



Critical Challenges. **Practical Solutions.**



Energy & Environmental Research Center (EERC)

CARBONSAFE-NORTH DAKOTA INTEGRATED CARBON STORAGE COMPLEX FEASIBILITY STUDY

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U.S. Department of Energy
National Energy Technology Laboratory
Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting
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Critical Challenges. **Practical Solutions.**

NORTH DAKOTA CARBONSAFE

- Address technical and nontechnical challenges specific to commercial-scale deployment of a CO₂ storage project in central North Dakota.
- Long-term goal: develop a certified (permitted) geologic storage opportunity should a business case for CO₂ storage emerge.



PROJECT PARTNERS



INDUSTRIAL COMMISSION OF NORTH DAKOTA
LIGNITE RESEARCH COUNCIL



GREAT PEOPLE GREAT PARTNERS

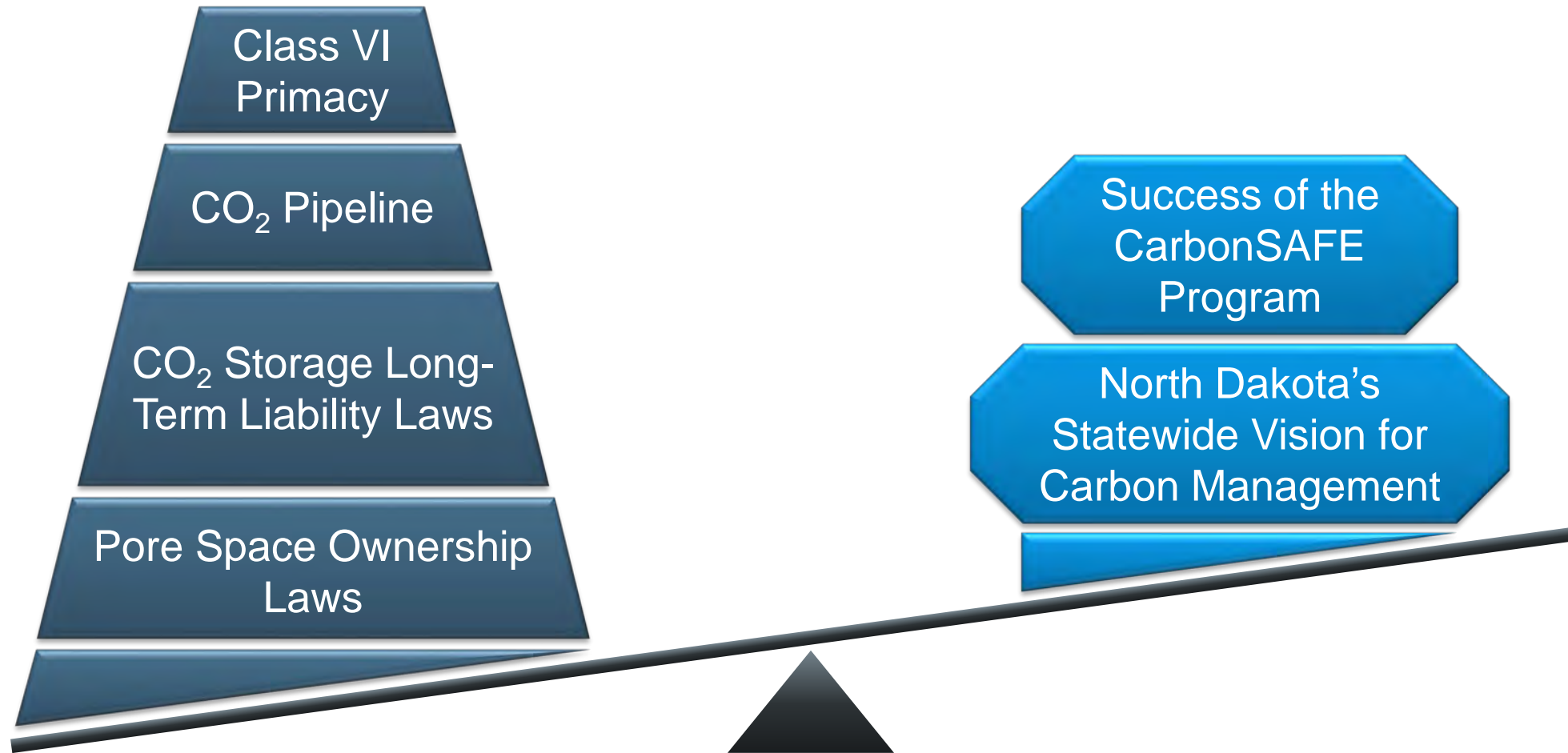


PROJECT OBJECTIVES

- Evaluate two ideal geologic storage complexes located adjacent to separate coal-fired facilities.
 - One has readily available CO₂ and an existing CO₂ pipeline.
 - The other is associated with a planned integrated CO₂ capture and storage project with a time line coincident with the CarbonSAFE Program.
- Gauge public support.
- Conduct a regulatory and economic analysis.



