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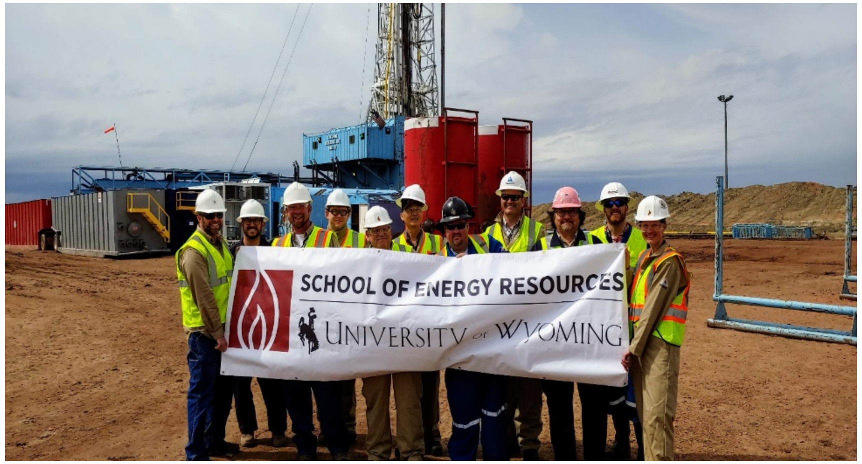

UNIVERSITY of WYOMING

CarbonSAFE Wyoming: Commercial-Scale Carbon Storage Complex Feasibility Study at Dry Fork Station, Wyoming

DE-FE0031624

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U.S. Department of Energy

National Energy Technology Laboratory

Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture,

Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting

August 26-30, 2019

Disclaimer

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Presentation Outline

- Technical status
- Accomplishments
- Lessons learned
- Synergy opportunities
- Project summary
- Appendix
  - Benefit to the program
  - Project overview
  - Organization chart
  - Gantt chart
  - Bibliography

Technical Status

1. **Project Objectives and Background**
2. **Field Operations**
3. **Analytical Progress**

Wyoming CarbonSAFE: Project Area

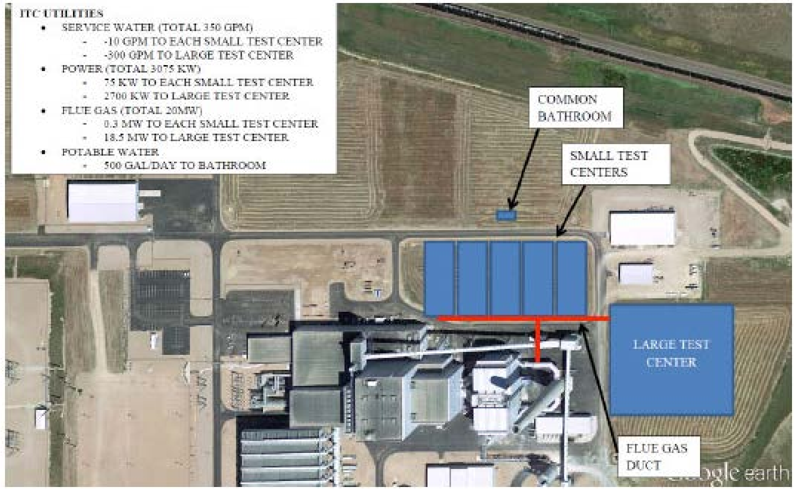
- At Dry Fork Station, operated by Basin Electric Power Cooperative
- Wyoming Integrated Test Center (WY-ITC)

<u>Dry Fork Station</u>

✓ Built in 2007, on-line in 2011

✓ 385 MW Power Plant

✓ 3.3 Million tons of CO_2/year



<u>WY-ITC</u>

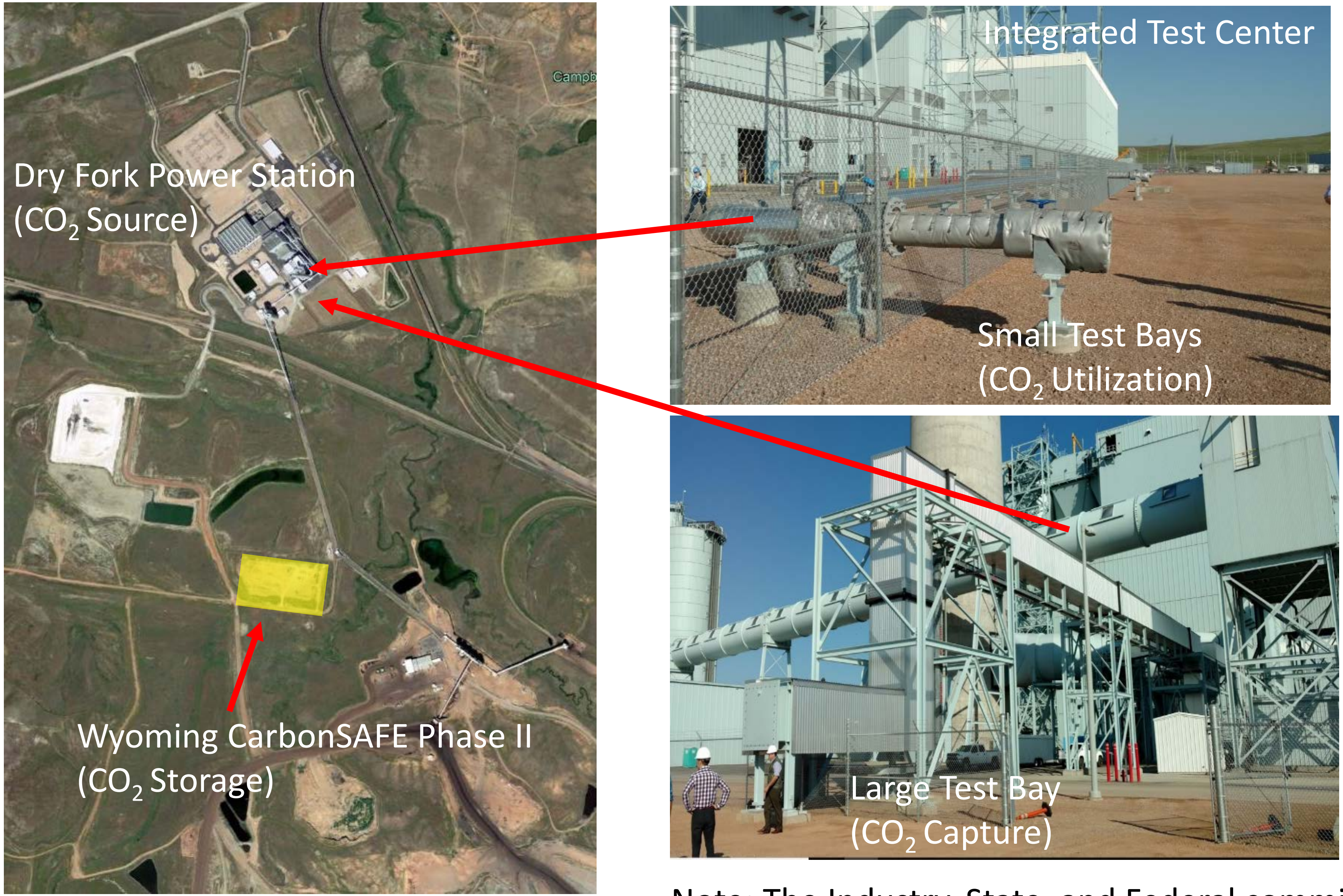
✓ Started in fall 2017

✓ Test CO_2 capture/CCUS technologies

✓ $20 Million public/private investment

✓ NRG COSIA Carbon XPRIZE ($20M global competition to develop breakthrough technologies for CO_2 emissions)

