# CLASS VI PERMIT PRE-OPERATIONAL TESTING PLAN

## 40 CFR 146.87

SHELL U.S. POWER AND GAS
ST HELENA PARISH SITE

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Revision No. 0
November 2022

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# Table of Contents

## LIST OF FIGURES



## LIST OF TABLES

# 1.0 FACILITY INFORMATION

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|---|---|
| **Facility Name:** | Shell St Helena Parish site<br>Two Class VI Injection Wells |
| **Facility Contact:** | Jason Dupres/U.S. Environmental and Regulatory Lead<br>150 N. Dairy Ashford Rd., Houston, Texas 77079<br>(832) 377-0687<br>Jason.dupres@shell.com |
| **Well Locations:** | SOTERRA IF 1-1<br>[redacted] |
| | SOTERRA IT 2-1<br>Greensburg, St Helena Parish, Louisiana<br>[redacted] |

This *Pre-Operational Testing Plan* describes how Shell U.S. Power and Gas (Shell) will obtain data from the drilling and completion of the proposed injection and monitor wells at or adjacent to the sequestration project in St Helena Parish. A total of two injection wells and three monitoring wells are proposed to meet the injection and storage needs for the facility. The injection wells will be completed into two injection zones as identified within "*Section 2 – Site Characterization*" of the Project Narrative Report (submitted in **Module A** – Project Information Tracking). This Pre-operational Testing Plan has been designed, and meets the requirements, of USEPA 40 CFR §146.87.

## 1.1 INTRODUCTION

This plan contains a comprehensive pre-operational data acquisition strategy across the confining and injection zones (*i.e.*, the Sequestration Complex) at the Shell St. Helena Parish site. These data will be used for site specific determination to evaluate the injection rates, injection volumes, assist with final surface facility design, update of the site model, revalidation of the Area of Review (AoR), and to reduce subsurface uncertainties.

The proposed injection zones for this project are:

1. Frio Formation (Soterra IF 1-1 Injection Well)
2. Wilcox Formation
3. Tuscaloosa Formation (Soterra IT 2-1 Injection Well)

This Pre-Operational Testing Plan has been designed to reduce uncertainty and define the depth, thickness, mineralogy, lithology, porosity, permeability, and geomechanical information of the Injection Zones, the overlying Confining Zone, and other relevant geologic formations in the project area. In addition, formation fluid characteristics will be obtained from the Injection Zones and other critical intervals to establish baseline data against which future measurements may be compared after the start of injection operations.

Shell is requesting to permit two injection wells for this phase of the sequestration project. These wells will be completed into one or more of the project Injection Zones described above. All injection wells will follow the 40 CFR §146.87(a), (b), (c), and (d) and standards for logging and testing requirements. Coring will be adaptive and based upon well spatial variability, wellbore conditions, core recovery, and core quality as each project well is drilled. All wells will demonstrate mechanical integrity prior to receiving authorization to inject. The data obtained in this plan will be used to validate and update, if necessary, the "*Area of Review and Corrective Action Plan*" (submitted in **Module B**), to define and reduce uncertainties with the site characterization, revise the "*E.1-Testing and Monitoring Plan*" (submitted in **Module E**), and determine final operational procedures and limits.

This pre-operational logging and testing strategy has been developed based upon the needs and requirements for the Injection Wells (Section 2.0) and for the in-zone monitoring well(s) (Section 3.0).

# 2.0 INJECTION WELLS – TESTING STRATEGY

The following tests and logs will be conducted during drilling, casing installation, and after casing installation in accordance with the testing required under 40 CFR §146.87(a), (b), (c), and (d). The tests and procedures are described below and in the "*5.0 Proposed Injection Well Construction Information*" section of the Project Narrative (submitted in **Module A**).

All logging and well testing plans will be submitted to the UIC Director 30 days prior to commencing the operations. The UIC director will be provided the opportunity to witness all operations for the drilling and testing of the Injection Wells per the 40 CFR §146.87(f) standard.

## 2.1 DEVIATION CHECKS

A series of injection wells will be drilled at or adjacent to the Shell St. Helena Parish site. The wells are planned to be installed as vertical completions. Wellbore deviation measurements will be conducted at sufficient intervals during the drilling of all phases of the wells. Additionally, a final deviation/gyroscopic survey will be conducted from total depth to the surface in each well.

## 2.2 LOGGING PROGRAM

The well logging program will cover open hole and cased hole for all drilling stages of the injection wells. The logging program will meet all requirements set forth by the EPA Class VI standards and will be used to determine *in-situ* formation properties such as: thickness, porosity, permeability, lithology, formation fluid salinity and reservoir pressure [per 40 CFR 146.87].

A detailed mud logging program will be developed based upon the target depths for each injection well. Cuttings will be caught from surface to total depth (+/-14,500 feet), with adaptive sampling through the proposed Confining Zone and Sequestration Complex. Three sets of mud samples will be collected with an initial sampling rate of every 90 feet for the surface hole section and every 30 feet thereafter to total depth. However, sample density may increase depending on parameters and conditions during drilling. Gas chromatograph sampling (at a minimum of C1 through C4) will also be employed and correlated across the cuttings and drilling for onsite analysis. Isotubes will be collected every 90 ft to have baseline gas measurement.

Table 1 provides information on potential logging run types and the data that each run may provide. Please note that this table is not all encompassing but includes commercially available logs that are commonly run in the wellbores for data acquisition.

**Table 1: Potential Logging Runs and Data Acquisition**

| Logging tools | Data Acquisition |
|---|---|
| Gamma Ray (GR), Caliper, Spontaneous Potential (SP), Resistivity, Density, Neutron | Correlation, Shale Volume, Porosity, Saturations, Hole Size |
| Sonic compressional and shear (P&S) | Porosity, Mechanical Properties |
| Formation Micro-Imager borehole images (resistivity or sonic) | Structure, Environmental Deposition, Fractures |
| Magnetic Resonance | Porosity, Free and Bound fluids, Permeability |
| Elemental Capture Spectroscopy (ECS) | Lithology |
| Spectral GR | Clay Minerals – differentiate between elements in the clays |
| Dynamic/Wireline formation tester | *In situ* Fracture Pressure<br>Formation Pressure and Fluid Samples<br>Mobility |
| Production Logging Tool (PLT) | Injection Rates downhole |
| Sidewall Coring Tool (rotary or percussion) | Porosity, Permeability, Bulk Density |
| Temperature Log | Geothermal Gradient<br>Baseline for Fluid Migration. |
| Vertical Seismic Profile (VSP) | Tie in to 2D regional profile. Baseline for Indirect monitoring |
| Cement Bond Log, Variable Density Log, Casing Collar Locator | Casing & cement integrity |

The following sections detail the approach for logging in the open hole and cased hole sections of each injection well and their corresponding completions**.** The injection wells have been designed with three phases: surface hole, intermediate hole, and injection hole. For the Soterra IF1-1 (Frio Injector) this well will also include a fourth phase, the open hole section where wireline (WL) logging will be performed to collect data from the lower geologic formations – Wilcox and Tuscaloosa.

