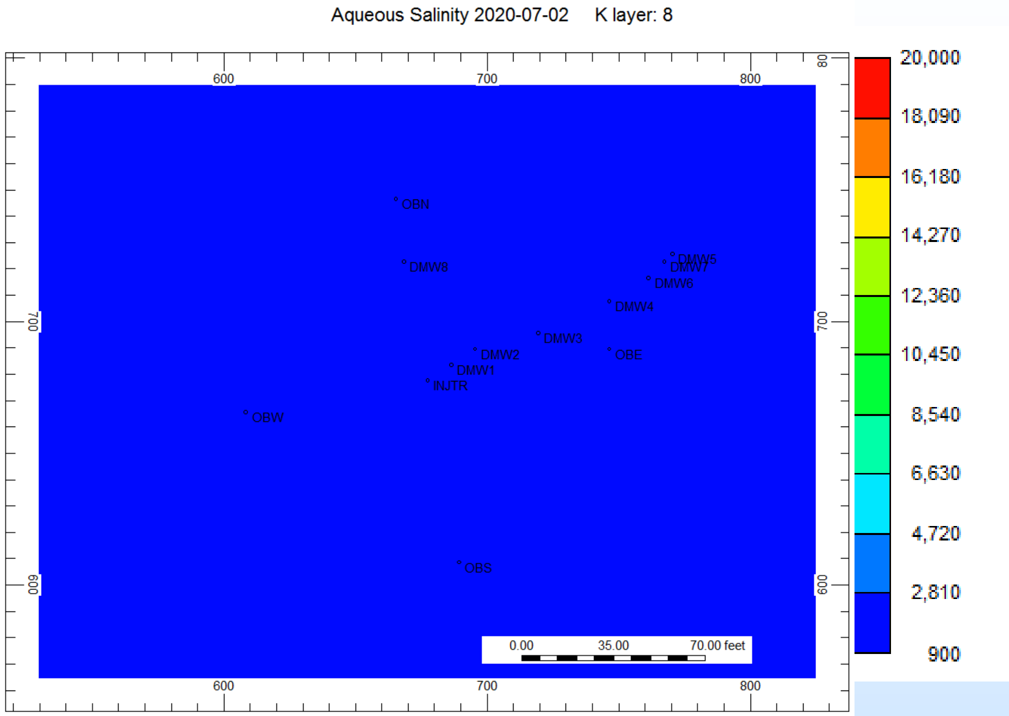
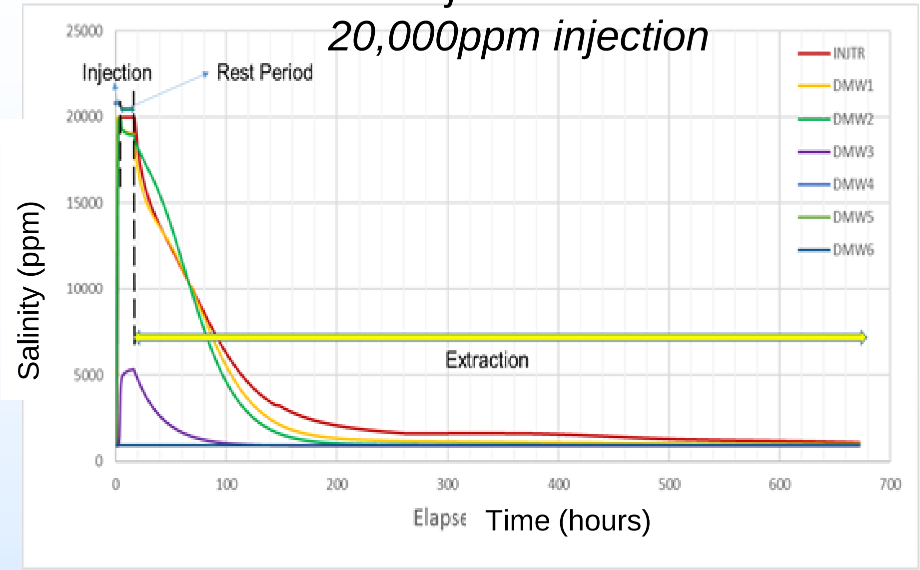
Ahmadian et.al. Q3BP1 Report

