



ATTACHMENT C

Pre-Operational Logging and Testing Program

Gulf Coast Sequestration, LLC (G1037)

Project Minerva, Cameron Parish
Minerva South CCS Well Nos. 001 & 002

EPA Project Id: R06-LA-0002

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45031 & 45032

CERTIFICATION

Per LAC 43:VII §3603.H.1, the geoscientific aspects of the Pre-Operational Logging have been prepared by or under the supervision of a licensed Professional Geologist authorized to practice by and in good standing with the Louisiana Board of Professional Geoscientists.

Kaycee M. Garrett

LA License No. 1325

I, Kaycee M. Garrett, certify that I have personally examined and am familiar with the information submitted in this document and the attached documents, and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete.



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FACILITY INFORMATION

Facility Name:	Minerva Facility
Injection Wells:	Minerva South CCS Well No. 001 (MS CCS 1) Minerva South CCS Well No. 002 (MS CCS 2)
Facility Contact:	David Cook, CEO 5599 San Felipe Street, Suite 1450, Houston, Texas 77056 (713) 419-6808; dcook@gcscarbon.com
Well Locations:	Sec 3, T12S, R13W, Cameron Parish, Louisiana MS CCS 1 (North American Datum (NAD) 1927) Surface: 30° 02' 34.10"N, 93° 40' 20.63"W Bottom-Hole: 30° 02' 34.10"N, 93° 40' 20.63"W MS CCS 2 (NAD 1927) Surface: 30° 02' 33.84"N, 93° 40' 20.48"W Bottom-Hole: 30° 02' 13.74"N, 93° 40' 42.07"W

1 INTRODUCTION

The Louisiana Department of Conservation and Energy (C&E) oversees Class VI Injection Wells under its Underground Injection Control (UIC) program. Gulf Coast Sequestration, LLC (GCS) plans to implement the Pre-Operational Logging and Testing Program for Minerva South CCS Well No. 1 (MS CCS 1) and Minerva South CCS Well No. 002 (MS CCS 2) in accordance with LAC 43:XVII §3601-3633, pending approval from the C&E Secretary of Conservation.

This plan encompasses several critical components of the pre-operational strategy:

- **Injection Well Logging & Testing:** The two Class VI injection wells are strategically positioned to optimize access to the pore volume of the upper Frio Formation, enhancing CO₂ flow into the project area reservoirs. GCS will conduct coring, logging, and testing to characterize the confining and injection formations and to evaluate the structural integrity of the injection wells.
- **In-Zone Monitoring Well Conversion:** GCS will convert an existing wellbore into Minerva South In-Zone Well No. 001 (MS IZ 1) to monitor the CO₂ plume and microseismic activity post-injection.
- **Baseline Monitoring of the Underground Source of Drinking Water (USDW) and Above Confining Zone (ACZ):** Before injection, GCS will establish a baseline geochemical dataset for groundwater quality within the USDW and ACZ. This will involve two existing freshwater wells, Well Nos. 5891Z and 5893Z, and two proposed ACZ monitoring wells, Minerva South USDW Well Nos. 001 and 002 (MS USDW 1 and MS USDW 2).

A topographic map depicting the referenced wells and the delineated Area of Review (AoR)



is included as Figure C.1-1, along with a type log cross-section in Figure C.1-2.

2 PRE-INJECTION INJECTION WELL TESTING PLAN

The following tests and logging will be conducted during drilling, casing installation, and after casing installation of the injection wells in accordance with the testing required under LAC 43:XVII §3617.B. Figure C.2-1 and Figure C.2-2 show the wellbore schematics of MS CCS 1 and MS CCS 2, respectively.

2.1 DEVIATION CHECKS

Deviation measurements will be conducted approximately every 500' while drilling the surface hole, and approximately every 100' during construction of the intermediate and long-string hole sections of each well. The deviation measurement which includes depth, inclination of the wellbore from vertical and the direction of the deviation (azimuth) will be taken using Measurement While Drilling (MWD) technology incorporated into drilling assemblies. Real time deviation surveys will be acquired while drilling and ensure the well is drilled according to the planned well trajectory.

After the installation and cementing of the long-string casing in MS CCS 2, a gyro deviation survey will be run in the tangent section from ~2,200' MD/TVD to 8,600' MD / 7,808' TVD of the cased borehole as a final check of the deviation of the wellbore.

2.2 TESTS AND LOGS

The tests and logs planned to be conducted in the two injection wells during drilling, after drilling in the open-hole prior to casing, and after installation of casing and cement are listed in Table C.2.2-1 and Table C.2.2-2 for MS CCS 1 and Table C.2.2-3 and Table C.2.2-4 for MS CCS 2. Table C.2.2-5 and Table C.2.2-6 list the proposed pre-operational testing schedules for each injection well, respectively. Example tool specification sheets are provided as Appendix C-I.

