Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

Williston Basin Associated CO_2 Storage Field Laboratory

DE-FE 0031694

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National Energy Technology Laboratory
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Partners

U.S. DEPARTMENT OF ENERGY

Project Goal and Objective

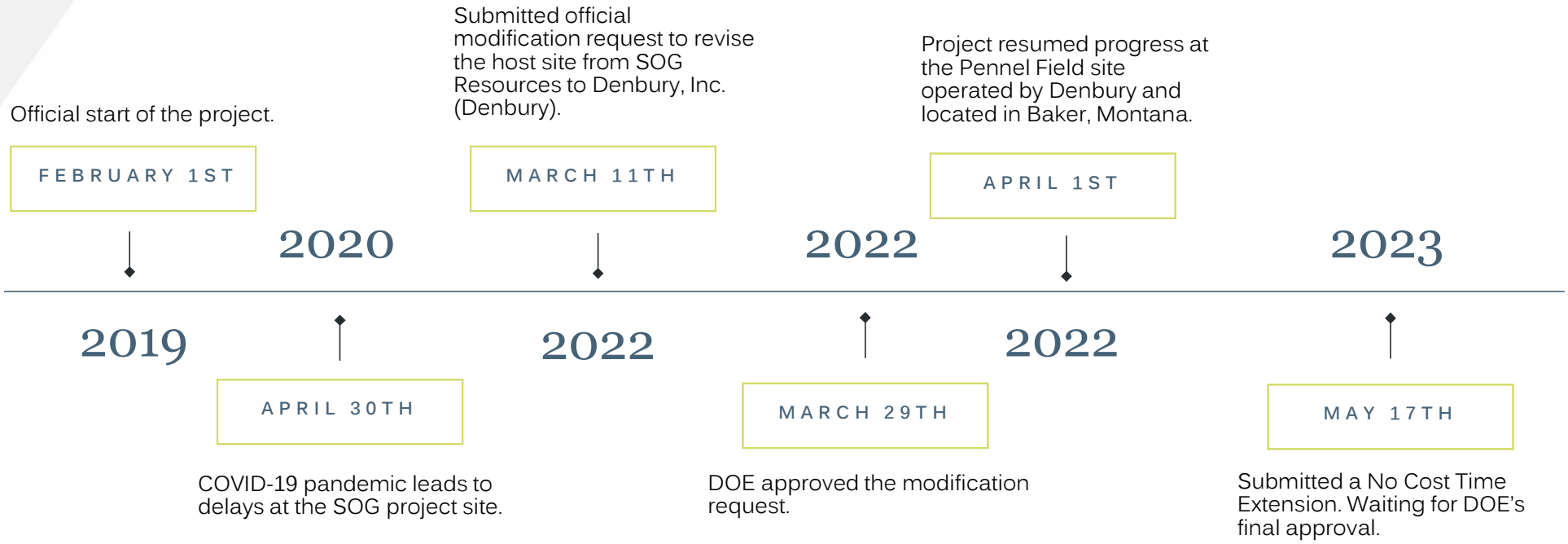
Goal: To advance associated geologic storage of CO_2 in the Williston Basin by establishing the Williston Basin Associated CO2 Storage Field Laboratory (WBCFL).

- Generate field-based data on CO_2 EOR with associated storage in stacked reservoirs.
- Characterize a Residual Oil Zone for EOR and associated storage.
- Evaluate a monitoring, verification, and accounting (MVA) technique for its applicability to stacked CO_2 storage complexes.

Task/Subtask Breakdown

- **Task 1 – Project Management, Planning, and Reporting**
  - Subtask 1.1 – Project Management and Planning
  - Subtask 1.2 – Project Reporting and Technology Transfer
- **Task 2 – Fluid Behavior Studies**
  - Subtask 2.1 – Sample Collection and Compositional Analysis
  - Subtask 2.2 – MMP Studies
  - Subtask 2.3 – EOS and PVT Studies
- **Task 3 – Field Site Reservoir Characterization**
  - Subtask 3.1 – Core Sample Identification and Collection
  - Subtask 3.2 – Laboratory Determination of Petrophysical Properties
  - Subtask 3.3 – Field Monitoring of Reservoirs
  - Subtask 3.4 – Static Geomodeling
  - Subtask 3.5 – Dynamic Modeling
- **Task 4 – Active Seismoelectric Technology Demonstration**
  - Subtask 4.1– Active Seismoelectric Survey
  - Subtask 4.2 – Follow-Up Active Seismoelectric Survey
- **Task 5 – Life Cycle Analysis**
  - Subtask 5.1 – Life Cycle Analysis of the Field Test
  - Subtask 5.2 – Life Cycle Analysis of Stacked Storage

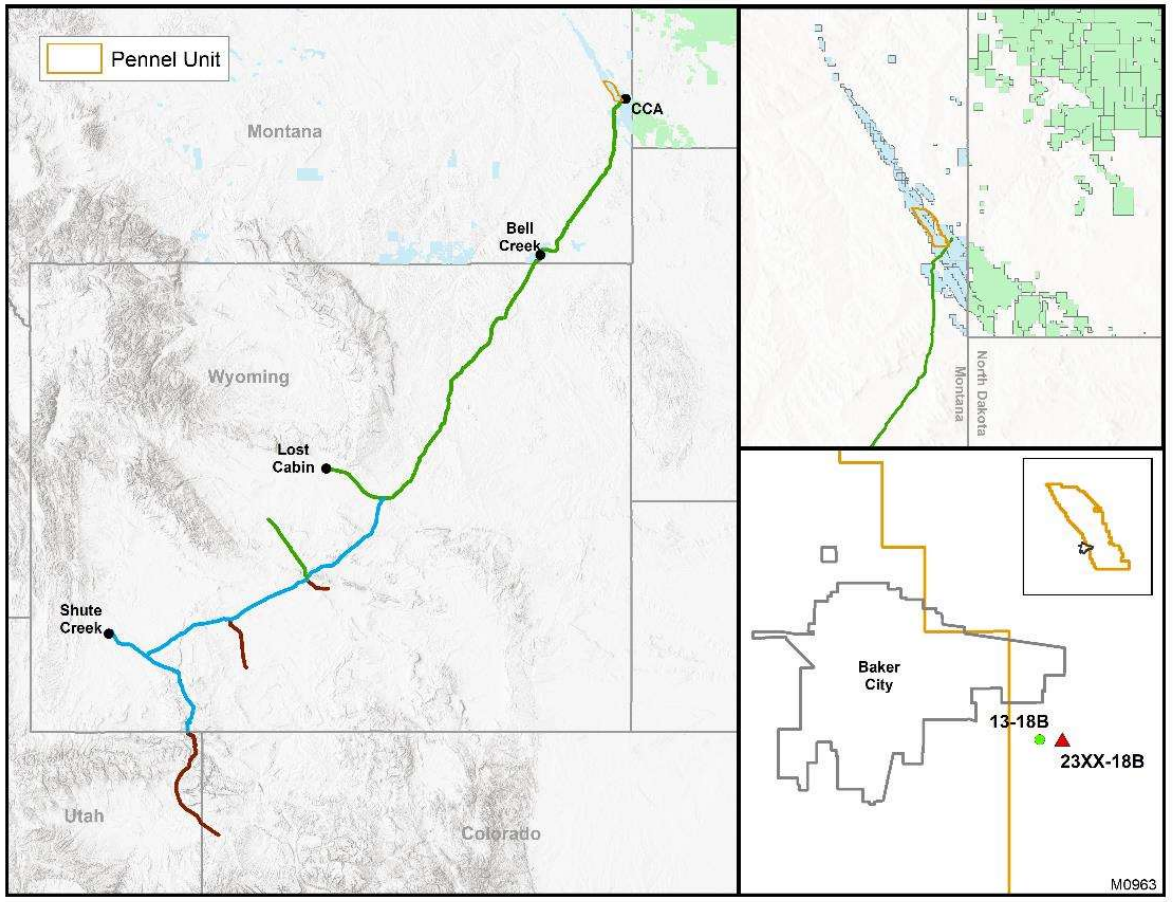
Project Management, Planning, and Reporting