5.1: Fluid Flow Modeling

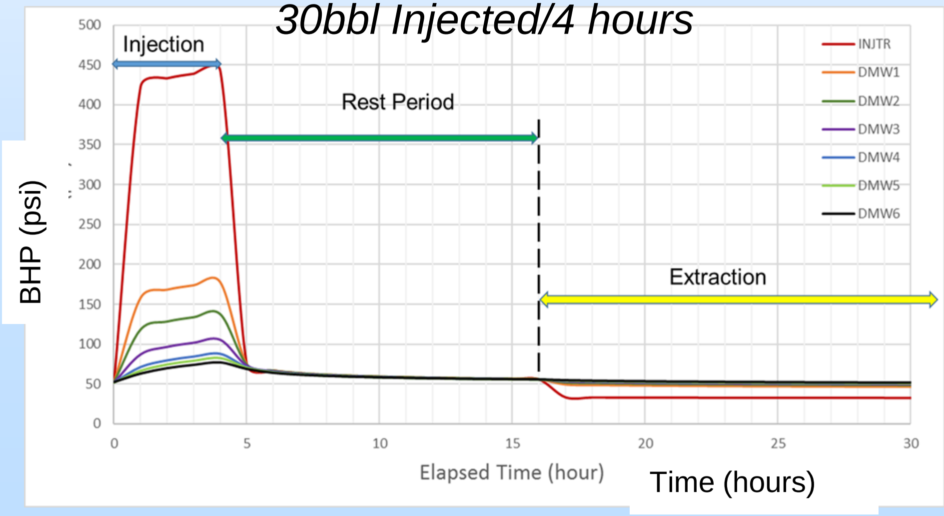
180 BPD Injection Case- Movie



Salinity Modeling- 180BPD/ 30bbl Injected / 4 hours 20,000ppm injection



Pressure Modeling- 180BPD/ 30bbl Injected/4 hours



- Simulation start date: July 1st.
- Injection Start Date: July 4th 0:00 am
- Resting time start after 4 hours of injection, and lasting 12 hours.
- Extraction started at July 4th 16:00 pm.
- The video ends at July 11th, 0:00 am