At Project Minerva, the stratigraphic units of interest, in descending order, include:

1. Base of the Lowermost USDW: Quaternary interval
2. Upper Confining Zone: Anahuac Formation
3. Injection Zone: Upper Frio Formation
4. Lower Confining Zone: Upper Frio Formation

2.2.1 Open Hole Logging and Testing Plan

Logs will be run, surveys conducted, and tests performed to determine/verify reservoir properties such as depth, thickness, porosity, permeability, lithology, and formation fluid chemistry in relevant geologic formations below in accordance with the testing required under LAC 43:XVII §3617.B:

1. Base of the lowermost underground source of drinking water (USDW)
2. Upper Confining Zone



3. Injection Zone
4. Lower Confining Zone

The open-hole logging and test program will include the following:

- **Mudlogging** provides continuous analysis of drilled cuttings and fluid from the well borehole brought to the surface by circulating the drilling medium or mud. Mud logging also includes drilling operation parameters including depth, pressure, temperatures, mud flow rates, drill rates, rotation speed, rate of penetration, oil, and gas shows (if any), circulated total gas and gas composition. The information is used to assess the formation drilled and help in deciding casing setting and coring depths, downhole pressure changes and to optimize drilling performance.
- **Spontaneous Potential (SP) log** measures the electric potential (in millivolts, mV) difference between an electrode at the surface of the well and the moving electrode in the borehole. The information is processed to display the electric potential (if any) between the drilling mud and formation fluid. Thus, the result and quality are dependent on the mud type and difference in salinity between the mud and formation. The SP log is used to differentiate shale from more permeable sandstone (or carbonate) formation and the interval thickness of these units. The SP can also be used to estimate formation salinities.
- **Gamma Ray (GR) log** measures the natural radioactivity of naturally occurring minerals in the formation (in API units) and used to differentiate shales (which have high gamma counts due to radioactivity inherent in clay minerals) from sandstone and carbonates with low natural radioactivity. The spectral GR version most logged in wells provides both the total gamma ray log and fractional component of potassium (%), thorium (ppm), and uranium (ppm). This information allows for assessment of clay type and minerals in the formation. The GR log is used to determine the shale/clay content of the formation. Furthermore, GR logs from different wells are used for stratigraphic correlation of formation units across target area.
- **Resistivity log** records formation resistivity in ohm-meters and measures formation and/or formation fluid resistivity to electrical current. The resistivity data is interpreted to determine conductive (salt water-bearing) vs. non-conductive (freshwater or hydrocarbon) fluid bearing zones. The resistivity logs provide resistivity measurement to different depths of investigation into the formation, that is used to assess permeable sandstone formation from non-permeable shale or tight interval.
- **Caliper log** measures borehole diameter and is used to assess the shape of the borehole, especially if the caliper is multi-arm caliper. The data from caliper log is used for cement volume calculations, borehole correction of well logs and geo-mechanical analysis.
- **Temperature log** records borehole temperature and is used to generate geothermal gradient for target area and formation.



- **Density and Neutron logs** measures the electron density and hydrogen ion concentration of formation rock and fluids respectively and are used to generate a continuous total and/or effective porosity log of the formation based in well-established industry equations.
- **Acoustic or Sonic log** records the transit time or velocity of a sound wave across defined formation intervals between a source and a receiver in the tool. The wave form recorded at the receiver comprises different energy modes; the compressional and shear energy modes are generally of primary interest. The compressional sonic data is also used to estimate formation porosity and, along with density logs, for generating synthetic seismic logs to tie seismic data with well logs. The combination of the compressional and shear data is used for geo-mechanical analysis, fracture detection and other geophysical modeling.
- **Borehole Image log** provides an acoustic image or resistivity image of the borehole based on sonic waves or resistivity measured from multiple caliper arms and/or pads. Resistivity based image is more applicable with conductive drilling fluid, while the acoustic image is preferred in oil-based mud. The information from the borehole images is analyzed to assess stratigraphic and structural features including but not limited to structural dips, presence and orientation of faults and/or fractures, and formation stress. This tool also provides positional information such as inclination and azimuths that complement other wellbore deviation surveys.
- **Nuclear Magnetic Resonance (NMR) log** records the induced magnet moment of hydrogen nuclei (protons) contained within the fluid-filled pore space of porous media (reservoir rocks). Hydrogen protons in solids or bound to surfaces show differences in responses compared to bulk fluids in pore space. Hence this log is used to determine the total and effective porosity, permeability, and pore size distribution of target formations.
- **Wireline Formation tester** is a wireline tool used to measure in situ formation fracture pressure and temperature and acquire formation samples at multiple depths of the well borehole.
- **Formation Integrity Test (FIT)** to determine the strength and integrity of a newly drilled section of a well. The FIT is performed by gradually increasing the pressure in the wellbore to a predetermined value and then holding it for a period of time. The test results are used to determine the maximum mud weight that can be used to drill the next section of the well, and to evaluate the bonding strength of the cement around the casing shoe.
- **Sidewall coring tool** is run in the well bore hole to cut and recover plug size formation samples from the side wall of the well bore at multiple depths. The plug size samples are suitable for quantitative core analysis, similar to plugs recovered from whole cores. Rotary and percussion tools will be assessed in the field to determine which is optimum for recovering samples.



