Class VI Injection Well Application

Attachment 07: Testing and Monitoring Plan
40 CFR 146.90

Compass Project

Carle Springs, DeWitt County, Illinois

17 May 2023

Navigator CO₂

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Project Information

Project Name: Compass

Project Operator: Heartland Greenway Carbon Storage, LLC

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Project Location: Carle Springs, DeWitt County, IL

CO_2 Injection Well #1 (NC_INJ1) Location
Latitude: 40.281983°
Longitude: -89.005617°

CO_2 Injection Well #2 (NC_INJ2) Location
Latitude: 40.281981°
Longitude: -88.991517°

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List of Acronyms

3D	three-dimensional
ACZ	above confining zone
AoR	Area of Review
APT	annulus pressure test
ASTM	American Society of Testing and Materials
BGS	below ground surface
BHFP	bottomhole flowing pressure
CCS	carbon capture and sequestration
CO_2	carbon dioxide
CCL	casing collar locator
CFR	Code of Federal Regulations
DIC	dissolved inorganic carbon
DTS	distributed temperature sensor
EPA	Environmental Protection Agency
EPSG	European Petroleum Survey Group
ERRP	Emergency and Remedial Response Plan
fbgl	feet below ground level
FOT	fall-off test
GR	gamma ray
HGCS	Heartland Greenway Carbon Storage, LLC
IBDP	Illinois Basin–Decatur Project
IL-ICCS	Illinois Industrial Carbon Capture and Storage Project
IRIS	Incorporated Research Institutions for Seismology
KH	flow capacity
MAIP	maximum allowable injection pressure
Mc	magnitude of completeness
MIT	mechanical integrity test
MS	mass spectrometry
NC_ACZ1	Compass Above Confining Zone Well #1
NC_ACZ2	Compass Above Confining Zone Well #2
NC_INJ1	Compass Injection Well #1
NC_INJ2	Compass Injection Well #2
NC_MA1	Mahomet Aquifer Monitoring Well #1
NC_MA2	Mahomet Aquifer Monitoring Well #2
NC_OBS1	Compass Deep Observation Well
PISC	Post Injection Site Care
PNL	Pulsed Neutron Logging
PSI	pounds per square inch
PTA	pressure transient analysis
QA	Quality Assurance
QASP	Quality Assurance and Surveillance Plan
RAT	radioactive tracer
SCADA	Supervisory Control and Data Acquisition
SM	standard method
TBD	to be determined

TD	total depth
TDS	total dissolved solids
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water

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1. Overall Strategy and Approach for Testing and Monitoring

The Testing and Monitoring Plan presented in this document provides details on how the Compass Project will monitor the site pursuant to 40 CFR 146.90.

1.1 Testing and Monitoring Plan Strategy

The Compass Project has developed a risk-based Testing and Monitoring Program that includes operational, verification, and environmental assurance components that meet or exceed the regulatory requirements of 40 CFR 146.90 (Attachment 01: Narrative, 2023). The Compass Project Testing and Monitoring Program is based on experience gained from other carbon capture and sequestration (CCS) projects and Class VI permit development, as well as extensive geologic evaluation and computational modeling.

Goals of the monitoring strategy include, but are not limited to:

- Fulfillment of the regulatory requirements of 40 CFR 146.90,
- Protection of underground sources of drinking water (USDW),
- Risk mitigation over the life of the project,
- Verification that NC_INJ1 and NC_INJ2 are operating as planned while maintaining mechanical integrity,
- Acquisition of data to validate and calibrate the models used to predict the distribution of CO_2 within the injection zone,
- Support Area of Review (AoR) re-evaluations over the course of the project.

The Testing and Monitoring Plan will be adaptive over time, and is subject to alteration should one of the following potential scenarios occur:

- Project risks evolve over the course of time outside of those envisioned at the beginning of the project,
- Significant differences between the monitoring data and predicted computational modeling results are identified,
- Key monitoring techniques indicate anomalous results related to well integrity or the loss of containment.

Monitoring activities can be separated into three categories based on various objectives: operational, verification, and assurance monitoring.

- *Operational monitoring* focuses on day-to-day injection operations such as system performance.

- *Verification monitoring* confirms that the CO_2 remains contained within the selected storage complex. The CO_2 plume and pressure front development are monitored over time to provide data for model calibration. Integration of verification monitoring data into project models allows the project to demonstrate conformance between the computational modeling and the testing and monitoring data collected during the operations and post injection phases of the project's lifecycle.
- *Assurance monitoring* is at surface and near-surface (i.e., soil, groundwater, USDWs, etc.) to monitor for any changes from baseline pre-injection sample data that might indicate CO_2 or injection zone fluid migration towards surface.

These three categories cover a range of monitoring objectives including:

- Well operations,
- Containment,
- Non-endangerment of USDWs,
- Capacity,
- Injectivity,
- Injection pressure, and
- Conformance.

Table 1 provides of summary of the general monitoring strategy with subcategories.

Table 1: Summary of general monitoring strategy for the Compass Project

Monitoring Action	Monitoring Objectives	Monitoring Technology
CO_2 stream analysis	Purity of the CO_2 stream	Lab analysis, chromatography
CO_2 plume monitoring	Verification/conformance, Containment, Non-endangerment of USDWs	Time-lapse seismic data, pulsed neutron logging (PNL), fluid sampling with aqueous geochemistry
Pressure front monitoring	Injection pressure, Injectivity, Verification/ conformance	Downhole pressure sensors in the injection and deep observation wells, seismic monitoring
ACZ Changes	Containment, Non-endangerment of USDWs	Downhole pressure sensors in ACZ monitor wells, fluid sampling with aqueous geochemistry, PNL
Project well integrity	Containment, Non-endangerment of USDWs	Temperature logging, PNL, annular pressure monitoring, mechanical integrity tests (MIT), pressure fall-off tests (FOTs), corrosion monitoring, testing of emergency shut-down systems
Reservoir performance	Injectivity	Wellhead and downhole pressure sensors, FOTs
Seismicity	Containment, Non-endangerment of USDWs, Induced seismicity	Surface-based or downhole passive seismic monitoring arrays

Monitoring Action	Monitoring Objectives	Monitoring Technology
Groundwater and deep fluid monitoring	Containment, Non-endangerment of USDWs, Assurance	Fluid sampling with aqueous geochemistry

1.2 Storage Complex

A site-specific stratigraphic chart of geologic formations present at the Compass Project site is shown in Figure 1. The specific intervals to be monitored are as follows:

- Mt. Simon Sandstone (injection zone),
- Ironton-Galesville Sandstone (ACZ),
- St Peter Sandstone (lowermost USDW, contingency only),
- Shallow groundwater including Mahomet Aquifer.

Based on work completed for the Illinois Basin–Decatur Project (IBDP) and Illinois Industrial Carbon Capture and Storage Project (IL-ICCS), which is located approximately 27 miles from the Compass Project Site, the St. Peter Sandstone is expected to be the lowermost USDW at the site (Gollakota and McDonald, 2014; Attachment 01: Narrative, 2023).

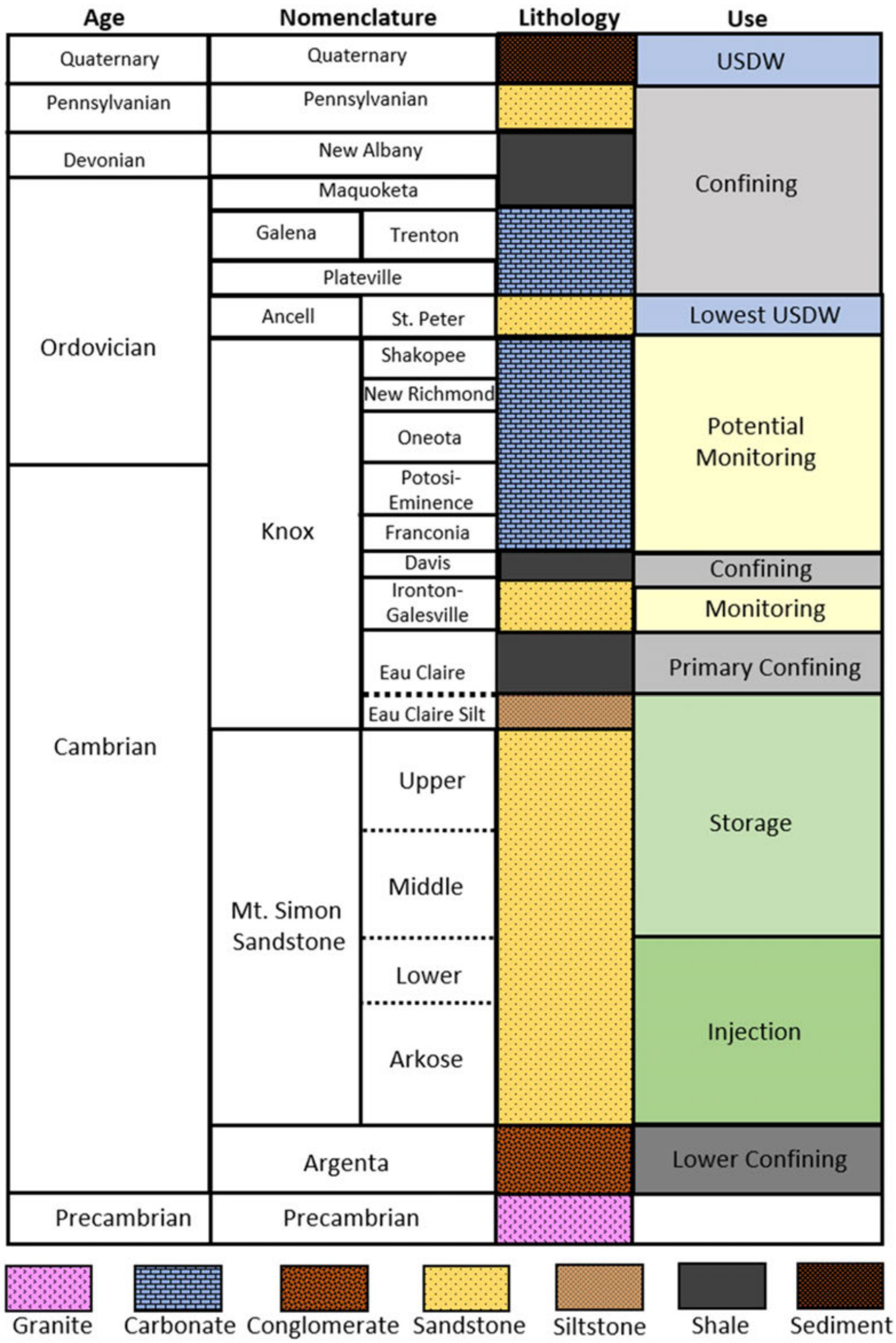

Figure 1: Site-specific Illinois Basin stratigraphic column with age, nomenclature, generalized lithology, and zone of use.

1.3 AoR and Project Wells

Figure 2 and Table 2 show the injection and deep observation wells for the project. Figure 2 shows the predicted extent of the CO_2 plume 50 years into the post injection period as well as the pressure based AoR. Figure 3 illustrates the predicted CO_2 plume development at different points out to 50 years in the post injection period. The current CO_2 plume and pressure front predictions have been used to inform the spatial extent of the Testing and Monitoring Plan. Figure 4 and Figure 5 show cross sections of the CO_2 plume 50 years into the PISC period through NC_INJ2 and NC_OBS1 and NC_INJ1 and NC_OBS1, respectively.

The AoR and Corrective Action Plan includes a discussion of the technical basis for the current AoR (Attachment 02: AoR and Corrective Action Plan, 2023). Once NC_INJ1 and NC_INJ2 have been drilled, the data gathered as part of the Pre-Operational Testing Program will be used to update the current static model and the computational modeling as well as how the monitoring data will be used to re-evaluate the AoR over the injection phase of the project (Attachment 02: AoR and Corrective Action Plan, 2023; Attachment 05: Pre-operational Formation Testing Program, 2023). The updated models will be used to verify or re-evaluate the current AoR, and associated Testing and Monitoring Plan should it be necessary (Attachment 02: AoR and Corrective Action Plan, 2023).

The NC_OBS1 well is located approximately 3,000 feet from both NC_INJ1 and NC_INJ2. It is estimated that the CO_2 will breakthrough at NC_OBS1 between three and five years after injection operations commence based on the computational modeling (Attachment 02: AoR and Corrective Action Plan, 2023). The primary objectives of the NC_OBS1 well are to monitor injection zone pressures at a distance from NC_INJ1 and NC_INJ2 and to obtain fluid samples from the well prior to CO_2 breakthrough. Fluid samples from the injection zone will allow the project to characterize the changes in aqueous geochemistry and the rock matrix in the early years of the project. Once the CO_2 breaks through at NC_OBS1, the project will utilize PNL tools to characterize the development of the vertical CO_2 plume over time at a distance from NC_INJ1 and NC_INJ2. The far field pressure measurements will be used to calibrate the computational modeling during the operations and post injection site care (PISC) phases of the project.

