7.0 TESTING AND MONITORING PLAN 40 CFR 146.90

MARQUIS BIOCARBON PROJECT

Facility Information

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Well name: MCI CCS 3

Well location: PUTNAM COUNTY, ILLINOIS
S2 T32N R2W
Latitude: 41.27026520 N, Longitude: 89.30939322 W

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7.0 Testing and Monitoring Plan

7.1 Overall Strategy and Approach for Testing and Monitoring

This Testing and Monitoring Plan describes how Marquis Carbon Injection LLC will monitor the site pursuant to 40 CFR 146.90.

The Testing and Monitoring Plan has been developed in conjunction with the project risk assessment to reduce the risks associated with carbon dioxide (CO_2) injection. Goals of the monitoring strategy include:

- Meeting the regulatory requirements of 40 CFR 146.90
- Protecting underground sources of drinking water (USDWs)
- Ensuring that the MCI CCS 3 well is operating as planned
- Providing data to validate and calibrate the geological and dynamic 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. The Plan will be reviewed periodically, no less often that once every five years, to incorporate monitoring and operational data recorded and the most recent area of review re-evaluation.

Also, the plan can be adjusted between period reviews to respond:

- As project risks evolve over the course of the project
- If significant differences between the monitoring data and predicted dynamic modeling results are identified
- If key monitoring techniques indicate anomalous results related to well integrity or the loss of containment

An amendment to the plan or a demonstration that no amendment to the Plan is necessary shall be submitted to the Director as follows:

1. Within one-year of a AoR re-evaluation;
2. Following any significant changes to the facility; or
3. When required by the Director.

Figure 7-1 illustrates the modeled CO_2 plume at the end of the injection period. The AoR and Corrective Action Plan, Permit **Section 2**, (40 CFR 146.84 (b)) describes the data and computational techniques used to model the development of the CO_2 plume during injection. It describes the data collected in the characterization well (MCI MW 1) and how it was used to build the static earth model (SEM) also incorporating the two-dimensional (2D) and three-dimensional (3D) seismic data. In addition, it explains how the data collected as part of this

Testing and Monitoring Plan will be used to re-evaluate the AoR over the pre-operational and injection phases of the project (40 CFR 146.84 (e)). Permit **Section 5** describes the data that will be collected in MCI CCS 3 that will be used to confirm the model and AoR during the post construction / pre-injection phase of the project prior to injection.

Certain outcomes of the testing and monitoring activities described below may trigger action according to the Emergency and Remedial Response Plan, Permit **Section 10**, (40 CFR 146.94 (a)).

The Testing and Monitoring Plan will utilize several direct and indirect monitoring technologies throughout the injection and post-injection site care (PISC) phases of the project that will monitor:

- Daily activities of the injection operations
- Development of the CO_2 and pressure plumes in the storage formation over time
- Well integrity
- CO_2 or brine containment within the injection reservoir
- Groundwater quality in multiple aquifers, including the deepest USDW (Gunter Sandstone) and the deepest water-bearing formation above the caprock (Galesville Sandstone)

Note that tools and techniques listed in this plan are a minimum type of measurement that will be taken. More advanced measurement techniques may be employed to aid in operational and safety risk as long as the goal of each measurement is fulfilled.

7.1.1 Deep Well Monitoring

This plan includes two deep monitoring wells and one monitoring well above the confining zone in the locations designated in **Figure 7-1**. The description of the wells is as follows:

- Proposed MCI MW 2 which extended the depth of the confining layer and injection zones and is within the CO_2 plume.

- Existing MCI MW 1 that was the stratigraphic test well. Which extends the depth of the confining later and injection zones. This deep well will be used for extended field monitoring. It will be used as a contingency in the monitoring plan. Should the need arise for cross-well measurements or downhole measurements, like Vertical Seismic Profile (VSP), this well will be employed as an additional data point to confirm CO_2 plume movement.

- Proposed MCI ACZ 1 will be installed adjacent to the MCI CCS 3 well that extends to the confining layer which will monitor the aquifers above the confining layer.

All monitoring wells that transect the Eau Claire seal will be completed to the same Class VI standards as the injection well. Injection operations will be monitored through a range of continuous, daily, and quarterly techniques as detailed in the Well Operations Plan, Permit **Section 6**, (40 CFR 146.82(a)(8), 146.87). The water content and chemical composition of the CO_2 stream will be monitored downstream of the final compression and dehydration (40 CFR 146.90 (a)). Corrosion coupons composed of the same material as the well components and CO_2-delivery piping will be placed in the delivery piping to the well head and analyzed on a quarterly basis for signs of corrosion and loss of mass that may be indicative of future potential well integrity issues. Additionally, every 6 years after the beginning of injection through the end of the post-closure period, the MCI CCS 3 well itself will be assessed for signs of corrosion using well logging techniques, such as multi-finger caliper logging or an ultrasonic casing evaluation tool. (40 CFR 146.90 (c).

Continuous recording devices will monitor wellhead injection pressure, temperature, and mass flowrate (40 CFR 146.90 (b)) to MCI CCS3. The injection mass flowrate will be directly measured at the surface to monitor the cumulative mass of injected CO_2 and ensure compliance with the permit injection limits.

Pressure and temperature data will be recorded from MCI CCS3 continuously on surface and in down hole before and after injection. The pressure and temperature will be measured using a pressure transducer and thermocouple, respectively. The transducer and thermocouple will continuously capture baseline data and throughout injection.

The annular pressure between the tubing and the injection casing strings and the annular fluid volume will also be monitored on a continuous basis in the injection well, MCI CCS 3 (40 CFR 146.90 (b)). The data from MCI CCS3 will be linked to a distributed control system (DCS) to record the operations data, control injection rates, and initiate system shutdown, if required. The DCS system will be used to adjust the volume of annular fluid, and thereby pressure, in the annular space to meet the operational and regulatory objectives.

In the deep monitoring wells, the annulus between the casing and tubing string is fill with a brine fluid and sealed. A gauge will be installed on the surface of each of the deep monitoring well to monitor the annular pressure, and readings will be logged weekly.

The objective of annular pressure monitoring is to identify sustained casing pressure (SCP), loss in pressure, or annular fluid loss. This could be an indication of leaks in downhole tubulars or loss of well integrity.

Confidential, Privileged, or Sensitive Business Information

[redacted]

Figure 7 - 1: CO_2 plume for the Marquis BioCarbon Project.

The well integrity of the injection and deep monitoring wells will be monitored using a range of internal and external mechanical integrity evaluation methods. Initially, a mechanical integrity test (MIT) will be performed on the MCI CCS 3 and MCI MW 2 following the well completion to confirm internal integrity as per the Pre-Operations Testing Plan, Permit **Section 5**, (40 CFR 146.82(a)(8) and 146.87). External mechanical integrity will be confirmed through continuous temperature monitoring and annual temperature data using a DTS collection system on MCI

CCS 3, MCI MW 2, and MCI MW1 and compared to baseline temperature logging data to identify any deflections from the temperature gradient that could indicate fluid flow behind the casing (40 CFR 146.90 (e)).

Confidential, Privileged, or Sensitive Business Information [redacted] During the injection phase of the project, a PFO test will be conducted in the MCI CCS 3 well at least once every five years. If there is an injection pressure increase of more than 10%, over a period of one month, compared to the computational model, then a PFO test will be conducted sooner (40 CFR 146.90 (f)). The objective of the PFO testing is to periodically monitor for any changes in the near wellbore environment that would impact injectivity or cause injection pressures to increase (EPA, 2013). The formation characteristics obtained through the PFO testing will be compared to the results from previous tests to identify any changes over time and will be used to calibrate models.

Confidential, Privileged, or Sensitive Business Information [redacted] If confirmed, this would trigger external well integrity testing of the injection and deep monitoring wells and may trigger the emergency response actions found in the Emergency and Remedial Response Plan (Permit **Section 10**).

Pressure and temperature sensors in the deep monitoring well (MCI MW 2) will be used to measure variations in the storage formation in the pre-operational, injection, and post-injection phases of the project (40 CFR 146.90 (g)). These sensors will continuously record data. This deep monitoring well will also be used to collect fluid samples from the storage formation to monitor for changes in the water chemistry over time and verify when the leading edge of the CO_2 plume reaches the MCI MW 2 well.

Pulsed Neutron Capture (PNC) logs will be acquired in MCI CCS 3, MCI MW 2, and MCI ACZ 1 well to identify the intervals and concentration of CO_2 across the injection zone and primary confining zone. This pressure and PNC log data will also be used to calibrate the dynamic modeling over the injection and PISC phases of the project.

