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Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

BASIN ELECTRIC CARBON STORAGE RESEARCH PROJECT – NOVEL MONITORING TECHNIQUES

FECM/NETL Carbon Management Research Project Review Meeting
Pittsburgh, PA, August 5-9, 2024

Presenter: Trevor Richards, Subtask Manager

Fossil Energy Related Resources (FERR) Subtask 1.6
DE-FE0024233

ACKNOWLEDGMENT

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DISCLAIMER

PRESENTATION OUTLINE

- Project background, partners, scope, and timeline
- Accomplishments and status of project activities
- Summary of best practices, lessons learned, and next steps

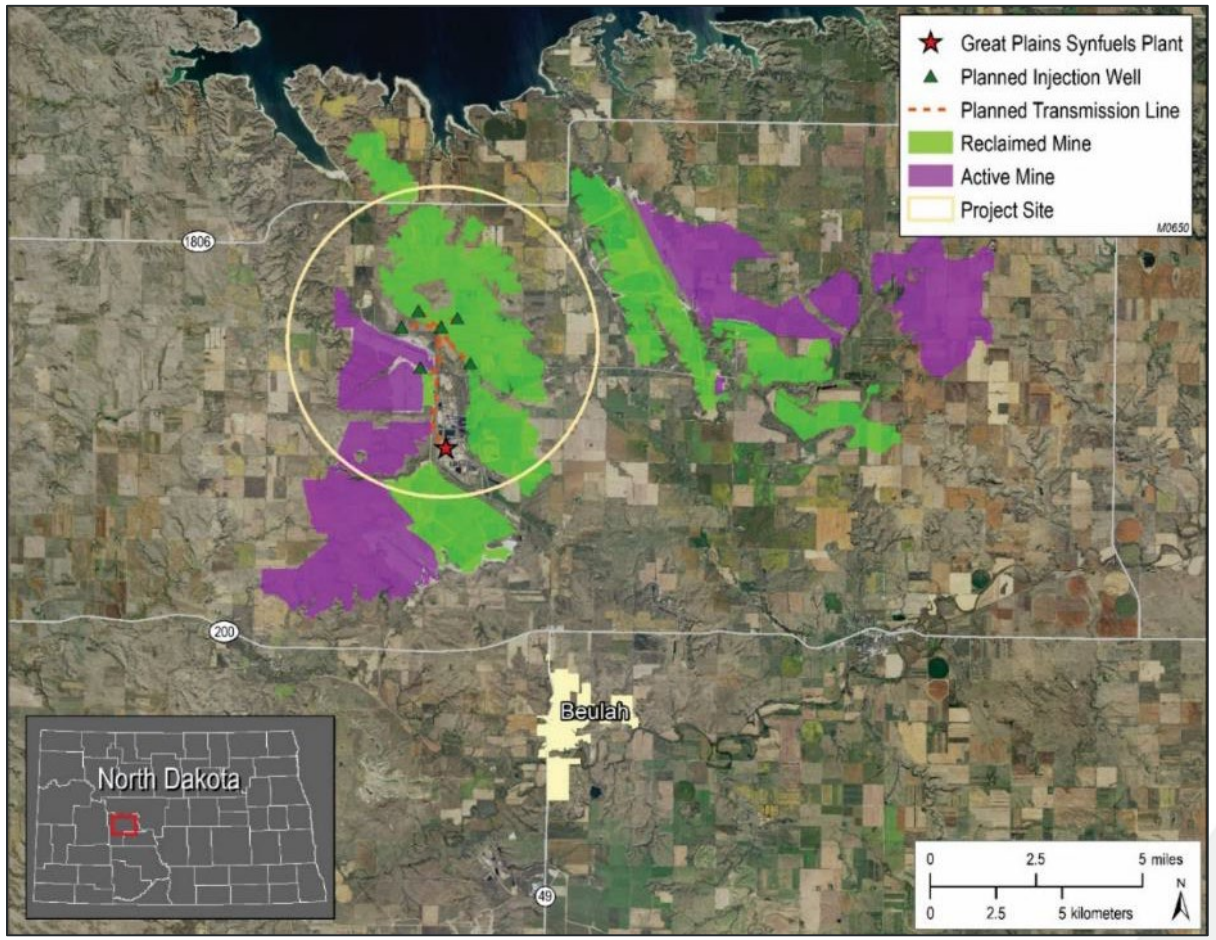
Great Plains Synfuels Plant, Beulah, ND

PROJECT BACKGROUND

- The Great Plains Carbon Dioxide (CO_2) Sequestration Project.[1]
  - **Largest coal-based Class VI project operating in the world (>2.7 million tonnes annually)**.

- The EERC is leading applied research at an active CO_2 storage project (map at right) **to establish novel carbon storage monitoring techniques as commercial methods**.

- DOE has awarded the EERC $6.5 million over a 2-year performance period (March 1, 2023, through May 31, 2025).
  - The EERC collected baseline data under five research activities in Phase 1 (~$1.4 million).
  - **The EERC was recently awarded an additional $5.1 million for Phase 2 operational monitoring.**



[1] Order Nos. 32250-52, Class VI - Geologic Sequestration Wells | Department of Mineral Resources, North Dakota (nd.gov)

PROJECT PARTNERS

BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

Parent company of Dakota Gasification Company (DGC)

Great Plains SYNFUELS
DAKOTA GASIFICATION COMPANY
A BASIN ELECTRIC POWER COOPERATIVE SUBSIDIARY

Operator of Great Plains Synfuels Plant (CO_2 source) and entity with approved Class VI permit

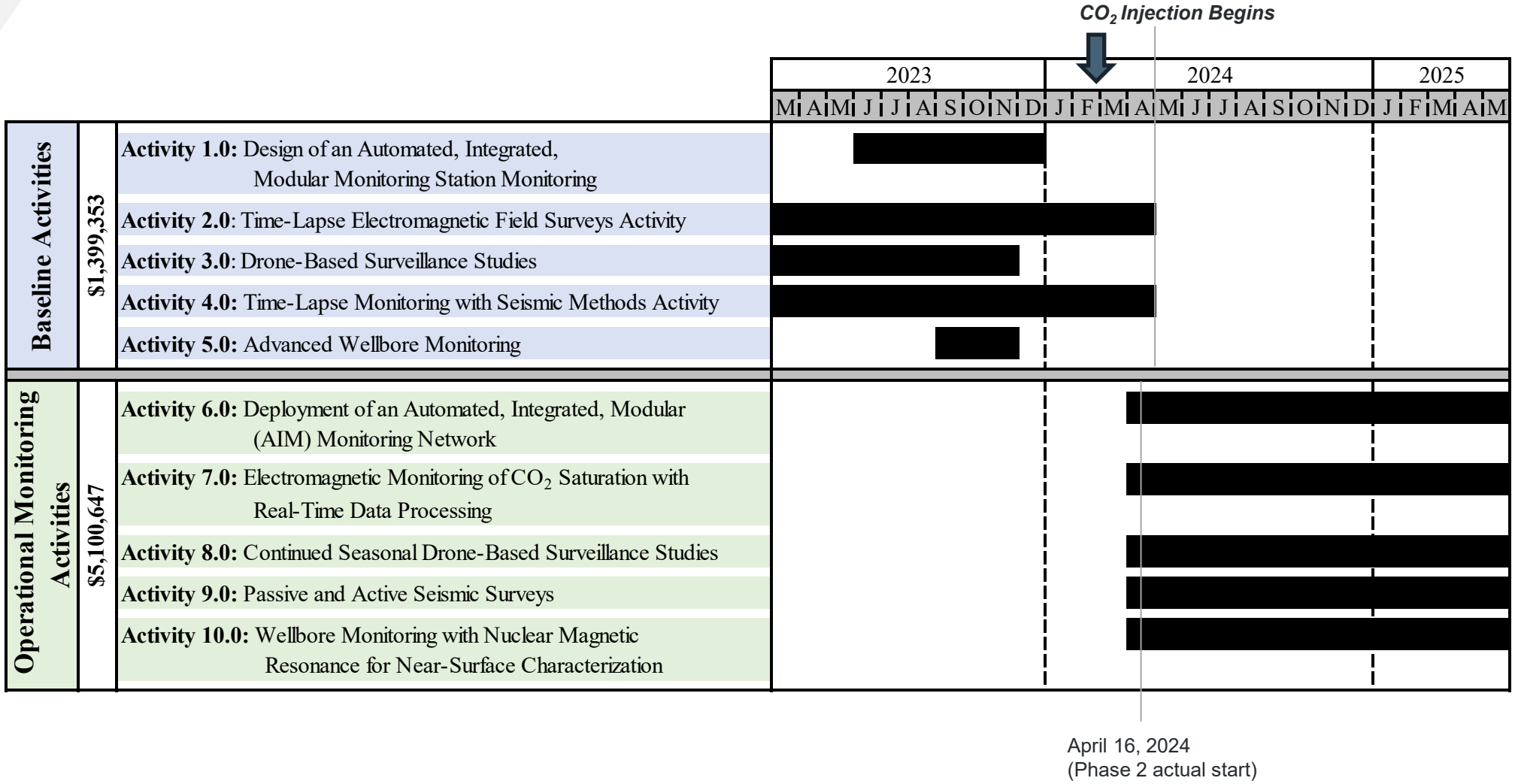
CARBON VAULT

Injection well operator and compliance monitoring management company

North American COAL
FREEDOM MINE
THE COTEAU PROPERTIES COMPANY

Principal landowner

PROJECT TIMELINE



RESEARCH SCOPE (PHASED APPROACH)