At present, EERC is working with DOE on a NCTE to extend the project timeline to September, 2025

Project Location / CO_2 Source

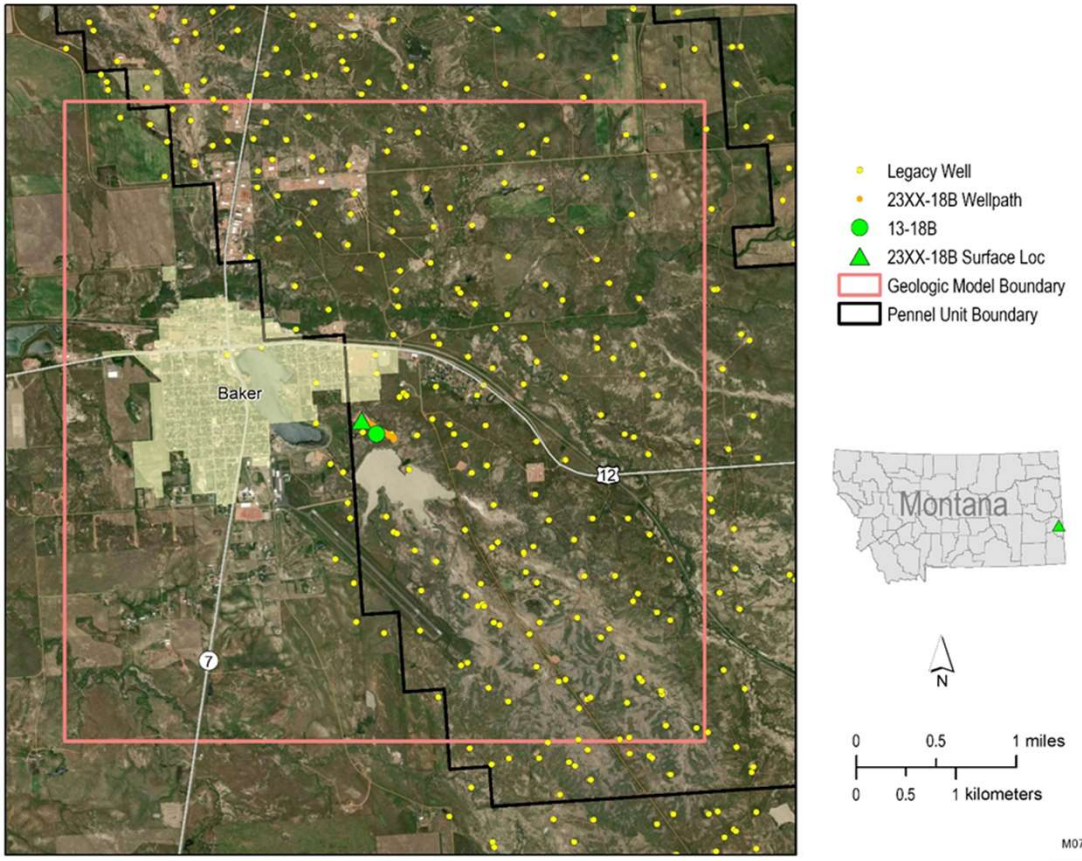
- Near Baker, MT
- Cedar Creek Anticline
- CO_2 Sourced from Shute Creek and Lost Cabin Gas Plants (WY)