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[redacted]

Figure 7 - 2: Stratigraphic column from MCI MW 1 well located at the Marquis BioCarbon Project site.

7.1.2 Shallow Groundwater Monitoring

The shallow groundwater monitoring program consists of five wells (MCI GW 1-5) located on land owned by Marquis. GW 1-4 wells are existing shallow wells identified on **Figure 7-1**. The well on the Figure marked with a box around a well identifier is where GW 5 will be located. An existing or new groundwater well will be used as part of the monitoring program. If GW 5 is a new well, it will be installed according to the Illinois Department of Public Health regulations. Representative cores will be taken during the drilling, and the monitoring well location and well logs will be available through the Illinois State Geological Survey. The monitoring well will be constructed of 2-inch PVC materials and threaded connections. A slotted well screen will be installed that is appropriately sized for the formation, and the well will be drilled shallower than 300 feet. A well head will be placed on the surface, and the well will be easily accessible for monitoring. The well will be developed, and sampling will be conducted in accordance with the shallow groundwater monitoring procedures in this section and **Appendix 7.A**.

To establish a baseline of the seasonal variation in the aqueous geochemistry of these shallow groundwater wells, sampling will be collected prior to the start of CO_2 injection. Throughout the injection and Post-Injection Site Closure (PISC) phases of the project, the results of the aqueous geochemistry and stable isotope analyses will be compared to the baseline conditions for any indication of CO_2 or brine migration into the shallow groundwater aquifer. If indications of CO_2 or brine are found in the shallow groundwater aquifer, it will trigger the emergency response actions found in the Emergency and Remedial Response Plan (Permit **Section 10**).

7.1.3 Seismic Monitoring

Several indirect monitoring techniques will be deployed to monitor the development of the CO_2 plume and the associated pressure front through the injection and post-injection project phases (40 CFR 146.90 (g)). Time-lapse three-dimensional (3D) surface seismic data will be used to qualitatively monitor the CO_2 plume development and calibrate the computational modeling results over time. Confidential, Privileged, or Sensitive Business Information [redacted]

Background seismic activity will be monitored continuously using a site-specific microseismic monitoring network designed to optimize the accuracy of the event locations and event magnitudes (**Section 7.8.3**). Collection of microseismic background data will begin 4-6 months prior to injection. The location of individual stations within this network can be adjusted as required in response to monitoring results or future AoR re-evaluations. The location of the stations that have been installed around the MCI CCS 3 are depicted on **Figure 7-10.**

The project site is in an area of Illinois with low rates of seismic activity and risk (Permit **Section 1**, Project Narrative). The primary goals of continuous background seismicity monitoring are to:

- Determine whether there is induced seismic activity;

- Monitor the spatial extent of the pressure front from the distribution of seismic events; and
- Identify activity that may indicate failure of the confining zone and possible containment loss.

7.1.4 Monitoring Schedule

Table 7-1 presents the general schedule and spatial extent for the monitoring activities in the baseline and injection phases of the project. Refer to the PISC and Site Closure Plan (Permit **Section 9**) for discussion of the monitoring plans related to the PISC phase. Changes to the monitoring schedule may occur over time as the project evolves. For instance, if anomalous results are identified in the existing monitoring data, confirmation sampling will be conducted within 10 days, and additional monitoring data may be acquired through subsequent investigations into the anomalous results. Likewise, if the CO_2 plume behaves in a stable and predictable manner for many years through the injection phase of the project, some monitoring may be reduced in frequency. Any such changes to the Testing and Monitoring Plan will be made in consultation with the Underground Injection Control (UIC) Program Director (40 CFR 146.90 (j)).

Monitoring Activity	**Baseline Data Frequency**	**Injection Phase Frequency (Note 1)**	**Location**	**Formation top / Depth Range (ft, MD) (Note 2)**
Assurance Monitoring:				
Shallow Groundwater Sampling (Note 2)	Once/quarter	Twice/year	MCI GW 1 - 4 existing wells and GW 5 existing or new well within AoR	Confidential, Privileged, or Sensitive Business Information [redacted]
Isotope Analysis	Once/quarter	Twice/year	MCI GW 1 - 4 existing wells and GW 5 existing or new well within AoR	Confidential, Privileged, or Sensitive Business Information [redacted]
Operational Monitoring:				
CO_2 Stream Sampling and Lab Analysis	N/A	Quarterly (Note 6)	After Last Stage of Compression and Before Injection	Confidentia [redacted]
Corrosion Coupon Analysis	N/A	Quarterly	CO_2 Delivery Plant Piping to Wellhead	Confidentia [redacted]
CO_2 Stream real time Analysis including N_2, H_2O and O_2	NA	Quarterly (Note 7)	CO_2 Delivery Plant Piping to Wellhead	Confidentia [redacted]
CO_2 Surface Injection Pressure (Injection Stream)	N/A	Continuous	Wellhead - MCI CCS 3	Confidential, Privileged, or Sensitive Business Info [redacted]
CO_2 Surface Injection Temperature	N/A	Continuous	Wellhead - MCI CCS 3	Confidential, Privileged, or Sensitive Business Inf [redacted]

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency (Note 1)	Location	Formation top / Depth Range (ft, MD) (Note 2)
CO_2 Down hole Injection Pressure	Continuous	Continuous	MCI CCS 3	[redacted]
CO_2 Down hole Injection Temperature	Continuous	Continuous	MCI CCS 3	[redacted]
Mass CO_2 Injection Rate	N/A	Continuous	Pre-Wellhead (Before wellhead after compressors)- MCI CCS 3	[redacted]
Annulus Pressure	N/A	Continuous	MCI CCS 3	[redacted]
		Weekly	MCI MW 1	[redacted]
		Weekly	MCI MW 2	[redacted]
		Weekly	MCI ACZ 1	[redacted]
Annulus Fluid Volume Added	NA	Continuous	MCI CCS 3	[redacted]
Wellbore Temperature Profile (storage formation) (DTS Fiber Optic)	Once	Annually	MCI CCS 3	[redacted]
Monitoring well Temperature Profile (Storage Formation) (DTS Fiber Optic)	Once	Annually	MCI MW 1 MCI MW 2	[redacted]
PFO Tests	Once	Every 5 years	MCI CCS 3	[redacted]

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency (Note 1)	Location	Formation top / Depth Range (ft, MD) (Note 2)
Verification Monitoring:				
Fluid Sampling				
Gunter Sandstone	Twice/year	Twice/year	MCI ACZ 1	[redacted]
Galesville Sandstone	Twice/year	Twice/year	MCI ACZ 1	
Mt. Simon Sandstone	Twice/year	Twice/year	MCI MW 2	
Isotope Analysis	Twice/year	Twice/year	MCI ACZ 1 MCI MW 2	[redacted]
Pressure – Temperature Sensors				
Gunter Sandstone	Continuous	Continuous	MCI ACZ 1	[redacted]
Galesville Sandstone	Continuous	Continuous	MCI ACZ 1	
Mt. Simon Sandstone	Continuous	Continuous	MCI MW 2	
PNC Logging	Once	Once/ year	MCI MW 2 MCI ACZ 1	[redacted]
Microseismic Monitoring	4 to 6 months prior to injection	Continuous	Surface stations	[redacted]
Time-lapse 3D Surface Seismic Data	Once	Every 5 years or 4 Million Tonnes of CO_2 injection, whichever occurs first	Surface	[redacted]

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency (Note 1)	Location	Formation top / Depth Range (ft, MD) (Note 2)
Corrosion Monitoring – multi-finger caliper logging or ultrasonic casing evaluation	NA	Every 6 years after beginning of injection	MCI CCS3	[redacted]
Modeling of CO_2 Plume/AoR:				
Dynamic Modeling	Once	Every 5 years or 4 Million Tonnes of CO_2 injection, whichever occurs first	Storage Formation	[redacted]

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency (Note 1)	Location	Formation top / Depth Range (ft, MD) (Note 2)
Notes: 1) Minimum frequency 2) All depths are estimates based on stratigraphic test well. Actual depths will be confirmed once wells are drilled, and installation plans are completed. 3) An evaluation and request were submitted to the Program Director to utilize existing shallow wells located within the AoR as part of the groundwater monitoring program. For establishing baseline, sampling of the deep wells will occur during well drilling and prior to start of injection. 4) Confidential, Privileged, or Sensitive Business Information [redacted] 5) Microseismic stations have been installed to collect background data. See **Figure 7-10** which shows current location of stations. Stations may be relocated if necessary, and documentation showing basis for the change and new location will be retained in the facility records. 6) After construction of the injection well and initial startup of the well and reaching steady state, the first quarterly CO2 stream sampling and lab analysis will be conducted. 7) After initial startup of the well and during the first quarter, continuous CO_2 stream analysis will be conducted by a dedicated real time Gas Chromatograph (GC). After the first quarter, continuous analysis will be collected by the GC for a 7-day period each quarter during the injection phase.				