Phase 1 (baseline):

- Drone-based surveillance studies
- Design of an automated, integrated, modular (AIM) monitoring station
- Advanced wellbore monitoring methods
- Time-lapse electromagnetic (EM) field surveys
- Time-lapse monitoring with active and passive seismic surveys

Phase 2 (operational monitoring):

- Continued seasonal drone-based surveillance studies
- Deployment of an AIM monitoring network
- Wellbore monitoring with nuclear magnetic resonance (NMR) for near-surface characterization
- EM monitoring of CO_2 saturation with real-time data processing
- Passive and active seismic surveys

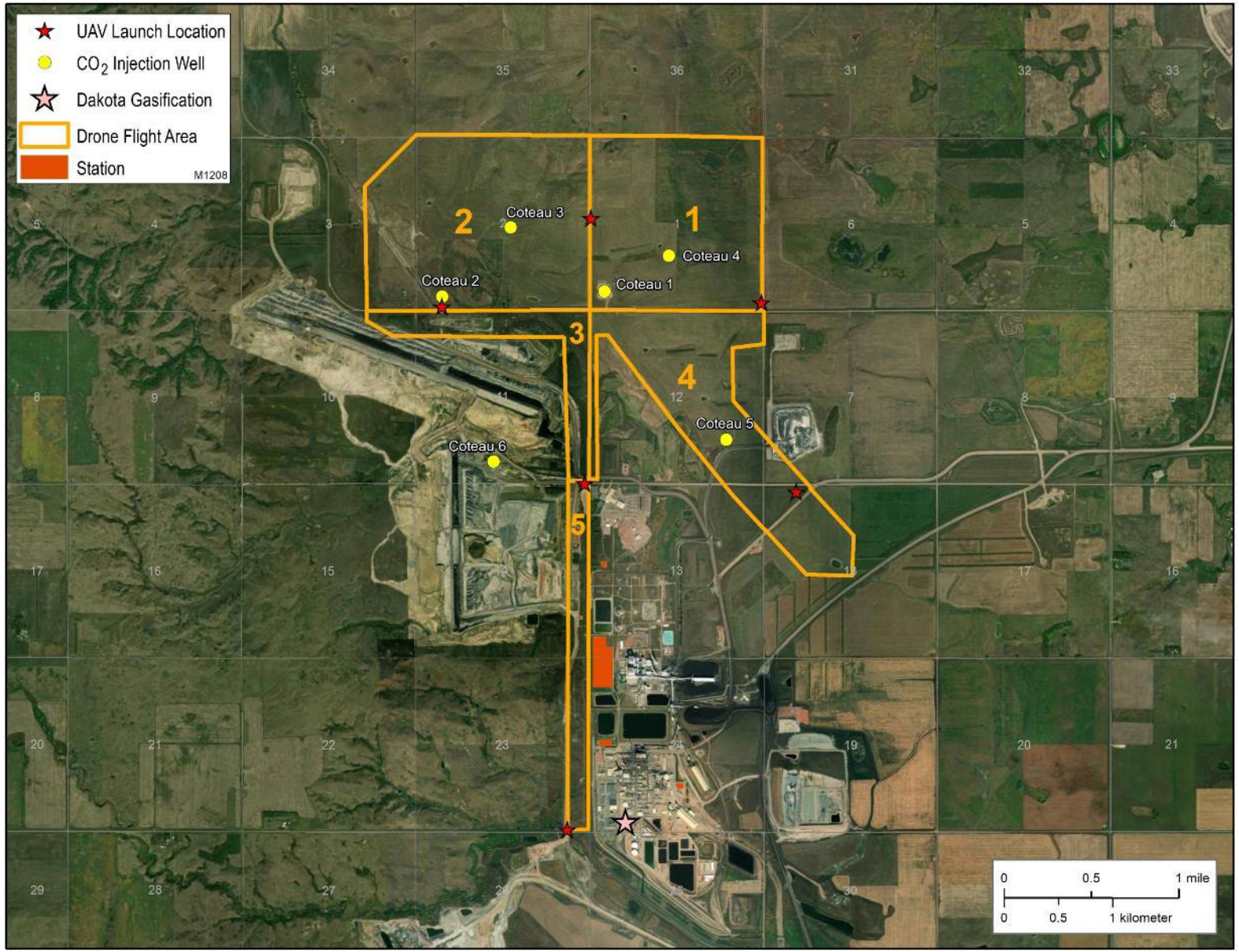
DRONE SURVEYS

Phase 1

- Drone data collected and processed during Phase 1 baseline activities, including:
  - Lidar data
  - Photogrammetric imagery
  - Multispectral imagery
  - Thermal scans

Phase 2

- Repeat survey completed July 2024
- Next mission planned for October 2024



DIGITAL ELEVATION MODEL EXAMPLE

Lidar – Digital Elevation Model

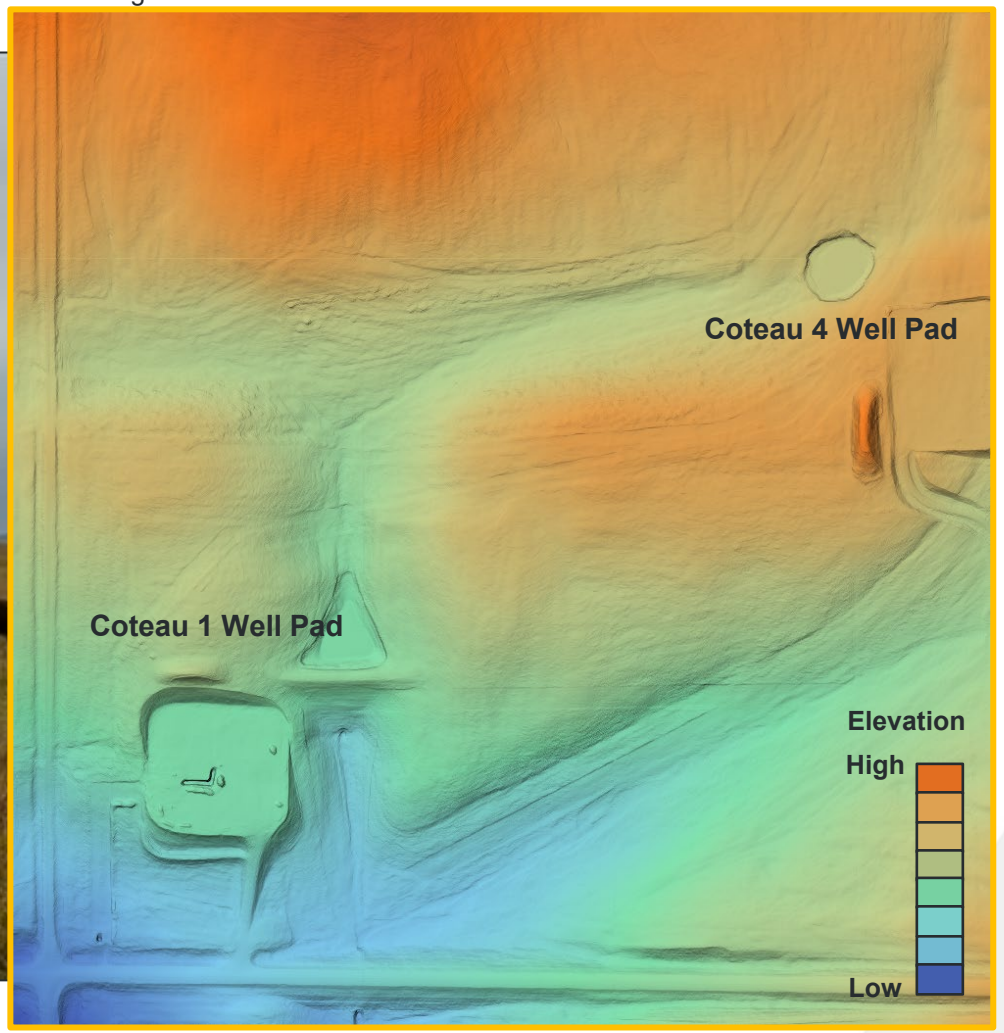
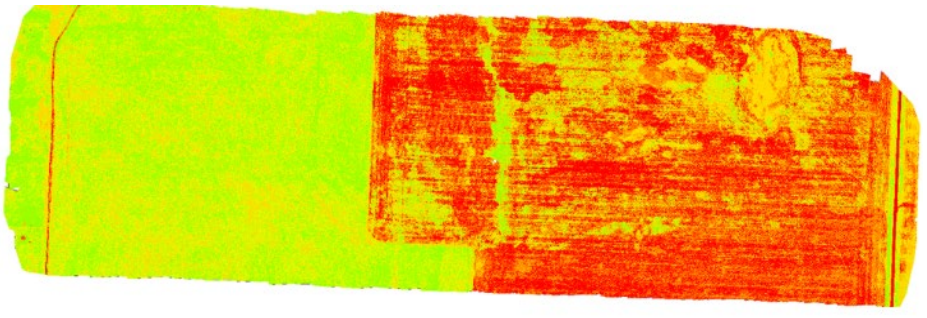