### 2.2.1 Soterra IF 1-1 – Frio Injection Well

Planned completion for this well is as follows:

- Surface Hole – 13-3/8”, 54.5#, J55 BTC set at 2,900 ft (approximate) in a 17-1/2” hole.
    - Open Hole Logging
    - Cased Hole Logging
- Intermediate Hole – 9-5/8”, 47#, P110IC BTC set at 4,800 ft (approximate) in a 12-1/4” hole.
    - Open Hole Logging
    - Cased Hole Logging
    - Pressure Testing (optional)
- Injection Hole – 7”, 29#, P110IC BTC from 0 – 4,750 ft (approximate) and 7”, 29#, SM25CRW-125 VAM 21 from 4,750 – 6,800 ft (approximate)
    - Open Hole Logging
    - Cased Hole Logging
    - Rotary Side Wall Coring (optional)
    - Pressure Testing Fluid Samples
    - Micro Frac
    - Production Logging Tool (optional)
- Open Hole – 6” open hole from 6,800 – 14,800 ft (approximate)
    - Open Hole Logging
    - Pressure (optional)

#### *2.2.1.1 Surface Hole Logging Program*

The surface hole for the Soterra IF 1-1 well will be analyzed using wireline logging techniques (Table 2), with the following geophysical logs planned upon reaching casing point in the Pliocene Formation (~ 2,900 feet). The depth of the surface casing will be set below the lowermost USDW

(Jasper Aquifer) and will be cemented to surface. This section will be drilled with water-based mud and will have logging while drilling gamma ray (LWD-GR) in the bottom hole assembly (BHA).

**Table 2: Surface Hole Logging Runs – Soterra IF 1-1**

| **Open Hole - 17-1/2-inch Hole Size** | |
|---|---|
| **Well Log** | **Data Acquisition Profile** |
| Spontaneous Potential | Spontaneous Potential and formation fluid salinity |
| Resistivity | Fluid conductivity, presence of fresh vs. saline water, Saturation |
| Gamma Ray | Clay content -total radioactive count rate |
| Sonic | Acoustic mechanical Properties, compressional and shear wave velocities / travel times, Porosity |
| Open Hole Caliper | Borehole diameter and log correction; identify washouts |
| **Cased Hole – 13-3/8-inch Casing Size** | |
| **Well Log** | **Data Acquisition Profile** |
| Radial Cement Bond | Determine the integrity of the cement radially |
| Variable Density | Well completion quality/cement integrity and fast formation arrival effects |
| Temperature | Develop temperature profile. Establish Baseline gradient. |

Note: Additional diagnostic logs may be run at the discretion of Shell U.S. Power and Gas's geological staff and/or consultants or as directed by the authorized regulatory UIC Director.

In addition to the wireline logs listed in Table 2, Shell may opt to take pressure point data in the surface hole geology.

#### *2.2.1.2 Intermediate Hole Logging Program*

The intermediate open hole will be analyzed using wireline logging techniques outline in Table 3. The open-hole is approximately to a depth of 4,800 and will penetrate the Frio Confining Zone. Once the Intermediate Casing has been set and cemented to surface, cased hole logs (Table 3) will be run. This section will be drilled with oil-based mud and will have LWD-GR in the BHA.

**Table 3: Intermediate Hole Logging Runs – Soterra IF 1-1**

| **Open Hole - 12-1/4-inch Hole Size** | |
|---|---|
| **Well Log** | **Data Acquisition Profile** |
| Resistivity | Fluid conductivity, presence of fresh vs. saline water |
| Gamma Ray | Clay content |
| Density-Neutron | Porosity and saturation |
| Open Hole Caliper | Borehole diameter and log correction; identify washouts |
| Sonic | Acoustic mechanical Properties, compressional and shear wave velocities / travel times |
| Dynamic/Wireline Formation Tester *(optional)* | Sample formation pressures |
| **Cased Hole – 9-5/8-inch Casing Size** | |
| **Well Log** | **Data Acquisition Profile** |
| Radial Cement Bond | Determine the integrity of the cement radially |
| Variable Density | Well completion quality/cement integrity and fast formation arrival effects |
| Temperature | Develop temperature profile. Establish Baseline gradient |

Note: Additional diagnostic logs (Table 1) may be run at the discretion of Shell U.S. Power and Gas's geological staff and/or consultants or as directed by the authorized regulatory UIC Director.

#### *2.2.1.3 Injection Hole Logging Program*

The Injection Hole will be analyzed using wireline logging techniques (Table 4), with the following open and cased hole geophysical logs planned upon reaching a total depth (~6,800 feet). The bulk of additional wireline and data acquisition will be collected through this phase, as the Frio Formation is the targeted Injection Zone for the Soterra IF 1-1 Injection Well. This section will be drilled with oil-based mud and will have LWD-GR in the BHA.

Once additional data has been collected, the Injection Hole casing will be installed and then be cemented from casing shoe and up through the Confining Zone with an acid resistant cement. The well will then be cemented with standard cement from Confining Zone to surface and wireline cased-hole logging (Table 4) will be performed.

**Table 4: Injection Hole Logging Runs – Soterra IF 1-1**

| Open Hole – 8-1/2-inch Hole Size | |
|---|---|
| **Well Log** | **Data Acquisition Profile** |
| Whole Core | Whole core acquisition from confining zone and injection zone |
| Resistivity | Fluid conductivity, presence of fresh vs. saline water; |
| Spectral Gamma Ray | Clay content – energy of gamma emissions to differentiate between elements |
| Density-Neutron | Porosity and saturation |
| Open Hole Caliper | Borehole diameter and log correction; identify washouts |
| Formation Microimager (or equivalent) | Identify fractures and breakouts in the formation |
| Elemental Capture Spectroscopy | Elemental and clay content; lithology |
| Nuclear Magnetic Resonance | Nuclear magnetic resonance; T1 and T2 relaxation times; permeability, bound water, and movable fluid properties |
| Sonic | Acoustic mechanical Properties, compressional and shear wave velocities / travel times |
| Dynamic/Wireline Formation Tester | Sample formation pressures and/or fluids; mini-frac testing |
| Rotary Sidewall Core (optional) | Formation rock samples to supplement whole core and further rock characterization |
| Production Logging Tool (optional) | Injection contribution in specific zones |
| **Cased Hole – 7-inch Casing Size** | |
| **Well Log** | **Data Acquisition Profile** |
| Radial Cement Bond | Determine the integrity of the cement radially |
| Variable Density | Well completion quality / cement integrity and fast formation arrival effects |
| Temperature | Develop temperature profile. Establish Baseline Gradient |

Note: Additional diagnostic logs (Table 1) may be run at the discretion of Shell U.S. Power and Gas's geological staff and/or consultants or as directed by the authorized regulatory UIC Director.

#### *2.2.1.4 Lower Open Hole Logging*

Soterra IF 1-1 will also drill an open hole to an approximate depth of 15,000 feet to acquire data for additional potential targeted Injections Zones for the St. Helena Parish site. This section will be drilled with oil-based mud. Open hole geophysical logs planned are contained in Table 5. After data has been acquired, the open hole will be plugged back with cement into the 7" casing shoe of the Injection Hole to approximately 6,800 ft.

**Table 5: Open Hole Logging Runs – Soterra IF 1-1**

| Open Hole – 6-inch Hole Size | |
|---|---|
| **Well Log** | **Data Acquisition Profile** |
| Resistivity | Fluid conductivity, presence of fresh vs. saline water |
| Gamma Ray | Clay content -total radioactive count rate |
| Density-Neutron | Porosity and Saturation |
| Sonic | Acoustic mechanical Properties, compressional and shear wave velocities / travel times |
| Open Hole Caliper | Borehole diameter and log correction; identify washouts |
| Dynamic/Wireline Formation Tester (optional) | Sample formation pressures |

Note: Additional diagnostic logs may be run at the discretion of Shell's geological staff and/or consultants or as directed by the authorized regulatory UIC Director.