NORTH DAKOTA'S LEVERAGE

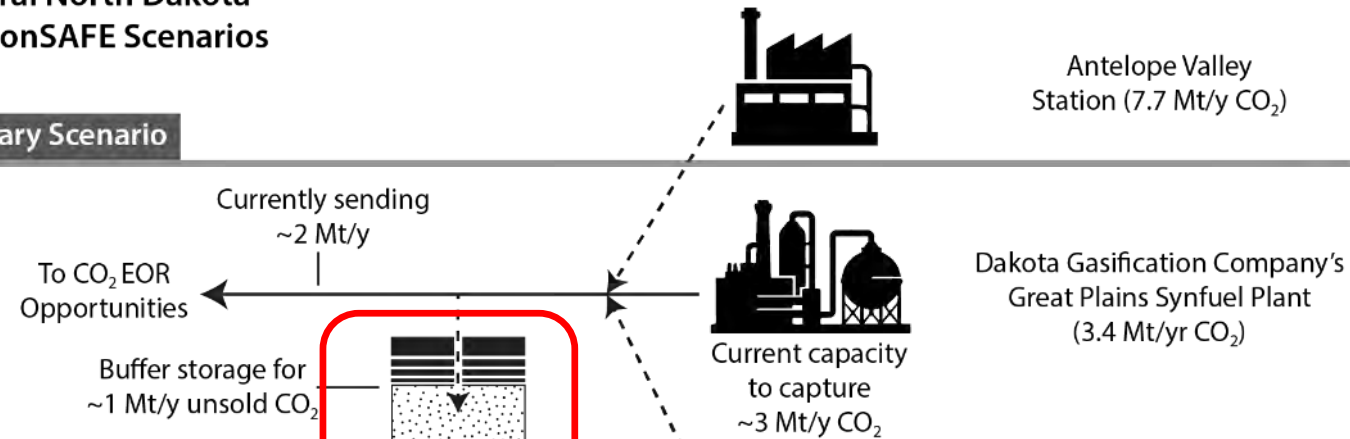


NORTH DAKOTA CARBONSAFE CO₂ SOURCE OPTIONS

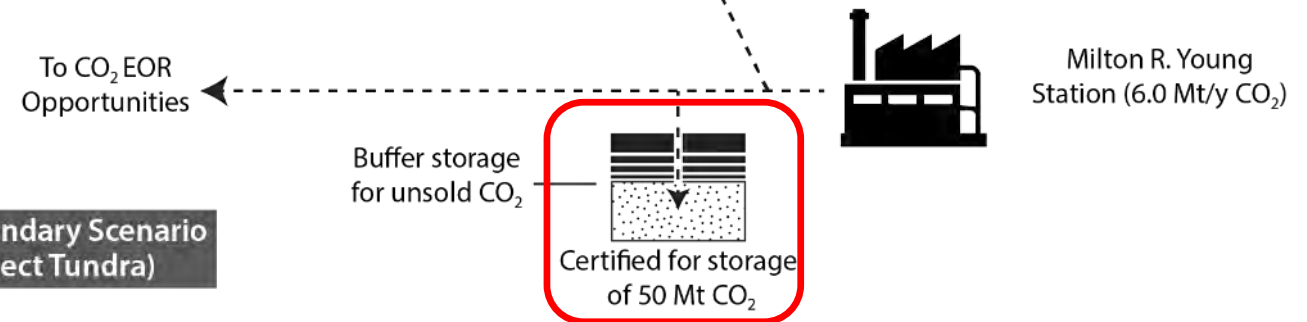


Central North Dakota CarbonSAFE Scenarios

Tertiary Scenario

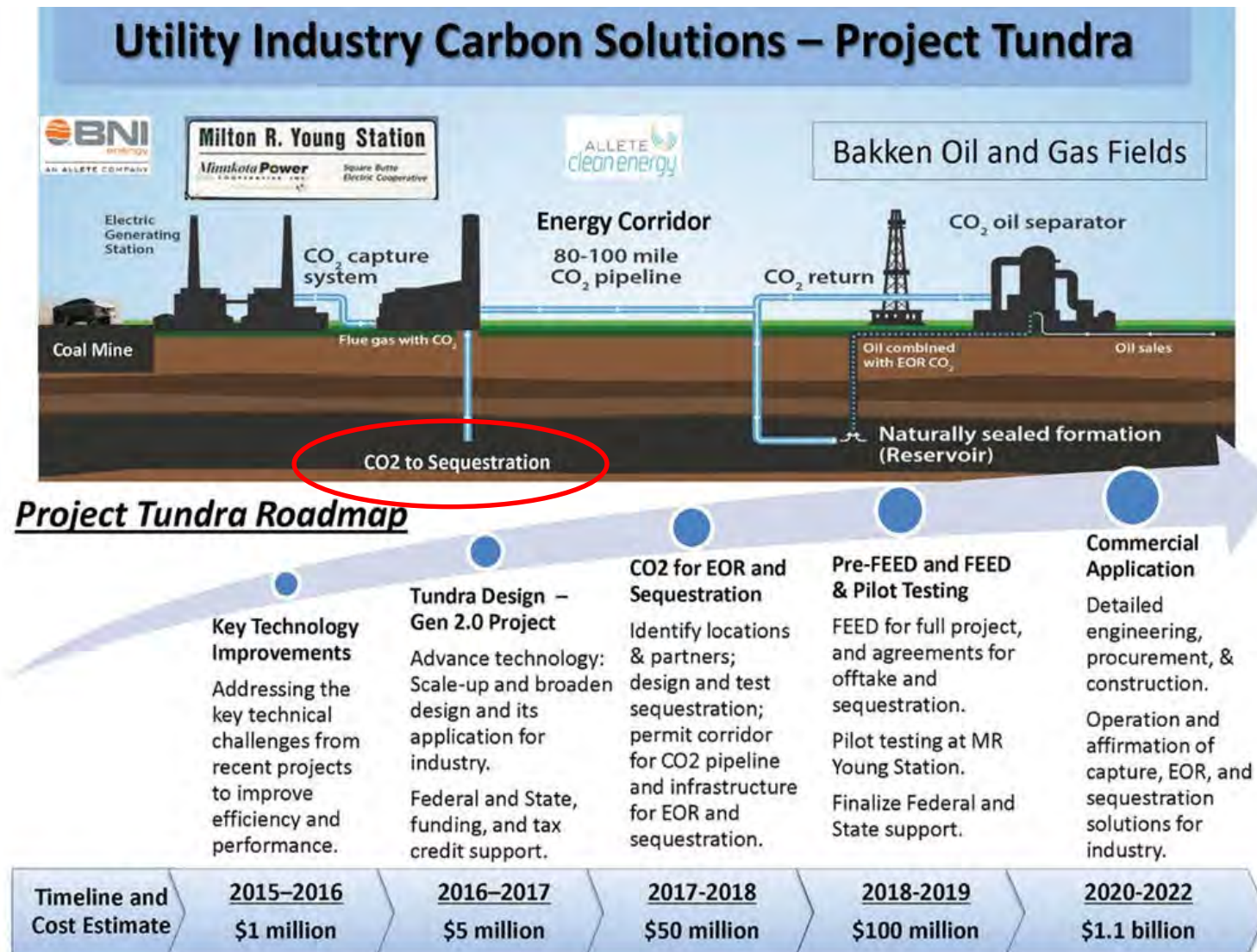


Primary Scenario

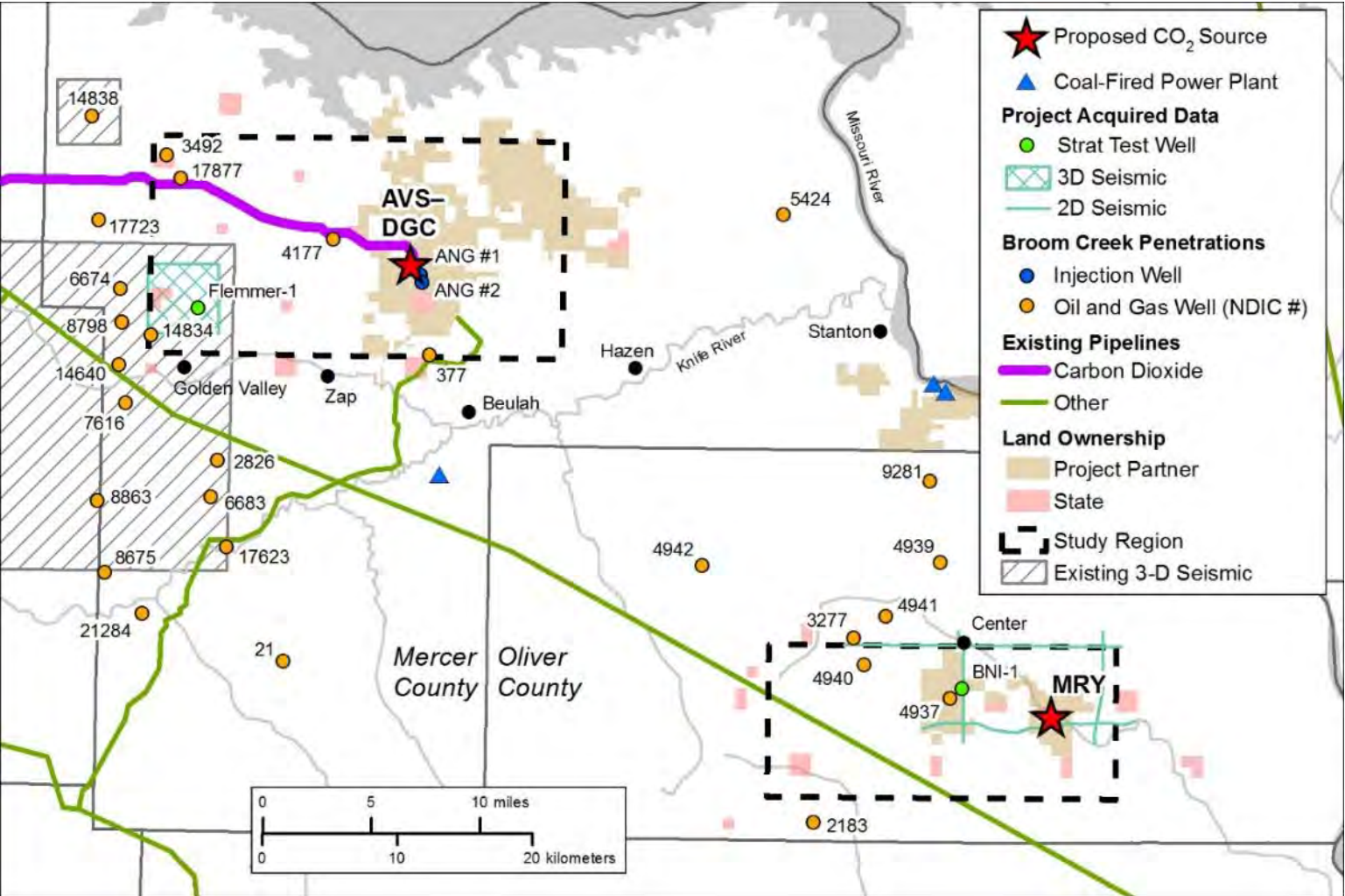


Secondary Scenario (Project Tundra)

PROJECT TUNDRA: A VERY NICE FIT



PROJECT AREA AND SUBSURFACE GEOLOGY

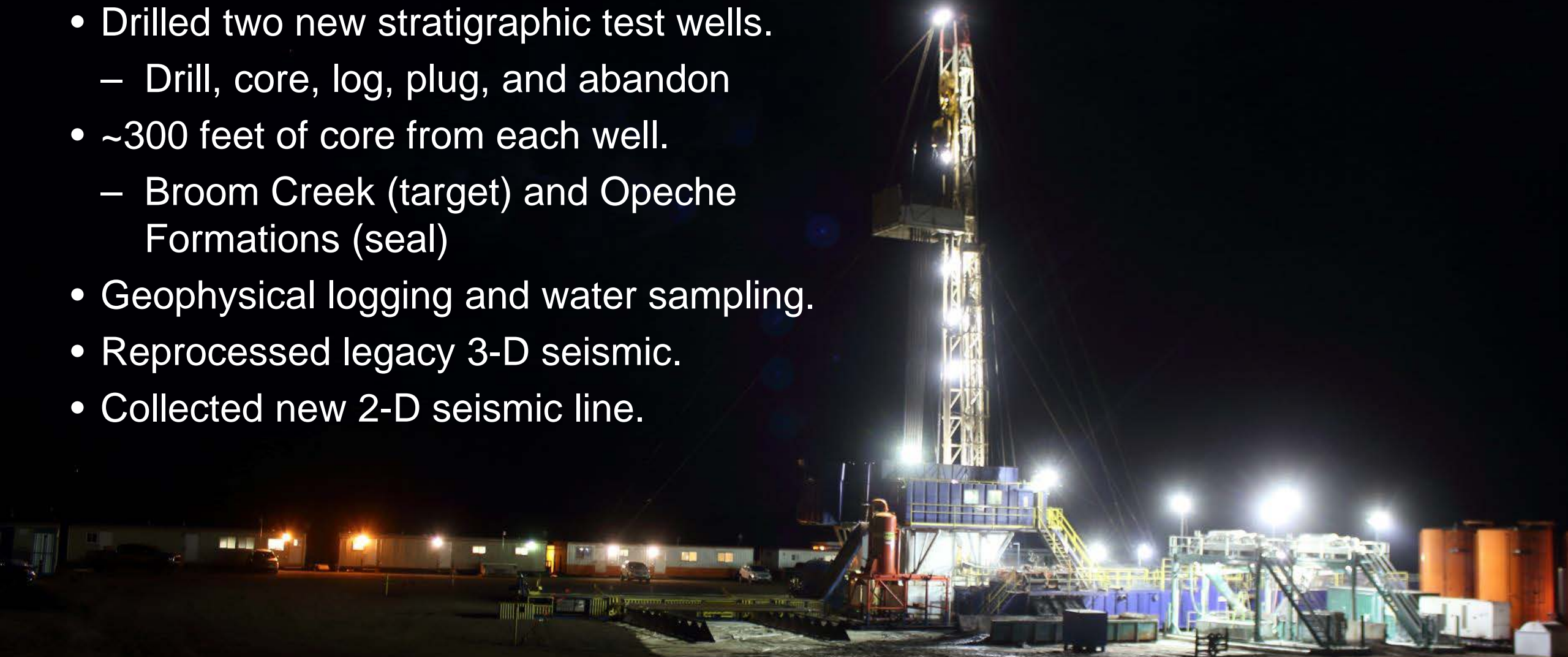


Stratigraphic Column				
Period	Rock Unit	Depth m (ft)	Thickness m (ft)	Storage Assessment Unit
Quaternary and Tertiary Units			375 (1230)	
		375 (1230)		
Cretaceous	Hell Creek			Aquifers and Saline Formations
	Fox Hills		90 (295)	
	Cretaceous Shales	465 (1525)	752 (2467)	Secondary Seal
Cretaceous				
		1217 (3992)		
			100 (328)	Saline Formations
Cretaceous	Dakota Group	1317 (4320)		
	Inyan Kara		75 (246)	
		1392 (4566)		
Jurassic	Swift			Primary Upper Seals
	Rierdon			
	Piper			
Triassic	Spearfish		312 (1024)	
Permian				
Permian	Opeka			
Permian	Broom Creek	1704 (5590)	82 (269)	Target Saline Sink
Pennsylvanian	Amsden	1786 (5859)		Primary Lower Seal

Target Horizon:
Broom Creek Formation

GEOLOGIC CHARACTERIZATION

- Drilled two new stratigraphic test wells.
 - Drill, core, log, plug, and abandon
- ~300 feet of core from each well.
 - Broom Creek (target) and Opeche Formations (seal)
- Geophysical logging and water sampling.
- Reprocessed legacy 3-D seismic.
- Collected new 2-D seismic line.



