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April 30, 2020

Ms. Karlene Fine Executive Director North Dakota Industrial Commission State Capitol, 10th Floor 600 East Boulevard Avenue Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: Deliverable (D) 2 for Integrated Carbon Capture and Storage for North Dakota Ethanol Production Phase III; Contract No. R-038-047; EERC Fund 23627

Attached is the D2: North Dakota Geologic CO₂ Storage Permits Template for the subject project. If you have any questions, please contact me by phone at (701) 777-5013, by fax at (701) 777-5181, or by e-mail at kleroux@undeerc.org.

Sincerely,

DocuSigned by: Konfler

Kerryanne M. Leroux Principal Engineer

KML/bjr

Attachment



NORTH DAKOTA GEOLOGIC CO₂ STORAGE PERMITS TEMPLATE

Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase III Task 3 – Deliverable D2

Prepared for:

Karlene Fine

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Contract No. R-038-047

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NORTH DAKOTA GEOLOGIC CO₂ STORAGE PERMITS TEMPLATE

EXECUTIVE SUMMARY

Well drilling and CO₂ storage facility permits issued by the North Dakota Industrial Commission (NDIC) Department of Mineral Resources (DMR) are required to implement geologic CO₂ storage in North Dakota. The Energy & Environmental Research Center (EERC) has developed two permit templates to assist a technical permit writer in preparing 1) an application for permit to drill (APD) a stratigraphic test well and 2) a storage facility permit (SFP) application that are consistent with North Dakota Underground Injection Control (UIC) Class VI statutes and regulations. The APD template includes options for the design and permitting of a stratigraphic test well that can be transitioned for use as a UIC Class VI-compliant injection or monitoring well. To that end, this template also provides information for preparing the injection well permit that is required to convert and operate the stratigraphic test well to a CO₂ injection well, which can be filed in concert with the SFP application.

No SFPs have yet been issued in North Dakota. The permit application templates presented incorporate learnings and clarifications that have been garnered as the first projects advancing carbon capture and storage (CCS) in North Dakota work through the SFP process with the DMR. Each section provides a description of the intent of the section, references the relevant requirements in the North Dakota Century Code (NDCC) and North Dakota Administrative Code (NDAC), and provides a description of evidence or exhibits to be included within the section. The templates incorporate formatting that is both structured to present the information required in the permit application in a functional, logical, and consistent fashion and aligned with the permit review and public hearing process.

NORTH DAKOTA GEOLOGIC CO2 STORAGE PERMIT TEMPLATES

1.0 INTRODUCTION

1.1 Overview

The Energy & Environmental Research Center (EERC), in conjunction with its government and industrial partners, is conducting feasibility and implementation studies for commercial carbon capture and storage (CCS) projects in North Dakota. Specifically, in partnership with Red Trail Energy, LLC (RTE), the North Dakota Industrial Commission (NDIC), and the U.S. Department of Energy (DOE), the EERC is investigating the commercial capture and geologic storage of carbon dioxide (CO₂) from the 64-million-gallon dry mill RTE ethanol facility, which emits an average of 180,000 metric tons of CO₂ annually.

Well drilling and CO₂ storage facility permits (SFP) are required to construct and operate a geologic CO₂ storage project in North Dakota. An application of permit to drill (APD) is required to drill a stratigraphic test well, which is used to acquire the necessary downhole data to complete a CO₂ SFP in North Dakota. The NDIC Department of Mineral Resources (DMR) Oil and Gas Division (Commission) has authority to regulate the geologic storage of CO₂ granted by the North Dakota Century Code (NDCC) (Chapter 38-22 Carbon Dioxide Underground Storage) and primacy to administer the underground injection control (UIC) Class VI Program. The North Dakota Administrative Code (NDAC) (Chapter 43-05-01 Geologic Storage of Carbon Dioxide) contains the regulations that predominantly govern CO₂ storage activities in the state of North Dakota.

The EERC and RTE engaged the Commission during the planning stages of a stratigraphic test well intended to support the development of an SFP application. As such, the stratigraphic test well is part of a critical path to achieving UIC Class VI compliance and has laid the foundation for what is likely to be the first CO₂ SFP application to be submitted in North Dakota. Several recommended practices and clarifications related to well design, geologic characterization, well testing, and the UIC Class VI requirements resulted from these permit discussions, the more significant of which are captured in call-out boxes throughout these templates. To date, approval to drill a stratigraphic test well for the first geologic storage project in North Dakota has been approved (NDIC File No. 37229).

This document provides application templates for the two permits that are required to move forward with the commercial geologic storage of CO₂ in North Dakota: the APD and the SFP. It also provides the information necessary to prepare an application to convert and operate a Class VI-compliant stratigraphic well as a CO₂ injection well, which is the final regulatory approval necessary prior to beginning the operations of the CO₂ storage facility.

Because CCS efforts are subject to site-/region-specific geologic and operational factors, NDIC may require additional information for permit approval. Therefore, the review of the relevant statutes and regulations in collaboration with NDIC representatives, other regulating authorities, and project partners is strongly recommended prior to submittal to ensure proper

interpretation of APD and SFP application requirements and to ensure these requirements are adequately addressed. In addition, CO₂ storage incentive programs may have different (or potentially conflicting) requirements from those required for permitting compliance. Therefore, including program administrators in collaborations during the development stages of a CCS project is also recommended to ensure project compatibility with any potential incentive programs.

1.2 Template Terminology (see also Figure 1-1)

Numerous terms-of-art are used throughout the North Dakota statutes and regulations that require definition to ensure the proper interpretation of the permit requirements. A list of these terms is provided here. In addition, Figure 1-1 is provided specifically to present a simplified view of the regulatory terminology which establishes specific boundaries based on notification requirements and permit evaluation areas. The areas and zones in Figure 1-1 are identified and defined among the terms in this section.

 area of review (AOR) – region surrounding the geologic sequestration project where underground sources of drinking water (USDWs) may be endangered by the injection activity (NDAC 43-05-01-01 §4).

AOR: defined by the UIC program, establishes the boundaries of required long-term monitoring and emergency response plans.

- capillary pressure the pressure required to move a fluid from a capillary or a pore space. It is a function of the properties of the fluid and surface and the dimensions of the space. The fluid is held in place if the attraction between the fluid and surface is greater than the interaction of fluid molecules (75 FR [Federal Register] 77229).
- carbon dioxide produced by anthropogenic sources which is of such purity and quality that it will not compromise the safety of geologic storage and will not compromise those properties of a storage reservoir that allow the reservoir to effectively enclose and contain a stored gas (NDCC 38-22-02 §1).
- confining zone a geologic formation, group of formations, or part of a formation stratigraphically overlying the injection zone that acts as a barrier to fluid movement. For injection wells operating under an injection depth waiver, confining zone means a geologic formation, group of formations, or part of a formation stratigraphically overlying and underlying the injection zone (NDAC 43-05-01-01 §11).
- emergency event an event that poses either 1) an immediate (or acute) risk to human health, resources or infrastructure or 2) a potential (or chronic) risk to these same receptors should conditions worsen or no mitigative/remedial emergency responses be taken.
- CO₂ plume extent the areal extent that will be occupied by geologically stored CO₂ over the life of the project as defined by geologic modeling and dynamic simulation (i.e., following injection cease and stabilization of the plume).

pore space amalgamation: The storage facility area consists of the CO₂ plume extent (as previously defined) plus a 0.5-mile buffer (NDCC 38-22-08 §12); this is the area that will be considered by NDIC for pore space amalgamation. Pore space amalgamation is the administrative process defined by North Dakota statute that grants the Commission the authority to permit CO₂ storage facilities and to require that the pore space owned by nonconsenting owners be included in a storage facility and subject to geologic storage (NDCC 38-22-10). The storage operator is mandated by law to obtain the consent of persons who own at least 60% of the storage reservoir's pore space (NDCC 38-22-08 §4). The law also mandates the storage operator make a good-faith effort to obtain consent from all persons who own the storage reservoir's pore space (NDCC 38-22-08 §4).

- facility area areal extent of the storage reservoir (NDAC 43-05-01-01 §16).
- incident events that do not pose either an acute or chronic risk to human health, resources, or infrastructure and do not warrant emergency responses.
- injection zone a geologic formation, group of formations, or part of a formation that is of sufficient areal extent, thickness, porosity, and permeability to receive CO₂ through a well or wells associated with a geologic sequestration project (NDAC 43-05-01-01 §27).



EERC KL57858.AI

Figure 1-1. Surface (left; modified from DMR) and subsurface (right) areas/zones relevant to APD and SFP permit requirements for CCS projects in North Dakota.

- maximum acceptable pressure front the critical reservoir pressure at which the magnitude of brine leakage into an USDW would exceed a certain threshold level based on the noendangerment requirement (i.e., the level at which water quality impacts in the USDW could be expected plus a safety factor).
- pressure front the zone of elevated pressure and displaced fluids created by the injection of CO₂ into the subsurface. The pressure front of a CO₂ plume refers to a zone where there is a pressure differential sufficient to cause the movement of injected fluids or formation fluids into USDW (NDAC 43-05-01-01 §38).
- pore space a cavity or void, whether natural or artificially created, in a subsurface sedimentary stratum (NDCC 38-22-02 §5).
- storage facility the reservoir, underground equipment, and surface facilities and equipment used or proposed to be used in a geologic storage operation. It does not include pipelines used to transport CO₂ to the storage facility (NDCC 38-22-02 §7).

pressure front: the pressure required to raise the formation fluids to a USDW.

pore space: open spaces in rock or soil. These are filled with water or other fluids such as brine (i.e., salty fluid). CO_2 injected into the subsurface can displace preexisting fluids to occupy some of the pore spaces of the rocks in the injection zone.

- storage reservoir a subsurface sedimentary stratum, formation, aquifer, cavity, or void, whether natural or artificially created, including oil and gas reservoirs, saline formations, and coal seams suitable for or capable of being made suitable for injecting and storing CO₂ (NDCC 38-22-02 §8).
- thief zone a formation between the storage unit and the USDW with higher permeability that could accept fluids (CO₂ or brine) and thus reduce the potential vertical flux of these fluids from a storage reservoir to overlying units.
- underground sources of drinking water (USDW) an aquifer or any portion of an aquifer that supplies drinking water for human consumption, or in which the groundwater contains fewer than 10,000 milligrams per liter total dissolved solids and is not an exempted aquifer as determined by the Commission under NDAC 43-02-05-03 (NDAC 43-05-01-01 §45).

2.0 WELL-DRILLING PERMIT

For the purposes of this template, the APD has been developed as a stratigraphic test well APD template. A complete storage facility permit requires data and information obtained from core, geologic formation testing and sampling, and wireline logging within the facility area of a geologic storage project. While there may be instances where existing data (i.e., core and log data) can be used for the SFP in lieu of drilling a stratigraphic test well, in many cases the operator will need to drill a well prior to applying for an SFP to collect the necessary data.

Stratigraphic Test Well Design Options

- 1) <u>Traditional test well</u> that will be openhole-plugged after all of the necessary data, testing, and sampling have been collected.
- 2) A test well that has been constructed to UIC Class VI standards and designed for later conversion to a <u>future Class VI-compliant CO₂ injection well</u>. Core, geologic formation testing and sampling, and wireline logging will be collected during drilling and well construction, as appropriate.
- 3) A test well that has been constructed to UIC Class VI standards and designed for later conversion to a <u>future Class VI-compliant monitoring well</u>. Core, geologic formation testing and sampling, and wireline logging will be collected during drilling and well construction, as appropriate.

An option for accelerating deployment of CCS is to permit and drill a stratigraphic test well designed and constructed in a manner that provides a pathway to convert the well to a UIC Class VI-compliant injection well (e.g., strategic use of CO₂-resistant materials). The stratigraphic test well transition pathway is addressed in this template, which includes a request for approval to convert the well to a CO₂ injection well and an application to inject CO₂. Within 1 year of drilling and construction, the storage operator has the option to apply for temporary abandoned observation (TAO) well status. The TAO status determination will be based on the demonstration of mechanical integrity witnessed by a representative from the Commission. The TAO status, if granted, is allowed for 1 year, with the potential to request extensions in 1-year increments. This process creates a transition pathway that accounts for the time it will take to receive all of the necessary regulatory approvals to ultimately begin injection operations.

2.1 Application for Permit to Drill (NDAC 43-02-03)

The APD comprises prepermit filings, APD information (i.e., both general and well-specific information), and APD attachments, all of which are entered into the NorthSTAR electronic permitting system. It is important that the data and information provided in the electronic form are consistent with the data and information that are presented throughout the application and in the APD attachments (e.g., the casing depth in the electronic form should be the same as the depth in the drilling prognosis and the casing program).

2.1.1 Prepermit Filings

The storage operator is required to complete and submit the following prepermit filings:

- An organization report (NDIC Form 2-NDAC 43-02-03-11). The exact entity name that is registered with the Secretary of State should be used in this filing.
- Submission of all APDs through NorthSTAR, access to which requires an established NorthSTAR account that can be obtained by registering a new organization through the NDIC's NorthSTAR webpage.
- The filing of a single-well plugging and reclamation bond of \$50,000 with NDIC. As part of this effort, it is important that the storage operator communicate with NDIC's Bond Assistant and Permit Manager since an APD cannot be issued until the bond has been approved by NDIC (NDAC 43-02-03-15).

2.1.2 APD Information (NDAC43-02-0316)

The APD is required to be submitted through NorthSTAR, NDIC's electronic permitting system.

2.1.2.1 General Information

The general information required to complete the APD consists of the addresses and phone numbers of the operator and surface owners and the approximate date that the site work will start. The storage operator is required to provide evidence that the well is not located within 500 feet of an occupied dwelling. If the well is located within 1320 feet (i.e., ¹/₄ mile) of an occupied dwelling, the applicant is required to provide an affidavit of mailing that documents the owners of all such dwellings has been notified (NDCC 38-08-05).