In addition to the wireline logs listed in Table 5, Shell may opt to take fluid samples in the lower open hole formations to establish baselines.

### 2.2.2 Soterra IT 2-1 – Tuscaloosa Injection Well

Planned completion for this well is as follows:

- Surface Hole – 13-3/8”, 54.5#, J55 BTC set at 3,000 ft (approximate) in a 17-1/2” hole.
    - Open Hole Logging
    - Cased Hole Logging
- Intermediate Hole – 9-5/8”, 47#, P110IC BTC set at 13,550 ft (approximate) in a 12-1/4” hole.
    - Open Hole Logging
    - Cased Hole Logging
    - Pressure Testing (optional)
- Injection Hole – 7”, 29#, P110IC BTC from 0 – 14,150 ft (approximate) and 7”, 29#, SM25CRW-125 VAM 21 from 14,150 – 14,750 ft (approximate)
    - Open Hole Logging
    - Cased Hole Logging
    - Rotary Side Wall Coring (optional)
    - Pressure Testing
    - Fluid Samples
    - Micro Frac

#### *2.2.2.1 Surface Hole Logging Program*

The surface hole for the Soterra IT 2-1 well will be analyzed using wireline logging techniques (Table 6), with the following geophysical logs planned upon reaching casing point in the Pliocene Formation (~ 3,000 feet). The depth of the surface casing will be set below the lowermost USDW (Jasper Aquifer) and will be cemented to surface. This section will be drilled with water-based mud and will have LWD-GR in the BHA.

**Table 6: Surface Hole Logging Runs – Soterra IT 2-1**

| **Open Hole - 17-1/2-inch Hole Size** | |
|---|---|
| **Well Log** | **Data Acquisition Profile** |
| Spontaneous Potential | Spontaneous Potential and formation fluid salinity |
| Resistivity | Fluid conductivity, presence of fresh vs. saline water, saturation |
| Gamma Ray | Clay content -total radioactive count rate |
| Sonic | Acoustic mechanical Properties, compressional and shear wave velocities / travel times, porosity |
| Open Hole Caliper | Borehole diameter and log correction; identify washouts |
| **Cased Hole – 13-3/8-inch Casing Size** | |
| **Well Log** | **Data Acquisition Profile** |
| Radial Cement Bond | Determine the integrity of the cement radially |
| Variable Density | Well completion quality/cement integrity and fast formation arrival effects |
| Temperature | Develop temperature profile. Establish Baseline gradient. |

Note: Additional diagnostic logs may be run at the discretion of Shell's geological staff and/or consultants or as directed by the authorized regulatory UIC Director.

In addition to the wireline logs listed in Table 6, Shell may opt to take pressure point data in the surface hole geology.

#### *2.2.2.2 Intermediate Hole Logging Program*

The intermediate section be analyzed using wireline logging techniques (Table 7), with the following open and cased hole geophysical logs planned to be run upon reaching casing depth into the base of the Austin Chalk Formation at an approximate depth of 13,550 feet. The intermediate casing will be cemented to surface. This section will be drilled with oil-based mud and will have LWD-GR in the BHA.

**Table 7: Intermediate Hole Logging Runs – Soterra IT 2-1**

| **Open Hole - 12-1/4-inch Hole Size** | |
|---|---|
| **Well Log** | **Data Acquisition Profile** |
| Resistivity | Fluid conductivity, presence of fresh vs. saline water |
| Gamma Ray | Clay content |
| Density/Neutron | Porosity and saturation |
| Open Hole Caliper | Borehole diameter and log correction; identify washouts |
| Sonic | Acoustic mechanical Properties, compressional and shear wave velocities / travel times |
| Dynamic/Wireline Formation Tester *(optional)* | Sample formation pressures, fluids |
| **Cased Hole – 9-5/8-inch Casing Size** | |
| **Well Log** | **Data Acquisition Profile** |
| Radial Cement Bond | Determine the integrity of the cement radially |
| Variable Density | Well completion quality/cement integrity and fast formation arrival effects |
| Temperature | Develop temperature profile. Establish Baseline gradient |

Note: Additional diagnostic logs (Table 1) may be run at the discretion of Shell's geological staff and/or consultants or as directed by the authorized regulatory UIC Director.

### *2.2.2.3 Injection Hole Logging Program*

The Injection Hole will be analyzed using wireline logging techniques (Table 8), with the following open and cased hole geophysical logs planned upon reaching total depth of ~14,750 feet (~ 200 feet below the base of the Lower Tuscaloosa Formation). The Injection Hole casing will then be cemented with acid resistant cement (or equivalent) across the injection zone and into the overlying containment Zone (Tuscaloosa Marine Shale). The remainder of the casing will be cemented to surface using standard cement. The bulk of additional wireline and acquisition of data will be collected through this phase, as the Lower Tuscaloosa Formation is the targeted Injection Zone for the Soterra IT 2-1 Injection Well. This section will be drilled with oil-based mud and will have LWD-GR in the BHA.

**Table 8: Injection Hole Logging Runs – Soterra IT 2-1**

| **Open Hole – 8-1/2-inch Hole Size** | |
|---|---|
| **Well Log** | **Data Acquisition Profile** |
| Whole Core | Whole core acquisition from confining zone and injection zone |
| Resistivity | Fluid conductivity, presence of fresh vs. saline water |
| Spectral Gamma Ray | Clay content – energy of gamma emissions to differentiate between elements |
| Density/Neutron | Porosity and saturation |
| Open Hole Caliper | Borehole diameter and log correction; identify washouts |
| Formation Microimager (or equivalent) | Identify fractures and breakouts in the formation |
| Elemental Capture Spectroscopy | Elemental and clay content; lithology |
| Nuclear Magnetic Resonance | Nuclear magnetic resonance; T1 and T2 relaxation times; permeability, bound water, and movable fluid properties |
| Sonic | Acoustic mechanical Properties, compressional and shear wave velocities / travel times |
| Dynamic/Wireline Formation Tester | Sample formation pressures and/or fluids and mini-frac testing |
| Rotary Sidewall Core (optional) | Formation samples |
| **Cased Hole – 7-inch Casing Size** | |
| **Well Log** | **Data Acquisition Profile** |
| Radial Cement Bond | Determine the integrity of the cement radially |
| Variable Density | Well completion quality / cement integrity and fast formation arrival effects |
| Temperature | Develop temperature profile. Establish Baseline Gradient |

Note: Additional diagnostic logs (Table 1) may be run at the discretion of Shell’s geological staff and/or consultants or as directed by the authorized regulatory UIC Director.

### 2.2.3 Analysis and Reporting

After the open and cased hole logging program has been completed for all Injection Wells, Shell will prepare an evaluation and interpretation of all the logs prepared by a knowledgeable and expert log analyst [per 40 CFR §146.87(a)]. The report will include:

- The date and time of each test, the data of wellbore completion, and the data of installation of all casings and types of cements.
- Chart (graphical) results of each log and any supplemental data.
- The name of the logging company and log analyst and information on their qualifications.
- Interpretation of the well logs by the log analyst, including any assumptions, determination of porosity, permeability, lithology, thickness, depth, and formation fluid salinity of relevant geologic formations; and
- Any changes in interpretation of site stratigraphy based upon the analysis of the logs and tests that were run.

