CarbonSAFE Wyoming: Integrated Commercial Carbon Capture and Storage (CCS) Prefeasibility Study at Dry Fork Station, Wyoming

SCHOOL OF ENERGY RESOURCES

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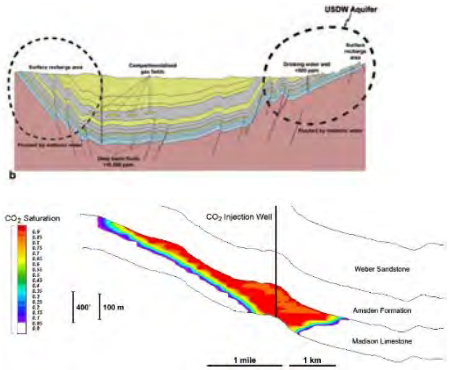
University of Wyoming

2018 Mastering the Subsurface through Technology Innovation, Partnerships and Collaboration

Project Overview: Goals and Objectives

Identify (Economic) Saline Storage proximal to the Dry Fork Power Station

a. "Establish a CCS Coordination Team"
b. "Develop a Plan to Address Challenges of a Commercial-Scale CCS Project"
c. "High Level Technical Sub-Basinal Evaluation and CO_2 Source Assessment"



Meet the team

- *University of Wyoming's (UW) Carbon Management Institute*
- *Basin Electric Power Cooperative (Dry Fork Station)*
- *Wyoming Infrastructure Authority (WIA)/ ITC*
- *Energy & Environmental Research Center (EERC)*
- *Advanced Resources International, Inc. (ARI)*
- *Wyoming Municipal Power*
- *Office of the Wyoming Governor*
- *UW's Enhanced Oil Recovery Institute (EORI)*
- *UW's Center for Energy Economics & Public Policy*
- *UW's College of Law*
- *Schlumberger*
- *KKR*
- *Carbon GeoCycle*

Team members at Dry Fork Station

CarbonSAFE Dry Fork: Primary CO_2 Source

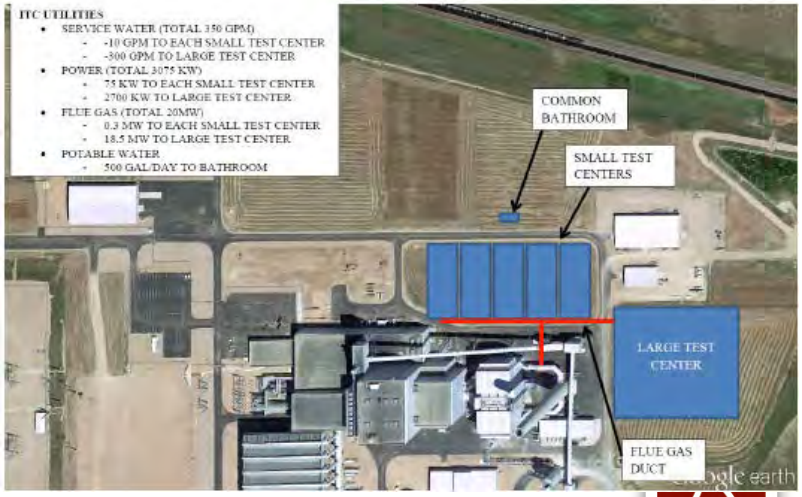
- Dry Fork Station (Basin Electric Power Coop)
- Wyoming Integrated Test Center (WY-ITC)

Dry Fork Station

- ✓ Built in 2007
- ✓ 385 MW Power Plant
- ✓ 3.3 Million tons of CO_2/year

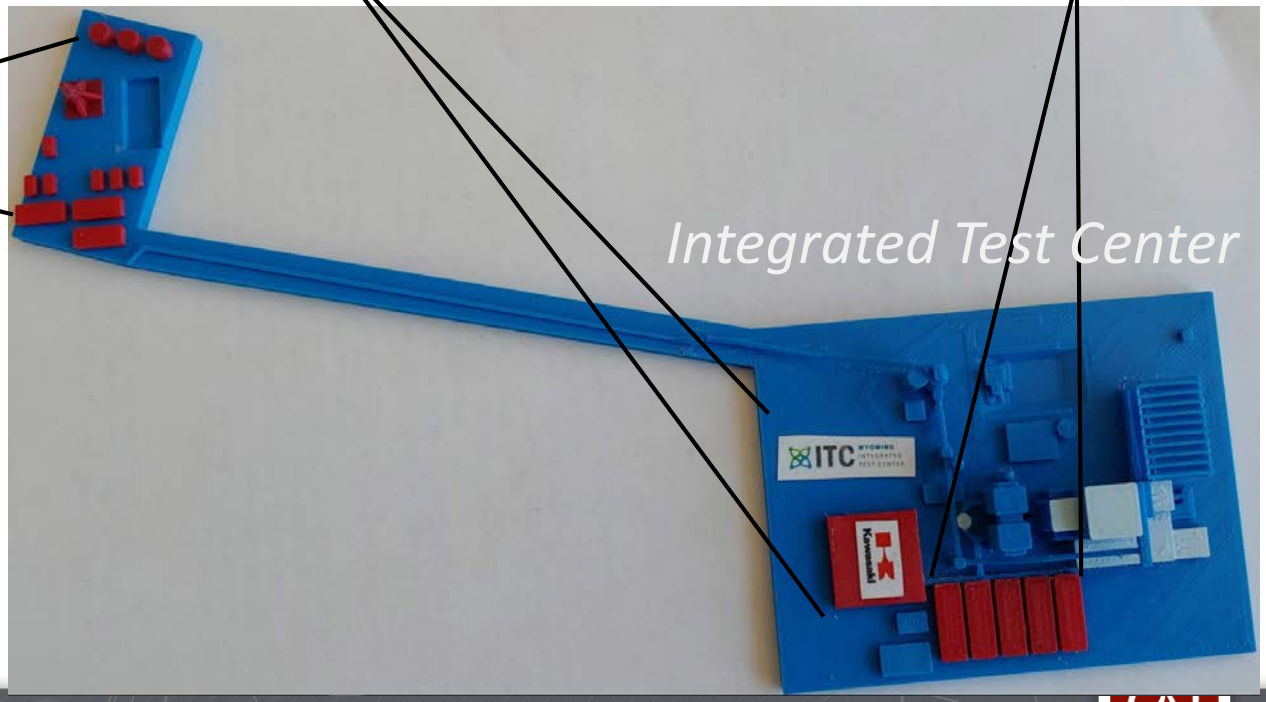
WY-ITC

- ✓ Completed 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)



Synergies with the Wyoming Integrated Test Center

CarbonSAFE
Phase II



Favorable Economics

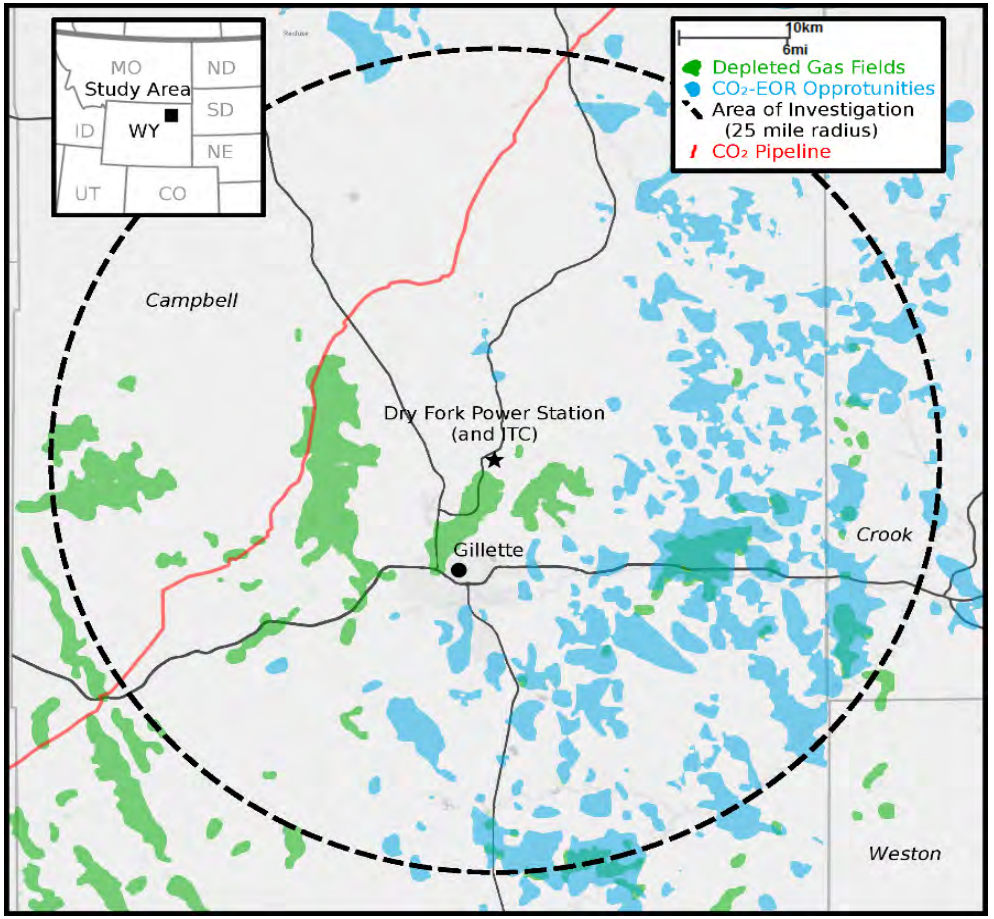
Project scenario:

Storage

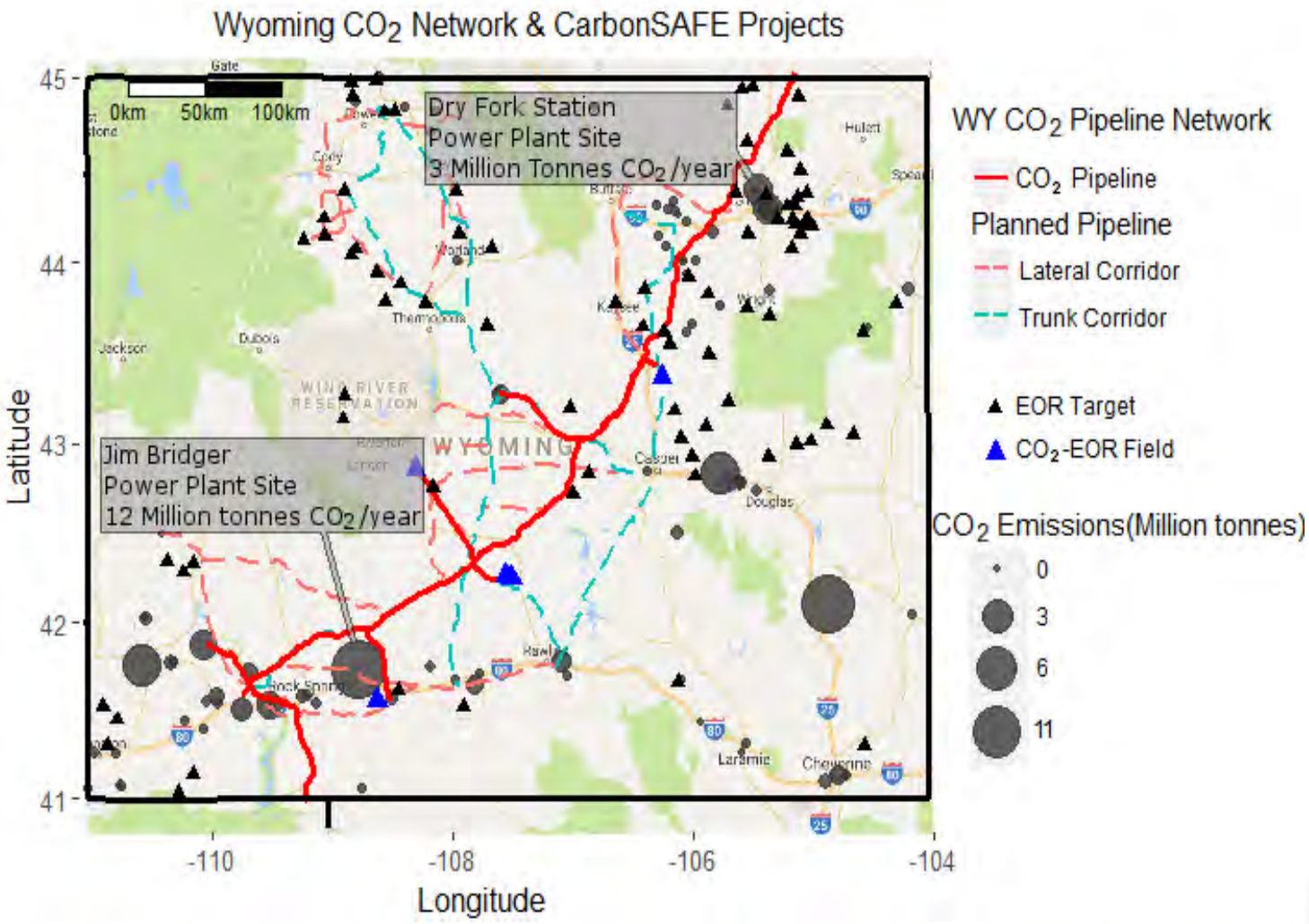
- **Saline reservoirs**
- CO_2-EOR opportunities
- Depleted gas fields

Favorable Economics

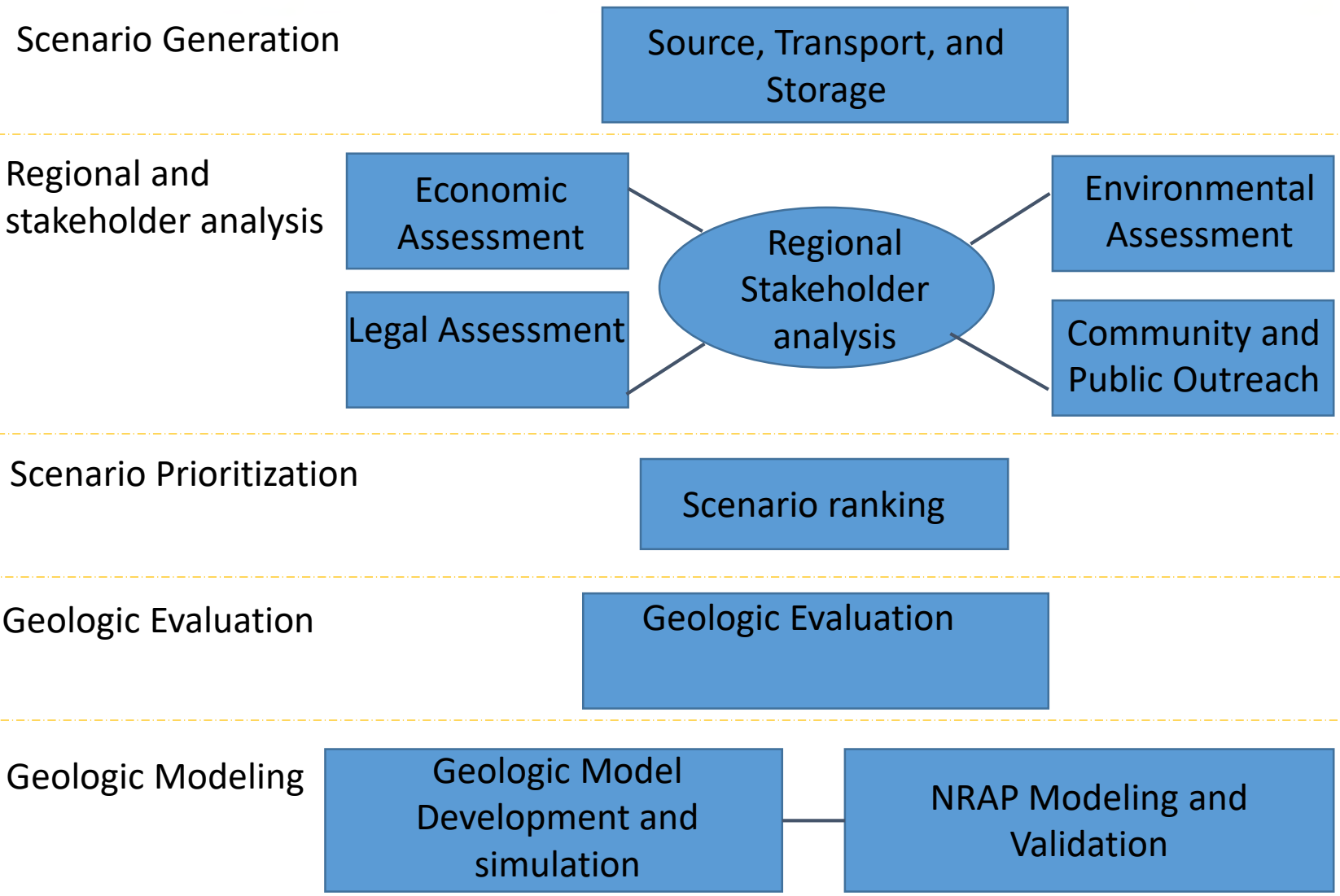
- Co-location of coal supplies CO_2 source, CO_2 transport, EOR, and CO_2 storage opportunities
- ITC
- Use of existing pipelines for utilization off-site