Table 7-1: General schedule and spatial extent for the testing and monitoring activities for the Marquis BioCarbon Project.

7.1.5 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 shallow USDW aquifer are described in the Quality Assurance and Surveillance Plan (QASP) (**Appendix 7.A**). These measurements will be performed based on best industry practices and the QA protocols recommended by the service contractors selected to perform the work.

7.1.6 Reporting Requirements (40 CFR 146.91)

Marquis Carbon Injection LLC will provide notification and reports to the Director, including the results of all testing and monitoring activities in compliance with the requirements under 40 CFR 146.91 for each permitted Class VI Well as follows:

7.1.6.1 Electronic Reporting

Marquis Carbon Injection LLC will provide reports, submittals, notifications, and records to the Director in an electronic format approved by the EPA to the following website at https://gsdt.pnnl.gov/ unless an alternative method is instructed to be used by the EPA.

7.1.6.2 Semi-Annual Reports

Semi-Annual Reports for MCI CCS 3 shall contain the following information:

(a) Any significant changes to the physical, chemical, and other relevant characteristics of the carbon dioxide stream from the proposed operating data;

(b) Monthly minimum, average, and maximum values for injection pressure, flow rate and daily volume, temperature, and annular pressure;

(c) A description of any event that exceeds the operating parameters for the annulus pressure or injection pressure specified in the permit;

(d) A description of any event which triggers the shut-off systems based on permit operational alarm value setpoints required pursuant to 40 CFR 146.88(e), along with the response measures implemented;

(e) The monthly volume and/or mass of the carbon dioxide stream injected over the reporting period and the volume and/or mass injected cumulatively over the life of the Marquis Biocarbon Project;

(f) Monthly annulus fluid volume added or produced; and

(g) Monitoring results required in the Testing and Monitoring Plan, including:

   i. In tabular form, the: (1) daily maximum injection pressure; (2) daily minimum annulus pressure; (3) daily minimum value of the difference between simultaneous measurements of annulus and injection pressure; (4) daily volume; (5) daily maximum flow rate; and (6) average annulus tank fluid level; and (6) average annulus tank fluid level; and

ii. Graph(s) of the monitoring as required, or of daily average values of these parameters. The injection pressure, injection volume and flow rate, annulus fluid level, annulus pressure, and temperature shall be submitted on one or more graphs, using contrasting symbols or colors, or in another manner approved by the Director; and

iii. Results of any additional monitoring identified in the Testing and Monitoring Plan.

7.1.6.3 Thirty Day Reporting

Within 30 days, Marquis Carbon Injection will report:

(a) Periodic tests of mechanical integrity;

(b) Any well workover or stimulations;

(c) Any test of any monitoring well required by the permit; and

(d) Any other test of the injection well conducted by the permittee if required by the Director.

7.1.6.4 Twenty-Four Hour Reporting

Within 24-hours, Marquis Carbon Injection will report to the Director any permit non-compliance which may endanger human health or the environment and/or any events that require implementation of actions identified in the Emergency and Remedial Response Plan (Section 10.0). Any information shall be provided orally within 24 hours from the time the permittee becomes aware of the circumstances. Such verbal reports shall include, but not be limited to the following information:

(a) Any evidence that the injected carbon dioxide stream or associated pressure front may cause an endangerment to a USDW, or any monitoring or other information which indicates that any contaminant may cause endangerment to a USDW;

(b) Any noncompliance with a permit condition, or malfunction of the injection system, which may cause fluid migration into or between USDWs;

(c) Any triggering of the shut-off system required (i.e., down-hole or at the surface);

(d) Any failure to maintain mechanical integrity;

(e) Pursuant to compliance with the requirement at Section 146.90(h) for surface air/soil gas monitoring or other monitoring technologies, if required by the Director, any release of carbon dioxide to the atmosphere or biosphere; and

(f) Actions taken to address the unexpected movement of injection fluid or formation fluid in a manner than may endanger USDWs during the construction, operation or post-injection site care periods as outlined in the Emergency and Remedial Response Plan.

A written submission to document any required 24-hour report will be provided to the Director in an electronic format within five days of the time Marquis Carbon Injection becomes aware of the circumstances identified in Section 7.1.6.4. The electronic submission shall contain the following:

(a) A description of the noncompliance and the cause;

(b) The period of the noncompliance, including exact dates and times; and

(c) If the noncompliance has not been corrected, the anticipated time it is expected to continue, as well as actions taken to implement appropriate protocols outlined in the Emergency and Remedial Response Plan; and

(d) Steps taken or planned to reduce, eliminate and prevent a reoccurrence of the noncompliance.

7.1.6.5 Additional Reports

If applicable, the following additional reports will be submitted to the Director in an electronic format:

- Compliance Schedules – Reports of compliance or noncompliance with, or any progress reports on, interim and final requirements contained in any compliance schedule of this permit will be submitted no later than 30 days following each schedule date.
- Transfer of Permits – The Marquis Carbon Injection permit will not be transferrable to any person except after notice is sent to the Director at least 30 days prior to transfer and the requirements of 40 CFR 144.38(a) have been met. Pursuant to the requirements of 40 CFR 144.38(a), the Director will require modification or revocation and reissuance of the permit to change the name of the permittee and incorporate such other requirements as may be necessary under the Safe Drinking Water Act.
- Other Noncompliance – All other instances of noncompliance not otherwise reported with the next monitoring report. Other noncompliance reports shall contain the information listed in Section 7.1.6.2.
- Other Information – When Marquis Carbon Injection becomes aware of failure to submit any relevant facts in the permit application or that incorrect information was submitted in a permit application or in any report to the Director, such factual or corrected information will be provided within 10 days in accordance with 40 CFR 144.51(I)(8).

- Report on Permit Review – Within 30 days of receipt of the Class VI permit, Marquis Carbon Injection LLC will certify to the Director that he/she has read and is personally familiar with all terms and conditions of the permit.

7.1.7 Notification Reporting Requirements

Advanced reporting shall be provided in an electronic format notifying the Director of the following:

7.1.7.1 Well Testing

At least 30 days advance notification of any planned workover, stimulation, or other well test.

7.1.7.2 Startup After Triggering of the Shut-Off System

Advance written notice of startup after triggering of the shut-off system required (i.e., down-hole or at the surface) in accordance with 40 CFR 146.88(f).

7.1.7.2 Planned Changes

As soon as practical, advance notification of any planned physical alterations or additions to the permitted injection facility, other than minor repair/replacement or maintenance activities. An analysis of any new injection fluid shall be submitted to the Director for review and approval at least 30 days prior to injection. The Director approval may result in a permit modification.

7.1.7.3 Anticipated Noncompliance

Advance written notice of any planned changes in the permitted facility or activity which may result in noncompliance with permit requirements.

7.1.8 Recordkeeping Requirements

Marquis Carbon Injection will retain records of the following for a period of at least 10 years from collection:

(a) All monitoring information, including all calibration and maintenance records and all original chart recordings for continuous monitoring instrumentation. Such monitoring information shall include:

i. The date, exact place, and time of sampling or measurements;

ii. The name(s) of the individual(s) who performed the sampling or measurements;

iii. A precise description of both sampling methodology and the handling of the samples;

iv. The date(s) analyses were performed;

v. The name(s) of the individual(s) who performed the analyses;

vi. The analytical techniques of methods used; and

vii. The results of such analyses

(b) All reports required by the Class VI permit, including records from pre-injection, active injection, and post-injection phases.

The following records will be maintained for a period of at least 10 years after site closure:

- Records of all data required to complete the permit application form for the Class VI permit and any supplemental information (e.g., modeling inputs for AoR delineations and re-evaluations, plan modifications) submitted under 40 CFR 144.27, 144.31, 144.39, and 144.41;
- Records of information used to develop the demonstration of the alternative post-injection site care timeframe;
- Well plugging reports, post-injection site care data, and the site closure report; and
- Records concerning the nature and composition of all injected fluids.

7.1.9 State Contact Information

In accordance with 40 CFR 146.82(a)(20), only the State of Illinois is within the area of review for the Marquis Biocarbon project. There are no other States, Tribes or Territories within the AoR. Contact information for the State of Illinois will be directed through:

Illinois Environmental Protection Agency (IEPA)
Underground Injection Control Program
Bureau of Land – #33
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois. 62794-9276
(217) 782-3397 (Main Office)
(217) 524-3300 (UIC Wells)
Epa.ContactUs@illinois.gov

7.2 Carbon Dioxide Stream Analysis (40 CFR 146.90 (a))

Marquis Carbon Injection LLC 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.

