17th International Conference on Greenhouse Gas Control Technologies, GHGT-17

20th -24th October 2024 Calgary, Canada

# Exploring the feasibility of a carbon dioxide storage hub in western North Dakota

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**Abstract**

The University of North Dakota Energy & Environmental Research Center (EERC) and project partner ONEOK, Inc. (ONEOK) are investigating the feasibility of establishing a $CO_2$ (carbon dioxide) storage hub in western North Dakota—in the heart of the Williston Basin. The conceived Roughrider Carbon Storage Hub would store $CO_2$ captured from six gas-processing plants owned and operated by project partner ONEOK and a planned gas-to-liquids plant. This 2-year U.S. Department of Energy-sponsored Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Phase II feasibility study is evaluating the aggregation of the $CO_2$ captured from these seven sources for injection into stacked geologic storage complexes. The proposed hub includes several aspects that make it a highly qualified candidate for a feasibility study with a notably reduced project risk profile. These include 1) a project partner (ONEOK) with a committed goal to reduce greenhouse gas emissions; 2) prior subsurface data analysis supporting a potential stacked storage configuration with adequate $CO_2$ storage resource; 3) commitment from local, regional, and state-level stakeholders; and 4) a state with U.S. Environmental Protection Agency underground injection control Class VI primacy. ONEOK's assets in the Williston Basin provide significant environmental benefits by capturing and processing natural gas that may otherwise be flared or vented. Storing $CO_2$ from these gas-processing facilities will reduce overall $CO_2$ emissions in the basin while providing essential services to producers there and contributing to continued energy independence in the domestic markets.

*Keywords:* carbon capture; storage; CCS; hubs and clusters; feasibility; gas processing; North Dakota

## 1. Introduction

Through the acquisition, analysis, and interpretation of geologic information, the project team of University of North Dakota Energy & Environmental Research Center (EERC) and ONEOK, Inc. (ONEOK), via the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative, is investigating the feasibility of using stacked storage complexes in McKenzie County, North Dakota, to store at least 50 MMt of $CO_2$ within 30 years. A potential commercial $CO_2$ storage project of this size is supported by the existence of established and tested pore space ownership legislation and the long-term liability policy of North Dakota. The study region in McKenzie County (Figure 1) overlies a nearly 15,000-ft (4570-meter)-thick sequence of sedimentary rocks in the Williston Basin. As part of the project, a stratigraphic test well is being drilled through the entire sequence of sedimentary rock near the depocenter of the Williston Basin.

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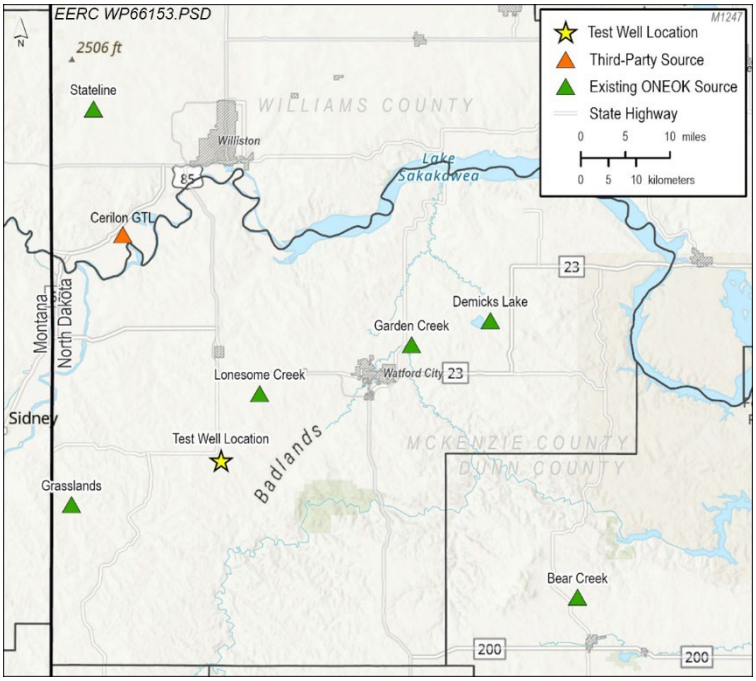


Fig. 1. Proposed CarbonSAFE Roughrider Carbon Storage Hub scenario envisioned for northwestern North Dakota.