Table 2: Proposed Compass Well Locations (European Petroleum Survey Group (EPSG) 26916)

Well Long Name	Well Name	X, feet EPSG 26916	Y, feet EPSG 26916	Ground Level, (feet)	Measured Depth (feet)	Purpose
Injection Well 1	NC_INJ1	1081042	14635777	713	6817	CO_2 Injector
Injection Well 2	NC_INJ2	1084975	14635687	730	6824	CO_2 Injector
Deep Observation Well 1	NC_OBS1	1082998	14633481	729	6860	Injection Zone Observation Between the Injector Wells
Above Confining Zone Monitoring Well 1	NC_ACZ1	1081141	14635771	711	4486	Above Confining Zone Monitor Near NC_INJ1
Above Confining Zone Monitoring Well 2	NC_ACZ2	1085075	14635682	728	4509	Above Confining Zone Monitor Near NC_INJ2
Mahomet Aquifer Monitoring Well 1	NC_MA1	1080941	14635774	710	350	Mahomet Aquifer Monitor near NC_INJ1
Mahomet Aquifer Monitoring Well 2	NC_MA2	1084875	14635686	727	350	Mahomet Aquifer Monitor near NC_INJ2

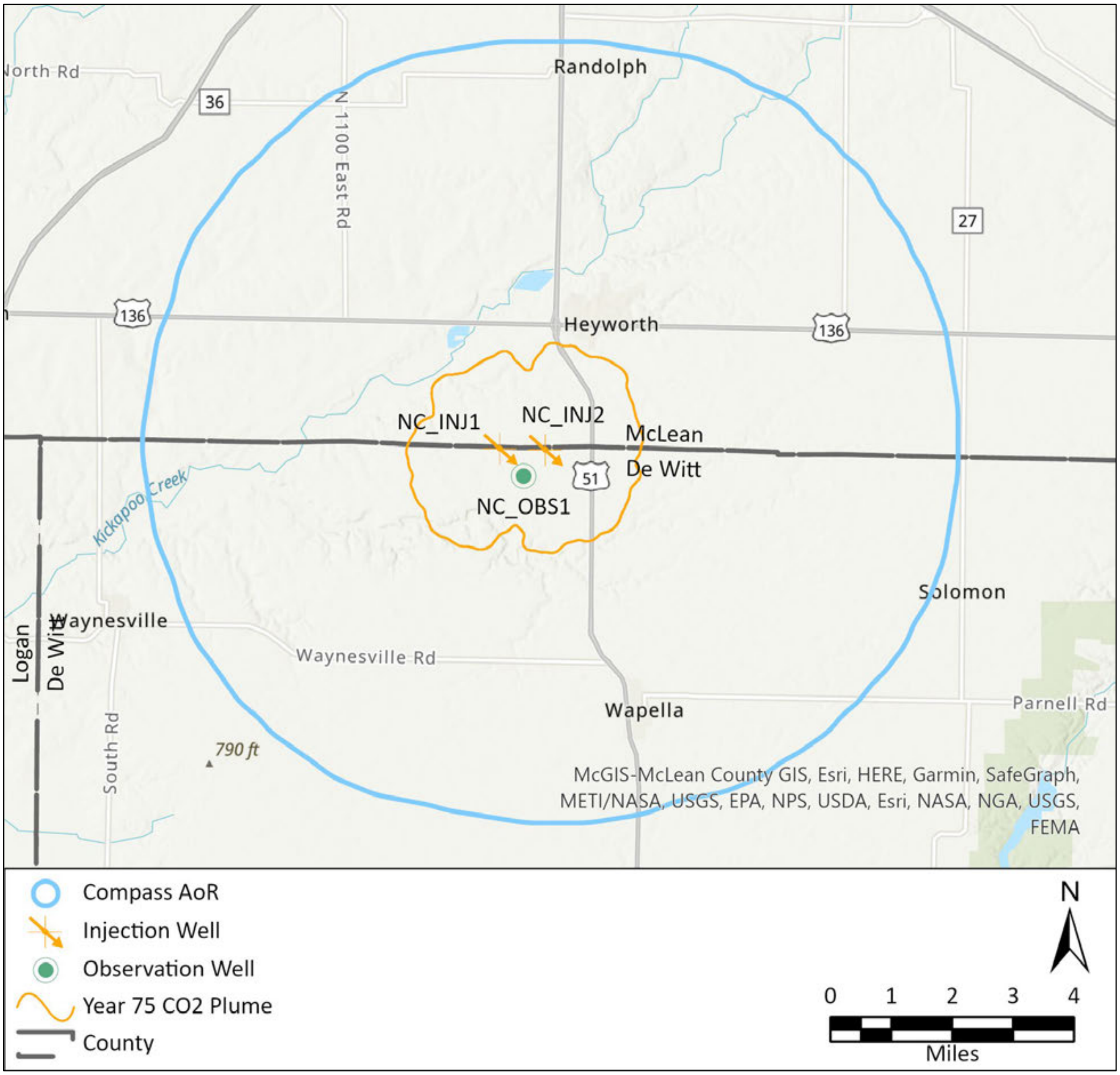

Figure 2: Map of Compass Project location, proposed location of the injection and deep observation wells, simulated extent of the CO_2 plume 50 years post injection, and AoR based on the delta pressure front after 25 years of injection.

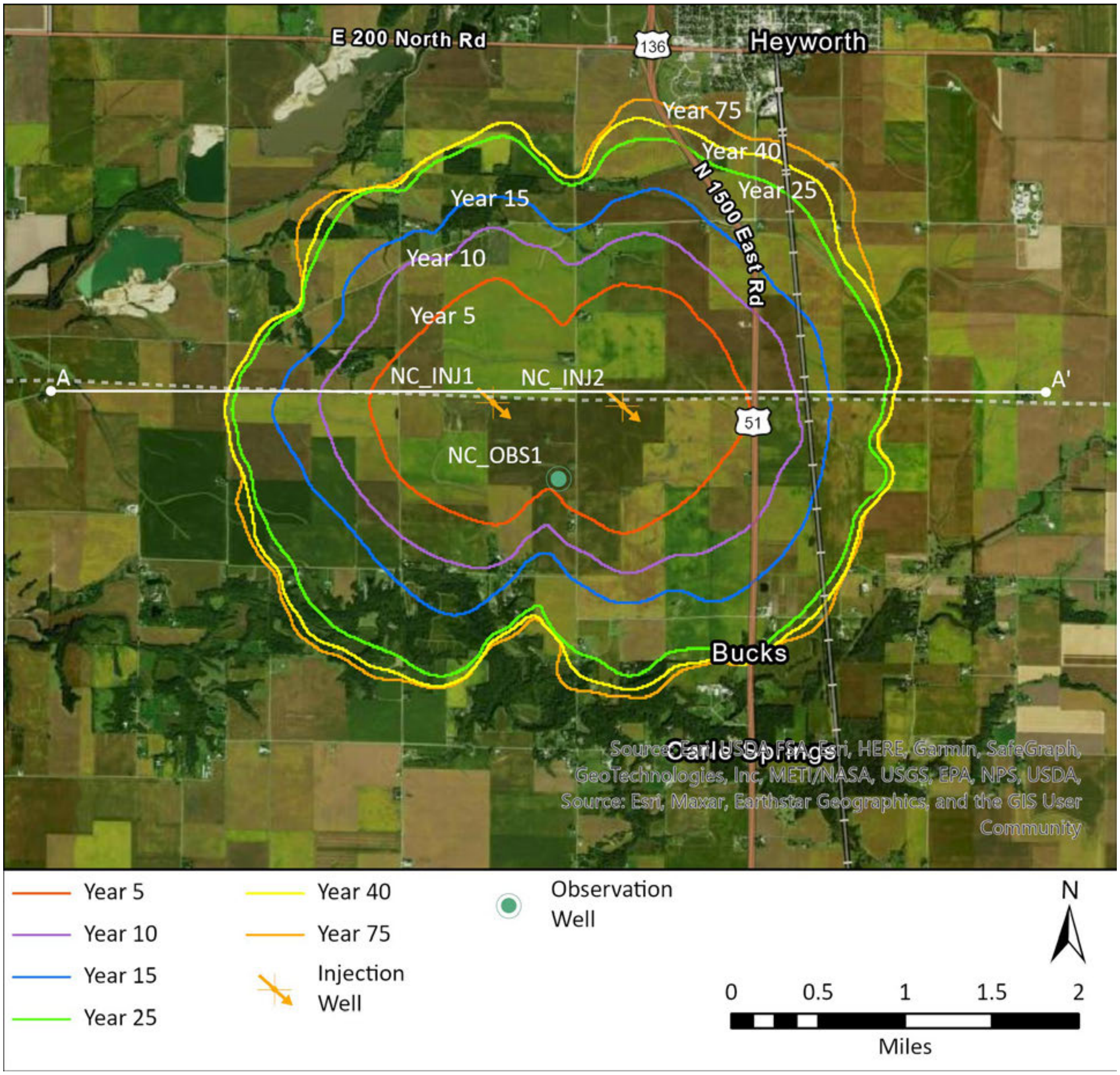

Figure 3: Time-lapse CO_2 plume development map over 5, 10, 15, 25 (injection end), 40 (15 years post injection) and 75 (50 years post injection). Note the relative stability of the CO_2 plume radius in the PISC phase of the project. Due to the proximity of the above confining zone (NC_ACZ1 and NC_ACZ2) and Mahomet Aquifer (NC_MA1 and NC_MA2) monitoring wells to the injection wells (NC_INJ1 and NC_INJ2), the ACZ and Mahomet Aquifer monitoring well symbols are not shown on this map. Cross section A-A' is shown in Figure 4.

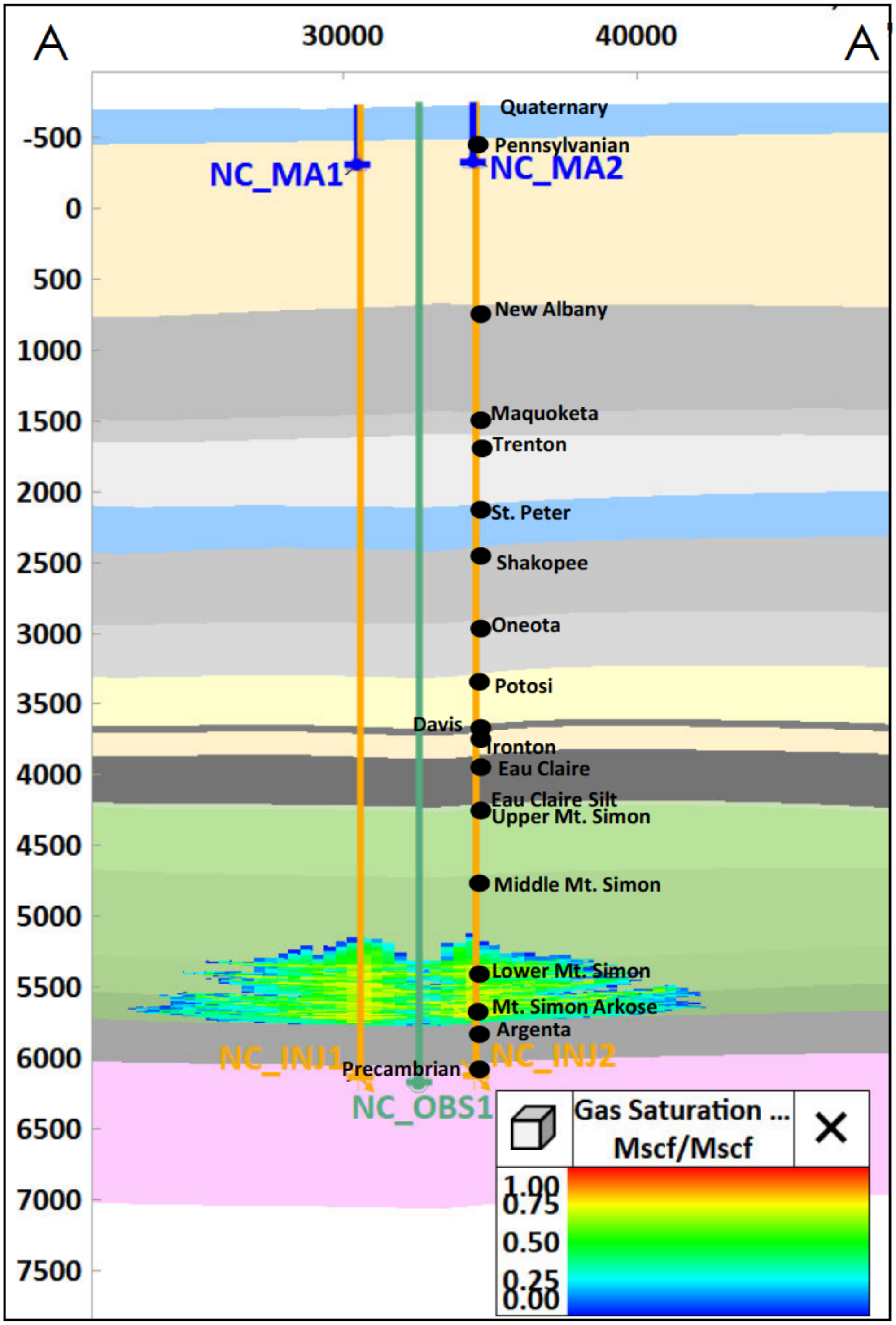

Figure 4: A-A' Cross-section of CO_2 plume year 75 (50 years post injection through NC_INJ1 and NC_INJ2. Note that NC_OBS1 has been projected onto the cross section. Vertical exaggeration=5x.