2.2 APD Attachments

Several attachments are required to be developed by the storage operator to complete the APD. These attachments are described in the remainder of this section in the order in which they will likely be reviewed by NDIC.

2.2.1 Attachment 1: Plat Package

The APD includes 1) an accurate well location plat certified by a registered surveyor showing the location of the proposed well with reference to the nearest lines of a governmental section and referenced to true north; 2) an accurate pad layout which indicates a cut-and-fill diagram and additional construction required, i.e., water bars, culverts, etc.; 3) a facility layout, i.e., location of surface facilities on well pad; and 4) road access to the well location. If drill cuttings will be buried on location (i.e., a dry-cuttings pit), the location of the dry-cuttings pit needs to be included on the facility layout plat. Typically, closed mud systems are utilized for drilling in North Dakota and drill cuttings are hauled away from the drill site and disposed of in a solid waste landfill. If a closed mud system will be utilized, the application needs to include the name and address of the solid waste landfill and a statement that a closed mud system will be used. Examples for a plat package are provided in Appendix A.

2.2.2 Attachment 2: Geological Prognosis

This attachment, a geological prognosis, presents such information as the estimated depth to the top of objective horizons (measured depths [MD]); the estimated depth to the top and thickness of important geologic markers such as members or zones potentially containing usable water, USDWs, oil, gas, or other valuable deposits; and the identification of the formation at total depth, including the identification of all potential confining layers above and below the zone of interest. Table 2-1 provides an illustrative example of a geological prognosis for a well drilled in the Williston Basin in North Dakota.

Table 2-1. Illustrative Example of Geological Prognosis for a Well Drilled in Western North Dakota (values are provided for illustrative purposes only and site-specific data are required for an actual APD); note that in some cases MD can be different than true vertical depth

| Formation | Formation Measured Depth, ft True Vertical Depth, ft | | Lithology |
|--------------|--|------|--|
| Fox Hills | 1526 | 1526 | USDW |
| Pierre | 1826 | 1826 | Shale (seal) |
| Greenhorn | 3992 | 3992 | Shale |
| Mowry | 4415 | 4415 | Shale |
| Inyan Kara | 4770 | 4770 | Sandstone, siltstone, and shale |
| Swift | 5091 | 5091 | Shale |
| Rierdon | 5493 | 5493 | Shale and carbonate |
| Piper Marker | 5752 | 5752 | Shale |
| Spearfish | 5963 | 5963 | Siltstone, sandstone, mudstone, and shale |
| Minnekahta | 6100 | 6100 | Limestone |
| Opeche | 6108 | 6108 | Shale (cap rock) |
| Broom Creek | 6273 | 6273 | Sandstone and dolomite |
| Amsden | 6536 | 6536 | Dolomite, sandstone, anhydrite, and limestone |
| Total Depth | 6790 | 6790 | Dolomite, sandstone, anhydrite, and limestone |

2.2.3 Attachment 3: Drilling Program and Prognosis

The drilling program and prognosis provide the technical detail of the plans for drilling and completing the injection well. Examples of the information and content of this attachment are as follows:

- Proposed total depth (including MD and true vertical depth) to which the well will be drilled
- Estimated depth to the top of important geologic markers
- Estimated depth to the top of objective horizons
- Proposed drilling mud program for surface hole and vertical hole

- Proposed openhole and cased-hole logging program
- Proposed well testing, coring, and geologic characterization program
- Proposed casing program including size and weight
- Proposed depth and formation at which each casing string is to be set
- Proposed amount of cement and placement procedure to be used
- Estimated top of cement
- General completion procedure
- Other pertinent information

2.2.4 Attachment 4: Proposed Drilling Mud Program

The storage operator provides information regarding the proposed mud program for both the surface and production holes in this attachment. Examples of the information to include for the surface and production holes are provided in Tables 2-2 and 2-3, respectively. These tables should be completed as a representation of the proposed drilling mud program. It should be noted that the proposed mud program described here is generic. Additional detail will likely be available for inclusion in this attachment at the time of the actual submission of the APD based on the recommendations of the mud engineer and wellbore conditions.

Lessons Learned – Oil-Based Versus Saltwater Gel Drilling Fluids: Although an oilbased mud may be often favored by oil industry, saltwater gel-based mud may be used to drill the Class VI injection well. Using saltwater gel mud has additional benefits compared to an oil-based mud when drilling and coring the injection well, such as:

- 1) Low cost in terms of cost per barrel.
- 2) Stronger cement bond to the casing and formation that increases the likelihood of a quality cement bond.
- 3) Sandstone formation with native brine being more compatible with a saltwater gel mud than oil-based mud. Oil-based mud presents a potential risk of damage to saline formations, which may ultimately reduce injectivity (i.e., clogging pore throats in the sandstone) and/or negatively impact core and sample testing results.

Table 2-2. Illustrative Mud Program for Surface Hole (values are provided for illustrative purposes only, and site-specific data are required for an actual APD)

| Drilling Fluid System | Measured Depth, ft | Mud Weight, ppg | Yield Point, lb/100 ft ² | Funnel Viscosity, sec/qt | Chlorides, mg/L |
|--------------------------|-----------------------|--------------------|--|--------------------------------|--------------------|
| Freshwater | 0-1926 | 8.4–9.0 | 1–2 | 27–40 | <5% |

| Drilling Fluid System | Measured Depth, ft | Mud Weight, ppg | Yield Point, lb/100 ft ² | Plastic Viscosity, cP | Chlorides, mg/L | API Fluid Loss, cm ³ |
|--------------------------|-----------------------|-----------------------|--|--------------------------|---------------------|------------------------------------|
| Saltwater Gel | 1926–6790 | 9.8–10.4 | 10–14 | 6–8 | 165,000– 180,000 | <10 |

Table 2-3. Illustrative Mud Program for Production Hole (values are provided for illustrative purposes only, and site-specific data are required for an actual APD)

2.2.5 Attachment 5: Casing Program (NDAC 43-02-03-21)

This attachment will include a description of the casing program, which includes the casing properties. Surface casing is required to be set at least 50 feet below the base of the lowest USDW (e.g., Fox Hills Formation). For well design, it is recommended to propose 100 feet of surface casing below the base of the USDW to ensure compliance with the 50-ft requirement (i.e., design surface casing to be set 100 feet into the Pierre Formation). Examples of the information to include in the casing program and casing properties are described in Tables 2-4 and 2-5, respectively. Tables 2-4 and 2-5 provide an example of the site-specific casing program information and casing properties required in the APD submittal.

Table 2-4. Illustrative Description of Casing Program (values are provided for illustrative purposes only, and site-specific data are required for an actual APD)

| Section | Hole Size, in. | Casing OD, in. | Weight lb/ft | Casing Seat | Casing Seat MD, ft | Grade, Connection | Objective |
|------------|-------------------|-------------------|-----------------|----------------|-----------------------|---|-----------------------------------|
| Surface | 131⁄2 | 9 ⁵ /8 | 36 | Pierre | 1926 | Carbon steel, STC ¹ | Cover shallow freshwater aquifers |
| Production | 83/4 | 7 | 29 | Amsden | 6790 | Carbon steel, LTC ² ; CO ₂ -resistant premium thread | Production casing |

¹ Short Thread Coupling.

² Long Thread Coupling.

Table 2-5. Illustrative Description of Casing Properties (values are provided for illustrative purposes only and site-specific data are required for an actual APD)

| OD,1 | Grade | lb/ft | Connection | ID, ² | Drift, | Burst, | Collapse, | Yiel (| ld Strength 1000 lb) |
|------|--------------------------------|-------|-------------------|------------------|--------|--------|-----------|-----------|-------------------------|
| in. | | | | in. | in. | psi | psi | Body | Connection |
| 95/8 | Carbon steel | 36 | STC | 8.921 | 8.765 | 3520 | 2020 | 564 | 453 |
| 7 | Carbon steel | 29 | LTC | 6.184 | 6.059 | 8160 | 7030 | 676 | 587 |
| 7 | CO ₂ - resistant | 29 | Premium thread | 6.184 | 6.059 | 8160 | 7030 | 676 | 676 |

¹ Outer diameter.

² Inner diameter.

Casing and Cement: CO₂-resistant casing and cement are not required for the entire wellbore (e.g., surface casing and cement is not required to be CO₂-resistant). The well needs to be designed and constructed to withstand the effects of the CO₂. CO₂-resistant materials are required by NDIC for any portion of the well that will be in or near direct contact with the injected CO₂, such as the tubing and packer the sections of casing and cement located in the injection zone and upper confining zone, etc.

2.2.6 Attachment 6: Cement Proposal (NDAC 43-02-03-21)

Table 2-6 is an example of the cement types and properties that are required as part of the APD.

| Table 2-6. Illustrative Cement Proposal (values are p | provided for illustrative purposes only, |
|---|--|
| and site-specific data are required for an actual APE | |

| Casing, | Ta | il | Lead | | Planned | Planned |
|---------|-----------------------------------|---------|------------------|---------|-----------|---------------|
| in. | Slurry | Top, ft | Slurry | Top, ft | Excess, % | Volume, sacks |
| 95/8 | Class "G" cement | 1426 | Class "G" cement | Surface | 75 | 915 |
| 7 | CO ₂ -resistant cement | 5950 | Class "G" cement | Surface | 75 | 780 |

2.2.7 Attachment 7: Illustrative Wellbore Schematic

The storage operator is required to provide a schematic of the wellbore in this Attachment of the APD. An illustrative example of one such schematic for an injection well is provided in Figure 2-1.

2.2.8 Attachment 8: Coring, Testing, and Logging Program

An evaluation program for the coring, testing, and logging of the stratigraphic test well is provided in this attachment. Additional information of importance includes the descriptions of the pressure control equipment, the drilling procedure, and the postcompletion plan. Examples of the content that is required for each of these topics is provided in the remainder of this section.

NDIC-Stated Coring Preference: Include the collection and analysis of geologic core through the CO₂ storage injection zone and a minimum of 50 ft from the overlying and underlying confining zones. This is not a requirement but rather a recommendation from the NDIC. The purpose of this recommendation is to demonstrate the depth and characteristics of the geology as it transitions between rock types from the target injection zone (i.e., impermeable lithology in the confining zones to a porous, permeable lithology in the injection zone). There can be porosity intervals above and below the Inyan Kara and Broom Creek Formations as the rock type transitions. Collection of sufficient core of the confining zones will aid the operator in demonstrating upper and lower confinement.



Figure 2-1. Illustrative example of a Class VI injection wellbore schematic.

2.2.8.1 Geologic Evaluation Program

Examples of the summary information for inclusion in the stratigraphic test well geologic evaluation program are as follows:

- Mudlogging a process of capturing rock sample cuttings from the return mud stream during well drilling and subsequent documentation (i.e., logging) of geologic name, lithology, mineral analyses, and oil and gas shows by depth. The APD includes a description of the depth interval that will be covered by the mud log and the intervals at which sample cuttings will be obtained.
- Cores specifies the formations from which cored sample intervals will be obtained using specialty drilling tools.
- Wireline logging describes the openhole and cased-hole electrical and mechanical logging program that will be performed on both surface and long-string sections. Examples of the type of logs and information required include the following:
 - Openhole logging Resistivity, spontaneous potential (SP), porosity, gamma ray (GR), and caliper logs are required by NDIC on both surface and long-string sections from total depth to the surface. Additional logs (e.g., acoustic, spectral GR, fracture finder, and fluid sampling) are also recommended in the long-string section for reservoir characterization.
 - Cased-hole logging To determine if the cement has been set over the casing, NDAC 43-05-01-11.2 requires a radial cement bond log (RCBL), variable-density log (VDL), casing collar locator (CCL), temperature, and GR log.

NDIC-Stated Logging Preference: An ultrasonic CBL run on the long-string casing is preferred by NDIC to meet both the RCBL requirement and the requirement to demonstrate external mechanical integrity.

- Wireline formation tester specifies the formations that will be subjected to this type of formation pressure test and fluid sampling.
- Drillstem testing (DST) specifies the formations that will be subjected to this type of test which mechanically isolates the formation for pressure and fluid sampling.
- Other testing methods, if proposed, are provided.

Should additional tests be proposed as part of this evaluation program, a description of these topics is provided in this APD attachment.

2.2.8.2 Pressure Control Equipment (NDAC 43-02-03-23)

Well control during all phases of the drilling, logging, casing runs, cementing, testing, etc., is mandated by NDIC and by industry best management practices. Well control equipment is

typically referred to as blowout prevention equipment (BOPE). The BOPE includes a description, accompanied by exhibits, of the type of equipment that will be used, e.g., blowout preventers, choke manifolds, and accumulators, including the operational procedures and frequency for testing and documentation of this equipment. An illustrative example of BOPE is provided in Figure 2-2.



Figure 2-2. Illustrative example of wellhead and BOPE schematic for an injection well (modified from Schlumberger).

2.2.8.3 Drilling Procedure

Examples of the information included in the drilling procedure, which is required for each drilling interval from ground level to the total depth of the well, include the following:

- Hole size
- Type of drilling mud
- Bit and casing specifications
- Detailed drilling procedure
- Detailed coring, testing, and logging procedures
- Specific cementing procedures
- Cementing and casing evaluation procedures (NDAC 43-05-01-11.2)

2.2.8.4 Postcompletion Program (NDAC 43-05-01-09 §3)

Within 30 days after the conclusion of well drilling and completion activities, the storage operator is required to provide project-specific reports, exhibits, documentation, and descriptions of the drilling, logging, coring, cementing, and well integrity evaluations of the stratigraphic test well.