Within this sequence of rock are four promising candidates for the geologic stacked storage of $CO_2$. As part of the geologic appraisal process, 4-inch-diameter whole core is planned to be taken from each of the four candidate storage horizons. The data derived from the core analysis will augment existing information to build geologic models of each storage horizon. Because the project location is in the heart of Williston Basin oil production, specific technical and nontechnical challenges will need to be investigated during this project. These challenges include addressing pore space and pore pressure competition, regulatory aspects of $CO_2$ storage in potential mineral-bearing horizons, and public perception. Beyond the subsurface evaluation, the project is also investigating the pipeline requirements (potential sizes and routes) to transport $CO_2$ captured from each $CO_2$ source facility to the central storage hub facility.

This feasibility study is evaluating the aggregation of $CO_2$ captured from seven sources for injection into geologic storage complexes in a stacked storage configuration. Specifically, the Roughrider Carbon Storage Hub scenario is looking at six gas-processing plants owned and operated by project partner ONEOK and a planned gas-to-liquids (GTL) plant by Cerilon (Figure 1). Previous subsurface data analysis by both the Plains $CO_2$ Reduction (PCOR) Partnership and a specific investigation sponsored by ONEOK identified the Inyan Kara, Broom Creek, Mission Canyon, and Deadwood Formations as potential secure $CO_2$ storage horizons. Data analysis and modeling results indicate the prospective $CO_2$ storage resource potential of these formations in the area of interest (AOI) to be approximately 200 MMt in a 36-square-mile area. In addition, our proposed approach leverages economies of scale and the potential for efficiency and optimization through grouping of natural gas-processing facilities, a proposed GTL plant, and existing pipeline right of way. This synergy ensures success for the CarbonSAFE Initiative and prepares the storage hub for entry into a DOE CarbonSAFE Phase III project that will pursue further characterization and the development of storage facility permits (SFPs).

Several characteristics support the qualifications and future success of this $CO_2$ storage hub feasibility study. These include 1) a project partner with a committed goal to reduce greenhouse gas (GHG) emissions; 2) prior subsurface data analysis results supporting a stacked storage scenario with adequate $CO_2$ storage volume; 3) commitment from local, regional, and state-level stakeholders; and 4) a state with Class VI primacy. In addition, there is potential for

expansion/flexibility to include additional $CO_2$ sources (including direct air capture). In aggregate, these project characteristics combined with the EERC's extensive experience with carbon capture and storage (CCS) through the PCOR Partnership Program Initiative and previous CarbonSAFE efforts (Phases II and III) make this scenario a viable CCS stacked storage system that can be realistically constructed and permitted for operation.

**Nomenclature**

| | |
|---|---|
| AOI | area of interest |
| AOR | area of review |
| CCS | carbon capture and storage |
| $CO_2$ | carbon dioxide |
| DOE | U.S. Department of Energy |
| EERC | Energy & Environmental Research Center |
| GHG | greenhouse gas |
| GTL | gas to liquids |
| NDCC | North Dakota Century Code |
| NDIC | North Dakota Industrial Commission |
| NETL | National Energy Technology Laboratory |
| NGL | natural gas liquids |
| OGRP | Oil and Gas Research Program |
| PCOR Partnership | Plains $CO_2$ Reduction Partnership Program |
| TDS | total dissolved solids |
| SFP | storage facility permit |
| UIC | underground injection control |

## 2. Partners

Several public and private entities have pledged support for this project. These major participants include ONEOK, Computer Modelling Group, SLB, and the North Dakota Industrial Commission Oil and Gas Research Program (OGRP). These partners are providing critical support in the forms of financial backing, site access, collaboration on societal considerations and impacts, operations data, risk assessment and evaluation, and software access and support needed to achieve the project objectives.

