Underground Injection Control – Class VI Permit Application for Rose CCS Project Injection Wells No. 01, No. 02, and No. 03

SECTION 5 – TESTING AND MONITORING PLAN

Rose Carbon Capture and Storage Project

Claimed as PBI

ExxonMobil Low Carbon Solutions Onshore Storage LLC

February 2024

SECTION 5 – TESTING AND MONITORING PLAN

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5.0 Testing and Monitoring Plan

Consistent with the requirements of 40 Code of Federal Regulations (CFR) 146.90, ExxonMobil Low Carbon Solutions Onshore Storage LLC (ExxonMobil) developed a comprehensive Testing and Monitoring Plan strategy for the Rose Carbon Capture and Storage (CCS) Project (Project) using a risk-based approach. The data collection strategy includes injectate monitoring, corrosion monitoring of the well tubular, mechanical, and cement components; pressure fall-off testing; seismic profiling; well logging; continuous monitoring of injection rate and pressure; groundwater quality monitoring; carbon dioxide (CO2) plume and pressure front tracking. The data generated from implementation of the Plan provides the basis to verify the confinement of the injectate in the permitted injection formations during the active injection phase of the Project. The post-injection phase of monitoring is provided in Section 7 – Post-Injection Site Care (PISC) and Site Closure Plan consistent with the structure of the Underground Injection Control (UIC) Class VI Permit Application for the Project. In conjunction with careful site selection and Area of Review (AoR) delineation, this Plan will be a critical component of the successful operation, PISC, and eventual closure of the Project.

A key feature of the Testing and Monitoring Plan is the alignment between the injection operation plan and the geological site features that determine CO2 plume and pressure front migration. This Plan puts forth a data collection plan to confirm whether the injection is working according to the permit requirements. The testing and monitoring strategy also includes a phased/triggered approach for the incremental implementation of testing and monitoring technology, consistent with U.S. Environmental Protection Agency's (EPA's) presentation of phased/triggered monitoring in the *Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance*. Overall, the risk of underground source of drinking water (USDW) endangerment is mitigated by balancing the increases in CO2 plume and pressure front size with the collection and analysis of data to track migration and assess the potential for leaks through the upper composite confining zone (UCCZ).

ExxonMobil intends for the review process for the Plan and subsequent iterations to continue throughout the life of the Project. An adaptive approach will be employed with respect to monitoring frequency of select parameters, whereby monitoring may be decreased based on positive test results. Monitoring results will be presented in semiannual reports, wherein data will be evaluated, and any monitoring frequency modification would be justified. Baseline data will be collected and comparisons to the baseline data will be made during the operational period of the Project. The adaptive approach will be applied if the data collected during the injection period shows results within the expected range. An ongoing dialogue between ExxonMobil and the UIC Program Director is envisioned, marked by tying the Plan reviews to the AoR reevaluation frequency. Consistent with the discussion of AoR reevaluation in Section 3 – Area of Review and Corrective Action Plan, a defined schedule is proposed to address situations where there is a change in the AoR or if other circumstances change, while affording an efficient review process if the AoR reevaluation confirms that the Plan is appropriate as written. In this way, testing and monitoring results that indicate corrective action is required trigger the mitigation measures identified in the AoR reevaluation (Section 3), and the Emergency and Remedial Response Plan (Section 8), if needed, will be triggered at the appropriate time.

5.1 Objectives

The following objectives were developed for the Testing and Monitoring Plan in alignment with 40 CFR 146.90:

- Use site characterization data, the site geologic conceptual model, and the results of computational modeling to identify areas or issues of potential concern for the Project;
- Consider how possible leakage pathways and uncertainties in confining zone and injection zone properties could affect the AoR boundaries and include this uncertainty in the testing and monitoring strategy;
- Select testing and monitoring strategies and technologies that are tailored to the site-specific risk profile in conformance with the requirements; and
- Identify Project-specific factors to consider or incorporate in evaluating the data collected from the Testing and Monitoring Plan, which may indicate the potential risk to or endangerment of USDW, as well as deviations from permitted conditions.

5.2 Overall Strategy and Approach for Testing and Monitoring Plan

The Class VI Rule requires various testing and monitoring activities to identify potential risks to, and the potential for endangerment of, USDWs during the injection phase of the Project. ExxonMobil consulted with the EPA, Region VI UIC Program Director, and the Railroad Commission of Texas in pre-application discussions to identify the testing and monitoring activities that were best suited for the Project. The site features that affect the degree of risk and potential for endangerment of a USDW include:

Claimed as PBI [redacted]

Of these features, the key risk factor that is most critical for the design of this Plan is the potential for Claimed as PBI [redacted]. ExxonMobil completed a variety of technical tasks discussed in Section 3 – Area of Review and Corrective Action Plan to identify and evaluate the potential for Claimed as PBI [redacted]

Other potential risks associated with the Project were deemed to be of a lower probability and consequence.

Therefore, a focused testing and monitoring approach was considered reasonable and appropriate to address the following risk scenarios:

Claimed as PBI [redacted]

Figure 5-1 presents a summary of the risk assessment process for the lifecycle of the Project.

Claimed as PBI [redacted]

As shown in Figure 5-1, the anticipated risk level is Claimed as PBI [redacted] The injection well locations and injection intervals were selected to provide separation from geologic features (e.g., faults) that could potentially contribute to CO_2 or brine crossflow between the injection zone and USDW. The maximum injection pressure will be maintained below the potential hydraulic fracturing or activation pressure of a natural fault to mitigate the potential for CO_2/brine leaks through seal(s) due to mechanical fracturing or migration of CO_2/brine along faults. State-of-the-art construction and mechanical integrity testing will be employed to reduce the potential for the loss of external mechanical integrity, which could potentially release CO_2. The composition of the injectate stream will be managed and monitored such that unexpected reactions with the potential to impact containment are mitigated. Monitoring and predictive reservoir modeling are being used to limit the potential for CO_2 plume and pressure front migration to encounter artificial penetrations that have the potential for CO_2 or brine crossflow from the injection intervals to the lowermost USDW.

