TESTING AND MONITORING PLAN
40 CFR §146.90

Brown Pelican CO_2 Sequestration Project

1.0 Facility Information and Plan Overview

Facility name: Brown Pelican CO_2 Sequestration Project
BRP CCS1, CCS2 and CCS3 Wells

Facility contact: Caroline Huet, Carbon Certification Lead
[redacted]

Well location: Penwell, Texas
[redacted]

This Testing and Monitoring Plan describes how Oxy Low Carbon Ventures, LLC (OLCV), will monitor the Brown Pelican CO_2 Sequestration Project (BRP Project or Project) site pursuant to 40 CFR §146.90. Testing and monitoring data will be used to demonstrate that the CO_2 Injection wells are operating as planned, the CO_2 plume and pressure front are behaving as predicted, and that there is no endangerment to Underground Sources of Drinking Water (USDW). In addition, the testing and monitoring data will be used to validate and adjust the geocellular and simulation models used to predict the distribution of the CO_2 within the storage zone to support Area of Review (AoR) re-evaluations and a non-endangerment demonstration at site closure.

Results of the testing and monitoring activities described below may trigger action according to the Emergency and Remedial Response Plan.

2.0 Overall Strategy and Approach for Testing and Monitoring

The Testing and Monitoring Plan was designed to monitor and mitigate the key risks identified for this project that are described in the Emergency and Remedial Response Plan (part of this application). During the Injection and Post-injection periods, those risks include the potential for: well integrity failure, leakage to USDW, natural disasters, induced seismicity or critical surface impacts. The testing and monitoring methods included in this document are mitigations and controls to prevent CO_2 or brine leakage out of the Injection Zone that could endanger the USDWs, migrate to a different stratum, or create a risk for people or the environment.

In addition, the testing and monitoring program is tailored to track the migration of the CO_2 plume and development of the pressure front within the Injection Zone. Data will be collected prior to injection to establish a baseline. Data collected during the injection and post-injection periods from the testing and monitoring program will help to validate the simulation models and re-evaluate the AoR.

The testing and monitoring program includes controls and mitigations in the following categories:

1. Carbon dioxide stream analysis
2. Continuous recording of operational parameters: injection rate, volume, pressure, temperature, and internal mechanical integrity
3. Corrosion monitoring and leak detection
4. Above confining zone monitoring, including the first permeable zone above the confining zone, USDW, and the near-surface
5. Internal and external mechanical integrity testing
6. Pressure fall-off testing
7. Carbon dioxide plume and pressure front tracking
8. Surface Monitoring

The methodology and frequency of testing and monitoring methods is expected to change throughout the life of the project. Pre-injection monitoring and testing will focus on establishing baselines and ensuring that the site is ready to receive injected CO_2. Injection phase monitoring will be focused on collecting data that will be used to calibrate models and ensure containment of CO_2. Post-injection phase monitoring and testing is designed to demonstrate CO_2 plume stabilization and ensure containment. The testing and monitoring plan will be reviewed at least once every five years and will be amended, if necessary, to ensure monitoring and storage performance is achieved and new technologies are appropriately incorporated.

Data obtained from the testing and monitoring plan will be used to inform operational decisions on the quantity and rate of CO_2 injected and potential containment actions. Data will be used to improve computational model forecasts. Data that is interpreted to be inconsistent with model predictions will trigger additional testing, monitoring and evaluation.

A summary of the proposed testing and monitoring methods and timing of testing and monitoring is listed in Table 1.

[redacted]

[redacted]

[redacted]

[redacted]

2.1 Well Monitoring Network Design

Multiple testing and monitoring objectives described in Table 1 will be accomplished by evaluating data from monitoring wells (Table 2). These wells will provide direct measurements to compliment indirect measurement methods for monitoring the AoR. In addition, data from monitoring wells will be used to characterize fluid chemistry and isotopic composition throughout the stratigraphic column. A summary of data by well type is shown in Table 3.

OLVC plans to install Single Reservoir-level (SLR) wells in the Injection Zone, Above Confining Zone (ACZ) wells in the first permeable layer above the confining zone, and an Underground Source of Drinking Water Aquifer (USDW) monitor well in the lowermost USDW. Prior to initial injection into the Injection Zone, OLCV will install at least one SLR, one ACZ, and one USDW. Two additional SLR wells are planned to be constructed. The need for additional monitoring wells will be evaluated as needed, and at least annually during the injection period and until plume stabilization. OLCV describes below the locations of monitoring wells to be installed prior to first injection and the proposed locations of future monitoring wells.

In addition to SLR wells, the Injection Zone will be monitored with data collected in Water Withdrawal wells (WW). The WW wells will extract brine to manage pressure in the Injection Zone. [redacted] The CO_2 injectate plume is not expected to reach the WW1, WW3 and WW4. If the CO_2 plume does reach these WW wells, they will be shut in. The CO_2 injectate plume is expected to reach WW2. When the plume in the Holt sub-zone reaches WW2, the well will be plugged above the Holt and continue to produce brine from the upper portion of the Lower San Andres. The CO_2 injectate plume from the upper part of the Lower San Andres (Lower San Andres sub-zone and G1 sub-zone) is not expected to reach the WW2.

