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March 30, 2022

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

RE: Final and Comprehensive Report for Midwest AgEnergy Group / NDIC Renewable Energy Development Fund Grant Contract Number R-047-058.

Ms. Fine:

Please find enclosed the Final and Comprehensive Report for Project R-047-058 *Seismic Survey to Advance Potential for CO2 Storage in Eastern ND*.

The project was completed on schedule and under budget. Actual project costs totaled \$539,808.85. MAG has received \$238,163.16 from NDIC as reimbursement for 50% of project expenses incurred through November 30, 2021. MAG is requesting \$31,741.27 from NDIC upon satisfactory review of this final report.

If you have any questions regarding this report, please contact me at 701-442-7503 or at adunlop@midwestagenergy.com.

Sincerely:

A handwritten signature in blue ink that reads "Adam C Dunlop".

Adam C Dunlop
Director Technical Services
Midwest AgEnergy Group



Seismic Survey to Advance Potential for CO₂ Storage in Eastern ND

Final & Comprehensive Project Report

March 31, 2022

Contract R-047-058

This report was prepared by Midwest AgEnergy Group pursuant to an agreement with the Industrial Commission of North Dakota, which partially funded the project through the Renewable Energy Program.

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Project Summary

The objective of this project was to gather subsurface information required to achieve a better understanding of the potential for safe and permanent CO₂ storage in deep saline formations in eastern ND. A 2D seismic survey was conducted in Stutsman County at least 50 miles east of the nearest known commercially available seismic line.

Midwest AgEnergy (MAG) has successfully navigated all aspects of the project. Activities performed included: procurement of qualified expert contractors, determining seismic line location, permitting, pre-acquisition equipment inspection and quality control, public outreach and notifications, seismic data acquisition, processing the data, and interpreting the signals and drawing conclusions.

A competitive bid process was utilized to select qualified contractors to facilitate permitting, QA/QC, seismic acquisition, and interpretations.

The 2D line was permitted through North Dakota Industrial Commission Department of Mineral Resources. Slight adjustments were made to the proposed line locations to optimize project data collection and minimize risk to existing infrastructure.

Data acquisition commenced on October 15th and concluded on October 22nd. A total of 47.76 linear miles were acquired. There were no negative community impacts, and all work was performed in a safe and professional manner.

Processing of raw data was completed by the end of November 2021. Data was of excellent quality and fit for purposes of the project. Several iterations were required to achieve optimal noise attenuation and signal conditioning for interpretation.

Interpretation of signals was conducted by staff at the EERC. The quality of data utilized for interpretation was good. Several items were identified which could make geological sequestration of CO₂ in the study area challenging. Of primary concern on the Deadwood target formation were marginal depth to keep CO₂ in liquid form, limited gross formation thickness, limited dissipation interval and lower confining unit, and fault systems extending from basement rock into the overburden rock. The western most edge of the area evaluated appears to present the greatest opportunity of geological storage of CO₂.

The original project budget was estimated to be \$649,280. Total actual expenses incurred were \$539,809.

Next steps for entities desiring to sequester CO₂ in eastern ND could be to extend the study further to the West where it is believed target formations get deeper and thicker. Additional 3D seismic data could also be collected to determine extent of faulting observed in the area studied for this project.

Project Activities

Critical elements of this project were securing high quality geophysical data in a safe, responsible, and cost-effective manner, and maintaining positive public relationships throughout the project.

Contractor Selection:

Professional contractors were utilized for the data acquisition, processing, and permitting. MAG followed a contractor prequalification process to ensure those selected have demonstrated a safe and efficient job performance. The first stage gate in project management was reviewing contractor proposals for adherence to the acquisition parameters specified in the RFP. Only contractors who could achieve the technical requirements and were within the cost estimates provided in the original project budget were considered.

In June of 2021, Midwest AgEnergy solicited proposals for acquisition services for approximately 40 miles of 2D seismic data collection. Six companies provided proposals. Paragon Geophysical was selected and the contract was finalized in September 2021 for them to perform seismic acquisition services.

Discovery Acquisition Services, LLC was contracted to obtain the Geophysical Exploration Permit.

RPS was added as subcontractor to MAG. They provided services associated with selection of technical specifications for the acquisition, quality control, and assistance in project management.