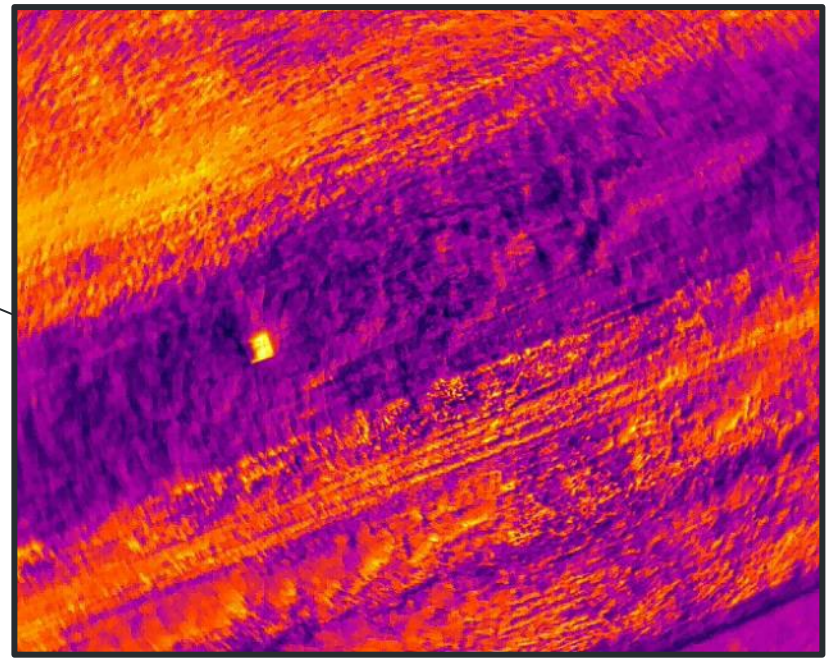
IMAGE PROCESSING EXAMPLES

Photogrammetric Image

Multispectral Image (1 mi x 0.25 mi)

Normalized Difference Vegetation Index



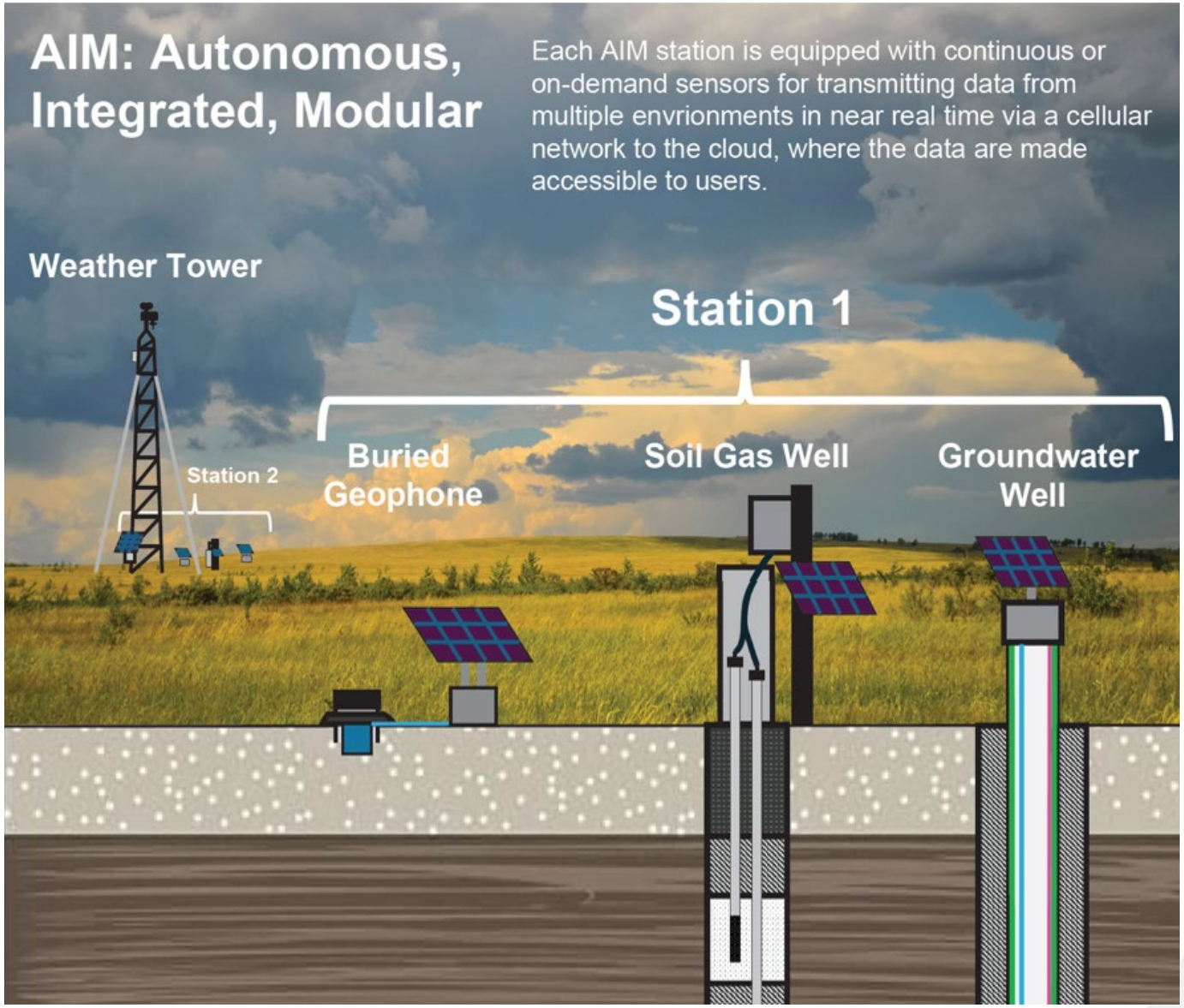


Temperature

THE AIM CONCEPT

Phase 1

- Design of the AIM monitoring system includes equipment and materials required to collect near-real-time measurements of atmospheric, soil gas, and groundwater conditions as well as seismic and seismicity responses.
- Data streams will be transmitted via cellular and made accessible through cloud-based software.
- This activity included collaboration with DGC and Coteau Properties Company staff to select equipment and locations for deployment.