The accompanying Class VI Rule testing and monitoring requirements address the potential risk scenarios identified by ExxonMobil as warranting monitoring and testing. Scenarios that were found to have elevated risk will be the subject of corrective action prior to operations. Three artificial penetrations Claimed as PBI [redacted].

An array of data collection technologies was screened to identify the most reasonable and appropriate methods for the Testing and Monitoring Plan. The screening criteria include: (1) selection of appropriate direct and indirect mature monitoring technologies; (2) cost benefit analysis of each technology to mitigate potential; and (3) a mix between continuous and periodic implementation schedule. ExxonMobil recognizes mature technologies based on their Technology Readiness Levels (TRL), as defined by the International Energy Agency in their report *Energy Technology Perspectives, 2020; Special Report on Carbon Capture Utilisation and Storage.* This scheme is applicable to any technology, including those described in Table 5-1 for implementation on the Project. As described on Figure 5-2, mature technologies are those with Claimed as PBI [redacted] and higher.

Claimed as PBI

[redacted]

Table 5-1 provides a summary of mature technologies selected for tracking the CO2 plume and pressure front. Consistent with the stated interests of the EPA, the Testing and Monitoring Plan is intended to be a flexible approach using appropriate technologies and techniques that are refined and adapted based on site-specific information over time. ExxonMobil will continue to assess the feasibility of emerging technologies and conduct performance evaluations to continue to improve the performance of the testing and monitoring system.

ExxonMobil will communicate with the UIC Program Director on plans and the potential for updates to the Testing and Monitoring Plan. Through the combination of proven and emerging technology pilot testing, a cost-effective testing and monitoring strategy will be maintained for the Project that measures the CO2 plume and pressure front migration paths and serves to provide reliable data for reevaluating the AoR model.

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5.3 Use of Phased and/or Triggered Approach

The testing and monitoring strategy for CO_2 plume and brine pressure front tracking makes use of the phased and/or triggered approach to scale the testing and monitoring network with the extent of the AoR and the site features that warrant monitoring. The goal of the approach is to provide the data necessary to demonstrate that USDWs are protected from the potential leakage of CO_2 or brine. The scaling aspect of the strategy is aligned with the staged-injection approach outline in Section 3 – Area of Review and Corrective Action Plan that Claimed as PBI [redacted] The initial monitoring network is based Claimed as PBI [redacted] deemed appropriate to track the CO_2 plume and brine pressure front during that time period. From that point, the AoR reevaluation process will be used to assess the adequacy of the testing and monitoring program to detect potential leakage should it occur and make recommendations for changes if necessary to demonstrate protection of USDWs.

Claimed as PBI [redacted]

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5.4 Mechanical Integrity Test Methods

5.4.1 Internal Mechanical Integrity Testing – Annulus Pressure Test

In accordance with 40 CFR 146.89(b), ExxonMobil will assess the internal mechanical integrity of each injection well by performing annulus pressure tests after the well has been completed, prior to injection, and annually thereafter. Annular pressure testing verifies the Part I or internal integrity of the annulus between casing and tubing above the packer. During well construction, prior to the installation of the injection tubing and packer, the casing will also be pressure tested to the maximum anticipated annulus-surface pressure to verify its integrity.

The annular pressure tests are designed to demonstrate mechanical integrity of the casing, tubing, and packer. These tests will be conducted by pressuring the annulus to a minimum of Claimed as [redacted] pounds per square inch (psi) surface pressure.

The injection tubing annulus pressure will be continuously monitored at the wellhead during all other times. The tubing annulus pressure will be recorded and reported to the regulatory permitting authority in semiannual reports to demonstrate compliance with casing integrity requirements.

5.4.2 External Mechanical Integrity Testing

Following the requirements of 40 CFR 146.89(c), ExxonMobil will perform an annual Part 2 external mechanical integrity test (MIT). Claimed as PBI [redacted]

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[redacted]

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[redacted]

Claimed as PBI [redacted]

- Procedures for Acquiring a Temperature Log
  - A temperature log with gamma ray and casing collar locator will be obtained prior to injection activities to establish baseline conditions and to identify any potential local temperature anomalies that may exist.
  - Shut-in the well for a minimum of 24 hours, targeting 36 hours of shut-in time, if possible, based on operational needs.
  - Rig-up wireline company and perform temperature log from surface to total depth.
  - Pull temperature tool out of hole. If anomalies are present, re-log well at least 8 hours after initial pass to re-establish sufficient conditions. If none are identified, rig-down wireline company.

Per EPA *Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance*, dated March 2013, any temperature logs will be evaluated by comparing the relative differences of the log to a baseline log. If the log is comparable to the temperature log on the baseline log, it is considered a successful demonstration of mechanical integrity.

An oxygen activation tool will be used for the purpose of detecting and quantifying the flow of water in or around the well using the following procedures.