- **MWD (Measurement While Drilling)** is used to measure and transmit real time downhole information to surface (including inclination and azimuth) for wellbore position verification. MWD tools provide real time surveys, continuously or on pipe connections, using positive or negative pressure pulse or frequency modulation mud telemetry. Power is provided by either an integral turbine or batteries. Mud-pulse signals are received at the standpipe manifold and decoded. Drill pipe screens are run in the top tool joint to prevent damage to the downhole components.
- **LWD (Logging While Drilling)** measures and transmits real time formation data to surface. GCS will utilize the following sensors: gamma ray, resistivity, density and pressure while drilling (PWD).

Table C.2.2-1 and Table C.2.2-3 list the logs and other downhole tools run during drilling and in the open-hole sections of MS CCS 1 and MS CCS 2 respectively, and the approximate combination in which they will be run, as well as the technical information that the tools will deliver.

2.2.1.1 Conductor Hole Interval

The 26" conductor is driven to about 150' MD/TVD to secure the surface sediments prior to drilling the surface hole. There is no hole drilling associated with driving the conductor pipe and thus no open-hole data acquisition.

2.2.1.2 Surface Hole Interval

The surface hole is planned to be drilled from approximately 0' - 3,000' MD/TVD in both injection wells. This interval is ideally terminated in a shale bed, which can be located by the mudlogger using cuttings samples circulated back to the drill floor. The deepest USDW in this area has been mapped at around 1,250' MD/TVD, so the surface hole extends far below the USDW. The purpose for drilling so far below USDW is to install surface casing at a depth where the formation compressive strength is adequate to support all future drilling forces (compressive strength generally increases with depth).

Deviation checks will be taken using the MWD in the drilling assembly every 500' to ensure that the well bore is per the planned trajectory. Once the surface hole has reached a suitable depth of around 3,000' MD/TVD, the drilling assembly will be removed, and open-hole wireline tools will be run.

The following logs will be run simultaneously in the Surface Hole section (Table C.2.2-1 and Table C.2.2-3) to delineate the formation lithologies and correlate formation tops (SP/GR), verify the depth of the USDW from resistivity logs, and to assess the wellbore size and condition (caliper). The caliper log will be used for estimating cement volumes required for this interval and assess the borehole temperature.

- Spontaneous Potential ("SP"),
- Gamma Ray ("GR")
- Resistivity



- Caliper
- Temperature

2.2.1.3 Intermediate Hole Interval

The intermediate hole section is planned to be drilled from the surface casing setting depth down to approximately 150' above the top of the Injection Zone (see Figure C.2-1 and Figure C.2-2). Upon drilling out of the surface casing, a formation integrity test will be conducted after drilling approximately 10' - 15' of new hole. Approximately 2,000psi will be exerted against the formation (combined drilling mud hydrostatic plus applied pressure) to confirm the compressive strength at this depth. This data serves the dual purpose of proving that the formation is strong enough to withstand expected drilling mud weights required to drill to Hole Section TD and providing a data point for estimating formation fracture pressure.

Mud logging is planned to aid in determining when the Upper Confining Zone is reached, and deviation checks will be performed using the MWD in the drilling assembly to ensure hole is as per planned well trajectory.

Wireline logs will be run to assess the formation characteristics of the stratigraphy above the Upper Confining Zone and the section of the Upper Confining Zone drilled in this hole section. The formation characteristics include lithology, petrophysical properties (porosity, permeability), and fluid properties such as salinity. Borehole image logs will identify structural and stratigraphic features such as formation dip, faults, fractures (if any), and provide input for geomechanical modeling. Furthermore, a sidewall core tool (rotary or percussion) will be run to take rock samples (plugs) in shales and sandstone intervals in this hole section

As noted in Table C.2.2-1 and Table C.2.2-3, the wireline logs and tests across the intermediate hole section include the following:

- GR/SP
- Resistivity
- Caliper
- Temperature
- Neutron
- Density
- Acoustic
 - Compression and shear logs in MS CCS 1
 - Compression only in MS CCS 2
- Borehole image log
- Sidewall coring

2.2.1.4 Long String (Injection) Hole Interval



Upon drilling out of the intermediate casing, a FIT will be conducted after drilling approximately 10' - 15' of new hole. Approximately 2,000psi will be exerted against the formation (combined drilling mud hydrostatic plus applied pressure) to confirm the compressive strength at this depth. The long-string interval covers part of the Upper Confining Zone, the entire Injection Zone and Lower Confining Zone for both wells.

In MS CCS 1, whole cores will be acquired in the Upper Confining Zone, Injection Zone and Lower Confining Zone. Coring in the second injection well, MS CSS 2 (not currently planned for this well) will be contingent on the core recoveries in the MS CSS 1.

Modeling and frequent deviation checks will be performed while drilling this hole section.

Wireline logs and tests in the long-string hole section have been planned to aid formation characterization of the Upper Confining Zone, Injection Zone and Lower Confining Zone. In addition to the logs and tests run across the intermediate hole section, an NMR log is planned to aid assessment of effective porosity, permeability and mineralogy of the target zones. Summary of open-hole wireline logs and tests in the long-string section include:

- GR/SP
- Resistivity
- Caliper
- Temperature
- Neutron
- Density
- Acoustic
 - Compression and shear logs in MS CCS 1
 - Compression only in MS CCS 2
- Borehole image log (only in MS CCS 1)
- NMR log (only in MS CCS 1)
- Wireline formation tester (only in MS CCS 1)
- Sidewall coring

2.2.2 Cased Hole Logging and Testing Plan

Logging and tests are planned upon casing installation and cementing of the different wellbore sections in accordance with the testing required under LAC 43:XVII §3617.B.1.