Project partner ONEOK has extensive experience working with key stakeholders in northwestern North Dakota—including landowners, state and federal agencies, and local and tribal communities—to construct and operate midstream infrastructure. ONEOK's midstream assets in North Dakota include over 12,000 miles of natural gas-gathering pipelines, over 300 miles of NGL pipelines, and six processing facilities with the capacity to process and treat almost 2 Bcf per day of natural gas. As a midstream service provider experienced in the gathering, transportation, storage, and distribution of natural gas, ONEOK is well-positioned to provide similar $CO_2$-related services for companies in need of a $CO_2$ storage solution. Project partner ONEOK is committed to reducing GHG emissions. In September 2021, ONEOK announced that it would target a 2.2-MMt reduction of its combined Scope 1 and Scope 2 emissions by 2030 (a 30% reduction in total operational emissions attributable to ONEOK assets in 2019).

Cerilon and its affiliates are developing the world's lowest-carbon-footprint GTL facility. This proposed downstream industry will require new skills and create new jobs as, currently, North Dakota has no GTL facilities. In addition, the GTL facility and associated $CO_2$ captured from the conversion process will support the CCS industry and associated infrastructure. Cerilon sees CCS as an integral component of its corporate vision and long-term goals. The GTL facility is anticipated to initially contribute nearly 1.8 MMt of captured $CO_2$ per year and scale to up to 4 MMt of captured $CO_2$ per year for safe, permanent storage in potential conjunction with the proposed Roughrider Carbon Storage Hub.

The OGRP provided financial resources for drilling the deep stratigraphic test well. This feasibility project will help the OGRP:

- Understand the technical and economic feasibility of aggregating and storing low-volume $CO_2$ sources associated with gas processing in western North Dakota.
- Generate an opportunity for geologic storage and an available source for $CO_2$ that could be used to produce incremental low-carbon oil using $CO_2$ EOR while simultaneously supporting North Dakota's produced gas industry and associated markets.
- Inform participation, investment, and development decisions in a carbon storage hub by ONEOK and other current and future operators of distributed sources within the project region.
- Position the project for future design, optimization, and geologic $CO_2$ storage facility permitting through private and/or future DOE funding opportunities.

## 3. $CO_2$ Sources

Northwestern North Dakota is home to several existing industrial $CO_2$ sources, including gas-processing facilities and pipeline compressor stations, and is a target for a planned GTL facility. In the proposed scenario, $CO_2$ from seven of these facilities will be amalgamated for geologic storage (Table 1 and Figure 2).

Table 1. $CO_2$ Sources for the Roughrider $CO_2$ Storage Hub

| Facility | Annual $CO_2$ Output, Mt |
|---|---|
| Bear Creek Gas Plant | 20,000 |
| Lonesome Creek Gas Plant | 42,000 |
| Demicks Lake Gas Plant | 52,000 |
| Garden Creek Gas Plant | 74,000 |
| Grasslands Gas Plant | 77,000 |
| Stateline Gas Plant | 89,000 |
| Cerilon GTL Plant* | 1,800,000** |
| Total $CO_2$ per Year | 2,154,000 |

* Planned.
** Expected to grow to ~4 MMt per year.

## 4. Regulatory Regime

North Dakota was the first of three states with underground injection control (UIC) Class VI well primacy. This primacy status has proven to be a strong driver for the growth of carbon capture, utilization, and storage project planning in the state, as has general public acceptance and regulatory approval of several EERC-led Class VI SFPs. As further evidence for the general support of CCS, a December 2021 public opinion poll [1] on issues related to energy in North Dakota conducted by the North Dakota Lignite Energy Council showed that 76% of voters in the state are in favor of using carbon capture compared to just 17% who are opposed. This sentiment is very consistent across partisan lines, as 74% of Republicans, 74% of Independents, and 81% of Democrats back the use of CCS technology in the state.