2.2.8.5 Logging and Testing Program (NDAC 43-05-01-11; NDAC 43-02-03-38.1)

During the drilling and construction of a stratigraphic test well, the storage operator is required to provide documentation and exhibits that demonstrate that appropriate logs, surveys, and tests were performed to determine or verify such information as the depth, thickness, porosity, permeability, lithology, and salinity of any formation fluids in all relevant geologic formations. These data are necessary to ensure conformance of the well construction with the requirements under NDAC 43-05-01-11 and to establish accurate baseline data against which future measurements may be compared. The storage operator is also required to submit to the Commission a descriptive report prepared by a log analyst that includes an interpretation of the results of such logs and tests.

Examples of the details of the coring, logging, and testing program that are required to comply with these requirements are discussed.

Table 2-7 provides examples of the type of information that should be considered as part of the proposed coring program. Included in this information is the identification of the coring interval, the specification of the formations from which the interval was taken, and a description of the core, e.g., diameter and length.

 Table 2-7. Illustrative Example for Coring Program Details

 (values are provided for illustrative purposes only and require replacement)

| Interval Identification | Source of Core | Description of Core |
|-------------------------|----------------|-------------------------------|
| X feet to Y feet | Formation Name | Cylindrical (with dimensions) |
| 6223–6586 | Broom Creek | 4-in. whole core |

2.2.9 Attachment 9: Coring Program (NDAC 43-05-01-11.2 §2)

It should be noted that NDIC may require the storage operator to core specific formations in the borehole. To the extent that these requirements are anticipated, all such coring events should be included in this description of the coring program.

Core Requirements: North Dakota requires (NDCC 38-08-04 and NDAC 43-02-03-38.1) all core to be shipped to the state's core library within 180 days of completion of drilling operations. The North Dakota Geological Survey's Wilson M. Laird Core and Sample Library is located on the University of North Dakota campus in Grand Forks. A request for an extension can be made on a Form 4 Sundry Notice. Core analysis is also required to be submitted to the NDIC 30 days following completion of the analysis. A request for extension of time can also be made for the analysis submission.

Logging and Testing Program (NDAC 43-05-01-11.2 §1b and §1c)

A logging and testing program for both the open- and cased-holes is provided in this attachment. An illustrative example of a testing and coring program associated with the well drilling is provided in Figure 2-3. Examples of the type of information provided by these logs and tests are as follows:

- Logging and testing before and upon installing the surface casing: 1) resistivity, spontaneous potential, and caliper logs before the casing is installed; 2) an RCBL and VDL to evaluate cement quality radially; and 3) a temperature log after the casing is set and cemented.
 - Logging and testing before and upon installation of the production (long-string) casing: 1) resistivity, spontaneous potential, porosity, caliper, GR, fracture finder logs, and any other logs the Commission requires for the given geology before the casing is installed; 2) an ultrasonic CBL (see previous callout box "NDIC-Stated Logging Preference") and VDL; and 3) a temperature log after the casing is set and cemented.

Table 2-8 provides an example of the logging and testing details that will be used to demonstrate compliance with the permit requirements. Note that the GR log must be run to ground level and the CBL run on the intermediate or production casing.

2.2.10 Attachment 10: Other Requirements

Other project-specific considerations may need to be accounted for as part of the APD. The storage operator needs to demonstrate that there are no conflicts with the NDIC drilling permit review policy (NDIC-PP) by providing evidence with a complete APD submittal that all documents follow NDIC regulations and permit requirements.



Figure 2-3. Illustrative example of the logging and coring program.

| Туре | Description | Depth Intervals | Justification |
|---|-----------------------------------|------------------------|--|
| Triple-Combo, Caliper and SP | Surface section – openhole | 1926–0 | Quantify variability in reservoir properties. Identify wellbore volume to calculate cement volume. |
| RCBL–VDL– CCL–GR– Temperature Log | Surface section – cased hole | 1926–0 | Identify cement bond quality radially. Detect if cement channels exist. Evaluate the cement top and zonal isolation. |
| Triple-Combo, SP, Dipole Sonic (with 4-arm caliper), Spectral GR, Fracture Finder Log, Wireline Formation Testing | Long-string section – openhole | 6790–1926 | Determine depth, thickness, porosity, permeability, lithology, and salinity of any formation fluids. Dipole sonic and the fracture finder log quantify if fractures exist in the Broom Creek Formation and the confining layer. Wireline formation testing collects reservoir fluid from the Broom Creek Formation for testing of potential fluid and mineralogical reactions between injected fluid and formation fluid chemistry. This test can provide accurate real-time reservoir pressure measurements, permeability measurements, and can also provide the minimum in situ stress magnitude of formation by performing a mini-frac test/s. |
| Ultrasonic CBL– VDL–CCL–GR– Temperature Log | Long-string section – cased hole | 6790–0 | Identify cement bond quality radially. Detect if cement channels exist. Evaluate the cement top and zonal isolation. |

Table 2-8. Example for Logging and Testing Program Details (values are provided for illustrative purposes only and require replacement)

3.0 STORAGE FACILITY PERMIT (NDAC 43-05-01 Geologic Storage of Carbon Dioxide)

This template for the SFP application provides a description of what is required in each section of the permit application to comply with the applicable portions of the NDCC and NDAC; however, the template does not necessarily describe how to prepare the specific materials, maps, or technical exhibits. The template represents an overview of the topics and types of information that are needed to populate an SFP application, which includes the following five sections: 1) pore space access, 2) geologic exhibits, 3) AOR exhibits, 4) supporting permit plans, and 5) injection well and storage operations. These five sections should be presented in this order as it comports with the general order of presentations that are typically made during the testimony provided at the administrative hearing, which is part of the regulatory process required for approval of the SFP application.

A good working knowledge of the appropriate NDCC, NDAC, and other NDIC policies and guidelines is required to prepare and submit a successful SFP application. A crosswalk between the primary sections of the SFP application template and the relevant portions of the NDCC and NDAC is provided in a table in Appendix B of this document. For each section of the application, the applicable portion of the NDAC and NDCC is listed along with the specific requirements that are embodied in the statute and/or regulations. This crosswalk ensures the generation of a compliant SFP application.

A cover letter accompanying the SFP application package should be filed with the NDIC in order to begin the regulatory review process. Upon SFP application submission, the NDIC will perform an initial review to determine whether the application is complete. The NDIC has 1 year from the date the SFP application is deemed complete to issue a final decision regarding the application. The remainder of this section of the template describes in detail the contents of each major section of the SFP application.

3.1 Pore Space Access (NDCC 38-22-08 §4, §5, and §14; NDCC 38-22-10; and NDAC 43-05-01-08 §1 and §2)

North Dakota law explicitly grants title of the pore space in all strata underlying the surface of lands and waters to the overlying surface estate, i.e., the surface owner owns the pore space (NDCC 47-31 Subsurface Pore Space Policy). Furthermore, prior to initiating the storage of CO₂, the North Dakota statute for the geologic storage of CO₂ mandates that the storage operator obtain consent of landowners who own at least 60% of the pore space of the storage reservoir. The statute also mandates a good faith effort be made to obtain consent from all pore space owners and that all nonconsenting pore space owners are or will be equitably compensated. North Dakota law grants NDIC the authority to require pore space owned by nonconsenting owners to be included in a storage facility and subject to geologic storage through pore space amalgamation. Amalgamation of pore space will be considered at the administrative hearing as part of the regulatory process required for consideration of the SFP application.

This section of the SFP is focused on the notification process and conduct of a hearing before the Commission that involves the CO₂ storage operator and the parties that are involved in the pore space amalgamation process. The information that is required at the hearing to support the pore space amalgamation process is also described.

3.1.1 Proof of Notification

The Commission will notify the CO₂ storage operator when a pore space amalgamation hearing date is scheduled on the docket. Upon receiving that notification, the CO₂ storage operator is required to notify all owners (surface and mineral), mineral lessees, and any operator of mineral extraction activities within the facility area and within 0.5 mile of its outside boundary. The notification includes information about the proposed CO₂ storage project, details of the scheduled hearing, and a statement that the Commission will address pore space amalgamation at the hearing. The CO₂ storage operator is required to provide the Commission with an affidavit of mailing to certify that these notifications have been made. This notice must be given to each mineral lessee, mineral owner, and pore space (surface) owner at least 45 days prior to the hearing.

3.1.2 Pore Space Owner and Lessees

The CO₂ storage operator is required to identify all the owners and lessees that need to be notified and all pore space owners involved in the amalgamation process. This can best be demonstrated by creating multiple maps, examples of which are provided below:

- A map showing the extent of the pore space that will be occupied by CO₂ over the life of the project.
- A map with the legal descriptions showing the extent of the CO₂ plume.
- Quarter-by-quarter, pore space (surface) ownership maps with an ownership legend if landownership is in small parcels and complex.
- A series of maps showing the storage reservoir boundary and 0.5 mile (0.8 kilometers) outside of the storage reservoir boundary with a description of:
 - Pore space ownership, surface owner, and pore space lessees of record.
 - Each operator of mineral extraction activities by type, e.g., coal, oil and gas, etc.
 - Each mineral lessee of record.
 - Each owner of record of minerals.

3.2 Geologic Exhibits

Geologic and hydrogeologic technical evaluations of the carbon storage project area are required as part of the SFP. More specifically, these technical exhibits should include information such as the geologic evaluations of the injection zone, confining zones, and storage reservoir and a hydrogeologic evaluation of underground sources of drinking water. These technical evaluations may include a combination of written technical descriptions, geologic exhibits, and relevant maps of the project area, as discussed further in the remainder of this section.

3.2.1 Introduction

An overview of the geological characteristics of the storage project can be provided by utilizing exhibits such as a topographic map of the project area showing key geographic information, a stratigraphic column identifying the key geologic formations within the project area, and cross section (or cross sections) of the geologic formation into which the CO_2 will be injected, i.e., injection zone. It would also be useful to identify the surface location of the CO_2 injection well on the cross sections.

To aid in their interpretation, a brief written description of the regional geology and the geology of the storage reservoir may be developed to accompany the exhibits. The latter includes information such as the formation names, the lithology, the average depth and thickness of the storage reservoir in the project area, and source references.

3.2.2 Injection Zone

3.2.2.1 Description of Injection Zone

The targeted injection zone is described in detail in this section of the template including information such as described in Table 3-1 and, if necessary, using exhibits as listed below to aid in the understanding of the information in the table:

- An areal (e.g., satellite image) map and a surface (e.g., section, township, range, etc.) map that show the areal extent of the injection zone formation.
- A map from the geologic model of the site that provides a visual depiction of facies changes in the injection zone accompanied by a brief description.

Use of fence diagrams, which are derived from a combination of logs from existing wells in the project area and modeled type logs, may also be considered to visually depict the facies changes across the project area.

| Injection Zone Properties | | | | | | |
|---------------------------|-----------------------------------|------------------------|--|--|--|--|
| Property | Description | | | | | |
| Formation Name | Broom Creek | | | | | |
| Lithology | | Sandstone, dolomite | | | | |
| Formation Top, ft | 6273 | | | | | |
| Thickness, ft | 263 (sandstone 152, dolomite 169) | | | | | |
| Capillary Pressure, psi | 0.69 (gas–water system) | | | | | |
| Geologic Properties | | | | | | |
| Formation | Property | Description | | | | |
| Broom Creek | Porosity, % | 21.97 (10.22–31.53) | | | | |
| (Sandstone) | Permeability, mD | 193.87 (17.62–1677.49) | | | | |
| Broom Creek | Porosity, % | 10.08 (3.39–17.09) | | | | |
| (Dolomite) | Permeability, mD | 1.026 (0.02–40.67) | | | | |

Table 3-1. Description of CO₂ Injection Zone (values are provided for illustrative purposes only and require replacement)

3.2.2.2 Geochemical Information of Injection Zone

A discussion of the predicted interaction and compatibility of the CO₂ stream within the formation following its injection is required. The primary interactions of interest are absorption, dissolution, and mineralization processes. A report describing the findings, testing methods performed, and quality assessment and quality control will be included in this portion of the SFP application.

3.2.2.3 Identification of Data and Information Sources

It is important to identify the source of the data and information used to characterize the injection zone (e.g., core data, geophysical data, well logs, outcrop), distinguishing between those data and information that were collected as part of the geologic site characterization for the project (e.g., core, logs, seismic) from those data that were obtained from other available information (e.g., nearby well logs, research papers, previously acquired existing seismic, etc.). A report describing these findings will be included in this portion of the SFP application.

3.2.3 Confining Zone

3.2.3.1 Description of Upper and Lower Confining Zones

The upper and lower confining zones associated with the storage reservoir can be described using information such as that presented in Table 3-2, which includes information for both zones such as:

- Depth of the formation tops.
- Thickness.
- Mineralogy.
- Porosity (average and range) and permeability (average and range).
- Capillary pressure.

Table 3-2. Description of Depositional Environment of Upper and Lower Confining Zones (values^{1,2} are provided for illustrative purposes only and require replacement)

| Contining Zone Properties | | | | | |
|--|----------------------|----------------------|--|--|--|
| | Description | | | | |
| Property | Upper Confining Zone | Lower Confining Zone | | | |
| Formation Name | Opeche | Amsden | | | |
| Lithology | Siltstone/shale | Dolomite/shale | | | |
| Formation Top, ft | 6108 | 6536 | | | |
| Thickness, ft | 165 | 101 | | | |
| Porosity, % | 9.45 (0.1–16.0) | 7.86 (0.1–29.3) | | | |
| Permeability, mD | 0.21 (0.02–1.5) | 0.04 (0.001–178.0) | | | |
| Capillary Entry Pressure, psi | 3000 | 185.85 | | | |
| Depth below Lowest Identified USDW, ft | 4282 | 4710 | | | |

¹ Sorensen, J.A., Smith, S.A., Dobroskok, A.A., Peck, W.D., Belobraydic, M.L., Kringstad, J.J., and Zeng, Z., 2009, Carbon dioxide storage potential of the Broom Creek Formation in North Dakota—a case study in site characterization for large-scale sequestration, *in* Grobe, M., Pashin, J.C., and Dodge, R.L., eds., Carbon dioxide sequestration in geological media—state of the science: AAPG Studies in Geology 59, Tulsa, OK, American Association of Petroleum Geologists, p. 279–296.