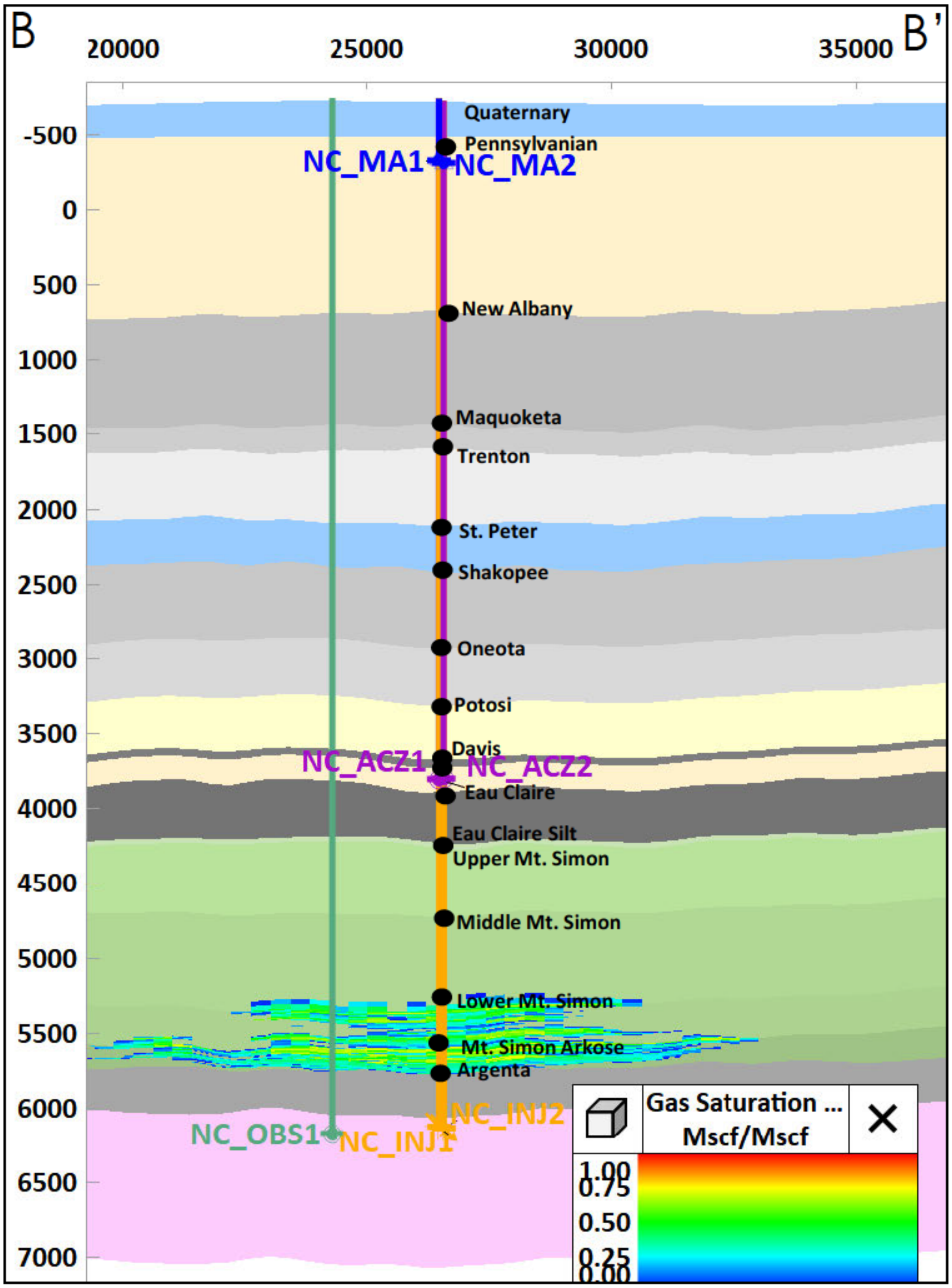

Figure 5: B-B' Cross-section of CO_2 plume year 75 (50 years post injection) along NC_INJ2 and NC_OBS1. Vertical exaggeration=5x.

1.4 Summary of Testing and Monitoring Plan Components

Operational monitoring serves to ensure all procedures and processes associated with the project are safe and well integrity is maintained. Continuously recorded data that will monitor the response of the injection zone includes:

- Injection rate and volume,
- Wellhead injection pressure,
- Injection well annulus pressure and fluid volume, and
- Lower Mt. Simon Sandstone / Arkose zone pressure and temperature.

The verification monitoring will provide data that will be used to evaluate the vertical and horizontal CO_2 plume development over time and identify any potential CO_2 migration beyond the confining zone. The primary components of the CO_2 plume monitoring consist of PNL in the project wells and time-lapse three-dimensional (3D) surface seismic monitoring. The pressure front development will be monitored with downhole pressure sensors in NC_INJ1, NC_INJ2, and NC_OBS1 as well as continuous passive seismic monitoring. In addition, the ACZ monitoring wells will provide further verification that the injection zone fluids are being contained below the confining layer through downhole pressure monitoring and fluid sampling in the Ironton-Galesville formations.

The assurance monitoring component of the program will monitor the shallow groundwater aquifers, including the Mahomet Aquifer, for any indications that injection zone fluids have migrated into the near surface. Fluid samples will be taken from shallow groundwater aquifers on a regular basis to analyze the aqueous geochemistry.

One of the primary goals of the testing and monitoring plan is to continue to demonstrate the activities of this project are safe for the health of the public and environment. To help facilitate this demonstration, the Quality Assurance and Surveillance Plan (QASP) has been developed to ensure the quality of the demonstration methods meet the requirements of the EPA Underground Injection Control (UIC) Program for Class VI wells (Attachment 11: QASP, 2023).

Table 3 shows a summary of the activities, monitoring points, and purpose of each activity in the Testing and Monitoring Plan. The activities are discussed on more detail in sections that follow in this document.

Table 3: Summary of Testing and Monitoring Activities

Activity	Location(s)	Purpose
CO_2 stream analysis		
CO_2 stream analysis - downstream	CO_2 Delivery Pipeline	Monitor injectate quality and composition
Continuous Recording		
Injection rate	NC_INJ1, NC_INJ2	Monitoring injection rate
Injection volume	NC_INJ1, NC_INJ2	Monitoring injection volume
Injection pressure	NC_INJ1, NC_INJ2 Wellhead	Monitoring injection pressure
Wellhead pressure	NC_ACZ1, NC_ACZ2 Wellhead	Monitoring above confining zone
Downhole pressure	NC_ACZ1, NC_ACZ2	
Annular pressure	NC_INJ1, NC_INJ2 Wellhead, NC_OBS1 Wellhead	Monitoring annulus pressure

Activity	Location(s)	Purpose
Annular fluid volume	NC_INJ1, NC_INJ2 Wellhead, NC_OBS1 Wellhead	Monitoring annulus fluid volume changes
Downhole pressure	NC_INJ1, NC_INJ2 Injection Interval, NC_OBS1 Injection Interval	Monitoring injection zone
Downhole temperature	NC_INJ1, NC_INJ2 Wellbore	Monitoring injection zone, wellbore integrity
Passive seismic monitoring	Various Monitoring Stations	Injection zone and confining zone integrity
Well Integrity		
Corrosion monitoring	CO_2 Pipeline at the project site	Monitoring injectate, wellbore integrity
Mechanical integrity (internal)	NC_INJ1, NC_INJ2 Wellhead, NC_OBS1 Wellhead	Wellbore integrity
Mechanical integrity (external)	NC_INJ1, NC_INJ2 Wellbore, NC_OBS1 Wellbore	Wellbore integrity
Cement Evaluation	NC_INJ1, NC_INJ2 Wellbore, NC_OBS1 Wellbore, NC_ACZ1, NC_ACZ2 Wellbore	Wellbore integrity
CO_2 Plume and Pressure Front Tracking		
Pulsed Neutron Log	NC_INJ1, NC_INJ2 Wellbore, NC_OBS1 Wellbore	CO_2 saturation, vertical plume development
Downhole pressure	NC_OBS1 Injection Zone, NC_INJ1, NC_INJ2 Injection Zone	Monitoring injection zone pressure, plume monitoring, confining zone integrity
Passive seismic Monitoring	Minimum of 5 stations TBD	Injection zone and confining zone integrity
Time-lapse 3D Seismic Data	Area sufficient to image modeled area of CO_2 plume	Indirect measurement of plume development and overburden
Fluid Sampling		
Shallow Ground Water Sampling (Glacial Deposits)	Shallow wells spatially distributed throughout the AoR, NC_MA1, NC_MA2	Detection of changes in aqueous geochemistry for the shallow USDWs.
Above Confining Zone Sampling (Ironton-Galesville)	NC_ACZ1, NC_ACZ2	Detection of changes in aqueous geochemistry above the confining zone.
Injection Zone Monitoring (Lower Mt. Simon Sandstone / Mt Simon Arkose)	NC_OBS1	Detection of changes in aqueous geochemistry, and CO_2 saturation in the injection zone.

1.4.1 CO_2 Stream Analysis and Corrosion Monitoring

The chemical composition of the CO_2 stream will be monitored downstream of the final compression unit and upstream of NC_INJ1 and NC_INJ2 (40 CFR 146.90 (a)). Corrosion coupons composed of the same material as the well components and CO_2-delivery pipeline will be placed in the delivery pipeline and analyzed on a quarterly basis for signs of corrosion and loss of mass that may be indicative of future potential well integrity issues (40 CFR 146.90 (c)). If signs of corrosion are identified in the coupons, this may trigger further well integrity testing.

1.4.2 Injection Well Monitoring

Injection operations will be monitored through a range of continuous, daily, and quarterly techniques as detailed in the well operations plans for both injection wells (Attachment 06A: NC INJ1 Well Operations, 2023; Attachment 06B: NC INJ2 Well Operations, 2023).

Continuous recording devices will allow monitoring of injection pressure, rate, and volume (40 CFR 146.90 (b)). The injection rate will be monitored using an orifice meter prior to entering the wellhead. The calculated injection volumes will, in turn, be used to update the computational models at regular intervals throughout the injection phase of the project (Attachment 02: AoR and Corrective Action Plan, 2023).

The annular pressure between the tubing and the injection casing strings as well as the annular fluid volumes will also be monitored on a continuous basis (40 CFR 146.90 (b)). These data will be linked into a supervisory control and data acquisition (SCADA) system to record the operations data, control injection rates, or initiate system shutdown, if needed. The SCADA system can also be used to adjust the volume of annular fluid, and thereby pressure, in the annular space to meet the operational and regulatory objectives.

1.4.3 Mechanical Integrity Testing

In addition to the annular pressure and fluid volume monitoring, the well integrity of NC_INJ1, NC_INJ2, and NC_OBS1 will be monitored using a range of internal and external mechanical integrity evaluation methods. The same methods of mechanical integrity testing (MIT) will be performed on each well.

1.4.3.1 Internal Mechanical Integrity Testing

The regulatory standard for internal MIT is performing an annulus pressure test (APT). This test will be run to regulatory standards after the well completion to confirm internal integrity as per the Pre-Operational Testing Program (Attachment 05: Pre-operational Formation Testing Program, 2023). Further details on the APT standards and methods of performing it are provided in Section 6.1.1.

1.4.3.2 External Mechanical Integrity Testing

The external mechanical integrity of the wells will be confirmed through annual temperature and PNL logging. These logs will be compared back to baseline logs to identify any unexpected deviations that could indicate CO_2 flow or accumulations behind the casing above the injection zone (40 CFR 146.90 (e)). Further details on these logs and the methods of performing them will be provided in a later section in Section 6.2.