7.2.1 Sampling Location and Frequency

The high-pressure CO_2 post dehydration and final compression prior to injection into MCI CCS3, will be continuously monitored by a dedicated real time Gas Chromatograph (GC). After startup and through the first quarter, the GC will continuously measure CO_2, N_2 and O_2 and provide these component values. After the first quarter, continuous analysis will be collected by the GC for a 7-day period each quarter during the injection phase.

After authorization to inject, the CO_2 stream will be sampled after the last stage of compression and dehydration and prior to injection into MCI CCS3 during steady-state operations to obtain representative CO_2 samples. Sampling and analysis will be conducted quarterly by the following dates each year: 3 months after initial sample, 6 months after the initial sample, 9 months after the initial sample, and 12 months after the initial sample. Currently, there is no plan to add tracers to the CO_2 stream.

Very little variation (<5%) is expected in the composition of the CO_2 that comes from the fermentation process CO_2 scrubbers due to the consistency of the process. In addition, the CO_2 stream will pass through at least one scrubber prior to entering the compressor and the piping to the wellhead. As such, quarterly sampling of the CO_2 injection stream after the compressors and dehydrator and prior to injection will be sufficient to accurately track the composition of the stream and confirm chromatograph results.

7.2.2 Analytical Parameters

Samples of the injection stream will be collected for chemical analysis. Based on data obtained from historic sampling / testing and modeling of the dehydration system, the samples will be analyzed for constituents identified in **Table 7-2**. The CO_2 compression system that will be used to inject the off gases into the MCI CCS 3 well has been selected. The compressor design includes the use of a triethylene glycol (TEG) gas dehydration system to remove moisture from the gas stream. After authorization to inject is obtained, initial samples of the injection stream will be collected in a sampling station that can purge and collect samples in a container that can be sealed prior to transfer to an accredited the laboratory. The species included for analysis may be expanded depending on the results of those analyses. Gas concentration analyses will be performed by a laboratory that holds a National Environmental Laboratory Accreditation and uses standardized procedures for gas chromatography, mass spectrometry, detector tubes, and photoionization. Samples of the CO_2 stream will be collected on a quarterly basis for chemical analysis.

Group	**Constituent**	**Rational**	**Method (Note 1)**	**CO_2 Spec**
Gases	Carbon Dioxide (CO_2)	Major constituent of CO_2 stream	ISBT 2.0	99%+
	Nitrogen (N_2)	Minor constituent of CO_2 stream	ISBT 4.0	<1 percent
	Oxygen (O_2)	Indicator of atmospheric contribution	ISBT 4.0	<500 ppm

Group	Constituent	Rational	Method (Note 1)	CO_2 Spec
	Hydrogen Sulfide (H_2S)	Not Expected to be Present. Minor constituent of CO_2 stream	ISBT 14.0	<20 ppm
	Total Hydrocarbons (Note 2 & 3)	Minor constituent in carry-through gas from CO_2 compressor dehydration system (Note 2)	ISBT 10.0	<50 ppm
	Ethanol		ISBT 11.0	<10 ppm
	Acetaldehyde		ISBT 11.0	<10 ppm
	Methane		ISBT 10.1	<1 ppm
Note 1: An equivalent method may be used with prior approval of the UIC Program Director.				
Note 2: Modeling of the system was conducted to determine the constituents collected in compressor knockout pots, emitted directly to the atmosphere, captured in the TEG dehydration process, and percentage retained with the liquified stream being injected. Gas stream constituents from CO_2 scrubber emissions testing were used in the model. Note 3: Analysis of hydrocarbons was based on the scrubber exhaust stream, but there is some variation possible due to the fermentation process and day-to-day operations.				

Table 7-2: Summary of analytes to be measured in the CO_2 stream.

7.2.3 Sampling Method – CO_2 Injection Stream Gases

The GC sample take off point on the high-pressure CO_2 discharge header will be equipped with a 2”CL900 RF sample quill equipped with a pressure regulator and isolation valve assembly. The GC will be physically located and mounted in the main CCS building. The GC communication and analog outputs will be connected to the facility distributed control system (DCS) control panel system. The GC will continuously measure CO_2, N_2 and O_2 and provide these component values after startup and during the first quarter. After the first quarter, continuous analysis will be collected by the GC for a 7-day period each quarter during the injection phase. The GC component values will be displayed in real time to the HMI.

The following is an example of the type of sampling system that could be used. Grab samples of the CO_2 stream will be obtained for analysis of the components present in the injection stream. Samples of the CO_2 stream will be collected after the 6-stage compression and prior to the injection well (MCI CCS3) where the stream is representative of the gas being injected. Confidential, Privileged [redacted]

(**Figure 7-3 and 7-3(a)**). Quick-connect fittings are attached to the cylinder's ¼-inch national pipe thread (NPT) fittings, and the cylinder is easily connected into the system. [redacted] Proper sampling technique is critical for any gas analysis program. Therefore, great care will be taken to ensure that the cylinder is not contaminated by atmospheric gas and the sample is representative of the CO_2 in the pipeline. A typical standard sampling system design is shown below in **Figure 7-3** and **7-3(b)**. The installed sample system will be a standard manual sampling station provided as a package from an analyzer vendor. Samples will be shipped to the lab after collection in accordance with the standard operating procedures (SOPs) found in Section B2 of the QASP (**Appendix 7.A**). Further details related to sampling methods can also be found in Section B2 of the QASP.

Figure 7 - 3(a): Example of double-ended sample cylinder (Atlantic Analytical Laboratory, 2021).

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[redacted]

Figure 7 - 3(b): Example Schematic of a Gas Sampling System with a High-Pressure Cylinder

7.2.4 Laboratory to be Used/Chain of Custody and Analysis Procedures

A nationally accredited environmental laboratory will analyze the CO_2 stream samples. The third-party laboratory will follow standard sample handling and chain-of-custody guidance (EPA 540-R-09-03, or equivalent). Details can be found in the QASP (**Appendix 7.A**).

7.3 Continuous Recording of Operational Parameters (40 CFR 146.88 (e)(1), 146.89 (b), and 146.90(b))

Marquis Carbon Injection LLC will install and use continuous recording devices to monitor injection pressure and temperature, mass injection rate, pressure on the annulus between the tubing and the long string casing, the annulus fluid volume added, and the temperature and pressure of downhole, as required at 40 CFR 146.88 (e)(1), 146.89 (b), and 146.90 (b). The details are described in the following sections.

7.3.1 Monitoring Location and Frequency

Marquis Carbon Injection LLC will perform the activities identified in Table 7-3 to monitor operational parameters and verify internal mechanical integrity of the MCI CCS 3 well. All monitoring will take place at the locations and frequencies shown in Table 7-3. All of the data recorded on a continuous basis will be connected to the main facility through a DCS system. The hourly average value of the parameter being continuously monitored and logged shall be recorded for purposes of reporting. If the electronic data logging system is out of service, field monitoring of manual gauges will be recorded at least twice per shift (i.e., every 6 hours).

Parameter	Device(s)	Location	Minimum Sampling Frequency (Notes 1 & 2)	Minimum Recording Frequency (Notes 2 & 3)
Confidential, Privileged, or Sensitive Business Information [redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Parameter	Device(s)	Location	Minimum Sampling Frequency (Notes 1 & 2)	Minimum Recording Frequency (Notes 2 & 3)
Confidential, Privileged, or Sensitive Business Information [redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Notes:

(1) 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.

(2) 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.

(3) If system communication is lost for greater than 30 minutes, manual field monitoring of gauges will be conducted every 6 hours or twice per shift for both CO_2 surface injection pressure and annulus surface pressure. Logs will be maintained in the facility records.

Table 7-3: Sampling devices, locations, and frequencies for continuous monitoring of MCI CCS 3.

7.3.2 Monitoring Details

7.3.2.1 Continuous Recording of Injection Pressure

The CO_2 injection pressure will be monitored on a continuous basis down hole and at the wellhead of the MCI CCS 3 well to ensure that injection pressures do not exceed 90% of the fracture propagation pressure of the injection zone (40 CFR 146.88 (a)). Further details are found in the Well Operations Plan (Permit **Section 6**). If injection pressure exceeds 90% of the injection zone fracture pressure, then the injection process will be automatically shut down in accordance with the Well Operations Program.