THE CORE

- **Flemmer-1**
- Broom Creek thickness: 263'
- Total sand thickness: 169'
 - Intervals: 53', 34', 65', 17'
- **BNI-1**
- Broom Creek thickness: 273'
- Total sand thickness: 124'
 - Intervals: 89', 19', 16'



CAP ROCKS



Mottled with Rip-Up Clasts



Rip-Up Clasts



Laminated Siltstone and Anhydrite



Mottled Siltstone



Soft Sediment Deformation



Interbedded Siltstone/Shale

SANDSTONES (RESERVOIR)



Chevrons



High-Angle Bedding



Fluid Escape



Truncated Bedding



Massive, Friable



Very Friable

CARBONATES AND ANHYDRITES (BAFFLES)



Fusulinids



Crinoid



Anhydrite



Fusulinid



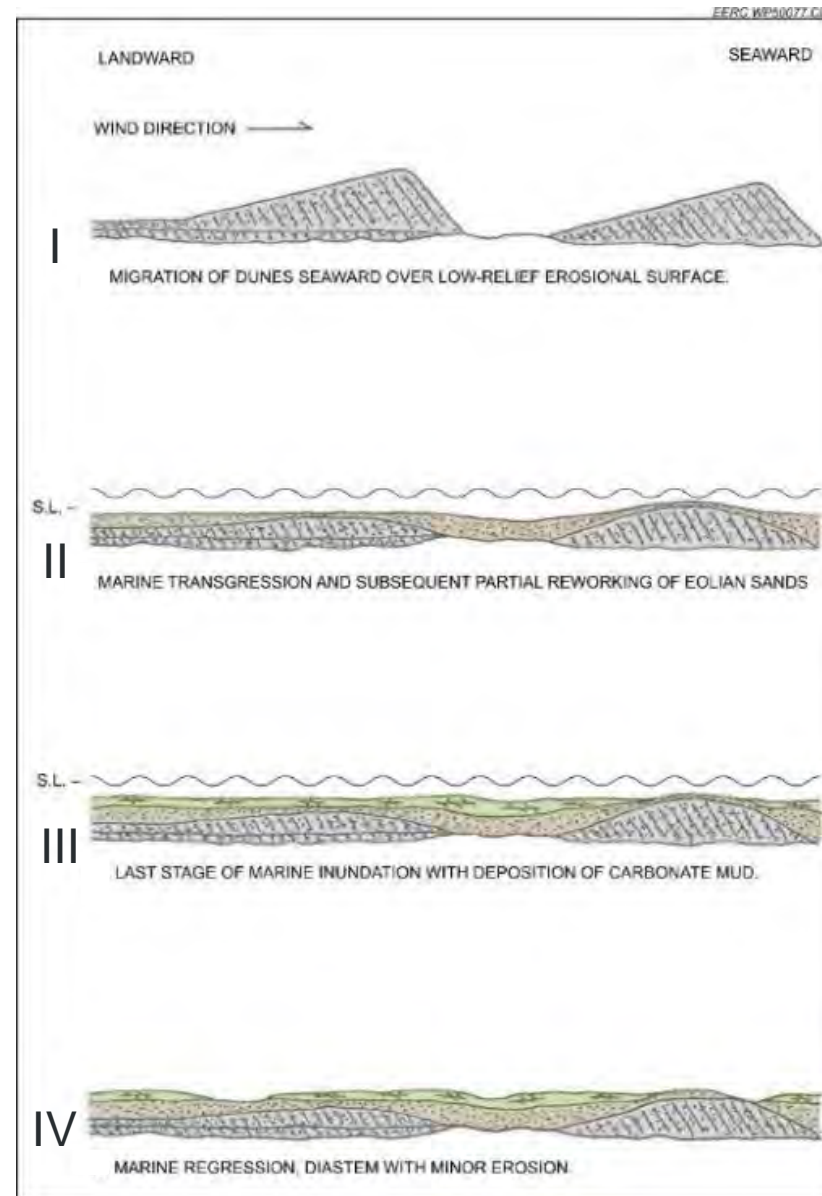
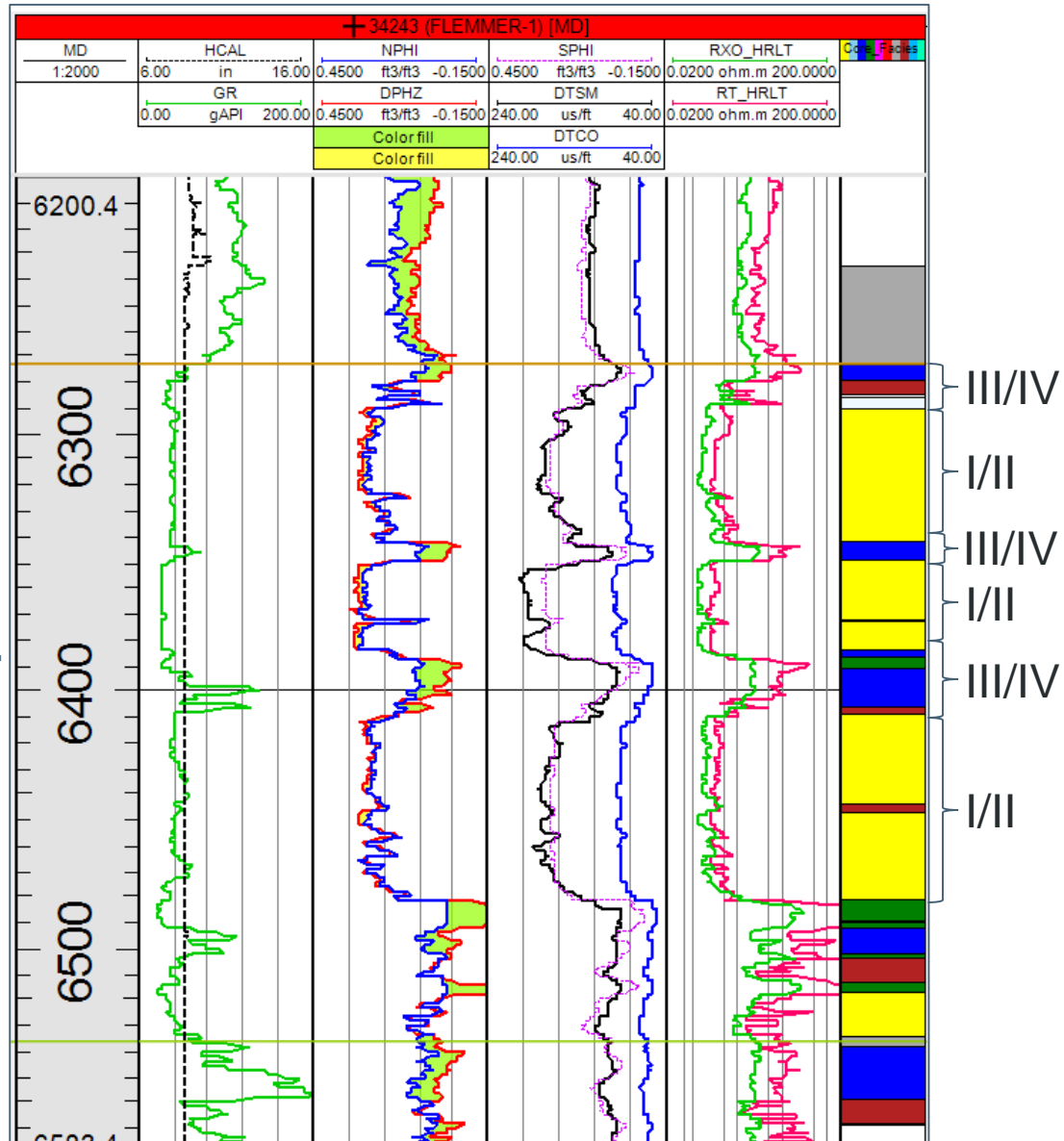
Anhydrite



Vertical Fracture?