² Center for Economic Geology Research website, (2020) www.uwyo.edu/cmi/_files/docs/de-fe0009202.pdf (accessed 2020).

Exhibits similar to those provided for the injection zone will provide the data for both the upper and lower confining zones, as listed below:

- A surface map that shows their areal extent.
- A map from the geologic model of the site that provides a visual depiction of facies changes, accompanied by a brief description.

Use of fence diagrams, which are derived from a combination of logs of existing wells in the project area and modeled type logs, should also be considered to visually depict the facies changes in these confining zones across the project area.

3.2.3.2 Geomechanical Information of Confining Zone

A description of the geomechanical characteristics of the confining zone will provide evidence that the confining zone is free of transmissive faults or fractures and is of sufficient areal extent and integrity to contain the injected CO₂. The geomechanical description includes information on fractures, stress fields, ductility, rock strength, and in situ fluid pressure.

3.2.3.3 Faults, Fractures, and Seismic Activity

If there are known or suspected faults or fractures that may transect the confining zone in the AOR, provide evidence that the faulting or fracturing does not compromise the integrity of the storage reservoir. Specifically, the location and orientation of the faults/fractures should be provided along with an assessment of the probability that they would interfere with containment of the CO_2 and/or formation brine.

Additional information regarding tectonic activity at a regional level can provide a valuable perspective for understanding the faults, fractures, and seismic activity of the storage site. Similarly, providing a description of the seismic history, including the presence, depth, and frequency of seismic events in North Dakota will also provide valuable information. Presentation of this information in a report with exhibits including citations to specific scientific publications provides sufficient evidence necessary for the regulatory review.

Lastly, the seismic activity report will include examples of regional maps and cross sections to depict any faulting, fractures, and tectonic activity as well as a national seismic activity map to provide the proper context for the regional data and information.

3.2.3.4 Additional Confinement Beyond Immediate Confining Zones

It is important that all additional confining formations within the geologic storage system that lie above the immediate confining zones be identified and characterized by providing information such as presented in Table 3-3. In addition, consideration should also be given to providing a cross-sectional view that shows the location of these additional confining zones relative to the injection zone along with a statement that these additional confining formations are free of transmissive faults and, in combination with the immediate upper confining zone, are capable of preventing vertical movement into USDWs.

| require replacement) | | | | | | | |
|----------------------|-----------|-----------|---------------|---------------------------|--|--|--|
| Name of | | Formation | | Depth below Lowest | | | |
| Formation | Lithology | Top, ft | Thickness, ft | Identified USDW, ft | | | |
| Pierre | Shale | 1826 | 2166 | 0 | | | |
| Greenhorn | Shale | 3992 | 423 | 2166 | | | |
| Mowry | Shale | 4415 | 355 | 2589 | | | |
| Inyan Kara | Sandstone | 4770 | 321 | 2944 | | | |
| Swift | Shale | 5091 | 402 | 3265 | | | |
| Rierdon | Shale | 5493 | 259 | 3667 | | | |
| Piper Kline | Limestone | 5752 | 106 | 3926 | | | |
| Piper Picard | Shale | 5858 | 105 | 4032 | | | |
| Spearfish | Siltstone | 5963 | 137 | 4137 | | | |
| Minnekahta | Limestone | 6100 | 8 | 4274 | | | |

Table 3-3. Description of Zones of Confinement above the Immediate Upper Confining Zone (values are provided for illustrative purposes only and require replacement)

These confining zone analyses can be used to identify those that act as pressure dissipation zones (i.e., thief zones) and/or are targeted as monitoring zones for CO₂, temperature, pressure, water quality, etc.

3.2.3.5 Identification of Data and Information Sources

A written description of the geologic confinement characteristics and mechanisms, including the rock properties that prevent the migration of CO₂ beyond the storage reservoir, is an important element of the SFP. It is important that the source of the data and information used to characterize the upper and lower confining zones (e.g., core data, geophysical data, well logs, outcrop) be identified, distinguishing between those data and information collected as part of the geologic site characterization for the project (e.g., core, logs, seismic) from data obtained from other available information (e.g., nearby well logs, research papers, previously acquired existing seismic, etc.).

3.2.4 Storage Reservoir

A description of the storage reservoir can be accomplished using a combination of exhibits that include a discussion regarding the geologic structure and formation thickness. These exhibits should include information such as the identification of all geologic characteristics that control the isolation of stored CO₂ and associated formation fluids within the storage reservoir, including structural spill points and stratigraphic discontinuities. This evaluation needs to describe the storage reservoir's mechanisms of geologic confinement, including properties, regional pressure gradients, structural features, and adsorption characteristics with regard to the ability of that

confinement to prevent migration of carbon dioxide beyond the proposed storage reservoir. A candidate list of the exhibits for consideration are as follows:

- Geologic structure
 - A visual depiction of confinement zones across the project area using logs from existing wells in the project area and modeled type logs using fence diagrams (see description of upper and lower confining zones).
 - A structure map of the formation top of the storage reservoir.
 - A structure map of the base of the formation of the storage reservoir.
 - A cross section of the storage reservoir showing any structural spill points and stratigraphic discontinuities.
 - Structural and stratigraphic cross sections that describe the geologic conditions of the storage reservoir.
- Formation thickness
 - An isopach map of the storage reservoir(s) thickness.
 - An isopach map of the primary containment barrier thickness (i.e., the upper confining zone) for the storage reservoir.
 - An isopach map of the secondary containment barrier(s) thickness for the storage reservoir.

3.2.5 Protection of USDWs

The primary purpose of this section is to provide information identifying the overall isolation and protection of the lowest USDW. Included in this section of the SFP is a discussion of the formation names, depths, and thicknesses of the geologic overburden along with the depth and length of each of the secondary seals above the injection zone. Information on the well penetrations in the area are provided in maps upon which the wells are identified. Well status, details on steel casing and cementing isolation, as well as the status of plugged and abandoned wells, which are essential to the protection of USDWs, are discussed in other sections of this template.

Brief descriptions and illustrations of the hydrogeology in the storage facility area, including the identification of key groundwater formations, should also be considered for inclusion in this section of the template by providing hydrogeologic maps and cross sections. Examples of the information included in these maps are listed below:

• A cross section of the groundwater formations showing general vertical and lateral limits across the project area.

- Identification of the different uses of the groundwater formations in the area (e.g., drinking water, stock water, irrigation water, etc.).
- Description of the expected groundwater quality for the various groundwater uses.
- Direction of groundwater flow.

Included in this section of the SFP is an areal map that shows the location of all groundwater wells across the project area identified by well type, i.e., water use. For reference, the wellsite and facility locations should also be shown on this map, and the distance from the closest groundwater wells to the injection well(s) needs to be clearly identified. If present, a brief description of the main source of drinking water for any nearby city or community should also be considered.

3.3 Area of Review Exhibits

The storage facility permit is required to define an AOR and contain a corrective action plan. The AOR of a CO_2 storage project is the region surrounding the proposed CO_2 injection well where USDWs may be endangered by the injection activity. The NDAC defines the AOR as the areal extent of the CO_2 storage reservoir, an area 1 mile outside of the CO_2 storage reservoir boundary, and the area encompassed by the maximum acceptable pressure front caused by injection activities. The regulations require that the AOR be delineated using computational modeling and that it be reevaluated periodically during the lifetime of the geologic storage project.

The corrective action plan focuses on the identification and evaluation of all wells within the AOR that penetrate the upper confining formation of the storage reservoir. If warranted, corrective action will be defined for those wells that represent potential leakage pathways of concern, and a schedule for the implementation of the corrective action, i.e., prior to injection or phased over time, should be presented.

3.3.1 AOR Delineation

The storage facility permit is required to have a separate section titled "Area of Review Delineation," which will require maps of the AOR as delineated using computational modeling. These maps include information such as all critical boundaries, the location of any proposed injection wells or monitoring wells, the presence of significant surface structures or land disturbances, and the location of water wells and any other wells. The specific requirements for this section include a written description accompanied by the supporting maps and tables.

3.3.1.1 Written Description

A written description of the method used for AOR delineation (i.e., methods and assumptions) is required along with a discussion of, and when, any corrective action would be needed. Plans for providing continued updates of the AOR delineation are also required. At a minimum, current regulations require that a reevaluation be done every 5 years during a state-required review of the permit. Included in the AOR delineation should be information such as 1) the computational model that is used, including specifics regarding all of the software that will

be used; 2) the site characterization data and assumptions upon which the models are based; and 3) the integration of the areas of predicted CO_2 plumes and pressure fronts to produce a site-specific AOR. In addition, it is recommended that a permit section titled "Assumptions and Justification" be developed to present the reasoning that was used to support the assumptions that were made in the computational model.

Modeled interpretation of the pressure front and its potential impact on USDWs through the subsurface movement of CO₂ and/or brine is also an important part of this section of the SFP application. Critical supporting information of this effort includes information such as baseline geochemical data on subsurface formations, including all USDWs within the AOR (i.e., USDWs, water wells, and springs), as well as maps and stratigraphic cross sections of all USDWs within the AOR. The maps and cross sections should include details such as 1) the locations of the sources of drinking water relative to the injection zone; 2) the direction of water movement, where known; 3) and general vertical and lateral limits.

3.3.1.2 Supporting Maps

Several additional maps are required to provide support for the AOR delineation. Several examples of these maps, including a brief discussion of each, are provided below:

- AOR maps The storage facility evaluation area includes the areal extent of the CO₂ storage reservoir and 1 mile outside of the CO₂ storage reservoir boundary, plus the extent of the maximum acceptable pressure front caused by injection activities, also known as the AOR. Examples of maps that depict the delineation of the AOR include:
 - Maps showing the injection well location, the injection zone contours, the areal extent of the CO₂ plume, the facility area (the plume area plus 0.5-mile buffer), the storage facility permit hearing notice boundary (1-mile AOR boundary beyond the CO₂ plume boundary), the pressure front-defined AOR boundary, and the AOR (pressure front plus 1.5-mile buffer).
 - Map of delineated AOR, which should include all boundaries, the location of any proposed injection wells or monitoring wells, key surface structures and land disturbances, the location of groundwater wells, and any oil and gas wells.
 - Maps showing the following within the combined AOR and SFP evaluation area:
 - All wells, including water, oil, and natural gas exploration and development wells, highlighting those wells that penetrate the storage reservoir or primary or secondary seals overlying the storage reservoir.
 - All other man-made subsurface structures and activities, including coal mines.
 - Areal extent of all man-made surface structures that are intended for temporary or permanent human occupancy.
 - Any productive existing or potential mineral zones occurring within the storage reservoir area and within 1 mile outside of its boundary.
 - A final map for the AOR that includes the following information:
 - Number or name and location of all injection wells
 - Number or name and location of all producing wells
 - Number or name and location of all abandoned wells
 - Number of name and location of all plugged wells or dry holes

- Number or name and location of all deep stratigraphic boreholes
- Identify any state-approved or U.S. Environmental Protection Agency (EPA)approved subsurface cleanup sites
- Identify surface bodies of water
- Identify any springs
- Name and location of all mines (surface and subsurface)
- Name and location of all quarries
- Identify all known water wells
- Identify any other pertinent surface features
- Identify all structures intended for human occupancy
- Identify any state, county, or Indian country boundary lines
- Identify all state and federal highways and county roads
- Should the AOR extend across state jurisdictions, it is required that a list of the state contacts be submitted to the Commission and included in the permit.
- CO₂ storage reservoir map a map showing the following within the CO₂ storage reservoir:
 - Boundaries of the CO₂ storage reservoir
 - Location of all proposed wells
 - Location of proposed cathodic protection boreholes
 - Any existing or proposed aboveground facilities

3.3.2 Corrective Action Evaluation

A review of the wells identified in the AOR that penetrate the storage system is required along with a description of any necessary corrective actions and a schedule for their implementation. Included as part of the well assessment are activities such as the following:

- Documentation, such as the post-plugging report and the CBL, that all abandoned wells have been plugged in a manner that prevents the CO₂ or associated fluids from escaping the storage reservoir.
- A determination, such as an engineering review of well logs and construction records, and a statement that all operating wells have been constructed in a manner that prevents the CO₂ or associated fluids from escaping the storage reservoir.
- A description of each well which includes the following information:
 - Well type (oil, gas, injection, storage)
 - Well status (producing, shut-in, temporarily abandoned, plugged and abandoned)
 - Date drilled
 - Location (latitude/longitude and legal location)
 - Depth
 - Record of plugging, if appropriate, including:
 - Depth of plugs (top and bottom)
 - Type of plug placement (balanced plug, etc.)
 - Number of cement sacks

- Type of cement
- Displacement fluid (mud or water)
- Record of completion including:
 - CBL evaluation
 - Cement top
 - Isolation across the injection zone (above and below injection zone)
 - Completed formation name
 - Completed or perforated interval
 - Current records or other pertinent information (tubing, packer, artificial lift equipment, etc.)

3.3.3 Reevaluation of AOR and Corrective Action Plan

It is required that the storage operator routinely reevaluate the AOR and corrective action plan, with the period between evaluations not to exceed 5 years. As part of the SFP, the application describes the following:

- Any monitoring and operational conditions that would warrant a reevaluation of the AOR prior to the scheduled 5-year reevaluation date.
- How monitoring and operational data (e.g., injection rate and pressure) will be used to inform a reevaluation of the AOR and corrective action plan, including how the computational model that was used to determine the AOR will be updated and what operational data will be used as the basis for that update.
- How corrective action, if necessary, will be conducted, including 1) what corrective action will be performed prior to, or following, injection and 2) how corrective action will be adjusted if there are changes in the AOR.