Table 2—Planned wells used for monitoring

Regulatory Well Name	Project Well Name	Anticipated Drill Date	Purpose	~TD (ft)	Latitude (NAD 27)	Longitude (NAD 27)
Shoe Bar 1	SLR1	[redacted]	Injection zone monitor	[redacted]	31.76343602	-102.7034981
Shoe Bar 2SLR	SLR2	[redacted]				
Shoe Bar 3SLR	SLR3					
Shoe Bar 1AZ	ACZ1					
Shoe Bar 1USDW	USDW1					
Shoe Bar 1WW	WW1					
Shoe Bar 2WW	WW2					
Shoe Bar 3WW	WW3					
Shoe Bar 4WW	WW4					

[1]Stratigraphic test wells, already drilled
[2]Anticipated TD following conversion to monitor well
[3]Anticipated TD following conversion from Injection Zone monitor to Above Confining Zone monitor
[4]Anticipated TD following plugging above Holt zone

[redacted]

[redacted]

2.1.1 SLR monitoring wells

The SLR well locations were selected based on potential leakage pathway scenarios, and on the computationally simulated plume and critical pressure front. The modelled CO_2 plume and pressure front extends semi-radially from the BRP CCS1, CCS2 and CCS3 wells. SLR wells were placed to detect movement of the plume and pressure front.

OLCV proposes a phased drilling approach to allow for incorporation of operational data to the monitoring plan. The data obtained during early CO_2 injection may result in adjusting the well locations or timing of drilling. The proposed location, timing and data collected in SLR wells is described below:

- The Shoe Bar 1 well is a stratigraphic test well that was completed in February 2023. This [redacted]
- [redacted]

- [redacted]

The SLR wells will be completed with tubing and packer, will isolate the casing and formations in the Upper San Andres and Grayburg formations (Upper Confining Zone), and will have open perforations in the Lower San Andres (Injection Zone) to allow direct measurements in the [redacted]

The figure below illustrates the design of proposed SLR1 well. Refer to Appendix A of the Injection Well Construction Plan for a wellbore diagram of SLR2 and SLR3.

[redacted]

Figure 1—SLR1 schematic

2.1.2 ACZ Monitoring Wells

The ACZ1 well is located in close proximity [redacted]. The need for additional ACZ monitoring wells will be evaluated as-needed, and at least annually during the injection period and until plume stabilization.

The Shoe Bar 1AZ well is a stratigraphic test well that was drilled in August 2023. It will be referred to as the ACZ1 throughout the Testing and Monitoring Plan. [redacted]

The figure below shows the design for the Shoe Bar 1AZ after conversion to the AZ1 monitor well.

[redacted]

Figure 2—ACZ1 schematic after conversion to monitoring well from Shoe Bar 1AZ stratigraphic test well

[redacted]

2.1.3 USDW Monitoring Well

A USDW-level well will be drilled and completed in the lower portion of the Dockum aquifer, which is the lowermost USDW. This well will be used to collect baseline geochemical and isotopic information about the USDW prior to the commencement of CO_2 injection and will be used to monitor groundwater geochemistry and dissolved gas during the injection phase of the project.

[redacted]

The figure below shows the wellbore diagram for the USDW1 well.

[redacted]

Figure 3—USDW Monitoring well

2.2 Other Monitoring Techniques

In addition to utilizing a well-based network to monitor pressure, temperature, and fluid and dissolved gas chemistry of the subsurface, OLCV will also utilize surface and near-surface methods to monitor CO_2 containment. Additional details on geophysical monitoring methods are described in Sections 11 and 12 of this document. Near-surface soil and soil gas monitoring is described in Section 8.2.

2.3 Quality Assurance Procedures Summary

A Quality Assurance and Surveillance Plan (QASP) for testing and monitoring activities, required pursuant to 40 CFR §146.90(k), is provided as a separate document.

2.4 Reporting Procedures Summary

OLCV will report the results of all testing and monitoring activities to the EPA in compliance with the requirements under 40 CFR §146.91.

3.0 Carbon Dioxide Stream Analysis

OLCV will analyze the CO_2 stream during the operation period to yield data representative of its chemical and physical characteristics and to meet the requirements of 40 CFR §146.90(a).

The source of the CO_2 for the Project is a Direct Air Capture (DAC) facility that is located near the proposed CO_2 sequestration site. [redacted]

3.1 Location and Frequency

[redacted]

[redacted]

Table 4—CO_2 Injectate Stream Specification

[redacted]

Table 5—CO_2 injectate stream monitoring method and frequency

[redacted]

[redacted]

[redacted]

3.3 Sampling Methods

[redacted]

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

[redacted]

<u>4.0 Continuous Recording of Operational Parameters</u>

OLCV will install and use continuous recording devices to monitor injection pressure, rate, volume; the pressure on the annulus between the tubing and the long string casing; and the temperature of the CO_2 stream, as required by 40 CFR §146.88(e)(1), §146.89(b), and §146.90(b).

4.1 Monitoring Location and Frequency

[redacted]

Table 6—Continuous Monitoring Methods and Frequency

[redacted]

[redacted]

4.2 Description of Methods and Justification

4.2.1 Pressure and Temperature Monitoring

[redacted]

[redacted]

4.2.2 Injection Rate and Volume Monitoring

[redacted]

The project will follow the equations from 40 CFR Part 98-Subpart RR for CO_2 mass calculation.

4.2.3. Packer fluid / Annulus Volume Monitoring

[redacted]

[redacted]

4.2.4. Justification of Continuous Monitoring Methods and Backup Options

[redacted]

5.0 Corrosion Monitoring and Surface Leak Detection

To meet the requirements of 40 CFR §146.90(c), OLCV will monitor well materials during the operation 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.