Wyoming CarbonSAFE : Research Hub

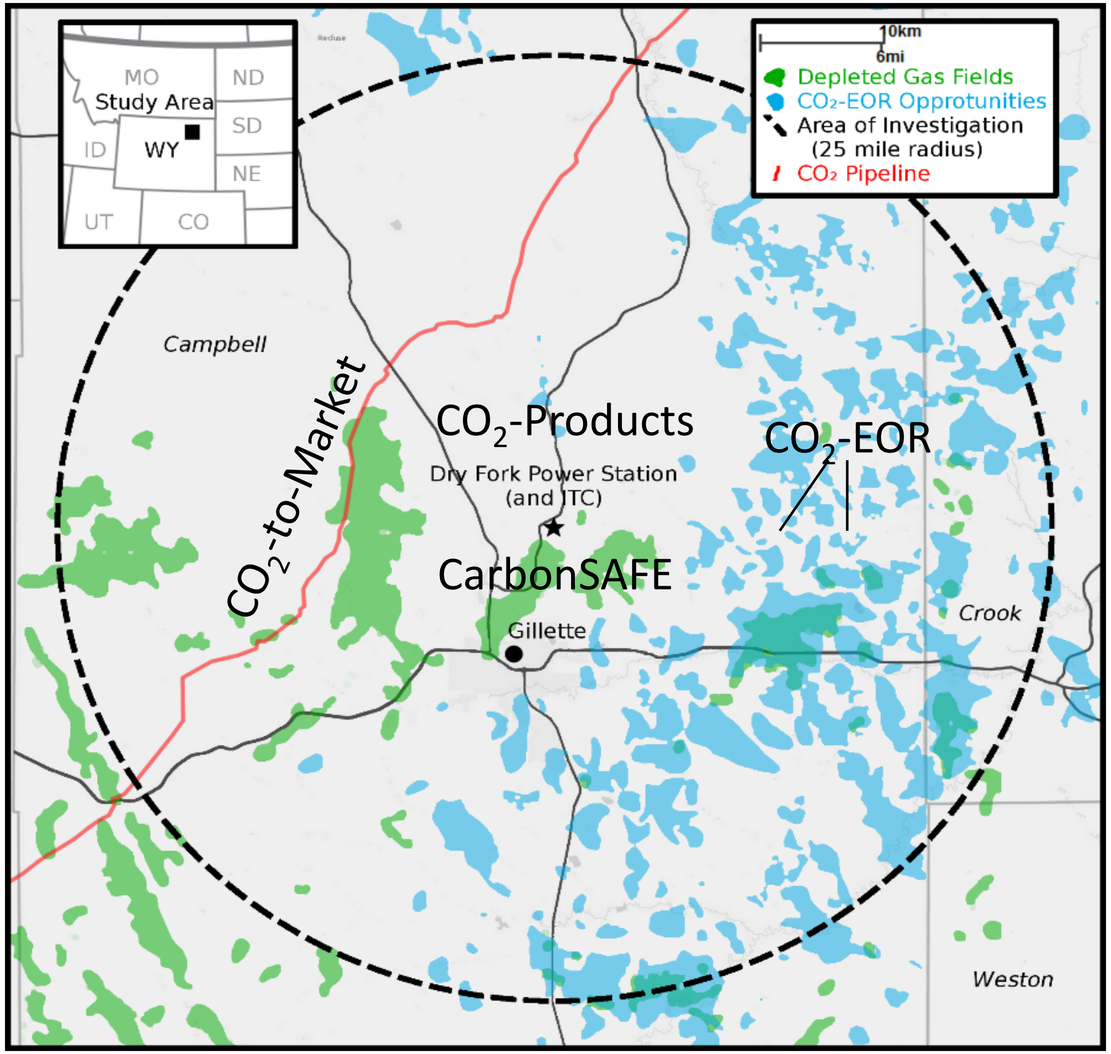


Note: The Industry, State, and Federal commitments

Wyoming CarbonSAFE: Carbon Management Epicenter

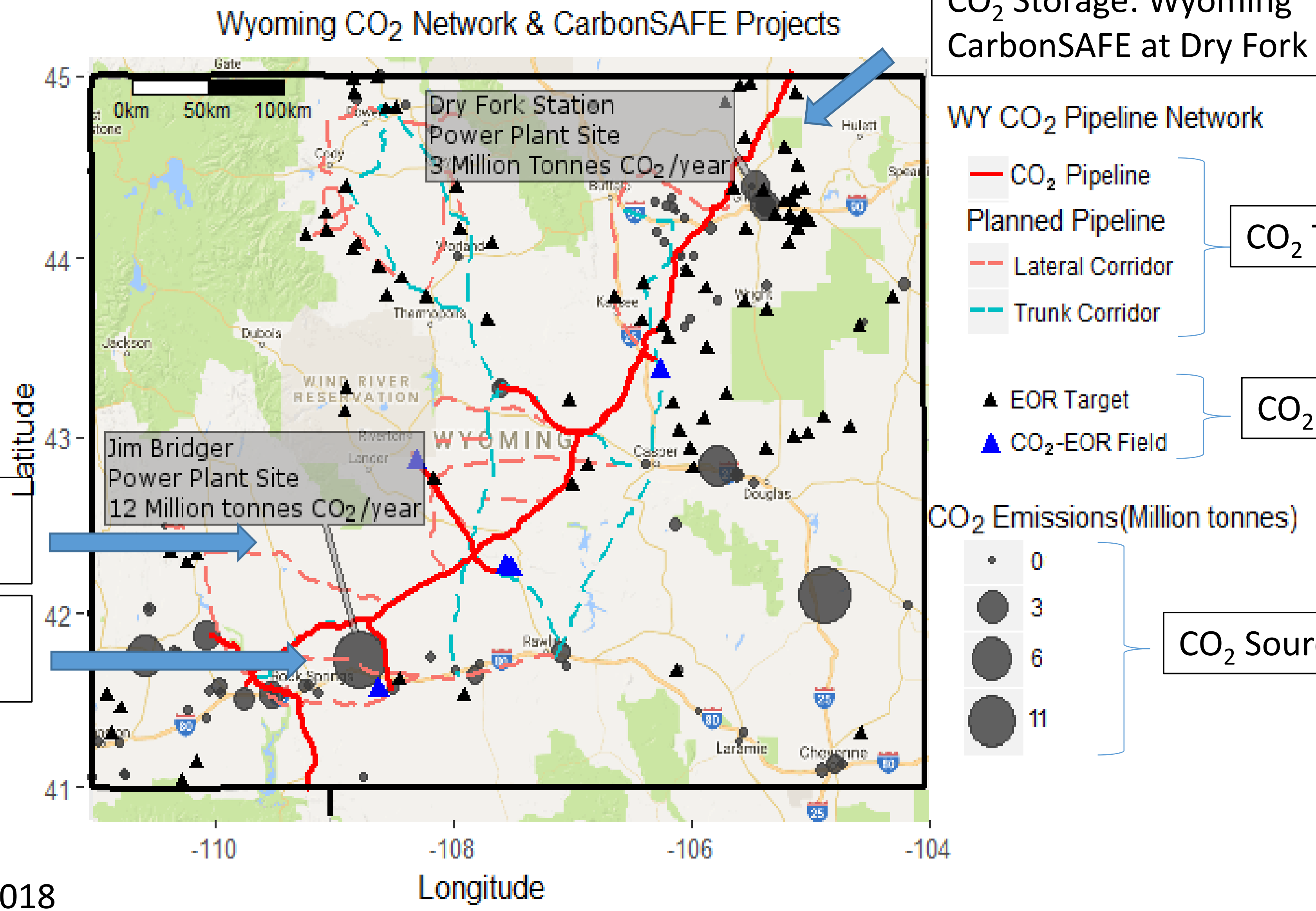
Gillette WY – Carbon Valley

- ✓ Stacked storage: Saline reservoirs (Wyoming CarbonSAFE)
  - ➢ Located below Dry Fork Station
- ✓ Utilization: CO_2-EOR opportunities
  - ➢ Proximal EOR fields
  - ➢ Proximal to CO_2 pipeline
- ✓ Capture/Utilization: WY Integrated Test Center/ACPEC
  - ➢ Breathe (Bangalore, India) - common fuel and petrochemical feedstock.
  - ➢ C4X (Suzhou, China) – chemicals and bio-composite foamed plastics.
  - ➢ Carbon Capture Machine (Aberdeen, Scotland) – solid carbonates and building materials.
  - ➢ CarbonCure (Dartmouth, Canada) – stronger, greener concrete.
  - ➢ Carbon Upcycling UCLA (Los Angeles, CA, USA) – CO_2 absorbing concrete replacements .
  - ➢ JCOAL & Kawasaki Heavy Industry (Japan) – CO_2 Capture
  - ➢ Membrane Technology Research (Ca., Industry) – CO_2 Capture
  - ➢ Unv. Kentucky (CA/KY) – CO_2 Capture
  - ➢ TDA(CO/WY) – CO_2 Capture



From Quillinan et al., 2018

Wyoming Integrated CO_2 Management Map



CO_2 Storage: Wyoming CarbonSAFE at Dry Fork

CO_2 Transport

CO_2 Utilization

CO_2 Source

CO_2 Storage: LaBarge Platform

CO_2 Storage: Rock Springs Uplift

From Quillinan et. al, 2018

CarbonSAFE (Storage, Assurance, and Facility Enterprise)

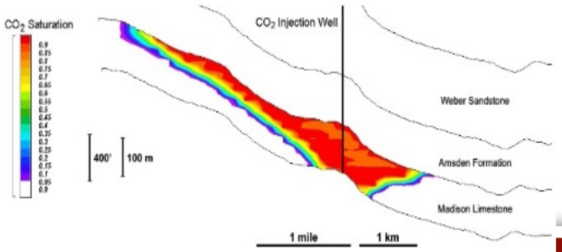
- Projects… will address **key research gaps** in the path toward the **deployment** of carbon capture and storage (CCS) technologies, including the development of **commercial-scale** (50+ million metric tons CO_2) **geologic storage sites for CO_2 from industrial sources…**

- Projects under CarbonSAFE aim to **develop integrated CCS complexes** that are **constructed and permitted for operation in the 2025 timeframe**

- **Get there through sequential Phases…**

  - ***Phase 1*** Integrated CCS Pre-Feasibility,
  - <u>***Phase 2* Storage Complex Feasibility,**</u>
  - ***Phase 3*** Site Characterization,
  - ***Phase 4*** Permitting and Construction.

- **What about Carbon Capture?** That's a different DOE program



Wyoming CarbonSAFE Phase II Project Objectives

*Wyoming CarbonSAFE is focused on investigating the **feasibility** of practical, secure, **permanent**, **geologic storage** of carbon dioxide **(CO_2)** emissions from coal-based electricity generation facilities near Dry Fork Station Gillette, Wyoming….*

Research questions/gaps for Phase II Feasibility Study

Things we are looking for…..

- ✓ Is there sufficient pore volume in the subsurface to store commercial quantities of CO_2?
- ✓ Can the CO_2 be injected safely? Stored permanently?
- ✓ What are the risks/costs/policy/public perception?
- ✓ Site-specific technology needs?

https://www.youtube.com/watch?v=UoYnC4h7_Dg&feature=youtu.be

Detailed Phase II Projects Objectives

I. **Field Operations and Data Collection**
   I. Drill a stratigraphic test well and collect data
   II. Collect new 3-D seismic survey and lease existing data
   III. Geophysical logging
II. **Stacked Storage Complex Analysis and Interpretation**
   I. Rock & fluid characterization
   II. Geochemical modeling
   III. Well log interpretation
   IV. Seismic interpretation
   V. Geomechanical analysis
III. **Modeling and Reservoir Simulations**
   I. Update models with new data
   II. Simulate CO_2 Injections
   III. Performance assessments
   IV. Validate NRAP tool set
IV. **Community & Public Outreach, Legal, and Economic Analyses**
V. **Future Phase Site Development**
   I. MVA Plan
   II. Focused Wellbore analysis
   III. Risk Assessment
   IV. Statewide CO_2 Assessment

Field Operations Step 1: Public Outreach

Community and public outreach:

CAMPBELL COUNTY PUBLIC LIBRARY

2101 S 4-J Rd, Gillette, WY • Feb. 21, 2019 @ 6:00 PM

Doors open at 5:30 PM for a free, light dinner and snacks.

• **Moderator: Dr. Jean Garrison, Professor and Director of the Office of Engagement and Outreach, University of Wyoming** •

6:00 PM • Why Carbon Capture is Important for Wyoming's Economic Future: A Climate Policy Overview

Kipp Coddington, Director of Energy Policy & Economics, School of Energy Resources (SER), University of Wyoming

Coal and other fossil fuels face unrelenting governmental and private sector pressures to reduce their emissions of greenhouse gases such as carbon dioxide (CO2). Pressures arise from international accords such as the Paris Agreement and from national sources, such as California's continuing advancement of a suite of low-carbon policies. Wyoming's leadership in responding to these challenges through implementation of state-level CCUS policies and projects will be discussed.

6:50 PM • The Science of Carbon Capture, Utilization and Storage (CCUS): Wyoming Case Studies and Wyoming CarbonSAFE

Scott Quillinan, Geologist and Director of Research, School of Energy Resources, UW

Fred McLaughlin, Ph.D., P.G. Manager & Senior Research Scientist, Center for Economic Geology Research, School of Energy Resources, UW

For the past decades, UW's SER has sought to advance the science of CCUS. One current research aims to provide carbon storage options north of Gillette at the Wyoming Integrated Test Center in support of on-going Carbon Capture research efforts. As will be explained in this talk, the goal is to understand the technical challenges of geologic storage of carbon using data from Wyoming CCUS case studes: How to determine storage capacity. How to assess the ramifications of long-term confinement. What are the risks? The talk further introduces "Wyoming CarbonSAFE," a potential future project that seeks to implement the economic, safe and secure storage of 50 million tons of CO2 near Gillette.

7:40 PM • Carbon Capture and Communities: The Role of Social License

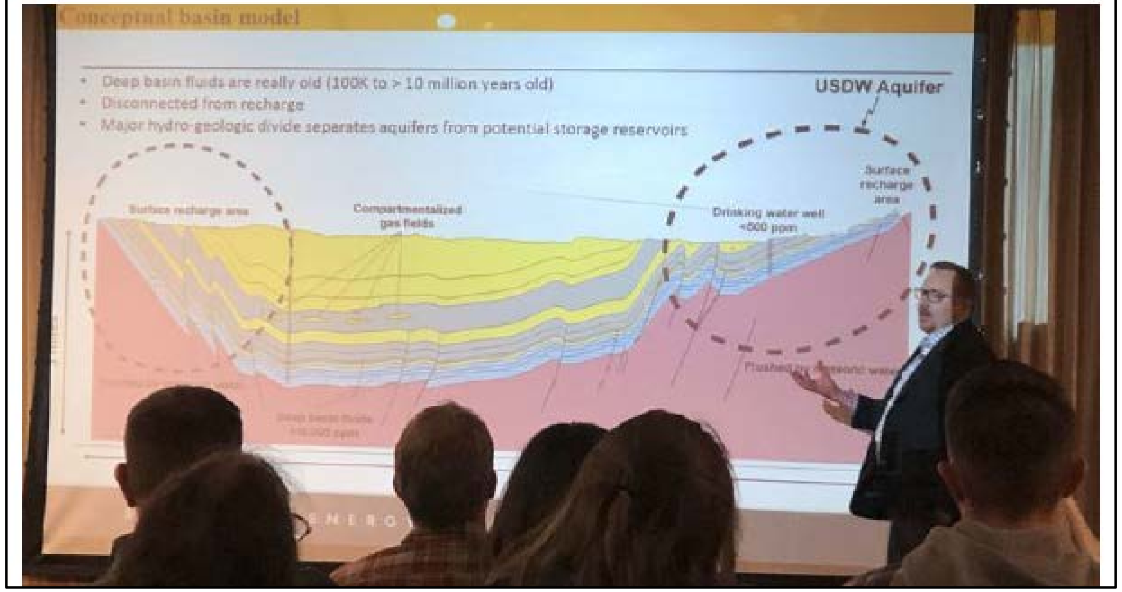
Jessica Western, Ph.D., Senior Research Scientist, Human Dimensions in Natural Resources; Director, Collaboration Program in Natural Resources; Ruckelshaus Institute, Haub School of Environment and Natural Resources, UW

"Social License" refers to the acceptance of a company or industry's standard business practices and operating procedures by its employees, stakeholders and the general public. In the context of CCUS, public acceptance and understanding of the technology and the projects implementing it is key to their ultimate success. Dr. Western will present an overview of the concept of "Social License," and then the audience will be invited to participate in a facilitated discussion regarding carbon capture and the current research concerning carbon sequestration in northern Wyoming and the potential impacts on the local communities, from economics and energy to health and the environment.

Carbon research earning a 'social license' in Gillette

UW CarbonSAFE project will drill more than 10,000 feet into the Powder River Basin

By GREG JOHNSON NEWS RECORD MANAGING EDITOR gjohnson@gillettenewsrecord.net Feb 22, 2019



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A Low-Carbon Future for Wyoming Fossil Fuels? Update on the University of Wyoming's Carbon Capture Research in Campbell County

Wyoming coal and natural gas face unrelenting climate policy pressure to reduce their emissions of greenhouse gases. Carbon Capture research suggests that this technology may play an important role in enabling these fuels to thrive in the future. Wyoming leads research, policy and infrastructure development in Carbon Capture technology. Its university pursues several large research projects in both China and Wyoming, including an ongoing effort at Dry Fork Station near Gillette. This Saturday University program will explain the UW research at Dry Fork Station, including the drilling of a test well that should provide additional geologic information to inform, in part, if such a project would be feasible in the future. The three talks will examine the geological, economic and social impact, both potential and actual, of this research. At the conclusion, audience members will be invited to participate in a facilitated discussion about Carbon Capture, Utilization and Storage (CCUS) and the local community.