3.4 Supporting Permit Plans (NDACC 43-05-01-05)

Ten supporting plans are required as part of the SFP permit application. The required plans (with statutory reference) include the following:

- Emergency and Remedial Response Plan (NDAC 43-05-01-05 §1d; NDAC 43-05-01-13)
- Financial Assurance Demonstration Plan (NDAC 43-05-01-05 §1k; NDAC 43-05-01-09.1)
- Worker Safety Plan (NDAC 43-05-01-05 §1e; NDAC 43-05-01-13)
- Corrosion and Monitoring and Prevention Plan (NDAC 43-05-01-05 §1f; NDAC 43-05-01-15)
- Surface Leak Detection and Monitoring Plan (NDAC 43-05-01-05 §1g; NDAC 43-05-01-14)
- Subsurface Leak Detection and Monitoring Program (NDAC 43-05-01-05 §1h)
- Well Casing and Cementing Program (NDAC 43-05-01-05 §1i; NDAC 43-05-01-09)
- Testing and Monitoring Plan (NDAC 43-05-01-05 §11; NDAC 43-05-01-11.4)
- Plugging Plan (NDAC 43-05-01-05 §1m; NDAC 43-05-01-11.5)
- Postinjection Site Care and Facility Closure Plan (NDAC 43-05-01-05 §1n; NDAC 43-05-01-19)

The required content of each of these plans is described in the remainder of this section.

3.4.1 Emergency and Remedial Response Plan (NDAC 43-05-01-05 § 1d; NDAC 43-05-01-13)

The emergency and remedial response plan (ERRP) is required to address those events that occur during the geologic storage of the CO₂ that have the potential to move injection fluid or formation fluid in a manner that may endanger a USDW during the operation or postinjection site care periods. Other emergency events may also include 1) CO₂ leakage to the atmosphere and 2) CO₂ migration outside of the storage reservoir permitted facility area, including migration into other nonpermitted formations, i.e., thief zones.

The ERRP describes the actions that the storage operator will take to address emergency events. If there is evidence that the injected CO_2 and/or associated pressure front may cause endangerment to a USDW, the storage operator is required to implement the following response protocol:

Cease injection activities.

- 1. Take all steps reasonably necessary to identify and characterize any pressure buildup and/or subsurface fluid movement.
- 2. Notify the NDIC DMR UIC Program Director of the emergency event within 24 hours.
- 3. Execute detailed response plans as presented in the applicable portions of the ERRP.

Regarding the cessation of CO₂ injection, discussions with the NDIC DMR UIC Program Director are necessary to determine if a gradual or temporary cessation of injection (using a set of preestablished parameters) may be appropriate. In addition, it is recommended that a set of emergency contacts (both internal and external) be developed and maintained during the life of the geologic storage project (see Section 3.4.1.5 Emergency Communications Plan).

Given that it is not possible to predict the specific nature of an emergency event or when it will occur, the ERRP is required to provide a framework that can be used to identify and classify an incident, develop a set of specific emergency response actions, describe the available

emergency personnel and equipment, and develop an emergency communications plan. In addition, a process for reviewing and, if necessary, updating the ERRP over the lifetime of the project is required. These elements of the framework are briefly described below.

3.4.1.1 Identification of Local Resources and Infrastructure

The storage operator is required to identify the local resources and infrastructure near the geologic storage project that may be impacted by an emergency event. Local resources may include municipal USDWs, potable groundwater wells, lakes, or other surface water bodies; infrastructure might include wellheads, local or interstate roads, railroad tracks, or structures of nearby towns or cities. A map of the local area that provides the locations of these key resources and infrastructure, where relevant, will be included in this section of the plan.

3.4.1.2 Identification and Classification of Potential Emergency Events

For the purposes of this plan, an "emergency event" is an event that poses either 1) an immediate (or acute) risk to human health, resources, or infrastructure or 2) a potential (or chronic) risk to these same receptors should conditions worsen or no mitigative/remedial emergency responses be taken. On the other hand, events that do not pose either an acute or chronic risk to human health, resources, or infrastructure do not warrant emergency responses and are designated as "incidents." Essentially, the primary defining factor of an emergency event is whether the event has an immediate or imminent potential to result in an acute or chronic risk rather than simply having the potential to produce such a risk at some time in the future.

A site-specific, screening-level risk assessment or some other technical evaluation of the geologic storage project is a useful tool for identifying the technical risk categories that could lead to an emergency event. Based on previous risk assessments performed on other geologic storage projects, a common list of events or circumstances that have the potential to require an emergency response for the protection of USDWs and which provide an initial foundation for an ERRP at any CO₂ storage site, is provided below:

- Injection or monitoring well integrity failure.
- Injection well monitoring equipment failure (e.g., inoperable shutoff valve, inoperable temperature or pressure gauge, etc.).
- Failure of storage reservoir cap rock.
- Presence of unknown faults or fractures.
- Presence of undocumented, leaking (legacy) wells within the AOR.
- Induced seismic event occurs which results in new faults or fractures, the activation of existing faults or fractures, damage to legacy wells, or other outcomes which lead to the migration of fluids (CO₂ or formation brine) beyond the storage reservoir.

In addition to these project/operational events, the occurrence of a natural disaster (e.g., earthquake, tornado, lightning strike, etc.) also represents an event that may warrant emergency response planning as part of the ERRP.

The above list of events should be periodically reviewed and, if necessary, modified (i.e., emergency events are either added, deleted, or both) to reflect site-specific considerations. This modified list of potential "emergency events" can be used as the basis for the development ERRP.

3.4.1.3 Emergency Response Actions

For each of the emergency events identified above, the ERRP is required to contain an emergency response action. The emergency responses should build upon the response protocol presented earlier in Section 3.4.1. In all cases, the goal of the initial steps of the response protocol is to stop the emergency event and notify the emergency contacts as soon as possible. This should be followed by a more in-depth technical assessment that leads to the design and implementation of a remedial action plan, all of which should be done in consultation with the NDIC DMR UIC Program Director. An example of this approach is presented here for the vertical movement of brine or CO₂ into a USDW. This event could be caused by one of several failures, including failure of the confining zone, loss of mechanical integrity of the injection or monitoring well, or if the brine or CO₂ plume encounters an unknown fault, fracture, or well in the AOR. The immediate and primary responses to injection-related fluid migration into any USDW or surface water are cessation of CO₂ injection, notification of the emergency contact list, identification and location of the source of the release, and implementation of corrective action to stop the release. The location, size of the release, and access will control the course of the remedial action. In the event of an impact on water quality within a surficial aquifer system that directly affects water-supply wells, point of use, withdrawal water treatment, or alternate water-supply remedies would be implemented as an appropriate remedial response. Table 3-4 provides a summary of the basic actions required to respond to a detected "event."

3.4.1.5 Emergency Communications Plan

In the event of an emergency, it is necessary for the storage operator to have available a communications plan which, depending upon the emergency event, will define both internal and external contacts to secure immediate assistance. Information, such as the following, may be provided to each of the contacts:

- Facility name, address, location, and telephone number
- Name of person reporting the incident
- Date and time of incident
- Nature of the incident, e.g., material released, etc.
- Extent of the incident, e.g., source and quantity of material released
- Media impacted by release (air, soil, and groundwater).
- Identify specific contractors and equipment vendors capable of providing necessary services and equipment to respond to such leaks or loss of containment.

In the event of an emergency requiring outside assistance, it is also important that the storage operator have a plan for managing communications with the public.

3.4.1.6 ERRP Reviews and Updates

The content of the ERRP includes items such as a schedule for reviewing and updating the ERRP on an annual basis. Examples of possible review schedules are suggested in the state regulations and include:

- At least once every 5 years following its approval by the permitting agency.
- Within 1 year of an AOR reevaluation.

| Fable 3-4. Illustrative Example of Permit Information Requirements: Response to Potenti | al |
|--|----|
| Emergency Event* | |

| Item | Description/Comments | |
|---|---|--|
| Immediately investigate and identify events that may result in a shutdown (downhole or at the surface). | The procedure that will be used to identify the cause of a shutdown should be described, considering the following potential events: Injection or monitoring (verification) well integrity failure. Injection well monitoring equipment failure (e.g., shutoff valve or pressure gauge, etc.). A natural disaster (e.g., earthquake, tornado, lightning strike). Fluid (e.g., brine) leakage to a USDW. CO₂ leakage to USDW or land surface. Induced seismic event. | |
| Determine the severity of an event, categorizing it either as an "emergency" or an incident. | A procedure for categorizing an event as either an emergency or incident should be provided. | |
| Define actions that will be implemented should an event be classified as an incident. | If an event is classified as an incident, the following actions should be taken: 1. Ensure all personnel are accounted for and that the storage facility is secure. 2. Determine cause of incident and use findings in operator training and to implement procedures as necessary to prevent reoccurrence. 3. Resume plant operations and injection. | |
| Define actions that will be implemented should an event be classified as an emergency. | If the event is classified as an emergency and/or the injection well appears to lack mechanical integrity or if required monitoring indicates the well may lack mechanical integrity, the following actions should be taken: Immediately cease injection. Take all steps necessary to determine whether there may have been a release of the injected carbon dioxide stream or formation fluids into any unauthorized zone. Notify NDIC within 24 hours. Perform a root cause analysis to determine cause of emergency or incident and use findings in operator training and to implement procedures as necessary to prevent reoccurrence before resuming injection. Before resuming injection, operator will restore and demonstrate mechanical integrity to the satisfaction of the NDIC. Notify the NDIC when injection can be expected to resume. | |

* This information is required if a shutdown (downhole or at the surface) is required.

• Within a prescribed period (to be determined in coordination with the permitting agency) following any significant changes to the injection process, the injection facility, or an emergency event.

• As required by the permitting agency.

If the review indicates that no amendments to the ERRP are necessary, the storage operator is required to provide the permitting agency with the documentation supporting the "no amendment necessary" determination. If the review indicates that amendments to the ERRP are necessary, it is required that these amendments be made by the storage operator and be submitted to the permitting agency within a specified period, e.g., 3 months, following their identification.

3.4.2 Financial Assurance Demonstration Plan (NDAC 43-05-01-09.1)

A financial assurance demonstration plan (FADP) is required and must be a qualifying financial responsibility instrument: surety or cash bond, trust fund, letter of credit, insurance policy, self-insurance, escrow account, or any other instrument NDIC finds satisfactory. A qualifying financial responsibility instrument must be sufficient to cover the cost of any corrective action that may be required at the geologic storage facility during any of its phases of operation, well plugging, postinjection site care and facility closure, emergency and remedial response, and endangerment to USDWs. A potential list of activities, which require coverage by the FADP and for which cost estimates are required, is presented in Table 3-5.

| require replacement) | | | |
|--|-------------------------|--|--|
| Activity | Total Cost, \$ millions | | |
| Performing Corrective Action on Wells in AOR | 0.62 | | |
| Plugging Injection Wells | 2.70 | | |
| Postinjection Site Care | 18.3 | | |
| Site Closure | 3.40 | | |
| Emergency and Remedial Response Actions | 26.7 | | |
| Endangerment of USDWs | 6.44 | | |

 Table 3-5. Illustrative Example of Cost Estimates for Financial Assurance

 Demonstration (values³ are provided for illustrative purposes only and

 require replacement)

The FADP is required to demonstrate that the financial instrument meets the criteria that are specified in the regulations regarding the level of coverage, protection of coverage, maintenance of the qualifying financial responsibility through project completion, and notifications of changes in conditions (e.g., adverse company financial conditions, changes in the funds required for performing required corrective actions, etc.) that require changes to the financial instrument (refer to NDAC 43-05-01-09.1).

There are specific requirements for using multiple qualifying financial responsibility instruments for specific phases of CO₂ storage project outlined in NDAC 43-05-01-9.1 §1f.

³ U.S. Environmental Protection Agency, 2013, Underground injection control permit applications for FutureGen 2.0 Morgan County Class VI UIC Wells 1, 2, 3, and 4: FutureGen Industrial Alliance, Inc., U.S. Environmental Protection Agency, Region 5.

3.4.3 Worker Safety Plan (NDAC 43-05-01-05 §1e; NDAC 43-05-01-13)

The required worker safety plan includes discussions on topics such as the following:

- a. Carbon dioxide safety training.
- b. Safe working procedures at the storage facility wellsite.
- c. A training schedule for worker safety training including scheduled refresher courses and worker inspection procedures to ensure a safe working conditions (i.e., What should the worker do every time when entering the surface location?).

The storage operator is required to state that a fully compliant Worker Safety Program that meets all state and federal requirements for worker safety protections, including Occupational Safety and Health Administration (OHSA) and NFPA (National Fire Protection Association), will be maintained and implemented.

More specifically, information provided in the Worker Safety Plan includes the following statements: 1) that all operations employees will receive training related to health and safety, operational procedures, and emergency response according to the roles and the responsibilities of their work assignments; 2) initial training will be conducted by, or under the supervision of, a project operations manager or a designated representative; and 3) trainers will be thoroughly familiar with the operations plan and the ERRP.

Included in the CO₂ safety training program are items such as annual training that teaches personnel to identify the dangers of CO₂, requirements for all employees and visitors to wear the proper personal protective equipment (PPE), and instructions for the performance of duties in ways that prevent the discharge of CO₂. The training could also include familiarization with operating procedures, and equipment configurations appropriate to the job assignment, as well as emergency response procedures equipment, and instrumentation. New personnel will be instructed before beginning their work. A contractor and visitor orientation to address and document CO₂ safety awareness to ensure all persons on-site are trained and aware of the dangers of CO₂ may also be considered.

The CO₂ safety training plan could also include information and frequency of refresher training for all appropriate operations personnel. This may include monthly briefings to operations personnel according to their respective responsibilities to highlight recent operating incidents, actual experience in operating equipment, and recent storage reservoir monitoring information.