Materials (Table 7) have been selected to mitigate and inhibit corrosion. The suitability of the materials has been determined with published performance data from materials suppliers. A summary of materials is listed below. These materials will be monitored via coupons that will be exposed to the CO_2 injectate stream.

Table 7—List of Equipment with Construction Materials in Pipeline, Injectors, In-zone Monitor wells, and Above Confining Zone Monitor wells

[redacted]

5.1 Monitoring Location and Frequency

[redacted]

Table 8—Corrosion Monitoring and Surface Leak Detection Summary

[redacted]

5.2 Description of Methods and Justification

5.2.1 Corrosion Coupons

Samples of injection well materials (coupons) will be exposed to the injected CO_2 stream and monitored for signs of corrosion to verify that the well components meet the minimum standards for material strength and performance and to identify well maintenance needs. Coupons will be [redacted]

Table 9—Summary of Analytical Parameters for Corrosion Coupons

[redacted]

Coupon data will be evaluated by OLCV engineers to confirm that well components meet the standards for material strength and performance. Appropriate corrective action will be taken if needed to restore the well components to meet operational standards.

5.2.2. Casing Inspection Logs

OLCV intends to perform casing inspection logging (CIL) during planned well maintenance. Between planned maintenance events, OLCV may conduct a CIL, if corrosion coupon data indicates potential loss of material strength or performance inconsistent with operating standards.

5.2.3. Surface detection methods

[redacted]

6.0 Monitoring the Injection Zone

Injection-zone monitoring of pressure and temperature will be conducted to directly confirm the presence of absence of CO_2 at the monitoring well location.

6.1 Monitoring Location and Frequency

[redacted]

Table 10—Monitoring of the Injection Zone using SLR wells

[redacted]

[redacted]

6.2. Description of Methods and Justification

[redacted]

7.0 Monitoring the First Permeable Zone Above the Confining Zone

The first permeable zone above the confining zone, the Yates Formation, will be monitored with a dedicated well located close to the injection site. [redacted]

Together with shallow groundwater and near-surface monitoring (See Section 8 of this document), OLCV will monitor groundwater quality and geochemical changes above the confining zone during the operation period to meet the requirements of 40 CFR §146.90(d). The results of ground water sampling will be compared to baseline geochemical and isotopic data collected during the site characterization baseline, consistent with 40 CFR §146.82(a)(6), to obtain evidence of potential fluid or gas movement.

7.1 Monitoring Location and Frequency

[redacted]

Table 11—Monitoring above the confining zone

[redacted]

7.2 Description of Methods and Justification

[redacted]

8.0 Monitoring USDW Ground Water and the Near-Surface

[redacted]

For the BRP Project, the lowermost USDW and soil gas within the AoR will be monitored in accordance with 40 CFR §146.90(d) and 40 CFR §146.90(h), respectively, and at the frequencies specified in Table 12.

Table 12—Monitoring in USDW Well and in the Near-Surface

[redacted]

8.1. USDW Sampling

8.1.1 Monitoring Location and Frequency

[redacted]

[redacted]

8.1.2. Description of Methods and Justification

[redacted]

[redacted]

Table 13—Water Analysis Parameters

[redacted]

[redacted]

[redacted]

[redacted]

8.2. Near-Surface Soil and Soil Gas Sampling

8.2.1 Monitoring Location and Frequency

[redacted]

[redacted]

8.2.2 Description of Methods and Justification

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

9.0 Internal and External Mechanical Integrity Testing

OLCV will conduct tests to verify the internal and external mechanical integrity of the Injector Wells before and during the injection phase pursuant to 40 CFR §146.89(c), 40 CFR §146.90(e), 40 CFR §146.87 (a)(2)(ii), and 40 CFR §146.87 (a)(3)(ii)].

The purpose of internal mechanical integrity testing is to confirm the absence of significant leakage within the injection tubing, casing, or packers [40 CFR §146.89(a)(1)]. Continuous monitoring of injection pressure, injection rate, injected volume and annulus pressure will be used to ensure internal mechanical integrity. In addition, annulus pressure tests will be periodically conducted to confirm gauge measurements.

The purpose of external mechanical integrity testing is to confirm the absence of significant leakage outside of the casing [(40 CFR §146.89(a)(2))]. OLCV proposes to conduct temperature logging in the Injector wells on an annual basis to demonstrate external mechanical integrity. In addition, [redacted]

[redacted]

9.1 Testing Location and Frequency

Table 15 below provides a summary of the internal and external mechanical integrity monitoring methods and mechanical integrity testing (MIT) plans in the injector and monitoring wells.

To demonstrate internal mechanical integrity of the injector wells, OLCV will perform annular pressure tests during well construction and at least once every five years thereafter, coincident with well maintenance operations in which tubing and packer are pulled. Annular monitoring tests will be performed on SLR, ACZ and WW wells during construction and annually thereafter. [redacted]

[redacted]

OLCV engineers will monitor downhole P/T data to look for changes that could indicate leakage inside the annulus or outside of the casing. If anomalous measurements are recorded, OLCV personnel will immediately conduct further investigations to determine if there is evidence of surface leakage and take appropriate corrective action. If no surface leakage is detected, OLCV personnel will continue to evaluate the source of the anomalous data and may choose to conduct an annulus pressure test, wireline conveyed P/T gauge, or other logging tool to investigate the borehole integrity. If anomalous data is not found to be the result of operational changes, such as a rate change, injection operations in the affected well will be ceased until the source of the anomalous data is determined and/or corrective action it applied.