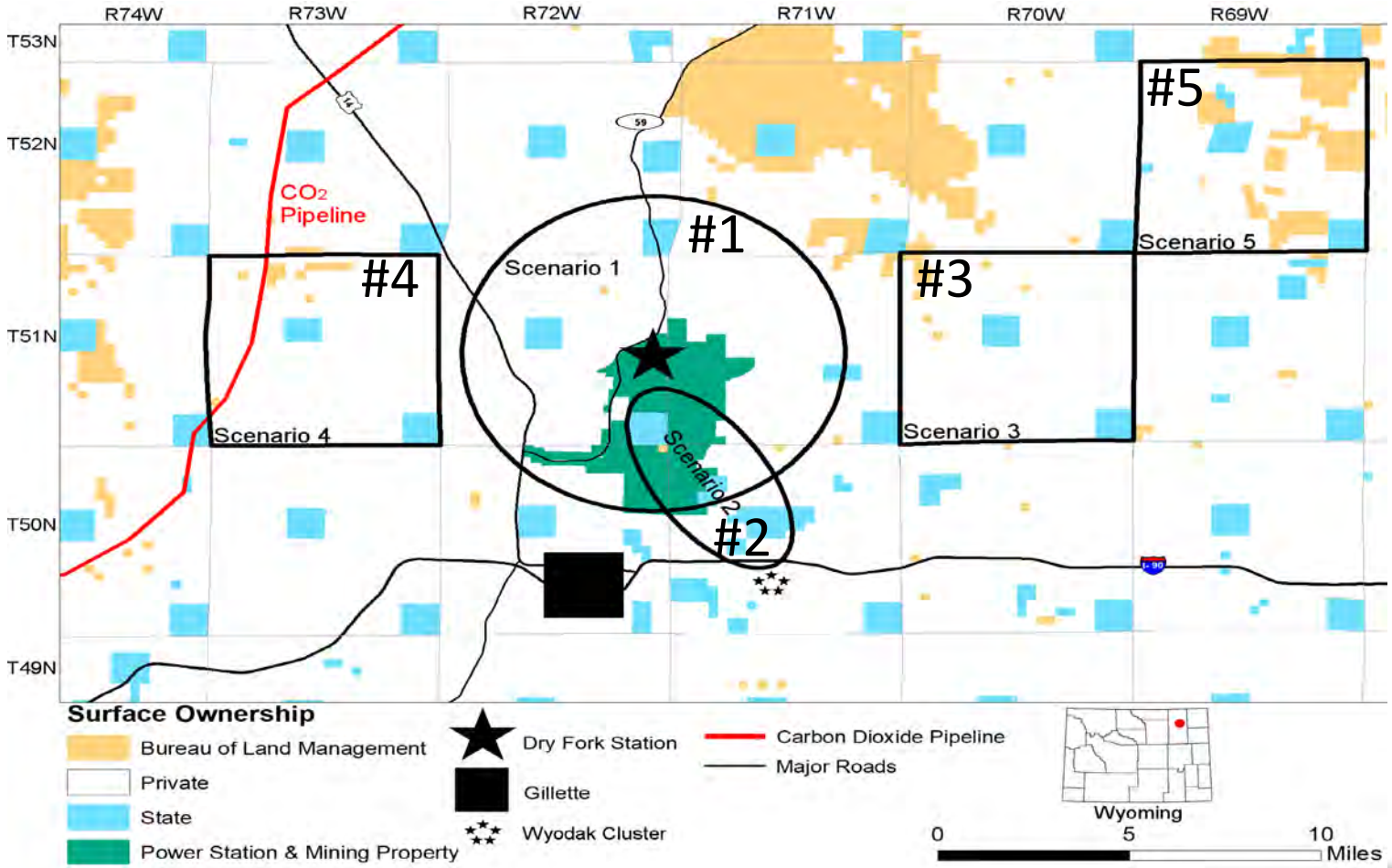
Synergies: CarbonSAFE Prefeasibility Phase I



Dry Fork Prefeasibility Project Map and Methodology



Scenario Generation



Summary Regional and Stakeholder Analysis – Phase 1

Environmental Analysis

- ✓ Protected Species
- ✓ Migration Corridors
- ✓ Wetlands and streams
- ✓ Groundwater
- ✓ Air Quality
- ✓ Protected Areas
- ✓ Cultural Resources
- ✓ Population Centers
- ✓ Slope Stability

Economic modeling

- ✓ Commercial project costs (CAPEX and OPEX)
- ✓ Revenue sources
- ✓ Infrastructure costs for future project phases (Various well types and the 3-D seismic survey)

Ownership

- ✓ Pore Space ownership
- ✓ Mineral Ownership
- ✓ Land Surface Ownership

Public Outreach

- ✓Wyoming State Agencies (WDEQ, WOGCC)
- ✓Gov. Mead's Office, State and local representatives
- ✓Public outreach plan

Legal Analysis

- ✓ Review of Wyoming CCUS laws

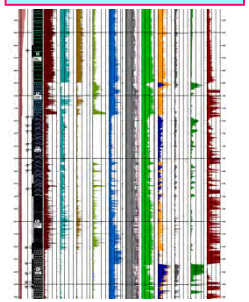
Geologic Evaluation: Geologic Reservoir Candidates

Geologic Evaluation preformed in – Phase 1

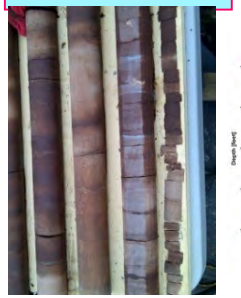
- Refine and rank the source, storage and transportation scenarios
- Collect core, outcrop, log and fluid data to inform geologic models and sealing capacity
- Wellbore analysis to determine seal integrity
- Begin/refine geologic modeling for each of the identified scenarios
- Define storage potential for the highest priority reservoirs
- Determine the extent of the CO_2 and pressure plume