WHITNEY ACADEMIC CENTER

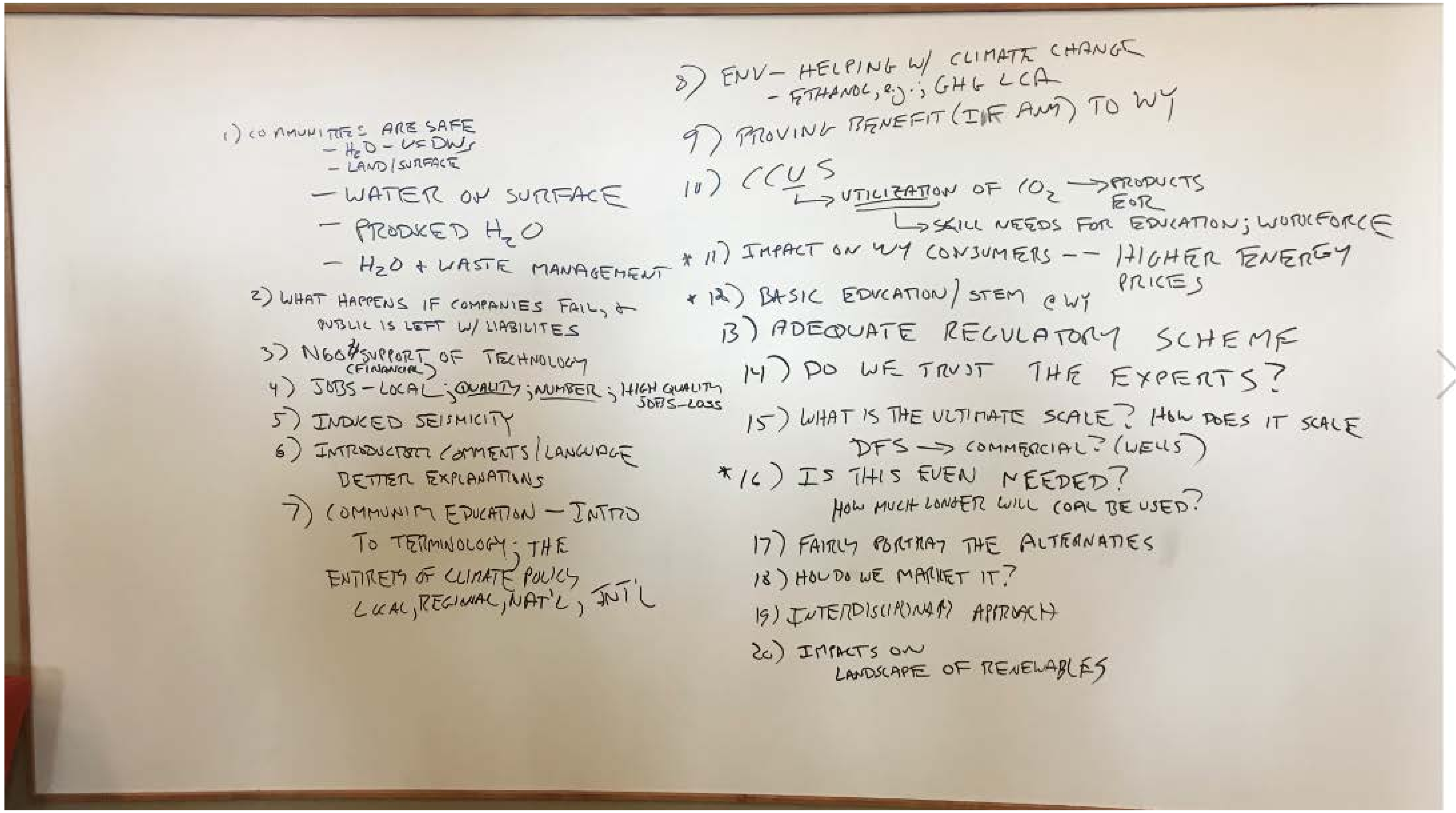
Sheridan College, Sheridan, WY • Feb. 23, 2019 @ 9:00 AM

Doors open at 8:30 AM for coffee and donuts.

Public Outreach

<u>Conversation with the community:</u>

1) Drinking water risk
2) Long-term liability
3) Induced seismicity
4) Community education
5) Jobs
6) Proving benefit to Wyoming
7) Adequate regulatory framework
8) Other minor concerns…



Whiteboard discussion with the community list of items to gain community support

Field Operations Step 2: Drilling and Sampling

Dirt work completed by Western Fuels

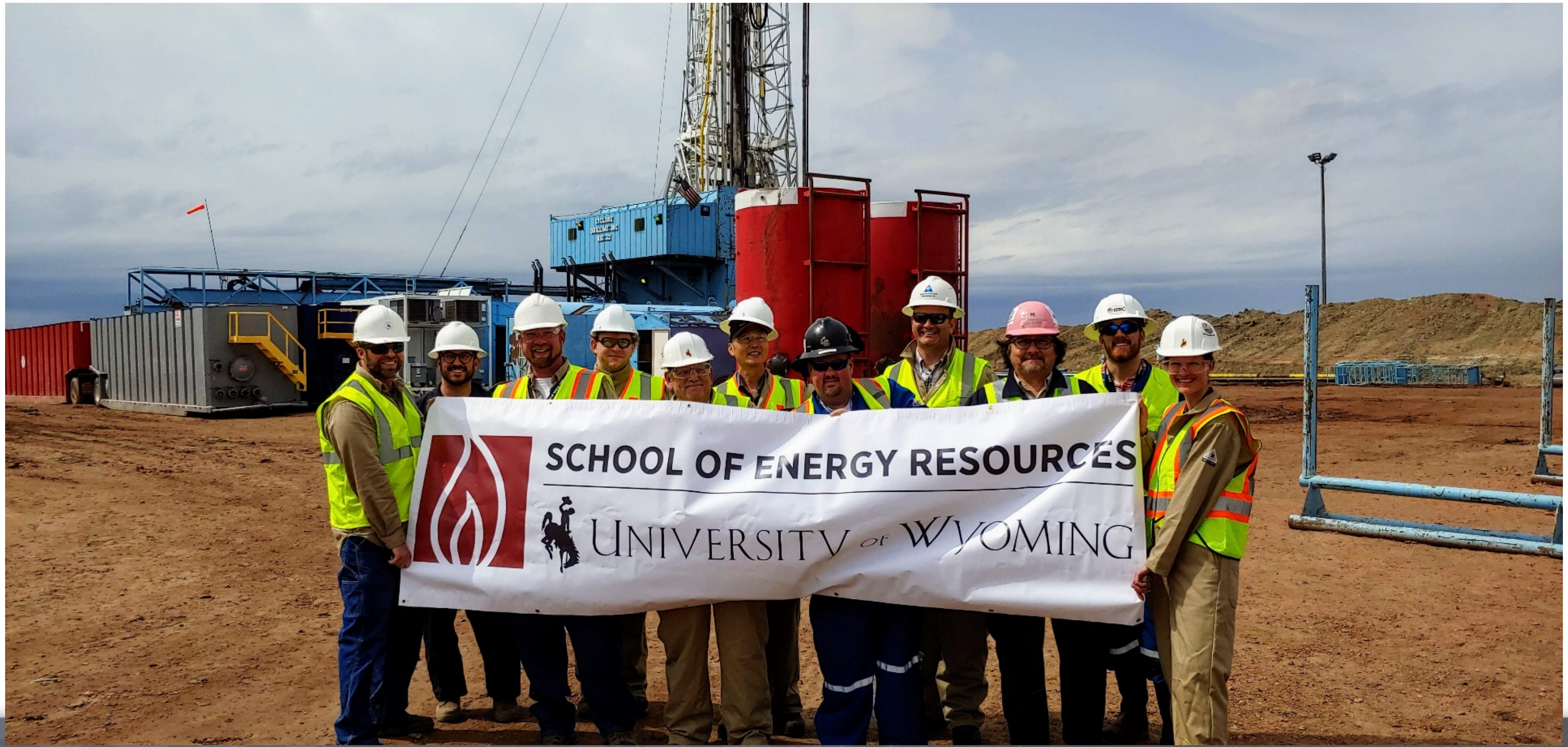
Site preparation

- Began March 31st (subsequent to permitting)
- Site work and environmental assessments completed by Western Fuels and Dry Fork Station

Scoria delivery

Field Operations: Drilling

- April 12th-May 7th
- Five stage research well field strategy
  - Surface Hole: from surface to 1200’
  - Intermediate Hole: from 1,200’ to 7,490’
  - Production Hole: from 7,490’ to 9,872’
  - Downhole sampling: Core, logging, formation fluids
  - Completing and plugging the well



Field Operations: Sampling

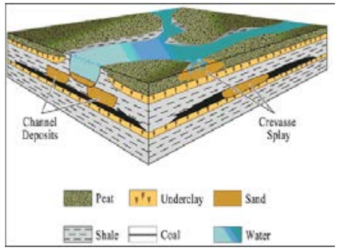
Coring Program

- Successfully collected ~620’ of core from 11 formations
- Roughly 16,000 lbs of rock

Field Operations: Core Targets

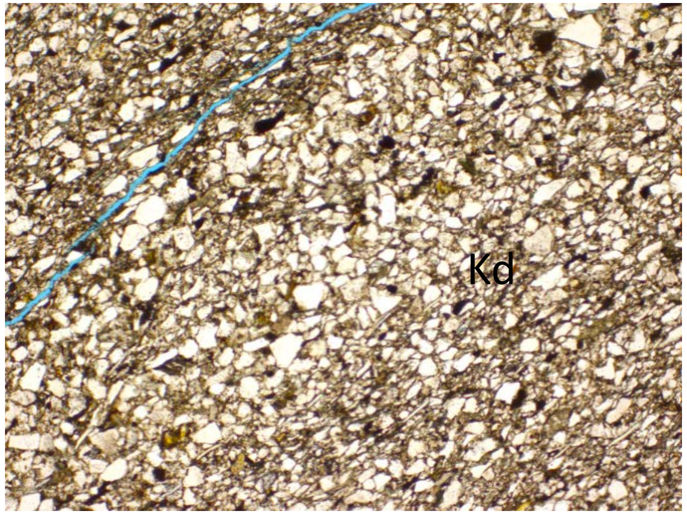
Age		Formation/Member
Recent		alluvium and stream terraces
Paleocene		Fort Union Formation
Upper Cretaceous		Lance Formation
		Fox Hills Sandstone
		Pierre (Lewis) Shale
		Niobrara Formation
		Carlile Shale
		Belle Fourche Shale
		Mowry Shale
Lower Cretaceous		Muddy Sandstone
		Skull Creek Shale
		all River (Dakota) Formation
		Lakota Formation
Upper Jurassic		Morrison Formation
	Upper Sundance	Redwater Shale member
	Lo	Hulett Sandstone member
		ckade Beaver Shale member
		anyon Springs Sandstone member
Middle Jurassic		Gypsum Spring Formation
Triassic		Spearfish Formation
Permian	Goose Egg Formation	Ervay Salt member
		Minnekahta Limestone
		Opeche Formation
Pennsylvanian		Minnelusa Formation
Mississippian		Madison Limestone

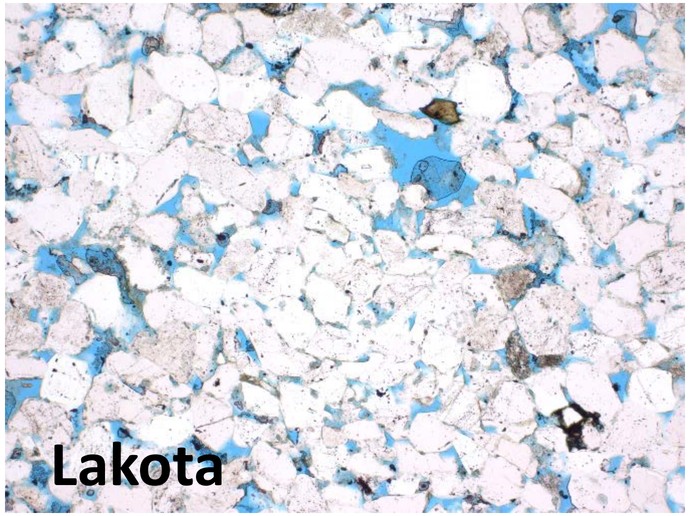
Cored Formation

	Muddy	Lakota/Fall River	Lower Sundance	Minnelusa
	12 ft, *n* 4-20%, *k .01 to* 1000 mD	60 ft, *n* 8-23%, *k .1 to* 450 mD	110 ft, *n* 2-18%, *k 38 to* 1083 mD	150 ft, *n* 6%, *k 170* mD
Formation				
Depositional Model	Channel and bar sands 	Alluvial plain and delta front 	Prograding shoreface and barrier island 	Near-shore dunes and sahbka evaporitic sea 
Challenges	• Discontinuous • Variable reservoir quality	• Variable reservoir quality • Water quality unknown	• Limited data • Water quality unknown • No core available	• Compartmentalized • Heterogeneous • Wells only pierce top