Table 15—Internal and External Mechanical Integrity Monitoring Methods and Frequency in Injector Wells

[redacted]

[redacted]

SLR and ACZ wells will also be monitored for mechanical integrity.

Table 16—Internal and External Mechanical Integrity Monitoring Methods in SLR, ACZ and WW wells

[redacted]

9.2 Description of Methods and Justification

9.2.1 Internal Mechanical Integrity Using Annular Pressure Tests

An annular pressure test is a common method to demonstrate internal mechanical integrity. The test is based on the assumption that pressure applied to fluids in the annular space should be constant unless there are significant changes in temperature or a fluid leak.

An overview of the annular pressure test procedure is as follows:

- Shut in the well to stabilize the pressures in the injectors.
- Connect the testing equipment to the annular valves and test surface lines to 1,500 psi above the testing pressure.

- Ensure there are no surface leaks from the pumping unit to the wellhead valve.
- Bleed any air in the system. If needed, fill the annular space with packer fluid and corrosion inhibitor (if so, it should require only a minimal amount).
- Record the initial tubing and casing pressure. The well will be tested to 500 psi in the annular space, and the pressure should not decrease more than 5% in 30 minutes.
- Monitor the tubing and casing pressures continuously. Record the final tubing and casing pressure, then bleed the pressure and volume. If the pressure decreases more than 5%, bleed the pressure, test the surface connection, and repeat the test. If there is an indication of mechanical failure, the operator will prepare a plan to repair the well and discuss it with the Program Director.

[redacted]

9.2.3 External Mechanical Integrity Testing Using Logging Tools

[redacted]

In the future, new technologies or tools may be proposed for further discussion with regulators. Additional details on tools can be found in Appendix A of this document.

10.0 Pressure Fall-Off Testing

OLCV will perform a pressure fall-off test prior to injection 40 CFR §146.87(e) and during the injection phase as described below to meet the requirements of 40 CFR §146.90(f).

10.1 Testing Location and Frequency

The table below summarizes the pressure fall-off testing plan for the injector well.

Table 17—Summary of pressure fall-off testing

Method	Pre-Injection	Injection	Post-Injection
Fall-off Testing	Prior to injection	At least once every five years during workovers	N/A

Pressure fall-off testing in the form of Step Rate Test will be conducted upon completion of the injection well to characterize reservoir hydrogeologic properties, aquifer response characteristics, and changes in near-well/reservoir conditions that may affect operational CO_2 injection behavior.

Following the commencement of injection operations, pressure fall-off testing will be conducted at least once every five years during injection and before well plugging. The objective of the periodic pressure fall-off testing is to determine whether any significant changes in the near-wellbore conditions have occurred that may adversely affect the well or reservoir performance.

10.2 Description of Methods and Justification

Pressure fall-off testing is a method of monitoring changes that may impact injectivity or pressure response in the near-wellbore environment. Additionally, pressure fall-off testing can be used to monitor wellbore mechanical integrity. The fall-off test is conducted by ceasing injection for a designed time period, and continuously monitoring the pressure and temperature with downhole gauges. The duration of the test is designed to measure the pressure recovery.

Pressure fall-off testing is a proven technology that is widely used in subsurface well operations. The results of pressure fall-off tests will be interpreted by engineers and geologists who are experienced in analyzing this type of data. Experienced senior advisors will be consulted to add additional technical insight. The interpretation will be used to confirm or update operational parameters and confirm wellbore mechanical integrity.

Pressure gauges used to conduct fall-off tests will be calibrated in accordance with the manufacturers' recommendations. In lieu of removing the injection tubing to recalibrate the downhole pressure gauges, their accuracy will be demonstrated by comparison with a second pressure gauge with current certified calibration, which will be lowered into the well to the same depth as the permanent downhole gauge. Calibration curves for the downhole gauge, based on annual calibration checks using the second calibrated gauge, can be used for the fall-off test. These calibration curves (showing all historic pressure deviations) will accompany the fall-off test data.

10.3 Interpretation of fall-off test results

Quantitative analysis of the pressure fall-off test response provides the basis for assessing near-well and larger-scale reservoir behavior. Comparison of diagnostic pressure fall-off plots measured before CO_2 injection and during the operational injection phases can be used to determine whether significant changes in well or storage reservoir conditions have occurred. Diagnostic derivative plot analysis (Bourdet et al., 1989; Spane, 1993; Spane and Wurstner, 1993) of the pressure fall-off recovery response is particularly useful for assessing potential changes in well and reservoir behavior.

Plotting the downhole temperature concurrent with the observed fall-off test pressure is useful to check for anomalous pressure fall-off recovery response. Commercially available pressure gauges typically are self-compensating for environmental temperature effects within the probe sensor (i.e., within the pressure sensor housing). However, if temperature anomalies are not accounted for correctly (e.g., well/reservoir temperatures are responding differently than registered within the probe sensor), erroneous pressure fall-off response results may be derived. Thus, concurrent plotting of downhole temperature and pressure fall-off responses is useful for assessing whether temperature anomalies may be affecting pressure fall-off recovery behavior. In addition, diagnostic pressure fall-off plots should be evaluated relative to the sensitivity of the pressure gauges used to confirm adequate gauge resolution (i.e., excessive instrument noise).

Standard diagnostic log-log and semi-log plots of observed pressure change and/or pressure derivative plots vs. recovery time are commonly used as the primary means for analyzing pressure fall-off tests. In addition to determining specific well performance conditions (e.g., well skin) and aquifer hydraulic property and boundary conditions, the presence of prevailing flow regimes can be identified (e.g., wellbore storage, linear, radial, spherical, double-porosity) based on characteristic diagnostic falloff pressure derivative patterns. A more extensive list of diagnostic derivative plots for various formation and boundary conditions is presented by Horne (1990) and Renard et al. (2009).