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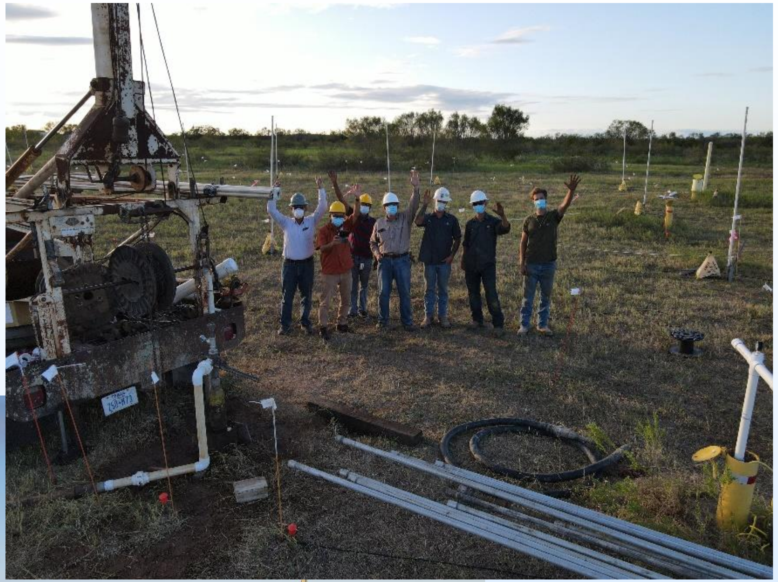
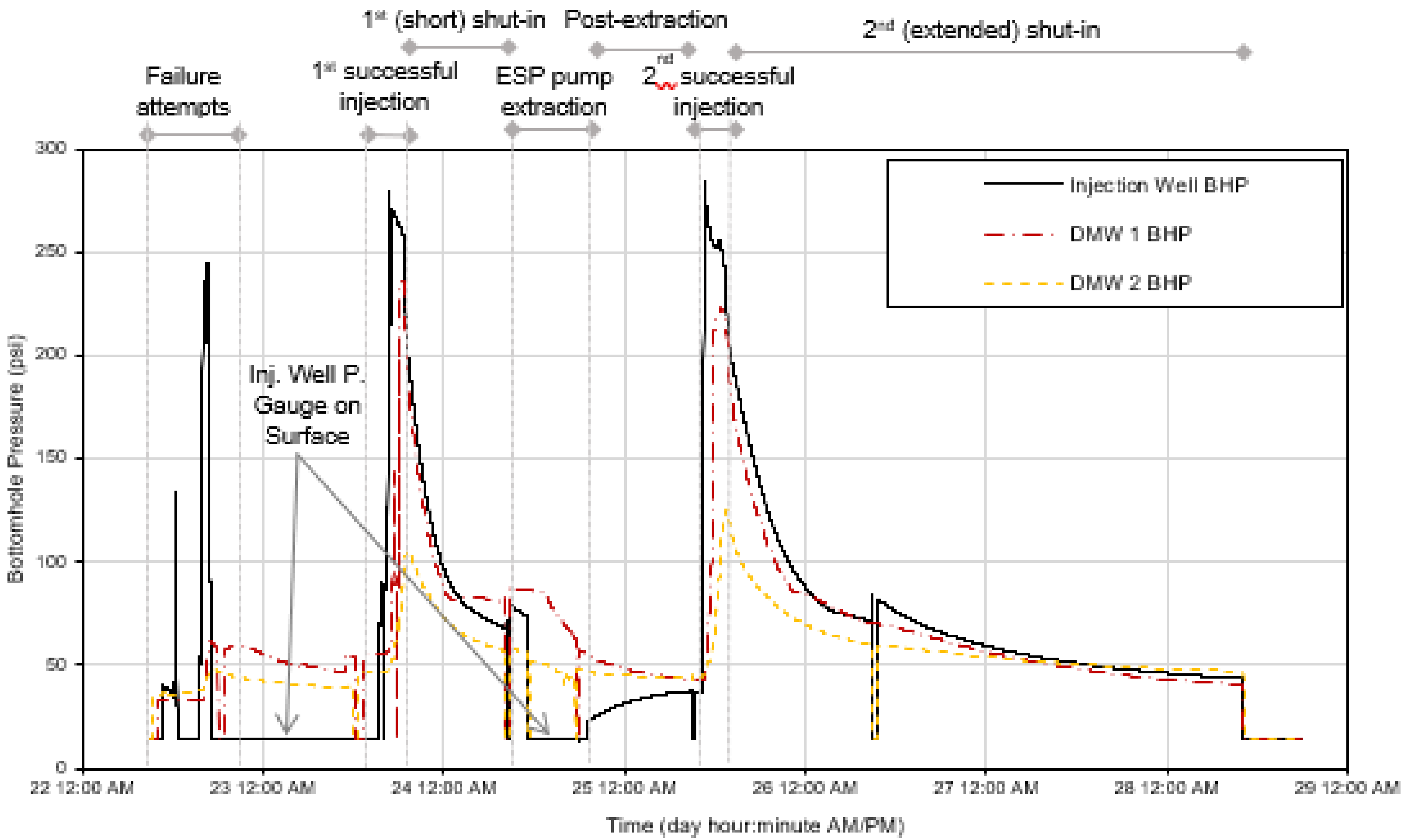
mini Pilot :   9/21-9/26/20 at DFTS