1.4.4 Pressure and Temperature Monitoring

The bottomhole pressure and temperature will be measured using gauges in the NC_INJ1, NC_INJ2, and NC_OBS1 wells that will continuously record these data and transmit them to surface. NC_OBS1 will be located within the area of the predicted 25-year CO_2 plume; the CO_2 plume is expected to intersect the well in the first three to five years of injection (Figure 3). This well will allow for pressure and temperature monitoring as well as periodic fluid sampling in the injection zone until such time as the CO_2 intersects the well. The variations in the pressure data will be used to calibrate and verify the computational modeling through the pre-operational, injection, and PISC phases of the project (40 CFR 146.90 (g)).

1.4.5 Plume Monitoring

A pressure fall-off test (FOT) will be conducted in the Mt. Simon Sandstone in NC_INJ1 and NC_INJ2 after they are drilled to establish the hydrogeologic characteristics of the injection zone (Attachment 05: Pre-operational Formation Testing Program, 2023). During the injection phase of the project, a FOT will be conducted in NC_INJ1 and NC_INJ2 at least once every five years unless increases in injection pressure indicate a need for a FOT sooner (40 CFR 146.90 (f)). The formation characteristics obtained through the FOT will be compared to the results from previous tests to identify any changes over time, and they will be used to calibrate the computational models.

NC_OBS1 will be used to monitor pressure and to collect fluid samples from the injection zone to monitor for changes in the aqueous geochemistry of the formation. It will also be used to verify when the leading edge of the CO_2 plume reaches the observation well.

PNL will be run in the NC_INJ1, NC_INJ2, and NC_OBS1 to monitor CO_2 saturations and vertical plume development adjacent to the wellbores. This logging can also be used to identify accumulations of CO_2 above the confining zone should there be CO_2 migration along the wellbore.

Both the pressure and log data will be used to calibrate and verify the computational modeling over the injection and PISC phases of the project.

Beyond the direct measurement techniques that the project will deploy, time-lapse 3D surface seismic surveys will be used to monitor the development of the CO_2 plume, and a passive seismic monitoring array will be used to monitor the associated pressure front through the injection and PISC phases (40 CFR 146.90 (g)). High resolution time-lapse 3D surface seismic data will be used to qualitatively monitor the CO_2 plume development and calibrate the computational modeling results over time. The time-lapse 3D surface seismic data will also be used to verify CO_2 containment within the injection zone, as any CO_2 accumulations in the overburden would result in seismic anomalies that would differ from the baseline seismic data. Source and receiver spacing and line intervals, and the resulting trace density will be designed to deliver full offset, full azimuth baseline data of sufficient resolution to image the target horizons.

The passive seismic monitoring array will be used to monitor for seismic events within the AoR using a phased approach. Initially, the monitoring array will be located close to injection wells. The array will be expanded to cover a larger area over time as the leading edge of the pressure front migrates away from the injection wells.

1.4.6 Shallow Groundwater Sampling and Monitoring

The shallow groundwater monitoring program will use 13 shallow groundwater wells that are spatially distributed within the AoR in near-surface groundwater aquifers and two dedicated Mahomet Aquifer monitoring wells adjacent to the injection wells (40 CFR 146.90 (d)). Baseline groundwater samples will be acquired from these wells to help characterize the variations in water quality within the AoR prior to the start of CO_2 injection.

The lowermost USDW at the Compass Project Site will be the St. Peter Sandstone (Attachment 01: Narrative, 2023). Formation fluid samples from the St. Peter Sandstone will be obtained from the ACZ wells when they are drilled to establish the baseline aqueous geochemistry within the formation (Attachment 05: Pre-operational Formation Testing Program, 2023).

Throughout the injection and PISC phases of the project, the results of the aqueous geochemistry sampling will be compared to the baseline conditions for any indication of CO_2 or brine migration into the shallow groundwater aquifers. If indications of injection zone fluids are found in a shallow groundwater aquifer, it will trigger the emergency response actions found in the Emergency and Remedial Response Plan (Attachment 10: ERRP, 2023).

1.4.7 Deep Groundwater Sampling and Monitoring

Two deep groundwater wells (NC_ACZ1, NC_ACZ2) will be drilled into the Ironton-Galesville formations to monitor above the confining zone (ACZ). Assuming fluid migration from the injection zone is most likely to occur along a wellbore, NC_ACZ1 and NC_ACZ2 will each be constructed close to the corresponding NC_INJ1 and NC_INJ2 wells.

NC_ACZ1 and NC_ACZ2 will be used to take formation fluid samples and to monitor pressure changes in the Ironton-Galesville formations (40 CFR 146.90 (d)). Injection zone fluid migration past the confining zone and into the ACZ monitoring zone will most likely be identified through pressure changes in the formation. Pressures will be monitored both at the wellhead and downhole in the ACZ wells.

1.4.8 Passive Seismic Monitoring

The project site is located in an area with low rates and low risk of natural seismic activity (Attachment 01: Narrative, 2023). It is not expected that natural seismicity will affect the project. The IBDP at the ADM facility in Decatur, IL, injected CO_2 into the basal Arkose interval of the Mt. Simon Sandstone and generated small seismic events throughout the injection phase of the project CO_2 despite maintaining injection below fracture pressure (Bauer et al., 2016).

Over 80 percent of the induced events were located in the Precambrian basement (Bauer et al., 2019). The IL-ICCS project, one mile north of IBDP, is currently injecting into the Arkose and Lower Mt. Simon units but about 130 feet higher stratigraphically and has significantly reduced the frequency of induced seismic events. The Compass Project also plans to inject in the Arkose and Lower Mt. Simon Sandstone and will use the findings from these other projects to mitigate and monitor for induced seismic activity to manage project risks (Attachment 10: ERRP, 2023).

The passive seismic monitoring will be used to accurately determine the locations and magnitudes of induced seismic events with the primary goals of:

- Addressing public and stakeholder concerns related to induced seismicity,
- Monitoring the spatial extent of the pressure front from the distribution of seismic events around the injection wells and as the pressure front expands,
- Identifying activity that may indicate failure of the confining zone and possible containment loss.

A surface-based passive seismic monitoring array will be designed with seismic monitoring stations at a range of azimuths to optimize the accuracy of the event locations and magnitudes. The design of the array will be informed by data collected during the Pre-operational Testing Program (Attachment 05: Pre-operational Formation Testing Program, 2023). This network can easily be expanded in response to monitoring results or future AoR re-evaluations as necessary.

1.4.9 General Testing and Monitoring Activity Frequency

Table 4 presents the general schedule and spatial extent for the monitoring activities in the baseline and injection phases of the project based on the current understanding of the site. The depth of monitoring gauges and testing ranges will be updated once the data from NC_OBS1 has been analyzed. Changes to the monitoring schedule may occur over time as the project evolves. Any such changes to the testing and monitoring plan or the PISC will be made in consultation with the UIC Program Director (40 CFR 146.90 (j)).

Table 4: General schedule and spatial extent for the testing and monitoring activities for the Compass Project

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency*	Location	Depth Range (MD feet)**
Groundwater Monitoring				
Shallow Groundwater Sampling	Quarterly	Biannual (twice/year)	13 shallow wells, NC_MA1, NC_MA2	~ 100 – 400 feet Mahomet Aquifer
Fluid Sampling	Biannual (twice/year)	Annual	NC_ACZ1, NC_ACZ2 NC_OBS1	Varying
Injection Well Monitoring				
Injection Pressure	NA	Continuous	NC_INJ1, NC_INJ2	Surface Above Packer
Injection Temperature	NA	Continuous	NC_INJ1, NC_INJ2	Surface Above Packer
Injection Rate	NA	Continuous	NC_INJ1, NC_INJ2	Surface
Injection Volume (Calculated)	NA	Continuous	NC_INJ1, NC_INJ2	Surface
Annular Pressure	NA	Continuous	NC_INJ1, NC_INJ2	Surface
Annular Fluid Volume	NA	Continuous	NC_INJ1, NC_INJ2	Surface
Mechanical Integrity Testing				
Mechanical Integrity Test (MIT) (Internal): Annulus Pressure Test	Once Once	As required	NC_INJ1, NC_INJ2 NC_OBS1	Surface Surface
FOT	Once	Every 5 years	NC_INJ1, NC_INJ2	Injection zone
MIT (External) Temperature Log	Once Once	Annually Annually	NC_INJ1, NC_INJ2 NC_OBS1	Varying Varying

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency*	Location	Depth Range (MD feet)**
Emergency Shut-down System Test	NA	Annually	NC_INJ1, NC_INJ2	Surface
Pressure Monitoring				
Annular Pressure	NA	Continuous	NC_INJ1, NC_INJ2 NC_OBS1	Surface Surface
Wellhead Pressure	NA	Continuous	NC_ACZ1, NC_ACZ2	Surface
Downhole Pressure	NA	Continuous	NC_INJ1, NC_INJ2 NC_OBS1 NC_ACZ1, NC_ACZ2	Above Packer Injection Zone (TBD) Ironton-Galesville (TBD)
CO_2 Stream Analysis				
CO_2 Stream Analysis	Once	Quarterly	CO_2 Pipeline	Surface
Corrosion Coupon Analysis	NA	Quarterly	Surface	Surface
CO_2 Plume and Pressure Front Verification Monitoring				
Pressure – Temperature Sensors	3 months prior to injection Continuous Continuous	 Continuous Continuous	NC_ACZ1***, NC_ACZ2*** NC_INJ1, NC_INJ2 NC_OBS1	Ironton-Galesville Fm. (TBD) Above Packer Injection Zone (TBD)
PNL	Once Once	Annually Annually	NC_INJ1, NC_INJ2 NC_OBS1	ACZ Interval, Confining Zone, Injection Zone
Passive Seismic Monitoring	6 months prior to injection	Continuous	Minimum 5 Stations within the pressure front	Confining Zone, Injection Zone, Precambrian Basement
Time-lapse 3D Surface Seismic Data	Baseline	Every 5-10 years	Area sufficient to image modeled CO_2 plume extent	Imaging of CO_2 plume and overburden

* Minimum frequency displayed in table
** To be confirmed after well is drilled
*** Temperature data will not be collected

1.5 Quality Assurance Procedures

Data quality assurance and surveillance protocols adopted by the project have been designed to facilitate compliance with the requirements specified in 40 CFR 146.90 (k). Quality Assurance (QA) requirements for direct measurements within the injection zone, above the confining zone, and within the lowermost USDW aquifer are described in QASP (Attachment 11: QASP, 2023). These measurements will be performed based on best industry practices, and the QA protocols recommended by the service contractors selected to perform the work.

1.6 Reporting Procedures

Heartland Greenway Carbon Storage, LLC (HGCS) will report the results of all testing and monitoring activities to the EPA in compliance with the requirements under 40 CFR 146.91. Reports will be submitted every 6 months commencing from the date CO_2 injection operations commence.

2. CO_2 Stream Analysis (40 CFR 146.90 (a))

The project will analyze the CO_2 stream during the injection phase of the project to provide data representative of its chemical characteristics and to meet the requirements of 40 CFR 146.90 (a). This section describes the measurements and sampling methodologies that will be used to monitor the chemical characteristics of the CO_2 injection stream. Additional details on technical standards, QA/QC policy, sample collection and storage policies, and analytical methods are provided in the QASP (Attachment 11: QASP, 2023).

2.1 Sampling Location and Frequency

Prior to the start of the injection phase, the CO_2 stream from the delivery pipeline will be sampled for analysis to obtain representative CO_2 samples that will serve as a baseline dataset. Once the injection phase commences, samples of the CO_2 injection stream will be collected quarterly from the CO_2 delivery pipeline for analysis. Quarterly sampling of the CO_2 injection stream should be sufficient to accurately track the composition of the stream.
Section 4.5 of the QASP document details the quality control mechanisms and activities to be performed should there be a statistically significant variance in an analyte measurement.

2.2 Analytical Parameters

Samples of the injection stream will be collected for chemical analysis to provide data representative of its characteristics. The samples will be analyzed for CO_2 purity, total hydrocarbons as methane carbon monoxide (CO), nitrogen oxides (NO_x), nitrogen (N_2), oxygen (O_2), methane, hydrogen sulfide (H_2S), sulphur dioxide (SO_2), acetaldehyde (AA), and ethanol. Baseline samples of the injection stream will be collected prior to the start of injection and the analytes included for analysis may be expanded depending on the results of those analyses. Gas concentration analyses will be done by a contracted third-party lab. The lab will specialize in gas analyses and routinely perform specialized analyses on CO_2 for industrial clients. Samples of the CO_2 stream will be collected on a quarterly basis for chemical analysis.