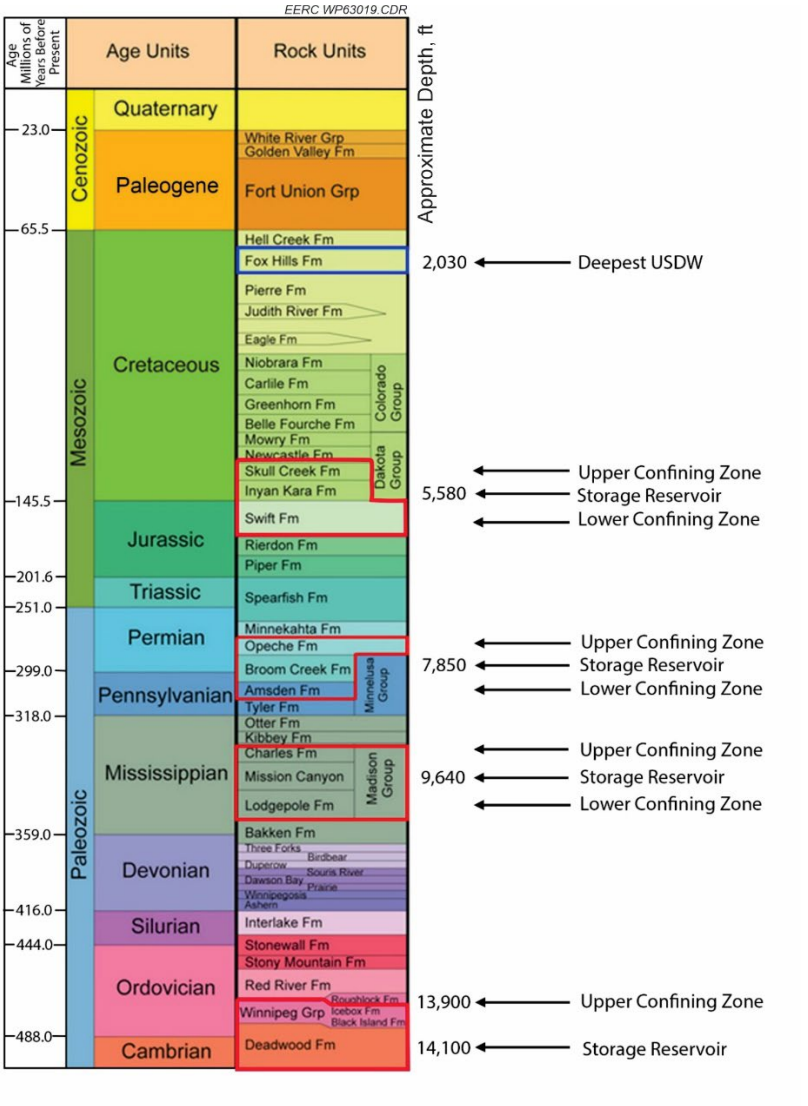


Fig. 2. Stratigraphic column illustrating the relationship among the stacked storage complexes in the study region. The highlighted red blocks indicate a single storage complex, which includes upper and lower confining zones and a storage reservoir.

A primary concern regarding large-scale injection of $CO_2$ into deep saline formations is the question of pore space ownership and the approach to amalgamating the required pore space to contain the injected $CO_2$. In anticipation of long-term $CO_2$ storage in geologic settings existing at depth in North Dakota, the state legislature amended the North Dakota Century Code (NDCC) in 2009 to clarify that pore space ownership is tied to the surface owner and cannot be severed from surface ownership. Specific to the geologic storage of $CO_2$, NDCC § 38-22 states:

> *"Geologic storage, however, to be practical and effective requires cooperative use of surface and subsurface property interests and the collaboration of property owners. Obtaining consent from all owners may not be feasible, requiring procedures that promote, in a manner fair to all interests, cooperative management, thereby ensuring the maximum use of natural resources."*

NDCC further provides guidance that if a $CO_2$ storage operator in North Dakota does not obtain the consent of all persons who own the storage reservoir's pore space, the North Dakota Industrial Commission (NDIC) may require

that the pore space owned by nonconsenting owners (up to 40%) be included in a storage facility and subject to geologic storage. This, in essence, amalgamates (i.e., unitizes) the reservoir's storage space to ensure maximum use of the natural resource.

Red Trail Energy, LLC, and Minnkota Power Cooperative have set the precedent for securing pore space through a long-term leasing approach in North Dakota in their approved North Dakota SFPs. The strategy for securing pore space rights for the proposed integrated CCS project would parallel these earlier successful $CO_2$ storage permit endeavors; therefore, the probability of securing pore space rights from private landowners is very high. The cost of securing rights to pore space is traditionally held in confidence. To date, all issued $CO_2$ SFPs in North Dakota have based pore space storage fees on a pro rata share of a landowner's surface acres within the extent of the SFP area. The actual rate of pore space access for this project would not be determined until landowner negotiations were complete during the compilation of the actual SFP.