Study Area

Two wells will be used for the project

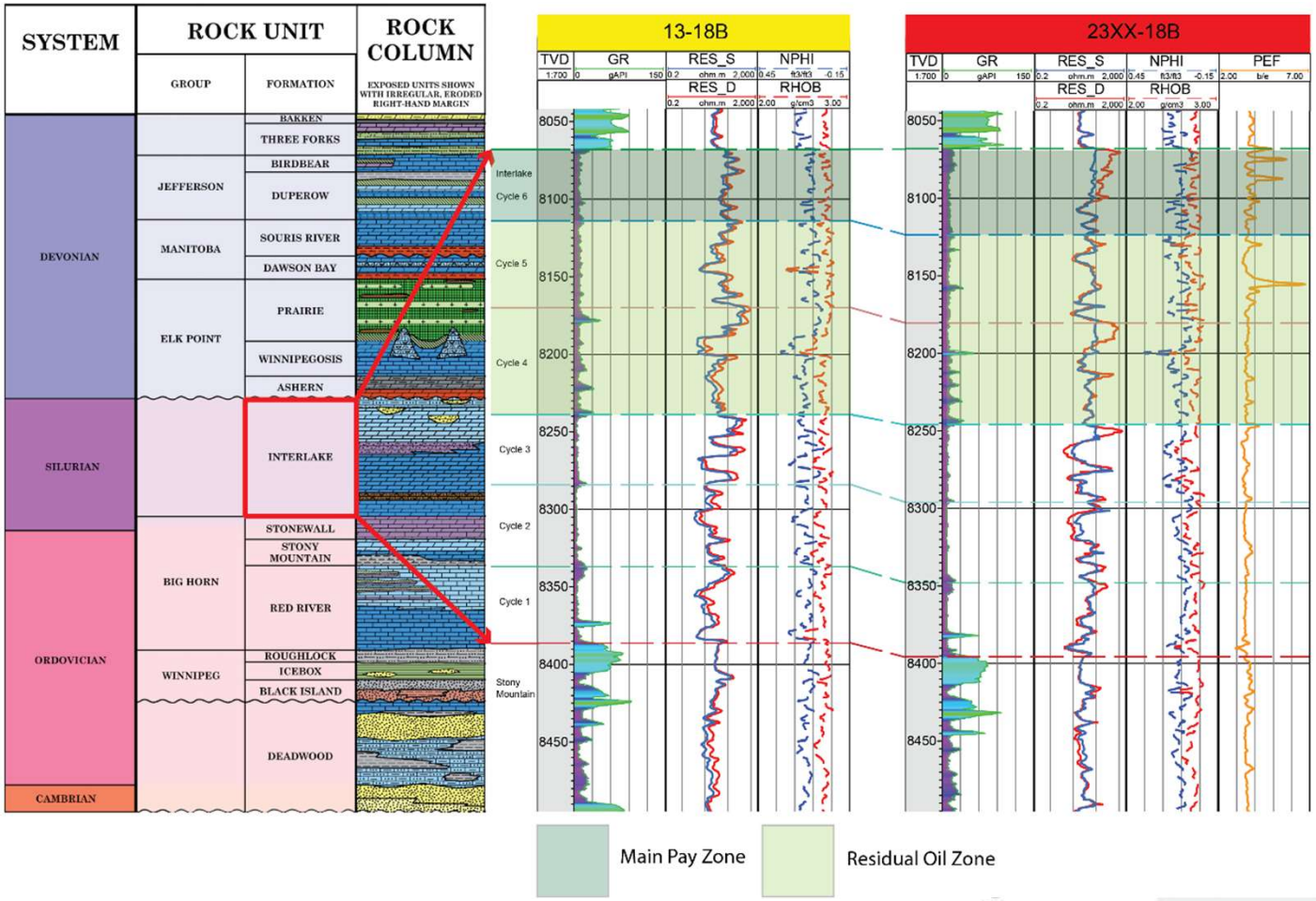
- 13-18B (Producer)
- 23X-18B (Injector)
- Additional legacy wells are used for development of a geologic model



Target Reservoir

- Interlake Formation
  - Upper Interlake – Main Pay Zone
  - Cycles 4 & 5 ROZ's
- 150 ft thick
- Porosity: 1.3 – 16.3%
- Permeability: 0.008 – 3.7 mD

Injection expected between September 2023 to December 2023



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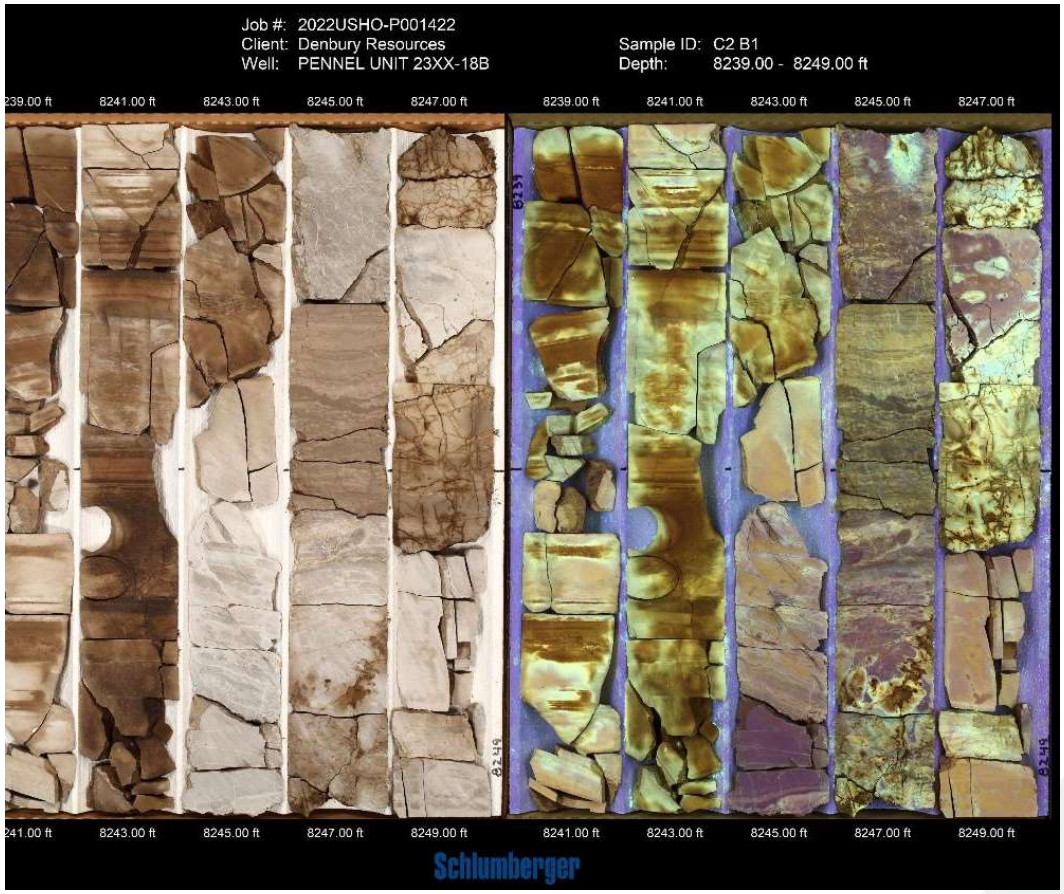
Core Characterization

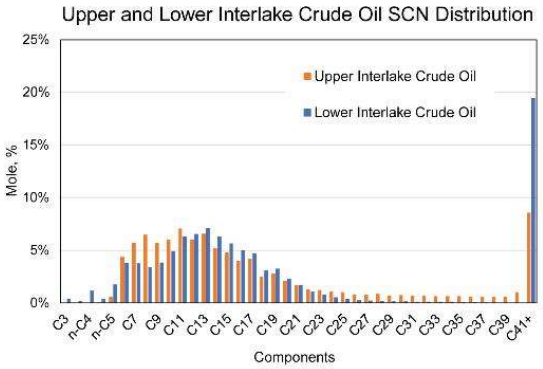
- Denbury drilled the 23X-18B (Injector) and collected core over the main pay and ROZ's

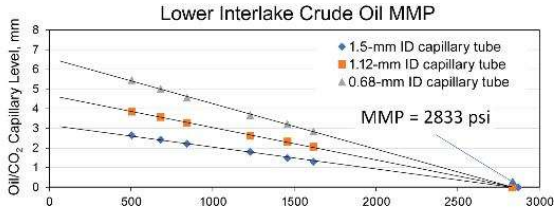
- Core analyses include:
  - P & P
  - XRD
  - MICP
  - Fluid saturations
  - NMR
  - SCAL