- Procedures for Acquiring Oxygen Activation (OA) Log
  - Rig-up wireline company and run logging tool into the injection zone.
  - Conduct a short baseline gamma ray Log and casing collar locator near the top of the injection zone prior to taking the stationary readings with the OA tool. Verify calibration of the OA tool.
  - All stationary readings will be taken with the well injecting fluid near maximum allowable rate, or as the average of recent flow rates allow, with minimal rate and pressure fluctuations.
  - Bottomhole cement checks will, at a minimum, include stationary readings to be taken near the base of the overlying confining zone and the base of the lowermost USDW.
  - Flow behind casing checks will be conducted near the top of confining zone and immediately above the injection zone.
  - If a false positive regarding flow is suspected, move uphole or downhole to rerun the log. Per EPA *Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance* dated March 2013, another option is to vary injection rate to (25, 50, and/or 75 percent [%] of maximum rate) to determine false positive.
  - If significant flow is indicated by the OA Log at a station, move uphole or downhole as necessary and take additional stationary readings to determine the area of fluid migration.
  - Pull OA tool out of hole and rig-down wireline equipment.

An OA test is considered passing when no upward-flow is detected outside of the injection zone. To minimize the potential of false positives, checks near the same depth will be performed on any anomalous log response as outlined in the procedure above. Threshold velocities for false positives will be determined based on the vendor's logging equipment.

5.4.3 Reporting Results of MIT

Annulus pressure test results will be submitted to the appropriate regulatory permitting authority within 30 days of completion. The logs recorded during external MIT will be submitted to the appropriate regulatory permitting authority such as the UIC Program Director within 30 days of the verification that the logging results are representative and acceptable.

5.5 Continuous Recording of Operational Parameters During Injection

ExxonMobil will install and use continuous measurement devices to monitor injection pressure, rate, and mass injected; the pressure on the annulus between the tubing and the long-string casing; and the temperature of the CO2 stream, as required under [40 CFR 146.88(e)(1), 146.89(b), and 146.90(b)]. Data will also be collected to document the addition or removal of any fluid from the annulus system. Data interfaces will be created for equipment that is not linked directly to a data management system or suitable equivalent, and it will be integrated into a unique surveillance platform. In the monitoring program, the sensors, transducers, and controllers will be connected in a central platform to monitor the operating conditions, set alarms for alerting operations of malfunction, and establish safety protocols in case of abnormal conditions. Alarms will additionally be set for pressures outside described tolerances (generally 90% of fracture gradient and prescribed wellhead pressures), and changes in annular pressure and fluid.

Instrument calibration standards, precision, and tolerances will be determined based on manufacturer recommendations. The automated control system data will be visually monitored for anomalies on a regular basis. Average values will be compared to baseline and predicted values to determine if there are any significant deviations relevant to integrity or containment.

The operating parameters, monitoring values, laboratory results, reports, and surveillance documents for the Project will be stored in a database to support AoR reviews, quality assurance / quality control review programs, and routine reporting. Table 5-2 provides a summary of the typical sampling devices, locations, and data storage frequencies for the continuous monitoring program. As may become necessary, paper records may be substituted for digital records at the discretion of the operator. Suitable equivalent devices may be used as technology availability and maintenance dictate.

Table 5-2: Sampling Devices, Locations, and Data Frequencies for Continuous Monitoring

Parameter	Device(s)	Location	Estimated Min. Sampling Frequency	Estimated Min. Recording Frequency
Surface Injection Pressure	Wellhead Pressure Logger	Surface, injection well piping	5 seconds	5 minutes
Downhole pressure gauge	Pressure Gauges	Injection Unit	5 seconds	5 minutes
Injection rate	Coriolis Meter	Central Pad piping	5 seconds	5 minutes
Injectate density	Coriolis Meter	Central Pad piping	5 seconds	5 minutes
Total mass injected	Coriolis Meter	Central Pad piping	5 seconds	5 minutes
Annular pressure	Pressure Gauge	Well Head	5 seconds	5 minutes
Annulus fluid volume	Pressure Gauge	Annulus System Tank	5 seconds	5 minutes
CO2 stream temperature	Coriolis Meter/Wellhead Pressure Logger	Well Head, injection well flowing	5 seconds	5 minutes
Note: The word “continuous” is used to express the frequency of measures collected during monitoring equipment operation is defined as the instrument’s normal data collection frequency as defined by the manufacturing. The frequency will vary by instrument and application. Measurements that are collected “continuously” will be averaged across a reasonable and appropriate time interval for reporting the detection monitoring results during the operational phase of the Project.				

5.5.1 Continuous Monitoring of Injection Rate and Volume

ExxonMobil will collect continuous measurements necessary to calculate and report the injection mass flow rate and volume in compliance with 40 CFR 146.90(b). A data management system or suitable equivalent will be used to facilitate continuous collection of intake pressure at the central pad transfer point, pressure within the distribution system to each injection well, and the wellhead of the injection wells.

A Coriolis flow meter will be used to measure the flow rate at the central pad and compute flow rates for each injection well. The Coriolis flow meter directly measures the mass flow rate of the injected fluid. Analytical methods will be conducted at a periodic interval to determine the mass percentage concentration of CO2 and CO. The mass percentage concentration of CO2 and carbon monoxide (CO) are multiplied by the total mass flow reading from the Coriolis flow meter to estimate the total mass of captured CO2 and CO for a given period. The meter will be placed directly at the point of injection. The meter will be calibrated to manufacturer specifications.

Claimed as PBI [redacted]

ExxonMobil will review and interpret the continuously monitored parameters to validate that they are within permitted limits. The data review will also include examination of trends to help assess the need for equipment maintenance or calibration. Semiannual reports of the monitoring data will be submitted to the regulatory permitting authority.