2.3 Sampling Method – CO_2 Injection Stream Gases

Gas samples of the CO_2 stream will be obtained to analyze the components present in the injection stream. Samples of the CO_2 stream will be collected between the CO_2 delivery pipeline and the injection wells using a ¼-inch sampling port in the flowline. Fittings will be consistent with those used by the contracted third-party laboratory who will be performing the analysis. The CO_2 stream will flow from the pipeline through an open ball valve, through a pressure reducer (regulator), and into the cylinder. The pressure regulator will reduce the pressure of the CO_2 stream to approximately 250 pound-force per square inch (psi) to ensure the CO_2 is in a gaseous state rather than a supercritical liquid.

Figure 6 provides an example of the sampling procedures used by Atlantic Analytical Company. Cylinders will be purged with sample gas (i.e., CO_2) at least five times prior to sample collection to remove laboratory-added helium gas and ensure a representative sample. The QASP contains more information on sampling methods (Attachment 11: QASP, 2023).

Introduction

Atlantic Analytical Laboratory (AAL) provides pre-cleaned and conditioned stainless steel and sulfur-inerted sampling cylinders as a convenience to our customers. Rental cylinders are available in a variety of sizes, including 75cc, 300cc, 500cc, and 1 liter. All cylinders are DOT rated for **1,800 psig** service, and are equipped with a burst-disc type relief valve set to approximately this pressure. All cylinders are dual ended, with **1/4" NPT** valve port fittings. **Cylinders are normally shipped with approximately 10 psig UHP grade helium backfill gas to prevent atmospheric contamination during shipment.** Cylinders can be shipped under vacuum upon request.

Safety

Before sampling, review all MSDS information related to the gases present. Always wear safety glasses, protective gloves, and other necessary safety equipment. Sampling cylinders are only to be used by personnel trained in handling pressurized gases. For safety, always assume any cylinder or gas line contains the maximum amount of pressure possible in the system. Whenever possible, ensure that the sampling cylinder outlet port is attached to an appropriate vent line to avoid a potentially hazardous buildup of the gas being sampled, especially for oxygen and flammable gases. **Refer to the back of this page for a diagram of a typical sampling setup.**

- **DO NOT** sample toxic, corrosive, pyrophoric, or extremely reactive gases with these cylinders.
- **DO NOT** sample cryogenic or liquefied gases using these instructions; instead, refer to separate instructions available from AAL for proper sampling techniques for these gases.
- **DO NOT EXCEED the MAXIMUM 1,800 PSIG fill pressure.** If the relief valve burst disc ruptures, the cylinder cannot be used for sampling - return to AAL immediately for repairs, cleaning, and recertification.

Equipment

Sampling cylinder, ¼" NPT brass end cap, ¼" NPT brass plug, ID tag.

Sampling Procedure

1) Remove the brass cylinder end cap and plug and store them in a clean, secure location.
2) Loosely connect the inlet valve of the sampling cylinder to the gas source valve.
3) Carefully open the gas source valve and purge the connecting fittings of air - then tighten these fittings. Keep the gas source valve open until step 11.
4) Carefully open the cylinder inlet valve to allow the sample gas to fill the cylinder.
5) Close the cylinder inlet valve. Do not over tighten, as this may damage the valve seat and cause leakage.
6) Open the cylinder outlet valve, and allow a majority the cylinder gas to vent. **DO NOT** blow down completely to atmospheric pressure, as this may cause outside contaminants to diffuse into the cylinder.
7) Close the cylinder outlet valve.
8) Repeat steps 4 - 7 a minimum of 5 times to ensure the cylinder has been purged of all fill gas and conditioned with the sample gas.
9) Open the cylinder inlet valve and partially open the cylinder outlet valve to allow the sample gas to flow through the cylinder for at least 2 minutes.
10) Close the cylinder outlet valve and wait at least 30 seconds for the cylinder to fully pressurize.
11) Close both the cylinder inlet and gas source valves - then carefully disconnect the cylinder. Beware of excess gas pressure trapped between the two valves which may release suddenly when disconnecting the cylinder.
12) Apply new teflon tape to the NPT threads on the inlet valve of the cylinder and the brass outlet plug and securely cap both ends of the cylinder. **DO NOT** over tighten fittings or thread damage may result.
13) Record all sample data on the cylinder ID tag **– please do not affix labels to the cylinder body.**
14) Package the cylinder in a DOT/IATA approved shipping box or container and insert a completed AAL "Analytical Testing Request" form. Follow all applicable shipping regulations including affixing the proper sample UN designation, shipping name, hazard labels, and identification of the sample contents on all courier paperwork.
15) Ship the sample to AAL via an express air (if eligible) or qualified ground courier as soon as possible.

Figure 6: Atlantic Analytical Laboratory gas sampling instruction sheet (Atlantic Analytical Laboratory, 2022).

2.4 Laboratory to be Used, Chain of Custody, and Analysis Procedures

A contracted third-party laboratory will analyze the CO_2 stream samples. The lab will specialize in gas analyses and routinely perform specialized analyses on CO_2 for industrial clients. The contracted laboratory will follow standard sample handling and chain-of custody guidance (EPA 540-R-09-03, or equivalent). The relevant QASP sections detail the following (Attachment 11: QASP, 2023):

- Section B.1.a: Laboratory to be used and quality
- Section B.3.e: Chain of custody
- Section B.4.a: Analysis procedures

3. Continuous Recording of Operational Parameters

The project will install and use continuous recording devices to monitor injection pressure; injection rate (and volume [calculated]); the pressure on the annulus; the annulus fluid volume added; and the temperature of the CO_2 stream, as required at 40 CFR 146.88 (e)(1), 146.89 (b), and 146.90 (b). The details are described in the following sections.

3.1 Monitoring Location and Frequency

The project will perform the activities identified in Table 4 to monitor operational parameters and verify internal mechanical integrity of NC_INJ1 and NC_INJ2. All monitoring will take place at the locations and frequencies shown in Table 5. All of the data recorded on a continuous basis will be connected to the main facility through a SCADA system.

Table 5: Sampling devices, locations, and frequencies for continuous monitoring.

Parameter	Device(s) ***	Location	Minimum Sampling Frequency*	Minimum Recording Frequency **
Wellhead Injection Pressure	Pressure Gauge	Wellhead	Every 10 seconds	Every 10 seconds
Formation Injection Pressure	Pressure Gauge	Above Packer Depth TBD	Every 10 seconds	Every 10 seconds
Wellhead Injection Temperature	Thermocouple	Wellhead	Every 10 seconds	Every 10 seconds
Formation Temperature	Temperature Sensor	Above Packer Depth TBD	Every 10 seconds	Every 10 seconds
Injection Rate	Orifice Meter	Inlet and Outlet to pipeline	Every 10 seconds Every 10 seconds	Every 10 seconds Every 10 seconds
Annular Pressure	Pressure Gauge	Wellhead	Every 10 seconds	Every 10 seconds
Annulus Fluid Volume	Accumulator	Wellhead	Every 1 minute	Every 1 minute

* Sampling frequency refers to how often the monitoring device obtains data from the well for a particular parameter. For example, a recording device might sample a pressure transducer monitoring injection pressure once every two seconds and save this value in memory.
** Recording frequency refers to how often the sampled information gets recorded to digital format (such as a computer hard drive). For example, the data from the injection pressure transducer might be recorded to a hard drive once every minute.
*** All calibration standards, methods of conformance, precision, and tolerance parameters are provided for the devices listed in the QASP (Attachment 11: QASP, 2023).

3.2 Monitoring Details

3.2.1 Continuous Recording of Injection Pressure

The CO_2 injection pressure will be monitored on a continuous basis at the wellhead to ensure that injection pressures do not exceed the calculated maximum allowable injection pressure (MAIP), determined, in part, by using 90% of the fracture pressure of the injection zone per 40 CFR 146.88 (a). If the injection pressure exceeds this value, then the injection process will be automatically shut down per the Well Operations Plans (Attachment 06A: NC INJ1 Well Operations, 2023; Attachment 06B: NC INJ2 Well Operations, 2023). Based on current information, 90% fracture pressure gradient is expected to be 0.639 psi/foot, and this value has been used to determine the maximum bottomhole and corresponding surface injection pressures. Table 6 summarizes the maximum allowable bottomhole flowing pressure (BHFP) after year 1 and year 5 as well as the maximum allowable injection pressure (MAIP) at surface for NC_INJ1 and NC_INJ2 (Attachment 06A: NC INJ1 Well Operations, 2023; Attachment 06B: NC INJ2 Well Operations, 2023). These results will be re-assessed with the data collected during the Pre-Operational Testing Program (Attachment 05: Pre-operational Formation Testing Program, 2023).

Table 6: Summary of BHFP and MAIP for NC_INJ1 and NC_INJ2

Parameter	NC_INJ1	NC_INJ2
Depth (MD feet)	6,052	6,064
Max Allowable BHFP (psi)	3,873	3,881
Year 1 BHFP (psi)	3,535	3,507
Year 5 BHFP (psi)	3,455	3,437
MAIP (Surface, psi)	2,417	2,422

Pressure will be continuously monitored by an electronic pressure transducer to ensure that the MAIP is not exceeded during injection operations. This electronic pressure transducer will feed into the SCADA system.

As is noted in the Well Operations section, several assumptions have gone into the calculations for the MAIP (Attachment 06A: NC INJ1 Well Operations, 2023; Attachment 06B: NC INJ2 Well Operations, 2023). To assist with the proper hydrostatic gradient evaluations, permanent downhole gauges will be used. The data gathered from this sensor will help to calibrate the surface pressure readings. The current plan is to use these gauges for calibration purposes until sufficient hydrostatic data has been collected. It is noted that these gauges are not considered to be a part of the routine testing and monitoring program, but for gradient calibration and model/simulation verification.

Any anomalies outside of the normal operating specifications may indicate that an issue has occurred within the well, such as a loss of mechanical integrity, blockage in the tubing, or a change in injection flowrate. Anomalous pressure measurements would trigger the need for further investigation of the cause of the change (40 CFR 146.89 (b)). The wellhead and downhole injection pressures will also be used to calibrate the computational modeling throughout the injection phase and PISC phases of the project.

3.2.2 Continuous Recording of Injection Mass Flow Rate

The mass flow rate of CO_2 injected into the wells will be monitored by an orifice meter. The orifice meter will be placed in the CO_2 delivery line near each well. The flow meters will be connected to the SCADA system for continuous monitoring and control of the CO_2 injection rate into the well.

3.2.3 Injection Volume

The injection volume will be calculated for each well using an orifice meter. The calculated volume will be used in the computational models to determine storage formation capacity and flow.

3.2.4 Continuous Recording of Annular Pressure

As discussed in the Well Operations Plans, the pressure on the annulus between the injection tubing and the long-string casing will be measured by an electronic pressure transducer with analog output that is mounted on the wing valve/annular fluid line connected to the wellhead of an injector (Attachment 06A: NC INJ1 Well Operations, 2023; Attachment 06B: NC INJ2 Well Operations, 2023). The transmitter will be connected to the well control system and the SCADA system to regulate the annular pressure.

Annular pressures are expected to vary during normal operations due to atmospheric and CO_2 stream temperature fluctuations; however, the well control system will be designed to maintain annular pressures of 100 psi in both injection wells (Attachment 06A: NC INJ1 Well Operations, 2023; Attachment 06B: NC INJ2 Well Operations, 2023).

In particular, the annular pressure is expected to fluctuate during start-up and shut-in operations as the tubing naturally expands and contracts in response pressure and temperature changes related to CO_2 flow, or lack thereof, in the tubing. Sudden changes in the annular pressure during routine injection operations are a sign of potential tubing or tubing packer integrity issues that will trigger further investigation through mechanical integrity testing.

3.2.5 Continuous Recording of Annulus Fluid Volume

As discussed in the Well Operations Plans, the volume of the annulus fluid between the injection tubing and the long-string casing will be measured using the accumulator levels and the brine reservoir level on the well control system (Attachment 06A: NC INJ1 Well Operations, 2023; Attachment 06B: NC INJ2 Well Operations, 2023). The accumulator and brine reservoir levels will be measured using a level transmitter. The transmitters will be connected to the well control system and to the SCADA system.

Similar to the annular pressure, the annular fluid volume is expected to fluctuate as atmospheric and injection stream temperatures change. These changes are expected to be most dramatic during start-up and shutdown operations. A significant change in the fluid volume in the accumulator or brine reservoir (i.e., fluid is being pumped from the reservoir to the annulus or fluid being pushed out of the annular space) during routine injection operations may be an indication of well integrity problems, as the fluid volumes would normally remain relatively constant, and will require further investigation.

3.2.6 Continuous Recording of CO_2 Stream Temperature

The temperature of the CO_2 injection stream will be continuously measured by an electronic thermocouple. The thermocouple will be mounted in a temperature probe in the CO_2 line at a location close to the pressure transmitter near the wellhead. The transmitter will be electronically connected to the SCADA system.