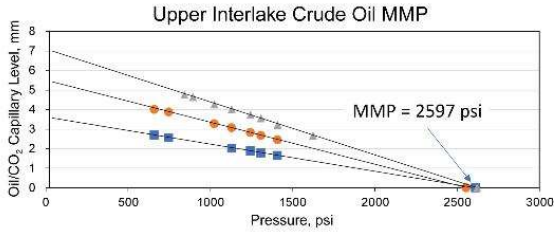


Fluid Studies

- Whole Crude Analysis
- CO_2 MMP
- Contact Angle
- IFT







Lower Interlake Crude Oil Contact Angle

Surrounding Phase Temperature	Produced Brine 200°F Pressure, psi	Contact Angle, °
	3000	140.47
	3300	140.35
	3600	140.14
	3900	140.05
	4200	139.84

Surrounding Phase Temperature	Carbonated Brine 200°F Pressure, psi	Contact Angle, °
	3000	148.02
	3300	148.04
	3600	147.85
	3900	147.48
	4200	147.36

Upper Interlake Crude Oil Contact Angle

Surrounding Phase Temperature	Produced Brine 200°F Pressure, psi	Contact Angle, °
	3000	120.53
	3300	120.12
	3600	119.75
	3900	119.47
	4200	119.27

Surrounding Phase Temperature	Carbonated Brine 200°F Pressure, psi	Contact Angle, °
	3000	145.03
	3300	144.46
	3600	144.70
	3900	144.62
	4200	144.25

Lower Interlake Crude Oil IFT

Surrounding Phase Temperature	Produced Brine 200°F Pressure, psi	IFT, mN/m
	3000	12.82
	3300	12.60
	3600	12.52
	3900	12.47
	4200	12.40

Surrounding Phase Temperature	Carbonated Brine 200°F Pressure, psi	IFT, mN/m
	3000	14.09
	3300	14.07
	3600	14.05
	3900	14.01
	4200	14.03

Upper Interlake Crude Oil IFT

Surrounding Phase Temperature	Produced Brine 200°F Pressure, psi	IFT, mN/m
	3000	7.28
	3300	7.00
	3600	6.71
	3900	6.16
	4200	6.07

Surrounding Phase Temperature	Carbonated Brine 200°F Pressure, psi	IFT, mN/m
	3000	9.89
	3300	9.77
	3600	9.54
	3900	9.32
	4200	9.06

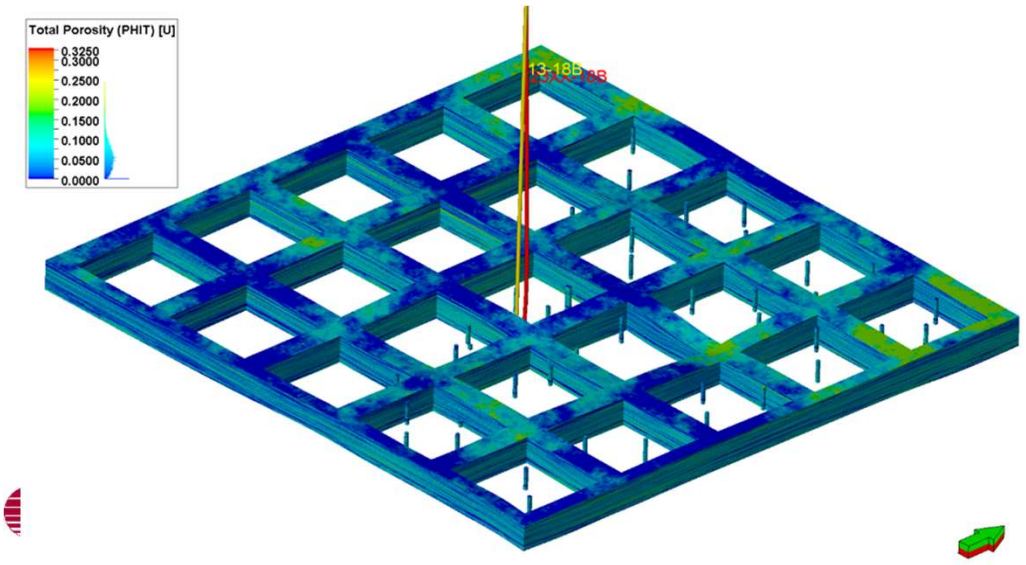
Geologic Model and Simulation

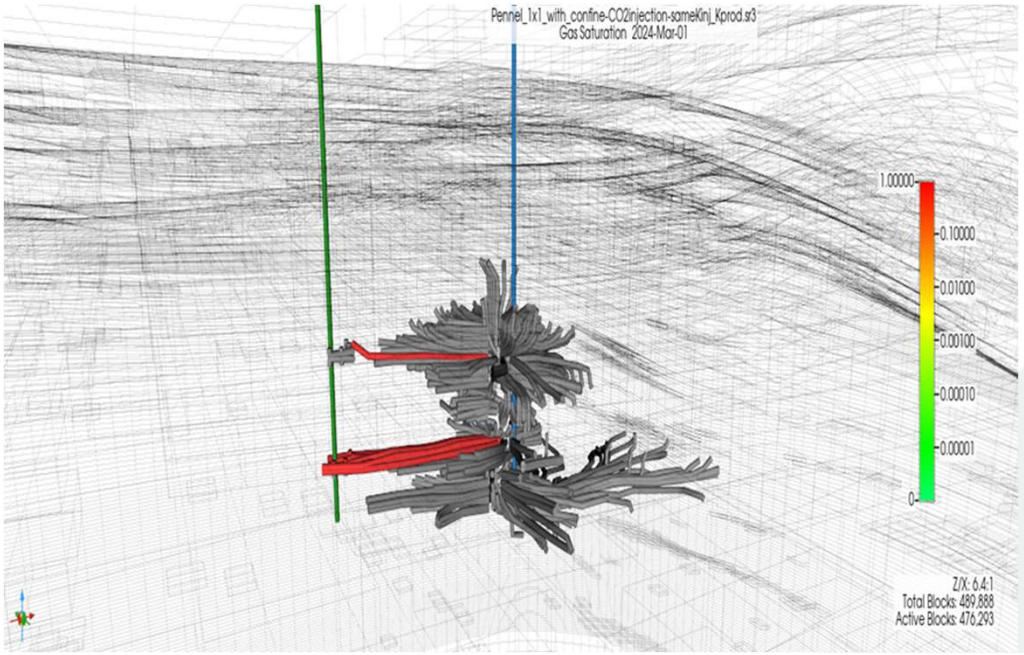
Model developed using:

- Core data
- Legacy well data

1) Max Injection = 5 mmcfpd
2) Max BHIP = 6000 psi
3) Max Production =
   a. 5 mmcfpd
   b. 2000 bwpd
   c. 500 bopd
4) Min BHPP = 1200 psi

- Simulations are still ongoing
- This view shows CO2 breakthrough occurring in approximately 2 months after injection begins
- Simulations will be updated as injection and production data is received

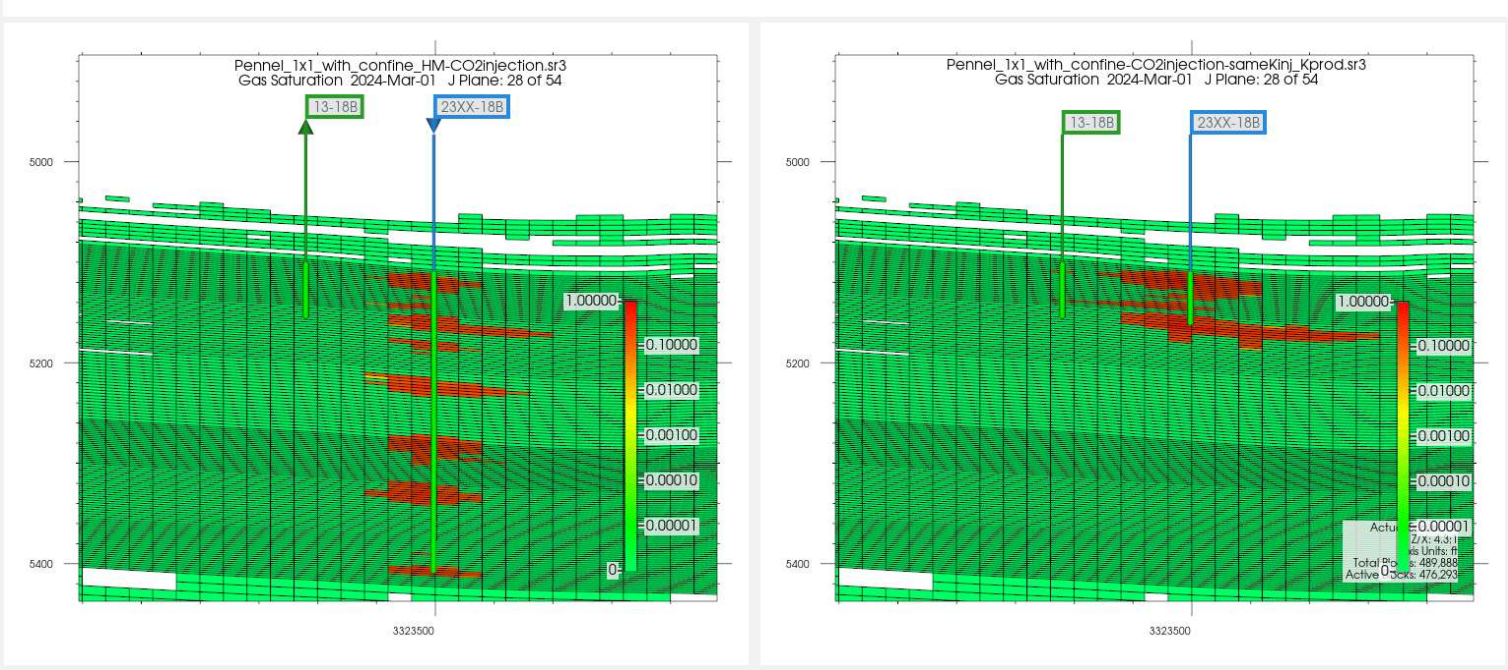




Gas saturation

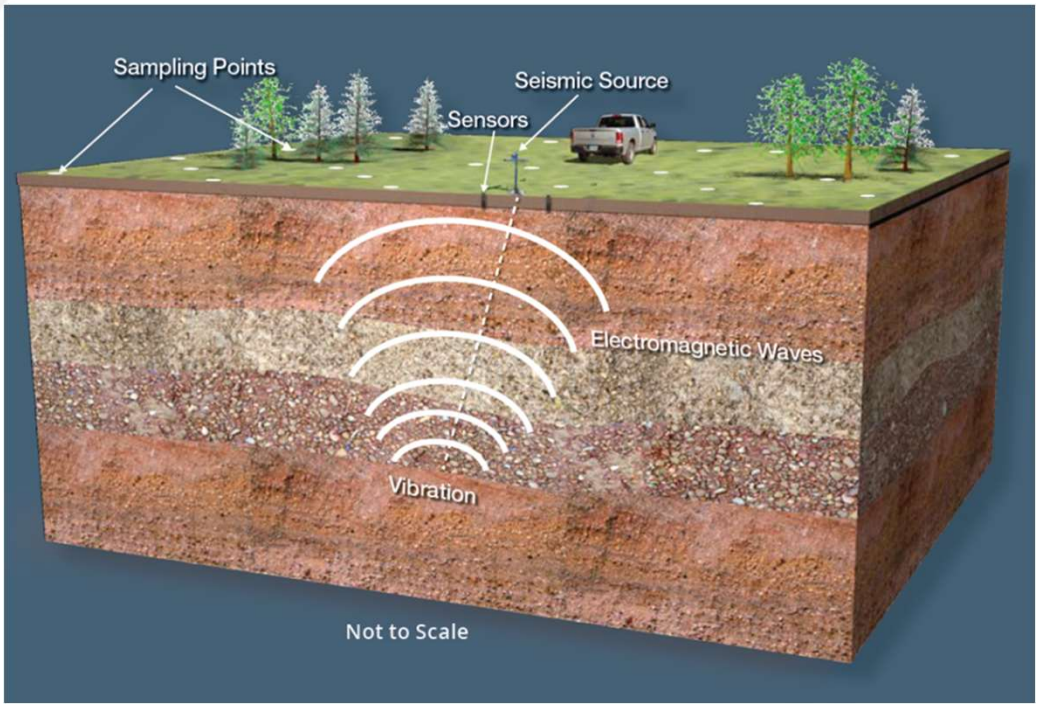
The gas is shown to breakthrough in March when injector is at the same depth as the production well