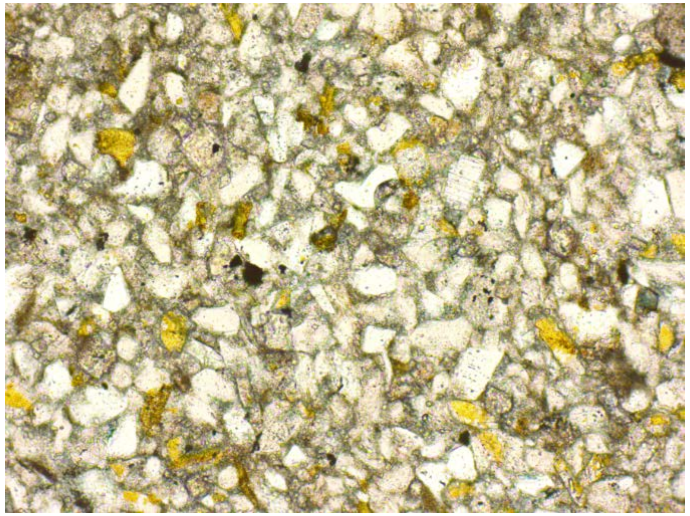
Analytical Progress: Core analysis

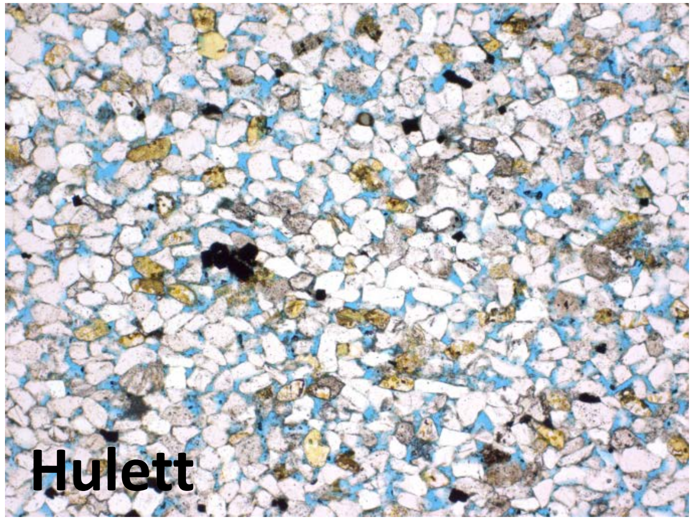
Cretaceous



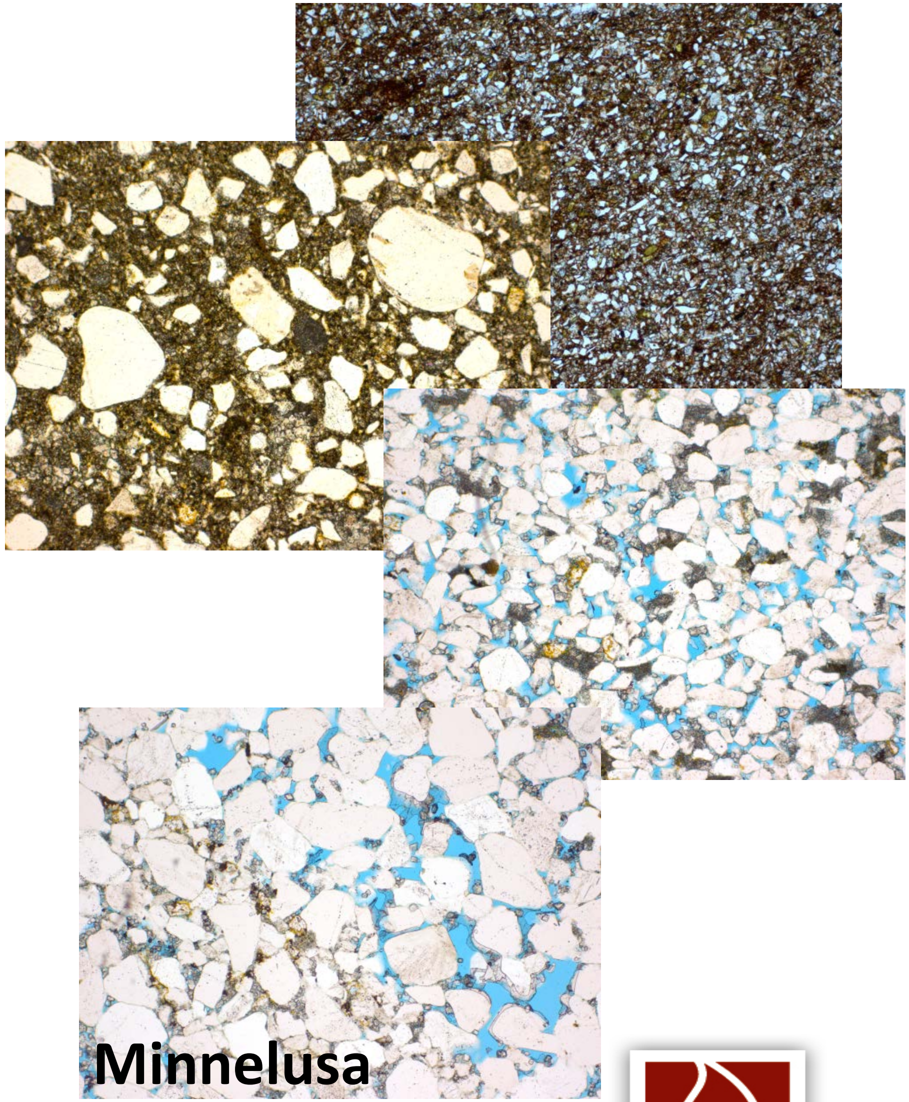


Jurassic





Paleozoic



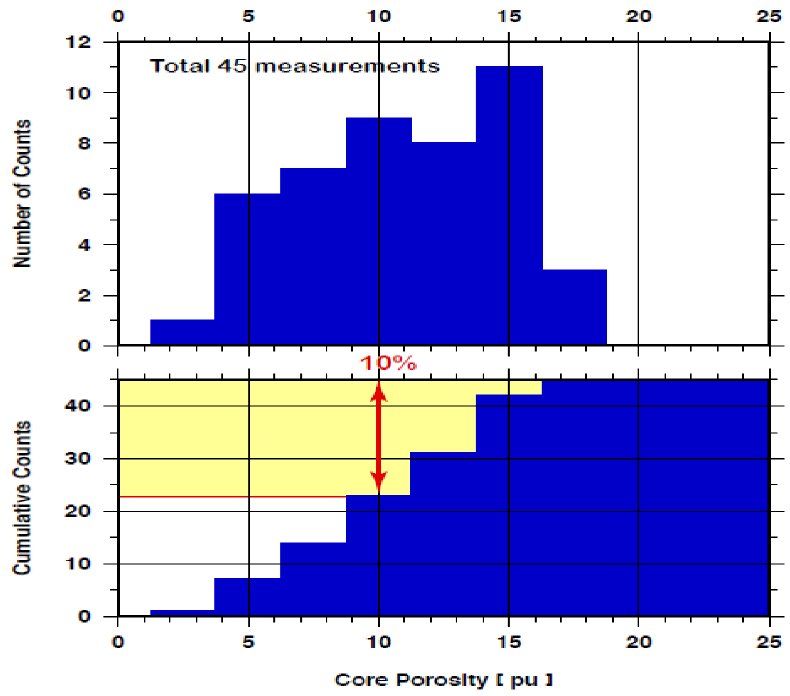
Field Operations: Sampling

Downhole Logging

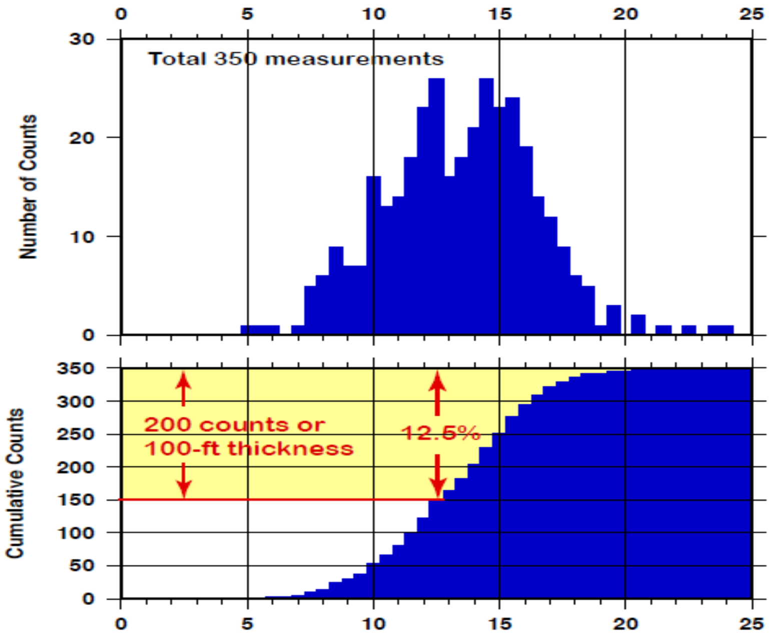
Schlumberger Log Suite
Platform Express
Caliper
Cement Volume
Array Induction With Linear Correlation
Compensated Neutron-Litho-Density
Triple Combo
Formation Micro Imager
Gamma Ray
Natural Gamma Ray Spectroscopy
Borehole Compensated Sonic
Modular Dynamic Tester
FMI HD Borehole Image Processing
Fracture Density Log with Image fracture Analysis
FMI HD Borehole Image Interpretation
Combinable Magnetic Resonance
Directional Print
General Purpose Inclinometry Tool
Shear Anisotropy Analysis with DT Compressional