5.5.2 Continuous Monitoring of Injection Temperature and Pressure at Injection Well]

ExxonMobil will perform continuous monitoring of the injection pressure, temperature, mass flow rate, and injection annulus pressure in compliance with 40 CFR 146.90(b). The injected CO2 stream pressure will be continuously monitored in the CO2 flowline near the wellhead interface. The annulus pressure will also be continuously recorded. The combined wellhead and downhole monitoring data will be used to continuously characterize the injection stream in detail.

ExxonMobil will review and interpret the monitoring data to confirm compliance with the operational limits of the injection permit for each well. The data review will include an analysis of trends for operational performance evaluation and routine maintenance. Periodic reports of the monitoring data will be submitted to the UIC Program Director.

5.5.3 Continuous Monitoring of Injection Temperature and Pressure in Reservoir

Reservoir temperatures and pressures will be measured using a Claimed as PBI [redacted] the Project will use additional support from the provider of the selected technologies to perform QC and verification of the data as well as calibration of the systems as needed. See Section 4 for well diagram(s). The Wellhead Pressure Logger will also continuously measure the temperature and can be used as a backup in case the DTS fails.

5.5.4 Continuous Monitoring of Annular Pressure and Volume (Tank Level)

The annular pressure between the tubing and the injection casing string will be monitored on a continuous basis. The pressure gauge on the annulus will be tied into the data management system or a suitable equivalent system and set to alarm if pressure or volumes move outside set tolerances. The annulus tanks in the well systems will be maintained with sufficient volumetric capacity to accommodate the anticipated volume fluctuations due to temperature and pressure limitations. The annulus tanks are to be equipped with a level transducer or an armored reflex sight glass and an independent liquid fill nozzle. If any annulus fluid is added or removed, it will be recorded. An annulus tank level is to be recorded on any day when injection occurs.

5.5.5 Positive Annular Pressure

Per 40 CFR 146.88(c), pressure will be maintained in the annulus at a value of at least Claimed as [redacted] psi greater than the injection pressure. ExxonMobil will fill the annulus with a non-corrosive fluid approved by the UIC Program Director. A system will be set up to maintain pressure in the annulus using compressed non-corrosive fluid or gas and it will be tied into the alarms or a suitable equivalent system designed to signal pressure drops below set-points.

5.6 Corrosion Monitoring

The tubing and casing materials will be monitored during the operational period for loss of mass, thickness, cracking, pitting, and other signs of corrosion to demonstrate that the well components continue to meet the minimum standards for material strength and performance. Monitoring will take place based on well-specific conditions that are encountered but will take place not less than once per year.

5.6.1 Monitoring Location and Frequency

Corrosion coupons will be placed in continuous contact with the CO2 stream in a selected location deemed representative of the three injection wells. The samples will be exposed to the process stream conditions immediately prior to injection using a recycle loop or sample retriever. Exposure is to be representative of conditions at the top of the tubing. Initially, coupons will be tested quarterly. After establishing service life trends, coupon testing frequency may be reduced but will be conducted at a minimum of once per year.

Casing inspection logs (CILs) (e.g., ultrasonic imaging tool, electromagnetic, cement bond log, and caliper) will be conducted on the long-string casing at a minimum frequency of once every five years at the time of permit renewal. Claimed as PBI [redacted]

5.6.2 Monitoring of Corrosion Coupon

Monitoring of well tubing and casing material corrosion will initially be conducted on a quarterly basis to evaluate the corrosion coupon monitoring system. After establishing service life trends, coupon testing frequency may be reduced but will be conducted at a minimum of once per year. A corrosion coupon station or rack will be provided as part of well-materials integrity monitoring. Any coupon in active use will be exposed to the stream composition to provide ongoing evaluation of material compatibility with the CO2 stream. The results will be reported to the regulatory permitting authority such as the EPA UIC Director semiannually.

The coupons will be assessed for corrosion using American Society for Testing and Materials (ASTM) and Association for Materials Protection and Performance (AMPP) standards for evaluating corrosion tests such as ASTM G1-03 (2017), Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens or a suitable equivalent. When the coupons are removed, they will be inspected visually for signs of corrosion or pitting. The weight and size of the coupons will be measured each time they are removed. The rate of corrosion will be calculated using a weight loss method where the rate equals the weight loss during the exposure period divided by the duration of the period.

The coupon initial baseline measurements will follow the recommendations of AMPP NACE SP0775-2023 (included in references). Coupons will be prepared from the material used to construct the injection well. A method of coupon preparation will be chosen that does not alter the properties of the metal. For example, grinding operations will be controlled to avoid high surface tensions/temperatures that could change the microstructure of the coupon. Coupons may be prepared by smooth grinding with 120 grit paper, by tumbling with loose grit, or blasting with abrasive blasting material. A consistent finish may be obtained by blasting with glass beads. The abrasives will be free of metallic particles. A permanent serial number shall be etched or stamped on each coupon. ExxonMobil will machine or polish the edges of the coupon to remove cold-worked metal if the cold-worked edges adversely affect the data. ExxonMobil will dry, measure length, measure width, measure thickness, and weigh the coupons to within ± 0.5 mg., record the mass, serial number, and exposed dimensions, calculate the surface area (including the edges) and record. The areas covered by the coupon holder and shielded areas of flush-mounted coupons will be excluded.

5.6.3 Cement Evaluation and Casing Inspection Logs

As discussed in Section 4 – Well Construction Plan and Operating Conditions, a cement bond log will be run after the casing has been run and cemented and sufficient cement-curing has taken place. Logging will be conducted sufficient to assess the quality of the cement. A multi-finger caliper log will establish the initial dimensions of the inner wall of the production casing after it is cemented. Following the installation of the completion equipment, including the tubing and packer assembly, an initial electromagnetic through-tubing CIL will be run. The CIL will serve as the baseline survey for potential future repeat surveys with the objective of enabling the detection of possible loss of metal mass.