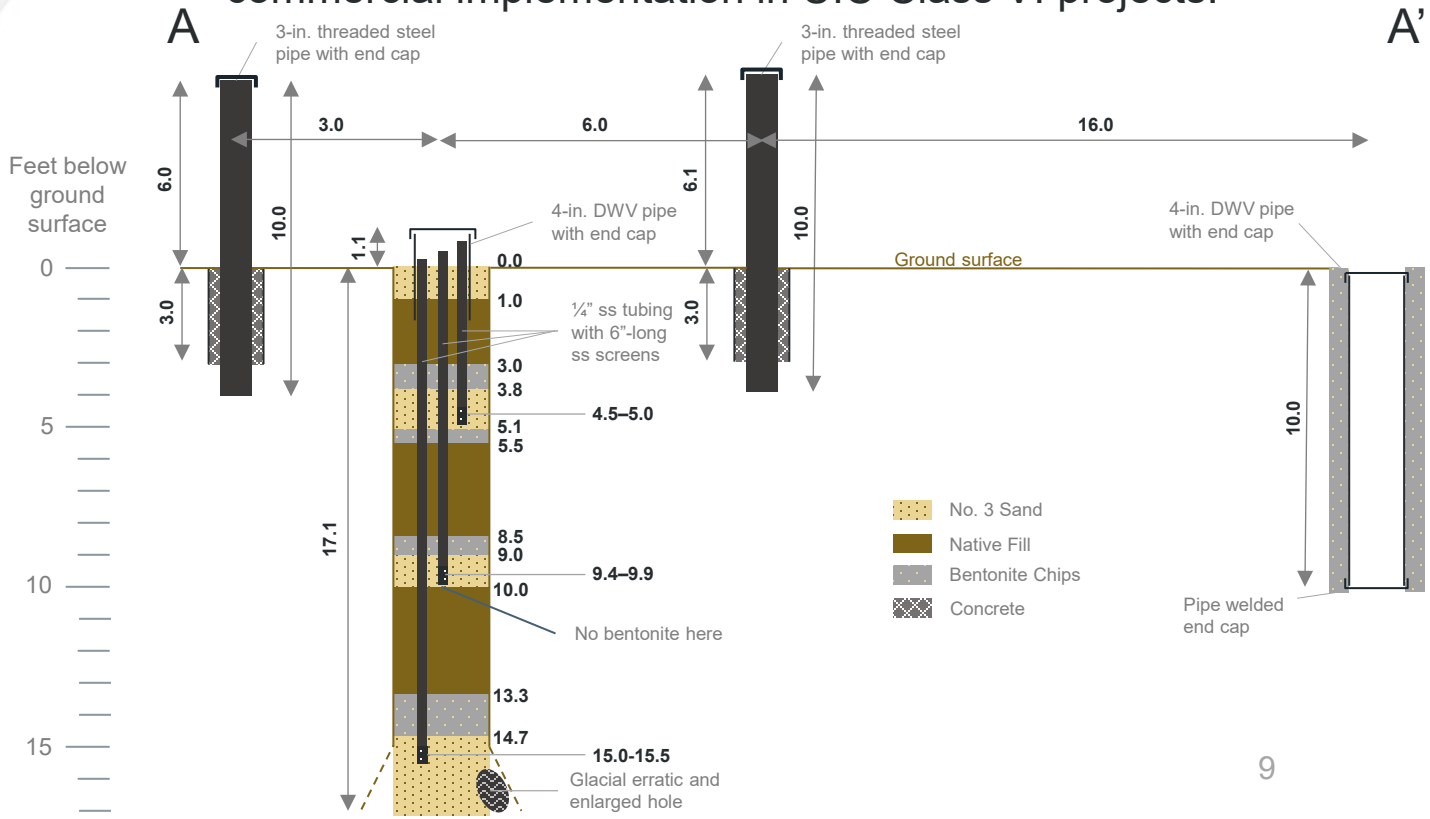
Presented at 2024 American Association of Petroleum Geologists' Capture, Utilization, and Storage Meeting.

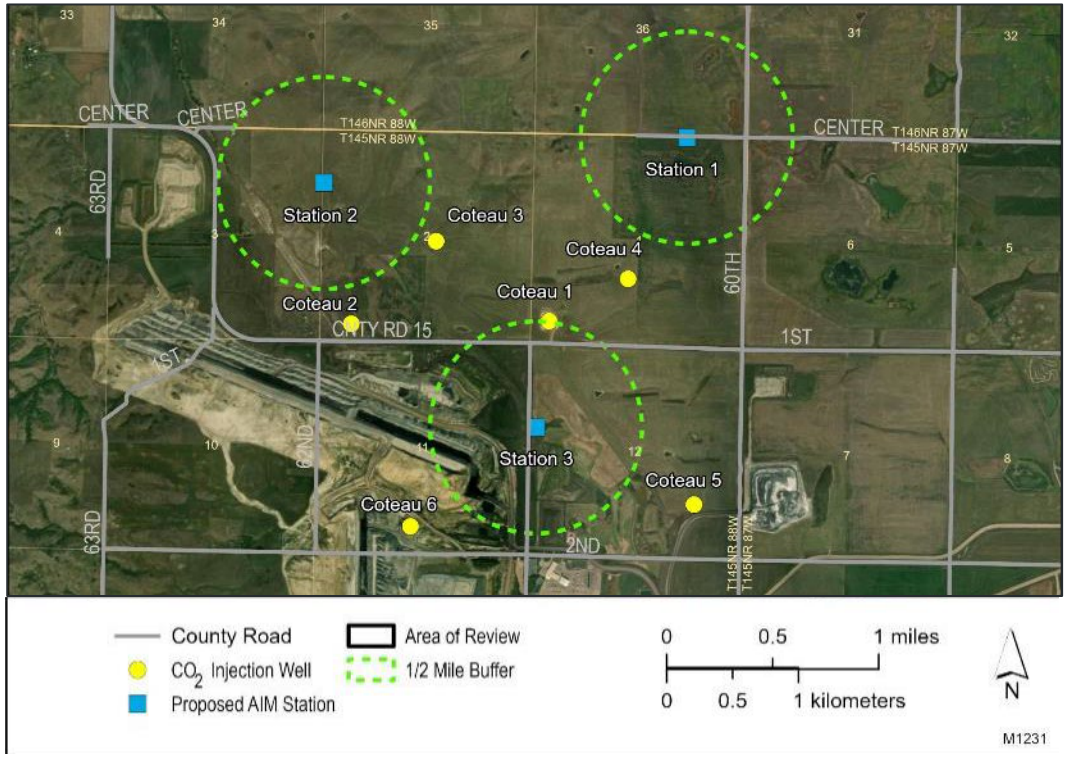
AIM DEPLOYMENT

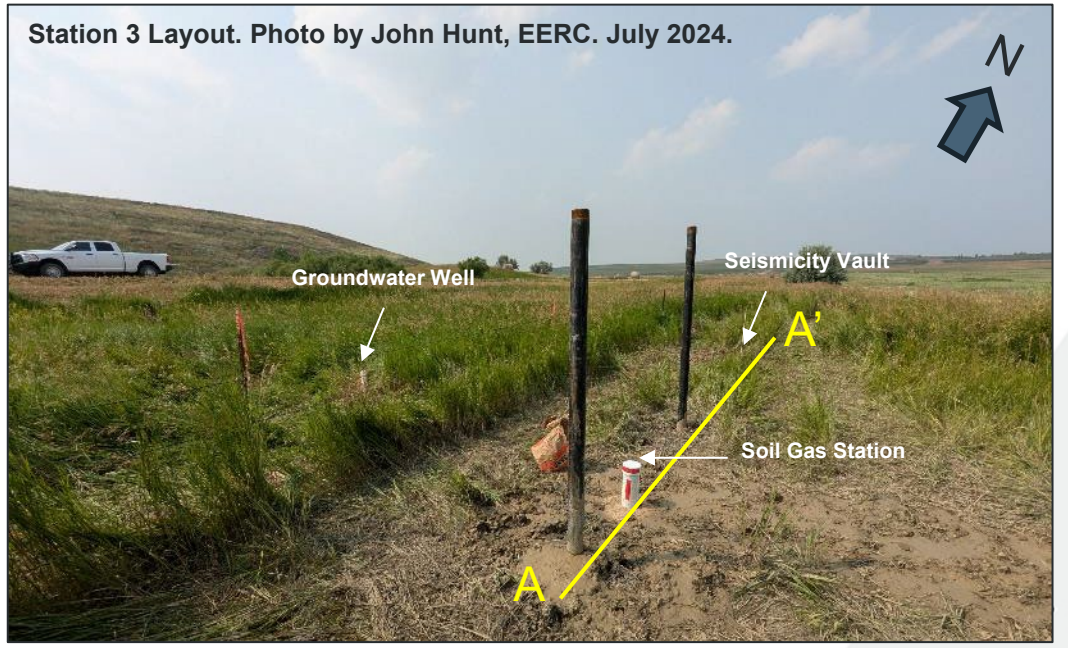
Phase 2

- The EERC will fabricate and deploy three AIM stations.
  - Installed nonsensor portion July 2024.

- AIM stations will begin monitoring fall 2024.
  - Testing the AIM concept will serve as a springboard for commercial implementation in UIC Class VI projects.