Field Work

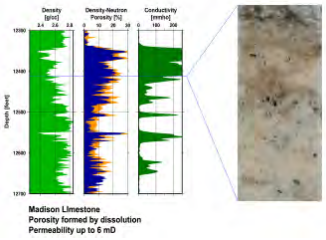
Log Analysis



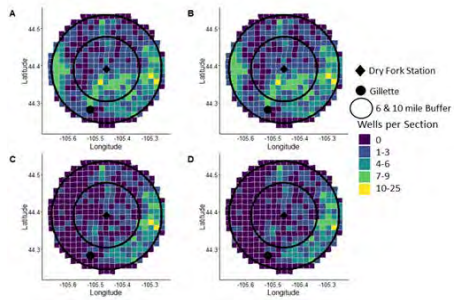
Core Analysis



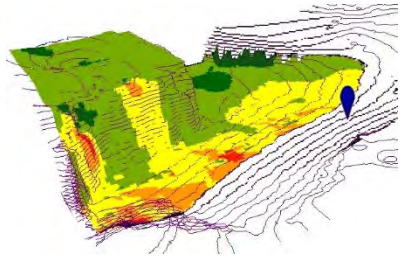
Petrographic Study



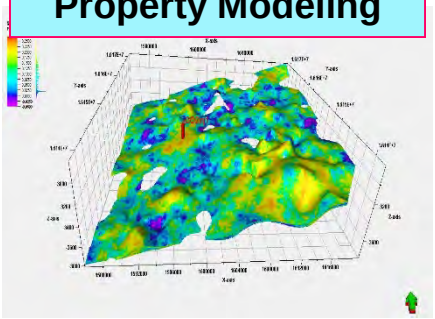
Wellbore Analysis



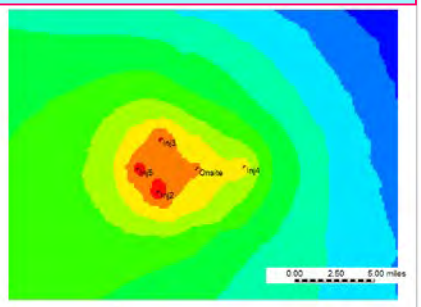
Hydrostratigraphy



Property Modeling



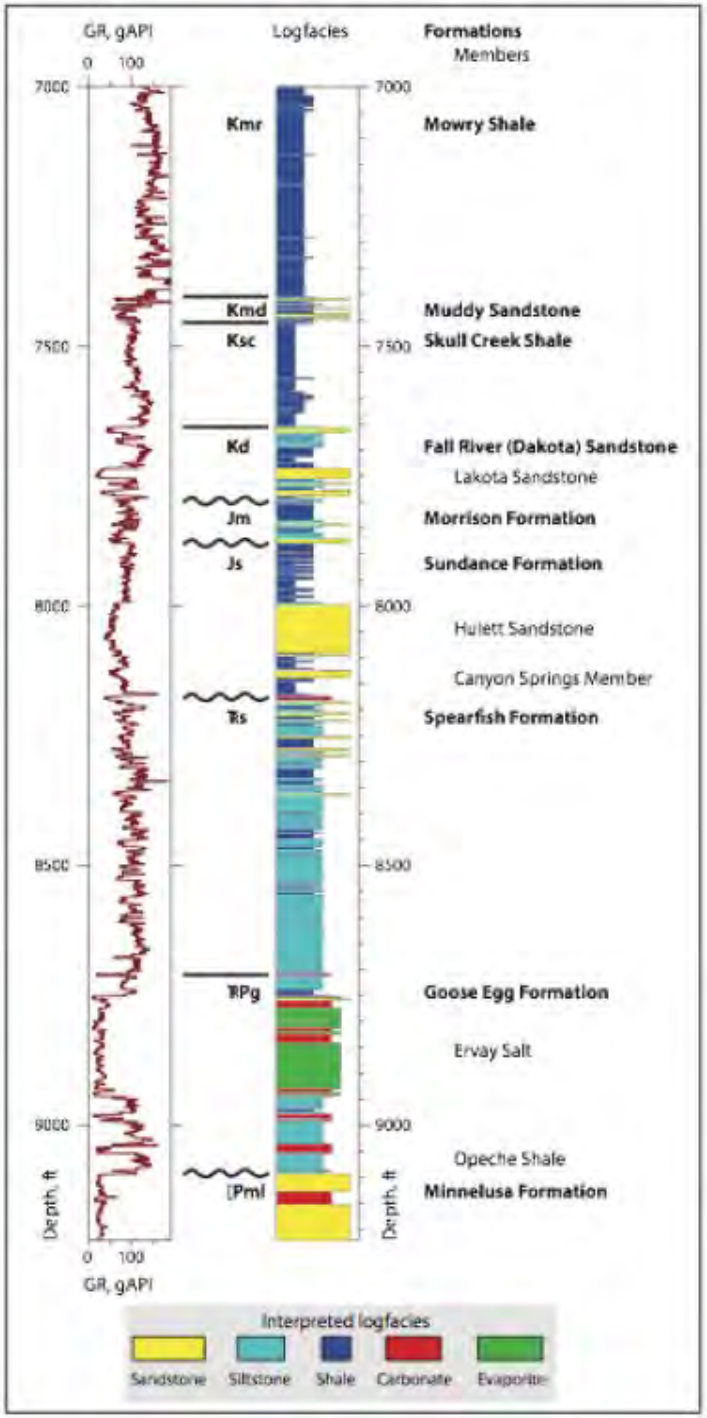
Numerical Simulation



Geologic Evaluation:

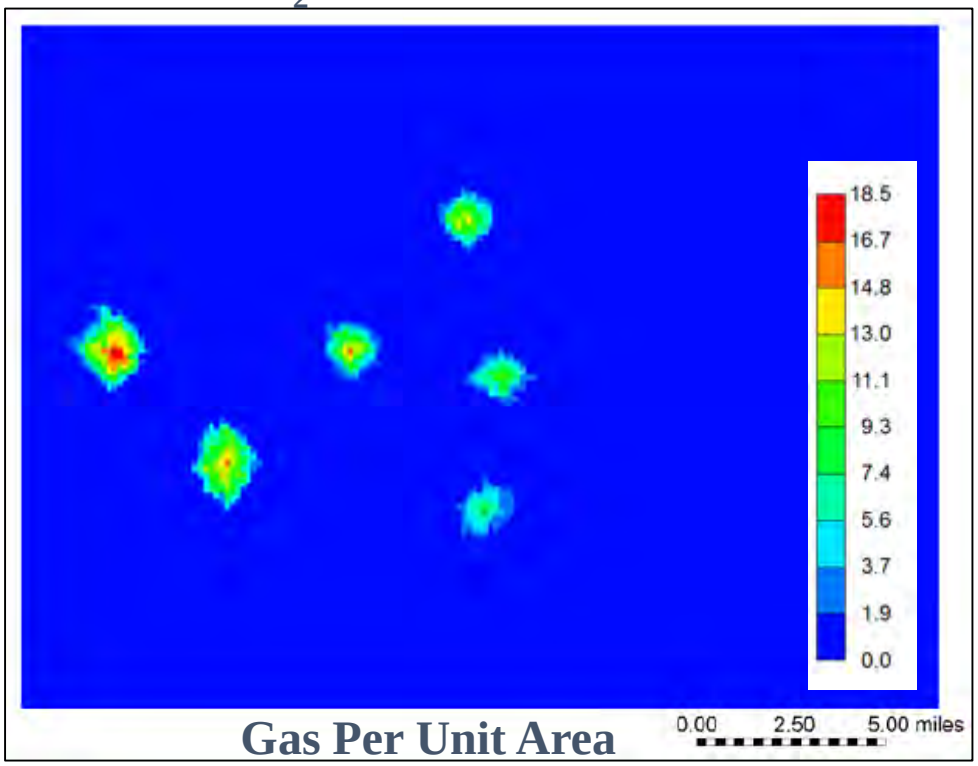
Storage Capacity Estimates

Target Formation	Φ_{avg} (%)	k_{avg} (mD)	Average Thickness (ft)	Storage Volume (Mt/mi^2)		
				P10	P50	P90
Minnelusa	13%	44	150	0.84	1.6	2.7
Lwr. Sundance	10%	220	110	0.47	0.89	1.5
Lakota/Fall River	15%	100	70	0.45	0.85	1.5
Muddy	9%	0.05	10	0.04	0.07	0.1
Total				**1.8**	**3.4**	**5.8**

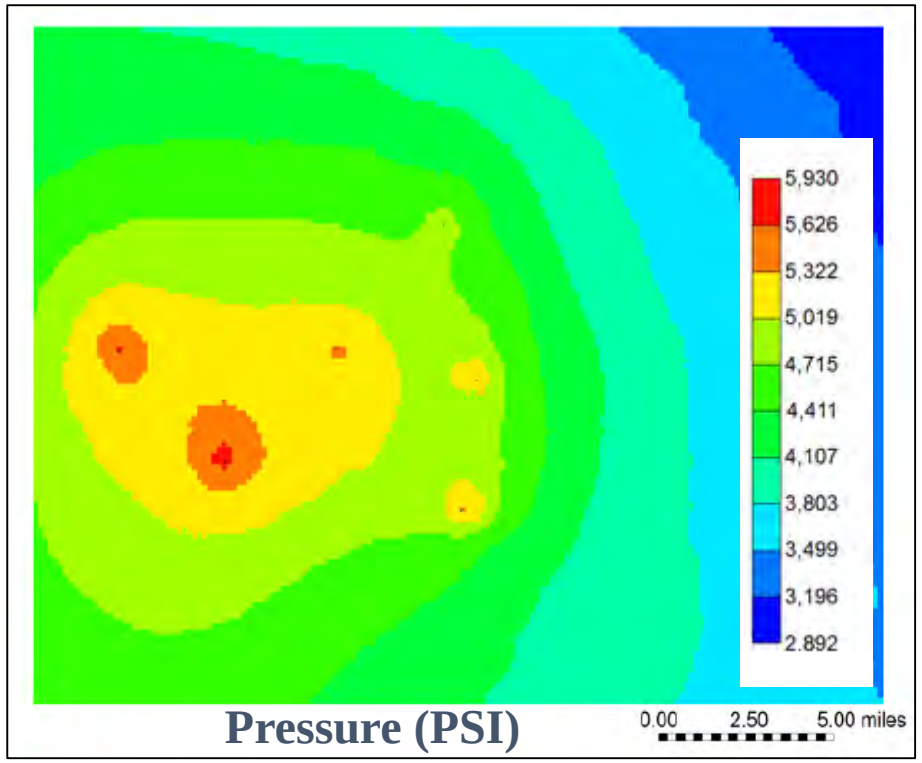


Injection Models: 50Mt in 25 years (6 Vertical Injectors)