Fluid Flow Modeling Calibration –Pilot #1 : 9/21-9/26/20



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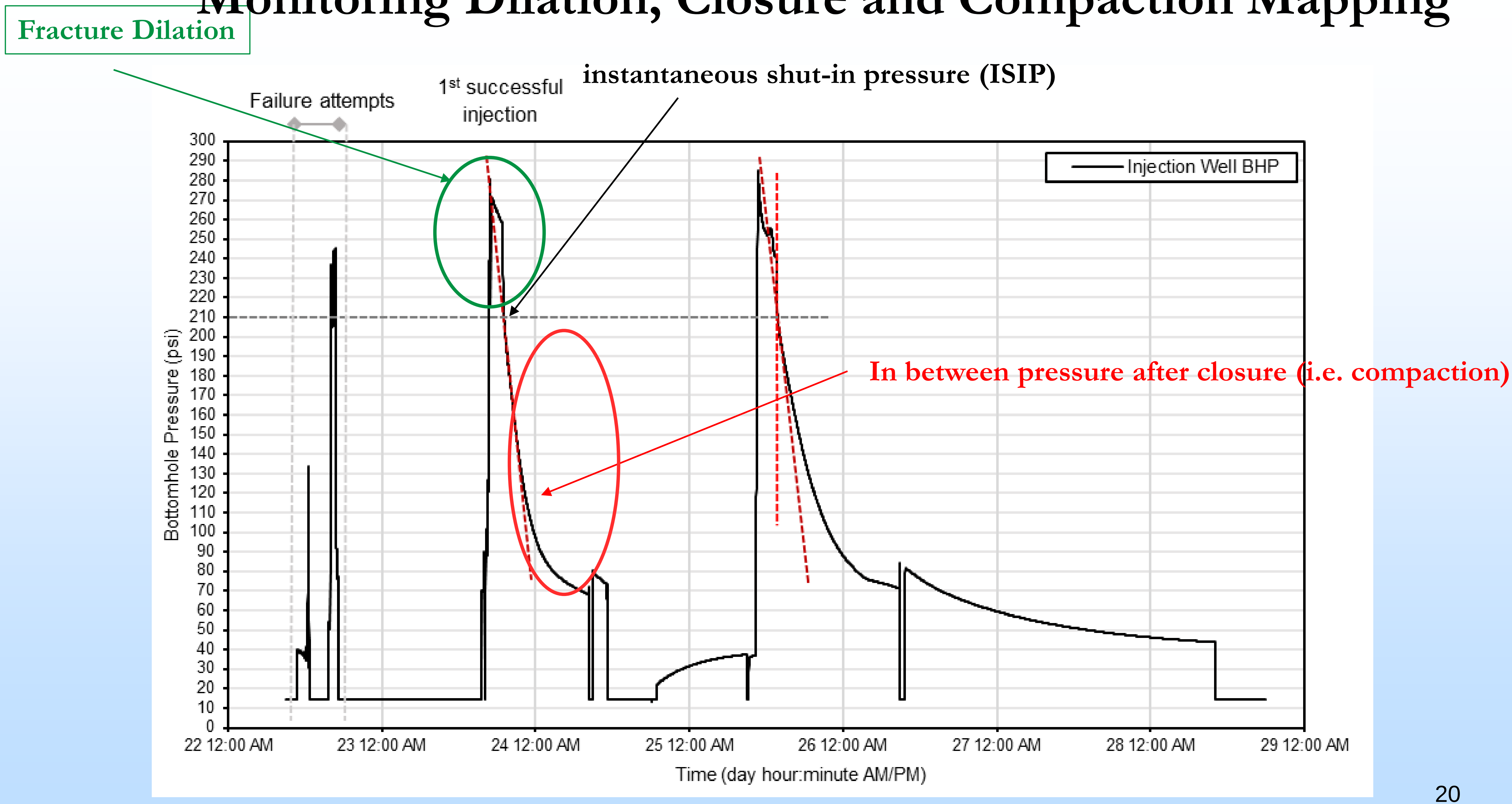
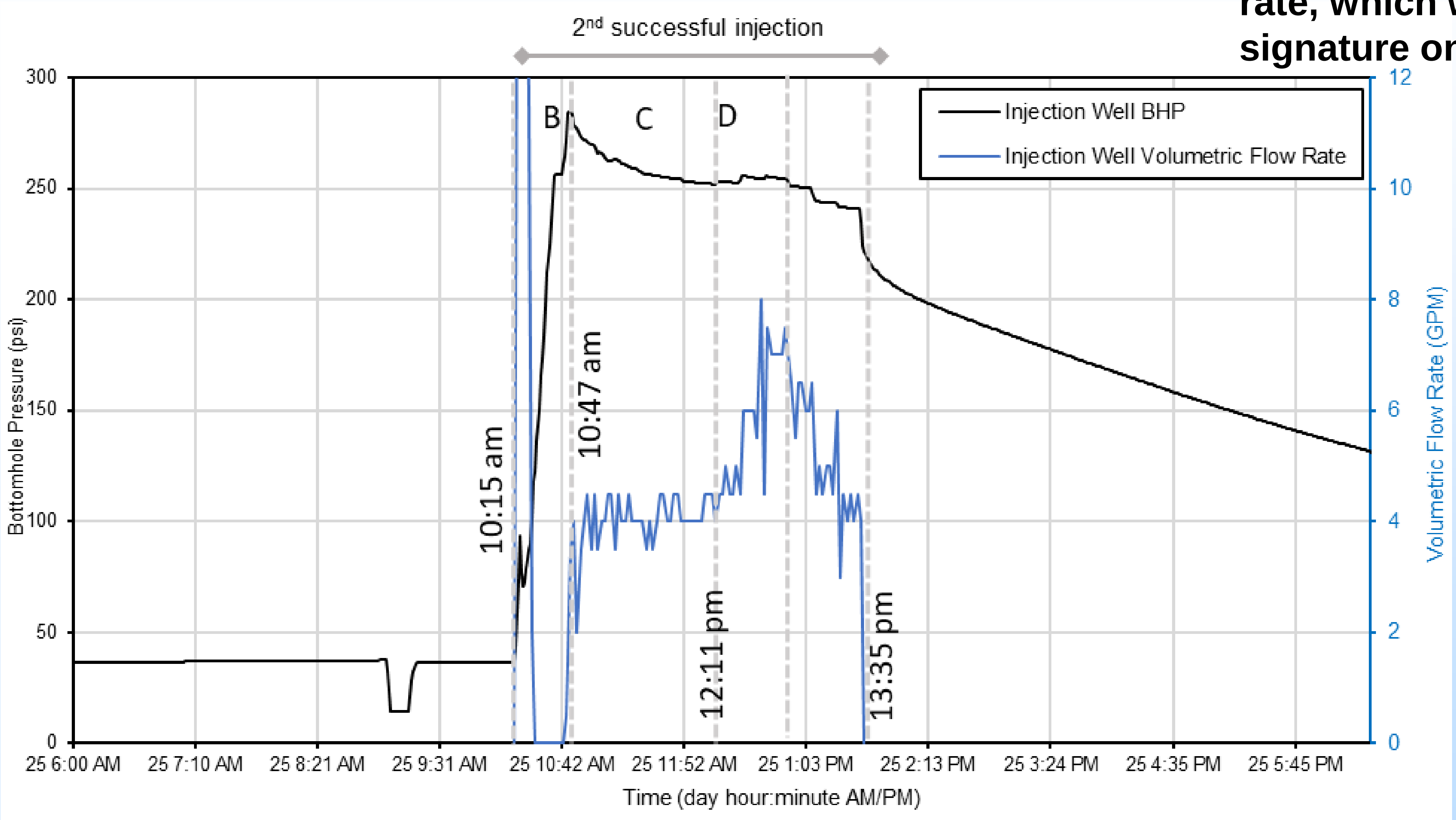
Monitoring Dilation, Closure and Compaction Mapping