SEIMAX Technologies was selected to process the acquired seismic data. Processing refers to assimilation of data from loggers and performing noise attenuation, velocity analysis, subsurface gain and deconvolution, and preparing final stacks and post stack migration.

The Energy and Environmental Research Center (EERC) was contracted to provide interpretation of processed information.

Permitting:

The second project stage gate was line placement and permitting. Significant effort was put into determining the optimal location and route for the 2D lines.

Evaluation of existing well data indicated a general thickening and increased depth of potential CO₂ storage formations to the west of the prospective study area. Therefore, the east/west 2D line was extended further to the west than originally planned and shortened on the east end to terminate near the Stutsman County line. Figure 1 illustrates original line locations and Figure 2 depicts the actual line location.

Discovery Acquisition Services, LLC was contracted to obtain the Geophysical Exploration Permit. A copy of the permit can be found in APPENDIX A.

The original project permitting plan was to only conduct exploration in road right of ways to avoid negotiating agreements with private property owners. During a pre-acquisition survey, we determined an unprecedented amount of utilities currently utilizing the right of way. In fact, about half of all county roads in the prospective study area had some sort of infrastructure buried in the right of way. To avoid impacting utilities, we were required to move many of the vibe points onto private property. The receivers remained in the road right of way.

Figure 1 Original 2D Line Placement



Figure 2 Final Permitted Line Placement



To maintain adequate distance from any infrastructure, the project permitted 27.4 linear miles of private property through agreements with 52 separate landowners. The project was able to gain access to all the property needed to perform a viable study and the property owners in Stutsman County were very accommodating. Securing these permissions added about 2 weeks to the original permitting timeline. The final source point map is provided in APPENDIX B.

Pre-acquisition equipment inspection and quality control

The third stage gate was pre-acquisition equipment inspection and quality control audit. This was conducted by a qualified geophysicist and other third-party individuals within RPS with an adequate level of expertise to ensure the vibroseis equipment functioned correctly and frequencies specified were optimal and properly incorporated into equipment.

Test Reports for Vibe Trucks

A technical audit was performed on the Paragon Geophysical seismic crew for the Midwest AgEnergy project in Spiritwood, North Dakota. Testing consisted of mechanical, hydraulic, and electrical testing of the I/O AHV-IV vibrators. Three vibroseis trucks were dedicated to the project with two operating in tandem and a third available as a backup.

A few minor mechanical deficiencies were observed in the equipment by the inspector. All of which were corrected prior to commencing testing and data collection activities.

Additional effort was required to get the appropriate sweep programmed into the equipment as well as communication with the recording system. These issues were resolved prior to data collection. A detailed technical audit report is provided in APPENDIX C.

Peak Particle Velocity Testing

Peak Particle Velocity (PPV) is the measurement commonly used to determine if vibrations have capacity to negatively impact infrastructure. Integrated Geotechnical Solutions (IGS) was contracted to monitor vibrations induced in the ground to ensure no negative impacts to infrastructure occurred as part of the project. A walk-away test was conducted prior to the production commencing to characterize levels of vibration at various distances from the source. This test verified that setbacks from infrastructure were appropriate and conservative. Figure 3 depicts measurements occurring in the walk-away test.

Figure 3



The main purpose of the PPV measurements were to monitor seismic vibroseis activities near any infrastructure during the seismic acquisition phase of the project. A tablet recording system was used to document the monitoring location and readings. IGS monitored 74 vibroseis source points during the project. All vibration events monitored were well below recommended safe operating levels. The ground vibration monitoring report is provided in APPENDIX D.

Acquisition:

Program Design and acquisition parameter selection:

The Spiritwood 2D seismic survey was conceived as a feasibility study for Geologic Sequestration of CO₂ produced at the Dakota Spirit AgEnergy (DSA) facility near Spiritwood, ND. The project consisted of two intersecting 2D seismic lines, each approximately 24 miles long. Project design had Receiver locations spaced at 27.5 ft intervals in the right of way along County Roads. The Source point interval was 110 ft, with approximately ½ acquired on the County roads and ½ in adjacent fields to observe State mandated buffer distances from infrastructure. The Seismic energy source was entirely Vibroseis.

The vibroseis energy source for the Spiritwood 2D consisted of Three (3) – AVH IV Commander Vibrators operating at 62,000 pounds with a sweep of 24 seconds, 2 – 96 Hz with a 325ms/500ms taper on a linear sweep. Acquisition parameters are delineated in Table 1 below.