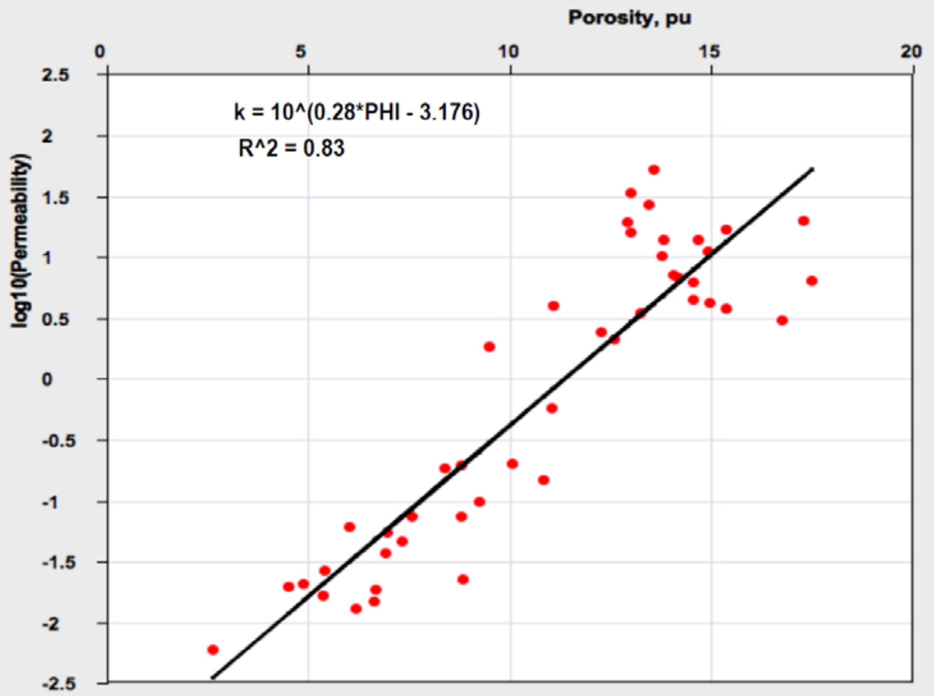
Analytical Progress: Core analysis

Core measurements

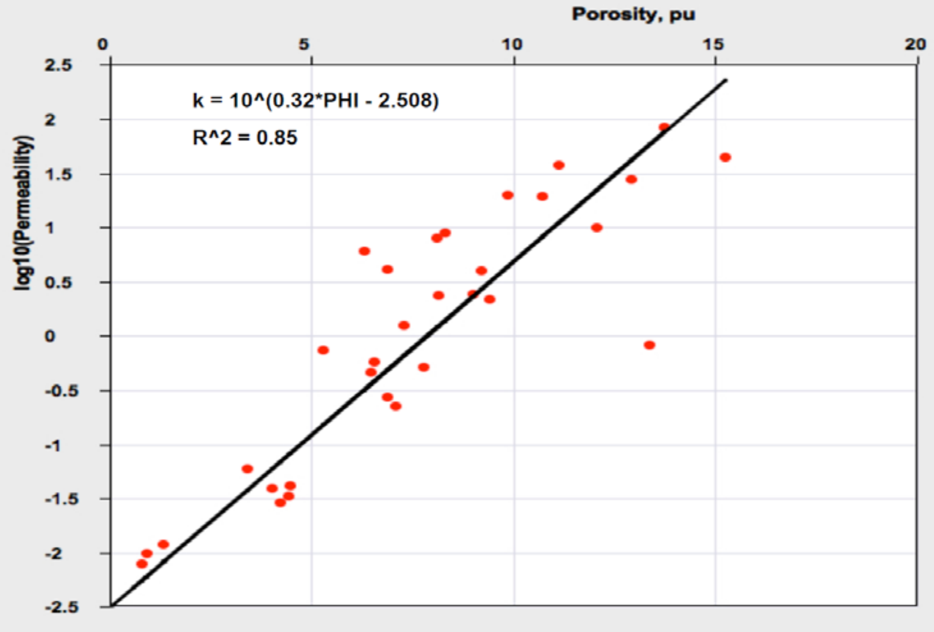


Petrophysical measurements



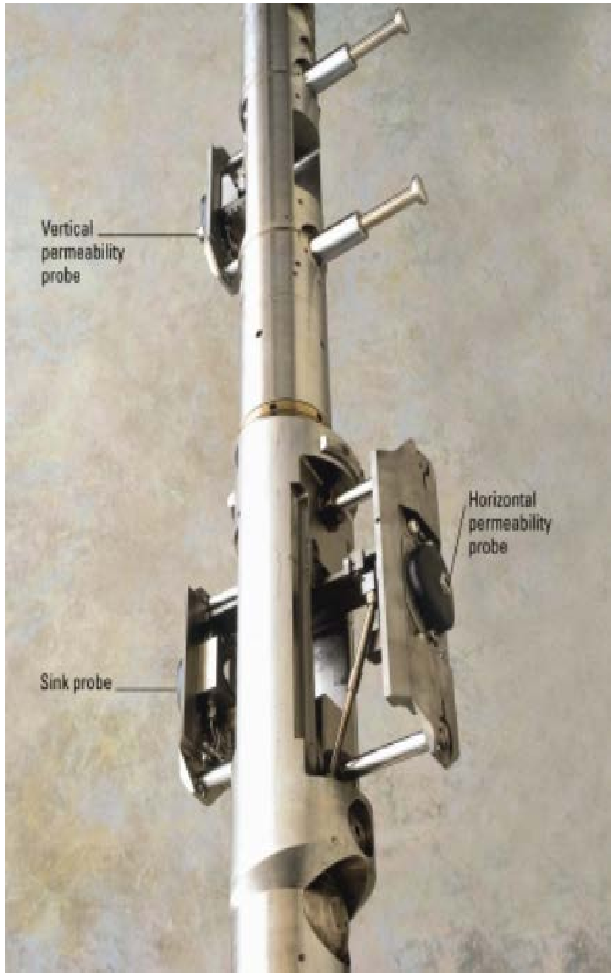


Analytical vs. measured permeability for Cretaceous-Jurassic sandstone samples



Analytical vs. measured permeability for the Minnelusa sandstones

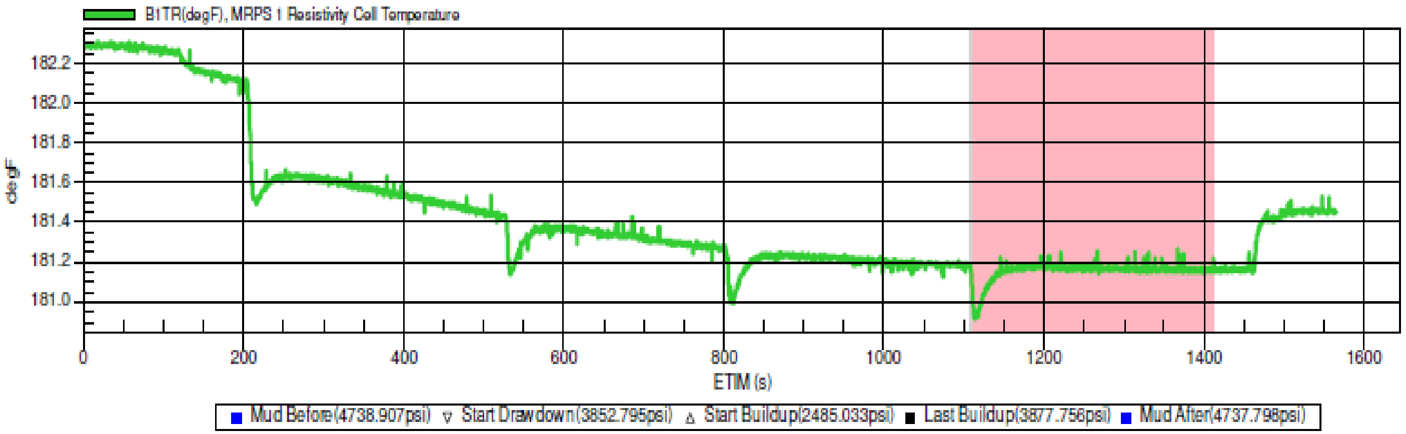
RESOURCES



Fluid sampling

- Basis of geochemical modeling
- Baseline analyses for UIC permit

Analytical Progress: Fluid data

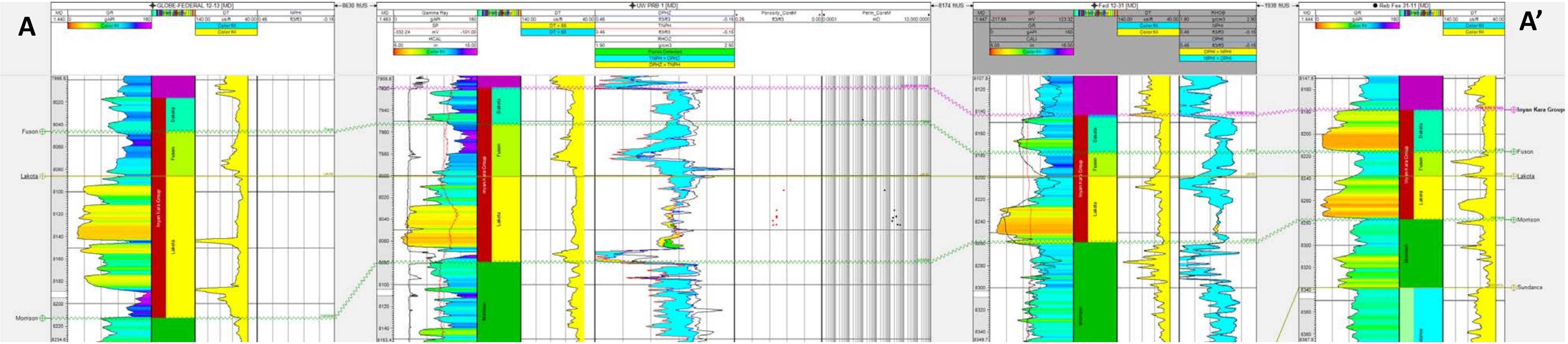


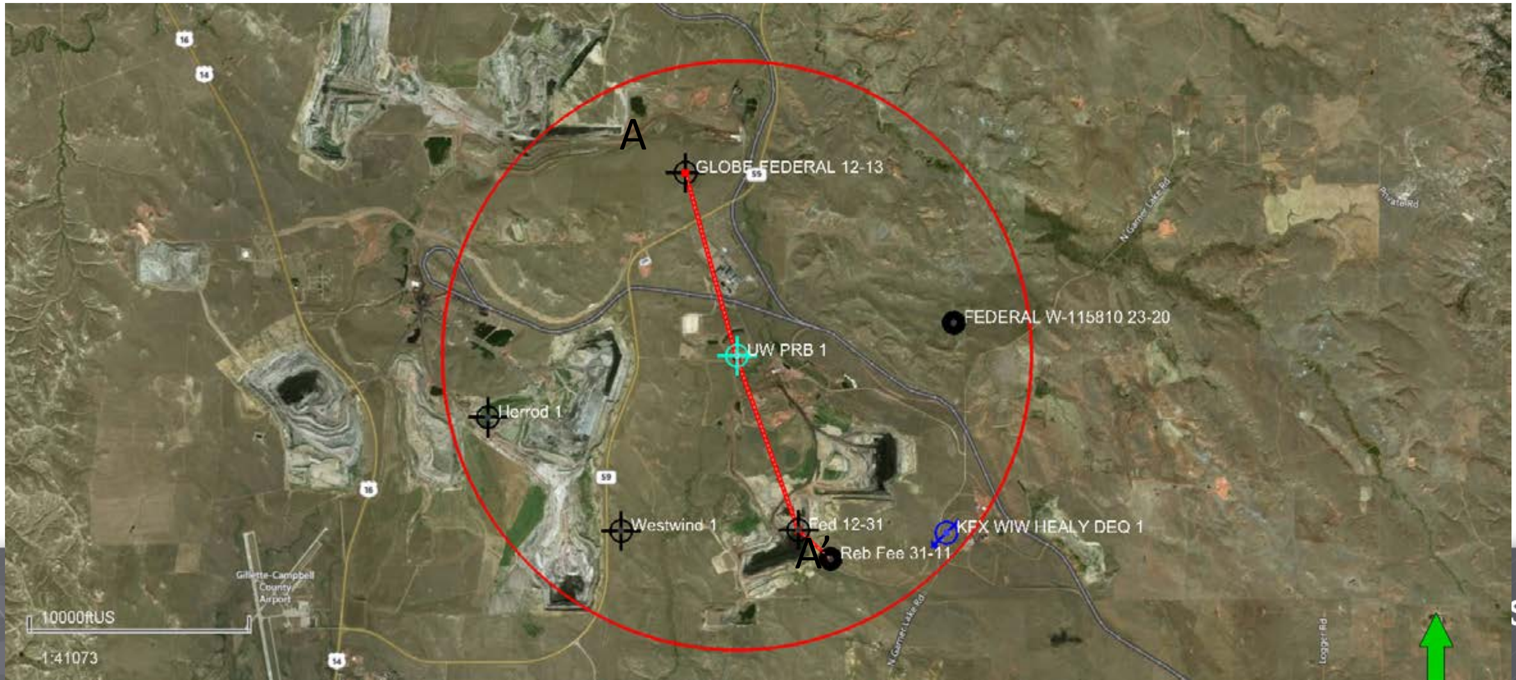
- Sampled priority reservoirs
- Resistivity, temperature and pH measurements were used in-situ to ensure representative samples
- Salinities range from 64K to 111K ppm
- All target formations meet salinity requirement for saline reservoir CO_2 injection

Sampled Formation	Depth (ft)	
Lakota Formation	*8060*	*68,659*
Hulett Sandstone	*8330*	*113,657*
Minnelusa Formation	*9380*	*110,204*
Minnelusa Formation	*9463*	*64,878*
Minnelusa Formation	*9544*	*111,180*
Minnelusa Formation (replicate)	*9544*	*110,575*

Analytical Progress: Subsurface analysis

Lakota Formation

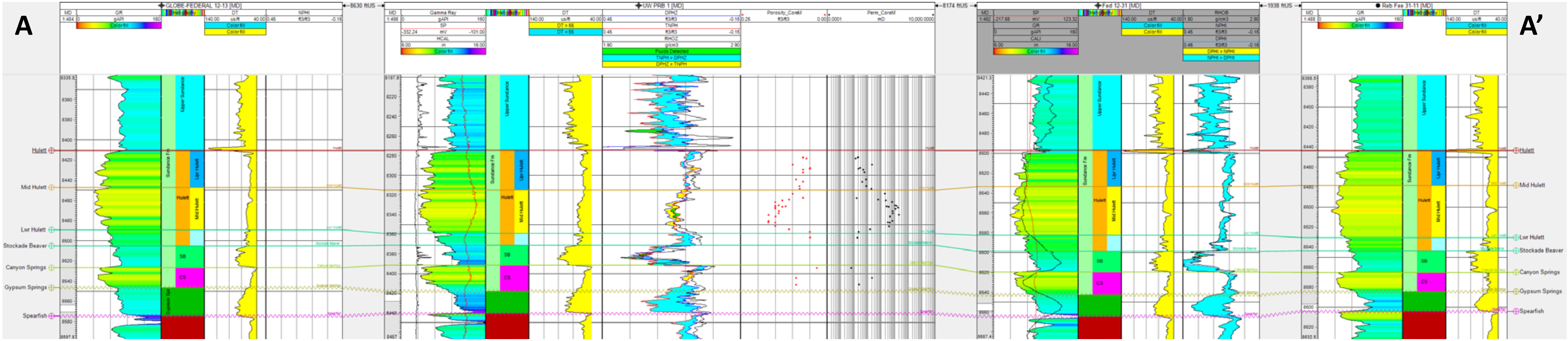


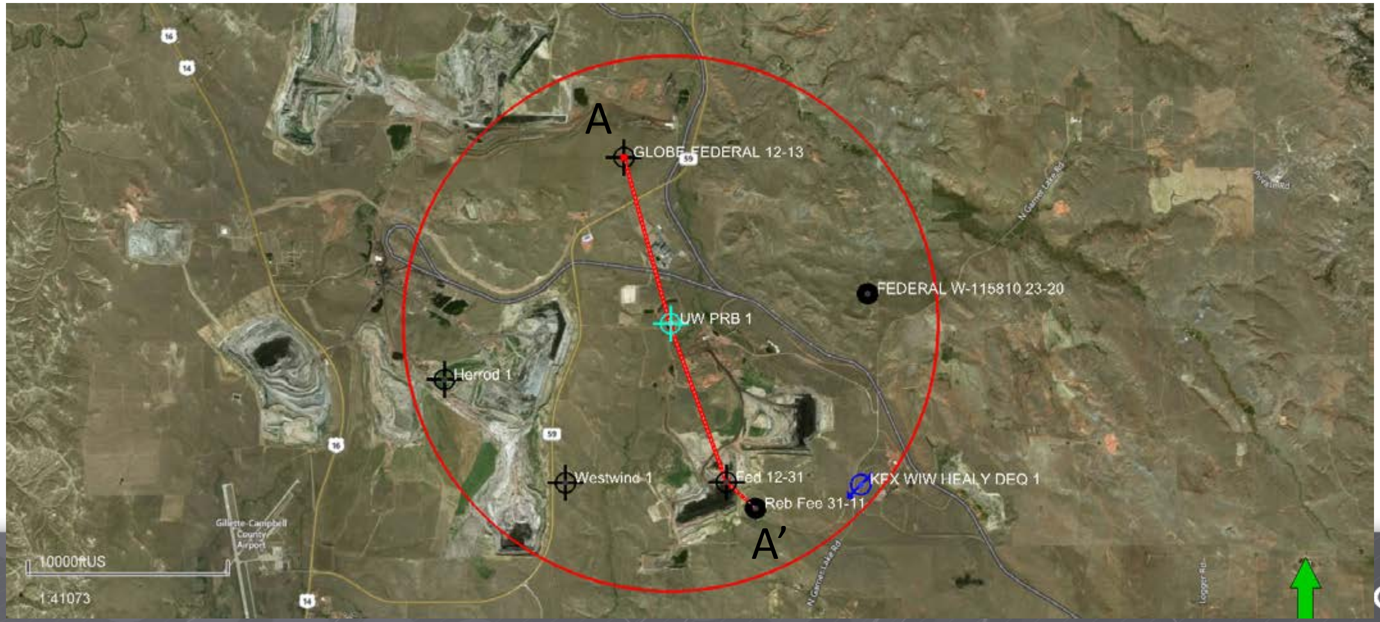


- Lakota channels are variable
- Average Φ of ~13%
- Internal flow units?