Reports will be submitted to the authorized regulatory UIC Director. The data acquired will be used to validate and/or reduce uncertanties presented in the "*Area of Review and Corrective Action Plan*" submitted in **Module B**, will be used to update "*2.0 – Site Characterization*" in **Module A**, and the for the final application for Carbon Capture and Storage (CCS) Project Certification. Results will also impact final operating parameters for the injection wells.

## 2.3 CORE PROGRAM

Petrophysical analysis is used in building a static geologic model. Acquired whole core, rotary sidewall core open-hole, and cased-hole logging data will be utilized to reduce uncertainty in the reservoir quality at the project site. The site-specific data collected during the drilling each injection well will be used in support of the local geology and future interactions of the static model and the dynamic simulations for the project.

The core program strategy (Tables 9 and 10) developed in this Pre-Operational Testing Plan for the St. Helena Parish site accounts for geologic uncertainties in the Confining and Injection Zones and has been developed specifically for each injection well to meet the standards outlined in 40 CFR §146.87(b).

Whole core will be collected in the injection well(s) from the Confining Zone using drilling fluids designed to reduce the swelling of formation clays and improve the quality of the retrieved core. The whole coring program will be adaptive with the possible acquisition of additional cores optional upon the recoveries from the first core attempt in each zone or to address spatial uncertainty.

The depth at which the whole core will be cut will be projected prior to drilling and then determined on site by the wellsite geologist during the drilling of the well. The site-specific core points will be determined by using the correlative analysis of the lithology and rate of penetration of the well being drilled, along with data from nearby offset open hole well logs and mudlogs. If insufficient amount of the formation core has been recovered in any core run, an additional core point may be selected and cut at the discretion of the company's wellsite geologist. Additionally, the insufficiently cored interval may be subsequently evaluated with additional rotary sidewall coring. Whole core depth intervals (as well as mudlog depth intervals) will be adjusted (depth-shifted) to be equivalent to open-hole logging depths.

Each injection well is planned to have rotary sidewall cores collected from the relevant regulatory intervals. These core samples may include other formations in the wellbore, such as dissipation intervals or secondary confining layers in the stratigraphic column, in order to characterize the mitigation potential of overlying and underlying geologic formations. A rotary sidewall coring program will be adaptive and based upon whole core recovery and the evaluated needs of the project.

### 2.3.1 Soterra IF 1-1 – Frio Injection Well

Shell plans to collect whole and sidewall cores from the Primary Frio Confining Zone and the Frio Injection Zone. Shell plans four core barrel runs (60 or 90-foot barrels) through the Injection Hole (approximately 4,800 feet to 6,800 feet) as shown in Table 9.

**Table 9: Whole Core Sampling Intervals – Soterra IF 1-1**

| Core Barrel No. and Proposed Top Depths (feet)* | Formation | Regulatory Intervals | Core Acquisition | Plug Count (estimate) |
|---|---|---|---|---|
| 1: 4,850 | Frio Formation | Confining Zone | Attempt 60 or 90-feet | 50 or 75 |
| 2: 5,160 | Frio Formation | Confining Zone | Attempt 60 or 90-feet | 50 or 75 |
| 3: 5,865 | Frio Formation | Injection Zone | Attempt 60 or 90-feet | 50 or 75 |
| 4: 6,600 | Frio Formation | Injection Zone | Attempt 60 or 90-feet | 50 or 75 |

**Depths may be adjusted optional on well and drilling prognosis*

Whole core quality will be reviewed, and core plugs will be selected carefully. Shell estimates that approximately 200 to 300 plugs may be selected. One hundred to 150 of the plugs are estimated to be selected for testing the Confining Zone, with a similar number of the plugs for testing of the Injection Zone. The total amount of plugs taken from the whole core will be dependent on core recovery and quality. Plug totals will be adjusted based upon the whole core acquisition.

Shell estimates that approximately 60 to 120 rotary sidewall cores will be recovered from the Frio Injection Zone in two runs using wireline. Depth selection and amounts will be based upon review of the open hole logs run through the Injection Hole section.

### 2.3.2 Soterra IT 2-1 – Tuscaloosa Injection Well

Shell plans to collect whole and sidewall cores from the overlying containment intervals of the Austin Chalk / Eagle Ford Formations and the Lower Tuscaloosa Injection Zone. Shell plans one continuous 270-foot core run through the Injection Hole (between ~14,000 – 14,750 feet) as shown in Table 10. Note: these proposed depths are tentative.

**Table 10: Whole Core Sampling Intervals – Soterra IT 2-1**

| Core Barrel No. and Proposed Top Depths (feet)* | Formation | Regulatory Intervals | Core Acquisition | Plug Count (estimate) |
|---|---|---|---|---|
| 1: 14,450 – 14,720 | Lower Tuscaloosa | Containment & Injection Zone | Attempt 270-feet | 235 |

**depths will be selected at time of drilling*

Shell expects at least 100 feet of the containment zone will be targeted during the continuous core run. The whole core will be reviewed for quality and plugs will be selected for testing in the lab. Shell estimates that approximately 235 plugs will be selected from the whole core. Approximately 100 plugs will represent the containment layer above the Lower Tuscaloosa, 120 plugs for representation of the Injection Zones, and 15 plugs to represent intra-reservoir confinement. The total amount of plugs taken from the whole core will be dependent on the core recovery and quality. Plug totals will be adjusted based upon the whole core acquisition.

In addition to the whole core, Shell may acquire rotary sidewall cores via wireline from the Lower Tuscaloosa Injection Zone. The rotary sidewall cores depth selection will be targeted across two main sand intervals to sample the heterogeneity in the facies. Depth selection and total plug acquisition amounts will be based upon review of the open hole logs run through the Injection Hole section.

### 2.3.3 Analysis

Detailed core analyses will be performed at a well-respected, experienced core laboratory, to characterize both the Injection and Confining Zones. Analyses will cover the range of rock properties found in the Injection and Confining Zones and will include (but not limited to):

1) Conventional/Routine Core Analysis
    a. Routine Core Porosity, Permeability (H / V), Grain Density, Petrography
    b. Thin Sections, SEMs, XRD, XRF
2) Special Core Analysis
    a. Stress Porosity, Permeability
    b. Core NMR

   c. Brine, CO2 Permeability
   d. Capillary Pressures
   e. Entry pressure on the seal
   f. Fluid Compatibility
   g. Wettability
   h. Relative Permeability

3) Geomechanics
   a. Rock Mechanics and Compressibility measurements
   b. Acoustic- Shear and compressional velocities
   c. Unconfined Compressive Strength, Tensile Strength

At a minimum, a lithologic core description, thin sections, x-ray diffraction (XRD), and x-ray fluorescence (XRF) will be performed to characterize compositional make-up of the key intervals and to reduce uncertainties that impact the depositional and flow environments. Adaptive special core analyses such as electrical property measurements and/or relative permeability measurements will be determined based upon quality of the core data and the evaluated needs for reducing uncertainty and risk.

The prescribed analysis of the collected core and fluid samples will be used to refine and enhance site characterization. Suggested analyses that are to be conducted are listed in the following tabulation (Table 11).