Ten years after $CO_2$ injection ends, the storage operator can apply for a certificate of project completion. If granted, the title to the storage facility and to the stored $CO_2$ transfer to the state. The Roughrider CCS project being studied in northwestern North Dakota would follow established state law and would file for a certificate of project completion following the requisite 10 years of postclosure stewardship. Prior to NDIC issuing a certificate of project completion and transferring ownership and liability to the state, the $CO_2$ storage operator has title to the $CO_2$ injected into and stored in a storage reservoir. While the storage operator holds title, the operator is liable for any damage the $CO_2$ may cause, including damage caused by $CO_2$ that escapes from the storage facility.

North Dakota has established an administrative fund as a bonding mechanism for a $CO_2$ storage facility, which accrues monies based on a fee for each ton of $CO_2$ injected for storage. The fee is based on NDIC's anticipated expenses it will incur in regulating storage facilities during their construction, operation, and preclosure. In addition, a $CO_2$ storage facility trust fund has been established. As with the facility administrative fund, the storage facility trust fund is built on a fee established for each ton of $CO_2$ injected for storage. The fee amount is based on NDIC's anticipated expenses associated with the long-term monitoring and management of a closed storage facility (NDCC Chapter 38-22).

## 5. Geology

The study region in McKenzie County, North Dakota, overlies a nearly 15,000-ft thick sequence of sedimentary rocks in the Williston Basin. Within this sequence of rock is the Cretaceous-aged Inyan Kara Formation, Permian-aged Broom Creek Formation, Mississippian-aged Mission Canyon Formation, and the Cambrian to Ordovician-aged Deadwood Formation, which together make for excellent candidates for the geologic stacked storage of $CO_2$ (Figure 2). This assertion is based on the formations' geologic and hydrogeologic characteristics, including porosity, permeability, thickness, estimated storage capacity and efficiency, and presence of upper and lower sealing formations.

The Inyan Kara is a clastic formation that includes coarse-to-fine sandstones, siltstones, and shales. The sandstone units of the Inyan Kara are composed of quartz, with minor components such as feldspar, coal, and interspersed plant fragments; siderite nodules/concretions; iron staining; and calcite cement. The average core porosity and average core permeability (geometric mean) for the Inyan Kara sandstone are 20% and 72 mD, respectively. It should be noted that commonly the permeability in the Inyan Kara is over 500 mD. In the AOI, the Inyan Kara Formation ranges from approximately 5560 to 5640 ft below the surface with an approximate thickness of 440 ft. Reservoir temperature and reservoir pressure are ~156°F and ~2343 psi, respectively. Total dissolved solids (TDS) of the brine in the Inyan Kara exceed 10,000 mg/L in the AOI.

The deposits of the Broom Creek Formation are predominantly coastal eolian dunes overlain by high-energy, shallow-marine environments of beach or offshore bar. In the AOI, the Broom Creek Formation ranges from approximately 7870 to 7998 ft below surface with an average thickness of 120 ft. The highly porous and permeable

sandstones along with interbeds of anhydrite and dolomite have an average porosity of 14% and permeability of 62 mD. Reservoir temperature and reservoir pressure are ~195°F and ~3767 psi, respectively. TDS of the brine in the Broom Creek Formation also exceeds 10,000 mg/L in the AOI. The ability of the Broom Creek Formation to be used as a storage target has already been proven, as it has received over 1 MMt of $CO_2$ via the Dakota Gasification Company U.S. Environmental Protection Agency UIC Class VI $CO_2$ injection wells and 180,000 Mt per year of $CO_2$ at the Red Trail Energy $CO_2$ geologic storage facility near Richardton, North Dakota.