3.2.7 Bottomhole Pressure and Temperature

Bottomhole pressure and temperature will be monitored prior to and during the injection phase of the project. These data will be used to assist with the calibration of the wellhead pressure measurements to determine the response of the formation to the injected CO_2.

The downhole pressure gauge will be set, just above the packer in the injection wells and will be programmed to continuously record the pressure and transmit it to surface.

After the wellhead/ injection zone pressure relationship has been defined, the wellhead pressure measurement will be the point of compliance for maintaining injection pressure below 90% of formation fracture pressure as per 40 CFR 146.88 (a). The downhole pressure and temperature data will also be used to calibrate the computational models.

4. Corrosion Monitoring (40 CFR 146.90 (c))

To meet the requirements of 40 CFR 146.90 (c), the project will monitor well materials and components during the operational period for loss of mass, thickness, cracking, pitting, and other signs of corrosion to ensure that the well components meet the minimum standards for material strength and performance (Table 7). This section discusses the measures that will be taken to monitor the corrosion of well materials used in the casing and tubing. For Class VI injection wells, corrosion monitoring of the well materials is required on a quarterly basis (40 CFR 146.90 (c)).

4.1 Monitoring Location and Frequency

The corrosion coupons will be retrieved and analyzed every three months after the date that injection commences. If the coupons show evidence of corrosion, NC_INJ1 and NC_INJ2 can be assessed for signs of corrosion using commercially available logging or other inspection tools.

4.2 Sample Description

The coupons will be made from the same materials as the long string casing and tubing (Table 7). Prior to placement of the corrosion coupons in the CO_2 stream, they will be weighed and measured for thickness, width, and length as a baseline measurement.

Table 7: List of equipment coupon with material of construction

Equipment Coupon	Material of Construction
Long String Casing	13Cr80 Steel Alloy and Standard Carbon Steel
Injection String	Standard Carbon Steel with TK-15XT Coating (Tuboscope)
Pipeline	Stainless Steel
Wellhead	Xylan coated iron
Packer	Nickel coated steel, nitrile

4.3 Monitoring Details

Corrosion monitoring of well materials will be conducted using coupons placed in the CO_2 pipeline (Figure 7). The coupons will be made of the same materials that are listed in the table above. An example of one such coupon is provided in Figure 8. The coupons will be removed quarterly and assessed for corrosion using American Society for Testing and Materials (ASTM) G1-03: Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens (ASTM G1-03, 2017). This method measures the corrosivity of steel to both aqueous and non-aqueous liquid wastes.

Upon removal, coupons will be inspected visually for evidence of corrosion, which may include pitting, cracking, and loss of mass or thickness. The weight and size (thickness, width, length) of the coupons will also be measured and recorded each time they are removed and compared to the baseline measurements. Corrosion rate will be calculated as the weight loss during the exposure period divided by the duration (i.e., weight loss method).

If the coupons show evidence of corrosion, NC_INJ1 and NC_INJ2 can be assessed for signs of corrosion using commercially available logging or other inspection tools. The frequency of running these inspection logs will be contingent on the corrosion data from the coupon monitoring program.

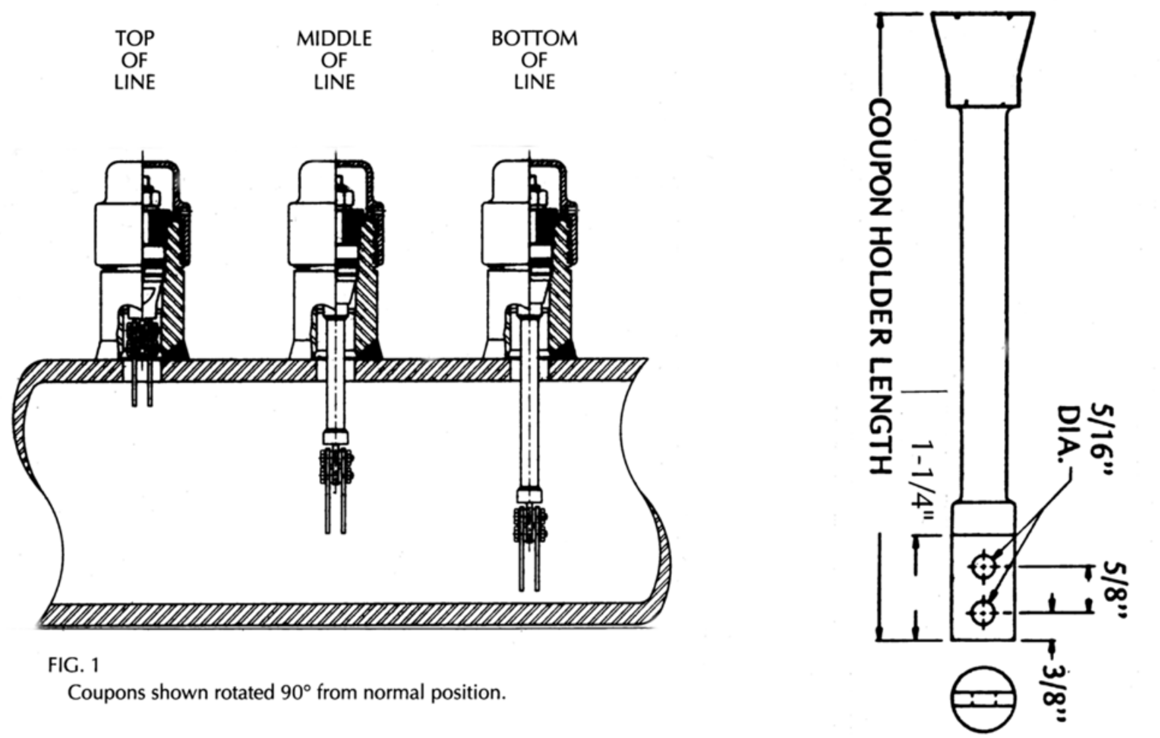

Figure 7: Corrosion coupon illustration in pipeline (Cosasco, 2022)

Figure 8: Type of corrosion coupons to be used for corrosion monitoring (Cosasco, 2022)

5. Above Confining Zone Monitoring (40 CFR 146.90 (d))

The project will monitor for changes to aqueous geochemistry above the confining zone during the operational period to meet the requirements of 40 CFR 146.90 (d).

5.1 Monitoring Location and Frequency

Table 8 shows the deep ACZ monitoring zone, lowermost USDW, and shallow groundwater monitoring methods, depths, and frequencies. The project will acquire a minimum of one year of shallow groundwater data before injection operations begin. Fluid samples from the Ironton-Galesville formations will be taken for analysis from NC_ACZ1 and NC_ACZ2 twice prior to the start of injection operations.

Table 8: Schedule for monitoring of pressure and aqueous geochemistry for the NC_ACZ1, NC_ACZ2, and shallow groundwater monitoring wells during the pre-operational and injection phases of the project.

Designated Wells	Target Formation	Monitoring Activity	Baseline Frequency	(Minimum) Injection Phase Frequency
Existing Wells TBD NC_MA1, NC_MA2	Shallow Groundwater Wells	Aqueous Geochemistry	Quarterly	Biannual
NC_ACZ1, NC_ACZ2	St Peter Sandstone	Aqueous Geochemistry	Once	If required (Contingency)
NC_ACZ1, NC_ACZ2	Ironton-Galesville	Wellhead Pressure	Continuous	Continuous (Every Hour)
		Downhole Pressure	Continuous	Continuous (Every Hour)
		Aqueous Geochemistry	Biannual	Annual

Given the thick and continuous nature of the Eau Claire Formation, the highest risk of CO_2 or brine migration out of the injection zone is along the NC_INJ1, NC_INJ2, and NC_OBS1 wellbores that will penetrate the Eau Claire Formation. As such, the ACZ wells will be drilled adjacent to the injection wells to help monitor for any CO_2 leakage or brine migration into the ACZ monitoring zone. Fluids from the deepest ACZ saline formation will be sampled twice prior to the start of CO_2 injection to characterize any natural variability in the fluids in the formation (Table 8).

Migration of CO_2 or brine into the Ironton-Galesville formations will likely first be identified through pressure changes in the formation. An increasing pressure trend in the ACZ monitoring zone would suggest that leakage across the confining zone has occurred. While any increasing trend in pressure will be evaluated, an increase in pressure that deviates more than 2% above baseline values will warrant additional monitoring and inspections to rule out the possibility of fluid leakage out of the injection zone. Such a change in pressure would initiate more frequent fluid sampling and analysis for aqueous geochemistry from the ACZ monitoring zone as well as additional external well integrity investigations in the NC_INJ1, NC_INJ2, or NC_OBS1.

Pressures in the ACZ monitoring interval will be monitored at the wellhead and downhole. The St. Peter Sandstone is the lowermost USDW (Attachment 01: Narrative, 2023). It will be sampled, and the baseline aqueous geochemistry will be established when the ACZ monitor wells are drilled. It will only be monitored on a regular basis as contingency should there be any indications that injection zone fluids have migrated into the Ironton-Galesville formations.

Figure 9 shows the distribution of the groundwater wells within the AoR (Attachment 02: AoR and Corrective Action Plan, 2023). The shallow groundwater monitoring program will include approximately 13 existing groundwater wells that will be spatially distributed within the AoR (40 CFR 146.90 (d)). Two dedicated wells will be drilled in the Mahomet Aquifer at the same location as the injection wells. Baseline shallow groundwater samples will be collected from existing shallow groundwater wells, NC_MA1, NC_MA2 within the AoR on a quarterly schedule starting at least one year before injection commencement to characterize the seasonal variations in groundwater quality within the AoR (Table 8).

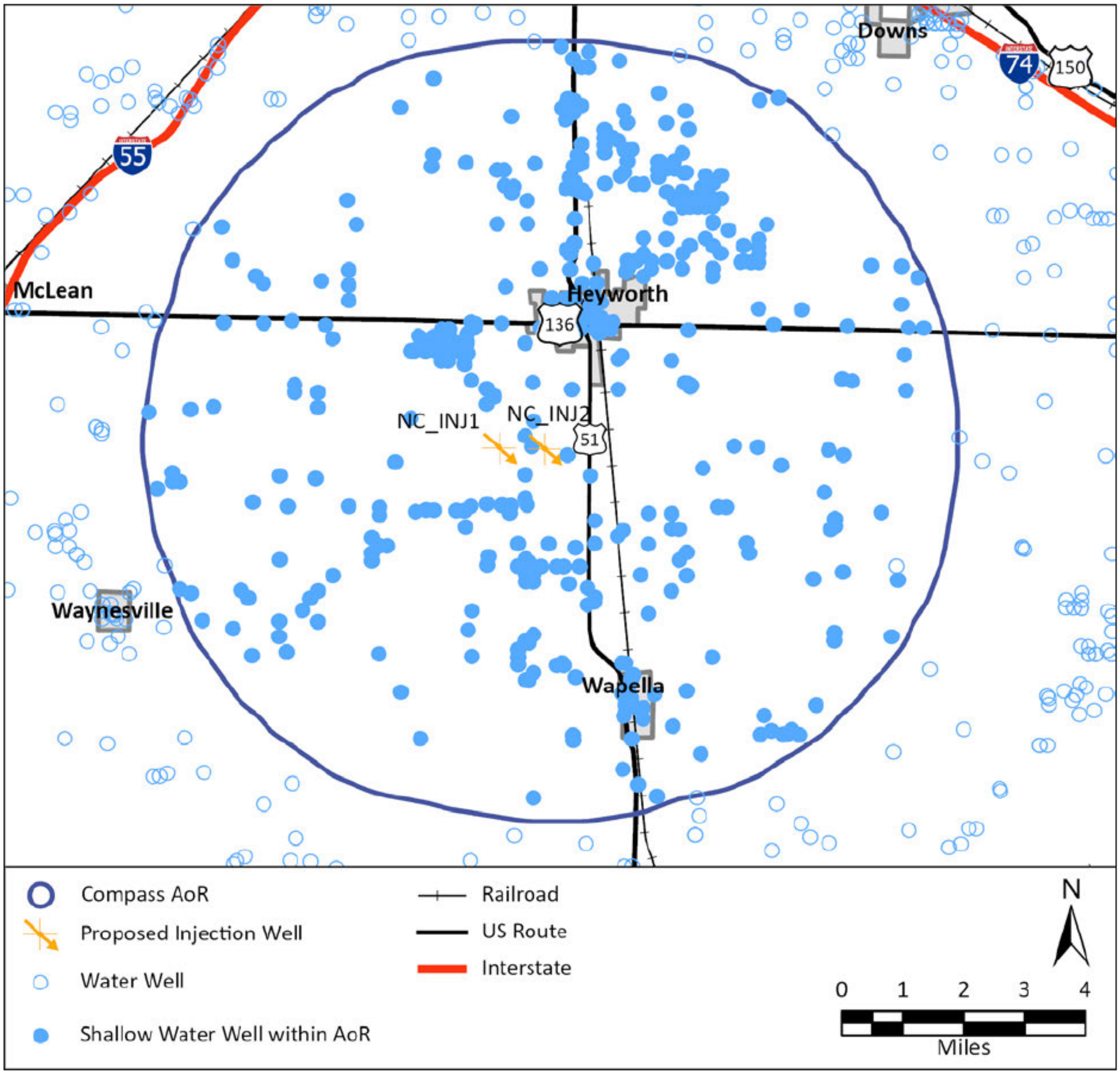

Figure 9: Shallow groundwater wells within the AoR annotated in blue.