Analytical Progress: Subsurface analysis

Hulett Sandstone

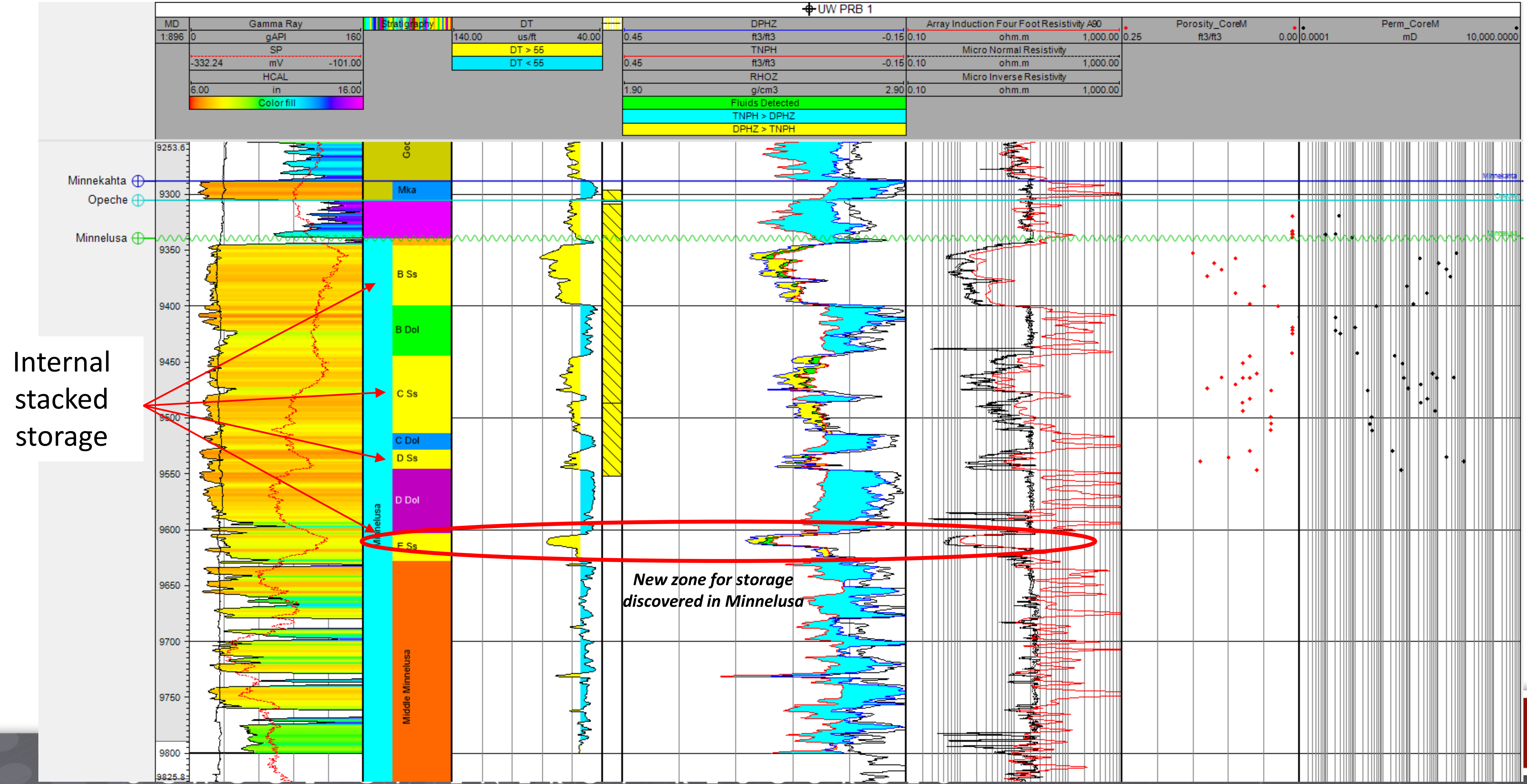




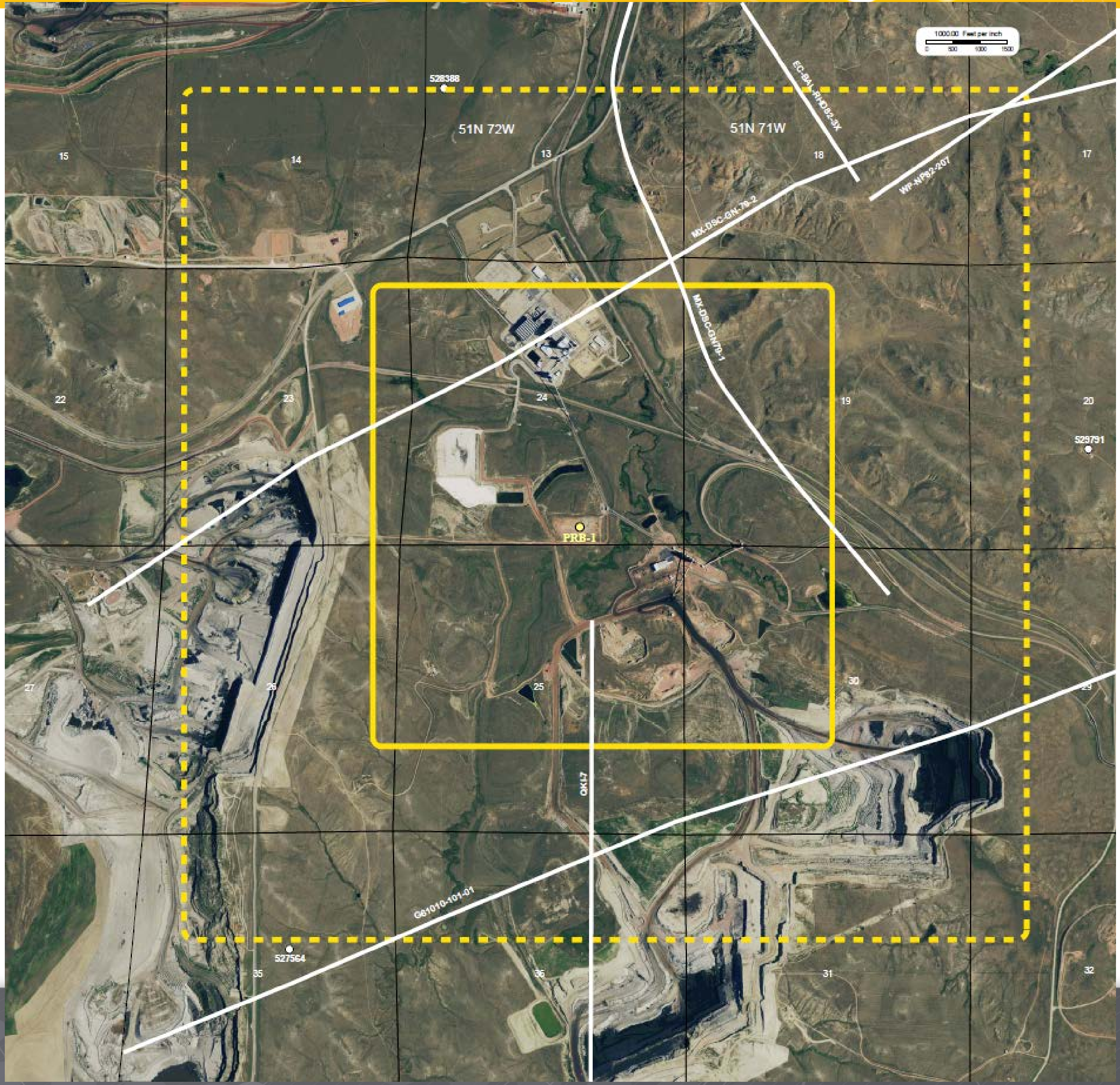
- Hulett is continuous throughout (~96 feet); seen basin-wide
- Three flow units
- The middle flow unit is the best injection target (Φ of 13%)