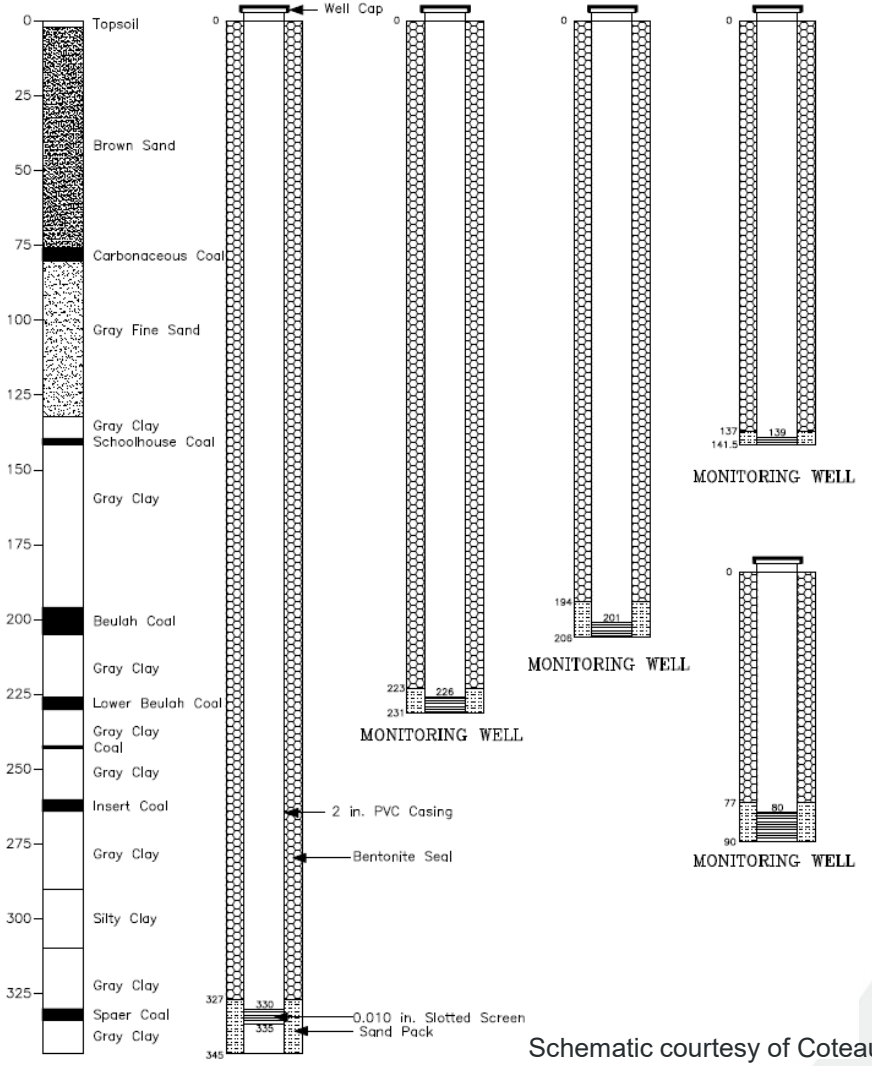
ADVANCED WELLBORE MONITORING METHODS

Phase 1

- The EERC and Vista Clara confirmed the feasibility of logging shallow groundwater wells on reclaimed mining land with NMR technology to observe possible seasonal saturation changes in near-surface aquifers.

Vista Clara's remote logging system deployed at Moab study site. https://www.vista-clara.com/2023/04/25/darya-morozovs-upcoming-presentation-at-2023-bioremediation-symposium/.

Example Well Schematic of Shallow Groundwater Well Within Project Area.



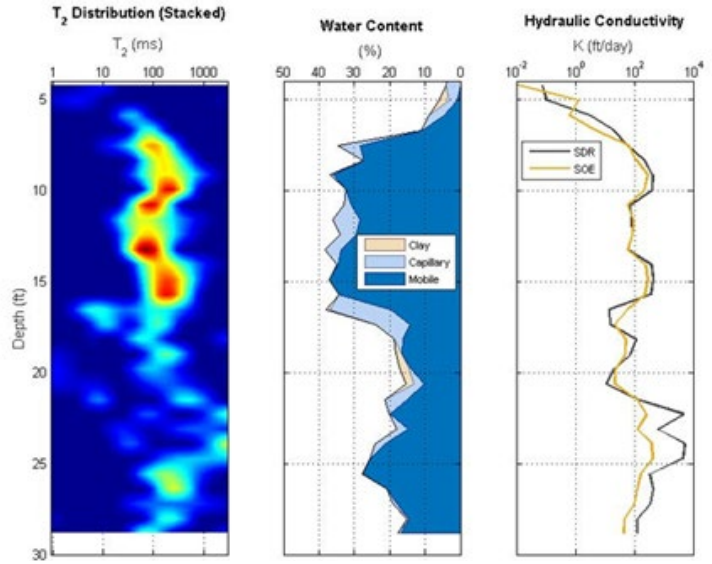
Schematic courtesy of Coteau.

NMR LOGGING

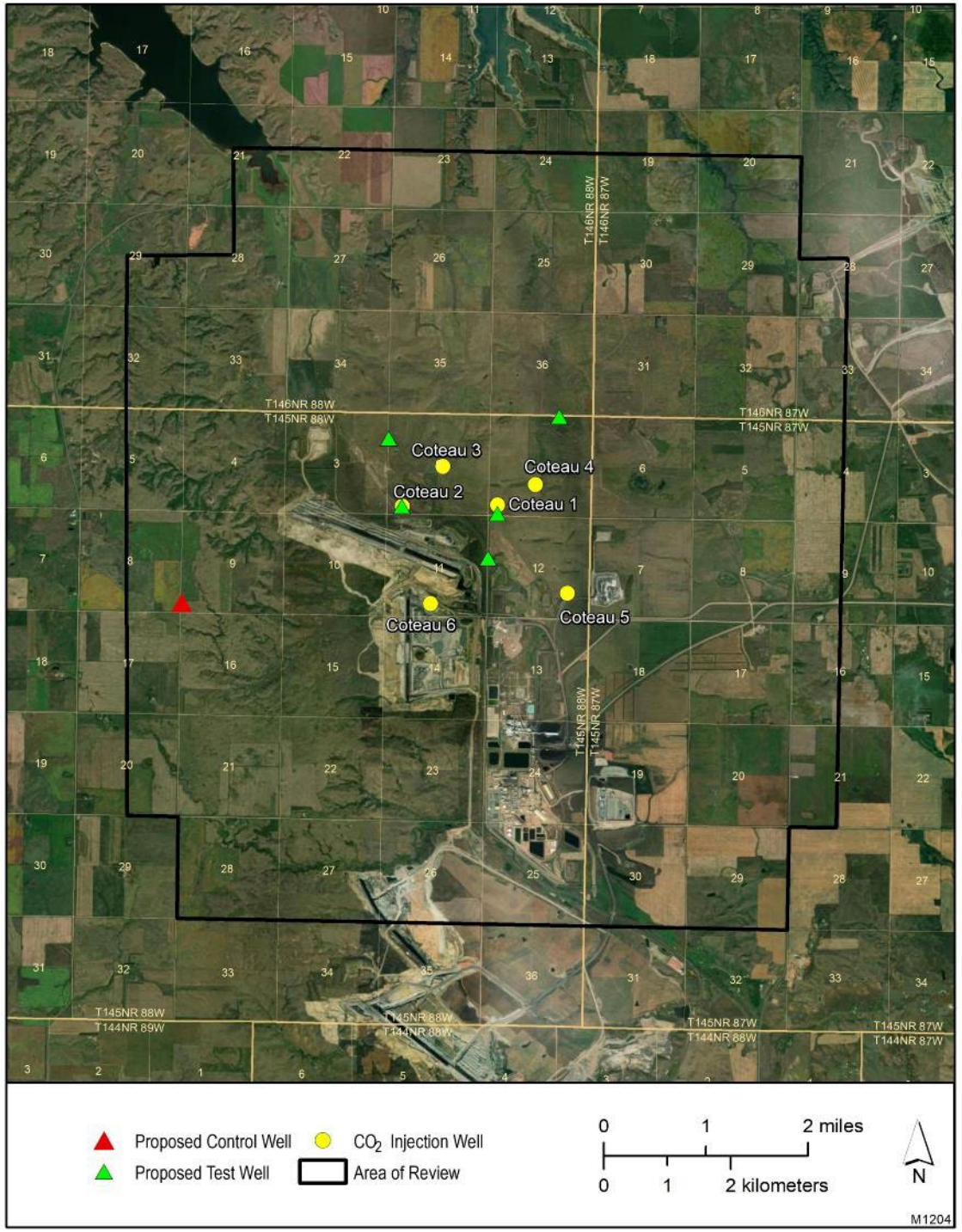
Phase 2

- NMR logs will be collected from six 2-in.-diameter polyvinyl chloride-cased groundwater wells in October 2024.

- NMR logging data will quantify saturation in shallow aquifers and may shed light on other natural processes (e.g., methane oxidation).