The wellhead pressure of the injected CO_2 will be continuously measured by an electronic pressure transducer located after the compression system and before the wellhead with the MCI CCS 3 well. The transmitter will be electronically connected to the DCS system located in the Control Building, which can shut down the system or change the flowrate depending on the pressures measured at the wellhead. The transducer will be calibrated prior to the start of injection operations, and as recommended by the manufacturer thereafter.

7.3.2.2 Continuous Recording of Injection Mass Flowrate

The mass flowrate of CO_2 injected into the well will be measured by a Coriolis mass flow meter. This flow meter will be placed in the CO_2 delivery line between the final compressor and the well. The Coriolis mass flow meter flow transmitter will have an output for instantaneous flow rates and density values along with a pulse output for totalization values (Micro Motion Elite Coriolis mass flow and density meter or similar). The Coriolis meter flow transmitter and P/T compensation transmitters will all be connected to the Measurement RTU flow computer system (Fisher FB 3000) for continuous monitoring and control of the CO_2 injection rate into the well. A hardwired signal will be connected from the Measurement RTU flow computer to the main DCS control panel via PROFINET. Two Coriolis mass flow meters will be supplied; this will provide one spare flow meter to allow for flow meter servicing and calibration. The mass flow meters will be calibrated annually.

7.3.2.3 Dynamic Modeling

In accordance with the AoR recalculation schedule, the data collected during the monitoring program will be analyzed and interpreted. The data will then be integrated into the static and dynamic models every 5 years or 4 million tons whichever is earlier, incorporating the data collected in the storage formation. The pressure, temperature and CO_2 plume data will be crucial to the AoR update. If there is confirmed anomalous data that could affect the AoR or CO_2 plume development, the static and dynamic models will be updated to show the effect of the data on the modeling results. AoR will then be re-established, and any necessary corrective actions will be taken. See Permit **Section 2.4** for additional details on AoR update.

7.3.2.4 Continuous Recording of Annular Pressure

As described in the Well Operations Program, the pressure on the annulus between the injection tubing and the long-string casing will be measured by an electronic pressure transducer with output, such as a Foxboro I/A Series® IAP20 or similar, that is mounted on the wing valve/annular fluid line connected to the wellhead of the MCI CCS 3 well. The transmitter will be connected to the well control system and the DCS system to regulate the annular pressure.

Annular pressure in MCI CCS 3 is expected to vary up to 20% during normal operations due to atmospheric and CO_2 stream temperature fluctuations. The annular pressure gauge will be calibrated annually, and the transducer will be recalibrated according to the manufacturer's recommendations.

Annular pressure between the casing and tubing string in the MCI MW 1, MCI MW 2, and MCI ACZ 1 well will be a simple pressure gauge at the wellhead checked weekly.

7.3.2.5 Continuous Recording of Annulus Fluid Volume

As described in the Well Operations Program, the volume of the annulus fluid between the injection tubing and the long-string casing will be measured using the brine reservoir level on the well annular control system. The brine reservoir level will be measured using a level transmitter (Rosemont 3051CD2A22A1AE5M5 or equivalent). The transmitters will be connected to the DCS system to regulate 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 startup and shutdown operations.

7.3.2.6 Continuous Recording of CO_2 Stream Temperature

The temperature of the CO_2 injection stream will be continuously measured using an electronic thermocouple. The thermocouple will be mounted in a temperature thermowell in the CO_2 injection stream at a location close to the pressure transmitter near the wellhead. The transmitter will be electronically connected to the DCS system. The transmitter will be calibrated prior to the start of injection operations and calibrated annually per manufacturer's instructions.

7.3.2.7 Down Hole Pressure and Temperature

Pressure and temperature data will be recorded from MCI CCS3 continuously on surface and in down hole before and after injection. The pressure and temperature will be measured using a pressure transducer and thermocouple, respectively. The surface and down hole pressure and temperature equipment will be calibrated over the full operational range according to manufacturers' specifications or recognized industry standards. The monitoring of the injection operations will be conducted through a distributed control system (DCS), and the computerized system will collect data from the sensors and record that data. The DCS system will also use alarms that will notify if the injection system is out of a specified range of operational parameters, and if the operational parameters are exceeded, the DCS will shut down the system. The managers, supervisors and operators will have the capability to monitor the injection system from the Marquis' control centers.

Any pressure anomalies outside of the normal operating specifications may indicate that an issue has occurred with the well, such as a loss of mechanical integrity or 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)).

Well diagrams depicting location of monitoring equipment is included **in Figures 7-4(a) – (d)** below.

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[redacted]

Figure 7 - 4(a): Monitoring Details re MCI CCS 3 (Injection Well)

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[redacted]

Figure 7-4(b): Monitoring Details re Completion of MCI MW-1 (original test well) as Monitoring Well

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[redacted]

Figure 7-4(c): Monitoring Details re MCI MW-2 (Deep Monitoring Well)

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[redacted]

Figure 7-4(d): Monitoring Details re MCI ACZ-1 (Above Confining Zone Well)

7.4 Corrosion Monitoring (40 CFR 146.90 (c))

Viking Engineering conducted a thermohydraulic analysis and corrosion assessment to evaluate the fitness for service of the 13Cr metallurgy based on the material properties, the in-situ conditions, and laboratory analytical test data for the water from the MCI MW-1 well. [redacted]

Marquis will be utilizing the Super Chrome 25 in the casing and tubing material within the Mt. Simon on MCI CCS 3, MCI MW-1 and MCI MW-2. By Marquis utilizing the Super Chrome material grade, which is a Super Duplex Stainless Steel, these well designs have increased pitting and corrosion resistance to formation fluids combined with CO_2 over the recommended 13Cr material.

Unlike a CO_2 stream from a wet mill ethanol plant that steeps the whole kernel corn in an aqueous solution of sulfur dioxide and lactic acid, Marquis dry mill ethanol plant grinds the entire corn kernel into a meal, and the meal is mixed with water and cooked to form a mash and liquefy the starch. Marquis has tested the CO_2 stream generated from the CO_2 Scrubbers at the Marquis' ethanol plant, and the presence of hydrogen sulfide has not been detected in the CO_2 scrubber exhaust. Marquis' third-party design engineers also have modeled the CO_2 scrubber exhaust through the compression and dehydration process to confirm the purity of the liquified CO_2 stream that will be injected into the well. Because of the differences in the production process, the CO_2 gas is in a low-risk category for potential corrosion.

Additionally, the following monitoring measures will be implemented to ensure the integrity of the 25Cr material is maintained:

(1) The water and oxygen content of the compressed CO_2 will be continuously monitored at the end of dehydration and prior to injection to confirm a water vapor [redacted]

(2) The water content and chemical composition of the CO_2 stream will be sampled and analyzed [redacted]

(3) Confidential, Privileged, or Sensitive Business Information [redacted]

(4) Confidential, Privileged, or Sensitive Business Information [redacted]

(5) A range of internal and external mechanical integrity evaluation methods (including temperature monitoring in the well bore and in well, injection pressure monitoring, annular pressure and fluid volume monitoring) described in this section will confirm continued mechanical integrity.

Marquis Carbon Injection LLC will monitor the well materials (**Table 7-4**) 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. This section presents the procedures that will be followed to monitor the corrosion of well materials used in the casing and tubing. (40 CFR 146.90 (c)).

7.4.1 Monitoring Location, Frequency, and Description

Marquis Carbon Injection LLC will track the following characteristics of the corrosion monitoring program.

1) Water and oxygen content of the compressed CO_2 will be monitored continuously and before the wellhead as outlined in **Table 7-1** and **Section 7.2.3**.

2) The CO_2 injection stream will be sampled and analyzed before the wellhead quarterly as described in **Section 7.2.3**, **Table 7-1** and **Appendix 7.A**.

3) Corrosion 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, 2017). This method measures the corrosivity of steel to both aqueous and non-aqueous liquids. 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). The corrosion coupons will consist of the metal components of the well.

Equipment Coupon	Material of Construction
Pipeline	Carbon Steel Alloy
Wellhead	Carbon Steel Alloy
Long String Casing	25Cr Steel Alloy / Carbon Steel Alloy
Injection Tubing	25Cr Steel Alloy
Packer	Corrosion resistant material

Table 7-4: List of equipment coupon with material of construction.