DEPOSITIONAL MODEL

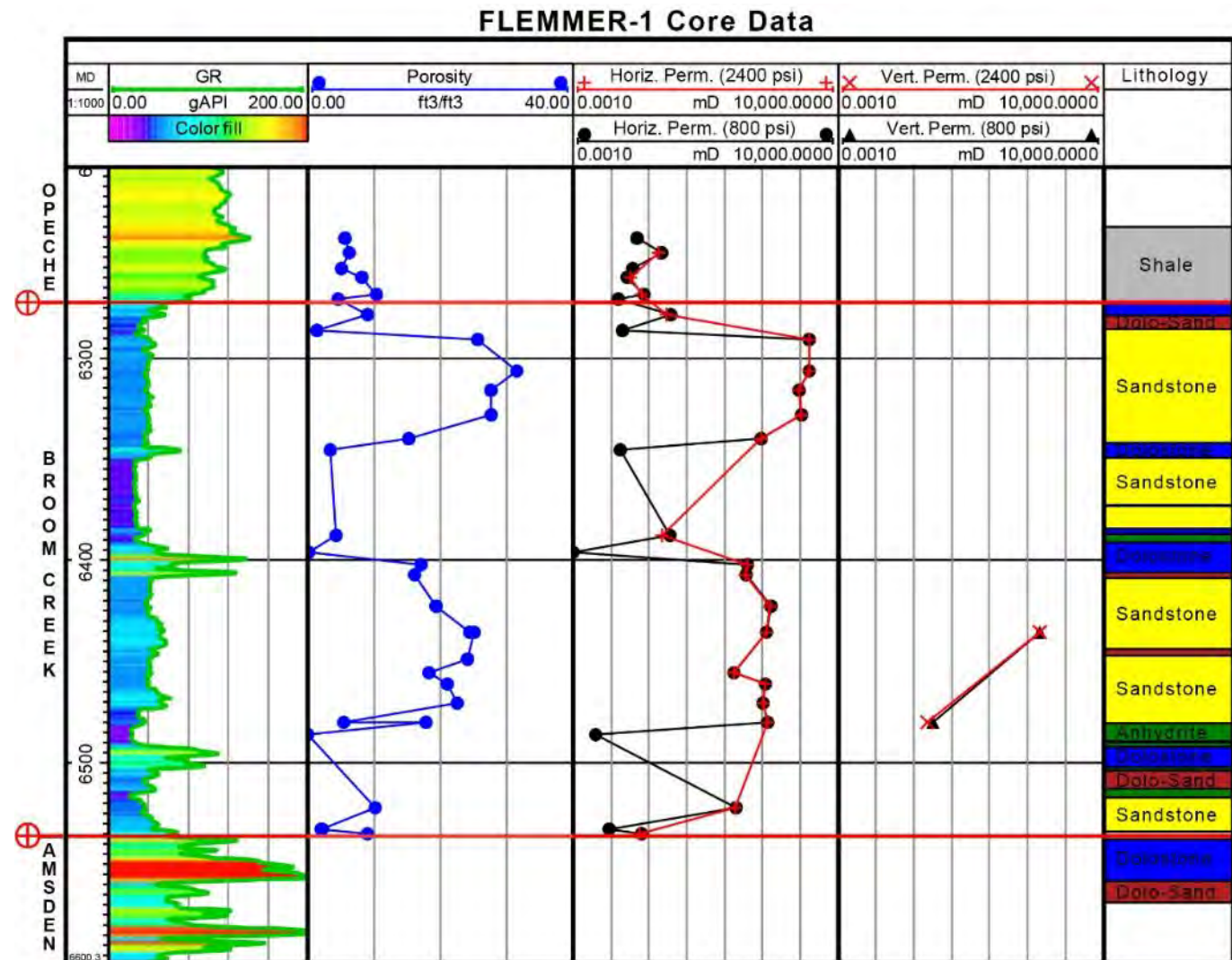
Flemmer-1



- Eolian-marine cycle (Rygh, 1990).
- Stacked sandstone and carbonate intervals indicate multiple cycles.

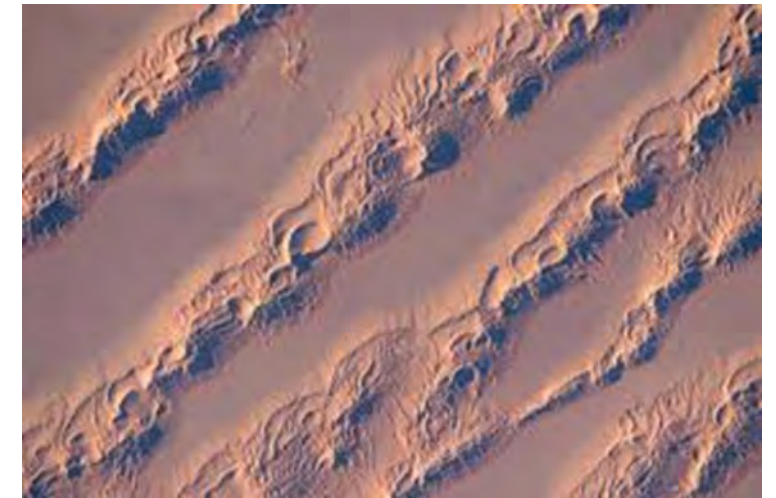
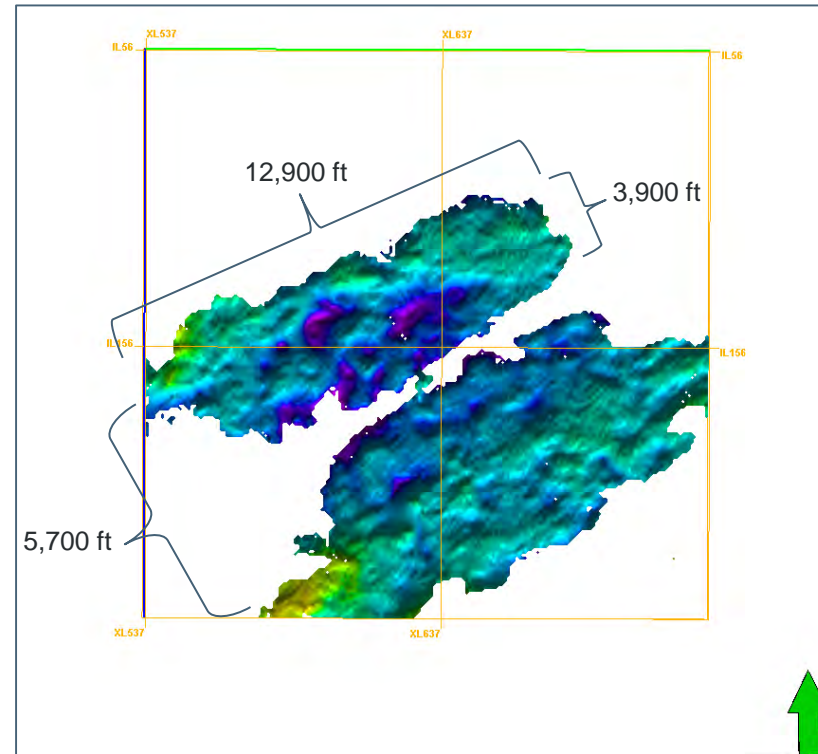
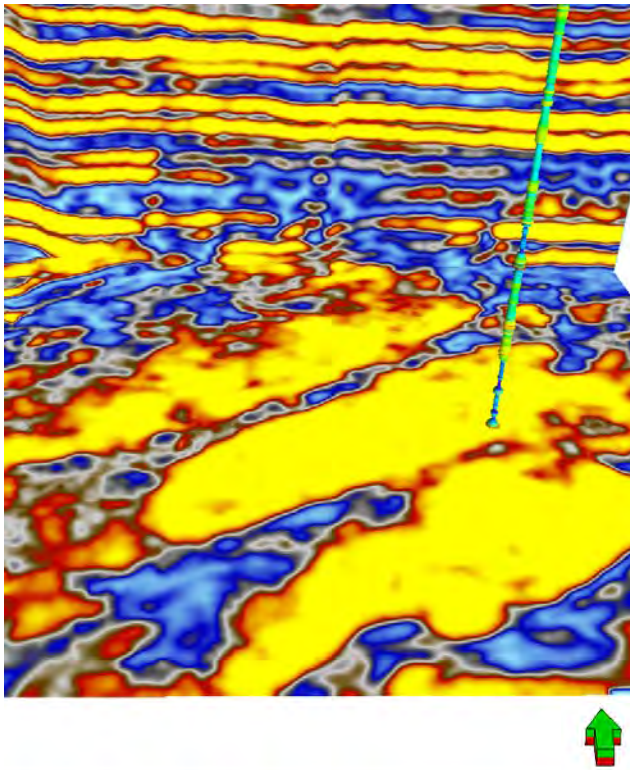
INITIAL LAB RESULTS