Table 1 Acquisition Parameters

ACQUISITION PARAMETERS AND EQUIPMENT	
Recording System	Sercel Wing
Geophone type	Mems
Geophones per channel	1
Energy source (Vibrator)	2 + 1 spare 60,00lbs AHV-IV
Sweep Parameters:	2 sweeps/24 seconds, 2-96Hz nonlinear +3dB octave
Record length	6 seconds
Sample rate	1 millisecond
Recording tape format	SEG-D
Shooting Technique	(Standard) Roll on Roll Off
Patch Size	144 x 144
Number of active channels	288
Receiver Interval	27.5'
Source Interval	110'
Total receiver groups	9170
Total source points:	1857

Acquisition equipment and crews began arriving in early October. Survey for receiver locations began October 5th. The layout for receivers was completed for the E/W line on October 6th and on the N/S line on October 8th.

Vibrator mechanical checks were started on October 11th. By October 15th, all equipment was tested and sweep tests completed. A sweep of 2-96hz, 24 sec sweep length, nonlinear was ultimately selected. APPENDIX E contains the results of SEIMAX Sweep test analysis.

Data acquisition commenced on October 15th and concluded on October 22nd. A total of 47.76 linear miles were acquired. There were 1857 source points and 9170 receiver points on the job. 24 of the planned vibration source points were unable to be utilized due to access issues.

Wind and rain were the biggest challenges faced during seismic line acquisition. High winds have capability to create interference when recording signals and thus temporarily delayed the project intermittently. A couple of heavy rain events early in the program lead to wet field conditions prohibiting access by the vibroseis trucks and causing some source points to be skipped. Overall, the project encountered 19.8 hours of weather-related standby.

When operating on county roads, the vibrator trucks utilized a plywood sheet on the vibrator deck to avoid any impacts to roads. No community impacts were observed related to the project. There were 12 receivers damaged on the project, all of which appeared to be from being struck by vehicle traffic operating in the road ditch right of way.

Overall, acquisition was a successful endeavor with more than 98.5% of the points recorded. The crews worked safely and there were no reportable incidents. The appropriate community members were kept

informed by project management and the permit agent developed good relationships with private property owners. A detailed quality control report for seismic operations is included in APPENDIX F.

Figure 4: Acquisition occurring near Dakota Spirit



Processing:

All available data was downloaded from nodes and sent to SEIMAX for processing on October 25th. Acquired data was reviewed and a geometry map created to evaluate source and receiver locations elevations, binning grid, CMP fold, wavelet and sweep parameters, raw shot QC, and brute stack.

SEIMAX followed the processing sequence described in Table 2. Seven detailed processing reports are included in APPENDIX G describing activities and illustrating progress completed throughout the processing sequence.

Table 2

1	Reformat Field Data	Convert all field data to SEIMAX internal format
2	Geometry Application	Visual verification of shots and receivers
3	Noise Attenuation I	Noise burst and spike suppression, linear de-noise
4	Tomographic Refraction Statics	Datum 1650', velocity correction of 6,000'/s
5	Surface Consistent Gain Correction I	Surface consistent amplitude compensation for shots and receivers
6	Surface Consistent Deconvolution	Spiking decon with 240 ms operator length, 0.1% Pre-whitening
7	Noise Attenuation II	Additional linear de-noise, spike/burst edits
8	Velocity Analysis I	Pick every 1 mile
9	Surface Consistent Residual Statics	1 st pass
10	Velocity Analysis II	Pick every 1 mile
11	Surface Consistent Residual Statics	2 nd pass
12	Noise Attenuation III	Additional linear de-noise, spike/burst edits
13	Surface Consistent Gain Correction II	2 nd pass
14	Initial Kirchhoff Pre-Stack Time Migration	Migration with 220 offset binning, migration dip of 50deg and aperture of 30,000'
15	Migration Velocity Analysis	Including anisotropic eta estimation
16	Final Kirchhoff Pre-Stack Time Migration	Migration with 220 offset binning, migration dip of 50deg and aperture of 30,000'
17	Residual Velocity Analysis	Pick every 0.5 mile, including anisotropic analysis
18	AVO Gather Conditioning	Radon, FX Filter, Offset Scaling
19	AVO Gathers & Stack	Full Stack and Angle Stacks (0-15, 15-30, 30-45)
20	Post-Migration Enhancements	Stack of Conditioned PSTM Gathers with FX Decon applied post-stack noise attenuation