Lastly, the storage operator plan needs to include a method to document and record worker safety training, at a minimum with the person's name, date of training, type of training (e.g., initial or refresher), and the instructor's name documented.

3.4.4 Testing and Monitoring Plan

The SFP requirements of the NDAC include several detection and monitoring plans. These include the following:

- Corrosion monitoring plan (NDAC 43-05-01-05 §1f; NDAC 43-05-01-15).
- Leak detection and monitoring plan for all wells and surface facilities (NDAC 43-05-01-05 §1g; NDAC 43-05-01-14).
- Leak detection and monitoring plan to monitor any movement of the CO₂ outside of the storage reservoir (NDAC 43-05-01-05 §1h).
- Testing and monitoring plan (NDAC 43-05-01-05 §11; NDAC 43-05-01-11.4).

Because the testing and monitoring plan incorporates the elements of all the other three detection and monitoring plans: 1) Monitoring and Prevention Plan, 2) Surface Leak Detection and Monitoring Plan, 3) Subsurface Leak Detection and Monitoring Program, this section of the SFP integrates these requirements into a single plan, which comprises the following:

- Written descriptions which describe in detail the testing and monitoring for the preinjection baseline, operational, and postinjection site care and facility closure phases of the project.
- Maps which show the location of the sample points and the types of samples that will be taken.
- Tables which will describe the type of samples, number of samples, and duration of sampling for each of the phases of the project.

3.4.4.1 Analysis of Injected CO₂

The storage operator is required to specify an appropriate analytical method to analyze the chemical and physical characteristics of the injected CO₂. An example of the types of chemical composition data of interest is shown in Table 3-6; physical characteristics of interest include density and viscosity.

All analytical methods used to generate these data should be consistent with standard analytical methods and techniques that are generally accepted by industry, and all testing should be performed and documented with enough frequency to yield representative characterization data of the CO₂ stream to be injected and stored.

| purposes only and require replacement) | | |
|--|---------------------|--|
| Component* | Measurement, vol%** | |
| Carbon Dioxide | 95 | |
| Ethane | <0.1 | |
| Propane | <0.1 | |
| n-Butane | <0.1 | |
| Hydrogen | <0.1 | |
| Nitrogen | 4 | |
| Methane | <1 | |
| Oxygen | <0.001 | |
| Water, ppm | 500 | |

Table 3-6. Illustrative Example of Chemical Components Targeted for Characterization in the Injected Carbon Dioxide Stream (values⁴ are provided for illustrative purposes only and require replacement)

* Not all components may be present, illustrative only.

** Unless otherwise indicated.

3.4.4.2 Leak Detection and Monitoring Plan: Wells and Surface Facilities

The testing and monitoring plan is required to include a leak detection and monitoring program for all wells and surface facilities as per NDAC 43-05-01-14. The plan is required to 1) identify the potential pathways for the release of CO₂ to the atmosphere, 2) identify potential pathways for the degradation of groundwater resources with a particular emphasis on USDW, and 3) identify potential pathways for the migration of CO_2 into any mineral zone within the facility area. Leak detection/monitoring efforts are required for the wellheads of all injection and subsurface observation wells, other surface components of the CO₂ injection system (e.g., flange connections, valves, etc.), and the CO₂ transport pipeline. Specifically, the plan describes the type of leak detection systems that will be used along with the location and inspection/testing schedule for each system. A written description, system diagrams and workflows, and a table of the system specifications should also be provided for each system. Where applicable, leak detectors must be integrated with automated warning systems and must be inspected and tested on a semiannual basis. If defective, the leak detectors must be repaired or replaced within 10 days. If necessary, the Commission may require that each repaired or replaced detector be retested. An extension of time for repair or replacement of a leak detector may be granted upon a showing of good cause by the storage operator. A record of each inspection must include the inspection results, must be maintained by the operator for at least 10 years, and must be made available to the Commission upon request. Refer to NDAC 43-05-01-14.

The storage operator is required to immediately report to the Commission 1) any leak detected at any well or surface facility; 2) any pressure changes or other monitoring data from subsurface observation wells that indicate the presence of leaks in the storage reservoir; and 3) any other indication that the storage facility is not containing CO₂, whether the lack of containment concerns the storage reservoir, surface equipment, or any other aspect of the storage facility.

⁴ National Energy Technology Laboratory, 2019, Quality guidelines for energy system studies: CO₂ impurity design parameters: U.S. Department of Energy, Systems Engineering & Analysis Directorate, NETL-PUB-22529. DOI: 10.2172/1566771, www.netl.doe.gov/projects/files/QGESSCO2ImpurityDesignParameters_010119.pdf (accessed 2020).

3.4.4.3 Leak Detection and Monitoring Plan: Movement of the CO₂ Outside of the Storage Reservoir

The storage operator is required to put in place a leak detection and monitoring plan that will be capable of verifying that the geologic storage project is operating as permitted; i.e., it is not endangering USDWs or resulting in the movement of CO₂ outside of the defined storage reservoir. This plan is often referred to as the monitoring, verification, and accounting (MVA) program. Similar to the leak detection and monitoring plan for the wells and surface facilities, this plan is also required to 1) identify the potential for the release of CO₂ to the atmosphere and 2) identify potential for the migration of CO₂ into any mineral zone within the facility area. See NDAC 43-05-01-05 §1h.

This plan typically includes the collection and characterization of samples taken from the surface, near surface, and subsurface environments of the storage reservoir. These samples should be collected during the preinjection, operational, and postinjection/closure phases of the storage project. Emphasis should be on the collection of data within the facility area, the CO₂ storage reservoir, and within 1 mile (1.61 kilometers) of the outside boundary of the facility area. All sampling analysis (e.g., groundwater well sample) filed with NDIC must be from a state-certified laboratory. See NDAC 43-05-01-11.4, NDAC 43-05-01-14.

3.4.4.3.1 Near-Surface Monitoring

Before injection begins, near-surface environmental monitoring establishes a baseline for naturally occurring levels of CO_2 in the surface and shallow subsurface environment. The purpose of this baseline is to provide a basis for comparing near-surface conditions before and after the injection of CO_2 is initiated. Following the collection of a baseline, continued monitoring during operational and postoperational phases should be continued, considering a reduced sampling frequency over time if the monitoring shows consistent levels of CO_2 when compared to the established baseline. All water sampling analyses (e.g., groundwater well sample) filed with NDIC must be from a state-certified laboratory. The state does not certify air gas samples. A qualified third-party laboratory should be used at the discretion of the operator. An example of how a near-surface environmental monitoring could be accomplished is discussed below:

- Soil gas monitoring can be deployed to assess the potential risks to USDW by determining the potential vertical movement of CO₂ from the storage reservoir through the soils within the AOR. Preinjection baseline data, if available, could be used to define the spatial distribution for the monitoring locations and set the frequency of the soil gas monitoring. The proposed monitoring program that is implemented will be project-specific and be focused on the identified risks to site-specific USDWs.
- A groundwater monitoring program can be designed to address potential risks of groundwater contamination by CO₂ or brine within the AOR. Baseline and periodic monitoring of groundwater quality and geochemical changes above the confining zone, or cap rock, are required as a means of assessing the movement of CO₂ through the confining zone in the subsurface. This monitoring will be accomplished by sampling fluids from freshwater wells or monitoring wells. The location and number of these wells

are based on project-specific USDW risk factors such as the CO₂ injection rate and volume, the geology, the presence of artificial penetrations such as abandoned oil and gas wells, and the baseline geochemical data. Any modeling that results in updates of the AOR evaluation would need to be addressed as part of the monitoring program design. These same factors will also dictate the frequency of monitoring that is required for the monitoring plan to be effective.

• Surface water monitoring within the AOR is not specifically required by the regulations. However, the storage operator could consider such monitoring to complement the nearsurface monitoring that is required by the regulations (see above) to provide another line of evidence for determining if the vertical migration of CO₂ and/or formation brines is occurring or has occurred. Surface water monitoring would require the acquisition of baseline samples from lakes, ponds, and various sites along perennial streams overlying the delineated subsurface CO₂ plume. This effort would establish a baseline for the presence of dissolved CO₂, methane, and other gases that may be present in surface waters. These same factors will inform the frequency of monitoring to provide an effective monitoring program throughout the duration of the storage operations.

The gathering and reporting of surface air quality monitoring data are required from sites designated during the operations phase (NDAC 43-05-01-11.4). The storage operator should also consider incorporating surface air quality monitoring into the PISC (postinjection site closure) plan. This may be best accomplished by sampling the ambient air at select soil gas monitoring station(s). This sampling and reporting effort would need to be coordinated with the capture plant air quality sampling program. It is important to note that the detection of CO₂ in the surface and near-surface environment alone is not sufficient to make the determination that CO₂ is escaping from the storage reservoir. Such a determination requires an established baseline with samples and data that account for normal seasonal fluctuations as well as in-depth quality assurance checks on sampling, handling, and analysis combined with retesting if anomalous or unexpected results are reported. For this reason, the gathering of baseline data in surface air and other environmental media before starting CO₂ injection is critical since it has been established at other sites that there may be natural, biological sources of CO₂ that are responsible for such observations. Ultimately, the goal of every sampling effort is to support a risk-based analysis that is focused on the protection of USDW.

3.4.4.3.2 Subsurface Monitoring (NDAC 43-05-01-05 §1h and §g2)

The goal of subsurface monitoring is to track the vertical and lateral movement of both the subsurface CO₂ plume and pressure front in the storage reservoir and AOR. A number of both direct methods and indirect methods can be deployed for this purpose as part of this testing and monitoring program as summarized in Table 3-7 and briefly discussed below:

• Injection zone testing. The storage operator is required to characterize in situ fluids (waters) within the facility area and within 1 mile (1.61 kilometers) of the outside boundary. See NDAC 43-05-01-05. Specific injection zone methods are typically detailed in the APD.

| Item | Description/Comments |
|---|--|
| Monitor injection pressure; the rate, volume or | Describe the proposed use of continuing recording |
| mass, and temperature of the injected CO ₂ ; and | devices for the monitoring of the required |
| the pressure of the annulus between the tubing | parameters. |
| and the long-string casing and the annulus fluid | |
| volume. | |
| Provide protections that are designed to alert the | • Define acceptable ranges for key operating |
| operator, and shut in the well when operating | parameters. |
| parameters diverge beyond permitted ranges or | • Provide alarms and automatic surface shutoff |
| gradients which should be specified in the permit. | systems or, at the discretion of NDIC, |
| | downhole shutoff systems or other mechanical |
| | devices that provide the required protections |
| | should operating parameters exceed acceptable |
| | ranges. |
| All Direct and Indirect, Surface and Sub | surface Monitoring Methods |
| 4. List of each method and purpose/explanation | • The monitoring methods that are proposed for |
| 5. Location/placement | monitoring the CO ₂ plume should be described |
| 6. Frequency of measurement | in detail, including both direct and indirect, |
| 7. Calibration of instrument(s) | surface and subsurface monitoring methods. |
| 8. Maintenance/testing/repair/replacement | • A schedule for the reporting of the monitoring |
| 9. Data reporting schedule | data should also be provided. |

Table 3-7. Permit Information Requirements: Plume Monitoring

- Indirect methods of testing geophysical. The storage operator is required to track the extent of the CO₂ plume using a combination of geophysical techniques, such as seismic, electrical, gravity, interferometric synthetic aperture radar (InSAR) or electromagnetic surveys, and downhole carbon dioxide detection tools. See NDAC 43-05-01-11.4.
- Indirect methods of testing downhole monitoring of injection and/or monitoring wells. The storage operator may track the extent of the CO₂ plume using several monitoring techniques such as wireline logging downhole formation attributes, CBLs, downhole temperature and pressure gauges, and fiber optic distributed temperature systems. In addition, process monitoring data that are collected at an injection well including injection rates and volume, surface injection pressures and temperature, and tubing-casing annulus pressure can provide valuable information regarding the potential movement of CO₂. See NDAC 43-05-01-05. The APD provides details on these indirect methods.

3.4.4.4 Injection Well Mechanical Integrity Demonstration – Testing and Monitoring Plan (NDAC 43-05-01-11.1, 43-05-01-11.2, 43-05-01-11.3, and 43-05-01-11.4)

The storage operator is required to demonstrate internal and external mechanical integrity of the injection well prior to injection and during operations until the well is plugged. The testing and monitoring plan should include an initial mechanical integrity test (MIT) demonstration prior to injection, both internally and externally, and include a schedule for periodic integrity tests during the operational and postoperational phases of the project. In addition, the testing and monitoring plan should address continuous monitoring requirements to demonstrate well integrity during injection operations (e.g., tubing-casing annulus pressure gauge). More details regarding each of these demonstrations are provided below:

- The internal MIT is considered common practice in the UIC program. This integrity demonstration typically consists of a 15-minute pressure test at approximately 1000 psi. NDIC requires notification and a representative of the Commission to be on-site to witness and approve the MIT. The MIT demonstration is required prior to injection and at least every 5 years, unless otherwise prescribed by the NDIC, once operations begin and until the well is plugged.
- The external mechanical integrity demonstration requirement poses additional challenges such as the cost of logging and wellbore configuration (i.e., permanent packer versus retrievable packer). The external mechanical integrity demonstration is required prior to injection and annually thereafter once operations begin and until the well is plugged. The regulations, which originate from the federal Class VI rule and have been adopted by North Dakota as part of Class VI primacy, the methods for external mechanical integrity demonstration log, 2) a temperature log, or 3) a noise log.