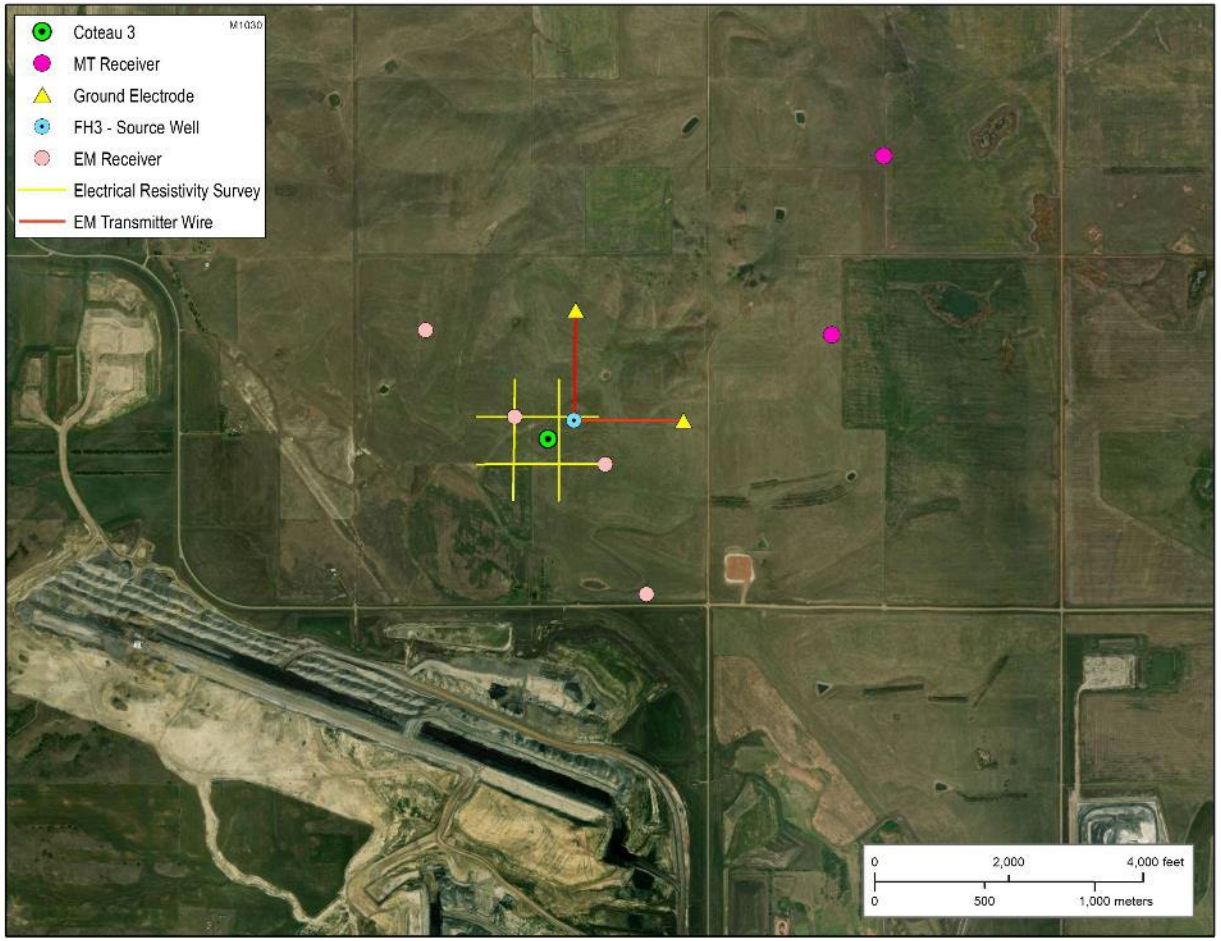
Example NMR data. https://www.vista-clara.com/2022/05/26/javelin-micro-1-75-inch-borehole-logging-tool-successfully-field-tested-in-moab-ut/.



EM FIELD SURVEYS

Phase 1

- Preliminary EM survey tested shallow and deep signal for planning and design of operational monitoring phase.
- Time-lapse EM surveys to observe current distribution of CO_2 saturation related to resistivity changes in the storage reservoir.
- Complementary shallow resistivity surveys will be acquired as for characterizing potential seasonal changes in the near-surface environment and improve processing results.
- We anticipate having tested and validated a charged well casing (CWC) EM survey method as an alternative geophysical solution for plume monitoring of CO_2 saturation extents.
- This CWC method reduces surface impact and allows for fast time-lapse processing relative to similar seismic monitoring options implemented at carbon capture and storage (CCS) sites.



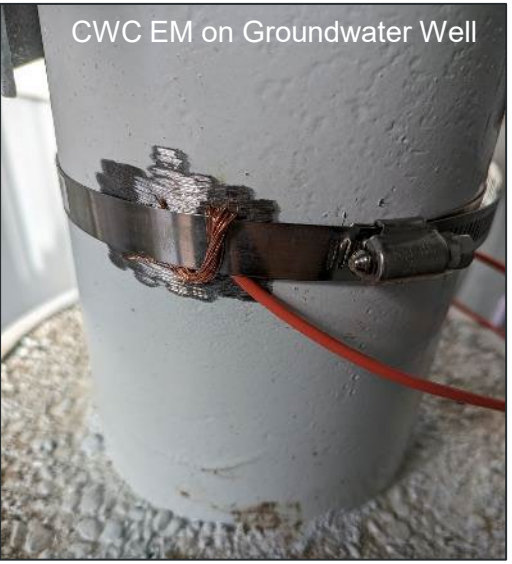
EM MAGNETOTELLURIC (MT) FIELDWORK


Zonge Transmitter and Current Monitor


AGI SuperSting Equipment


Staging for EM Equipment


Generator for Zonge Source


CWC EM on Groundwater Well


Preparing EM Electrodes (porous pot)


MT Sensor Install

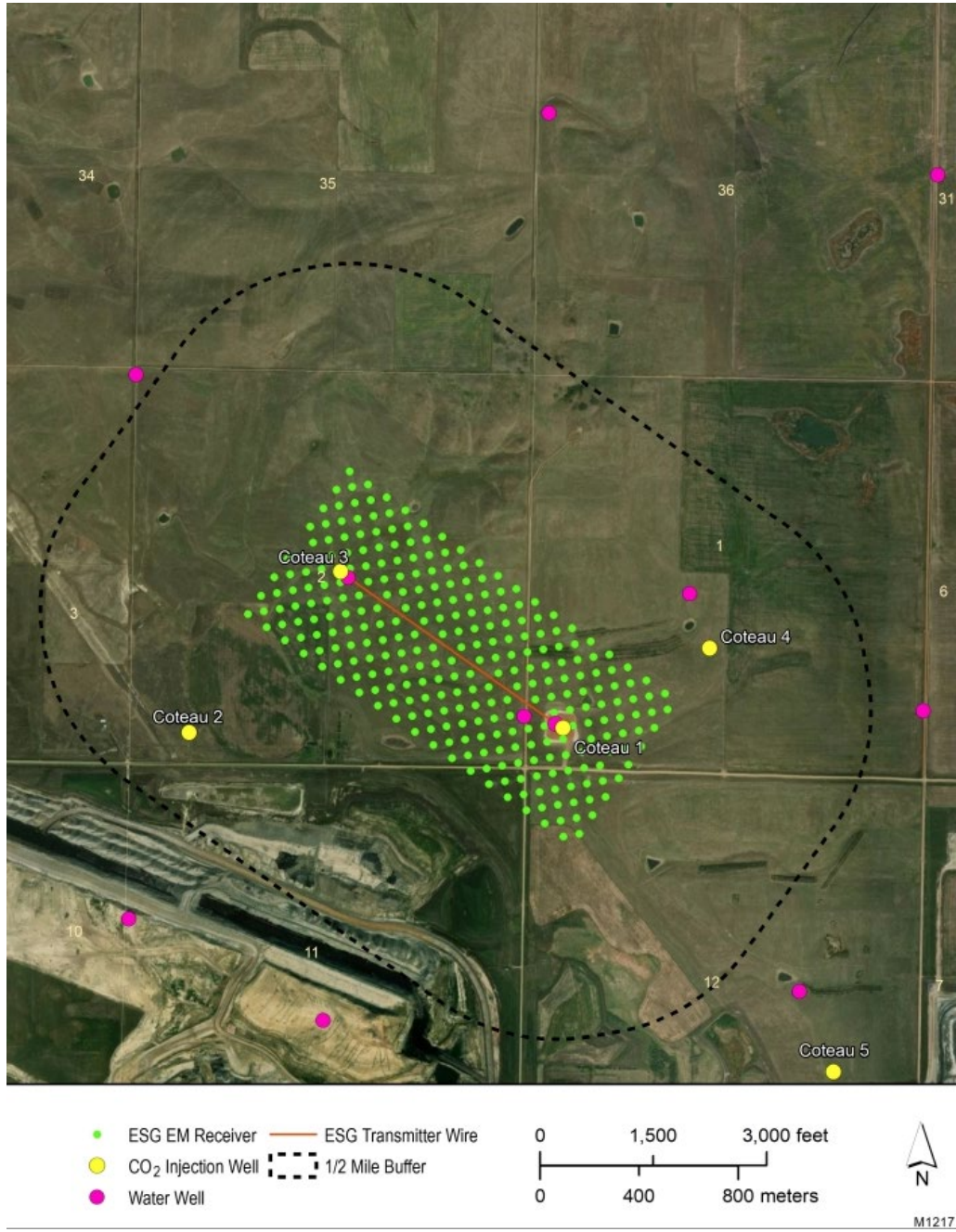

Deploying Transmitter Wire

EM MT

- The EERC plans to collect the first round of EM MT surveys in early August 2024.
- Fieldwork requires five-person crew for up to 9 days.
- 12–16 MT stations will require digging as follows:
  - Two 3-ft-long trenches up to 12 in. deep
  - One 6-in.diameter, 3-ft-deep hole
  - Two stations deployed each day with passive recording overnight.