Repeat electromagnetic CILs will only be performed if other monitoring measurements create concern about the integrity of the casing of the well, and the technical determination is made that a repeat CIL is most suitable to address those concerns. Examples include a loss of annulus pressure or anomalous distributed noise and temperature measurements using the fiber optic cables installed in the well. Changes in the recorded electromagnetic response in such a repeat CIL will be analyzed to identify and localize casing corrosion, addressing 40 CFR 146.89(d).

5.7 Pressure Fall-Off Testing

Required pressure transient fall-off testing will be conducted Claimed as PBI [redacted] he objective of periodic testing is to monitor for any changes in the near-well bore environment that may impact permeability and reservoir pressures during active injection. A report containing the pressure fall-off data and interpretation of the reservoir pressure will be submitted to the EPA within 30 days of the conclusion of the test. Although test procedures or methods may be changed based on request of the permittee and approval by the UIC Program Director, the following procedure is expected to be typical for such periodic monitoring.

5.7.1 Testing Method

The procedures to conduct a pressure fall-off test are as follows:

- Record data regarding test well injection at typical operating conditions (constant rate plus or minus 10%). Rate versus time data will be recorded during the injection period. Cumulative injection volume will also be recorded. Continue injection for a time equivalent to the projected duration of the fall-off necessary to observe analyzable radial flow. Note that significant rate variations may require more complicated analysis techniques.
- Verify operation of permanent monitoring equipment or rig-up downhole memory pressure gauge and run in well to a datum depth approved by the regulators.
- For pressure transient fall-off, obtain final stabilized injection rate and pressure for a minimum of Claimed as PBI [redacted]. Ensure that the injectate temperature has stabilized.
- Cease injection and monitor pressure fall-off. Continue monitoring pressure for a time sufficient to observe reservoir behavior. Wellbore pressure gradients will be obtained to establish fluid gradient.
- Stop test data acquisition, rig-down and release equipment.

5.7.2 Analytical Methods

Near-wellbore conditions, such as the prevailing flow regimes, well skin, reservoir properties and boundary conditions will be assessed through the use of standard pressure transient diagnostic plotting and well test simulators, as required. This assessment will be accomplished from analysis of observed pressure changes and pressure derivatives on standard diagnostic log-log and semi-log plots. Significant changes in the well or reservoir conditions will be identified by comparing pressure fall-off tests performed prior to initial injection with later tests. These well parameters resulting from fall-off testing will be compared against those used in AoR determination and site computational modeling. Notable changes in reservoir properties may dictate that an AoR reevaluation is necessary.

The pressure fall-off test results will be submitted to the UIC Director within 30 days of completion of the quality assurance / quality control verification of the pressure data.

5.7.3 Quality Assurance/Quality Control

The surface field equipment will undergo inspection and testing prior to operation. The pressure gauges will be calibrated prior to installation per manufacturer instructions. Documentation certifying proper calibration will also be enclosed with the test results. Further validation of the test results will be justified by extended collection of pressure data from the plugged and abandoned injection stages. The continuation of pressure monitoring in deeper, inactive stages allows for recording of the naturally occurring pressure decay. Pressure communication between stages may also be evaluated with this approach.

5.8 Monitoring of CO2 Stream

Consistent with 40 CFR 146.90(a), ExxonMobil will install and use measurement devices to analyze the chemical composition of the injection stream to assess the potential for interactions between CO2 and other injectate components and compatibility with the well completions materials. Temperature and pressure will also be measured at the sample collection point.

5.8.1 Sampling Frequency

Quarterly sampling of the CO2 stream is proposed for the first two years of operation, after which the frequency may be reduced to twice per year if the results of the CO2 stream analyses are consistent. If a new source is introduced after transition to semiannual sampling, quarterly sampling would be re-initiated from the time the new source is included in the CO2 stream for a period of one year. If a consistent stream composition is observed for a period of one year, sampling would be reduced to twice per year.

5.8.2 Sampling Methods

The quarterly measurements will be obtained by collecting representative samples of CO2 at a sample port on the Project's central pad beyond the last stage of compression in the compression build or similar point. Sufficient mixing and residence time in the system will have occurred at this sampling point for the sample to be representative of the injected CO2 stream. The sampling station will be equipped with the ability to purge and collect a gas sample into a sealed container. The central pad is the connection point between the CO2 pipeline and the sequestration field's distribution system.

Sampling activities will be conducted at the direction of site representatives and in accordance with the certified or accredited analytical laboratory procedures and will meet the minimum current standard EPA procedures. A sample will be collected by depressurizing the liquid stream and sampling the CO2 as a gas in either a Tedlar® bag, a Summa cannister, or laboratory-approved alternate. The grab sample will be sent to an independent contract laboratory for analysis.

Each sample will be accompanied by a facility or contract laboratory Chain-of-Custody (COC) form that provides a record of sample handling, starting with sample acquisition, documenting the sample transfer process up to laboratory analysis. Samples taken are to be logged in the field using the COC form. Sample transfer containers (e.g., coolers) will be sealed and delivered to the laboratory with a COC form. The COC form shall provide the following items recorded by the sampler:

1. Sample ID including code or name, in addition to date and time;
2. Name of sample collector; (include sampling company name if not site personnel);
3. Sample collection method;
4. Sample collection date;
5. Sample collection point; and
6. Sample presentation technique, as applicable.