CO_2 Saturation

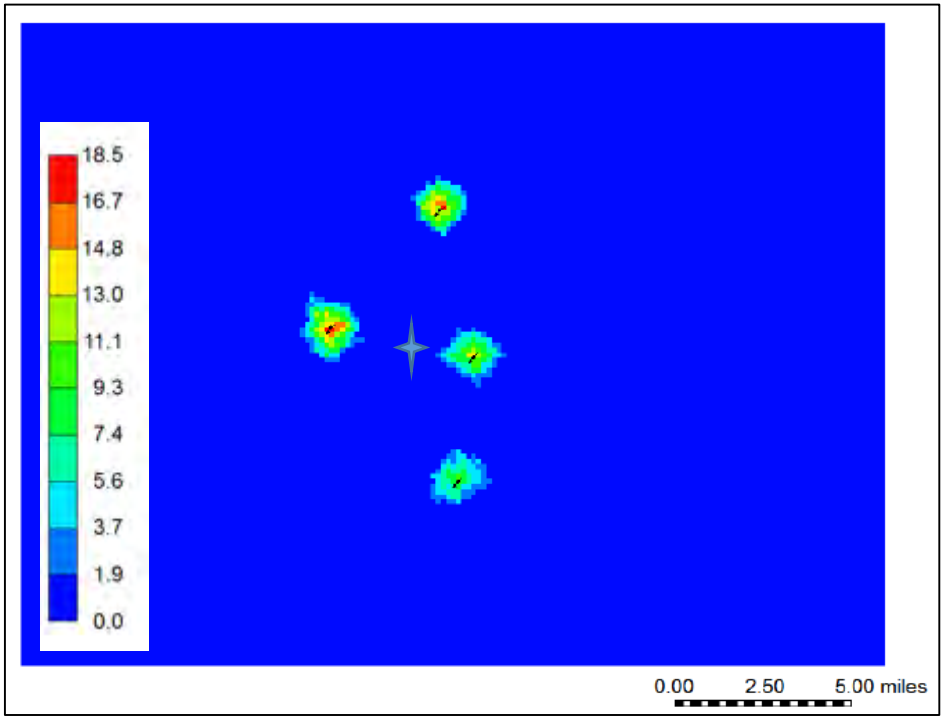


Pressure Plume



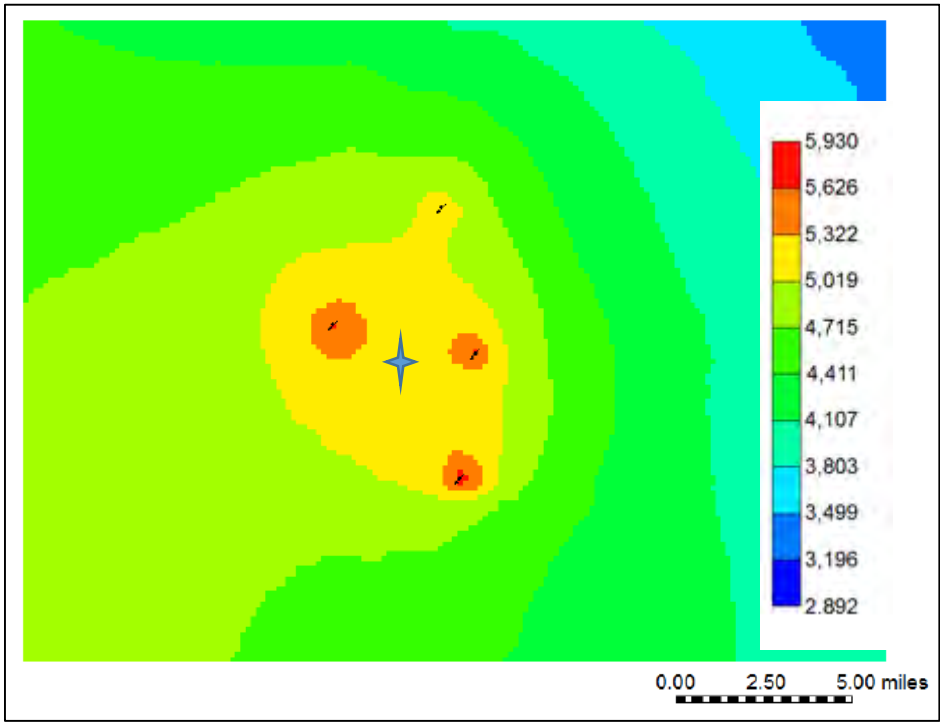
Injection Models: 50Mt in 25 years (4 Vertical Injectors & 1 Brine Production Well)

CO_2 Saturation



Gas Per Unit Area

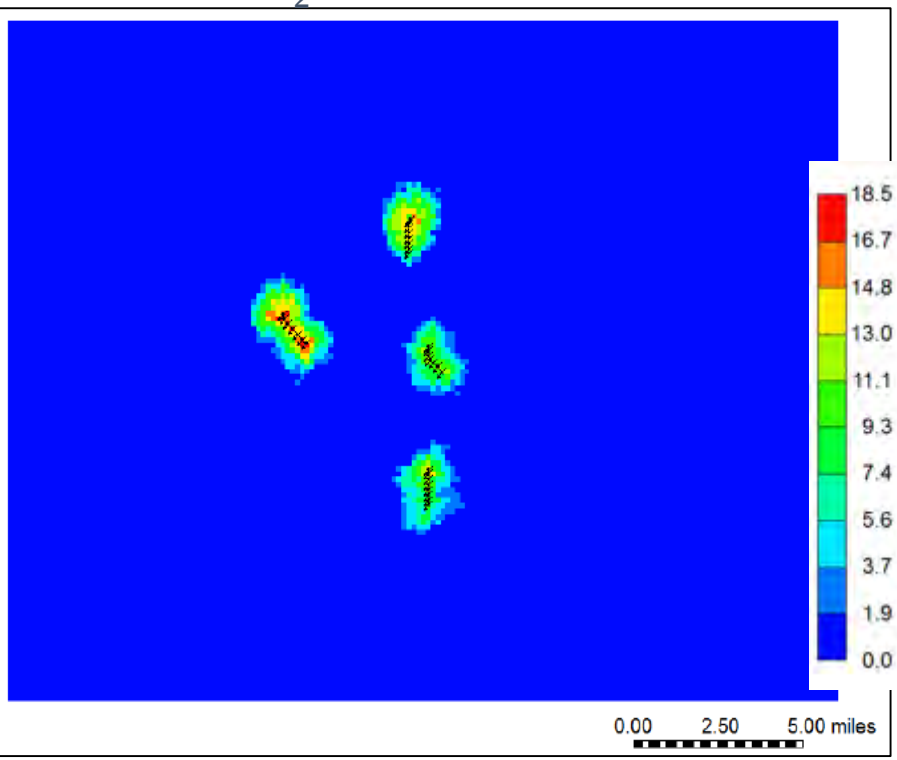
Pressure Plume



Pressure (PSI)

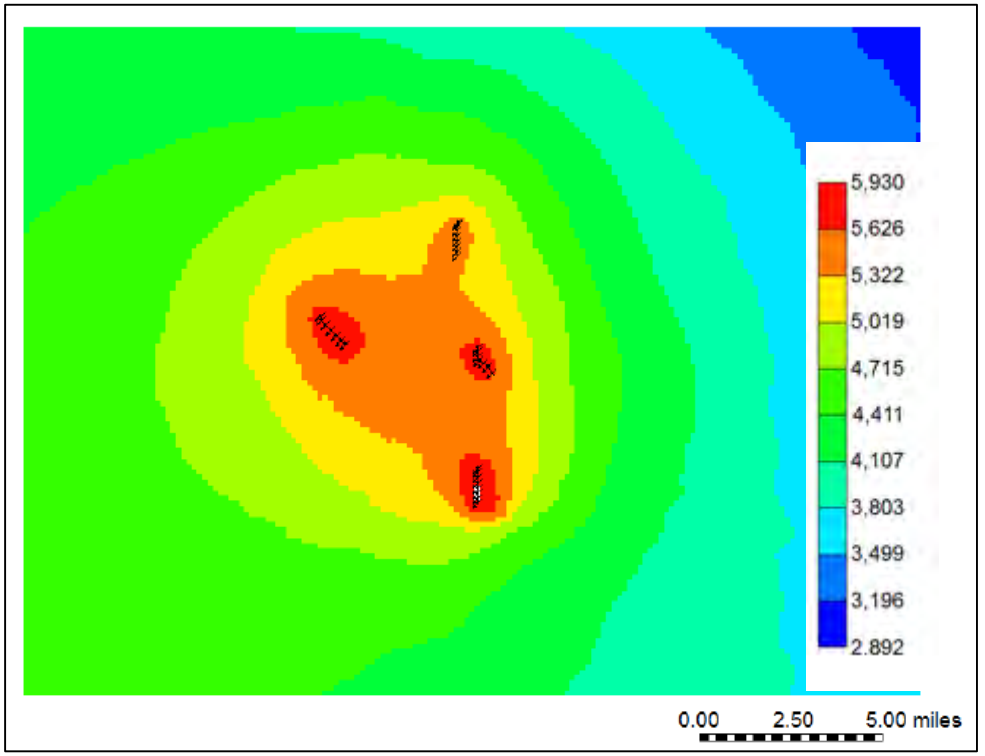
Injection Models: 50Mt in 25 years (4 Horizontal Injectors)