The accumulation of CO_2 or brine in an overlying aquifer will likely result in changes to the following parameters:

- Aqueous geochemistry parameters such as pH and alkalinity,
- Reaction of cements, mineral surface coatings, and clay particles with the CO_2 will liberate cations and anions into the aqueous phase,
- Carbon isotopes can be used to differentiate between existing CO_2 sources within the AoR and the injected CO_2.

If anomalous changes in the aqueous geochemistry are observed in the ACZ monitoring interval, new samples will be obtained from the affected formation to verify the changes. The frequency with which fluid samples are obtained the ACZ zone for analysis will also be increased.

If the injected CO_2 has a unique isotopic signature from the existing isotopes in the ACZ monitoring interval, a new round of samples will be collected for isotopic analysis from the affected formation. Anomalous changes may also trigger the need for additional well integrity testing in NC_INJ1, NC_INJ2, and NC_OBS1 to ensure that no well integrity issues have developed since the last set of external mechanical integrity tests. If injection zone fluids are detected in the ACZ monitoring interval, it may trigger regular sampling of the St. Peter Sandstone fluids as the lowermost USDW. Stable isotopes from the shallow groundwater samples will only be analyzed if anomalies are found in the ACZ monitoring interval or lowermost USDW.

A combination of anomalous pressure, geochemical, and well integrity testing data that shows a clear loss of integrity in the storage complex may result in the decision to acquire a time-lapse surface seismic survey to determine the size of a potential leakage accumulation. Further details on any remedial or emergency response are detailed in the ERRP portion of this permit application (Attachment 10: ERRP, 2023).

5.2 Analytical Parameters

Table 9 details the full suite of analytes that will be used to establish the baseline conditions from NC_OBS1, NC_ACZ1, NC_ACZ2, and the shallow groundwater monitoring wells. Once the project has established baseline conditions, it may reduce monitoring to a subset of analytes that are most likely to change as a result of interactions with CO_2; however, any changes will be in full consultation with the UIC Program Director. During the injection phase of the project, fluids from these wells will be sampled biannually to identify any changes to parameters aqueous geochemistry.

Table 9: Summary of analytical and field parameters for groundwater samples

Parameters	Analytical Methods *
Cations: Ca, Fe, K, Mg, Na, Si	EPA 6010B
Cations: Al, Sb, As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Se, Tl	EPA 200.8, EPA 245.1
Anions: Br, Cl, F, NO_3, and SO_4	EPA 300.0
Alkalinity	SM 2320B
Total Dissolved Solids (TDS)	SM 2540C
Total Organic Carbon (TOC)	SM 5310C
Dissolved Inorganic Carbon (DIC)	SM 5310C
Total and Dissolved CO_2	ASTM D513-06B
Stable Isotopes of δ13C	Isotope Ratio Mass Spectrometry **
pH	Field with multi-probe system
Conductivity/Resistivity	Field with multi-probe system
Temperature	Field with multi-probe system

* An equivalent method may be employed with the prior approval of the UIC Program Director.
** Gas evolution technique by Atekwana and Krishnamurthy (1998) with modifications made by Hackley et al. (2007)

Changes in these parameters during the injection phase of the project may provide an indication of CO_2 or brine movement above the confining zone. pH and alkalinity may be indicators of CO_2 migration above the confining zone; dissolved inorganic carbon analysis may provide direct evidence of CO_2 migration into these formations. δ13C values (of dissolved inorganic carbon) could provide an indication of fluid or CO_2 migration into the ACZ monitoring zone and may also provide information about the origin of any migrating fluids.

The relative benefit of each analytical measurement will be evaluated throughout the design and initial injection testing phase of the project to identify the analytes best suited to meeting project monitoring objectives under site-specific conditions. If some analytical measurements are shown to be of limited use, they will be removed from the analyte list and not carried forward through the operational phases of the project. Any modification to the parameter list in Table 9 will be made in consultation with the UIC Program Director.

Currently, there are no plans to use tracers during operations; however, as the monitoring plan is designed to be adaptive as project risks evolve over time and may be re-assessed later.

5.3 Monitoring and Sampling Methods

Pressure in the ACZ monitoring zone will be monitored from the wellhead and downhole. The gauges will record and transmit data the SCADA system once every 10 seconds. The downhole gauges will be installed in the ACZ wells when the wells are completed. The wellhead gauges will be installed at least three months prior to any injection to ensure that a sufficient baseline is established.

For ACZ fluid sampling, a bailer system will be used to collect the water samples. Prior to sample collection the well will be flushed to remove stagnant water from the well and ensure representative water is collected from the formation. The fluid removed from the well will be monitored for field parameters that are listed in Table 9. Once these parameters stabilize, it will be an indication that representative formation fluid is in the well at the time the sample is collected. Preservation/preparation methods, container type, and holding times for the analyte classes are presented in the QASP section of this application (Attachment 11: QASP, 2023).

5.4 Laboratory to be Used/Chain of Custody Procedures

The geochemical analyses and the isotopic analyses will be performed by contracted third-party laboratories that meet the standards and guidelines set forth in the QASP. Samples will be tracked using appropriately formatted chain-of-custody forms (Attachment 11: QASP, 2023).

6. Mechanical Integrity Testing

6.1 Internal Mechanical Integrity Testing

Internal mechanical integrity testing (MIT) refers to testing of seal integrity within, and between, injection string, long casing string, packer, and wellhead. The quality of these seals can be confirmed with an annulus pressure test (APT) and annular pressure monitoring. An APT will be conducted when the injection wells are completed. Annular pressure testing will be continuous in the injection wells. Table 10 presents the details for conducting the annular pressure MIT and the annular pressure monitoring.

Table 10: Internal mechanical integrity monitoring details

Testing/Monitoring Method	Frequency	Location of Monitoring	Parameters Measured
Annular Pressure Test	After completion	NC_INJ1and NC_INJ2 Wellheads, NC_OBS1 Wellhead	Pressure
Annular Pressure Monitoring	Continuous	NC_INJ1and NC_INJ2 Wellheads, NC_OBS1 Wellhead*	Pressure, temperature, annular fluid volume
*No continuous annular fluid volume monitoring			

An APT will be performed after the initial well completion. It is noted that the annulus will be filled with a non-corrosive fluid with some additives.

6.1.1 Annulus Pressure Testing (40 CFR 146.89(a))

The APT will be performed to exhibit internal mechanical integrity any time a component of the internal seals, detailed above, are broken or altered. The test will be performed consistent with approved and accepted guidance and regulation CFR 146.89 (a). In addition, an APT will be performed following an emergency shut-in due to a high-high or low-low annulus alarm should the cause of the alarm not be easily correlated to a change in temperature.

The APT will then be performed by pressuring up the annulus after the well has reached thermal equilibrium. Once this has occurred, the annulus will be pressured up to 1500 psi. A calibrated digital gauge will be installed on the annulus, and the pressure will be monitored for a period no less than 60 minutes.

The following procedure will be followed for all APTs that will be run.

1. Ensure well is in thermal equilibrium. Thermal equilibrium will be assumed under the following circumstances:
    a. Injection has not occurred for approximately 24 hours, or sufficient data indicates the wellbore temperature is static. The scenario constitutes a static APT.
    b. Injection is occurring at a constant rate (±5%), often referred to as a dynamic APT.
2. Install calibrated digital gauge on the casing-tubing annulus. Note initial pressures.
3. Increase annulus pressure to 1500 psi.
    a. Ensure to note the fluid level in the system prior to increasing the annulus pressure.
4. Disconnect annulus system and ensure the annulus is isolated.
5. Monitor the annulus and tubing pressure for a period of one-hour, taking readings every 10-minutes.
6. Once the test has concluded, reconnect the annulus system.
7. Blow the pressure down to the normal operating pressure.
8. Note the fluid level in the system.

6.1.2 Annulus Pressure Monitoring

The annular pressure will be continuously monitored throughout the operational period in conjunction with the annular pressure monitoring and control system to ensure internal mechanical integrity. Once injection operations commence, injection pressure, annular pressure, and annular fluid volumes will be monitored continuously in order to ensure that internal well integrity and proper annular pressure is maintained in both injection wells (Attachment 06A: NC INJ1 Well Operations, 2023; Attachment 06B: NC INJ2 Well Operations, 2023).

If a change in the annular pressure or annular fluid volume indicates a change that was not a result of temperature or injection rate alteration, the cause of the change will be investigated (Attachment 06A: NC INJ1 Well Operations, 2023; Attachment 06B: NC INJ2 Well Operations, 2023). Note that changes in the temperature of the injection stream can result in changes in the temperature of the annular space, leading to variations in annular pressure. Initial investigations would likely look at correlations between the temperature of the injection stream and the variations in annular pressure.

6.2 External Mechanical Integrity Testing (40 CFR 146.90 (e))

The project will conduct external MIT annually to meet the requirements of 146.89(c) and 146.90(e).

6.2.1 Testing Methodology and Frequency

External mechanical integrity refers to the absence of fluid movement through channels between the long casing string and the borehole or the intermediate casing string. Migration of fluids through this zone could result in contamination of USDWs; therefore, the external integrity of NC_INJ1, NC_INJ2, and NC_OBS1 will be confirmed throughout the injection phase of the project. External MIT activities will occur annually.

This project plans to use temperature monitoring to ensure external mechanical integrity. It is noted that the practice of running temperature logs to ensure external mechanical integrity is a generally accepted method used in Class I and II wells across multiple EPA regions. Radioactive tracer (RAT) logs can be run contingently to ensure external mechanical integrity, if required.

Table 11 shows the logs to be run to display external mechanical integrity, as well as the frequency with which they will be run and the depth range they will be run over.

Table 11: External mechanical integrity tests

Test	Well	Depth Range (MD feet)	Schedule
Temperature Log	NC_INJ1, NC_INJ2	Surface to Well TD	Annually
	NC_OBS1	Surface to Well TD	Annually
Radioactive Tracer Log	NC_INJ1, NC_INJ2	500 feet above packer to Well TD	If required

It is important to note that while PNL is not planned to be a direct method of displaying external mechanical integrity, it can be used to identify accumulations of CO_2 adjacent to the wellbore in intervals above the injection zone.

6.2.1.1 Temperature Logging

Temperature logging is used to establish a temperature profile of the well and make year to year comparisons to determine if any unexpected variations are present. Multiple temperature logging runs are acquired during each event in order to capture the temperature decay over a six-hour period (Table 12).

Temperature logs will be run using the same tool assembly as is presented in the RAT logging Section (7.2.1.2). The well will be shut-in, and a baseline temperature log will be run as per the schedule in Table 12. This will allow for four temperature curves to be plotted for each year that temperature logs will be performed. Temperature logs will be acquired from the bottom up.

Table 12: Temperature logging schedule for well integrity

Temperature Logging Run	Time Increment from Shut-in (hours)
Baseline	Shut-in
Second	1
Third	3
Fourth	6

6.2.1.2 Radioactive Tracer Logging

The primary purpose of RAT logging is to verify the absence of pathways along the wellbore for the upward migration of injection zone fluids. RAT logging will be performed in accordance with federal and state guidance if it is required.

RAT logs can be run while fluid is actively being injected into the well. As such, pressure, temperature, and rate data can be collected as part of the logging activities and reporting.

A RAT logging tool can be run on the same string as a gamma ray (GR), casing collar locator (CCL), and temperature tool. A summary of the general testing events is provided below.

1. Run baseline GR log across the zone of interest.
2. Run 5-minute statistical (stat) checks on the tool. These stat checks should be run in an area with a known low GR signature, and in an area with a known, higher GR signature. This check will help to ensure the tool is operating properly.
3. Run tracer chase sequence. A tracer will be ejected at least 300 feet above the packer, after which the tool will chase the tracer down the injection string and into the cased-hole interval by performing successive downward passes through the well. Multiple passes will be made over the perforated interval to ensure that all the tracer has exited the tubing and passed into the Mt. Simon Sandstone.
4. Run time-drive sequence. A tracer will be ejected at least 300 feet above the packer. After which the tool will be moved to just above the packer. The tool will record the GR measurements at the set depth for a minimum of 30 minutes. During this time, the tracer will be observed passing the tool and never have any upward movement.
5. Run final GR log across the zone of interest.