The Mission Canyon Formation is a regressive carbonate sequence within the larger carbonate Madison Group. Deposition of the Mission Canyon occurred in a variety of environments from open marine to coastal sabkha. The formation consists of mostly limestone and dolostone, with lateral gradations of anhydrites scattered throughout the basin. In the study area, the Mission Canyon lies at a depth of about 9840 ft, averages 750 ft thick, and is overlain by the Charles salts and underlain by the carbonate Lodgepole Formation. The porous and permeable skeletal oolitic grainstone and packstone have an average porosity of 6% and permeability of 5 mD. Reservoir temperature and pressure are ~206°F and 4575 psi, respectively. TDS of the brine in the Mission Canyon average about 220,000 mg/L.

The Black Island Formation comprises high-energy shallow marine sandstone (permeable storage intervals) and shale (impermeable layers). The sandy members (C sand and E member) of the Deadwood Formation comprise reworked quartz arenites of marginal marine environment and coarse-to-fine-grained quartzose and glauconitic sandstone that are locally conglomeratic at the base. The Black Island and Deadwood Formations are considered a single reservoir zone. The average porosity and average permeability (geometric mean) for the Deadwood Formation is 7% and 4 mD, respectively. In the AOI, the Black Island–Deadwood interval ranges from approximately 13,500 to 14,400 ft below surface with an approximate thickness of 900 ft. The reservoir temperature and pressure are ~252°F and ~6485 psi, respectively. TDS of the brine in the Black Island–Deadwood reach nearly 350,000 mg/L in the AOI.

The discrete geologic datasets derived from this project's activities (particularly the deep stratigraphic test well) support the development of four comprehensive 3D cellular models. These models will be used in dynamic simulation activities to accurately determine the area of review (AOR) extent associated with $CO_2$ and pressure plume development. Understanding the potential extent of the $CO_2$ and pressure plumes provides a foundation for understanding the magnitude of future pore space leasing requirements and monitoring, verification, and accounting.

When two or more $CO_2$ storage targets are in the subsurface at the same geographic location, a $CO_2$ storage project may pursue stacked storage. This arrangement results in multilevel $CO_2$ plumes from a single storage facility. Advantages of stacked storage include accessing more of the pore space available in a given area, allowing for a smaller project area and potentially reducing the AOR.

## 6. Community Engagement

Identifying societal considerations and impacts of the project and creating audience-specific engagement strategies are key elements of effective public engagement where stakeholders can become project partners. The project partners have the extensive regional knowledge, community relationships, and collective experience to produce and implement a plan that will further identify and respectfully engage communities and stakeholders. The project partners will invite their questions, listen to their concerns, inform their understanding of CCS, and document the public view of all aspects of geologic $CO_2$ management within the study region during the feasibility phase and subsequent phases of the project should they be approved.

The EERC and ONEOK are managing engagement activities. ONEOK has final approval of all materials prior to release. In keeping with the best practices outlined in the 2017 update of the Regional Carbon Sequestration Partnerships Best Practices Manual and based on the experience of the PCOR Partnership, outreach will be coordinated with project development plans and the leadership team. The project team will liaise with other outreach

efforts through a project outreach advisory group featuring outreach specialists from project partners and key stakeholders.

The current CarbonSAFE Phase II efforts are building on the EERC's PCOR Partnership outreach effort, which has been active in the region since 2003, the successful North Dakota CarbonSAFE Phase II project, the ongoing North Dakota CarbonSAFE Phase III project, and the now-commercial Red Trail Energy CCS project with a program of project-focused and broadly based general outreach on CCS. The PCOR Partnership's project-related outreach ranges from content on the PCOR Partnership public website to participation on outreach advisory panels, custom project-focused outreach materials, and engagement with local stakeholders. Regional outreach has been accomplished through original documentaries broadcast on public television as well as participation in educator workshops, library conferences, and decision-maker forums. All outreach is tracked, and both project and general outreach are supported by a public website featuring basic CCS information and access to a spectrum of original outreach materials, including streaming video clips and full-length documentaries, fact sheets, a regional atlas, and informational posters. The EERC's CCS outreach team is complemented by technical CCS experts and specialists in media relations, graphics, editing, and web programming.

## References

[1] LEC, 2022. Key findings from a recent statewide survey in North Dakota. https://lignite.com/wp-content/uploads/2022/01/North-Dakota-Energy-Key-Findings-Memo.pdf (Accessed 9/1/2024).