The cased-hole logging and test program will include the following:

- **Deviation log (Gyro)** is a deviation survey tool run in casing to measure the borehole position relative to the vertical in terms of inclination and direction (azimuth).
- **Temperature log** is like the open-hole temperature logs but run in casing to form a



baseline for future assessment of changes in borehole temperature due to fluid movement behind casing or within or into the wellbore. The temperature log in casing can aid in assessing the top of cement behind casing.

- **Cement evaluation logs** provide an assessment of the cement quality radially as part of well integrity and for zonal isolation, particularly the radial distribution of cement behind the casing, the casing to cement bond (traditionally known as cement bond index) and cement to formation bond in the form a variable density log (VDL). Modern cement evaluation tools provide an assessment of the cement distribution behind the casing to properly evaluate the cement quality around the circumference of the casing.
- **Casing inspection logs** provides an assessment of the condition of the inside casing surface such as roughness, build ups, holes, defects etc., and the casing thickness to assess any possibility of corrosion over time due to the CO₂ sequestration process.
- **Noise log** is a record of sound measured in the cased bore hole to assess well integrity, in particular flow behind and into (leaks) the well bore.
- **Oxygen activation** is also known as a water-flow log, is a method for detecting and measuring water flow in or around a borehole. The process involves activating oxygen with high-energy neutrons to create a nitrogen isotope, which then decays back into oxygen and emits a detectable gamma ray. Detectors placed above or below the tool count the gamma rays.
- **Pulsed Neutron capture log** is used to measure the sigma or capture cross section of a formation (how good a given formation captures thermal neutrons). The information is used to assess fluid saturation in the formation behind casing (independent of resistivity). When this log is run pre-injection (baseline log) and post CO₂ injection, the information gathered is used to assess changes in the fluid (water and CO₂) saturation with time due to CO₂ sequestrations.

Table C.2.2-2 and Table C.2.2-4 list the logs and other downhole tools run upon casing and cementing in the cased-hole sections of MS CCS 1 and MS CCS 2, respectively, and the technical information that the tools will deliver.

2.2.2.1 Conductor Pipe

There is no hole drilling associated with this conductor pipe and thus cased-hole logging is not applicable.

2.2.2.2 Surface Casing

Upon installing and cementing the surface casing, and after the required time allowed for the cement to set, cased-hole logs will run inside the casing to evaluate the quality of the cement job and record the borehole temperature as required under LAC 43:XVII §3617.B.1.b

The surface cased-hole logging consists of the following:

- Cased hole GR, for stratigraphic correlation; this log allows correlation with the GR



run previously in open-hole, so that the quality of the cement at any depth can be correlated to those formations logged at that depth.

- Cement evaluation log that provides radial assessment of the cement bond casing to cement bond) and variable density log to assess cement to formation bond. In addition, these logs will provide an assessment of top of cement, if not to surface.
- Temperature log

2.2.2.3 Intermediate Casing

Upon installing and cementing the intermediate casing, and after the required time allowed for the cement to set, cased-hole logs will run inside the casing to evaluate the quality of the cement job and record the borehole temperature as required under LAC 43:XVII §3617.B.1.c

The intermediate cased-hole logging and testing consists of the following:

- Cased hole GR
- Cement evaluation log
- Temperature log
- Noise log
- Casing pressure test to assess mechanical integrity of the casing
- Oxygen activation log

2.2.2.4 Long String Casing

Upon installing and cementing the long-string casing, and after the required time allowed for the cement to set, cased-hole logs will run inside the casing to evaluate the quality of the cement job and record the borehole temperature as required under LAC 43:XVII §3617.B.1.c

The long-string cased-hole logging and testing consists of the following:

- Cased hole GR
- Cased hole deviation survey (only in MS CCS 2)
- Cement evaluation log
- Casing inspection log (to assess baseline condition of the casing)
- Temperature log
- Noise log
- Oxygen activation log
- Pulsed Neutron log
- Casing pressure test



2.3 CORING PLAN AND ANALYSIS

Whole cores and side wall cores are planned to be acquired in the proposed Upper Confining Zone, Injection Zone and Lower Confining Zone, in accordance to the requirement under LAC 43:XVII §3617.B.2. Whole core will be acquired in the MS CCS 1. At least 15% of gross thickness will be collected in both the Injection Zone and Upper Confining Zone. Acquisition of whole core in MS CCS 2 will occur if core recovery is unsuccessful in MS CCS 1. Sidewall cores will be taken in both wells for geologic characterization where whole core was not collected. Table C.2.2-1 shows the sidewall and whole cores plan for MS CCS 1.

Whole cores are planned to be acquired in the long-string open-hole section, while sidewall core plugs are planned across the intermediate and long-string hole sections.

2.3.1 Whole Coring Plan

Acquisition of whole core will only occur in MS CCS 1. A contingency plan to acquire whole core in MS CCS 2 will be created, in the event that recovery is unsuccessful in MS CCS 1.