Data Interpretation:

Midwest AgEnergy (MAG) contracted the Energy and Environmental Research Center to interpret 47.76 linear miles of two-dimensional (2D) seismic data MAG acquired for characterizing the potential for geologic carbon dioxide (CO₂) storage near the Dakota Spirit ethanol plant, located about 10 miles east of Jamestown, North Dakota. The surveyed area presents several challenges for geologic CO₂ storage. General challenges include:

- 1) geochemical evidence which confirms underground sources of drinking water are at least present in Ordovician through Cretaceous subsurface units within the project area;
- 2) fault systems extending from the basement rock into the overlying stratigraphy require additional characterization with three-dimensional seismic data; and
- 3) storage capacity is limited by depth, which determines the relative density of CO₂.

Along the westernmost 6 miles of the east-west 2D line of the regional seismic survey (Line 10), the Deadwood Formation was identified as the most attractive potential reservoir target for geologic CO₂ storage in the area. However, the Deadwood Formation:

- 1) lacks a lower confining unit and lower dissipation interval to separate the basement rock from any potential injection activities; and
- 2) has a gross thickness which is relatively thin (between 50 and 70 feet on well logs and potentially less than 44 feet on the seismic data), presenting limited storage capacity despite observing typical values of porosity on well logs.

A comprehensive report prepared by the EERC is provided as APPENDIX H.

Interpretation Summary and Synthesis

Several technical criteria and considerations were evaluated from well logs and MAG's regional seismic survey. Below is a summarized list of key observations from the seismic interpretation and well file analysis.

- Basement-rooted faulting extending up into the Mesozoic subsurface geology occurs throughout the seismic data.
- Faulting is least common and less severe on the western end of Line 10.
- The Deadwood Formation thins in places that appear to represent basement topographic highs (e.g., northern end on Line 20), consistent with the observations of Ballard (1963).
- Thinning in the Deadwood can be seen where the leading peak on the top of the formation fades out on the seismic data.
- The Deadwood has good average porosity values (~15-20%) observed within the project area, but the formation lacks a basal confining unit and lower dissipation interval based on the well logs reviewed as part of this work and based on the interpretation of Nesheim (2017).
- Formation temperatures estimated from Bottomhole temperature data indicated that the Winnipeg Group and Deadwood Formation had sufficient temperatures for storing CO₂ in a

supercritical state. The Red River Formation also appears to reach an adequate temperature along the western end of Line 10.

- Mud weight data revealed that sufficient formation pressure might be achieved for reaching supercritical CO₂ conditions as shallow as 1,950 feet. A standard pressure gradient for freshwater gave a more conservative estimate of 2,500 feet.

Based on this set of key observations, it was determined that the most suitable location for potentially storing CO₂ in geologic reservoirs within the regional survey area is on the westernmost six miles of Line 10, about 16 miles west of the Dakota Spirit ethanol plant. In this area, the basement-rooted faults occur less commonly and do not extend up into the overburden rock. The gross thickness of the Deadwood is 50 and 70 feet. The thickness of the Deadwood in proximate wells aligns with the tuning analysis while the seismic interpretation along the western end of Line 10 could indicate thickness less than 44 feet. The possibility of the Deadwood being characterized as a freshwater aquifer and lack of a basal confining unit and lower dissipation interval below the Deadwood are key remaining challenges to consider for any potential geologic storage of CO₂ at this location.

Future Work

This report identified several opportunities for future work, which include: 1) obtaining a water sample from the Deadwood (i.e., assessing the feasibility of reentering NDIC File Nos. 370 or 406) to confirm TDS levels are >10,000 mg/L in the formation, and collecting Deadwood core to assess the physical properties of the reservoir; 2) extending the seismic survey area westward toward a deeper and thicker Deadwood section with a basal confining unit, lower dissipation interval, and less structural complexity; 3) refining petrophysics model to better understand reservoir quality in the Deadwood (additional logs would be recommended for digitization as part of this work); 4) performing a seismic inversion study to better classify seismic facies and characterize reservoir quality and thickness; and 5) collecting a 3D seismic survey to better characterize faulting in the area.