Data acquired from the analysis will be used to reduce uncertainties within the model. The analysis results will assist in "fine-tuning" the model. The whole core collection has been designed fully characterized the formations at the St. Helena Parish site.

**Table 11: Whole Core Analytical Program**

| Parameter | Measurement | Units |
|---|---|---|
| Porosity | Total Porosity | Percent |
| Permeability | Vertical Permeability<br>Horizontal Permeability | mD/nD |
| Relative Permeability | Relative Gas Permeability<br>Relative Aqueous Permeability | mD/nD |
| Saturation | Residual Aqueous Saturation<br>Residual Gas Saturation | Percent |
| Compressibility | Bulk Compressibility<br>Pore Compressibility | 1/Pa |
| Physical Properties | Rock Strength<br>Ductility<br>Elastic Properties | PSI<br>%<br>Pa |
| Lithology | Description | N/A |
| Rock/Soil Type | Petrology<br>Mineralogy | SEM<br>Thin sections |
| Capillary Pressure/Relative Permeability | Mercury methods / Porous-plate methods /Centrifuge methods | PSI/mD |

### 2.3.4 Reporting

Shell will submit a report prepared by a reputable and experienced core analyst for the details on the core results [per 40 CFR §146.87(b)]. It will include information on the collection and testing method, specific reports on the core intervals that were recovered, laboratory instrumentation calibration, analytical results in either tabular or graphic form, and core photographs and photomicrographs as appropriate. The report will be submitted to the UIC Director.

## 2.4 FORMATION PRESSURE AND FLUID ANALYSIS

The formation pressure measurement and sampling system will be used to quantify the pore pressure and sample the fluids are acquired downhole. The tool will be supplied by a third-party vendor using a downhole sampling tool. The *in-situ* downhole samples are preferred; however, surface samples may be collected for expediency.

The following formation pressure testing, and sampling procedures will be followed and adapted for any changes:

1. Rig up tool
2. Run in hole to above casing shoe at approximately 200 feet/min
3. Perform casing check
4. Run in hole to chosen correlation zone at around 150 feet/min
5. Log up correlation pass at around 50 feet/min
6. Perform pressure testing from the top of the targeted formation to the bottom of the formation at identified intervals
7. Perform fluid sampling at chosen intervals of high mobility (identified from pressure tests) with Oval Pad. Pump out around 100 L of volume while monitoring contamination for clean up
8. Pull out of hole at 150 feet/min to casing and 200 feet/min to surface

All sample containers will be labeled with durable labels and indelible markings. A unique sample identification number and sampling date will be recorded on the sample containers. The sample containers will be sealed and sent to an authorized third-party laboratory.

Repeat sampling and frequency (adaptive program) to be determined based on results. A proposed sampling plan in shown in Table 12:

**Table 12: Formation Pressure and Fluid Sampling Plan- Injection Wells**

| **Soterra IF 1-1 (Frio Injection Well)** | | |
|---|---|---|
| **Open Hole Phase** | **Pressure and Samples No.** | **Targeted Formation** |
| Intermediate Hole | 15 pressures | Permeable zone above confining zone to establish baseline |
| Injection Hole | 25 pressures and 3 samples | Frio Injection Zone |
| Open Hole | 25 pressures | Wilcox and Tuscaloosa Injection zones |
| **Soterra IT 2-1 (Tuscaloosa Injection Well)** | | |
| **Open Hole Phase** | **Pressure and Samples No.** | **Targeted Formation** |
| Intermediate Hole | 25 pressures | Permeable zone above confining zone to establish baseline |
| Injection Hole | 15 pressures and 2 samples | Tuscaloosa Injection Zone |

A minimum of approximately 1,000 cc will be attempted for each sampling station.

### 2.4.1 Analysis

An initial baseline fluid sample will be attempted from the each of the Injection Zones in the injection wells prior to the commencement of injection operations. These well fluid samples will provide the baseline measurements for formation fluids and document any spatial variability. Table 13 identifies the potential parameters to be monitored and the analytical methods Shell may utilize.

The initial parameters identified may be revised and include additional components for testing dependent on the initial geochemical evaluation. The fluid samples will be sent to a reputed and recognized third-party laboratory.

**Table 13: Summary of Potential analytical and field parameters for ground water samples – Injection Wells**

| Parameters | Analytical Methods |
|---|---|
| Dissolved $CO_2$ gas by headspace | Gas Chromatography (GC) |
| Dissolved $CH_4$ gas by headspace | Gas Chromatography (GC) |
| Hydrocarbons | Gas Chromatography (GC) |
| Dissolved inorganic carbon | Combustion |
| Isotopic composition of selected major or minor constituents (*e.g.*, Sr $^{87/86,}$ S) | Multi collector-Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS) |
| **Cations:**<br>Al, As, B, Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Pb, Sb, Se, Si, Ti, Zn, | ICP-MS or ICP-OES, ASTM D5673, EPA 200.8<br>Ion Chromatography, EPA Method 200.8, ASTM 6919 |
| **Anions:**<br>Br, Cl, F, $NO_3$, $SO_4$, | Ion Chromatography, EPA Method 300.8, ASTM 4327 |
| Total Dissolved Solids | EPA 160.1, ASTM D5907-10 |
| Alkalinity | EPA 310.1 |
| pH (field) | EPA Method 150.1 |
| Specific Conductance (field) | EPA 120.1, ASTM 1125 |
| Temperature (field) | Thermocouple |
| Turbidity | EPA 180.1 |
| Density | Modified ASTM 4052 |

### 2.4.2 Reporting

Shell will submit a report prepared by a specialist for the details on the fluid sampling results [per 40 CFR §146.87(b)]. It will include information pertaining to collection and testing methods, specific details on the collection of the samples and the calibration of test instrumentation as appropriate, with results presented in either tabular or graphic form, including any photographs as deemed appropriate for inclusion in said report. The report will be submitted to the UIC Director.

## 2.5 FRACTURE PRESSURE DETERMINATION

The fracture pressure of the Confining and Injection Zones must be determined or calculated pursuant to 40 CFR §146.87(d)(1). This information will be used (along with measured pore pressures in the injection zone) to determine appropriate injection pressures for the project wells. Shell will utilize density and sonic logs run in each injection well to determine the vertical stress ($S_v$). This vertical stress calculation will be conducted in conjunction with a detailed review of the formation microimager log run in the well, which will aid in the identification of any borehole breakouts or open fractures. Log based estimation of fracture pressure will be provided in absence of conclusive tests described below. The fracture/parting pressure of the Injection Zone and the Confining Zone, and the corresponding fracture gradients, will be determined in each wellbore. These testing and logging activities may be undertaken during the drilling of the injection or monitoring well(s) to determine the state of stress of the Injection Zone and the primary confining layer. In general, mini-frac testing is less invasive and less destructive on the test interval versus propagating a large fracture out into the formation as would occur during step-rate testing. Experience has demonstrated that fracture half-wing lengths could possibly extend hundreds of feet out into the formation, compromising the future integrity of the well completion across the Injection Zone as well as the overlying Confining Zone.

Immediately following the drilling and logging of the injection well(s), an open hole wireline formation tester, or equivalent, mini-frac will be done to determine the minimum horizontal stress of the formations (Injection Zone and Confining Zone) (Table 14). These mini-frac operations will be performed using the formation tester in dual-packer tool configuration for both the Injection Zone and the overlying Confining Zone to determine the horizontal stress.