- TDS of the brine sampled from the Broom Creek Formation ranged from 61,000 to 70,000 ppm.



3-D SEISMIC GEOBODY IDENTIFICATION

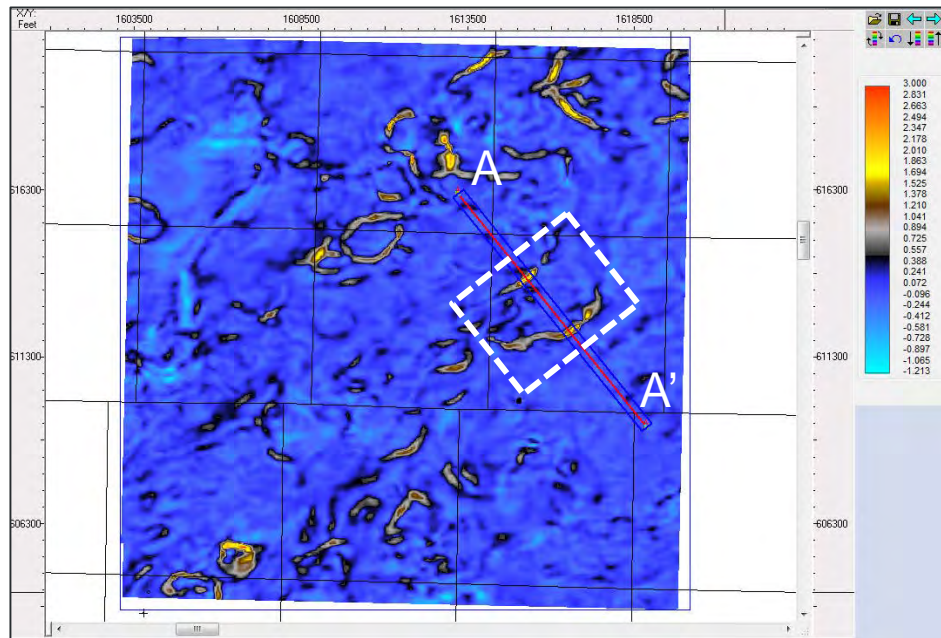
- SW–NE-trending features identified from 3-D seismic.
- Morphology and correlation to well log data suggest these are sand bodies.



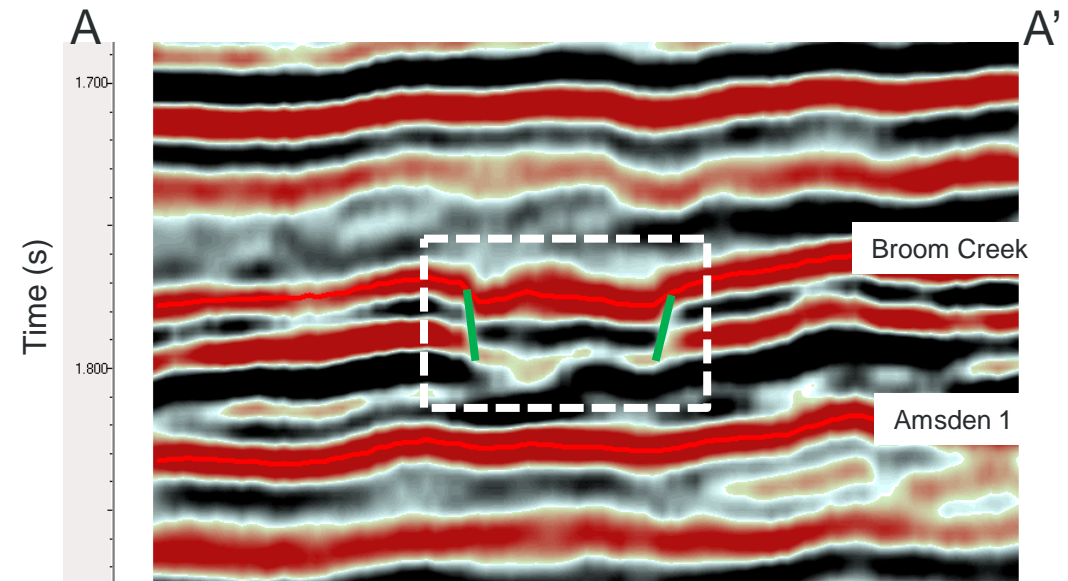
3-D SEISMIC STRUCTURAL INTERPRETATION

- Seismic attribute analysis aided identification of local (zonal) faulting.
- Faulting may be associated with subsidence due to salt dissolution.