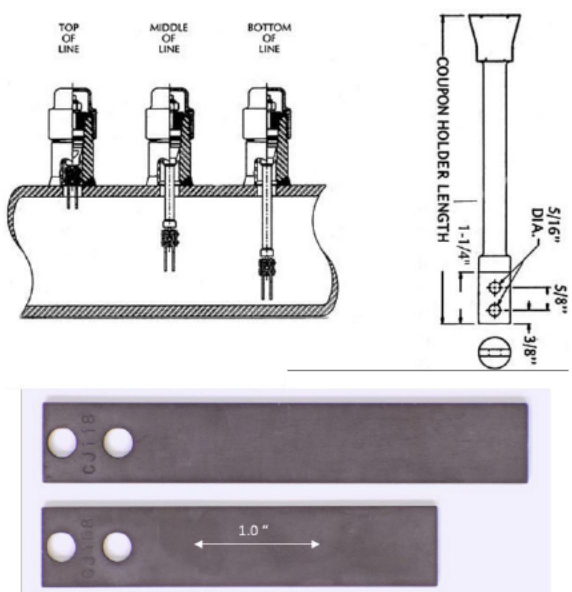

Figure 7 - 5: Type Corrosion coupon illustration in pipeline (top), types of coupons to be used for corrosion monitoring (below) (Cosasco, 2021).

4) Multifinger Caliper Logging will be performed every 6 years after the beginning of injection through the end of the post-closure period. Multifinger Caliper Logging requires the use of a down-hole inspection tool with arms/fingers move mechanically down the internal surface of the pipe or casing and send electrical signals which are calibrated into radial measurements. The tool assists in quantifying metal loss due to corrosion, scale

buildup, deposits, or other types of damage. If data from the coupon monitoring suggest there is the potential for corrosion of the well materials, the Multifinger Caliper log will be performed earlier.

5) Internal and External Mechanical Integrity evaluation methods location and frequency are described in Permit **Section 6**.

7.5 Above Confining Zone Monitoring (40 CFR 146.90 (d))

Marquis Carbon Injection LLC will monitor groundwater quality and geochemical conditions above the confining zone during the operational period to meet the requirements of 40 CFR 146.90 (d).

7.5.1 Monitoring Location and Frequency

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Table 7-5 shows the proposed deep ACZ monitoring methods, depths, and frequencies. [redacted] For establishing baseline, sampling of the ACZ well will occur during well drilling and prior to start of injection.

Target Formation	Monitoring Activity	Depth (ft, MD)	Baseline Frequency (Note 1)	Injection Phase Frequency
Gunter Sandstone	Pressure/ Temperature	[redacted]	[redacted]	[redacted]
Gunter Sandstone	Groundwater Geochemistry	[redacted]	[redacted]	[redacted]
Gunter Sandstone	Stable Isotopes	[redacted]	[redacted]	[redacted]
Galesville Sandstone	Pressure/ Temperature	[redacted]	[redacted]	[redacted]
Galesville Sandstone	Groundwater Geochemistry	[redacted]	[redacted]	[redacted]

Target Formation	Monitoring Activity	Depth (ft, MD)	Baseline Frequency (Note 1)	Injection Phase Frequency
Galesville Sandstone	Stable Isotopes	Confidential, Privileged, or Sensitive Business Information [redacted]	[redacted]	[redacted]
Confidential, Privileged, or Sensitive Business Information [redacted]				

Table 7-5: Monitoring schedule for the ACZ and shallow groundwater monitoring wells during the pre-operational and injection phases of the project.

Migration of CO_2 or brine into the ACZ aquifers will likely first be identified through pressure changes in the aquifers. An increasing pressure trend in either aquifer would suggest that leakage across the confining layer is occurring. While any increasing trend in pressure or temperature will be evaluated, an increase in pressure or temperature greater than 10% above baseline values will warrant additional monitoring and inspections to rule out the possibility of fluid leakage out of the storage formation. Such an increase in pressure or temperature would initiate more frequent fluid sampling and analysis for geochemical parameters from the aquifer with the pressure/temperature increase. An increase in pressures or temperatures in one of the deep ACZ aquifers may also trigger additional external well integrity investigations in the injection or deep monitor well.

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

- Aqueous geochemistry parameters such as pH and alkalinity
- Reaction of cements, mineral surface coatings, and clay particles with the CO_2 may liberate cations and anions into the aqueous phase
- Oxygen and carbon isotopes may be used to differentiate between existing CO_2 sources (if present) within the AoR and the injected CO_2

If anomalous changes in the aqueous geochemistry are observed in the MCI ACZ 1 monitoring zones, new samples will be obtained from the affected aquifer to verify the changes. The frequency with which fluid samples are obtained from each of the ACZ aquifers for analysis will be increased. As a precautionary measure, the fluid sampling frequency for the shallow groundwater monitoring wells will also be increased. If the injected CO_2 has a unique isotopic signature from the existing isotopes in the overlying aquifers, a new round of samples will be collected for isotopic analysis from the affected aquifer. Anomalous changes may also trigger the need for additional well integrity testing in both the deep monitoring well and the MCI CCS 3 well to ensure that no well integrity issues have developed since the last set of external MITs.

7.5.2 Analytical Parameters

Table 7-6 identifies the geochemical parameters to be monitored and the analytical methods to be used on all fluid samples collected from the MCI ACZ 1 well. Fluid samples collected from this well will be analyzed for cations, anions, pH, alkalinity, total dissolved solids (TDS), density, dissolved inorganic carbon, and conductivity/resistivity. The cations, anions, TDS, density, and conductivity/resistivity provide details of the overall geochemistry of these aquifers. Changes in these parameters during the injection phase of the project may provide an indication of CO_2 or brine movement above the confining layer. While pH and alkalinity may be indicators of CO_2 migration above the confining layer, the dissolved inorganic carbon analysis could provide direct evidence of CO_2 migration into these formations. Stable isotopes of C (in dissolved inorganic carbon), O, and H may provide an indication of fluid or CO_2 migration into the deep ACZ aquifers and may also provide information about the origin of any migrating fluids. The presence of Carbon-14 may provide an indication of CO_2 migration into the deep ACZ aquifers as any naturally occurring Carbon-14 originally in these aquifers would have decayed long ago.

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 7-6** will be made in consultation with the UIC Program Director.

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, this decision may be reassessed later.

Parameters	**Analytical Methods**	**Alternate Analytical Method**(Note 1)
Cations (Sodium (Na), Calcium (Ca), Magnesium (Mg), Barium (Ba), Iron (Fe), Potassium (K))	ASTM D1976	EPA Method 6020
Cation (Strontium (Sr))	ASTM D1976	EPA Method 6020
Anions (Chloride (Cl), Bromide (Br), Sulfate (SO_4))	ASTM D4327	EPA Method 300
pH	ASTM D1293	Standard Method (SM) 4500H
Alkalinity	ASTM D3875	SM 2320B
Total Dissolved Solids (TDS)	ASTM D5907	SM 2540C

Parameters	Analytical Methods	Alternate Analytical Method(Note 1)
Density	ASTM D4052	SM 2710F
Dissolved Inorganic Carbon	ASTM D513-11	SM 5310C
Conductivity/Resistivity	ASTM D1125	SM 2510B
Stable Isotopes of C, O, and H	CRDS Laser H Isotope Ratio Mass Spectrometry (IRMS) for C	(Note 1)
Carbon-14	Accelerator Mass Spectrometry (AMS)	(Note 1)

Note:
(1) If another alternative analytical method(s) is considered, prior approval will be obtained from the UIC Director.

Table 7-6: Summary of analytical and field parameters for groundwater samples.

7.5.3 Monitoring and Sampling Methods

Confidential, Privileged, or Sensitive Business Information [redacted] Continuous monitoring of pressure and temperature will occur through a transducer and thermocouple, respectively, in each region.

For fluid sampling, a bailer will be used to collect the water samples. Prior to sample collection the well will be purged to remove stagnant water from the well and ensure representative water is collected from the formation. The amount of water that will be purged will be determined by the volume of water and/or field parameter stabilization. The fluid purged from the well will be monitored for field parameters, such as pH, specific conductance, and temperature, using a calibrated water quality meter (Horiba U-53, or similar). 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 Table 7-7. The analytical methods for the metals require acidification with nitric acid, and the samples will be filtered. The remainder of the analyses do not require preparation or preservation other than chilling the samples. The samples will be collected in either glass or polyethylene bottles ranging in size from 50 milliliters (mL) to 1.5 liters (L). Hold times from the analytes range from 7 days for TDS to 1 year for the oxygen and hydrogen isotopes.