**Table 14: Summary of Mini Frac Testing for Injection Wells**

| Soterra IF 1-1 (Frio Injection Well) | | |
|---|---|---|
| **Open Hole Phase** | **Mini Frac** | **Targeted Formation** |
| Confining Zone | 1-2 stations | Frio Confining Zone to measure fracture pressure |
| Injection Zone | 1-2 stations | Frio Injection Zone |
| **Soterra IT 2-1 (Tuscaloosa Injection Well)** | | |
| **Open Hole Phase** | **Mini Frac** | **Targeted Formation** |
| Confining Zone | 1-2 stations | Tuscaloosa Containment Zone to measure fracture pressure |
| Injection Zone | 1-2 stations | Tuscaloosa Injection Zone |

Mini-frac testing will be conducted in Dual-Packer Mode to determine the fracture initiation, fracture breakdown and fracture propagation pressure. For stress testing to provide accurate information on the state of stress and breakdown pressure for the Injection Zone and the overlying Confining Zone, the tested interval must first be determined to have no pre-existing structural weaknesses, such as natural fractures. Proposed test intervals will be pre-screened with the processed formation microimager logging tool to ensure the absence of fractures and to select packer-setting depths for such testing.

**Confining Zone – Alternate Diagnostic Fracture Injection Test (DFIT)**

Another method to determine fracture pressure is using DFIT. In a diagnostic fracture injection test (DFIT), a relatively small volume of fluid is injected into the subsurface, creating a hydraulic fracture. The testing is essentially similar to the mini-frac test, but the test is conducted in either open or cased hole with dual packers straddling the test interval. After the fracture has been created and injection has ceased, the pressure in the wellbore is monitored for a set duration, which could range from several hours to several days. Formation pressures measured during the injection and recovery periods are used to infer properties of the formation, including the leak-off coefficient, permeability, fracture closure pressure (related to the magnitude of the minimum principal stress and the net pressure), and formation pressure.

During the initial DFIT injection phase, prior to the formation of a fracture, wellbore storage controls the pressure behavior and pressure increases with increasing injection volume. At formation breakdown pressure, a fracture is initiated in the formation. The initiation of a new fracture will cause a decrease in pressure while the expansion of an already existing fracture will cause pressure to plateau. Following breakdown, continued injection causes the fracture to extend further out into the formation (propagation pressure); once injection ceases, the well is shut in and the ISIP (initial shut-in pressure) is measured. The DFIT analysis primarily focuses on the analysis of the trends in propagation and shut-in pressure that occur in the hours and days immediately following the shutting in of the well.

In general, the DFIT procedure is as follows:

1. In a cased hole, perforate the well (small interval or full set).
2. Install high-resolution surface electronic memory gauges on wellhead and run high-resolution gauges downhole (set recording rate set to 1 second intervals). The use of high-resolution gauges will ensure that virtually all pressure changes are recorded (0.100 to 0.001 psi gauge resolution is recommended).
3. Load wellbore with water (KCl or saltwater with minimal additives as needed (to avoid clay swelling, etc.)).
4. Start pressure recording before pumping starts and end recording after the fall-off (pressure recovery) is complete.
5. Commence pumping. The injection rate/pressure should be high enough to breakdown the perforations and initiate a small fracture. After breakdown, the fluid injection rate should be increased to the designed maximum pressure limit and injection should be continuous at a steady rate for 3 to 5 minutes.
6. The step-down phase of the DFIT procedure should then be commenced. The rate should be stepped down to 75%, then 50%, and optionally 30% of the maximum rate. The duration of each step-down rate drop can be as short as 10 seconds.

7. Following the completion of the step-down phase, pumping will be immediately stopped, the total volume pumped will be recorded, and the wellhead will be secured to prevent tampering.
8. Rig down the pumping equipment without disturbing the isolated electronic gauges.
9. Collect the data from the pump unit as well as the acquisition setup.

#### 2.5.1 Analysis

The analysis of mini-frac test data is performed in two parts: pre-closure analysis and after-closure analysis. Pre-closure analysis consists of identifying closure and analyzing the early pressure falloff period while the induced fracture is closing. One of the parameters in fracture treatment design is the fracture closure pressure. This may not always be achievable or detectable especially in low permeability intervals.

Shell will attempt multiple cycles of mini-frac at individual stations to obtain a Pressure vs Time plot. The cycles consist of leak off, breakdown, and reopening cycles. The analysis of the data will focus on determining multiple pressure points as illustrated in Figure 1.