This sequence of logs will allow for investigation into any potential upward pathways for fluid migration out of the injection interval present during injection.

6.2.2 Testing Details

The data from each annual logging event will be compared to the baseline log to determine if there are any inconsistencies between the logs. If inconsistencies appear, the cause of the deviations will be determined, and additional logs will be performed over the entire depth of the well to substantiate results of the MIT logging.

7. Pressure Fall-off Testing (40 CFR 146.90 (f))

The project will perform pressure fall-off tests (FOT) during the injection phase as described below to meet the requirements of 40 CFR 146.90(f).

Pressure fall-off testing involves the measurement and analysis of pressure data from a well after it has been shut-in. FOT tests provide the following information:

- Confirmation of reservoir properties such as flow capacity (KH), which is used to derive average permeability,
- Formation damage (skin) near the well bore, which can be used to diagnose the need for well remediation,
- Changes in injection zone performance over time, such as long-term pressure build-up in the injection zone.

Average injection zone pressure can be used to calibrate computational modeling predictions of injection zone pressure to verify that the operation is responding as modeled/predicted.

7.1 Testing Location and Frequency

Fall-off tests will be run every five years on NC_INJ1 and NC_INJ2 during injection operations. An initial FOT will be run as part of the pre-operational testing to be performed on the well. The permanent downhole pressure gauges set above the packer will be used for the FOT. Surface monitoring equipment will be used to monitor injection data for the test.

7.2 Testing Details

To begin the FOT a constant rate injection period will be used for a minimum period of 24-hours. The rate will be kept within ±5% during this period and will be at a rate that is representative of the injection rate for normal operations.

Following this constant rate injection period, injection will cease, and the well will be shut-in at the wellhead. Pressure will be monitored for a period to be no longer than the constant rate injection period. Following the shut-in period, the well will be restarted, and routine injection operations will resume.

Surface monitoring equipment will be used to record the injection data. This test can be performed as a function of routine injection operations and will prevent any additional shut-in of the well other than what is necessary for the test.

The downhole pressure data will be collected, and pressure transient analysis (PTA) will be performed on the data. Analysis of the test data will be completed using PTA techniques that are consistent with guidance for conducting pressure fall-off tests.

8. CO_2 Plume and Pressure Front Tracking (40 CFR 146.90 (g))

The project will employ direct and indirect methods to track the extent of the CO_2 plume and the presence or absence of elevated pressure during the operation period to meet the requirements of 40 CFR 146.90 (g).

8.1 Plume Monitoring Location and Frequency

Table 13 presents the methods that the project will use to monitor the position of the CO_2 plume; this includes the activities, locations, and frequencies the project will employ. The parameters to be analyzed as part of fluid sampling in the injection zone and associated analytical methods are presented in Table 9. Quality assurance procedures for these methods are presented in the QASP (Attachment 11: QASP, 2023).

Table 13: CO_2 plume monitoring activities

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Direct Plume Monitoring				
Mt. Simon Sandstone	Fluid Sampling	NC_OBS1	Injection zone TBD	Annually
	PNL	NC_INJ1, NC_INJ2 NC_OBS1	ACZ monitoring interval to TD	Annually Annually
	Downhole Pressure and Temperature	NC_INJ1, NC_INJ2 NC_OBS1	Above Packer Injection zone TBD	Continuous
Indirect Plume Monitoring				
Entire Interval	Time-lapse 3D Surface Seismic Data	Over projected CO_2 plume	Area sufficient to image modeled CO_2 plume extent	Every 5-10 years, as appropriate
Entire Interval	Passive Seismic Monitoring	Minimum of five (5) Stations with expansion	Events within the pressure front	Continuous

Fluid samples will be obtained for analysis from the Mt. Simon Sandstone during the initial well completion and pre-operational testing program (Attachment 05: Pre-operational Formation Testing Program, 2023). The final sampling interval in the Mt. Simon Sandstone in NC_OBS1 will be determined after the well has been drilled and the well logs have been analyzed. The CO_2 plume is expected to intersect NC_OBS1 approximately three to five years after injection commences. Once free phase CO_2 breaks through at the NC_OBS1 sampling interval, the project will stop taking fluid samples from the injection zone.

Baseline PNL logs will be acquired in NC_INJ1, NC_INJ2, NC_OBS1, NC_ACZ1, and NC_ACZ2 prior to the start of injection operations. Once injection starts, PNL logs will be acquired in NC_INJ1, NC_INJ2, and NC_OBS1 once each year. PNL logs may be acquired in the ACZ wells as a contingency monitoring action.

A baseline 3D surface seismic survey will be acquired prior to the start of injection operations. Subsequent time-lapse 3D surface seismic surveys will be acquired every five to ten years after injection operations commence.

At this time, no continuous CO_2 plume monitoring has been planned for the project. The only monitoring technique that will take phased or adaptive monitoring approach is the passive seismic monitoring where it is expected that the monitoring array will increase in size over the operational life of the project. However, if during the reassessment of the AoR during the injection phase of the project, the AoR is shown to have grown, the Testing and Monitoring Plan will be reassessed (Attachment 02: AoR and Corrective Action Plan, 2023).

8.2 Plume Monitoring Details

As CO_2 is injected into the injection zone, the geochemistry of the fluids in the formation are expected to change. Geochemical modeling will be used to predict the geochemical changes to the Lower Mt. Simon Sandstone and Arkose Zone fluids once data from the pre-operational testing program has been collected (Attachment 05: Pre-operational Formation Testing Program, 2023).

The results of the geochemical will be delivered in the form of lab reports. Sections 5.2 and 5.3 of this document detail the sampling procedures and the analytical and field parameters that will be used for the fluid sampling. Details on the methods, containers, and preparation methods for the fluid sampling can be found in the QASP (Attachment 11: QASP, 2023). The project will stop taking fluid samples from the Mt. Simon Sandstone once free phase CO_2 is encountered at the sampling ports.

The PNL logs will be received as LAS files, and the interpreted products that can be imported into the static model. This logging data will be used to monitor the distribution and saturation of CO_2 adjacent to the wellbores in NC_INJ1, NC_INJ2, and NC_OBS1. The logs will be acquired through the Ironton-Galesville formations as well to confirm the absence of CO_2 accumulations along the wellbore above the confining zone in the ACZ monitoring zone. Technical details on the logging tools can be found in the QASP (Attachment 11: QASP, 2023).

Surface seismic data is delivered in a variety of formats including acquisition and processing reports and SEG-Y data files. The data will be processed using industry standard workflows for noise attenuation, demultiple, pre-stack migration, and time-lapse analysis. For time-lapse analysis, an assessment will be provided on the differences between the baseline and time-lapse surveys. The injection of CO_2 and expansion of the plume is expected to change the acoustic impedance and travel times of the seismic waves through the injection zone, and these changes will be used to track CO_2 plume development over time. The time-lapse surface seismic data will also be examined for changes that may suggest that CO_2 has migrated past the confining zone and into the overlying formation(s).

The results of the geochemical analyses, PNL, and time-lapse 3D surface seismic data will be integrated to evaluate the CO_2 plume development over time. The logging and time-lapse 3D surface seismic data can be incorporated into the static model for comparison to the computational modeling predictions at different points in time. The monitoring data can be used to constrain the computational modeling results and produce more accurate plume predictions over the course of the project. The logging data will be used to calibrate the computational modeling on a yearly basis and provide information on the vertical and horizontal plume development. It will also provide more detailed and direct measurement of CO_2 saturations than indirect seismic methods. The time-lapse 3D surface seismic data will be used to update the models every five to ten years. If the CO_2 plume monitoring data diverges significantly from the modelled plume predictions, it may result in a reassessment of the AoR (Attachment 02: AoR and Corrective Action Plan, 2023).

8.3 *Pressure Front Monitoring Location and Frequency*

Table 14 presents the methods that the project will use to monitor the position of the pressure front; this includes the activities, locations, and frequencies that the project will employ. Quality assurance procedures for these methods have been presented in the QASP (Attachment 11: QASP, 2023).

Table 14: Pressure front monitoring activities

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Direct Pressure-Front Monitoring				
Mt. Simon Sandstone	Pressure Monitoring	NC_INJ1, NC_INJ2 NC_OBS1	Above Packer Injection zone TBD	Continuous
Indirect Pressure-Front Monitoring				
Eau Claire Formation Mt. Simon Sandstone	Passive seismic monitoring	Minimum of five (5) Stations	Events within the pressure front	Continuous

The pressure sensors will be programmed to measure and record pressure and temperature readings every 10 sec. The pressure sensors in the injection wells will be set above the packers. In NC_OBS1, the pressure sensor will be set in the injection zone with the final depth to be determined once the well logs have been analyzed (Attachment 05: Pre-operational Formation Testing Program, 2023). The project will start recording pressures in the injection zone in the injection wells and the deep observation well in the quarter before injection operations commence.

Induced seismicity data will also be recorded on a continuous basis. This data will be sent to a cloud-based service via a cellular connection for data processing and archive. Baseline induced seismicity data will be acquired for four to six months prior to the start in injection operations. As the pressure front expands over time, the array may be expanded to better locate seismic events that occur at a greater distance from the injection wells. The AoR will be reassessed on a regular basis through the injection phase of the project, if the AoR increases in area then the Testing and Monitoring Plan will be reassessed (Attachment 02: AoR and Corrective Action Plan, 2023).

8.4 *Pressure Front Monitoring Details*

Sensors will be placed on the tubing string of NC_INJ1, NC_INJ2, NC_OBS1, NC_ACZ1, and NC_ACZ2 to monitor the pressures. Temperature will also be collected in NC_INJ1 and

NC_INJ2. The gauges will collect and transmit data to surface continuously. Refer to the QASP for technical information on the potential pressure gauges (Attachment 11: QASP, 2023).

The pressure data and temperature data for NC_INJ1, NC_INJ2, and NC_OBS1 will be stored as time-stamped data. It is expected that the pressure in the injection zone will begin to increase when injection operations begin. This data will be used to calibrate the computational modeling results over the injection and PISC phases of the project. Calibrating the computational model with pressure data from the injection zone will lead to more accurate predictions of pressure front behavior over time. The AoR and Corrective Action Plan further discusses how the pressure and temperature data will be used to calibrate the computational modeling, and how it might be used to trigger an early reassessment of the AoR (Attachment 02: AoR and Corrective Action Plan, 2023).

Initially, the passive seismic monitoring array will consist of five monitoring stations with one station located close to the injection wells, and the other four stations distributed around the AoR in proximity to the injection wells. The objective of the array will be to monitor induced seismic events within the pressure front with a magnitude of completeness (Mc) of 1.5. As the pressure front expands over time, the array number and aerial distribution of the stations may be increased to better locate induced seismic events that occur at a greater distance from the injection wells. The physical locations of these stations will be optimized through a design process once the data from NC_INJ1, NC_INJ2, and NC_OBS1 have been analyzed. The local array will be complemented with the addition of any relevant regional seismometer stations that are available through the Incorporated Research Institutions for Seismology (IRIS) to aid in positioning events from outside the AoR.

Each standalone station will likely consist of a seismometer, digitizer, solar with battery backup, and a cell modem/antenna. Triggered data will be processed to provide magnitude and location error ellipsoids on a real-time basis and results will be reviewed by a data processor and event data can be received by the project daily. Automatic notifications will be sent for events over a certain size. The event locations will be incorporated into the static model.

9. References

ASTM G1-03, 2017, ASTM G1-03: Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens, *in* Annual Book of ASTM Standards: ASTM International, p. 9.

Attachment 01: Narrative, 2023: Compass.

Attachment 02: AoR and Corrective Action Plan, 2023: Compass.

Attachment 05: Pre-operational Formation Testing Program, 2023: Compass.

Attachment 06A: NC INJ1 Well Operations, 2023: Compass.

Attachment 06B: NC INJ2 Well Operations, 2023: Compass.

Attachment 10: ERRP, 2023: Compass.

Attachment 11: QASP, 2023: Compass.

Bauer, R. A., M. Carney, and R. J. Finley, 2016, Overview of microseismic response to CO2 injection into the Mt. Simon saline reservoir at the Illinois Basin-Decatur Project: International Journal of Greenhouse Gas Control, v. 54, p. 378–388, doi:10.1016/j.ijggc.2015.12.015.

Bauer, R., W. R, S. Greenberg, and S. Whittaker, 2019, Illinois Basin - Decatur Project: Geophysics and Geosequestration, p. 339–369.

Gollakota, S., and S. McDonald, 2014, Commercial-scale CCS Project in Decatur, Illinois - Construction Status and Operational Plans for Demonstration: Energy Procedia, p. 5986–5993.