Early pressure fall-off recovery response corresponds to flow conditions in and near the wellbore, whereas later fall-off recovery response is reflective of reservoir conditions progressively farther from the injection well location. Significant divergence in pressure fall-off response patterns from previous tests (e.g., accelerated pressure fall-off recovery rates) may be indicative of a change in well and/or reservoir conditions (e.g., reservoir leakage). A more detailed discussion of using diagnostic plot analysis of pressure falloff tests for discerning possible changes to well and reservoir conditions is presented by the EPA (2002).

11.0 Carbon Dioxide Plume and Pressure Front Tracking

OLCV will monitor the CO_2 plume and pressure front using both direct and indirect methods pursuant to 40 CFR §146.90(g)(1) and (2). A summary of the methods used for CO_2 and pressure front tracking are provided in Table 18 below.

11.1. Monitoring Location and Frequency

Direct tracking methods include:

- Geochemical monitoring of fluids in the Injection Zone and shallow fluids and gasses. Note that a detailed description of geochemical characterization and monitoring is presented in Section 6 of this document.
- Pressure and temperature measurements from the Injection Zone, and the first permeable layer above the confining zone.

Indirect tracking methods include:

[redacted]

Table 18—Direct and indirect methods of tracking the CO_2 plume and pressure front

[redacted]

[redacted]

11.2 Description of Methods and Justification

The direct and indirect tracking methods described in this document meet and/or exceed the requirements of the Testing and Monitoring plan established in UIC Class VI. The proposed methods are proven technologies and have been used by the Operator to safely conduct subsurface operations for decades. Additional new technologies will be considered in a cost versus benefit analysis and added to the plan if they are deemed to be warranted.

11.2.1 Geochemical Monitoring

Geochemical monitoring will be employed in SLR, ACZ and USDW wells. These data will be compared with the pre-injection geochemical and isotopic characterization to constrain whether changes are observed. If changes are measured, then OLCV will constrain whether the compositional changes are likely to be the result of naturally occurring biological processes or another source. Additional detail on geochemical monitoring are described in Section 6 of this document.

11.2.2 Pressure and Temperature Monitoring

Pressure and temperature gauges will be deployed on the tubing above and below the injection packer to monitor bottomhole conditions in real time. In SLR wells, the gauges and cables will be selected to withstand CO_2 service conditions. ACZ wells are not anticipated to come in contact with CO_2. These data will be integrated in the SCADA system and surveillance platform. OLCV will routinely evaluate the data and interpret the results. If a change in pressure or temperature is recorded, OLCV will evaluate and attribute the source of the change. Additional details on downhole gauge instrumentation are described in the QASP document that is part of this application.

[redacted]

11.2.3 Saturation Detection Tool Method

[redacted]

11.2.4 Repeat Seismic Methods

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

12. Induced Seismicity Monitoring

12.1 Description of Methods and Justification

12.1.1 Traffic Light System for Monitoring Induced Seismicity

Based on information provided by the United States Geological Survey (USGS), the BRP Project area does not show high seismic activity that could endanger the containment of the CO_2 in the storage complex. Seismicity history is discussed in more detail in the Area of Review and Corrective Action Plan document of the permit.

Change of in-situ stresses on existing faults caused by human activities (e.g., mining, dam impoundment, geothermal reservoir stimulation, wastewater injection, hydraulic fracturing, and CO_2 sequestration) may induce earthquakes on critically stressed fault segments. To monitor potential induced seismicity due to the injection of CO_2 in the area, it is proposed that the project deploy surface seismometer stations.

While the historical seismicity of the project area indicates no earthquakes in the immediate vicinity, the operator intends to monitor the site with a seismic monitoring system for the duration of the project to ensure the safe operation of both the storage facility and adjacent infrastructure in the area. The seismic monitoring will be conducted with a surface array deployed to ensure detection of events above local magnitude (ML) 1.0, with epicentral locations within 10 miles of the injection well.

If an event is recorded by either the local private array or a public (national or state) array occurs within 10 miles of the injection well, OLCV will implement the response plan subject to detected earthquake magnitude limits defined below to eliminate or reduce the magnitude and/or frequency of seismic events:

[redacted]

[redacted]

12.1.2 Induced Seismicity Monitoring Network

A seismometer monitoring network will be deployed to determine the locations, magnitudes, and focal mechanisms of any injection-induced seismic events in case they occur. This information will be used to address public concerns and to monitor changes in induced seismicity risks with a goal of reacting to the perceived risk through adjustment of well operations as needed. A map of proposed new station locations is provided in Figure 10. Existing locations are provided as attachment in the GSDT. These station locations were used for modeling the expected sensitivity of the array at the project site. Locations are subject to change in order to optimize the station locations around surface infrastructure and access limitation and changes to the pressure plume modeled so as to provide optimum monitoring of the site.

[redacted]

Figure 10—Locations of proposed new passive seismic monitoring stations

The design and installation of the station array is performed by specialized contractors and include the following activities:

- Project management support to design the seismometer array, model the network performance, coordinate permitting and equipment installation, conduct testing and maintenance, and ensure optimum execution of the Project.
- Field operations to deploy seismic station instrumentation, run power and communication systems, monitor data quality, and do commissioning.