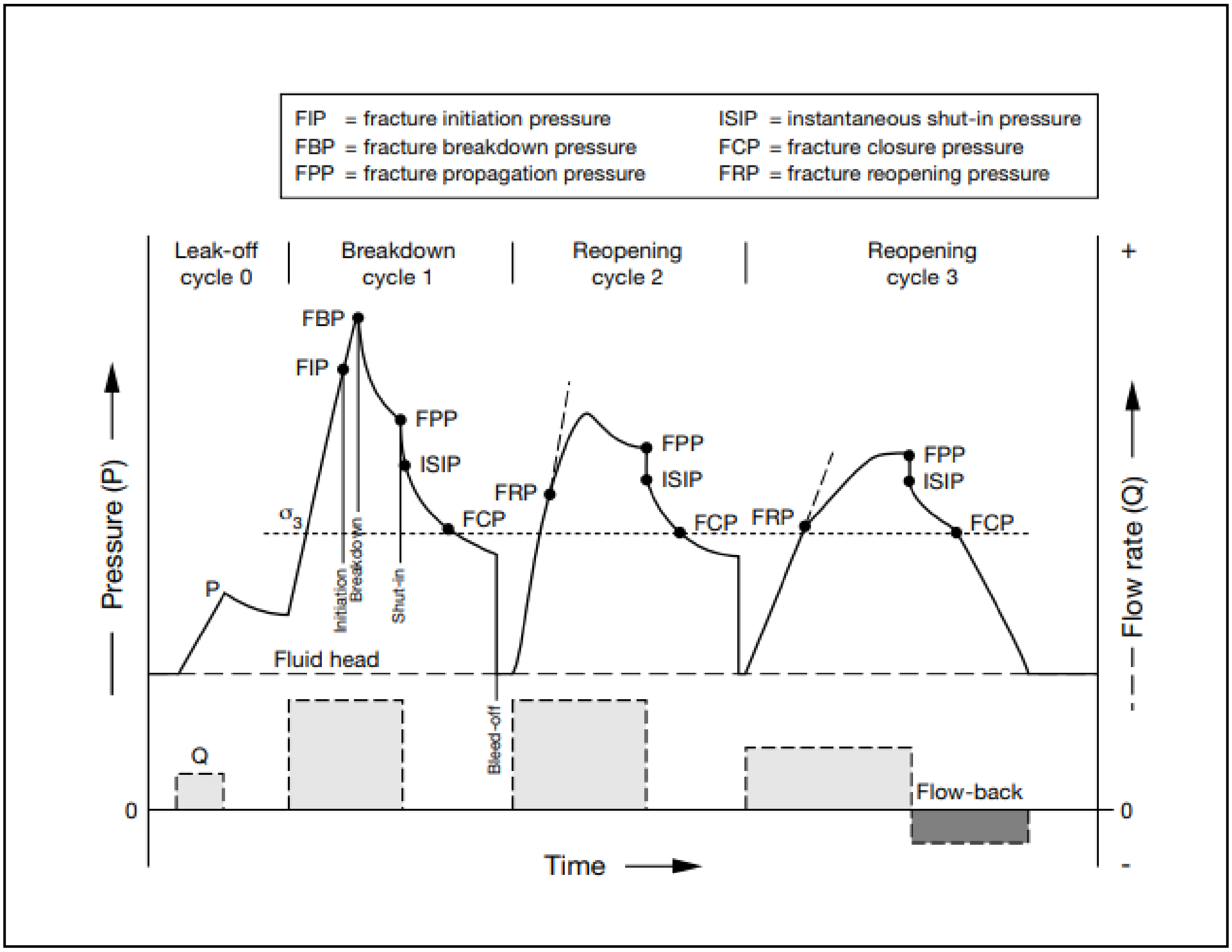


**Figure 1 – Example of mini frac test cycles showing the leak off, break down, and reopening cycles**

Fracture Closure pressure (if reached) will be determined using trendline gradient analysis from a Pressure Volume cross plot. Other suitable techniques might be used depending on quality of the data.

From the analysis, the expert will determine the following parameters where possible:

- Fracture Integrity Test and Leak Off Pressure
- Fracture Breakdown Pressure
- Fracture Propagation Pressure

- ISIP (Instantaneous shut-in pressure)
- Fracture Closure Pressure

### 2.5.2 Reporting

Shell will submit a report prepared by a specialist for the details on the formation fracture results [per 40 CFR §146.87(b)]. It will include information on collection and testing methods, specifics on the test run and calibration of instrumentation as appropriate, results in tabular or graphic form, and photographs as appropriate. The report will be submitted to the UIC Director.

## 2.6 DEMONSTRATION OF INJECTION WELL MECHANICAL INTEGRITY

Tabulated below is a summary of the Mechanic Integrity Tests (MITs) to be performed on the Injection Wells for the Shell St. Helena Parish site, after installation and prior to commencing sequestration injection operations. Tests conducted to ensure mechanical integrity of the wells are described in Table 15. The tests will include a pressure test of the well annulus using fluid or gas to ensure there are no leaks internal to the well. Additionally, a radioactive tracer survey or noise log (or equivalent) will be run to ensure there is no movement of fluid behind pipe. The purpose of these tests is to ensure that the well's integrity is mechanically sound and that there is no movement of formation fluid along the wellbore. If a well fails to demonstrate mechanical integrity, the well will be repaired prior to advancing to the next phase of commencing sequestration.

**Table 15: Summary of Mechanical Integrity Testing – Injection Wells**

| Class VI Rule Citation | Rule Description | Test Description | Program Period |
|---|---|---|---|
| 40 CFR §146.89(a)(1) | MIT – Internal | Pressure test using liquid or gas to determine that there is no significant leak in the casing, tubing, or packer | After construction |
| 40 CFR §146.87(a)(4) | MIT – External | Pressure test using liquid or gas to demonstrate the external mechanical integrity of the well | |
| 40 CFR §146.87(e)(1) | Testing prior to operating | Pressure fall-off test, pump test and injectivity test to verify the hydrogeologic characteristics of the injection zone | Prior to operation |

Shell will notify the EPA or the regulatory UIC Director least 30 days prior to conducting the test and provide a detailed description of the testing procedure to be performed. Notice and the opportunity to witness the test/log shall be provided to EPA or regulatory UIC Director at least 48 hours in advance of a given test/log. The wireline logs that will be run during such MITs are listed below (Table 16).

**Table 16: Mechanical Integrity Test Logging Summary - Injection Wells**

| Test | Description |
|---|---|
| Casing Inspection Log (Internal MIT) | To detect deformation, physical wear and or corrosion |
| Cement Bond Log (External MIT) | To evaluate integrity of cement job between the casing and the formation |
| Temperature or Noise Log or Pulsed Neutron Log / Tracer Survey using Oxygen Activation Log (External MIT) | To detect thermal or acoustic anomalies that deviate from the baseline gradient and thus detect the movement of fluid behind pipe |

In addition to running wireline logs, an Annulus Pressure Test (APT) will be run to verify the well integrity. The test will be run after well completion and prior to injection operations.

Pressures will be recorded on a time-drive recorder for at least 60 minutes in duration and the chart or digital printout of times and pressures will be certified as true and accurate. The pressure scale on the chart will be low enough to readily show a 5 percent change from the starting pressure. In general, the test procedure will be as follows:

1. Connect a high-resolution pressure transducer to the annulus and increase annulus pressure to at least 200 psig over the permitted maximum tubing/injection pressure. Conduct the Annulus Pressure Test (APT) by holding annular pressure a minimum of 100 psi above the well's maximum permitted surface injection pressure for a minimum of 60 minutes.

2. At the conclusion of the APT, annular pressure will be lowered to the well's normal, safe pressure and the pressure recording equipment will be removed from the wellbore.

A successful pressure test will "PASS" if the pressure holds to +/-5 percent of the starting pressure. **IF** the test indicates that the wellbore is not able to hold pressure for a selected period of time, then the test will be considered a "FAIL". The test will be repeated and if the well continues to "FAIL", the construction of the well may have lost its integrity. Additional tests at progressively lower pressures may be run to identify the pressure at which the annulus can hold a differential. Continuous monitoring of the annulus system will be reviewed to identify if there are any data that may lead to a potential leak and assist in diagnosing potential issues with the annulus. The test results will be shared with the UIC director. Reponses to potential loss of well integrity during the construction and testing phase are included in *"E.4 – Emergency and Remedial Response Plan"* submitted in Module E.

### 2.6.1 Reporting

Shell will submit a descriptive report prepared by an experienced log analyst that includes the results of any mechanical integrity test with the application for CCS Project Certification. At a minimum, the report must include:

- Chart and tabular results of each log or test;
- The interpretation of log results provided by the log analyst;
- A description of all tests and methods used;
- The records and schematics of all instrumentation used for the tests;
- The identification of any loss of mechanical integrity, evidence of fluid leakage, and remedial action taken;
- The date and time of each test;
- The name of the logging company and log analyst;
- For any tests conducted during injection, operating conditions during measurement, including injection rate, pressure, and temperature, flow rates (for tests run during well shut-in, this information must be provided relevant to the period prior to shut-in); and
- For any tests conducted during shut-in, the date and time of the completion of injection and records of well pressure re-equilibration.

## 2.7 FORMATION TESTING

Shell will perform pressure fall-off tests during the injection phase as described below to meet the requirements of 40 CFR §146.90(f) and LAC §3625.A.6 (State of Louisiana). Pressure fall-off testing will be conducted upon completion of each injection well to characterize baseline formation properties, as well as determine near wellbore/reservoir conditions that may impact the injection of carbon dioxide.

### 2.7.1 Pressure Falloff Testing

Shell will perform an initial (baseline) pressure fall-off test in each injection well using brine, including any chemical additives necessary to maintain quality hole condition or tubular integrity (*e.g.* clay stabilizers, oxygen scavengers, etc.). This will allow for baseline characterization of the reservoir transmissibility to fluid within the targeted Injection Zone(s). The initial pressure fall-off testing will be repeated using carbon dioxide within the first 60 days of initiation of injection operations. This will allow for comparison to the baseline fluid-to-fluid test with the change in the injection fluid from brine water to carbon dioxide.