CO_2 Saturation



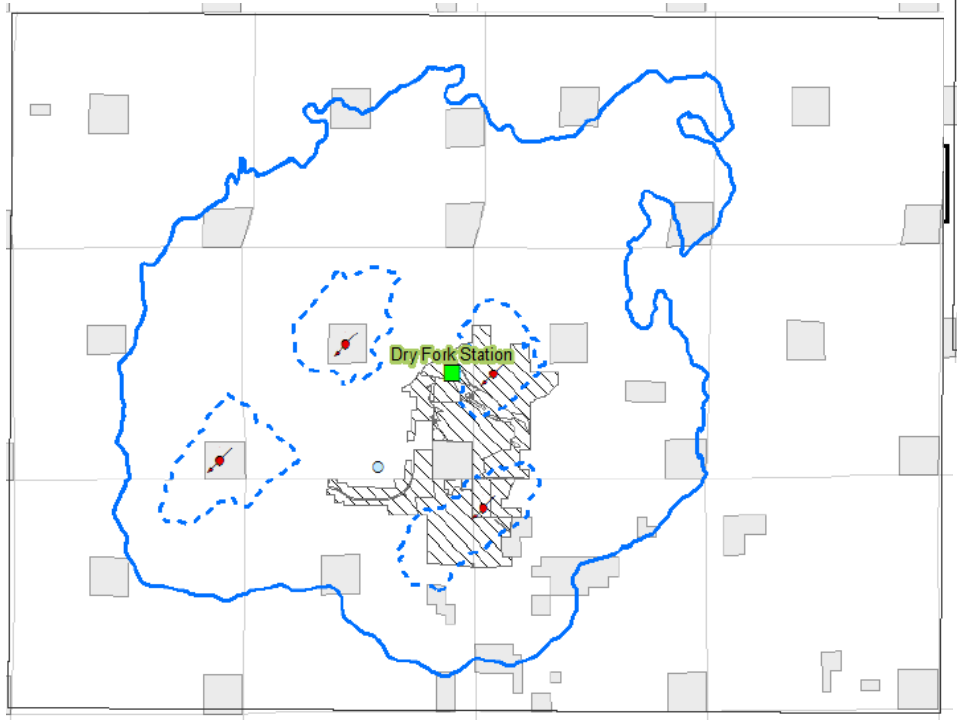
Gas Per Unit Area

Pressure Plume

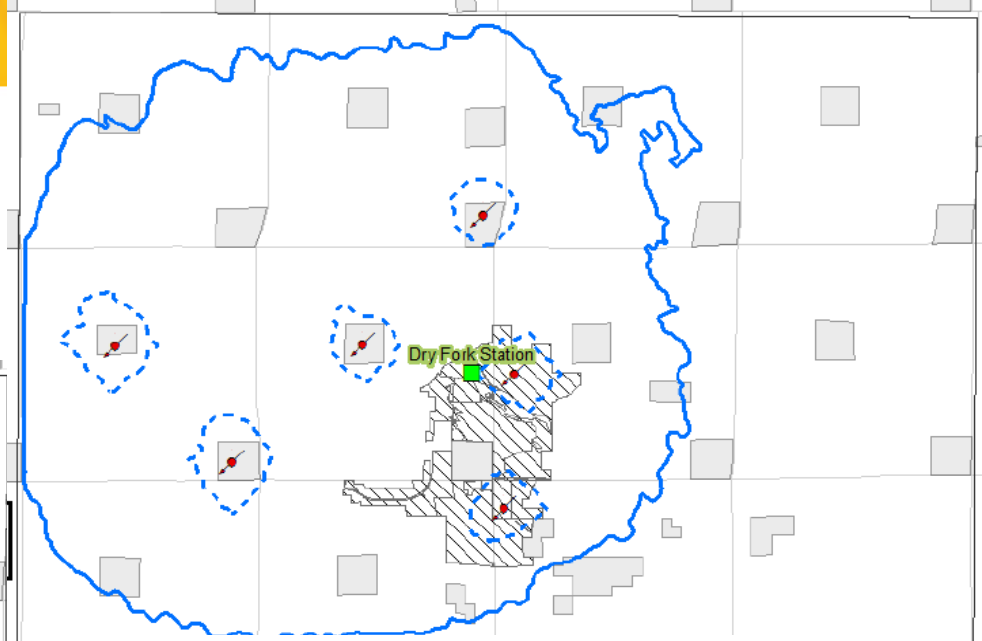


Pressure (PSI)