EM CWC

- Engineering Seismology Group Canada Inc. (ESG)* will perform first round of EM CWC surveys in early August 2024.
- Fieldwork requires an EERC representative plus up to an 8–10-person crew for up to 8 days.
- Transmitter will be connected to two ~1800-ft groundwater-monitoring wells adjacent to injection sites.
- All 288 EM receivers and additional sources (i.e., groundwater-monitoring wells) will require rebar to be placed 12–36 in. deep at each location.



** ESG Solutions is owned by Deep Imaging, a Texas-based subsurface imaging and frac diagnostics company.*

ACTIVE SEISMIC

Phase 1 baseline activities

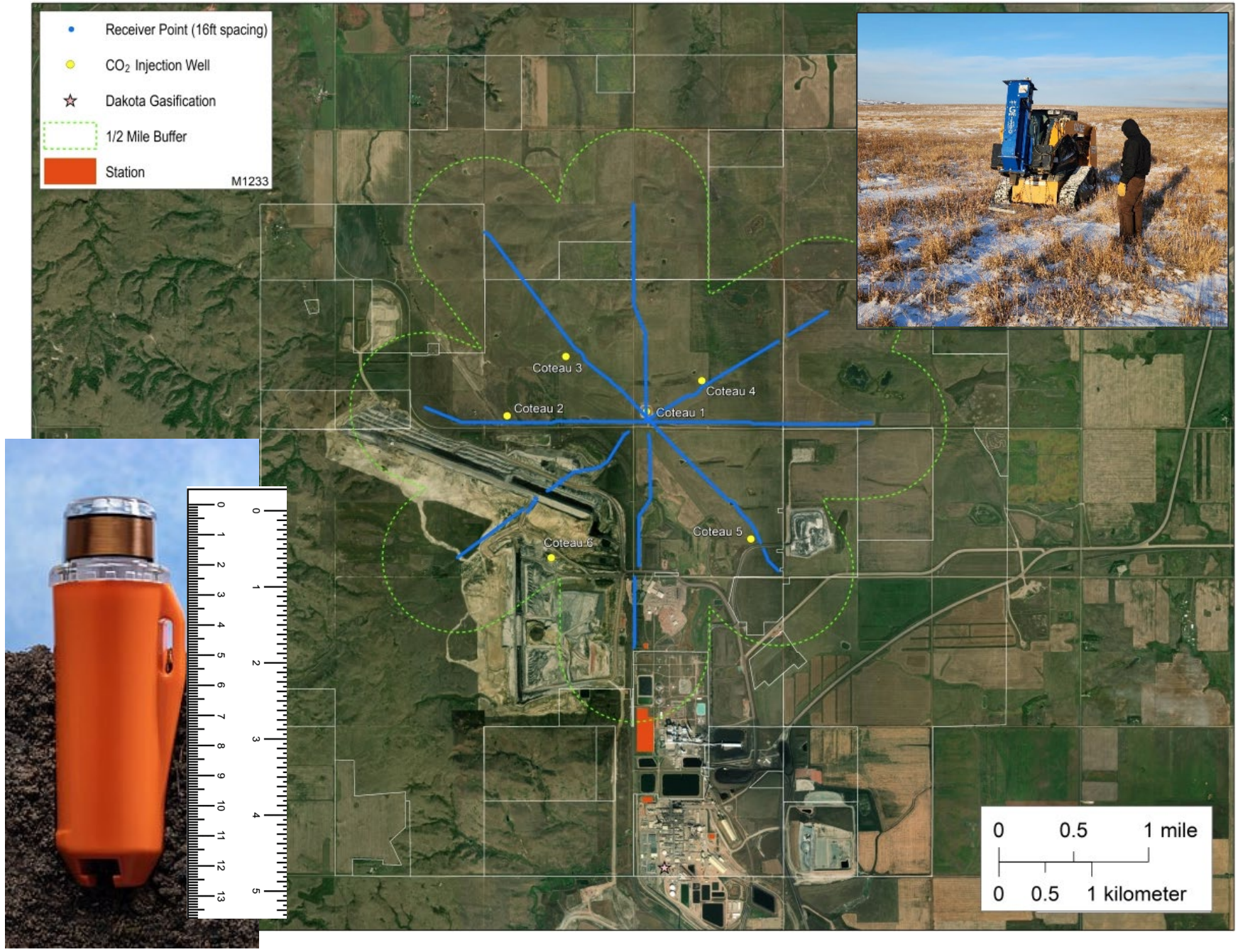
- Two types of low-energy, low-impact sources were tested the week of January 7, 2024, along a 2D profile shown on map below across two injection sites
- 970 Stryde sensors (few inches in size) were temporarily buried along 2D profile.

Above: Explor's Skid-Steer-Mounted Lightspeed Seismic Source (***actual footage***)

Below: Skid-Steer-Mounted Accelerated Weight Drop (AWD)