Conclusions

The landmark 2D seismic survey provided a good-quality baseline for adding insight to the regional structural and depositional interpretations of the Williston Basin near the Dakota Spirit ethanol plant. The data also helped to inform the carbon storage and bioenergy markets of the potential for carbon storage in deep saline formations over the survey area. The seismic interpretation and well log analysis revealed several challenges for developing a geologic CO₂ storage project in the area. Within regional seismic survey, the most suitable location for potential geologic storage of CO₂ is in the Deadwood Formation along the westernmost 6 miles of Line 10, about 16 miles west of the Dakota Spirit ethanol plant.

Budget

Total budgeted project costs were \$649,280 with NDIC grant allotment approved for 50% or up to \$324,640.

Table 3 reflects the actual project expense totals and final budget.

Table 3

Actual Final Budget 3/25/2022

Project Associated Expense	Total Cost	NDIC's Share	Applicant's Share (Cash)
Seismic Study Design & Tech Support	\$ 77,732.04	\$ 38,866.02	\$ 38,866.02
Permit/Notifications	\$ 65,215.00	\$ 32,607.50	\$ 32,607.50
Seismic Acquisition	\$ 330,126.81	\$ 165,063.41	\$ 165,063.41
Data Processing	\$ 15,000.00	\$ 7,500.00	\$ 7,500.00
Data Interpretation	\$ 30,000.00	\$ 15,000.00	\$ 15,000.00
Management / Reporting	\$ 21,735.00	\$ 10,867.50	\$ 10,867.50

Project Total	\$ 539,808.85
NDIC Eligible Amount	\$ 269,904.43
Applicant Cash Total	\$ 269,904.43
NDIC Interim Payment	\$ 238,163.16
Request for Reimbursement	\$ 31,741.27

The project was able to negotiate favorable mobilization and acquisitions costs with Paragon and was able to come in under the original budget amount in the acquisition category. Due to the challenges associated with moving the source points to avoid utilities, permitting costs for the project exceeded original budget.

Actual project costs totaled \$539,808.85. MAG has received \$238,163.16 from NDIC as reimbursement for 50% of project expenses incurred through November 30, 2021. Table 4 provides a summary of external project costs invoiced during the project. MAG is requesting \$31,741.27 from NDIC upon satisfactory review of this final report. Invoices supporting request for reimbursement are provided in APPENDIX I.

TABLE 4

Journal Entry	Series	TRX Date	Account Number	Account Description	Debit Amount	Originating Master Name
69862	Purchasing	8/19/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	7,975.00000	Discovery Acquisition Services
69893	Purchasing	8/25/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	22,271.25000	Paragon Geophysical Services Inc.
70051	Purchasing	9/21/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	3,000.00000	Discovery Acquisition Services
70181	Purchasing	10/7/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	29,268.00000	Discovery Acquisition Services
70233	Purchasing	10/14/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	6,800.00000	RPS Group Inc.
70271	Purchasing	10/20/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	55,678.13000	Paragon Geophysical Services Inc.
70346	Purchasing	10/29/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	70,911.66000	Paragon Geophysical Services Inc.
70376	Purchasing	10/31/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	181,265.77000	Paragon Geophysical Services Inc.
70390	Purchasing	11/8/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	24,972.00000	Discovery Acquisition Services
70470	Purchasing	11/19/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	40,907.80000	RPS Group Inc.
70638	Purchasing	12/15/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	15,000.00000	SEIMAX Technologies LP
70641	Purchasing	12/15/2021	990-81100-004	Carbon Sequestration - DSA 2D Phase	18,276.71000	RPS Group Inc.
70812	Purchasing	1/11/2022	990-81100-004	Carbon Sequestration - DSA 2D Phase	6,129.47000	RPS Group Inc.
70940	Purchasing	1/31/2022	990-81100-004	Carbon Sequestration - DSA 2D Phase	3,250.00000	RPS Group Inc.
71045	Purchasing	2/14/2022	990-81100-004	Carbon Sequestration - DSA 2D Phase	28,000.00000	University Of North Dakota
71088	Purchasing	2/21/2022	990-81100-004	Carbon Sequestration - DSA 2D Phase	2,368.06000	RPS Group Inc.
71189	Purchasing	3/7/2022	990-81100-004	Carbon Sequestration - DSA 2D Phase	2,000.00000	University Of North Dakota