A pressure fall-off test will be performed at 5-year intervals (within approximately +/-45 days of the anniversary of the previous test), for the lifetime of injection operations per 40 CFR 146.90(f). Periodic testing is expected to provide insight into the performance of the St. Helena Parish Site and potentially aid in assessing the dimensions of the expanding carbon dioxide plume, based on the expected lateral transition from supercritical carbon dioxide near the wellbore and to native formation brine beyond the plume. The Director may request more frequent testing which will be dependent on test results. A final pressure fall-off test will be run after the cessation of injection into each injection well.

**<u>Test Details</u>**

Testing procedures will follow the methodology detailed in "*EPA Region 6 UIC Pressure Falloff Testing Guideline-Third Revision (August 8, 2002)*"[1]. Bottomhole pressure measurements will be recorded downhole, and additional surface pressure data will also be acquired during testing operations.

The downhole pressure gauges will be capable of surface readout and will be deployed via wireline. Memory gauges may also be deployed downhole in wireline-retrievable expandable gauge hangers.

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[1] https://www.epa.gov/sites/default/files/2015-07/documents/guideline.pdf

The general testing procedure is as follows (and presumes that a wireline-deployed unit is used for the testing). **NOTE**: a dedicated downhole monitoring gauge may be used if installed on each of the injection wells:

1. Mobilize wireline unit to the injection well and rig up on wellhead.

2. Rig up a wireline lubricator containing a calibrated downhole surface-readout (SRO) pressure gauge with memory gauge installed in the tool string as a backup, to the adapter above the crown valve. Each gauge should have an operating range of 0 - 10,000 psi. Reference the gauge to Kelly bushing (KB) reference elevation as well as the elevation above ground level.

3. Open crown valve record static surface pressure prior to initiation of injection and run-in hole with SRO pressure gauge on wireline to just above the shallowest perforations in the completion. Whilst running in hole, stop at 1,000-foot increments and allowing the gauge to stabilize (5 minutes each stop). Record the stabilized temperature and pressure, establish baseline temperature and pressure gradients in the non-flowing wellbore.

4. With the SRO pressure gauge positioned just above the perforations, commence injection as per planned rate schedule.

5. Cease injection as rapidly as possible (controlled quick shut-in but avoiding any potential “water hammer” effects); cease pumping, close the control valve and the manual flowline valve at well site. Conduct the pressure fall-off test per planned test design

6. Perform a preliminary field analysis of the fall-off test data with computer-aided transient test software to estimate if or when the test objectives, in particular, the identification of radial flow condition, have been met. If sufficient data acquisition is confirmed, end fall-off test. If additional data is required, extend the fall-off test until the test objectives are met. After confirmation of sufficient data acquisition, end fall-off test.

7. Retrieve the SRO pressure gauge tool out of the well, stopping at 1,000-foot increments and allowing the gauge to stabilize (5 minutes each stop). Record the stabilized temperature

and pressure. Repeat the process to collect stabilized pressure data (5-minute stops) at 1,000-foot intervals and in the lubricator.

In performing a fall-off test analysis, a series of plots and calculations will be prepared to QA/QC the test, identify flow regimes, and determine well completion and reservoir parameters. It will also be used to compare formation characteristics such as transmissivity and skin factor of the near wellbore for changes over time. Skin effects due to drilling and completion (possible damage from perforation) will be assessed for the wells injectivity and potential well cleanouts in the future. These tests can also measure drops in pressure due to potential damage/leakage over time. In $CO_2$, it is anticipated that pressure drops may indicate multiple fluid phases. The analysis will be designed to consider all parameters.

Reports will be submitted to the EPA within 30 days of the test [per 40 CFR §146.91 (e) and §146.91 (b)(3)].

# 3.0 MONITORING WELLS – TESTING STRATEGY

The following tests and log acquisitions will be conducted during drilling, casing installation, and after casing installation in the monitor wells. As such, similar information to the injection wells may be gathered in the monitor wells. The project currently anticipates that three monitor wells will be drilled for the project.  Shell's current monitoring design has one in-zone (IZ) monitoring well spatially placed to the north if the injectors, monitoring the down hole conditions in the reservoirs. Additionally, two above-confining zone (ACZ) monitoring wells have been designed to target the first permeable zone above the Confining Zone and will monitor the down hole conditions and geochemical properties.

## 3.1 LOGGING PROGRAM

The well logging program in the monitor wells will cover open hole and cased hole for all drilling stages. The logging program will generally meet similar requirements as those for the injection wells. These data will be used to reduce uncertainty and will be used to determine *in-situ* formation properties such as: thickness, porosity, permeability, lithology, formation fluid salinity and reservoir pressure [per 40 CFR 146.87]. The logging program for the monitoring wells will be defined based on the well design and the logging requirements to track the $CO_2$ plume and pressure movement. The data gathered will also comply with LDNR requirements and the requirements of USEPA 40 CFR §146.87. The table below shows an example of a typical logging program for a monitor well. Additional data may be gathered as needed. Spontaneous Potential Log acquisition will be dependent of the mud type and may not be possible in synthetic/diesel/oil-based mud systems.

**Table 17: Potential Logging Runs – Monitoring Wells**

| Hole Section | Item | Data Acquisition |
|---|---|---|
| Surface Hole | Drilling | Mud Logs, Survey data |
| | OH Logging Run - WL | SP, GR, Res |
| | CH Logging Run - WL | CBL, VDL, Temp |
| Intermediate Hole Section | Drilling | Mud Logs, Survey |
| | OH Logging Run/s - WL | SP, GR, Res |
| | CH Logging Run - WL | CBL/VDL/Temp |
| Protection Hole Section | Drilling | Mud Logs, Survey |
| | OH Logging Run/s WL | SP, GR, Den, Neu, Res, Cali |
| | OH Logging Run – WL (optional) | RSWC Acquisition * 1 (60 plugs) |
| | OH Logging Run – WL (optional) | Wireline/Dynamic Formation tester and Sampling |
| | CH Logging Run - WL | CBL/VDL/Temp |
| | CH Logging Run - WL | MIT or Noise Log or Pulsed Neutron Log / Tracer Survey using Oxygen Activation Log |

Shell may perform additional logging during the Monitor Well construction phase to track the $CO_2$ to establish baselined for the in direct and direct monitoring of the pressure and plume front.

## 3.2 FORMATION PRESSURE AND FLUID ANALYSIS

Shell may acquire formation pressure and mobility data in the Above Confining Zone Monitoring and In Zone Monitoring wells to monitor the effectiveness of the primary seal and understand connectivity between the formations laterally and vertically.

Shell will acquire baseline fluid samples for the Miocene-aged saline formations in the Above Confining Zone Monitoring or from the In Zone Monitoring wells to monitor the effectiveness of the primary seal. Subsequent fluid sample might also be acquired to track the $CO_2$ pressure and plume front. Additionally, Shell will acquire baseline samples of the selected USDW formations. Samples collected will be sufficient to characterize laterally and vertically across the formations. Shell will follow the USEPA guidelines for pressure and fluid sampling.

### 3.3 FORMATION TESTING

Shell may perform additional pressure fall-off tests during the Monitor Well construction phase to understand the injection profile, fracture pressure and connectivity both laterally and vertically.