Standard laboratory COC forms that document the times and dates of all personnel handling the sample, along with standard labels and container seals sufficient to distinguish between samples and prevent tampering, will be acceptable.

Sample COC will be followed at all times during the sampling and subsequent analysis. COC will be used to document the handling and control necessary to identify and trace a sample from collection to final analytical results.

5.8.3 Analytical Plan

Table 5-3 presents the test parameters, analytical methods, and sample frequency for each test parameter. The selected parameters and constituents for analysis are consistent with the composition of the CO2 stream described in Section 4 – Well Construction Plan and Operating Conditions.

Table 5-3: Summary of CO2 Sampling and Analysis Plan

Parameter/Constituents	Analytical Method(s)[1]	Frequency[2]
CO2 Purity	ISBT 2.0, GC/DID or Method 3A	Quarterly
Water	ISBT 3.0, GC/FTIR, Method 320, EPA Method 4	Quarterly
Oxygen	ISBT 4.0, GC/DID or Method 3A	Quarterly
Nitrogen	ISBT 4.0, GC/DID or by difference	Quarterly
Sulfur Dioxide	ISBT 14.0, GC	Quarterly
Hydrogen Sulfide	ISBT 14.0, GC	Quarterly
Oxides of Nitrogen	ISBT 7.0	Quarterly
Total Hydrocarbons	ISBT 10.0, GC	Quarterly

Parameter/Constituents	Analytical Method(s)[1]	Frequency[2]
Carbon Monoxide	ISBT 5.0, GC/DID	Quarterly
Methane	ISBT 10.1, GC	Quarterly

FTIR = Fourier transform infrared; GC/DID = gas chromatography-discharge ionization detector; ISBT = International Society of Beverage Technologists

[1] Or suitable alternate analytical method may be used.
[2] Proposed quarterly sampling for the first two years of operation with the option to reduce frequency to twice a year after two years if the CO2 stream analytical results are consistent. The addition of a new source would require return to quarterly sampling for one year.

5.9 CO2 Plume and Pressure Front Tracking

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5.9.1 Direct Pressure Front Tracking

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Any periods of shut-in for an injection well may be observed and treated as a fall-off test by recording the shut-in wellhead pressure, bottomhole pressure, and temperature readings. This information, together with the continuous measurements obtained during regular operating conditions, will aid in updating the plume models and forecasts.

5.9.2 Plume and Pressure Front Tracking Using Indirect Geophysical Techniques

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5.10 CO2 Plume Tracking Using Groundwater Monitoring Data

5.10.1 Phased and Triggered Monitoring

The phased and/or triggered monitoring strategy was adopted for the installation of in-zone monitoring wells, potential additional USDW monitoring wells, soil gas monitoring wells, and air monitoring locations. The phased approach was deemed reasonable and appropriate based on the schedule of CO2 injection for three injection wells and the degree of protectiveness evident based on the geologic site characterization and demonstrated by the plume modeling. This type of approach allows the site-specific testing and monitoring strategies to be tailored to changes in predicted performance and in response to potential increased risks to USDWs identified or detected during the course of injection.

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[redacted]

5.10.2 Design of the Monitoring Well Network

The monitoring well network includes the monitoring wells that will be used to support compliance with the testing and monitoring requirements under the Class VI Rule. Combined with the monitoring of pressure build-up at each injection well, the design of the monitoring well network was selected to provide a high degree of confidence in detecting a leak through the confining zone that may endanger USDW. The relevant site data considered for the design of the monitoring well network included the phased injection depths, rate, and volume; the geology, and the presence of the legacy wells as required at 40 CFR 146.90(d)(1) and (2).

5.10.3 USDW Monitoring Well Construction

To comply with 40 CFR 146.90(d), a phased approach to USDW monitoring well installation is proposed. Initially, Claimed as PBI [redacted] will be completed at the locations shown on Figure 5-4. These locations were selected to provide a baseline of geochemical data in the vicinity of the following areas of significant interest:

Claimed as PBI [redacted]

The Chicot Aquifer is the most prolific USDW aquifer within the AoR, and its relatively shallow water-bearing zones are a target for completion of water wells, typically at depths ranging from approximately 150 to 400 feet (ft) below ground level (BGL) in the AoR. Claimed as PBI [redacted]

The deepest USDW formation is the Evangeline Aquifer at a depth of approximately Claimed as PBI [redacted] BGL at the Project site. Below this depth, the total dissolved solids (TDS) values were found to be greater than 10,000 mg/L. Claimed as PBI [redacted]

[redacted]

[redacted]

At this time, it was assumed that up to [redacted], if necessary, could be completed in a phased approach to expand USDW monitoring coverage commensurate with the expanse of the CO2 plume and pressure front. The target schedule for expansion is after an initial period from the start of operations. During this time, data will be collected to reduce the uncertainty in CO2 plume and pressure front migration. The locations of any potential additional USDW monitoring wells will be selected for areas where a risk of leakage either remains uncertain or plume and pressure tracking indicators that a leakage feature, such as a legacy well, warrant additional groundwater monitoring.

5.10.4 Summary of Water Well Data for the AoR

Table 5-5 provides a summary of general USDW monitoring well construction details for USDW Monitoring Wells No. 01, No. 02, and No. 03. The well construction details for additional USDW monitoring wells (if constructed) will be consistent with the construction details in Table 5-5.

A total of [redacted] water wells were identified in and near the AoR as listed on Table 5-6 from the Texas Water Development Board well registration list and the Texas Commission on Environmental Quality environmental well database. Appendix F-1 illustrates the location of the water wells. Each of these wells is completed in the Chicot Aquifer with a maximum depth of [redacted]. For planning purposes, the extent of the CO2 plume and pressure front relative to the water wells will be reviewed after sufficient data have been collected to assess whether additional USDW groundwater monitoring is needed for situations of potential USDW endangerment.