2.3.1.1 Upper Confining Zone

After successful FIT and drilling through the intermediate casing shoe that was set in the Upper Confining Zone, the long-string (injection) hole interval will be drilled to a depth suitable for coring. The conventional core will be large-diameter core (4" core barrel) drilled and subsequently preserved according to industry best practices. ~60' of core is planned to be cut in the Upper Confining Zone.

It is anticipated that core will be cut and handled as follows:

- Conventional core barrel assembly, with sealed inner barrel
- 4" diameter inner barrel
- 30' barrel length (optimum length to be confirmed during core capture operations)
- Mechanism to secure core in place to prevent loss of unconsolidated formation, if any
- Tripping-time schedule, to allow in-situ gases to release slowly as the core barrel is brought to surface, to eliminate damage to the core due to gas expansion
- On-site evaluation of the whole core still contained within the inner barrel, by characterization of the exposed ends as the inner barrel is cut into 3' lengths. A GR log can also be obtained with the core barrel at surface
- Sealing all exposed ends of the whole core at surface, for transportation to the laboratory

On-site evaluation of the recovered core together with comparison to offset well logs will confirm that a suitable section of the Upper Confining Zone was recovered.

2.3.1.2 Injection Zone and Lower Confining Zone

Drilling will continue to the next core point within the Injection Zone. This depth will be



chosen by evaluating the mud logger cutting samples with comparison to the offset well logs to confirm the Injection Zone has been reached. Approximately 75' of whole core will be collected.

It is anticipated that core will be cut and handled as follows:

- Conventional core barrel assembly, with sealed inner barrel
- 4" diameter inner barrel
- 30' barrel length (optimum length to be confirmed during core capture operations)
- Mechanism to secure core in place to prevent loss of unconsolidated formation, if any
- Tripping-time schedule, to allow in-situ gases to release slowly as the core barrel is brought to surface, to eliminate damage to the core due to gas expansion
- On-site evaluation of the whole core still contained within the inner barrel, by characterization of the exposed ends as the inner barrel is cut into 3' lengths. A GR log can also be obtained with the core barrel at surface
- Sealing all exposed ends of the whole core at surface, for transportation to the laboratory

2.3.2 Sidewall Core Acquisition Plan

Sidewall cores are planned to be acquired across the intermediate and long-string hole sections MS CCS 1 (Table C.2.2-1) and MS CCS 2 (Table C.2.2-2). Sidewall cores will be collected to supplement the whole core. The purpose of running a sidewall coring tool is to sample formations outside the conventionally cored interval, both within the Upper Confining Zone, Injection Zone and Lower Confining Zone. Log data will be used to optimize the sample depths for a variety of rock types, textures, and inferred depositional environments. Rotary and percussion coring tools will be tested during operations to determine which provides the highest recovery and sample quality. Note: Wellbore conditions will be assessed to minimize the risk of stuck pipe events; sidewall coring requires the pipe to be on a "stationary mode" for at least 20 minutes for each point, full circulation will be maintained to maximize efficiency on this operation.

2.3.3 Core Analyses

Detailed core analyses of the whole core, plugs taken at select depths from the whole core (Table C.2.3-1), and sidewall core plugs (Table C.2.3-2) will be done by a well-respected, industry leading laboratory to characterize the lithology, mineralogy, petrography, petrophysical and geo-mechanical properties of the all the relevant section samples. See Table C.2.3-3 for details on the Core Analyses Services.

The core analyses will include:

- Lithologic description (whole cores and/or plugs)
 - Texture, depositional and sedimentary features (grain size, shape, sorting,



- fractures (if any)), rock type and facies
- CT scan: High-resolution images of the core's internal structure, helping to identify fractures, bedding planes, and other features.
- Mineralogic and petrologic analyses (core plugs)
- X-Ray Diffraction 'XRD' and/or X-Ray Fluorescence 'XRF' for elemental mineral identification and quantification
 - Thin section petrography and/or scanning electron microscopy (SEM) for imaging rock fabric and pore geometry
- Petrophysical properties (core plugs)
- Grain and bulk density
 - Porosity
 - Permeability
 - Fluid saturation particularly assessment of residual or trapped gas saturation
 - Mercury injection capillary pressure (MICP)
 - Effective and relative permeability
 - Pore volume compressibility
- Geo-mechanical properties (core plugs)
- Rock strength
 - Tensile Strength: In order to establish the tensile strength of the Upper and Lower Confining Zone.
 - Compressive Strength: In order to establish the compressive strength of the Upper and Lower Confining Zone, a single stage triaxial Confined and/or unconfined test will be performed at multiple sample points from whole core within the Upper and Lower Confining Zone. Triaxial compressive strength tests are commonly used to simulate reservoir stress conditions to measure static mechanical properties (e.g., compressive strength, Young's modulus of elasticity and Poisson's ratio). Dynamic measurements (Vp/Vs) can be made concurrently for acoustic (sonic) log applications.
 - Shear Strength: Shear strength will be calculated using the Mohr-Coulomb equation with inputs from Multistage or Multisampling Triaxial laboratory analysis that will be performed at multiple sample points from whole core within the Upper and Lower Confining Zones.
 - Impact Strength: In order to establish the impact strength of the Upper and Lower Confining Zone (the Anahuac Formation), a Brinell Hardness test will be performed at multiple sample points from whole core within the Upper and Lower Confining Zone