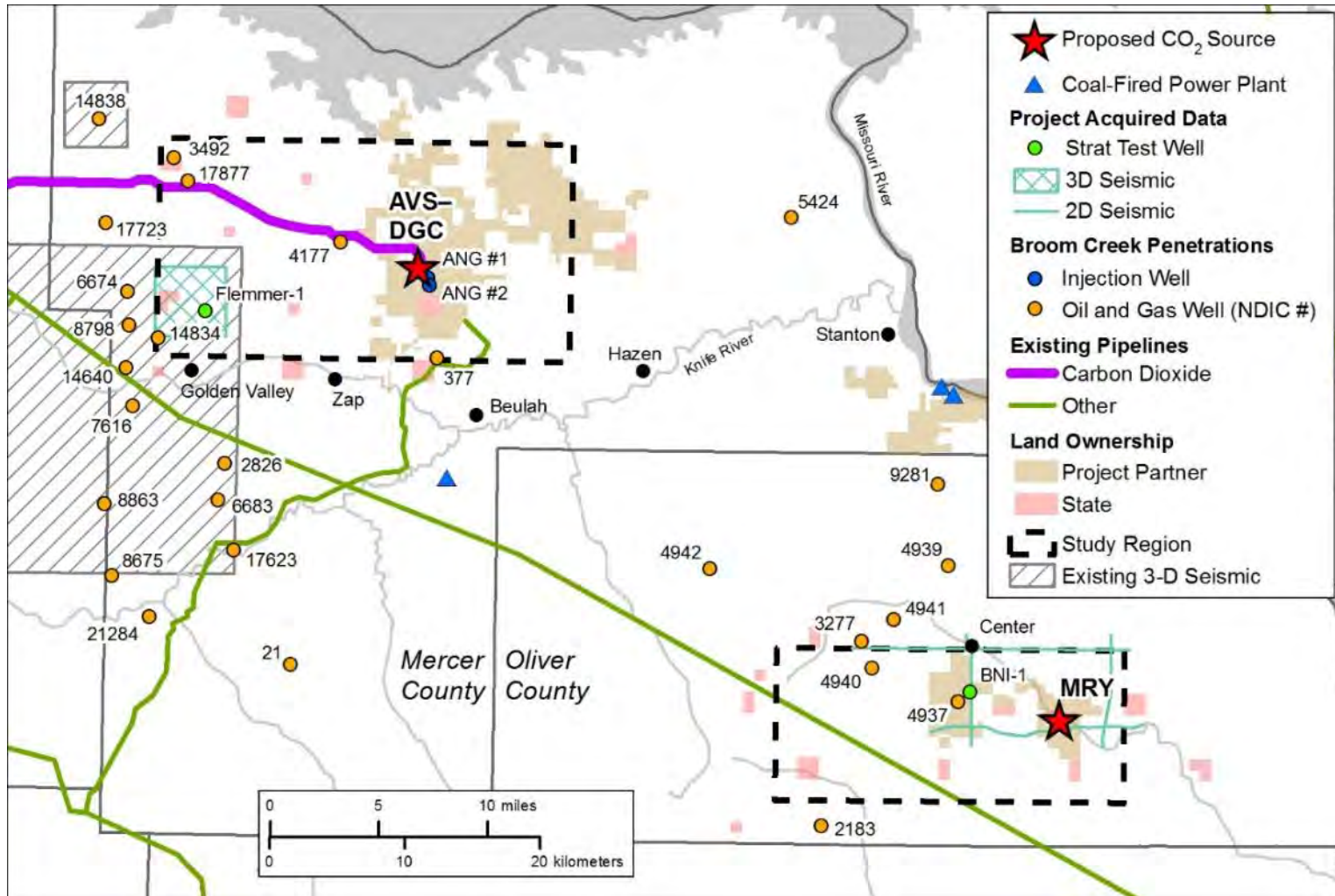
Broom Creek Top Dip Variance Map



Seismic Amplitude Data



PROSPECTIVE CO₂ STORAGE RESOURCE



AVS area: 336 Mt
MRY area: 277 Mt

Based on a P50 distribution of rock properties and 14% storage efficiency.

PUBLIC OUTREACH

Gauging local public acceptance of a potential CO₂ storage project.

- Formed a collaborative outreach advisory group.
- Developed a tailored set of outreach materials.
- Implemented outreach:
 - Stakeholder meetings
 - Open house meetings
- Will develop a public engagement plan for Phase III.



JANUARY FIELD TRIP



VIDEO PRODUCTION

- Partnered with Prairie Public Broadcasting to produce a 9-minute video on the aspects of CarbonSAFE.
- Will interview:
 - Representatives from ND's lignite mining and electric generation industry.
 - Experts in subsurface research.
 - State regulatory representatives.



REGULATORY AND ECONOMIC ANALYSIS

- Evaluating permitting requirements needed for future implementation of Class VI injection wells.
- Exploring site access agreement options, pore space acquisition, and short-term project liability.
- Examining specific economic needs and the incentives in place to make the proposed scenarios economically feasible for the project partners.



RISK ASSESSMENT WORKSHOP

- Led participants through a process to *identify potential technical and nontechnical risks that may preclude candidate storage complexes within our two proposed study areas from serving as commercial storage sites.*
- Generated a draft risk register based on the discussion at the workshop.
- Next steps: Finalize risk register and commence risk scoring.

SITE DEVELOPMENT PLAN



Create a detailed plan for development of an injection site within the storage complex in Phase III of CarbonSAFE.

- Site characterization plan
- CO₂ management strategy
- Risk assessment and mitigation strategies

ACCOMPLISHMENTS TO DATE

- Secured land access agreements to drill two stratigraphic test wells.
- Drilled, cored, logged, and plugged the two wells.
- Nearly 600 feet of core retrieved (~98% recovery).
- Began laboratory testing of the core.
- Collected new 2-D seismic data.
- Reprocessed legacy seismic data.
- Retrieved water samples from the target formation.
- Held monthly outreach advisory board meetings.

ACCOMPLISHMENTS TO DATE

- Held initial open house events for both project areas.
- Participated in numerous outreach opportunities (e.g., radio interviews, site interviews with local TV news, Lignite Energy Council meetings, ND Geological Society).
- Held initial risk assessment workshop.
- Initial geologic model built and populated with reservoir properties.
- Met with state regulators to discuss pore space amalgamation concepts and potential issues.
- Began development of broad-scale business case scenarios.

LESSONS LEARNED

- Don't drill in the heart of winter outside of the prime service area.
- Prepare for water sampling from poorly consolidated high-perm. sandstone.
- Reclaimed mine land represents a challenge for low-impact seismic collection.
- There are great landowners willing to help make a project successful!
- There is tremendous CO₂ storage potential in our area of investigation.

SYNERGY OPPORTUNITIES

- We are not working in a vacuum.
- Leveraging knowledge and experience gained through the RCSP Program.
- Contributing to public acceptance of CCS projects.
- Building a foundation for how states can efficiently permit and oversee commercial-scale CO₂ storage projects.



PROJECT SUMMARY

- Key findings
 - Superb reservoir properties
 - ♦ Internal baffles will aid in storage efficiency
 - Accepting public attitude
 - Great synergy with commercial endeavors
 - Supportive state regulatory entities
- Next steps
 - Dynamic simulation
 - Create development plan
 - Finalize economic investigation
 - More outreach



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THANK YOU!