External Mechanical Integrity Demonstration: It is recommended that the storage operator, in collaboration with NDIC, develop a cost-effective approach to perform external mechanical integrity. The method of the test will be determined by the well configuration. An ideal test method would allow for the log to be run through the tubing to reduce the interruption in injection operations. Alternatively, it may be both costly and operationally challenging to pull the tubing and retrieve the packer every year to conduct the external MIT. Other technologies may offer a more cost-effective solution to the annual external integrity demonstration (e.g., external fiber optic cable). The ultrasonic CBL is the NDIC-preferred method for the initial external mechanical integrity demonstration, while also demonstrating compliance with well casing and cementing requirements. The temperature log can be run through tubing and would be an acceptable method of external mechanical integrity demonstration during the operational phase of a CO₂ storage project.

3.4.4.5 Documentation of Testing and Monitoring Data/Information (NDAC 43-05-01-18)

It is important to be aware of the reporting requirements when performing testing and sampling for the SFP application. The storage operator is required to document the testing and monitoring results by preparing records that include the following:

- The date, exact place, and time of sampling or measurements
- The individual who performed the sampling or measurements
- The date analyses were performed
- The individual who performed the analyses
- The analytical techniques or methods used
- The results of such analyses

3.4.5 Plugging Plan (NDAC 43-05-01-11.5)

The storage operator is required to prepare, maintain, and comply with an injection well plugging plan that is acceptable to the Commission (see NDAC 43-05-01-11.5 for the specific requirements).

Figure 3-1 presents a generic wellbore schematic for an injection well (i.e., the wellbore configuration prior to plugging and abandonment), and Figure 3-2 presents an example of a plugged injection wellbore (i.e., the proposed configuration of the well following the plugging and abandonment procedure), which depicts the wellbore in Figure 3-1 following completion of the plugging process. Figure 3-2 provides information regarding the depth of cement plugs that will be placed in the well as part of the plugging process as well as the location of the cement retainer, the squeezed cement at the perforation intervals, and the cement placed at the bottom of the well. As was the case in Figure 3-1, the types of cement that are proposed for use are identified in Figure 3-2.

Figures of this type, accompanied by a detailed, step-by-step, plugging and abandonment procedure that will yield the plugged well shown in Figure 3-2, provide the necessary information in the permit application to meet the requirements (see NDAC 43-05-01-11.5 for the detailed plugging and abandonment requirements).

3.4.6 PostInjection Site and Facility Closure Plan (NDAC 43-05-01-19)

This PISC and facility closure plan describes the activities the storage operator will perform to meet the requirements of NDAC 43-05-01-19. During the postinjection phase, the storage operator is required to monitor groundwater quality, surface air quality, and track the position of the carbon dioxide plume and pressure front for a minimum of 10 years' postinjection. Prior to receiving certification for project completion (i.e., transfer of title) issued by NDIC, the storage operator will plug all wells not specifically transferred to the state as per NDAC 43-05-01-11.5, reclaim the site to its original condition, and submit a final assessment report and any other associated documentation to demonstrate that the CO₂ is contained within the storage facility (see NDAC 43-05-01-19 §9).

3.5 Injection Well and Storage Operations (NDAC 43-05-01-05 [SFP] and NDAC 43-05-01-11.3 [Injection Well Operating Requirements])

The injection well and storage operations' section of the SFP addresses the engineering criteria for operating the injection well in a manner that protects USDWs. The information that is required to comply with the permit requirements for injection well and storage operations is presented in Table 3-8.



Figure 3-1.Example of injection wellbore schematic.



Figure 3-2. Example of plugged injection wellbore.

| Item | Description/Comments |
|--|---|
| Injected | Volume |
| Total Injected Volume | The proposed total volume of injected CO_2 that was used in the modeling and dynamic simulations of the CO_2 injection should be provided. |
| Injectio | on Rates |
| Injection Well Name and Location Proposed Average Injection Rate Proposed Maximum Daily Injection Rate | The name and location of each injection well should be provided along with the proposed average and maximum daily injection rates that are part of the design basis for the project and that were used during modeling and simulation studies. |
| Pres | sures |
| Formation Fracture Pressure | The predicted formation fracture pressure that is calculated from the modeling and simulation studies should be provided. |
| Surface Injection Pressure | The proposed maximum allowable surface injection pressure should be provided based on the modeling and simulation studies. Except during stimulation, the storage facility operator shall ensure that the surface injection pressure does not exceed 90% of the fracture pressure of the injection zone to avoid the initiation of new fractures or propagation of existing fractures in the injection zone. The injection pressure must not initiate fractures in the confining zone or cause the movement of injection or formation fluids that endanger USDW. |
| Annulus Pressure | The proposed annulus pressure should be provided based on the modeling and simulation studies. The annulus between the tubing and the long string shall be filled and sealed with a noncorrosive fluid, approved by NDIC, with a pressure maintained that exceeds the operating injection pressure. |
| Bottomhole Pressure | The proposed average and maximum bottomhole pressures based on the modeling and simulation studies should be provided. |

Table 3-8. Permit Information Requirements: Storage Operations (preoperational characterization of the injection and confining zones)

4.0 INJECTION WELL PERMIT (43-05-01-09 WELL PERMIT APPLICATION REQUIREMENTS)

The final regulatory approval necessary prior to beginning injection operations at a storage facility is the Application for Carbon Dioxide Storage (ACDS). This application is a request for approval to convert and operate the TAO well that was originally permitted as a stratigraphic test well and constructed to Class VI well construction requirements (see Section 2.0 Well Drilling Permit) as a CO_2 injection well. The well conversion application can be filed concurrently with the SFP application. While the SFP application needs to be approved prior to receiving approval of the well conversion, the filing of these applications together will ensure the most efficient regulatory review and approval process.

The well-specific data and information that are required in an application to convert the TAO well to a Class VI CO₂ storage injection well are presented in NDAC 43-05-01-09 (Well Permit Application Requirements). In this instance, the application is focused on obtaining a permit to convert and operate a previously drilled and constructed stratigraphic test well for the purpose of geologic CO₂ storage.

4.1 General Information

The request for approval to convert the stratigraphic well will be made using the ACDS, which will be provided by the NDIC. The general information required to complete the form consists of the name of storage facility, the operator name, address, and phone number. The storage operator is required to provide specific information on the injection well, such as well location, injection zone and confining zone formation tops and thicknesses, bottom hole fracture pressure, fracture gradient, maximum injection pressure and rate. The form also requires specific information on the well construction and final well configuration of the tubing and packer.

4.2 Required Attachments

The storage operator is required to provide application attachments as listed in NDAC 43-05-01-09 §2 and §3. The permit application attachments are an update of the data and information provided in the stratigraphic test well APD. For instance, the proposed plats and pad layout cut and fill diagram (Appendix A) are required to be updated to the as-built well location plat and the well site facility layout diagram, including the surface injection system and its appurtenances. A wellbore schematic is required to be filed with updated as-built well construction information and the proposed injection well configuration showing the location of the perforations, tubing and packer specifications, and tubing depth and packer setting depth (example provided in Figure 4-1). The geophysical logs and ultrasonic CBL from the drilling and logging of the well will be considered as part of the regulatory review of this application. A conversion procedure describing the steps necessary to complete the well as a CO₂ storage injection well is required, a simplified example of the procedure is provided in this section. Data and information on the CO₂ stream are required to be filed by the applicant as part of a signed affidavit specifying the chemical constituents, their relative proportions, physical properties, and the source of the carbon dioxide stream. In addition, the application includes information on the compatibility of the carbon dioxide stream with fluids in the injection zone and minerals in both the injection and the confining zone,

based on the results of formation testing. Information on the compatibility of the CO₂ stream with the materials used to construct the well is required as part of the application to operate. It is recommended to review NDAC 43-05-01-09 §2 and §3 for a complete and detailed list of the required permit attachment items that are required to accompany the ACDS. A simplified example of a proposed conversion procedure and the injection well schematic (Figure 4-1) showing the proposed final well configuration are provided below:

- 1. Move-in and rig up (MIRU) workover rig.
- 2. Install blowout preventer (BOP).
- 3. Circulate to clean the wellbore.
- 4. MIRU wireline services.
- 5. Makeup and run in hole (RIH) perforation guns to perforate the injection zone. The perforation intervals are provided in this procedure.
- 6. RIH with retrievable packer and treating string.
- 7. Perform injectivity test.
- 8. Perform stimulation, if necessary. Stimulation program needs to be designed according to the injectivity test and formation solubility results. NDIC approval is required prior to performing well stimulation on the injection well (NDAC 43-05-01-11.3).
- 9. POOH retrievable packer and treating string.
- 10. RIH with CO2 resistant packer (provide packer setting depth) and CO₂ resistant injection tubing (provide tubing depth).
- 11. MIT pressure test packer and tubing-casing annulus. Contact NDIC to witness MIT 24 hours prior to MIT test. MIT well to 1,000 psi for 15 minutes or as directed by NDIC, charting pressure test. NDIC must witness MIT in accordance with state regulations. Well is ready for injection upon MIT approval from NDIC.
- 12. Nipple down BOP and nipple up wellhead.
- 13. Pressure test wellhead.
- 14. Rig down and move out workover rig.
- 15. The well is ready for installation of surface equipment to begin injection operations.



Figure 4-1. Example of final injection well configuration schematic.

As the applicant prepares the permit materials for submission, it is recommended to communicate with the NDIC regarding the commission's preferred method of receiving each application package (i.e., the SFP application and the ACDS). Approval of these applications complete the regulatory permitting process necessary to begin storage operations of the geologic CO₂ storage facility.



APPENDIX A

PLAT PACKAGE EXAMPLES



WELL LOCATION PLAT

[Company Name] [Company Address]

[Well Name]

[distance] feet from the [N/S/E/W] line and [distance] feet from the [N/S/E/W] line (surface location) Section [section], T. [township], R. [range] [county] County, North Dakota Surface owner @ Wellsite –[surface owner] Latitude [latitude], Longitude [longitude] (surface location)



Registered Land Surveyor in North Dakota stamp required

HORIZONTAL SECTION PLAT

[Company Name]

[Company Address]

[Well Name]

[distance] feet from the [N/S/E/W] line and [distance] feet from the [N/S/E/W] line (surface location)

Section [section], T. [township], R. [range]

[county] County, North Dakota

Surface owner @ Wellsite – [surface owner]

Latitude [latitude], Longitude [longitude] (surface location)



[Company Name] [Well Name] Section [section], T. [township], R. [range]

| Wellsite Elevation | [elevation] | MSL |
|--------------------|-------------|-----|
| Well Pad Elevation | [elevation] | MSL |

Excavation

[value] C.Y.

| Embankment | [value] C.Y. |
|-----------------------|--------------|
| Plus Shrinkage (+30%) | [value] C.Y. |
| | [value] C.Y. |

| Stockpile Topsoil (6") | [value] C.Y. |
|---|---------------|
| Road Embankment & Stockpile from Pad | [value] C.Y. |
| Disturbed Area From Pad | [value] Acres |
| NOTE | |

NOTE:

All cut end slopes are designed at 1:1 slopes & All fill end slopes are designed at 1 1/2:1 slopes

> Wellsite Location [distance] FSL [distance] FEL

| Composed By: | Surveyed By: | Approved By: | Date: | Project Number: |
|--------------|--------------|--------------|--------|------------------|
| [name] | [name] | [name] | [date] | [project number] |

[Well Name] Pad Layout



| N | Well Name | Elevation | Cut/Fill |
|----|------------|-------------|------------|
| [] | Well Name] | [elevation] | [cut/fill] |

| Composed By: | Surveyed By: | Approved By: | Date: | Project Number: |
|--------------|--------------|--------------|--------|------------------|
| [name] | [name] | [name] | [date] | [project number] |

EERC KL57905.AI

DocuSign Envelope ID: 1C9E7066-3BB1-4F14-85AA-56F4FAB4F35B

[Well Name] Roadway Typical Sections



DocuSign Envelope ID: 1C9E7066-3BB1-4F14-85AA-56F4FAB4F35B

[Operator Name] [Well Name] [distance] FSL & [distance] FEL [location] 1/4 [location] 1/4, Section [section] T. [township], R. [range] [county] County, North Dakota



| Map "[A,B,C] " | Legend |
|---------------------|----------------------------|
| County Access Route | Existing Roads — — — — — — |

EERC KL57906.AI

(Well Location Map)

Requirements:

- ID proximity to company-owned/leased surface
- ID proximity of proposed CO₂ injection well pad
- ID proximity of dry hole and producing wells
- ID occupied building/water supply pipelines, city limits, BLM lands, etc.

(EERC will prepare this)

EERC KL57907.AI

(Facility Map)

Facility map must provide the facility area, proposed injection well, proposed access roads, proposed well pad, facility property line, and city/town limits, railroads, highways, on a satellite image, etc.