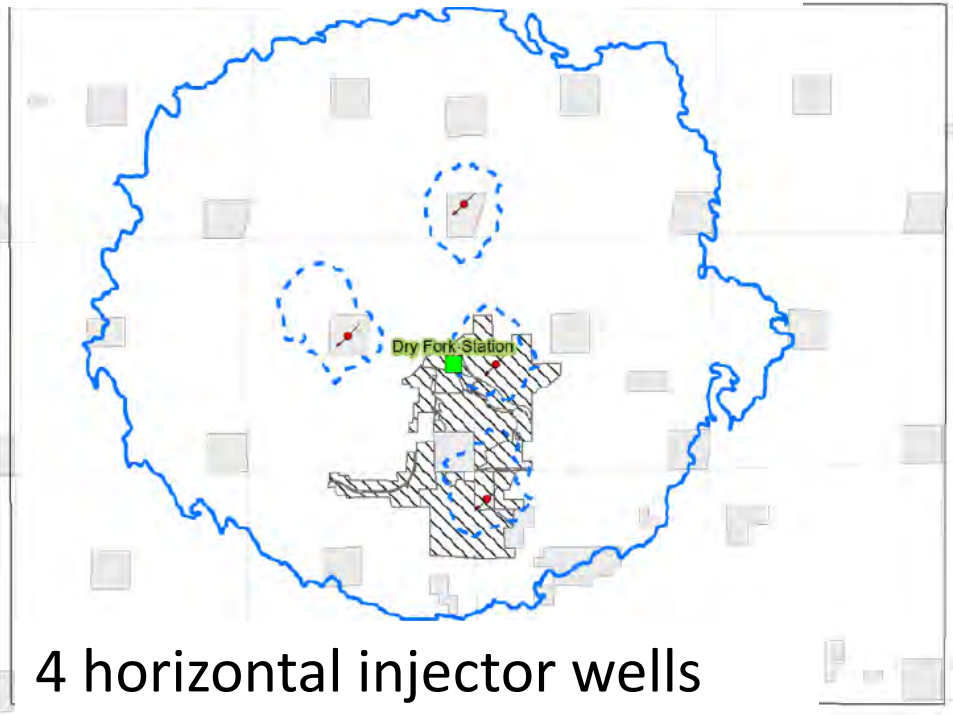
AOR Determinations: Minnelusa



4 injector wells, 1 brine extraction



6 injector wells

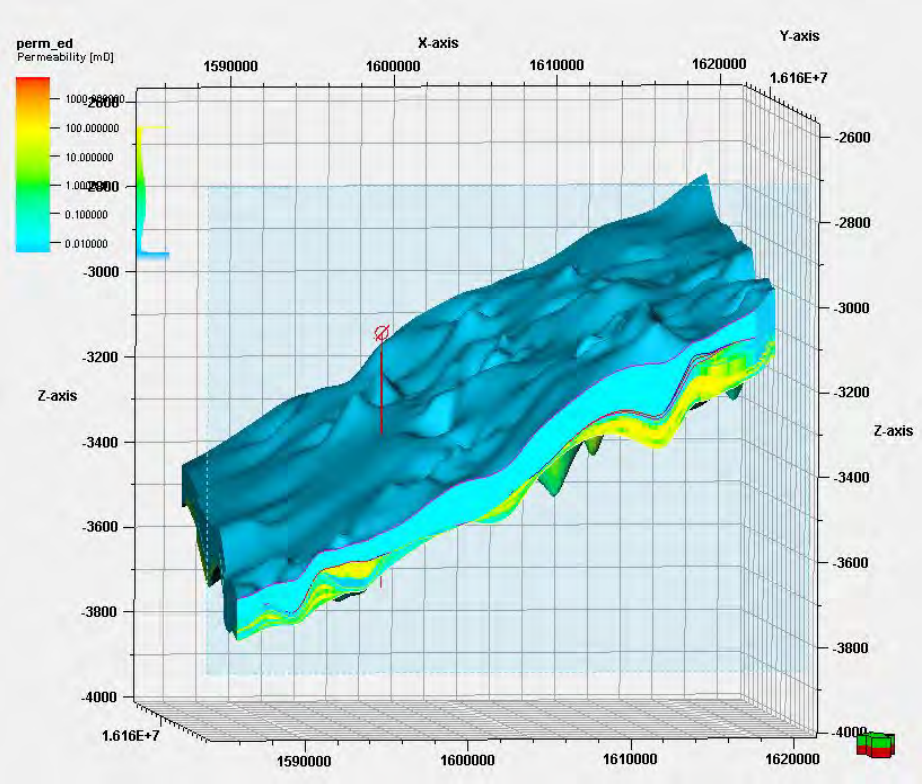


4 horizontal injector wells

Proxy Property Modeling of the Minnelusa Formation

The property model:

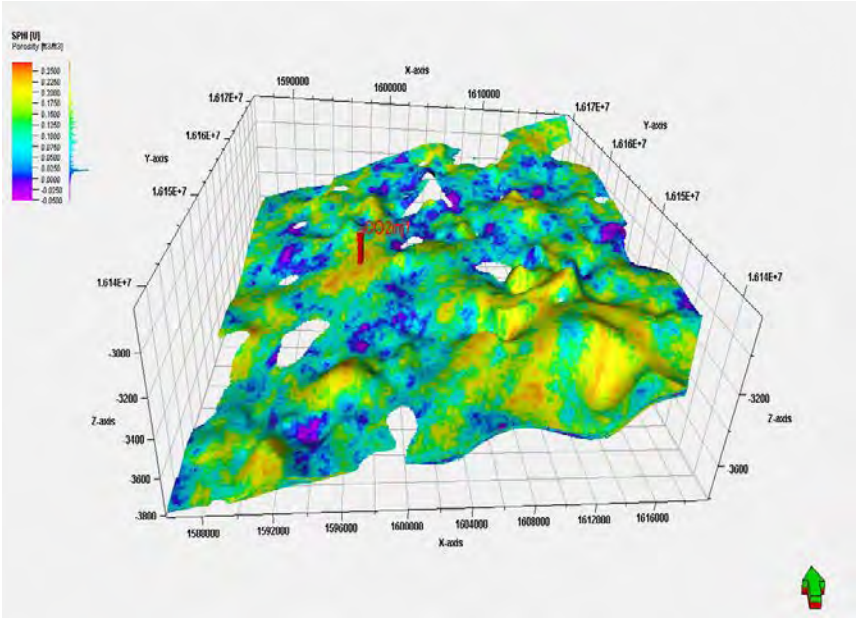
- T52 N and R69 W (6x6 miles)
- Depth from 6982 to 7837 ft
- Opeche Shale Seal
- Minnelusa Formation: 7 stratigraphic intervals within the Minnelusa
- B Sand primary target
- One CO_2 injection well.



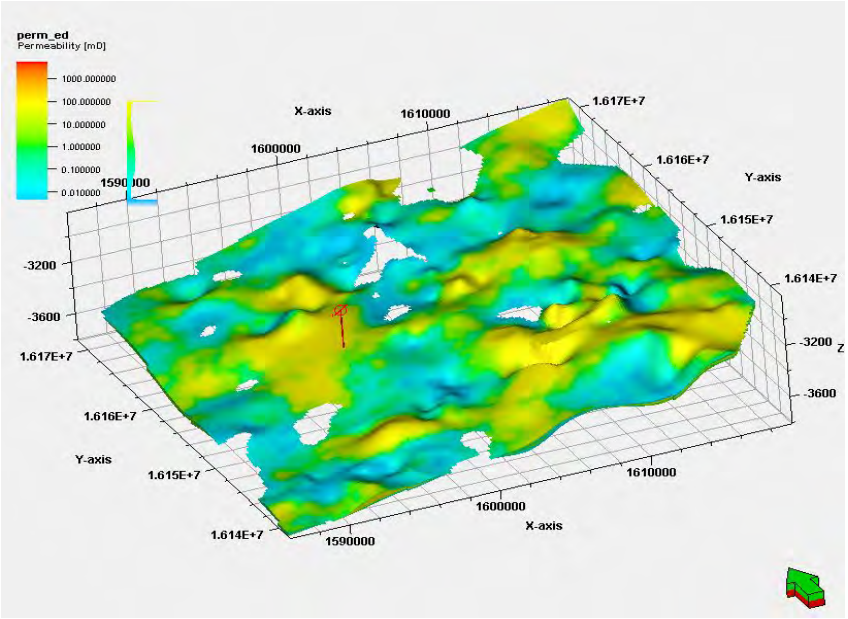
- Correlations: S. Fryberger and N. Jones
- Permeability (perm pore function): using Jiao et al., 2013
- Grid cells: is 451,584 (168x168x16), and X&Y:200 ft and Z=10 ft

Porosity and Permeability Distributions of Minnelusa B Sandstone

The porosity of B sandstone ranges from 0.01% to 27% with mean of 11%

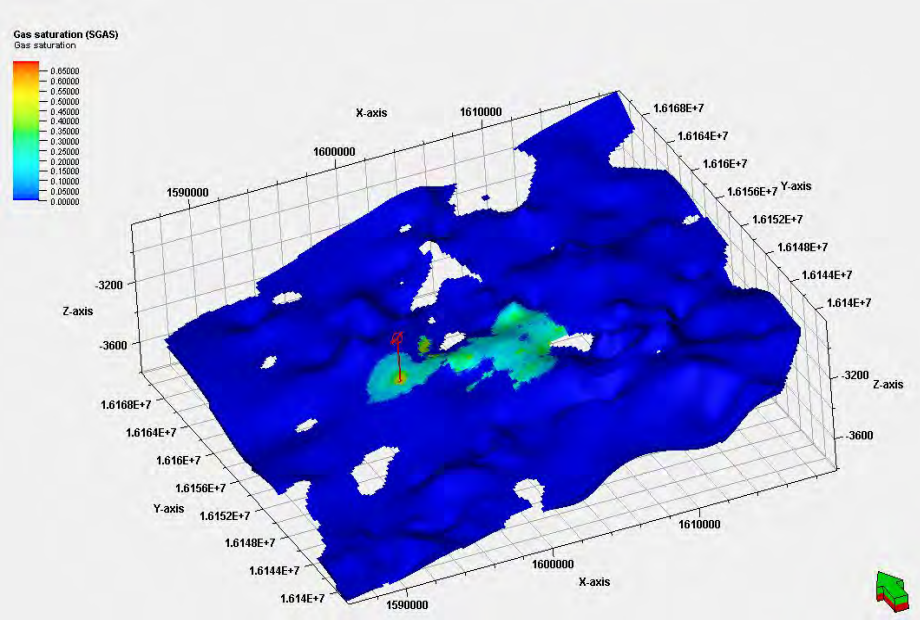


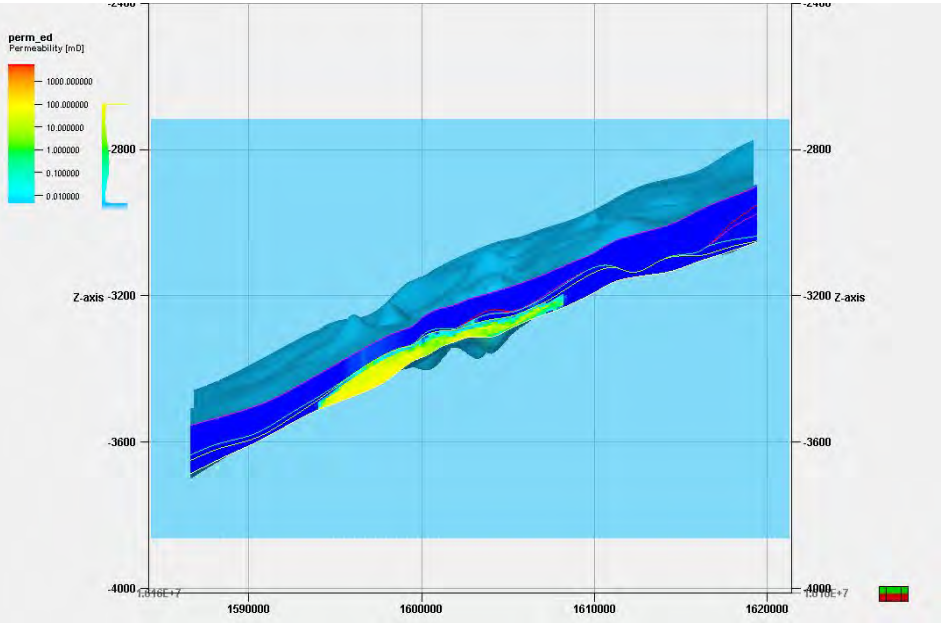
The permeability of B sandstone ranges from 0.004 to 100 mD with mean of 15.7 mD