Will be correlated to real time geophsyics

Flow rate mapping with EM Contrast Agents

Correlation of BHP and flow rate, which will impacts EM signature on Surface



DE-FE0031785 Q4BP1/BP2 Work and Beyond

Q1-Q4 BP2

- Calibration of Fluid Modeling
- Design of Field Experiments,
- Field Work, Construction
- Surveys
- Data Processing/Interpretation
- Publication and Reporting

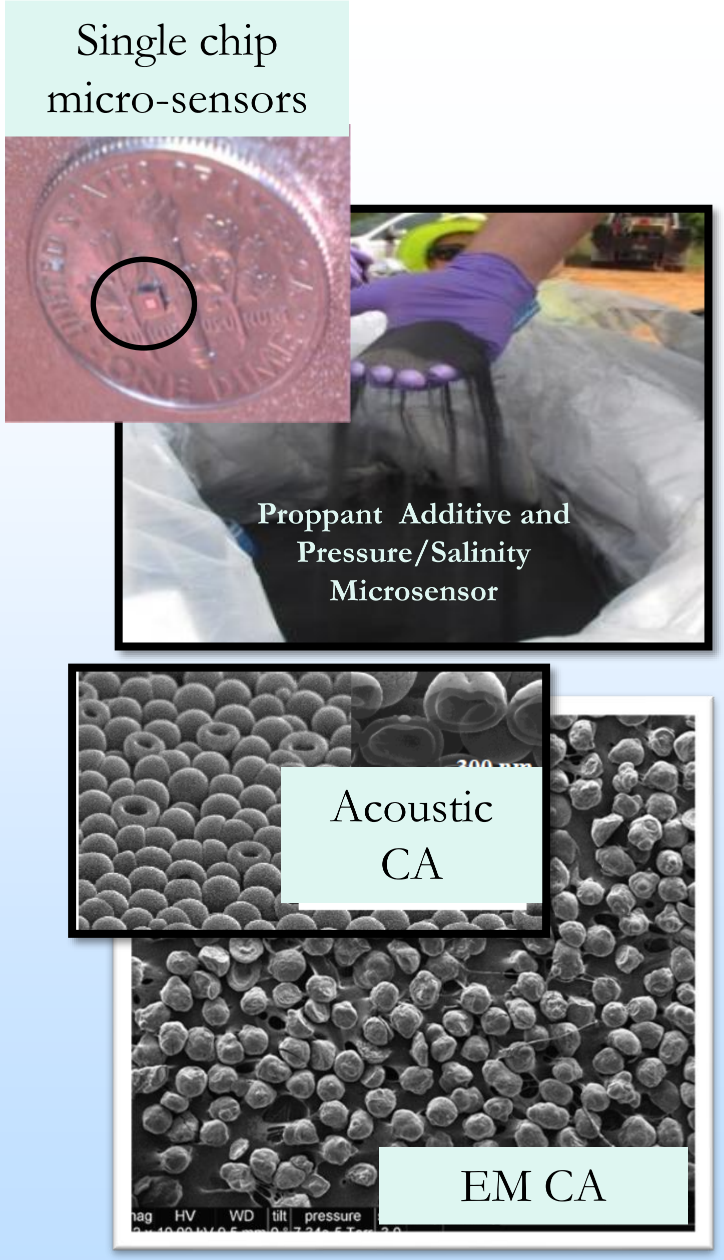
CY2021:

Collaborate with the NETL and the AEC to perform a reservoirs scale demo:

- Field test partner has been identified to demo CA based HF mapping ASAP
- Material, tool, validated models are available
- Well is pre-drilled and available
- Commercial partner has been identified
- We will be combining multiple CA properties (acoustic, EM) and microsensors to build more resolution for subsurface monitoring

Summary and Future Plans