- Data acquisition, system configuration, and process setup.
- Continuous support and monitoring for data verification and QA/QC.
- Continuous near-real-time reporting, including analyst reviews and alert notifications, for events at or above predetermined magnitude thresholds over the seismic area.

12.1.3 Seismicity Monitoring Equipment

[redacted]

13.0 Reporting

The results of all testing and monitoring are to be described in a semi-annual report that will be submitted to the EPA.

14.0 References

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TESTING AND MONITORING PLAN, APPENDIX A: LOGGING TOOLS

Brown Pelican CO_2 Sequestration Project

[redacted]

1.0 Facility Information

Facility name: Brown Pelican CO_2 Sequestration Project
BRP CCS1, CCS2 and CCS3 Wells

Facility contact: Caroline Huet, Project Manager
[redacted]

Well location: Penwell, Texas
[redacted]

2.0 Logging Tools

2.0.1 Cement Bond Log

Cement bond log (CBL) is a basic method to evaluate cement quality in the annulus. It is an acoustic wave measurement. The tool usually includes a transmitter and receiver set 3 ft apart. The acoustic wave is emitted by the transmitter, propagated down and across the annulus, and recorded by the receiver. The attenuation of the wave is analyzed to interpret the bonding behind the pipe. A signal coming from a properly cemented casing will be more attenuated than signals coming from a poorly cemented one.

The arriving signal recorded by the receiver is a mixed signal coming from casing, cement, mud, and formations. Each signal has its own pathway because signals travel at different velocities through each medium. The signal through the casing is the fastest, as sound travels the quickest through steel. As a result, it is the first signal detected on the receiver. The second signal most likely to arrive is the signal through the formation, and the last one is the drilling fluid signal, because sound travels more slowly in a liquid.

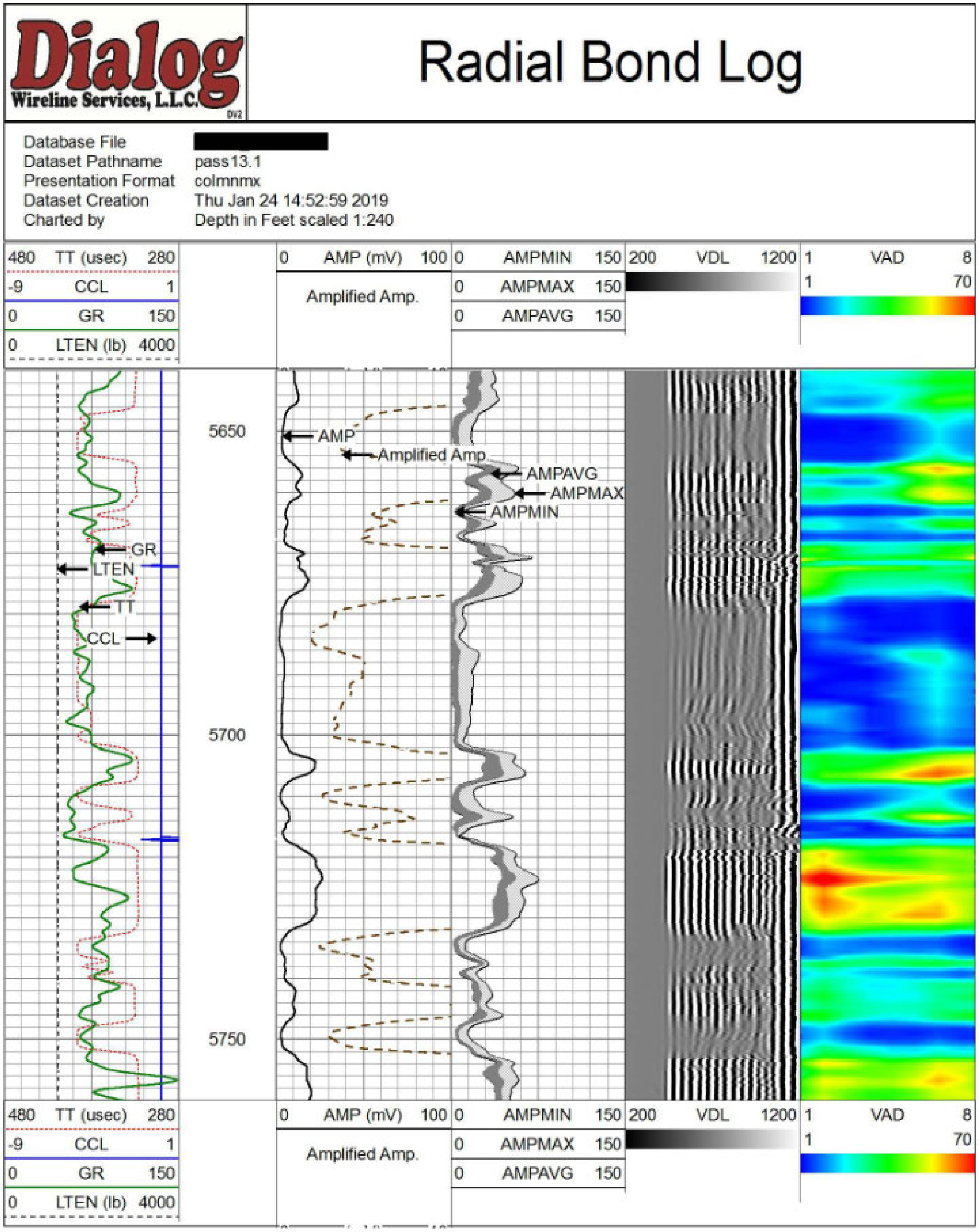

Figure 1—CBL and VDL Example from Dialog Wireline Services Web Page

Variable Density Log

A variable density log (VDL) is commonly used as an adjunct to the cement bond log and offers better insights with its interpretation. In most cases, micro-annulus and fast-formation-arrival effects can be identified using this additional display (Figure XX).