CO_2 Injection to B Sandstone

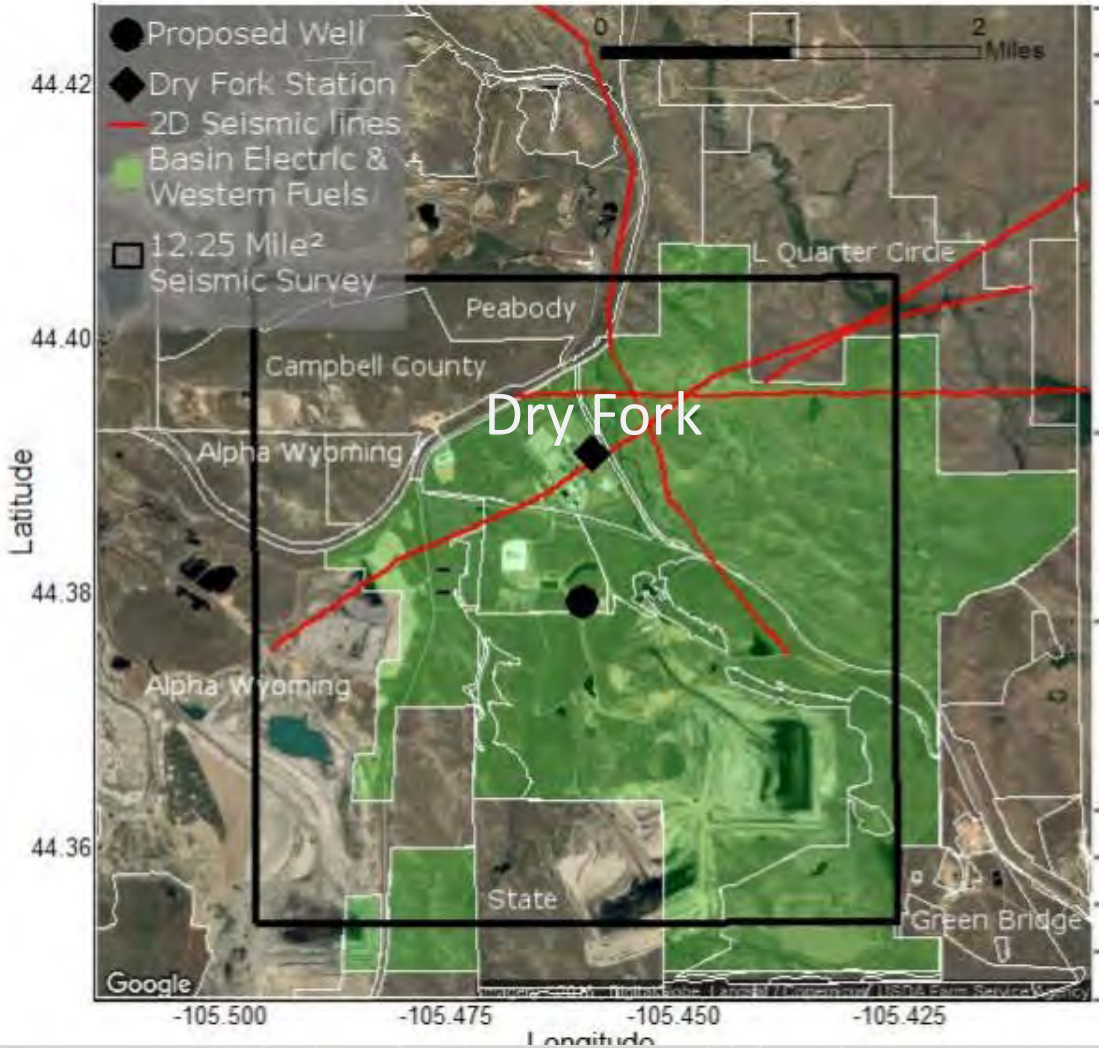
- CO_2 plume after **25 year injection**
- The farthest front of the **CO_2 plume** from the injection well is **1.5 miles.**
- The injected **CO_2 moved** through **Upper B Dolostone** and reached the **bottom of the Opeche Shale (caprock)**.





Next Steps: Storage Complex Feasibility

Phase II



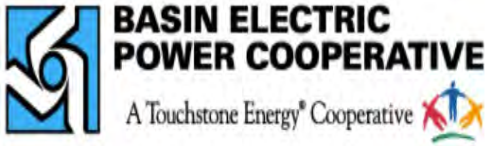
Age	Formation
Paleocene	Fort Union
Upper Cretaceous	Lance
	Fox Hills Sandstone
	Pierre (Lewis) Shale
	Niobrara Shale
	Carlile Shale
	Belle Fourche Shale
	Mowry Shale
Lower Cretaceous	Muddy Sandstone
	Skull Creek Shale
	Fall River (Dakota)
	Lakota
Jurrasic	Morrison
	Upper Sundacne
	Lower Sundance
	Gypsum Spring
Triassic	Spearfish
Permian	Opeche (Goose Egg)
Pennsylvanian	Minnelusa
Mississippian	Madison

Prefeasibility Summary (Accomplishments)

Plan for Commercial Scale CCUS

- ✓ **Capable Coordination team:** Experienced and diverse coordination team (Academia, Industry and Regulatory)
- ✓ **CO_2 Source:** Engaged Industry Partner- Coal fired power plant and the ITC CO_2 Capture and Utilization test facility
- ✓ **CO2 Transport:** Minimal transport, but existing statewide CO2 pipeline and pipeline ROW's
- ✓ **Saline Storage:** World class geologic reservoirs for storage
- ✓ **Pore Space Ownership:** Industry partner owns the pore space
- ✓ **Regulatory:** CCUS friendly regulatory environment, pending Application for WY Class VI primacy
- ✓ **Induced seismicity:** Low risk of induced seismicity
- ✓ **Public Acceptance:** This is coal country!
- ✓ **Favorable Economics:** Proximal EOR and CO_2 transport opportunity

Acknowledgements



Project Gantt Chart

Timeline		Task Dependency						2017												2018					
Task	Description	1	2	3	4	5	6	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1	**Project Management and Planning**																								
1.1	Project management plan																								
1.2	Reporting																								
1.3	Project management																								
1.4	Collaborative meetings																								
1.5	Kick-off meeting																								
1.6	Outreach to potential DFCT members																								
2	**Scenarios Generation**																								
2.1	Source & Transport Component Generation	x																							
2.2	Storage Component Generation	x																							
2.3	Scenario Component Combination and Screening	x																							
2.4	Scenario Prioritization	x		x	x	x	x																		
3	**Regional and Stakeholder Analysis**																								
3.1	Economic assessment	x	x																						
3.2	Legal Assessment	x	x																						
3.3	Environmental Assessment	x	x																						
3.4	Community and public outreach/assessment	x	x																						
4	**Geologic Evaluation**																								
4.1	Development of borehole catalog and risk assessment.	x	x																						
4.2	Subsurface Description	x	x																						
4.3	Hydrostratigraphy Description	x	x																						
4.4	Geophysical Description	x	x																						
5	**Geologic Model Development and Simulation**																								
5.1	Geocellular Modeling	x			x																				
5.2	Numerical Simulation	x			x																				
5.3	Identification of Future Characterization Activities	x	x	x	x		x																		
6	**NRAP Modeling and Validation**																								
6.1	NRAP Modeling	x			x																				
6.2	NRAP Comparison	x			x	x																			

Organization Chart

Figure 1. Organization Chart