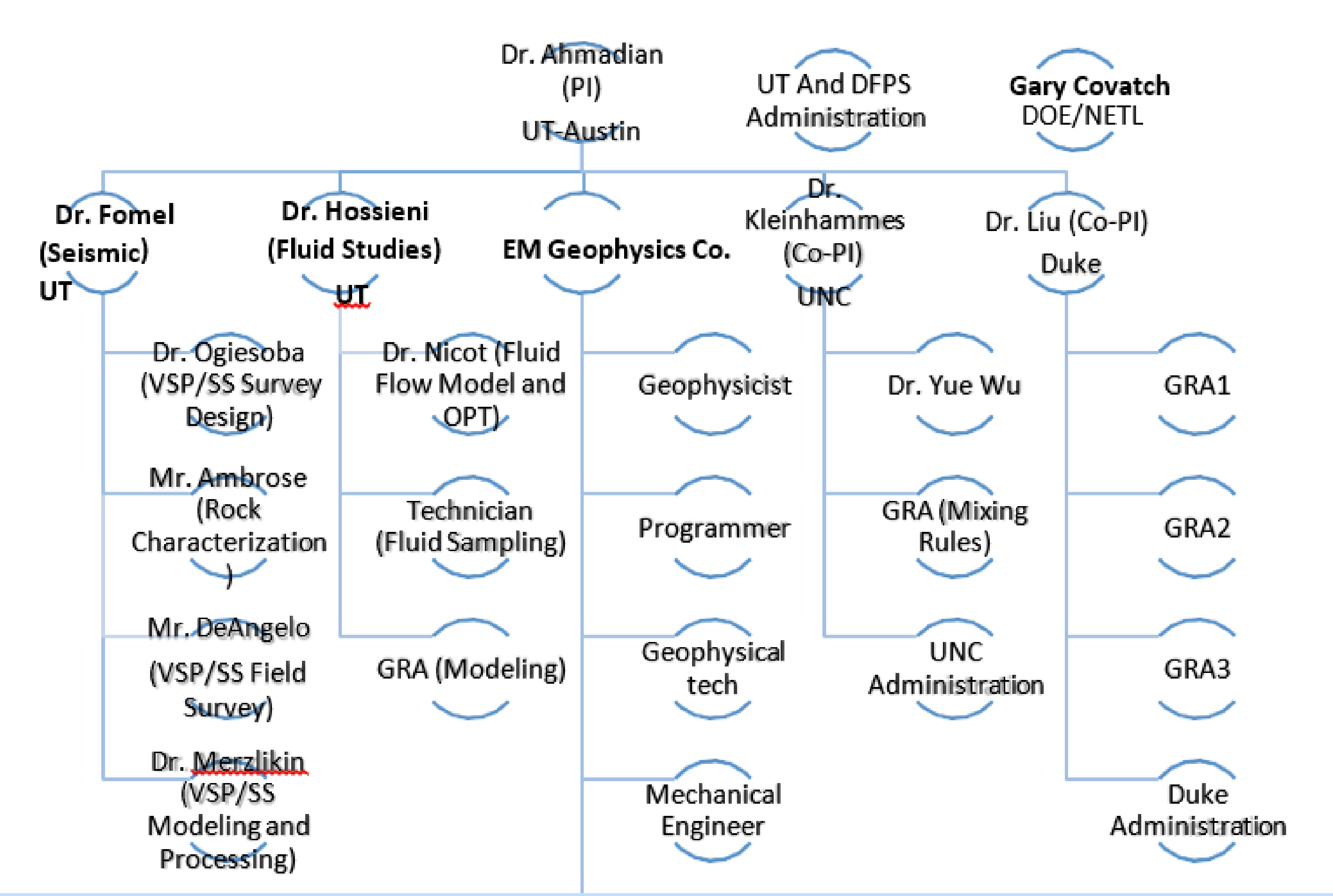
- A patent-pending sensor system for remote monitoring of *in situ* properties of HF has been proposed, developed and is being demonstrated
- We have successfully passed the major Go-no-Go milestones for BP1
  - CA-based sensors system displays a significant and measurable change under both pressure and salinity
- A machine learning based inversion approach is under development, which promises to reduce analysis time from days to minutes
- Fluid flow modeling and recent injections at DFTS is informing a number of injection scenarios to enable perturbations of the HF at DFTS for the proposed study
- Various geophysical modalities (EM, Acoustic, Seismic) and detection configurations will be combined to monitor the extent and geophysical properties of subsurface HF environment dynamically in near real time