Claimed as PBI

[redacted]

Groundwater samples will be collected using dedicated tubing and pumps capable of producing representative groundwater samples to the surface with the least pumping effort. The fluid sampling parameters and frequencies for the in-zone and USDW monitoring wells are shown in Table 5-4. Additional USDW monitoring wells will be added to assess the potential for USDW endangerment if necessary.

A wellbore schematic is provided for USDW Monitoring Wells No. 01 to No. 03 in Claimed as PBI [redacted]. The USDW monitoring wells will be completed to collect groundwater samples for the Chicot Aquifer at depths from approximately Claimed as PBI [redacted]

Claimed as PBI

[redacted]

5.10.6 Collection and Analysis of Groundwater Samples

Fluid samples will be taken periodically from the USDW monitoring wells and the [redacted]. The USDW monitoring wells target the Chicot Aquifer, which is the most used aquifer in the AoR for potable and non-potable purposes. The initial sampling frequency for the USDW monitoring wells is [redacted] This sampling frequency is for both the pre-injection phase and the first [redacted] years of injection. This [redacted] sampling characterizes the potential seasonal fluctuation in this USDW. After the initial phase, the sampling becomes [redacted] with the optimal season of data collection determined by analysis of the first years of [redacted] samples. [redacted]

Table 5-4 summarizes the parameters analyzed and the planned sampling frequency, which apply to the USDW and in-zone monitoring wells. Anomalous measurements will trigger re-sampling and additional data analysis, including a more detailed evaluation of data using statistical comparisons approved by EPA for detection monitoring programs. This analysis could also include geochemical modeling to compare the compositions of groundwater from before and during operations.

If warranted, other tests may be added to the evaluation if re-sampling and detailed analysis of the fluid samples does not satisfactorily rule out a leakage scenario.

Claimed as PBI

[redacted]

Measurements are performed on gases collected from the fluid samples by depressurizing them to atmospheric conditions in a controlled laboratory environment.

5.10.6.1 Analytical Methods

ExxonMobil will test the fluid samples and maintain results for the parameters listed in Table 5-4. If results indicate the existence of impurities in the injection stream, the diagnostic power of these constituents will be assessed to determine if they should be included in the analysis of the water samples. Testing results will be stored in an electronic database.

Fluid chemistry data will be monitored for deviations from baseline, predicted, and average values. If a significant variance occurs, the numerical model will be reevaluated. Potential geochemical signs that fluid may be leaking from the injection interval may be detected upon observation of the following trends:

- Change in TDS;
- Change in signature of major cations and anions;
- Increase in CO2 concentration;
- Decrease in pH;
- Increase in concentration of injectate impurities; and
- Increase in concentration of leached constituents.

5.10.6.2 Laboratory to be Used/COC Procedures

The analysis of the fluid samples will be transported to an accredited and state-approved laboratory. ExxonMobil will observe standard COC procedures and maintain records to allow full reconstruction of the sampling procedure, storage, and transportation, including any problems encountered.

5.10.6.3 Quality Assurance and Surveillance Measures

ExxonMobil will collect replicate samples and sample blanks for quality assurance/quality control purposes. The samples will be used to validate test results, if needed.

5.10.6.4 Plan for Guaranteeing Access to All Monitoring Locations

Placement of the well locations is optimized to be accessible from roads.

5.10.7 Injection Interval Monitoring

In-zone fluid samples were collected from the stratigraphic test well and are being analyzed for water quality and geochemical parameters. The results of these tests will be provided subsequently. No in-zone fluid sampling is proposed for the CO_2 plume or pressure front tracking.

5.10.8 Seismic Monitoring (Induced Seismicity)

Claimed as PBI [redacted]

[redacted]

[redacted]

[redacted]

5.11 Reporting Requirements

The Testing and Monitoring Plan was developed to achieve two reporting objectives:

- Provide the necessary data to verify predictions of CO_2 plume and pressure front movement; and
- Provide the basis for evaluating the model inputs, making necessary changes, and reevaluating the AoR.

In compliance with 40 CFR 146.91, ExxonMobil will provide reports to the UIC Program Director in routine semiannual reports that document the performance of the system and CO_2 plume and pressure front tracking data. Relevant records pertaining to the Class VI Testing and Monitoring program will be submitted to the EPA. In addition, ExxonMobil will follow the prescribed notification requirements for deviation from permit conditions, operational malfunction that may allow CO_2 or brine to migrate into or between USDWs, or for other evidence of USDW endangerment.

The semiannual reports will include the data collected during each reporting period and a list of notifications triggered during a semiannual period, if any. The following information is proposed for the routine performance reporting:

- Monthly average, maximum, and minimum values of injection pressure, flow rate and volume, and annular pressure;
- Monthly volume and/or mass of the CO2 stream injected over the reporting period, and the volume injected cumulatively over the life of the Project;
- Monthly annulus fluid volume added;
- Results of CO2 plume and pressure front tracking as described herein;
- Any significant changes to the physical, chemical, and other relevant characteristics of the CO2 stream from the proposed operating data that could impact plume migration or protection of USDWs;
- A description of any event which triggered a shut-off device required to 146.88 (e) and the response taken; and
- A description of any event that exceeded operating parameters for annulus pressure or injection pressure specified in the permit.

The semiannual reports will be submitted 30 days after the completion of the quality control, quality review of the data for each reporting period. Table 5-8 describes the non-routine reporting triggers, contents, and schedule.