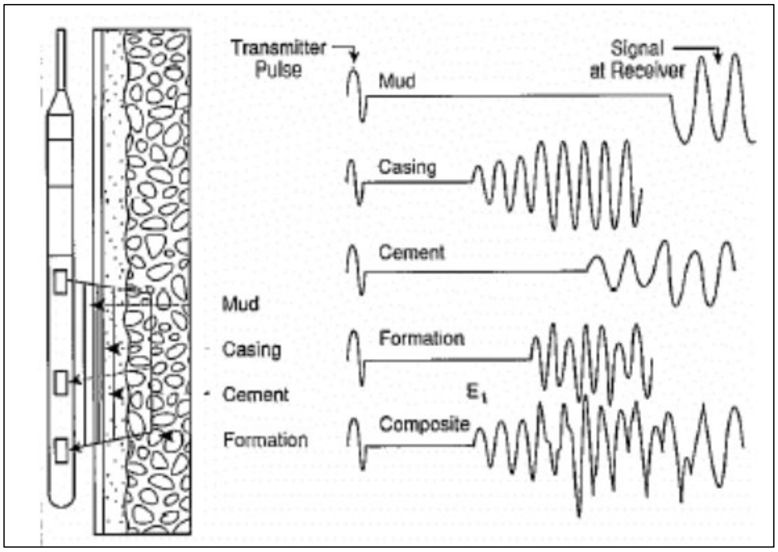

Figure 2—Signal received by CBL-VDL

The **USI[1] UltraSonic Imager Tool (USIT)** delivers an accurate, comprehensive, high-resolution confirmation of the pipe-to-cement bond quality and downhole pipe condition in real time. Casing inspection and monitoring applications include corrosion detection, identification of internal and external damage or deformation, and casing thickness analysis for collapse and burst pressure calculations.

The rate of decay of the waveforms received indicates the quality of the cement bond at the cement-casing interface. The resonant frequency of the casing provides the casing wall thickness required for pipe inspection. The resulting 360° data coverage enables evaluation of the quality of the cement bond and the determination of both the internal and external condition of the casing.

The **Isolation Scanner** (a service of Schlumberger) provides a combination of independent measurements that fully characterizes the annular environment, differentiating low-density solids from liquids to distinguish lightweight and contaminated cements from liquids. Its azimuthal coverage provides results around the entire circumference of the casing, pinpointing any channels in the cement and confirming the effectiveness of the annular barrier for zonal isolation.

[1] USI is a trademark of Schlumberger

The Isolation Scanner tool also identifies corrosion or drilling-induced wear through measurement of the inside diameter and thickness of the casing. The flexural wave measurement produces entirely new information from the third-interface echoes (TIEs) between the annulus and borehole or outer casing. The TIEs image the borehole shape, define the position of the casing within the borehole or outer casing, and image the outer string to reveal corrosion and damage.

2.0.2 Electromagnetic Log

The **Electromagnetic Pipe Xaminer®** (a Halliburton technology) induces a high-definition frequency (HDF) electromagnetic energy into the surrounding pipe, which propagates through the concentric well strings with no wellbore fluid influences. The interaction with the metal of the pipe returns a signal to the tool, yielding information about any metal loss in the tubulars. The magnitude and location of corrosion-induced defects are identified using HDF variance algorithms of the returning electromagnetic waves. This information leads to a quick total thickness calculation to determine the overall condition of the pipe structure. This technology enables users to examine the whole well with up to five concentric strings of pipe in one trip.

2.0.3 Temperature Log

Temperature logs are used to locate gas entries, detect casing leaks, and evaluate fluid movement behind casing. They are also used to detect lost-circulation zones and cement placement. Temperature logs are used as a basic diagnostic tool and are usually paired with other tools like acoustics or multi arms calipers if more in depth analysis is required.

Temperature instruments used today are based on elements with resistances that vary with temperature. The variable resistance element is connected with bridge circuitry or constant current circuit, so that a voltage response proportional to temperature is obtained. The voltage signal from temperature device is then usually converted to a frequency signal transmitted to the surface, where it is converted back to a voltage signal and recorded. The absolute accuracy of temperature logging instruments is not high (in the order of +- 5°F), but the resolution is good (0.05°F) or better, although this accuracy can be compromised by present day digitalization of the signal on the surface. The temperature instrument usually can be included in the string with other tools, such as radioactive tracer tools or spinners flowmeters. Temperature logs are run continuously, typically at cable speeds of 20 to 30 ft/min.