Parameters	Preservation/Preparation	Container	Holding Time
Total Metals by ICP Na, Ca, Mg, Ba, Sr, Fe, K	HNO_3 to pH<2, Filter 4-µm	1.5 L Poly	6 months
Anions Cl, Br, SO_4	Cool, 4±2°C, no chemical preservation	1 L Poly	28 days
pH	Cool, 4±2°C, no chemical preservation	1 L Poly	None
Alkalinity	Cool, 4±2°C, no chemical preservation	1 L Poly	28 days
Total Dissolved Solids	Cool, 4±2°C, no chemical preservation	1 L Poly	7 days
Specific Gravity	None	1 L Poly	None
Dissolved Inorganic Carbon	None	1 L Poly	7 days
H and O Stable Isotopes	None	50 mL Glass	1 year
C Stable Isotopes	Cool, 4±2°C, no chemical preservation	150 mL Poly	14 days
Carbon-14	Cool, 4±2°C, no chemical preservation	150 mL Poly	6 months

Table 7-7: Preservation methods, container type, and holding times for analyte classes.

7.5.4 Laboratory to be Used/Chain of Custody Procedures

The geochemical analyses will be performed by an accredited laboratory and the isotopic analyses will be performed by Isotech Laboratories. These laboratories may be substituted with other accredited laboratories with equivalent capabilities without modification to the Testing and Monitoring Plan. Samples will be tracked using appropriately formatted chain-of-custody forms. See the QASP for additional information (Appendix 7.A).

7.6 Mechanical Integrity Testing

7.6.1 Internal Mechanical Integrity Testing (MIT)

Internal mechanical integrity refers to the integrity or seal within the long casing string between the long casing string, tubing, and packer. The quality of this seal can be confirmed with MIT and annular pressure monitoring. Both methods will be used during the injection phase of this project to monitor and confirm internal mechanical integrity. **Table 7-8** presents the details for conducting the annular pressure MIT and the annular pressure monitoring.

Testing/Monitoring Method	Frequency	Location of Monitoring	Parameters Measured
Annular Pressure MIT	After completion or workover	Tubing/casing annulus	Ability to hold pressure testing
Annular Pressure Monitoring	Continuous	Tubing/casing annulus	Pressure, temperature, annular fluid volume

Table 7-8: Internal mechanical integrity monitoring details.

After the packer, tubing, and downhole equipment have been re-installed, the tubing/casing annulus will be filled with a corrosion-inhibited fluid, such as a potassium chloride (KCl) solution with additives. The temperature of the annular space will be allowed to stabilize, and an annular pressure MIT test will be conducted to ensure that there are no leaks in the tubing, casing, or packer. This approach is also described in the Pre-Operation Testing Program (Permit **Section 5.0**). The annular pressure test will be performed by pumping additional annular fluid into the annulus to increase the pressure to a pressure that exceeds the maximum injection pressure. The annular pressure will be monitored for a minimum of thirty-minutes (EPA, 2008). A change in pressure less than 3% of applied surface pressure would indicate normal internal mechanical integrity. Confidential, Privileged, or Sensitive Business Information [redacted] The volume of the recovered liquid returned from the annulus is expected to be proportional to the volume of the annulus and the amount of pressurization.

The annular pressure test will be repeated any time the packer has been released, for instance, during well workovers. An annular pressure test may also be repeated if there is an indication of lost internal integrity.

In addition to the annular pressure MIT, the annular pressure will be continuously monitored throughout the injection period in conjunction with the annular pressure monitoring and control system to ensure internal mechanical integrity. Once injection commences, injection pressure, annular pressure, and annular fluid volumes will be monitored continuously to ensure that internal well integrity and proper annular pressure is maintained.

Confidential, Privileged, or Sensitive Business Information [redacted]. Note that changes in the temperature of the injection stream can result in changes in the temperature of the annular space and variations in annular pressure. Initial investigations would focus on correlations between the temperature of the injection stream and the variations in annular pressure.

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

Marquis Carbon Injection LLC will conduct external integrity testing annually to meet the requirements of 146.89(c) and 146.90(e).

7.6.2.1 Testing Location 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 the MCI CCS 3 well will be confirmed throughout the injection phase of the project.

Temperature measurements will be acquired from the MCI CCS 3 well to monitor and ensure external mechanical integrity of the well. A baseline temperature measurement will be acquired in the MCI CCS 3 well after the well has been completed and the temperatures have returned to static conditions. Following the baseline log, temperature measurements will be acquired with the DTS technique, using an optical fiber sensor, after the start of injection. Temperature DTS data will be used to monitor the external mechanical integrity of the MCI MW 1 and MCI MW 2 continuously (**Table 7-9**). Oxygen activation logging will be performed as required, see Permit **Section 5.3.5.2**.

Test	Well	Depth Range (ft, MD)	Minimum Schedule
Temperature Measurements	Confidential, Privileged, or Sensitive Business Information [redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
Oxygen Activation Log	Confidential, Privileged, or Sensitive Business Information [redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]

Table 7-9: External mechanical integrity tests.

7.6.2.2 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 an oxygen-activation log will be performed over the zone where the inconsistency was found to substantiate results of the temperature measurements.

7.7 Pressure Fall-Off Testing (40 CFR 146.90 (f))

Marquis Carbon Injection LLC will perform PFO tests on MCI CCS3 during the injection phase as described below to meet the requirements of 40 CFR 146.90(f).

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

- Confirmation of hydrogeologic reservoir properties such as injectivity and average permeability
- Formation damage (skin) near the wellbore, which can be used to diagnose the need for well remediation/rehabilitation
- Changes in reservoir performance over time, such as long-term pressure buildup in the storage formation, that may indicate formation damage
- Average reservoir pressure that can be used to calibrate modeled predictions of reservoir pressure to verify that the operation is responding as modeled/predicted

7.7.1 Testing Location and Frequency

Pressure Fall Off (PFO) testing will be performed in the MCI CCS 3 well once every five years during the injection operations. However, additional PFO testing may be performed opportunistically if the system is shut down for a maintenance event, and the fall-off data may be collected and analyzed. In addition, data from these tests can be used to determine the duration of shut-in desired for the scheduled PFO testing. The scheduled PFO tests will likely be performed during scheduled shutdown events to prevent additional system downtime.

7.7.2 Testing Details

A PFO test has a period of injection followed by a period of shut in. The bottom-hole pressure is then monitored and recorded for sufficient time during both phases of the testing to make a valid observation of the pressure fall-off curve. The optimal duration for the shut-in periods will be determined through the opportunistic PFO test completed prior to the first scheduled PFO. To reduce the wellbore storage effects attributable to the pipe and surface equipment, the well will be shut-in at the wellhead nearly instantaneously with direct coordination with the injection facility operator. A steady injection rate will be maintained for a minimum of one week prior to the PFO. Additional data from the month prior to shut-in will also be included in the analysis of the PFO test. Downhole and wellhead pressure gauges will be used to record and monitor bottomhole pressures during the injection period and the fall-off period. Specifications for the pressure gauges are provided in the QASP.

Reservoir pressures will be measured to capture the change in bottom-hole pressure throughout the test period; this includes the rapidly changing pressures immediately following cessation of injection. The fall-off period will continue until radial flow conditions are observed as indicated by stabilization of the surface pressure and the plateau of the pressure derivative curve. The PFO test may also be truncated if boundary effects are encountered or if radial flow conditions are not observed. In addition to the radial flow regime, other flow regimes may be observed from the PFO test including spherical flow, linear flow, and fracture flow. The shut-in period of the fall off test is expected to last at least five days, but data collected during the opportunistic PFO test will be used to assess the duration of this phase of the test. Analysis of PFO test data will be done using transient-pressure analysis techniques that are consistent with EPA guidance for conducting PFO tests (EPA, 1998, 2002).

Pressure gauges that are used for the purpose of the PFO test will be calibrated according to the recommendations of the manufacturer and current calibration certificates will be provided with the test results to EPA.

A report containing the PFO data and interpretation of the reservoir ambient pressure will be submitted to the permitting agency within 90 days of the test.

7.8 Carbon Dioxide Plume and Pressure Front Tracking (40 CFR 146.90 (g))

Marquis Carbon Injection LLC will employ direct and indirect methods to track the extent of the CO_2 plume and pressure front during the operation period to meet the requirements of 40 CFR 146.90 (g).

7.8.1 Plume Monitoring Location and Frequency

Table 7-10 presents a summary of the methods that Marquis Carbon Injection LLC will use to monitor the location of the CO_2 plume, including the activities, locations, and frequencies. The parameters to be analyzed as part of fluid sampling in the injection zone and associated analytical methods are presented in Table 7-3. The corresponding QA procedures for these methods are presented in the QASP.

Confidential, Privileged, or Sensitive Business Information [redacted] The final sampling interval will be determined after the MCI CCS 3 well has been drilled and the well logs have been analyzed.