- Ductility of the Upper Confining Zone, Injection Zone and Lower Confining Zones will be calculated by measuring the uniaxial compressive strength during the triaxial single stage geomechanical test.
- In-situ stress formation tests to determine minimum and maximum horizontal stress

2.3.4 Reporting

Per LAC 43:XVII §3617.B.2, GCS will submit to the Secretary a detailed report prepared by a log analyst that includes: well log analyses (including well logs), core analyses, and formation fluid sample information. Methodology, notes on quality assurance of samples and calibration of instrumentation will also be included, as appropriate.

2.4 FORMATION TESTING PROGRAM

The formation testing program comprises formation integrity and fluid sampling tests to meet the requirement of LAC 43:XVII §3617.B.4.

2.4.1 Upper Confining Zone

The Upper Confining Zone is defined as the zone overlying the Injection zone that acts as a barrier to fluid movement above an Injection zone. The Upper Confining Zone must have sufficient rock strength, permeability, areal extent, and thickness to confine injected fluids within the Injection zone.

The confining formation overlying the Injection Zone, identified as the Upper Confining Zone, is the Anahuac Formation which conformably overlies the upper Frio Formation. The Anahuac Formation acts as a very effective, thick regional seal to many prolific hydrocarbon fields and so can be assumed to be rich in sealing lithologies (Swanson & Karlsen, 2009).

At Project Minerva, the Anahuac Formation extends from -6,600' TVDSS near Black Bayou Dome to over -9,200' TVDSS at the base of a syncline structure located northeast of the AoR. Depth across the AoR varies from -7,000' TVDSS to -8,400' TVDSS. The Anahuac Formation thickens from 800', north of the project area, to over 1,100', south.

2.4.1.1 Physical/Chemical Parameters

Formation integrity tests are planned to be performed to test the strength of the formations where the surface and intermediate casings are set (See Table C.2.2-1 and Table C.2.2-3). The intermediate casing is set in the Upper Confining Zone and the result of the formation integrity test will provide data for assessment of the fracture pressure and gradient of the Upper Confining Zone.

Upon drilling out of the intermediate casing, a formation integrity test will be conducted after drilling approximately 10' – 15' of new hole. Approximately 2,000 psi will be exerted against the formation (combined drilling mud hydrostatic plus applied pressure) to confirm the compressive strength at this depth.

The FIT test will be integrated with core analyses (Section 2.3.3) and borehole image logs (Section 2.2.1.4) to provide an assessment of geomechanical properties of the Upper



Confining Zone.

2.4.2 Injection Zone (Upper Frio Formation)

The Injection Zone at Project Minerva is the upper Frio Formation. The Injection Zone is comprised of stacked shoreline sandstones interbedded with shales. Gross thickness varies from approximately 1,400' to approximately 1,700' in the Project Minerva's AoR. Depth varies from 8,000' TVDSS to 10,200' TVDSS.

2.4.2.1 Physical/Chemical Parameters

The wireline formation tester records the fracture pressure and temperature of the formation at the sampling, and the conductivity of the fluid sample, in addition to acquiring the fluid samples. Multiple samples at different depths can be acquired with the wireline formation tester. The acquired fluid samples will be sent either to an onsite or offsite laboratory to determine fluid properties.

Wireline formation tester will be conducted in MS CCS 1 (Table C.2.2-1) to characterize the chemical and physical properties of the formation fluids in the Injection Zone (LAC 43:XVII §3617.B.4.c).

2.4.2.2 Formation Fluid Properties

Fluid sampling using a wireline formation tester will be conducted in MS CCS 1 (Table C.2.2-1) to characterize the chemical and physical properties of the formation fluids in the Injection Zone (LAC 43:XVII §3617.B.4.c).

The wireline formation tester records the pressure and temperature of the formation at the sampling location and the conductivity of the fluid sample, in addition to acquiring the fluid samples. Multiple samples at different depths can be acquired with the wireline formation tester. The acquired fluid samples will be sent either to an onsite or offsite laboratory to determine fluid properties.

The following information will be recorded and measured from the sampling operation and fluid sample analysis:

- Formation pressure and temperature
- Fluid temperature
- pH
- Fluid specific conductivity
- Fluid density
- Total dissolved solids (TDS – measure of salinity)
- Alkalinity
- Chemical composition
 - Major cations and anions: Ca²⁺, Mg²⁺, K⁺, Na⁺, Cl⁻, Br⁻, SO₄²⁻, and NO₃⁻



- Other constituents: Sr²⁺, Fe²⁺, Fe³⁺, Al, SiO²
- Trace elements such as As, Hg, Cu, Zn
- CO₂ and H₂S content (if any)

The geochemical analysis will be conducted to validate geochemical compatibility assumptions relating to formation water, Injection Zone mineralogy and the injectate (CO₂) stream.