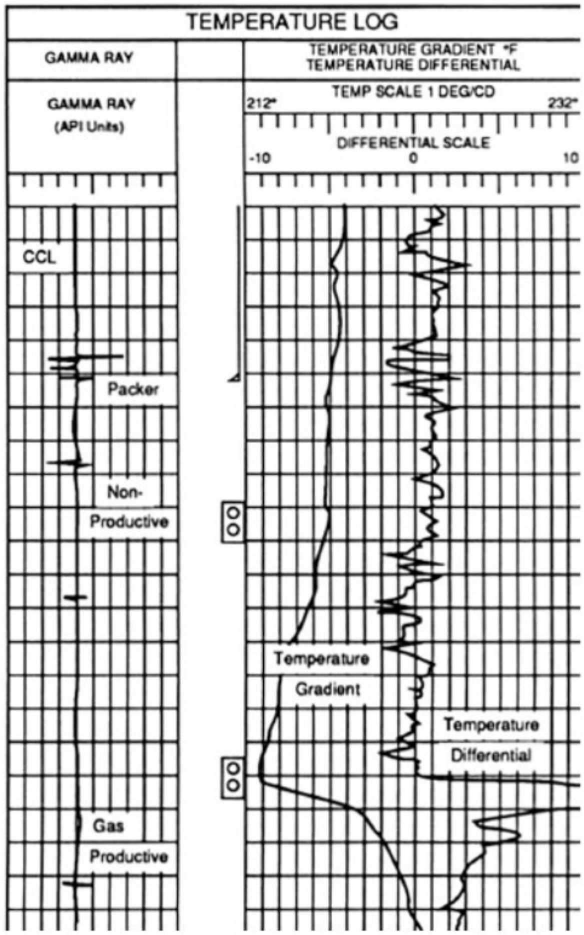

Figure 3—Example of temperature log output

2.0.4 Variable Density Log

A Variable Density Log (VDL) is a presentation of the acoustic waveform at a receiver of a sonic or ultrasonic measurement, in which the amplitude is presented in color or the shades of a gray scale. The variable-density log is commonly used as an adjunct to the cement-bond log and offers better insights into its interpretation. In most cases micro-annulus and fast-formation-arrival effects can be identified using this additional display.

2.0.5 UltraSonic Imager Log

The USI* UltraSonic Imager tool (USIT) uses a single transducer mounted on an Ultrasonic Rotating Sub (USRS) on the bottom of the tool. The transmitter emits ultrasonic pulses between 200 and 700 kHz and measures the received ultrasonic waveforms reflected from the internal and external casing interfaces. The rate of decay of the waveforms received indicates the quality of the cement bond at the cement/casing interface, and the resonant frequency of the casing provides the casing wall thickness required for pipe inspection. Because the transducer is mounted on the rotating sub, the entire circumference of the casing is scanned. This 360° data coverage enables the evaluation of the quality of the cement bond as well as the determination of the internal and external casing condition. The very high angular and vertical resolutions can detect channels as narrow as 1.2 in [3.05 cm]. Cement bond, thickness, internal and external radii, and self-explanatory maps are generated in real time at the wellsite.

2.0.6 Isolation Scanner Log

The Isolation Scanner™ cement evaluation service integrates the conventional ultrasonic pulse-echo technique with flexural wave propagation to fully characterize the cased hole annular environment while evaluating casing condition—even where the cement has a low acoustic impedance or is contaminated with mud. The Isolation Scanner service can accurately evaluate almost any type of cement— from traditional slurries and heavy cements to the latest lightweight cements. This service provides precise, real-time evaluation of the cement job and casing condition in a wider range of conditions than were previously possible with conventional technologies. Its azimuthal coverage provides a response around the entire circumference of the casing, pinpointing any channels in the cement and confirming the effectiveness of the annular barrier for zonal isolation. Processing provides a robust interpreted image of the material immediately behind the casing. The independent inputs of cement impedance and flexural wave attenuation from the Isolation Scanner service are inversely related to the properties of both the fluid inside the casing and the outside medium. This means that fluid effects are accounted for, eliminating the need for logging specific fluid-property measurements. The output is a solid-liquid-gas (SLG) map that displays the most likely material behind the casing.

2.0.7 Pulse Neutron Log (PNL)

Pulse neutron log (PNL) provides formation evaluation and reservoir monitoring in cased holes. PNL is deployed as a wireline logging tool with an electronic pulsed neutron source and one or more detectors that typically measure neutrons or gamma rays. High-speed digital signal electronics process the gamma ray response and its time of arrival relative to the start of the neutron pulse. Spectral analysis algorithms translate the gamma ray energy and time relationship into concentrations of elements. Each logging company has its own proprietary designs and improvements on the tool.

Schlumberger's Pulsar Multifunction Spectroscopy Service (PNX) pairs multiple detectors with a high output pulsed neutron generator in a slim tool with an outer diameter (o.d.) of 1.72 in. for through-tubing access in cased hole environments. The housing is corrosion-resistant, allowing deployment in wellbore environments such as CO_2. The tool's integration of the high neutron output and fast detection of gamma rays with proprietary pulse processing electronics, allows to differentiate and quantify gas-filled porosity from liquid-filled and tight zones. The tool can accurately determine saturation in any formation water salinity across a wide range of well conditions, mineralogy, lithology, and fluid contents profile at any inclination. Detection limits for CO_2 saturation for the PNX tool vary with the logging speed as well as the formation porosity. Detailed measurement and mechanical specifications for the PNX tool are provided in the QASP document. The wireline operator will provide QA/QC procedures and tool calibration for their equipment.

Haliburton's RMT-D reservoir monitor tool: The Halliburton Reservoir Monitor Tool 3-Detector™ (RMT-3D™) pulsed-neutron tool solves for water, oil, and gas saturations within reservoirs using three independent measurements (Sigma, C/O, and SATG). This provides the ability to uniquely solve simple or complex saturation profiles in reservoirs, while eliminating phase-saturation interdependency. The RMT-#D provides gas phase analysis to identify natural gases, nitrogen, CO_2, steam, and air. The tool has 2.125 in diameter OD that allows it to be run through tubing.

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