Critical Challenges. **Practical Solutions.**

APPENDIX

BENEFIT TO THE PROGRAM

- Goals:
 - Develop and validate technologies to ensure 99% storage permanence.
 - Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness.
 - Support industry's ability to predict CO₂ storage capacity in geologic formations to within $\pm 30\%$.
 - Develop best practice manuals for monitoring, verification, accounting (MVA), and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation.
- To progress toward full-scale carbon capture and storage deployment, the feasibility of a commercial-scale (50+ Mt CO₂) geologic storage complex for CO₂ must be established at one or more of the proposed sites. Activities outlined will gather data to address both the technical and nontechnical challenges associated with establishing feasibility. The results derived from implementation of the project will provide a significant contribution to DOE's Carbon Storage Program goals. Specifically, this project supports DOE Goals 1 and 2 by validating technologies that will improve reservoir storage efficiency, ensure containment effectiveness, and/or ensure storage permanence by collecting and generating fundamental geologic data from the subbasinal characterization of a potentially ideal CO₂ storage complex (Broom Creek Formation). This project also includes efforts to validate risk assessment tools developed by NRAP. Goal 3, the ability to predict CO₂ storage capacity in geologic formations to within $\pm 30\%$, will be addressed by integrating characterization data derived from the proposed project into geocellular and dynamic reservoir models for a commercial-scale geologic storage complex. In addition, this project supports Goal 4 by producing information that will be useful for inclusion in DOE best practices manuals focusing on monitoring, verification, accounting, and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation.

PROJECT OVERVIEW

GOALS AND OBJECTIVES

- Describe the project goals and objectives in the statement of project objectives.
 - How the project goals and objectives relate to the program goals and objectives.
 - Identify the success criteria for determining if a goal or objective has been met. These generally are discrete metrics to assess the progress of the project and used as decision points throughout the project.

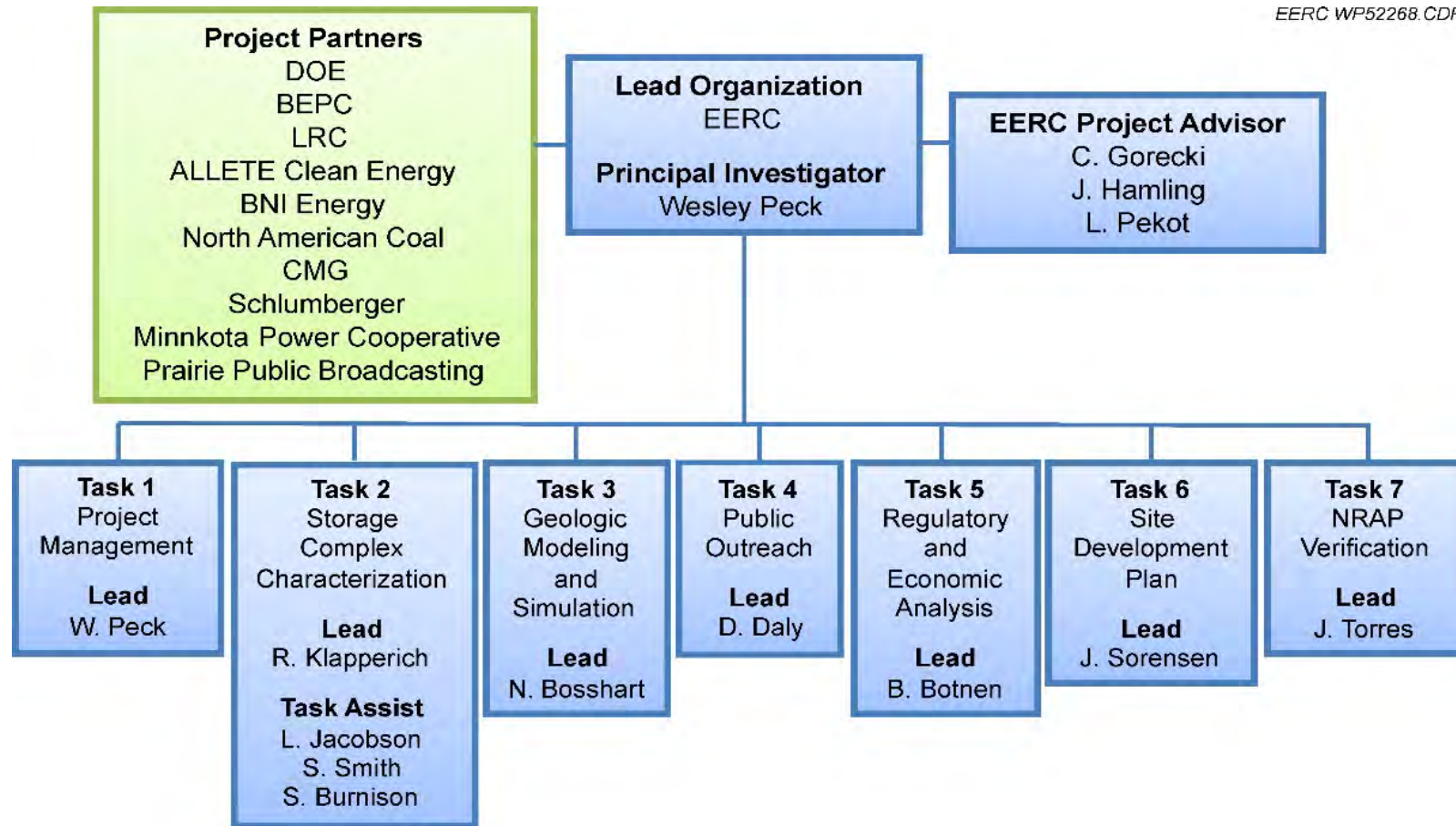
PROJECT OVERVIEW

GOALS AND OBJECTIVES

- The objective of this project is to determine the feasibility of developing a commercial-scale carbon dioxide (CO₂) geologic storage complex able to store 50+ million metric tons of CO₂ in central North Dakota safely, permanently, and economically. This objective is being met through the evaluation of two project study areas associated with two ideal geologic storage complexes located adjacent to separate coal-fired facilities in North Dakota: The Basin Electric Power Cooperative (BEPC)-owned Dakota Gasification Company (DGC) and the Minnkota-owned Milton R. Young (MRY) Station.
 - Each of the project activities will advance the state of knowledge for conducting commercial-scale CCS projects and provide lessons learned to each of these processes to help ensure the successful development of future commercial-scale projects. Furthermore, the proposed work will contribute directly to achieving DOE's goals of 1) developing and validating technologies that ensure 99% storage permanence, 2) improving reservoir storage efficiency while ensuring containment effectiveness, 3) supporting industry's ability to predict CO₂ storage capacity in geologic formations to within ±30%, and 4) developing best practices manuals.
 - This project is divided into two BPs that correspond to several project milestones. Several success criteria have been developed to help track the progress of the project and to indicate the successful completion of the project's objectives.

Task/ Subtask	Milestone Title	Planned Completion Date	Verification Method
2.2	M1 – Initiation of Well Drilling	11/30/17	Reported in subsequent quarterly report.
2.4	M2 – Completion of Seismic Reprocessing	1/31/18	Reported in subsequent quarterly report.
6.3	M3 – Risk Assessment Workshop Scheduled	2/28/18	Reported in subsequent quarterly report.
3.2	M4 – Identification of Inputs for NRAP Model(s)	7/31/18	Reported in subsequent quarterly report.
3.1	M5 – Completion of Geologic Modeling	8/31/18	Reported in subsequent quarterly report.
6.3	M6 – Updated Risk Assessment Workshop Scheduled	11/30/18	Reported in subsequent quarterly report.

ORGANIZATION CHART



GANTT CHART