2.4.3 Lower Confining Zone

The Lower Confining Zone is defined as the zone underlying the Injection zone that acts as an impermeable barrier to contain injectate and formation fluid in the Injection Zone. The Lower Confining Zone must have sufficient rock strength, low permeability, areal extent, and thickness to confine injected fluids within the Injection Zone.

A deep shale interval within the upper Frio Formation is designated as the Lower Confining Zone. This interval occurs at the base of the deepest sand in the upper Frio Formation present at the proposed injection site and is interpreted as laterally extensive, shale-dominated interval containing only discontinuous, thin sand layers. Depths range from approximately -8,900 ft TVDSS to about -10,700 ft TVDSS across the AoR. Gross thickness ranges from ~60ft to ~140 ft.

2.4.3.1 Physical/Chemical Parameters

Whole and sidewall core analyses (Section 2.3.3), and borehole image logs (Section 2.2.1.4) will be used to provide an assessment of geomechanical properties of the Lower Confining Zone. Additionally, all the tests and logs run in the long-string hole section (detailed in Section 2.2) will be used for characterization.

2.5 DEMONSTRATION OF MECHANICAL INTEGRITY

Per LAC 43:XVII §3617.B.1.d and LAC 43:XVII §3627.A, GCS will conduct tests and run logs to demonstrate that:

- There is no significant leak in the casing, tubing, or packer; and
- There is no significant fluid movement into a USDW through channels adjacent to the injection wellbore

Tests and log runs will include:

- Pressure test with liquid or gas
- Oxygen activation log
- Temperature or noise log
- Pulsed neutron log
- Casing inspection log

Table C.2.5-1 summarizes all internal and external mechanical integrity tests.



2.5.1 External Mechanical Integrity

In accordance with LAC 43:XVII §3617.B.1.d, external mechanical integrity will be tested in the following ways:

- Pressure test of each casing string upon installation and cementation. Prior to drilling out the plug in each casing string, a casing pressure test will be conducted not to exceed the burst pressure of that casing to assess the external mechanical integrity of that casing.
- Oxygen activation log to detect and measure water flow in or around a borehole.
- Temperature and noise logs to assess for any leakage.
- Pulsed neutron log to provide baseline assessment of fluid saturation behind casing for future post injection comparison.
- Casing inspection log to assess the condition of the casing and also provide baseline for future corrosion assessment.

2.5.2 Internal Mechanical Integrity

2.5.2.1 Annulus Pressure Test Procedures for Injection Wells

Upon completion of the injection wells, an annulus pressure test between the tubing and casing will be conducted to meet the requirement of LAC 43:XVII §3627.A.2.a.

Per LAC 43:XVII §3621.A.3-4, GCS will fill the annulus between the tubing and the long-string casing with a non-corrosive fluid approved by the Secretary, or a fluid containing a corrosion inhibitor approved by the Secretary. The initial annulus pressure test will include pressuring the annulus to an authorized injection pressure.

GCS will maintain tubing-casing annulus pressure that exceeds the operating injection pressure, unless the Secretary determines that such requirement might harm the integrity of the well or endanger a USDW. If reduced annulus pressure is required, GCS will submit a request in writing for approval.

After the injection tubing and packer is installed, the packer seal against the long-string casing wall will be tested by applying pressure to the annulus between the casing and injection tubing above the packer; the test (second test) will be charted to record that no leakage occurs. In addition, the fiber optic cable attached to the outside of the long-string casing will be able to monitor the temperature along the entire length of the casing (distributed array temperature) and will detect any leakage by showing a temperature change at any leak point. A tubing plug will be installed in an internal profile seat near the bottom of the tubing string, and pressure will be applied above it to test (third test) the tubing integrity. Test pressure will not exceed 80% of the tubing burst rating.

These three pressure tests satisfy the requirements of LAC 43:XVII §3627.A.1.a (40 CFR 146.89(a)(1)), with the first test occurring shortly after the well is drilled and the other two tests (packer and tubing) after all permits for injection have been obtained and the injection well has been completed.



2.5.2.2 Annulus Pressure Maintenance

Per LAC 43:XVII§3621.A.3-4, GCS will fill the annulus between the tubing and the long-string casing with a non-corrosive fluid approved by the Secretary or a fluid containing a corrosion inhibitor approved by the Secretary.

GCS will maintain tubing-casing annulus pressure that exceeds the operating injection pressure, unless the Secretary determines that such requirement might harm the integrity of the well or endanger a USDW. If reduced annulus pressure is required, GCS will submit a request in writing for approval by the Secretary.

2.6 HYDROGEOLOGIC TESTING

Upon completing the injection wells, including perforating the target injection zone, installing tubing and packers, GCS will conduct a pressure fall-off test and step-rate injectivity test to verify the hydrogeologic characteristics of the injection zone as requirement by C&E (LAC 43:XVII §3617.B.5). The tests will measure transmissibility, skin effects due to well construction and near borehole effect, injectivity of the formation, injection flowing and static pressures of the formation, and determine Maximum Surface Injection Pressures (MSIP) for the well. These tests will provide a baseline for well and reservoir performance over time. The following tests described below will be conducted in cased downhole conditions after perforation.

2.6.1 Static Fluid Level Test

A static fluid level test will be performed on both wells as part of the preoperational testing.