Analytical Progress: Subsurface analysis

Minnelusa Formation



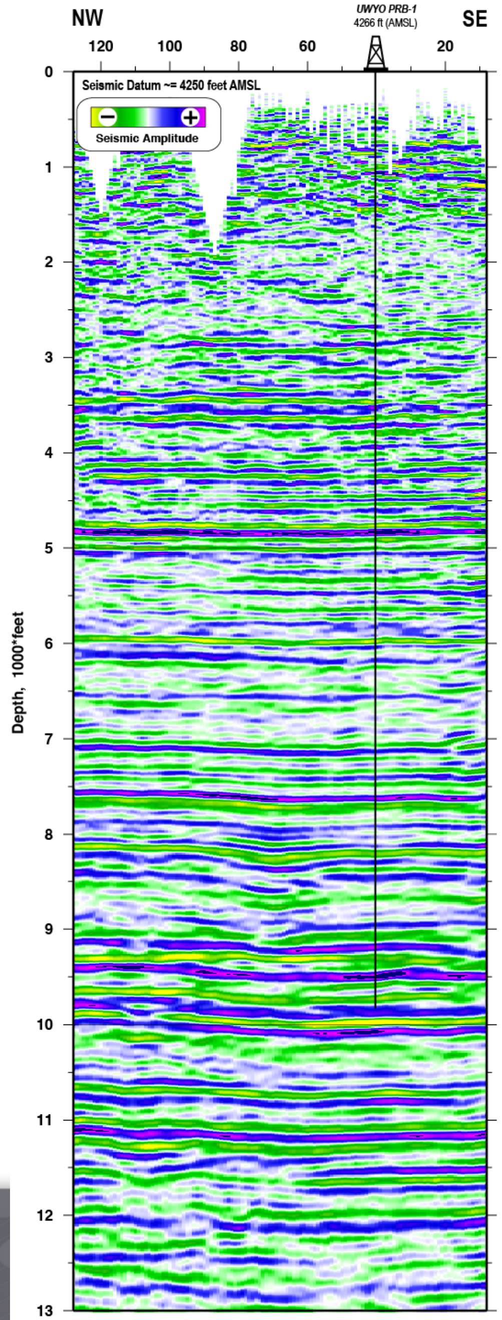
Field Operations Step 3: Seismic Survey

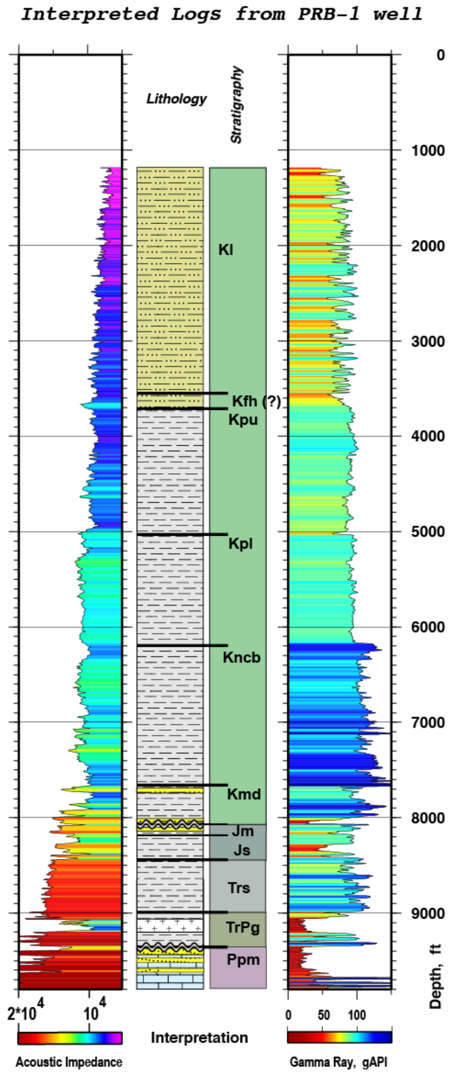


Core seismic area

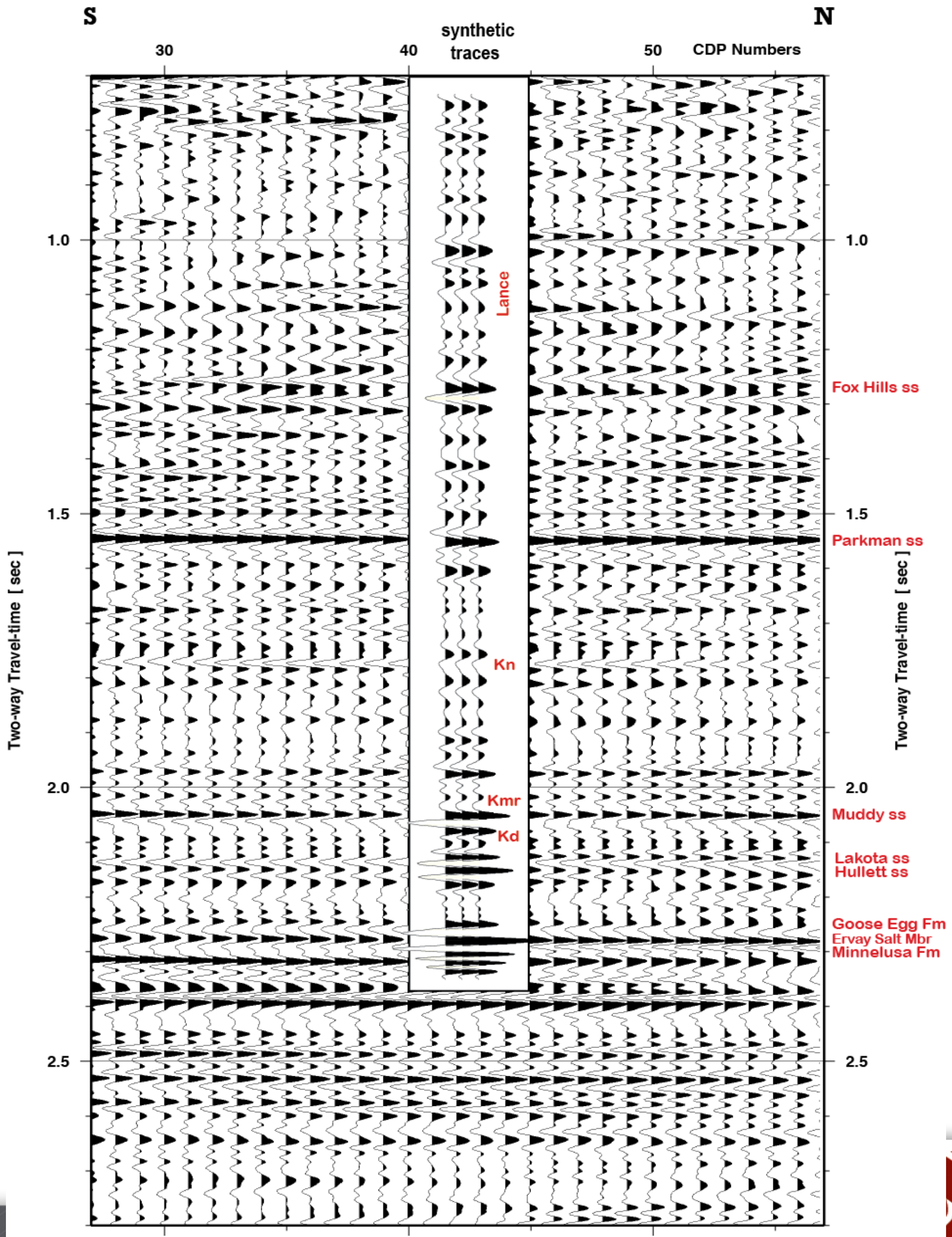
Seismic footprint

Analytical Progress: Geophysical analysis





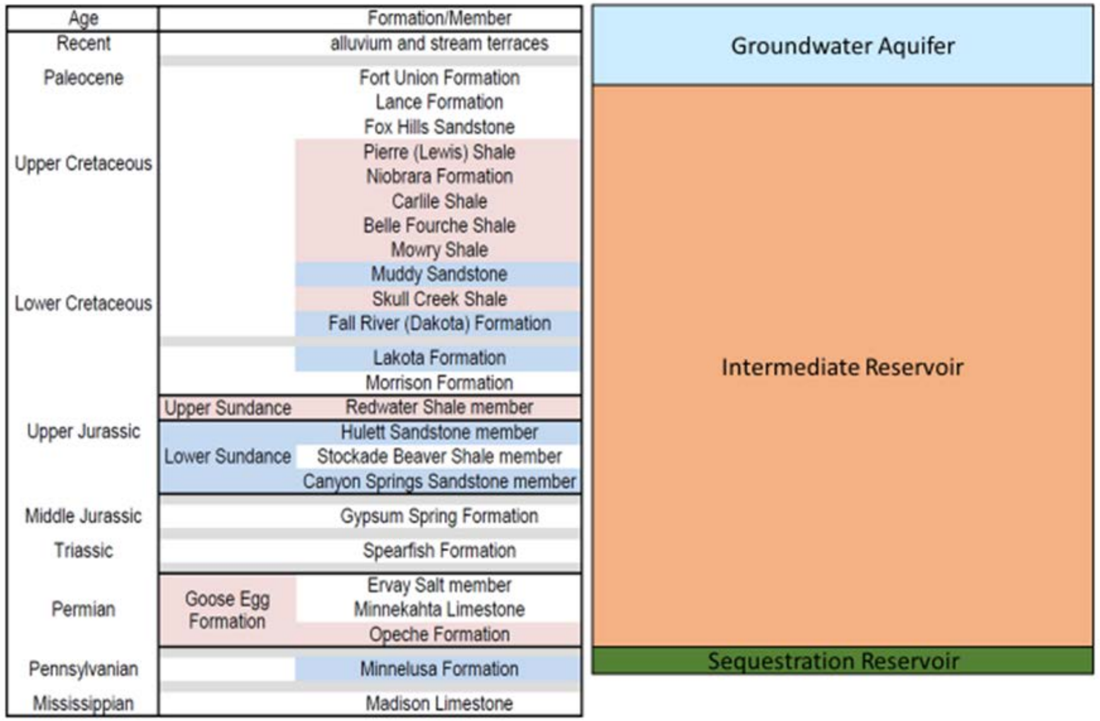
Depth converted seismic section through the central part of DFS study site along the GN79-1 seismic line with log data from the PRB-1 well (API 572720) shown along the southern edge of seismic section (3,750 ft east from the well head).

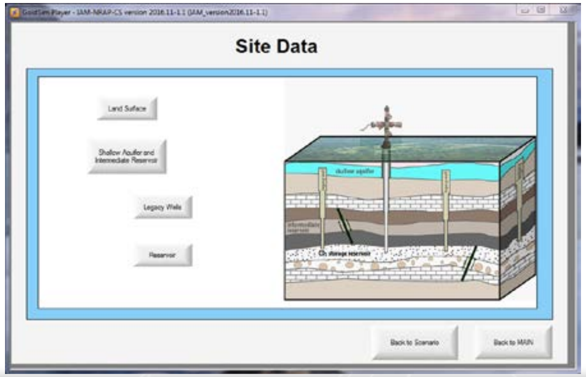


Synthetic seismogram (repeated three times in the insertion) with corresponding part of seismic section from line GN-79-1 (3,750 ft east from the PRB-1 well).

Using the NRAP-IAM tool to evaluate wellbore leakage risk at Dry Fork

- The IAM tool couples reduced order models (ROMs) in a stochastic modeling framework that allows for rapid simulations of entire system behavior over thousands of years (Pawar et al., 2017).
- Incorporates geologic, geochemical, and hydrologic data into a simplified reservoir simulation
- Considers CO_2 migration up legacy wells and subsequent leakage into intermediate reservoir, shallow aquifer and the atmosphere



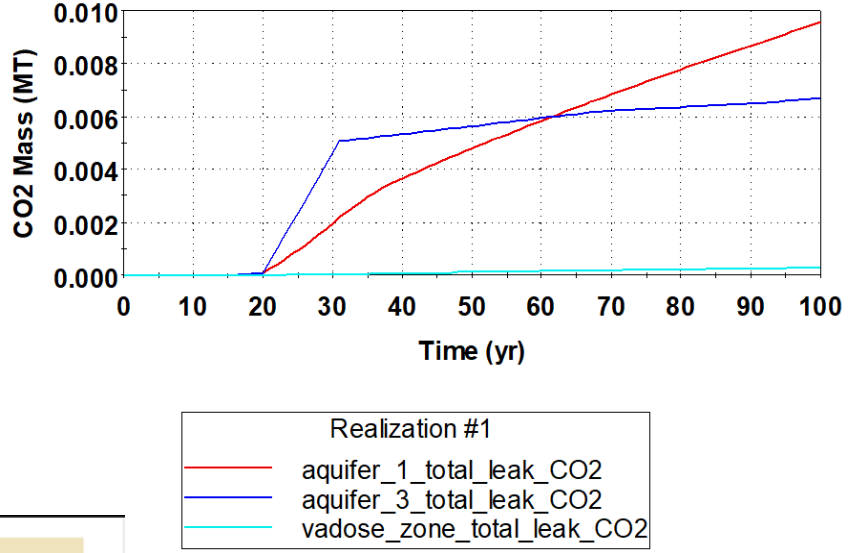


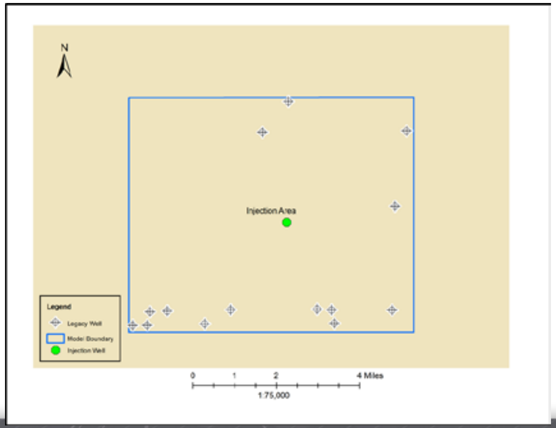
National Risk Assessment Partnership

Analytical Progress: Risk assessment via NRAP

Atmospheric Leakage Risk – Minnelusa Injection Case

- Fourteen legacy wells within the ~40 square mile area around DFS
- *Assume* a mix of uncemented wells and cemented wellbores, average cement permeability of 1 Darcy, and leakage through ALL wells
    - This likely represents a worst-case scenario
- Inject 400,000 tons of CO_2 (1-year injection) and monitor for 100 years
- Some migration of CO_2 occurs into intermediate and shallow aquifers (<2%)
- CO_2 leakage to the atmosphere is predicted to be negligible





National Risk Assessment Partnership

Wyoming's Separate CCS/CCUS Legal Regime

Wyoming law:

- ✓ Specifies who owns the pore space (Wyo. Stat. § 34-1-152 (2017))
- ✓ Establishes permitting procedures and requirements for CCS sites, including permits for time-limited research (Wyo. Stat. § 35-11-313 (2017))
- ✓ Provides a mechanism for post-closure MRV via a trust fund approach (Wyo. Stat. § 35-11-318 (2017))
- ✓ Provides a mechanism for unitization of storage interests (Wyo. Stat. § 35-11-315 (2017))
- ✓ Specifies that the injector, not the owner of pore space, is generally liable (Wyo. Stat. § 34-1-513 (2017))
- ✓ Clarifies that vis-à-vis storage rights, production rights are dominant but cannot interfere with storage (Wyo. Stat. § 30-5-501 (2017))
- ✓ Provides a certification procedure for CO_2 incidentally stored during EOR (Wyo. Stat. § 30-5-502 (2017))

Source: Wyoming Statutes

Accomplishments to Date

- Successfully implemented public outreach
  - Affirmed the community acceptance of CCS/CCUS both generally and for the Wyoming CarbonSAFE project specifically.
- Successfully permitted and drilled the Wyoming CarbonSAFE test well
- Successfully completed subsurface sampling and data collection program
- Prioritized storage targets
- Provided the first direct measurement of Φ and k of the Hulett Sandstone
- Established variable flow units within reservoirs
- Established the potential for stacked storage at the site (i.e. vertical reservoir confinement)
- EPA considerations met for Class VI permitting-saline formations, etc.
- Identified no mineral owner conflicts
- Wyoming regulations are affirmed to be suitable for commercial-scale CCS.