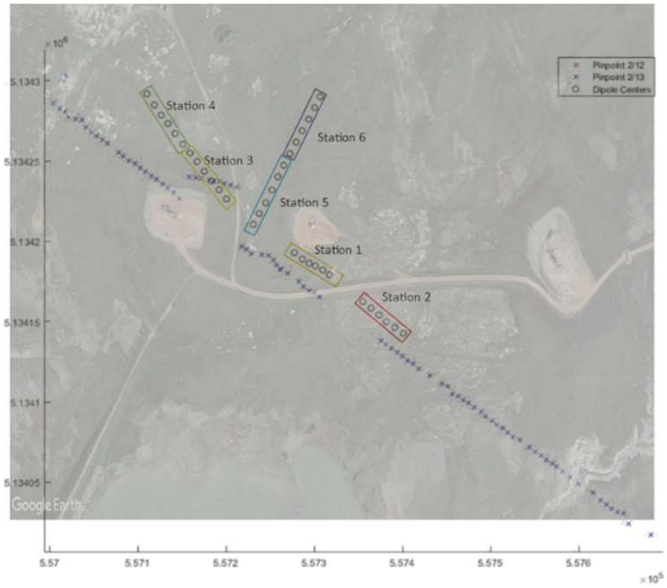
Gas saturation
March/01/2024



Monitoring

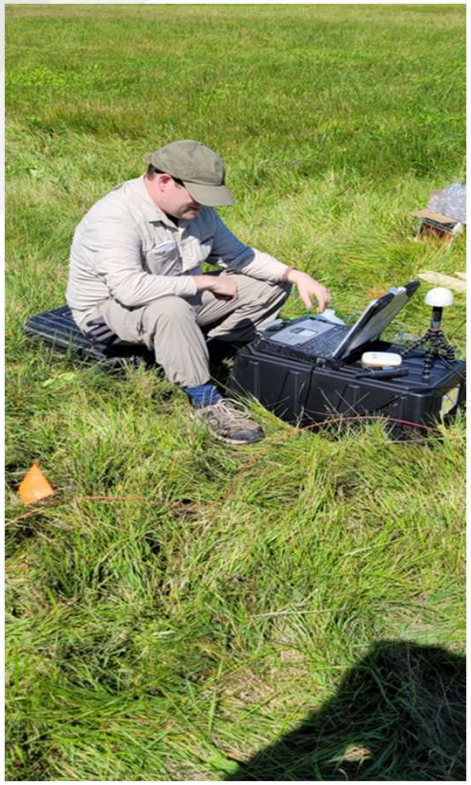
Traditional Seismic
Fiber Optics
Active Seismoelectric





Active Seismoelectric Technology Demonstration

Conducted over a select area of the stacked storage complex in the project field test area.



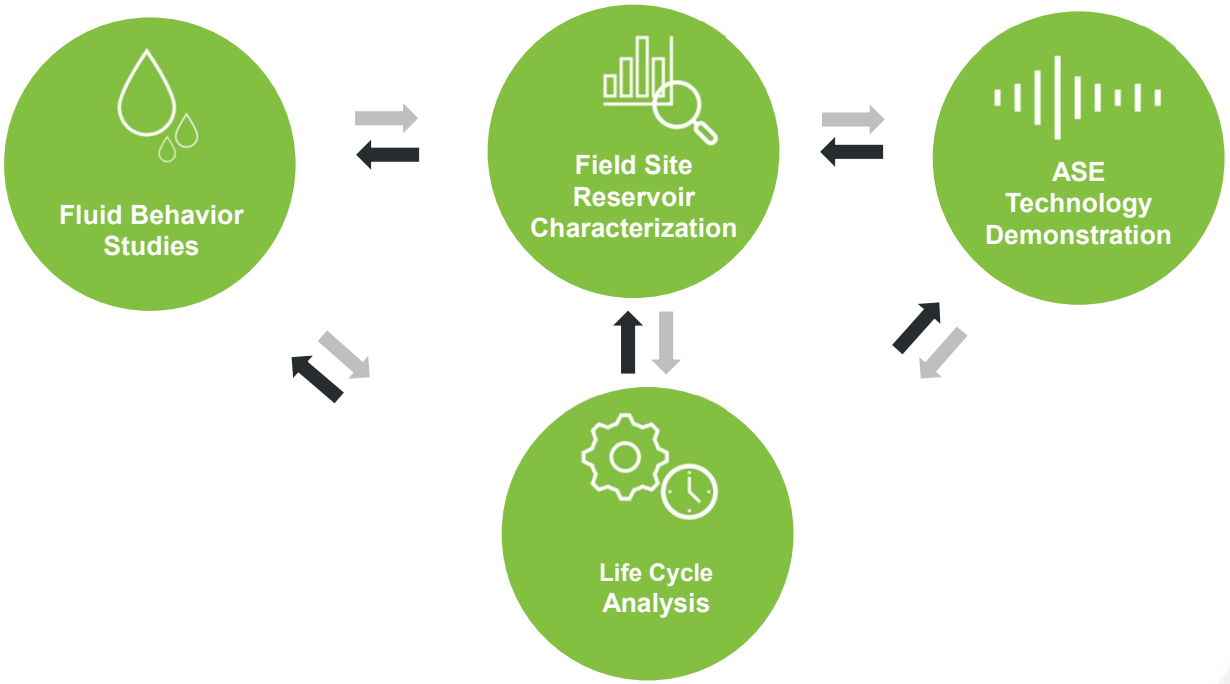
Significant accomplishments:

- Performed a small-scale ASE survey in Mentor, Minnesota, to refine field deployment strategies and examine the data processing workflow.
- Initial reservoir model values have been generated.
- A full ASE survey was conducted over a select area of the stacked storage complex in the project field test area. Surface vibroseis sourcing and near-surface impulse sources in a high-density array were recorded.
- Collected ASE data were processed using Zonge software to remove noise and enhance seismoelectric signal.
- Initial analysis was carried out on subsets of the ASE data collected in the initial survey. Interpretation of the ASE data is ongoing.

Life Cycle Analysis

BP1 and BP2 data generated during the following tasks will be used to conduct an LCA of the project field test:

- Fluid Behavior Studies
- Field Site Reservoir Characterization
- Active Seismoelectric Technology Demonstration
- Additional data obtained from active CO_2 storage projects in ND



Summary

Budget Period 1

- Determined the baseline reservoir characteristics of the stacked storage complex.
- Determined the effects of hydrocarbon gas impurities in the recycled CO_2 stream from stacked reservoirs on the optimization of CO_2 EOR and associated storage.
- Predicted seismoelectric response based on a forward model and acquire a baseline active seismoelectric (ASE) survey across the study field.

BP1 (Denbury Site)
Start Date: 4/1/2022
End Date: 3/31/2023

Summary

Budget Period 2

- Determine the reservoir response to pilot injection activities in a stacked complex in the context of associated CO_2 storage.
- Determine the effectiveness of ASE technology for ROZ characterization and MVA in a stacked storage complex.
- Conduct detailed life cycle analyses (LCAs) of the project field injection test and a hypothetical stacked storage project in the central portion of the Williston Basin.