Appendix

– These slides will not be discussed during the presentation, but are mandatory.

Organization Chart



Confidential Slide

Tasks and Status as of 7/30/20

Task	Subtask/Milestone Description	Planned Completion Date	Percent Complete as of 6/30/2020	Verification Method/ Deliverables	Comments
1.0	Project Coordination and Communication and Reporting	9/30/2020	75%	PMP, DMP, TMP Quarterly Reports, Continuation Application	1. PMP and DMP was updated. 2. TMP will be updated and will be submitted in BP2 3. Q2 BP1 reports were submitted to DOE. Two more reports remain.
2.0	Workforce Readiness for Technology Deployment	10/31/2020		Presentation file BP2 deliverable	1. BP2 deliverable will be submitted in Q1BP2.
3.0	1. Initial Lab Studies for HP/HS Responsive EAP 2. Lithology and Cores Studies	09/30/2020 07/30/2020	75% 95%	Q2 & 3 Reports Q1, 2, & 3 Reports	1. Initial lab studies have demonstrated that both pressure and salinity cause a marked impact on electric response. 2. We completed an extensive core characterization report describing 249ft (76m) of core from the DFPS.
4.0	1. VSP/seismic RTM Validation 2. Joint VSP/Seismic and EM Inversion	06/30/2020 09/30/2020	6/30/20 75%	Year 1 Topical Report	1. RTM code has been validated. 2. We tested our seismic modeling software for generating synthetic data for assessing the feasibility of the proposed workflow using a 12.5- to 2 - cm fracture. Fracture is detectable at 200 Hz.
5.0	1. Field Design: Fluid Flow Modeling 2. EM Sensitivity Analysis 3. VSP or Seismic Sensitivity Analysis	09/30/2020	80%	Year 1 Topical Report	1. A fluid flow model has been built and refined using prior fluid injection history from DFPS. Multiple simulations will be completed for different field injection scenarios. 2. Our EM sensitivity analysis has shown that even a 5% change in conductivity of the EAP-filled fracture can result in >1% contrast in the signal. 3. We created velocity and density models for seismic modeling and examined the seismic response to the fracture.