PNC logs will be used to identify differences in reservoir fluids near the wells and will be used to aid in monitoring the migration of the injected CO_2. PNC logs operate by generating a pulse of high energy neutrons, subsequently measuring the neutron decay over time and across a wide energy spectrum (Conner et al., 2017).

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Direct Plume Monitoring				
Upper Mt. Simon Sandstone	[redacted]	[redacted]	[redacted]	[redacted]
Upper Mt. Simon Sandstone	[redacted]	[redacted]	[redacted]	[redacted]
Galesville, Gunter, Eau Claire, and Mt. Simon Formations	[redacted]	[redacted]	[redacted]	[redacted]
Indirect Plume Monitoring				
Entire formation (0-TD)	[redacted]	[redacted]	[redacted]	[redacted]

Notes:
(1) Confidential, Privileged, or Sensitive Business Information [redacted]
(2) Confidential, Privileged, or Sensitive Business Information [redacted]

Table 7-10: CO_2 plume monitoring activities.

Baseline PNC logs will be acquired in the MCI-MW2, and MCI-ACZ 1 monitoring well prior to the start of CO_2 injection. During injection, they will be acquired in both wells each year.

Time-lapse 3D surface seismic is proposed as the primary indirect technique to monitor the development of the CO_2 plume during and after injection. A pre-injection baseline 3D seismic survey has been acquired in early 2022 (**Figure 7-5**). The same seismic survey will be acquired again at regular intervals, during injection (Every 5 years or 4 million tons injected), immediately preceding the cessation of injection and prior to the post-injection closure period, and at the 5 and 10-year post-injection control period. The seismic data collected will be compared back to the baseline survey. Processing techniques as referenced by Calvert, 2005, will highlight the location of the CO_2 at the time of each subsequent survey acquisition this is also referred to as "4D Seismic."

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Figure 7 - 6: 3D seismic baseline outline.

7.8.2 Plume Monitoring Details

Confidential, Privileged, or Sensitive Business Information [redacted] The results of the geochemical and isotope analysis will be delivered in the form of laboratory reports. **Section 7.5** of this document details the sampling procedures that will be used. Table 7-6 summarizes the analytical and field parameters for the fluid sampling. Table 7-7: Preservation methods, container type, and holding times for analyte classes. summarizes the methods, containers, and preparation methods for the fluid sampling. Further information can also be found in the QASP (**Appendix 7.A**). Confidential, Privileged, or Sensitive Business Information [redacted]

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Technical details on PNC logging tools can be found in the QASP (**Appendix 7.A**).

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 3D seismic surveys are specifically designed for the Marquis Biocarbon Project site. The previously acquired 2D seismic surveys provided insight into site-specific seismic characteristics, including seismic signal attenuation and the impact of background noise associated with the daily operations of the industrial plant. The 3D acquisition parameters provide significant uplift in data quality beyond what is normally expected from 3D geometry over 2D and have been included in the model.

The results of the geochemical and isotope analysis, PNC logging, and time-lapse 3D surface seismic data will all be integrated to develop a comprehensive understanding of the CO_2 plume development over time. PNC logging and time-lapse 3D surface seismic data can be incorporated into the SEM for comparison to the computational modelling predictions at different points in time. The data can be used to constrain the computational modelling results and produce better plume predictions over the course of the project.

If the CO_2 plume monitoring data diverges significantly from the modelled plume predictions, it may result in a reassessment of the AoR as per the AoR and Corrective Action Plan.

7.8.3 Pressure-Front Monitoring Location and Frequency

Table 7-11 presents the methods that Marquis Carbon Injection LLC will use to monitor the position of the pressure front, including the activities, locations, and frequencies.

QA procedures for these methods are presented in the QASP. The pressure/temperature sensors will be programmed to measure and record pressure and temperature readings every minute. The gauges will be retrieved for data download on a quarterly basis. A pair of gauges will be place in each zone to limit the possibility of data loss.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Direct pressure front monitoring				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Indirect pressure front monitoring				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 7-11: Pressure plume monitoring activities

Microseismic data will be recorded from a near surface-based network of sensors on a continuous basis. These data will be sent to a cloud-based service via a cellular connection for data processing and archive. Baseline microseismic data will be acquired for four to six months prior to the start of injection operations.

No phased or adaptive monitoring has been planned for the project in terms of expanding the monitoring network. However, if the AoR is reassessed over the injection phase of the project, the Testing and Monitoring Plan will be reassessed **Section 7**.

7.8.4 Pressure-Front Monitoring Details

[redacted] he gauges will be memory-style gauges, such as Pioneer Petrotech PPS25 or similar, that would record and store the data within the gauge. Refer to the QASP for technical information on the potential pressure/ temperature gauges (**Appendix 7.A**). The data will be downloaded from the gauges quarterly and stored electronically.

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[redacted]

The microseismic monitoring array has multiple near surface stations. See **Figure 7-10**. The number and physical locations of these stations were determined using a network design process.

Each standalone station consists of a seismometer, digitizer, solar panel with battery backup, and a cell modem/ antenna. Triggered data is processed to provide event magnitude and location information, and results are reviewed by a data processor and event data is received by the project daily. The event locations are incorporated in the SEM. Microseismic activity provides qualitative information on the spatial extent of pressure plume over time.

7.8.5 Time-lapse 3D Seismic Validation using Deterministic Seismic Forward Modeling

A robust modeling has been undertaken to indirectly detect subsurface changes associated with CO_2 injection at this site. This modeling was performed using data acquired at the project site, including Vertical Seismic Profile (VSP), wireline logging recorded in the MCI MW 1 well, and 2D seismic data.

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Using the recorded sonics (compressional and shear) and bulk density logs, a 1.5D, full elastic wave equation forward model was built. This model was conditioned in a manner consistent to the 2D seismic and comparable angle gathers were derived. The corresponding amplitude decay curve was extracted and compared to the 2D seismic equivalent (**Figure 7-6**).

The modeled (from logs) and measured (from 2D seismic) amplitude decay curves compare very favorably. This implies that we can use seismic data acquired at this site in pre-stack seismic inversion studies to predict subsurface rock properties and how they will change over time as a result on CO_2 injection.

The subsequent phase of the modeling exercise was twofold. A fluid replacement modeling workflow adjusts the pre-injection, recorded sonics (compressional and shear) and bulk density logs to simulate the expected log response after replacement of a portion of the formation water with CO_2. AVO synthetic gathers are then generated using the measured, pre-injections logs and the simulated, post-injection logs. The difference in these pre- and post-injection AVO synthetics quantifies the time-lapse seismic response that can be anticipated with injection of CO_2.

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[redacted] These modeled, processed synthetic responses are presented to show the anticipated effect of injecting CO_2 on the seismic amplitude versus angle (AVA) response. 3D seismic captures these modeled changes for injection into the lower members of the Mt. Simon. Injection into the upper and middle portions of the Mt. Simon yielded analogous results. Based on this quantitative analysis, a measurable change in both polarity of the seismic event associate with the top of the injection zone and pre-stack seismic response is expected.

After acquisition of the 3D seismic survey, the data was processed and included in the static earth model. Further interpretation augmented the 2D results confirming no basement highs or faults in the confirming layer.

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Figure 7 - 7: Raw 2D seismic gathers with corresponding conditioned pre stack gathers (top). Forward model built from recorded logs (middle). Comparison of measured amplitude with incidence angle for modeled log response and 2D seismic data (bottom).

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[redacted]

Figure 7 - 8: Change in simulated log response (left) and modeled time-lapse, pre-stack seismic amplitude difference (right) for CO2 fluid replacement in lower Mt. Simon.

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Figure 7 - 9: Change in amplitude versus incidence angle from pre- to post-injection (left). AVA attributes derived from post-injection synthetics demonstrate a clear separation of the injection zone from the background trend (right).

This modeling exercise shows that the injection of CO_2 into the proposed intervals appreciably changes the velocities and densities of the formation and thus the seismic response. Changes in the seismic amplitudes and AVO/AVA attributes provide a direct quantification of the changes resulting from CO_2 injection and plume growth. The results of this modeling study strongly indicate that four-dimensional (4D) seismic monitoring is a viable and robust means of long-term monitoring for this site.

As discussed, MCI has installed microseismic surface monitors to collect background data prior to injection. The location of individual stations within this network are shown on **Figure 7-10**, and those stations can be adjusted as required in response to monitoring results or future AoR re-evaluations.

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Figure 7 - 10: Present Location of Microseismic Stations

7.9 References

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Appendix 7.A Quality Assurance and Surveillance Plan

The Quality Assurance and Surveillance Plan is presented in a separate document accompanying this permit application.