BP2 (Denbury Site)
Start Date: 4/1/2023
End Date: 9/30/2025

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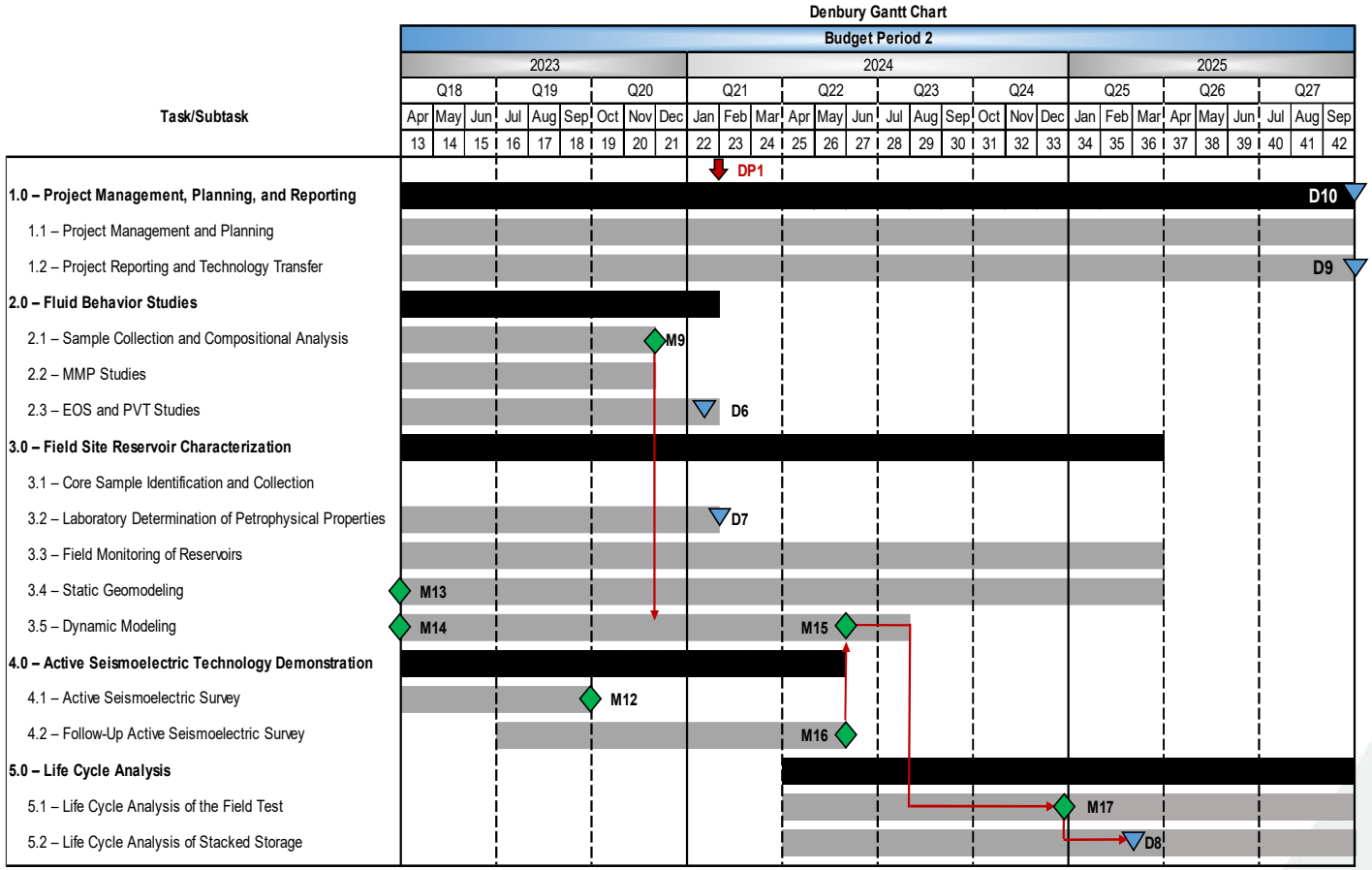
Budget Period 2 (Denbury Site)

Deliverables

- Deliverable 7 (**D7**) – Establishment of Associated Storage Field Test Site
- Deliverable 8 (**D8**) – LCA and Technoeconomic Assessment of a Hypothetical Stacked Storage Project
- Deliverable 9 (**D9**) – Data Submitted to NETL EDX
- Deliverable 10 (**D10**) – Development of the Associated Storage Field Site

Milestones

- Milestone 9 (**M9**) – Sample Collection Completed
- Milestone 12 (**M12**) – Baseline Active Seismoelectric Survey Processing Complete
- Milestone 13 (**M13**) – Updated Static Geomodel Initiated
- Milestone 14 (**M14**) – Initial Dynamic Modeling Initiated
- Milestone 15 (**M15**) – Updated Dynamic Modeling Initiated
- Milestone 16 (**M16**) – Repeat ASE Complete – Demonstration of ASE Technology
- Milestone 17 (**M17**) – Life Cycle Assessment of Dual-Pilot Project Completed



Budget Period 1 (Denbury Site)