Lessons Learned

- Year 2 research gaps/challenges for 50 MMT feasibility.
  - We need 3D seismic to fully extrapolate well site data to field site
  - We need to understand the heterogeneities in/across reservoirs at the study site
  - We need to define the lateral continuity of flow zones
  - We need to simulate storage capacities and pressure responses to injection
  - We need to refine MVA and risk management strategies with site specific data
  - We need to refine economic models to reflect understanding of operational constraints as well as new tax and market trends

Synergy Opportunities

International Programs:

Ministry of Economy, Trade and Industry of Japan

- Japan Coal Energy Center (JCOAL) (with GreenOre Clean Tech LLC and Columbia University) titled "Carbon Capture and Utilization and Carbon Recycling Process Development" at the Wyoming Integrated Test Center

Federal Programs:

Under Fossil Fuel Large-Scale Pilots (FOA-1788) NETL's Fossil Energy group

- DE-FE0031587 titled "Large Pilot Testing of the MTR Membrane Post-Combustion CO_2 Capture Process"
- DE-FE00031583 titled "UKy-CAER Heat-integrated Transformative CO_2 Capture Process in Pulverized Coal Power Plants".

State Programs:

Wyoming Integrated Test Center

- Flue gas carbon-to-products

Governor Gordon's Low-Carbon 5MW Coal-Generating Electricity echnology

- RFP through SER

Advanced Carbon Products Innovation Center (ACPIC)

- Coal-to-products with CO_2 management

Industry Programs:

TDA Research, Inc.

- Bimodal carbon capture pilot facility (membrane and amine)

Project Summary

Wyoming CarbonSAFE is located near Dry Fork Station in the most prolific coal basin in the United States. In year one of this program, the project team successfully drilled a research well and collected the subsurface data necessary to determine feasibility of commercial-scale CCS. In addition, the project team evaluated Wyoming's regulatory CCUS framework and determined they will support a commercial-scale project.

In Year 2 of this project, the team will collect a 3D seismic survey, import this data into the site's property models, and run dynamic simulations to test the fluid capacities and pressure response to injection. These results will be used to develop a low-risk, high capacity stacked storage operational strategy, finalize the site's MVA, risk, and economic studies in an effort to prove that commercial-scale CCS at the DFS site is holistically feasible.

The DFS study site is distinct as it has nearby access to commercial CO_2 *infrastructure, on-site reservoirs for stacked saline CS, multiple* CO_2*-EOR targets, an existing* CO_2*-to-products research facility (coal-to-products as well), funded* CO_2 *capture pilot plants, CCUS-favorable regulatory framework with Class VI primacy anticipated, as well as being the location of the newest coal-fired power plant in the lower 48--which would be a pragmatic target for long-term CCS technology implementation. Each of these factors bolster the site's feasibility for successful CCS/CCUS, meeting the primary objective of Phase II of the CarbonSAFE program.*

Wyoming CarbonSAFE Team

Meet the team

Thank you. Any questions?

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Appendix

Benefit to the Program

(a) *Controlling CO_2 Emissions*: By taking advantage of the PRB's favorable environment for large-scale geologic storage and synergies associated with the co-located ITC, this project should result in the eventual storage of over 50 Mt of CO_2 from a coal-fired utility in the PRB, a major U.S. coal supply region. (b) *Advancing the R&D Void Associated with the Characterization and Permitting of a Commercial-Scale Storage Complex*: The project's integration of data from the new test well, new 3-D seismic survey and purchased 2-D seismic survey with existing PRB datasets will advance scientific knowledge regarding extending initial site characterization to the commercial scale by, for example, extrapolating and interpreting data in stacked storage environments in the immediate vicinity of a coal-fired power plant. Making use of the team's expertise in regulatory matters under federal and Wyoming law, the project will advance best practices regarding: (1) Class VI permitting of commercial-scale storage projects; (2) project economics; (3) methods to reduce project technical and nontechnical risks to facilitate commercial financing; and (4) meaningful community outreach. (c) *Advancing DOE's Carbon Storage R&D Program Goals*. The project supports DOE's four Carbon Storage R&D Program goals. *Goal #1* (ensuring 99% storage permanence) will be addressed by site selection, development of a robust MVA plan and characterization of stacked storage with redundant competent confining units. *Goal #2* (improving storage efficiency and containment effectiveness) will be addressed through stacked storage, pressure management and the use of results from ongoing research at UW's High-Bay Research Facility, a world-class laboratory for fluid flow, including CO_2 through porous media including. *Goal #3* (supporting predicted storage capacity) will be supported by leveraging and validating the U.S. Department of Energy's National Risk Assessment Partnership risk assessment tools with traditional reservoir models and newly integrated site characterization data. *Goal #4* (best practices) will be supported by documenting the project's learnings and public dissemination of research results.

Project Overview

Goals and Objectives

Wyoming CarbonSAFE Project Objectives: To investigate the feasibility of establishing a commercial-scale (50+ million metric tons (Mt) of carbon dioxide (CO2)) geological storage complex in Wyoming's Powder River Basin (PRB) in the immediate vicinity of Basin Electric Power Cooperative's (BEPC) coal-fired Dry Fork Station (DFS).

The study will investigate stacked storage within four PRB stratigraphic units of varying lithology and depositional environments. Specific technical objectives include:

(1) evaluating storage complex feasibility using stacked storage and pressure management;
(2) identifying technical and non-technical risks that have the potential to prevent the storage complex from serving as a commercial storage site;
(3) developing site-specific commercial-scale approaches to MVA;
(4) generating analyses and approaches to support UIC Class VI well permitting in Wyoming;

Specific nontechnical objectives include:

(1) further refining a commercial-scale economic model and with regional financing approaches;
(2) preparing model project agreements;
(3) completing a regulatory analyses in support of Class VI well permitting, stored CO_2 liability management and the acquisition of pore space;
(4) preparing a CO_2 management strategy centered around DFS while considering regional sources;
(5) developing and implementing a dynamic public outreach plan;

Project Overview

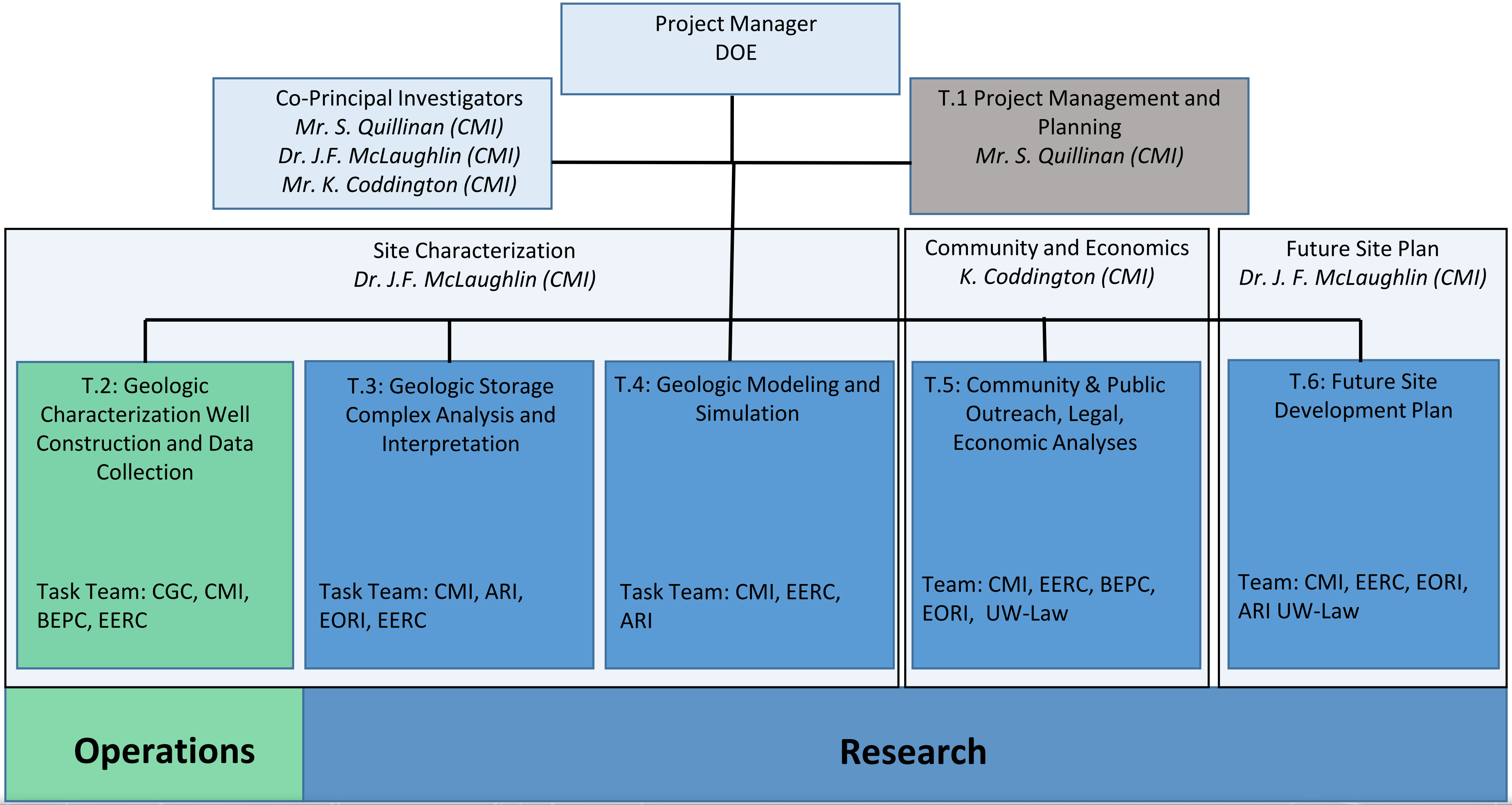
Goals and Objectives

Success criteria: In Year 1, the project team successfully met all of the project's milestones, deliverables and Go/No-Go success criteria. Success criteria were dependent on permitting and operational success, obtaining public support, successful data collection, and all-partner collaboration.

Milestone	Milestone Title	Planned Completion Date	Verification Method
M1	Kick-off meeting	11/06/2018	Attendance at meeting; Presentation file
M2	Outreach Workshop	06/01/2019	Summary description provided in quarterly report
M3	Initiate drilling characterization well	06/01/2019	Summary description provided in quarterly report
M4	Collect geologic core from target formations	04/01/2020	Summary description provided in quarterly report
M5	Identification of Class VI permitting requirements	07/31/2019	Summary description provided in quarterly report
M6	Perform Geologic Modeling to meet Class VI recommendations	05/30/2020	Summary description provided in quarterly report
M7	Plan for MVA including Phase III Baselining	07/31/2020	Summary description provided in quarterly report

Decision Point	Go / No-Go?	Circumstances Affecting the Decision	Objective Success Criteria	Coincide with a Milestone?
Permitting	Yes	One or more permits could be denied. The team might not have time to remediate and resubmit	Receive all necessary permits and approvals on or about 05/31/2019	No
Drilling	Yes	Technical challenges, mechanical failures, drilling speed, environmental protection, costs.	Complete the well in target zone(s) on budget on or about 08/31/2019	Milestone 3
3-D Seismic	No	The seismic impedance of the layers, estate permission, technical challenges and equipment availability.	Collect the full 12.25 mi^2 seismic on or about 01/31/2020.	No

Organization Chart



Gantt Chart

								Budget Period 1												Budget Period 2											
Timeline		Task Dependency						2018				2019												2020							
Task	Description	1	2	3	4	5	6	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
1	**Project Management and Planning**																														
1.1	Project management plan							D1																							
1.2	Reporting																														D2,3,4
1.3	Project management																														
1.4	Collaborative meetings																														
1.5	Kick-off meeting									M1																					
2	**Geologic Characterization Well Construction and Data Collection**																														
2.1	Permitting and approval	x																													
2.2	Site-preparation and logistics	x																													
2.3	Drilling	x															M3														
2.4	Sampling and logging	x																													
2.5	Conduct 3-D seismic survey	x																													
2.6	Evaluation of test well reuse and site closure	x																													
3	**Geologic Storage Complex Analysis and Interpretation**																														
3.1	Reservoir and seal rock analysis	x	x																									M4					D5
3.2	Formation fluid analysis and CO_2/brine/rock reaction modeling	x	x																												
3.3	Well log interpretation	x	x																												
3.4	Seismic processing and interpretation	x	x																												
3.5	Geomechanical characterization	x	x																												
4	**Geologic Modeling and Simulation**																														
4.1	Update geologic models	x	x	x																											
4.2	Perform CO_2 injection simulations	x	x	x																									M6, D6			
4.3	Perform CO_2-water-rock reactive transport modeling	x	x	x																											
4.4	Site performance assessment using NRAP-IAM-CS	x	x	x																											
4.5	Comparison of NRAP tools	x	x																												
5	**Community & Public Outreach, Legal, and Economic Analyses**																														
5.1	Community & public outreach	x			x												M2														D7
5.2	Legal and regulatory analyses	x			x																										
5.3	Economic analyses	x			x																										
6	**Future Site Development Plan**																														
6.1	Class VI permitting analysis	x			x	x												M5													
6.2	Develop a MVA plan	x																												M7	
6.3	Focused wellbore analysis	x																													
6.4	Risk assessment and mitigation	x			x																										
6.5	Statewide CO_2 interoperability assessment	x																													
6.6	Plans for Phase III Site Characterization	x	x	x	x	x																									D8

Bibliography

- Nothing to report