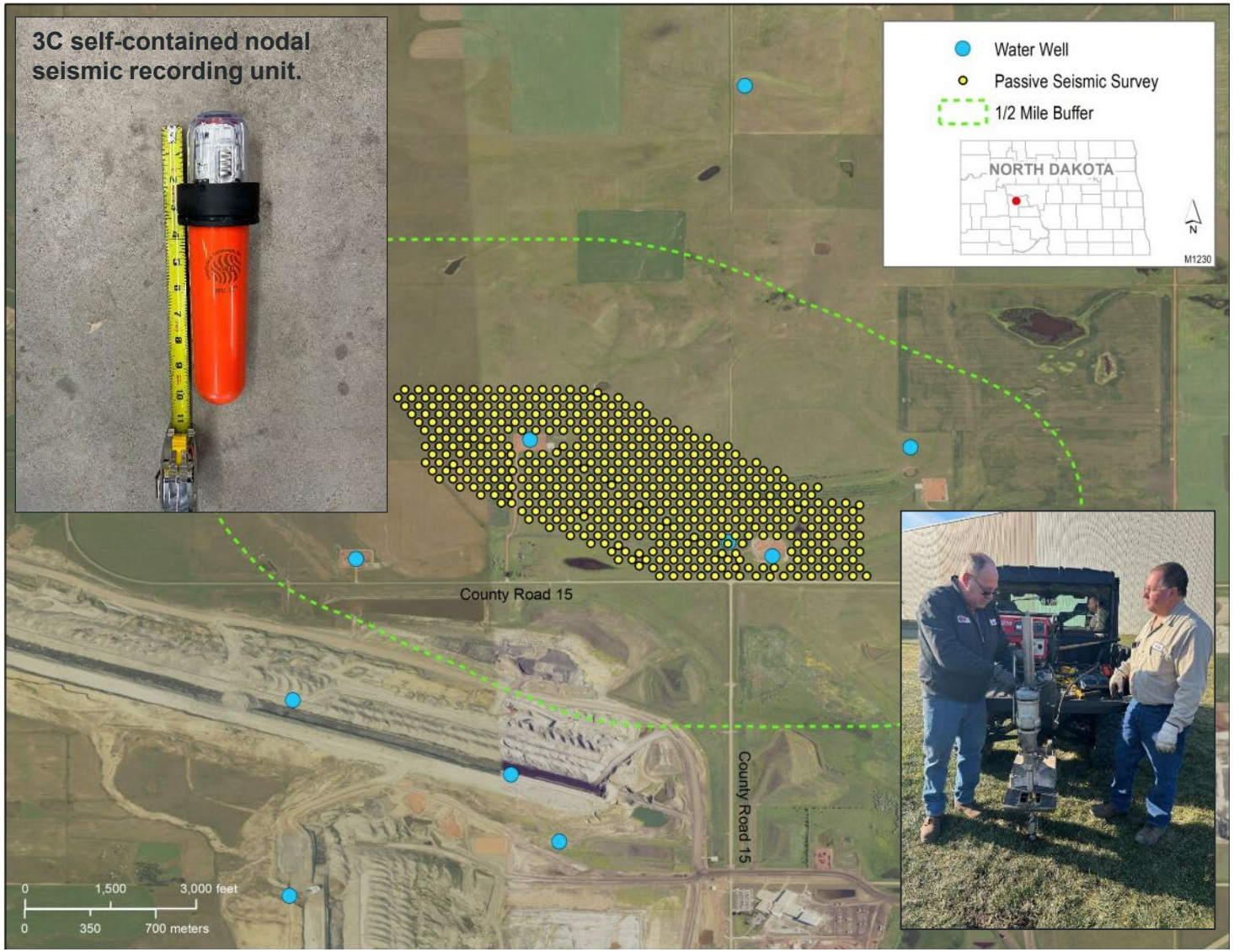
ACTIVE SEISMIC

- Acquire 2D seismic with an AWD seismic source in late August 2024 and late March 2025.
- Fieldwork requires a six-to-eight-person crew for up to 2 weeks.
- High-density Stryde sensors (at right) will be temporarily buried along 2D lines.
- The EERC will deliver a workflow for design optimization of 2D seismic reflection surveys using low-impact sourcing and compressive sensing techniques for more sustainable and cost-effective seismic data for monitoring CCS sites.



PASSIVE SEISMIC

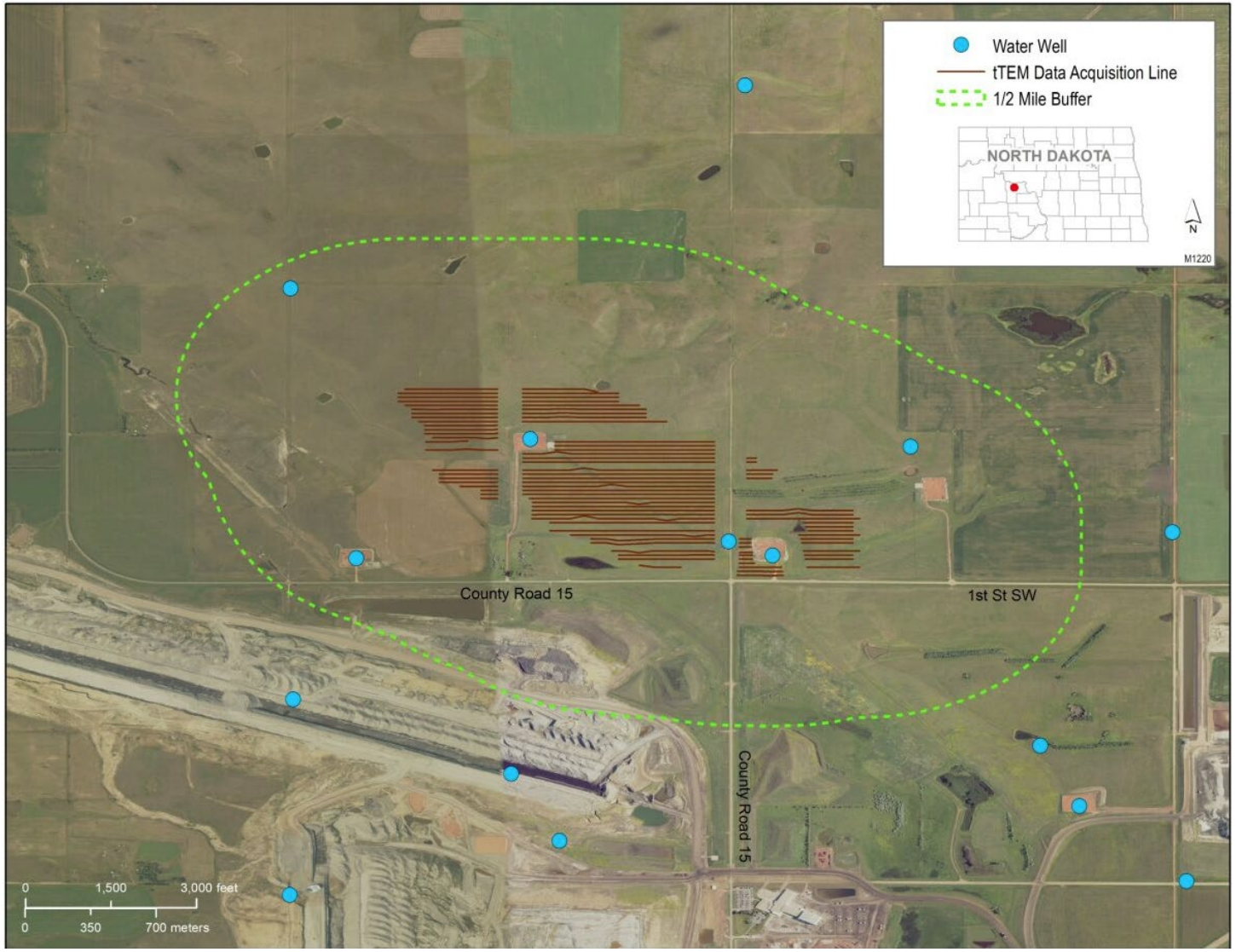
- In Phase 1, a baseline passive survey was collected. 500 Geophysical Technology Inc. (GTI) 3C NRU sensors were deployed and recorded for ~30 days.
- The phase 2 passive seismic survey is planned for October 2024.
- Deployment and pickup of the NRUs requires seven-person crew for 8 days.
- At the conclusion of this passive seismic activity, the EERC will have developed a new integrated method for passively monitoring CO_2 saturation and pressure with high-density seismic interferometry and geomechanics for mapping the CO_2 plume extent. The passive seismic survey data will be integrated with actively sourced 2D seismic and EM.



TOWED TRANSIENT EM METHOD

- The EERC will acquire a towed transient EM (tTEM) survey in early October 2024 to complement processing of passive seismic data.
- Field crew includes one third-party contractor and a two-person EERC crew for 2 days.

https://www.temcompany.com/project/the-ttem-geoscanner/



BEST PRACTICES, LESSONS LEARNED, AND RISK MANAGEMENT

Best practices:

- Communicate early and often with project partners to avoid delays with securing site access.
- Make sure a core group of representatives from each partnering entity is identified and stays up-to-date so that everyone understands the work planned before it begins.
- Build buffers in the timeline to anticipate planning around variable weather conditions.
- Set internal milestones and goals with the project team that are based on DOE milestones and deliverables to stay ahead and on track.
- Precheck equipment prior to going into the field.

Key lessons learned:

- Balance between hard “frozen” ground and ease of deployment
- Managing crew timing, safety and commercial operations of mine, facility and CCS project

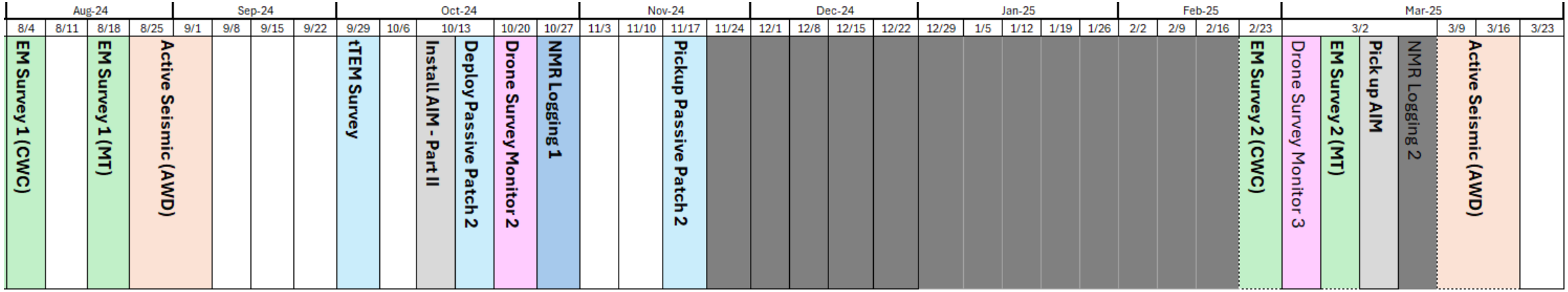
Risk management:

- Safety training (active mine operation)
- Crop and livestock management
- Site access agreements
- Supply chain sensitivities

PROJECT IMPACT AND NEXT STEPS

- Unique opportunity to demonstrate novel monitoring methods that are sustainable, cost-effective, and lower impact at the largest coal-based Class VI project in the world.

Timeline of Field Activities



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