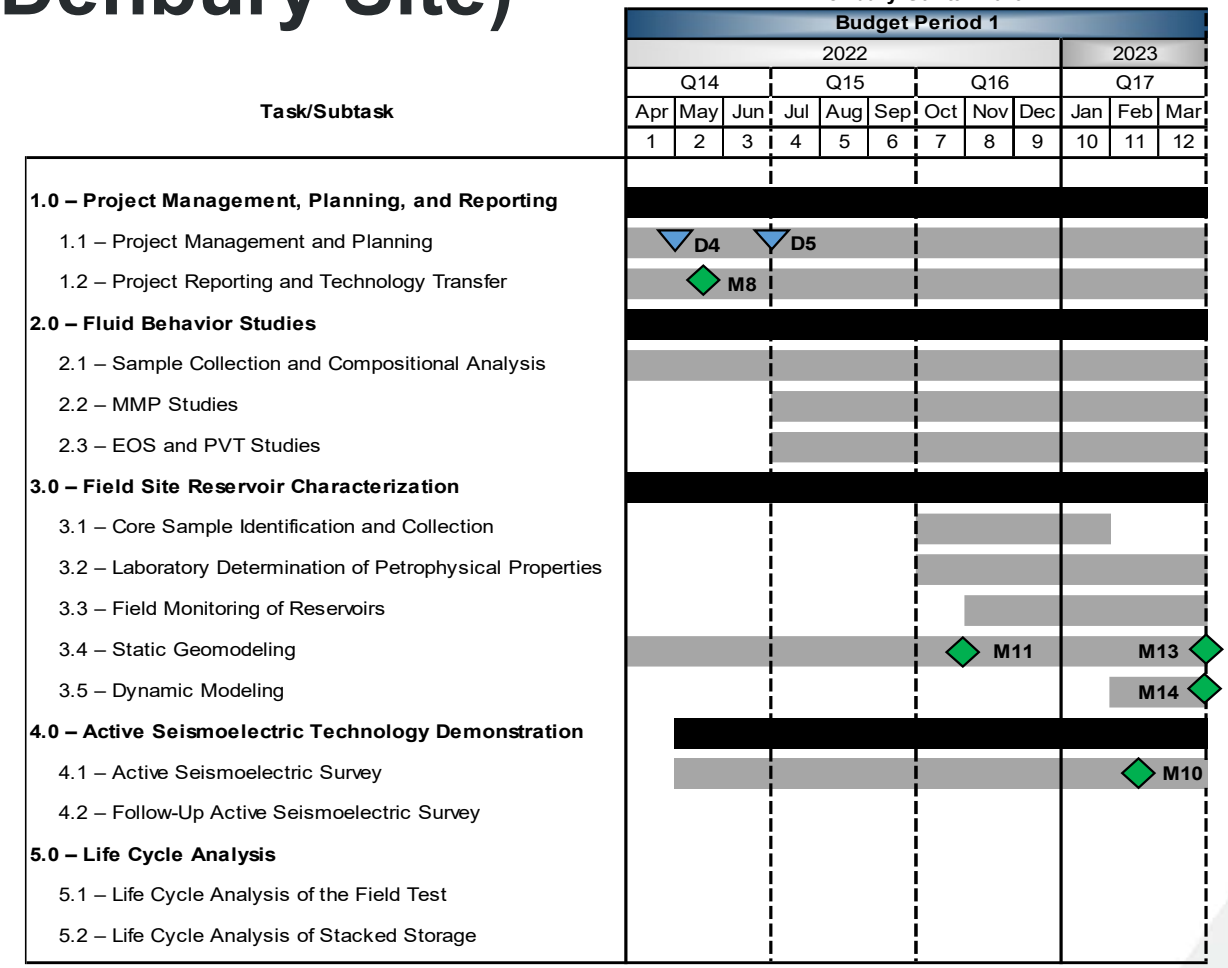
Deliverables

- Deliverable 4 (**D4**) – Project Management Plan
- Deliverable 5 (**D5**) – Technology Maturation Plan
- Deliverable 6 (**D6**) – Fluid Behavior Studies Summary Report

Milestones

- Milestone 8 (**M8**) – Project Kickoff Meeting Held
- Milestone 10 (**M10**) – Baseline ASE Survey
- Milestone 11 (**M11**) – Initial Static Geomodel Complete
- Milestone 13 (**M13**) – Updated Static Geomodel Initiated
- Milestone 14 (**M14**) – Initial Dynamic Modeling Initiated

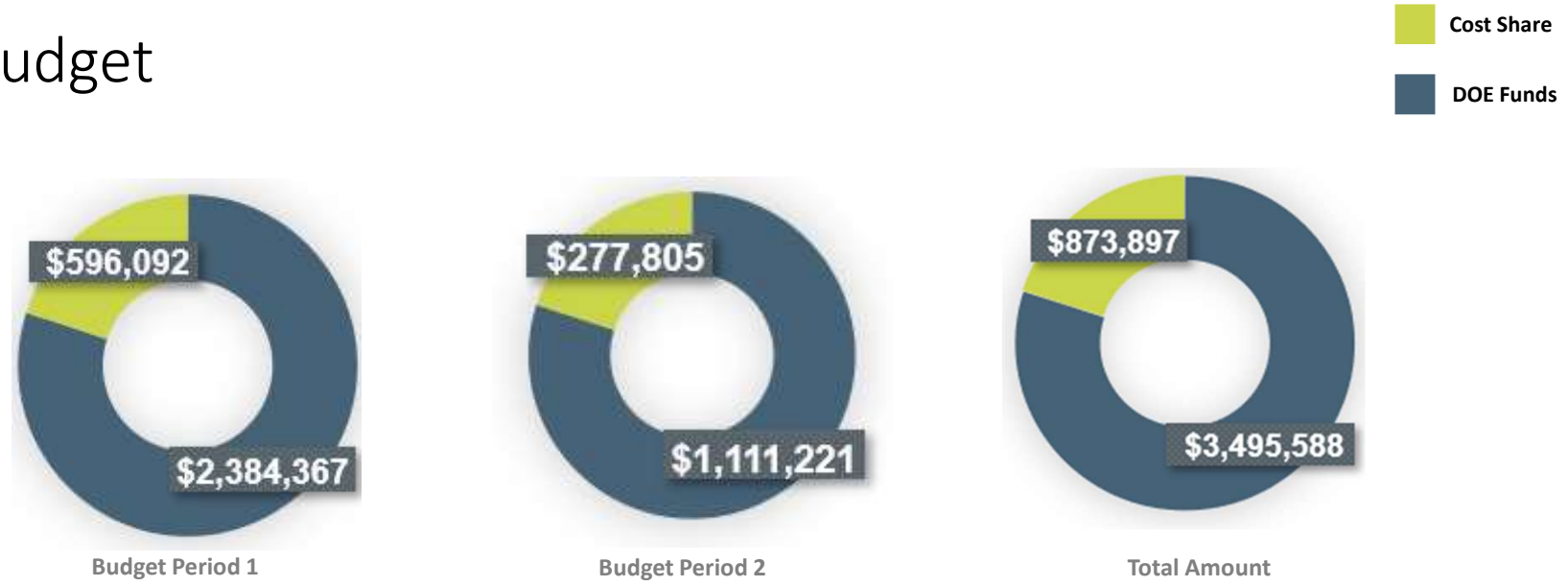
Denbury Gantt Chart



Deliverables

Task/Subtask Number	Deliverable Title	Due Date
1.1	D4 – Project Management Plan	Submitted on May 2, 2022
1.1	D5 –Technology(ies) Maturation Plan (TMP)	Submitted on July 6, 2022
2.3	D6 – Fluid Behavior Studies Summary Report	January 19, 2024
3.2	D7 – Demonstration of Active Seismoelectric Technology for MVA	January 31, 2024
5.2	D8 – LCA and Technoeconomic Assessment of a Hypothetical Stacked Storage Project in the Williston Basin	February 29, 2025
1.2	D9 – Data Submitted to NETL EDX	September 30, 2025
1.0	D10 – Development of the Associated Storage Field Site	September 30, 2025

WBFCL Budget



Budget Period 1 | Budget Period 2 | Total Amount

80% DOE funds

20% Nonfederal in-kind cost-share commitment with SLB