(EERC will prepare this)

EERC KL57908.AI



APPENDIX B

CROSSWALK OF TEMPLATE SECTIONS AND CITATIONS FROM NDCC AND NDAC ON CO₂ STORAGE



| Template Section | NDCC/NDAC Reference(s) | Requirement |
|---------------------|---|--|
| Template Section | NDCC 38-22-06 §3 and §4 NDAC 43-05-01-08 §1 and §2 | Requirement NDCC 38-22-06 3. Notice of the hearing must be given to each mineral lessee, mineral owner, and pore space owner within the storage reservoir and within one-half mile of the storage reservoir's boundaries. 4. Notice of the hearing must be given to each surface owner of land overlying the storage reservoir and within one-half mile of the reservoir's boundaries. NDAC 43-05-01-08 1. The commission shall hold a public hearing before issuing a storage facility permit. At least forty-five days prior to the hearing, the applicant shall give notice of the hearing to the following: a. Each operator of mineral extraction activities within the facility area and within one-half mile [.80 kilometer] of its outside boundary; b. Each mineral lessee of record within the facility area and one-half mile [.80 kilometer] of its outside boundary; c. Each owner of record of the surface within the facility area and one-half mile [.80 kilometer] of its outside boundary; d. Each owner of record of minerals within the facility area and within one-half mile [.80 kilometer] of its outside boundary; e. Each owner of record of minerals within the facility area and within one-half mile [.80 kilometer] of its outside boundary; e. Each owner of record of minerals within the facility area and within one-half mile [.80 kilometer] of its outside boundary; e. Each owner of record of minerals within the facility area and within one-half mile [.80 kilometer] of its outside boundary; e. Each owner of record of minerals within the facility |
| | | outside boundary; e. Each owner and each lessee of record of the pore space within the storage reservoir and within one-half mile [.80 kilometer] of the reservoir's boundary; and |
| | | Any other persons as required by the commission. The notice given by the commission. |
| | | 2. The notice given by the applicant must contain: |
| | | a. A legal description of the land within the facility area. |
| | | b. The date, time, and place that the commission will hold a hearing on the permit application. |
| | | c. A statement that a copy of the permit application and draft permit may be obtained from the commission. |

| Template Section | NDCC/NDAC Reference(s) | Requirement |
|----------------------|----------------------------|--|
| Geologic Exhibits | NDAC 43-05-01-05 §1b(1) | (1) The name, description, and average depth of the storage reservoirs. |
| | NDAC 43-05-01-05 §1b(2)(k) | (k) Data on the depth, areal extent, thickness, mineralogy, porosity, permeability, and capillary pressure of the injection and confining zone, including facies changes based on field data, which may include geologic cores, outcrop data, seismic surveys, well logs, and names and lithologic descriptions. |
| | NDAC 43-05-01-05 §1b(2) | (2) A geologic and hydrogeologic evaluation of the facility area, including an evaluation of all existing information on all geologic strata overlying the storage reservoir, including the immediate caprock containment characteristics and all subsurface zones to be used for monitoring. The evaluation must include any available geophysical data and assessments of any regional tectonic activity, local seismicity and regional or local fault zones, and a comprehensive description of local and regional structural or stratigraphic features. The evaluation must describe the storage reservoir's mechanisms of geologic confinement, including rock properties, regional pressure gradients, structural features, and adsorption characteristics with regard to the ability of that confinement to prevent migration of carbon dioxide beyond the proposed storage reservoir. The evaluation must also identify any productive existing or potential mineral zones occurring within the facility area and any underground sources of drinking water in the facility area and within one mile [1.61 kilometers] of its outside boundary. The evaluation must include exhibits and plan view maps showing the following: |
| | NDAC 43-05-01-05 §1b(2)(g) | (g) Identification of all structural spill points or stratigraphic discontinuities controlling the isolation of stored carbon dioxide and associated fluids within the storage reservoir. |
| | NDAC 43-05-01-05 §1b(2)c | (c) Any regional or local faulting. |
| | NDAC 43-05-01-05 §1b(2)(j) | (j) The location, orientation, and properties of known or suspected faults and fractures that may transect the confining zone in the area of review, and a determination that they would not interfere with containment. |

| Template Section | NDCC/NDAC Reference(s) | Requirement |
|-------------------------------|---|--|
| Geologic Exhibits | NDAC 43-05-01-05 §1b(2)(m) | (m) Information on the seismic history, including the presence and depth of seismic sources and a determination that the seismicity would not interfere with containment. |
| | NDAC 43-05-01-05 §1b(2)(n) | (n) Geologic and topographic maps and cross sections illustrating regional geology, hydrogeology, and the geologic structure of the facility area. |
| | NDAC 43-05-01-05 §1b(2)(d) | (d) An isopach map of the storage reservoirs. |
| | NDAC 43-05-01-05 §1b(2)(e) | (e) An isopach map of the primary and any secondary containment barrier for the storage reservoir. |
| | NDAC 43-05-01-05 §1b(2)(f) | (f) A structure map of the top and base of the storage reservoirs. |
| | NDAC 43-05-01-05 §1b(2)(i) | (i) Structural and stratigraphic cross sections that describe the geologic conditions at the storage reservoir. |
| | NDAC 43-05-01-05 §1b(2)(h) | (h) Evaluation of the pressure front and the potential impact on underground sources of drinking water, if any. |
| | NDAC 43-05-01-05 §1b(2)(l) | Geomechanical information on fractures, stress, ductility, rock strength, and in situ fluid pressures within the confining zone. The confining zone must be free of transmissive faults or fractures and of sufficient areal extent and integrity to contain the injected carbon dioxide stream. |
| | NDAC 43-05-01-05 §1b(2)(o) | (o) Identify and characterize additional strata overlying the storage reservoir that will prevent vertical fluid movement, are free of transmissive faults or fractures, allow for pressure dissipation, and provide additional opportunities for monitoring, mitigation, and remediation. |
| | NDAC 43-05-01-05 §1j | j. An area of review and corrective action plan that meets the requirements pursuant to section 43-05-01-05.1. |
| Area of Review Exhibits | NDAC 43-05-01-05 §1b(3) NDAC 43-05-01-05 §1a | NDAC 43-05-01-05 §1b(3) (3) A review of the data of public record, conducted by a geologist or engineer, for all wells within the facility area, which penetrate the storage reservoir or primary or secondary seals overlying the reservoir, and all wells within the facility area and within one mile [1.61 kilometers], or any other distance as deemed necessary by the commission, of the facility area boundary. The review must include the following: NDAC 43-05-01-05 §1a a. A site map showing the boundaries of the storage reservoir and the location of all proposed wells, proposed cathodic protection boreholes, and surface facilities within the carbon dioxide storage facility area. |
| | | |

| Template Section | NDCC/NDAC Reference(s) | Requirement |
|-------------------------------|-----------------------------|--|
| Area of Review Exhibits | NDAC 43-05-01-05 §1b(2)(a) | (a) All wells, including water, oil, and natural gas exploration and development wells, and other manmade subsurface structures and activities, including coal mines, within the facility area and within one mile [1.61 kilometers] of its outside boundary. |
| | NDAC 43-05-01-05 §1c | NDAC 43-05-01-05 §1c c. The extent of the pore space that will be occupied by carbon dioxide as determined by utilizing all appropriate geologic and reservoir engineering information and reservoir analysis, which must include various computational |
| | NDAC 43-05-01-05.1 §1a | NDAC 43-05-01-05.1 §1a a. The method for delineating the area of review, including the model to be used, assumptions that will be made, and the site characterization data on which the model will be based; |
| | NDAC 43-05-01-05.1 §1b(1-4) | b. A description of: The reevaluation date, not to exceed five years, at which time the storage operator shall reevaluate the area of review; The monitoring and operational conditions that would warrant a reevaluation of the area of review prior to the next scheduled reevaluation date; How monitoring and operational data (e.g., injection rate and pressure) will be used to inform an area of review reevaluation; and How corrective action will be conducted to meet the requirements of this section, including what corrective action will be performed prior to injection and what, if any, portions of the area of review will have corrective action addressed on a phased basis and how the phasing will be determined; how corrective action will be adjusted if there are changes in the area of review; and how site access will be guaranteed for future corrective action. |
| | NDAC 43-05-01-05 §1b(2)(b) | (b) All manmade surface structures that are intended for temporary or permanent human occupancy within the facility area and within one mile [1.61 kilometers] of its outside boundary; |

| Template Section | NDCC/NDAC Reference(s) | Requirement |
|-------------------------------|---|---|
| Section | NDAC 43-05-01-05 §1b(2) | (2) A geologic and hydrogeologic evaluation of the facility area, including an evaluation of all existing information on all geologic strata overlying the storage reservoir, including the immediate caprock containment characteristics and all subsurface zones to be used for monitoring. The evaluation must include any available geophysical data and assessments of any regional tectonic activity, local seismicity and regional or local fault zones, and a comprehensive description of local and regional structural or stratigraphic features. The evaluation must describe the storage reservoir's mechanisms of geologic confinement, including rock properties, regional pressure gradients, structural features, and adsorption characteristics with regard to the ability of that confinement to prevent migration of carbon dioxide beyond the proposed storage reservoir. The evaluation must also identify any productive existing or potential mineral zones occurring within the facility area and any underground sources of drinking water in the facility area and within one mile [1.61 kilometers] of its outside boundary. The evaluation must include exhibits and plan view maps showing the following: |
| Area of Review Exhibits | NDAC 43-05-01-05 §1b(3) NDAC 43-05-01-05.1 §2b | NDAC 43-05-01-05 §1b(3) (3) A review of the data of public record, conducted by a geologist or engineer, for all wells within the facility area, which penetrate the storage reservoir or primary or secondary seals overlying the reservoir, and all wells within the facility area and within one mile [1.61 kilometers], or any other distance as deemed necessary by the commission, of the facility area boundary. The review must include the following: NDAC 43-05-01-05.1 §2b b. Using methods approved by the commission, identify all penetrations, including active and abandoned wells and underground mines, in the area of review that may penetrate the confining zone. Provide a description of each well's type, construction, date drilled, location, depth, record of plugging and completion, and any additional information the commission may require. |
| | NDAC 43-05-01-05 §1b(3)(a-f) | (a) A determination that all abandoned wells have been plugged and all operating wells have been constructed in a manner that prevents the carbon dioxide or associated fluids from escaping from the storage reservoir. (b) A description of each well's type, construction, date drilled, location, depth, record of plugging, and completion. (c) Maps and stratigraphic cross sections indicating the general vertical and lateral limits of all underground sources of drinking water, water wells, and springs within the area of review; their positions relative to the injection zone; and the direction of water movement, where known. (d) Maps and cross sections of the area of review. (e) A map of the area of review showing the number or name and location of all injection wells, producing wells, abandoned wells, plugged wells or dry holes, deep stratigraphic boreholes, state-approved or United States environmental protection agency-approved subsurface cleanup sites, surface bodies of water, springs, mines (surface and subsurface), quarries, water wells, other pertinent surface features, including structures intended for human occupancy, state, county, or Indian country boundary lines, and roads. (f) A list of contacts, submitted to the commission, when the area of review extends across state jurisdiction boundary lines. |

| Template Section | NDCC/NDAC Reference(s) | Requirement |
|--------------------------|------------------------|--|
| Required Plans | NDAC 43-05-01-05 §1k | k. The storage operator shall comply with the financial responsibility requirements pursuant to section 43-05-01-9.1. |
| | NDAC 43-05-01-05 §1d | d. An emergency and remedial response plan pursuant to section 43-05-01-13. |
| | NDAC 43-05-01-05 §1e | e. A detailed worker safety plan that addresses carbon dioxide safety training and safe working procedures at the storage facility pursuant to section 43-05-01-13. |
| | NDAC 43-05-01-05 §1f | f. A corrosion monitoring and prevention plan for all wells and surface facilities pursuant to section 43-05-01- 15. |
| | NDAC 43-05-01-05 §1g | g. A leak detection and monitoring plan for all wells and surface facilities pursuant to section 43-05-01-14. The plan must: |
| | | (1) Identify the potential for release to the atmosphere. (2) Identify potential degradation of ground water resources with particular emphasis on underground sources of drinking water. (3) Identify potential migration of carbon dioxide into any mineral zone in the facility area. |
| | NDAC 43-05-01-05 §1h | h. A leak detection and monitoring plan to monitor any movement of the carbon dioxide outside of the storage reservoir. This may include the collection of baseline information of carbon dioxide background concentrations in ground water, surface soils, and chemical composition of in situ waters within the facility area and the storage reservoir and within one mile [1.61 kilometers] of the facility area's outside boundary. Provisions in the plan will be dictated by the site characteristics as documented by materials submitted in support of the permit application but must: (1) Identify the potential for release to the atmosphere. (2) Identify potential degradation of ground water resources with particular emphasis on underground sources of drinking water. (3) Identify potential migration of carbon dioxide into any mineral zone in the facility area. |
| | NDAC 43-05-01-05 §1i | i. The proposed well casing and cementing program detailing compliance with section 43-05-01-09. |
| | NDAC 43-05-01-05 §11 | 1. A testing and monitoring plan pursuant to section 43-05-01-11.4. |
| | NDAC 43-05-01-05 §1m | m. A plugging plan that meets requirements pursuant to section 43-05-01-11.5. |
| | NDAC 43-05-01-05 §1n | n. A postinjection site care and facility closure plan pursuant to section 43-05-01-19. |
Appendix B. Crosswalk of Template Sections and Citations from North Dakota Century Code (NDCC) Chapter 38-22 Carbon Dioxide Underground Storage and North Dakota Administrative Code (NDAC) Chapter 43-05-01 Geologic Storage of Carbon Dioxide

| Template Section | NDCC/NDAC Reference(s) | Requirement |
|--|-------------------------|---|
| Injection Well and Storage Facility Operations | NDAC 43-05-01-05 §1b(4) | (4) The proposed calculated average and maximum daily injection rates, daily volume, and the total anticipated volume of the carbon dioxide stream using a method acceptable to and filed with the commission. |
| | NDAC 43-05-01-05 §1b(5) | (5) The proposed average and maximum bottom hole injection pressure to be utilized at the reservoir. The maximum allowed injection pressure, measured in pounds per square inch gauge, shall be approved by the commission and specified in the permit. In approving a maximum injection pressure limit, the commission shall consider the results of well tests and other studies that assess the risks of tensile failure and shear failure. The commission shall approve limits that, with a reasonable degree of certainty, will avoid initiating a new fracture or propagating an existing fracture in the confining zone or cause the movement of injection or formation fluids into an underground source of drinking water. |
| | NDAC 43-05-01-05 §1b(6) | (6) The proposed preoperational formation testing program to obtain an analysis of the chemical and physical characteristics of the injection zone and confining zone pursuant to section 43-05-01-11.2. |
| | NDAC 43-05-01-05 §1b(7) | (7) The proposed stimulation program, a description of stimulation fluids to be used, and a determination that stimulation will not interfere with containment. |
| | NDAC 43-05-01-05 §1b(8) | (8) The proposed procedure to outline steps necessary to conduct injection operations. |