Table 5-9: Summary of Triggering Events for Notification and Reporting Schedule

Triggering Event	Reporting Schedule
Planned well workover, stimulation activities, or other planned test of an injection well.	Notification to the UIC Director, in writing, 30 days in advance of planned activity.
Completion of well workover.	30 days after completion of well workover.
Any test of the injection well conducted, if required by the UIC Director.	30 days after completion of any testing required by UIC Director.
Evidence of potential non-compliance with a permit condition, or malfunction of the injection system that may cause fluid migration into or between USDWs.	Verbal Notification – Reported within 24 hours of verification of non-compliance or malfunction.
Primary evidence that the injected CO2 stream or associated pressure front may cause an endangerment to a USDW.	Verbal Notification – Reported within 24 hours of verification of endangerment
A failure to maintain mechanical integrity.	Verbal Notification – Reported within 24 hours of verification of MIT failure
A statistically significant change to the physical, chemical, and other relevant characteristics of the CO2 stream from the composition described in the proposed operating plan.	Written Notification – Reported within 72 hours of verification of composition change.
An operational condition that exceeds operating parameters for annulus pressure or injection pressure as specified in the permit.	Verbal Notification – Reported within 24 hours of verification of non-compliance with permit conditions. Written Notification – Reported within 72 hours of verification of non-compliance with permit conditions.
A shut-off device anywhere in the injection well system that is triggered.	Verbal Notification – Reported within 24 hours of event. Written Notification – Reported within 72 hours of event.

ExxonMobil will submit all reports, submittals, and notifications to both the EPA and the Railroad Commission of Texas and retain records in accordance with 40 CFR 146.91(f) for a 10-year period after site closure. Additionally, injected-fluid data, including nature and composition, will also be retained for the 10-year period following site closure. Monitoring data will be retained for a minimum of 10 years post-collection, while well-plugging reports, PISC data, and the site closure report will be retained for 10 years after site closure.

5.12 Testing Plan Review and Updates

In accordance with 40 CFR 146.90(j), the Testing and Monitoring Plan will be reviewed and revised at a minimum of every five years to:

- Identify Project-specific factors that may warrant revision to the Plan;
- Incorporate information and changes necessary to monitor an increase in risk to or endangerment of USDWs; and/or
- Deviations from permitted conditions that require Plan modifications.

ExxonMobil will incorporate the collected monitoring data that characterizes the Project-specific factors and the changes needed, if any, to monitor increased potential risk to USDW and overall Plan compliance with the UIC Director's requirements. Plan amendments will be submitted within one year of an AoR reevaluation, following significant facility changes (such as the development of offset monitoring wells or newly permitted injection wells within the AoR), or as the UIC Director requires. Table 5-10 summarizes the various measurements discussed in the Testing and Monitoring Plan and the frequency of measurements for data collection and reporting purposes.

Table 5-10: Testing and Monitoring Plan Measurements and Frequency

Equipment / Measurement	Regulation	Objective	Claimed as PBI [redacted]
Coriolis flow meter	146.90b	Measure mass flow rate	Claimed as PBI [redacted]
Corrosion coupon	146.90c	Measure corrosion levels on the types of metal used in the Project	Claimed as PBI [redacted]
Injection stream sampling	146.90a	Provide more detailed analysis via periodic lab analysis of injection stream	Claimed as PBI [redacted]
Central pad temperature gauge	146.90a	Measure temperature of the total injection stream at the pad before partitioning to injections	Claimed as PBI [redacted]
Injection wellhead tubing P gauge	146.90a	Measure downstream of choke	Claimed as PBI [redacted]
Injection wellhead annulus P gauge	146.90b	Verify annulus pressure maintained	Claimed as PBI [redacted]
Injection annulus pressure test	146.89b	Verify absence of leak in annulus	Claimed as PBI [redacted]
Injection Well downhole pressure and temperature gauge for active/open injection interval	146.90b	Measure downhole pressure and temperature (injection mass to volume conversion, verifying that it is not exceeding maximum pressure)	Claimed as PBI [redacted]
	146.90f	Measure fall-off of pressure after abandoning injection stage and initiating injection in next stage above	Claimed as PBI [redacted]
	146.90g(1)	Direct measurement of pressure, sensitive to pressure from other injections, especially when injection intervals are staggered between wells	Claimed as PBI [redacted]
Injection well behind-casing fiber	146.90g(2)	DAS-VSP: main imaging fiber	Claimed as PBI [redacted]
	146.87a(3)(ii)	DTS for cement long portion of long-string casing where fiber is cemented in place	Claimed as PBI [redacted]

Equipment / Measurement	Regulation	Objective	Claimed as PBI [redacted]
	146.90e	Supplementary fiber for external MIT; does not cross the UCCZ, which is important for external MIT, but is closer to formation and may therefore have heightened sensitivity to potential flow through channels through or along cement	Claimed as PBI [redacted]
Injection well CIL	146.90e	Through-tubing log to detect loss of metal mass in casing due to corrosion	Claimed as PBI [redacted]
Claimed as PBI [redacted]	Claimed as PBI [redacted]	Claimed as PBI [redacted]	Claimed as PBI [redacted]
Claimed as PBI [redacted]	Claimed as PBI [redacted]	Claimed as PBI [redacted]	Claimed as PBI [redacted]
Claimed as PBI [redacted]	Claimed as PBI [redacted]	Claimed as PBI [redacted]	Claimed as PBI [redacted]
Claimed as PBI [redacted]	Claimed as PBI [redacted]	Claimed as PBI [redacted]	Claimed as PBI [redacted]
Claimed as PBI [redacted]			

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