2.6.2 Pressure Fall-Off Test

A short-term injection/falloff test will be performed to analyze reservoir permeability, determine injection potential, and evaluate skin damage (completion efficiency) of the wellbore. This test will provide a baseline standard to measure the effects of CO₂ injection. Subsequently, a pressure falloff test will be performed every five years or more frequently if required by the Secretary (LAC 43:XVII §3625.A.6). All this information will help improve the dynamic model and provide learnings for future data collection.

A falloff test is conducted by a long period of injection, followed by a long period of well shut in. Pressures are monitored prior to injection, during injection, and the observed drop of pressure until the formation reaches the initial static pressure. The test will be designed in accordance with the USEPA Region 6 UIC Pressure Falloff Testing Guidance (Third Revision – August 8, 2002). The wells will be shut-in for a sufficient period to allow for static conditions (*i.e.*, no injection prior to test). Two gauges will be installed downhole at the injection interval to obtain the initial bottomhole pressure. Continuous injection will occur at a steady pre-defined rate for an acceptable duration to produce a measurable pressure transient that will produce a falloff test. The gauges downhole will monitor the flowing bottomhole pressures. The well will be shut in at the wellhead (to minimize wellbore storage effects). The pressure falloff will be monitored until the well reaches radial flow (pressure response for the reservoir) and a final bottomhole pressure is measured. Note, no injection



will occur from offset wells during the pressure falloff tests. The injection will be isolated to the well actively being tested.

In performing a falloff 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 well's injectivity and potential well cleanouts in the future. These tests can also measure drops in pressure due to potential damage/leakage over time. In CO₂, it is anticipated that pressure drops may indicate multiple fluid phases. The analysis will be designed to consider all parameters.

2.6.3 Step Rate Injectivity Test

The step rate injectivity test will also support the requirement in the prior section for fracture pressure measurements.

A step-rate test (usually after the falloff test) will be used to determine the Maximum Surface Injection Pressure (MSIP), which should be less than or equal to the measured fracture closure pressure of the injection interval. A step-rate test will be developed for the Injection Zone in each well. Injection rates will be developed to span the initial pressures (minimum rate) and estimated fracture pressure (maximum rate).

Fluid will be injected in steps, plotting the injection pressure versus the injection rate (unconsolidated formations may require a tubing/packer setup). Injection will be held constant for each step for an equal length of time. Injection steps will be designed with a minimum of 5 steps with 20% rate increases. However, injection steps will be tailored to each well to optimize data collection and may result in more steps and a lower percent increase over time.

Rates and pressures will be recorded downhole and at surface. Injection rates and pressures will be plotted at the end of each step and analyzed for either a constant slope or a decrease in slope (which identifies when the formation fractures and loses the pressure held).

2.6.4 Reporting

Documentation guidelines will be followed by submitting the requested information at the conclusion of testing. Data submitted for both the fall-off test and injectivity or pump test include:

- Raw pressure data
- Flow data from the injection part of the test. For the Injectivity or pump test, include rate and time
- Test parameters (injection time, shut-in time, fluid viscosity, temperature, wellbore diameter, pressure gauge type and location)
- Semi-log plots used for data analysis



- Parameters calculated from the analysis
- Discussions of the results, including data quality and any anomalous values

2.7 TESTING VIA FIBER OPTIC CABLE

Fiber optic cable will be attached to the outside of the 9 5/8" long-string casing and will facilitate distributed temperature sensing (DTS) and distributed acoustic sensing (DAS). See WBS diagrams Figure C.2-1 and Figure C.2-2 .

2.7.1 Distributed temperature sensing (DTS)

Implemented via the fiber optic cable and allow temperature to be measured continuously along the entire length of the casing. Leak detection will be achieved by identifying temperature anomalies. See Testing and Monitoring Plan (Attachment D).

2.7.2 Distributed acoustic sensing (DAS)

A baseline vertical seismic profile (VSP) will be recorded prior to injection commencing and will be implemented via distributed acoustic sensing (DAS), conducted in a fiber optic cable. See Testing and Monitoring Plan (Attachment D).

2.8 TESTING SCHEDULE

Internal and external integrity testing and reservoir testing will continue through the operational life of the wells. The proposed testing descriptions, frequency, notifications, and reporting are described in the Testing and Monitoring Plan (Attachment D). See Table C.2.5-1

2.9 REPORTING

GCS will notify C&E at least 72 hours in advance of a given test/log.

Logging and testing results will be used to update the dynamic model and to modify data collection programs in successive wells. After the conclusions of drilling, GCS will prepare a report that includes an interpretation of the results of the logs. The report will be in electronic format and will include:

- The date and time of each test, the date of wellbore completion, and the date of installation of all casing and cement
- 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
- Any changes in interpretation of site stratigraphy based on formation testing logs



The results of the fluid analyses will help reduce uncertainty, improve the dynamic model, and define the AoR. Documentation guidelines will be followed. When this phase of work is complete, the following information will be submitted:

1. Type of sampling equipment used and field procedures
2. If the sample was pumped, flow rate, type of pump, location of the pump, and geochemical modeling results indicating the likely geochemical makeup of the fluids at downhole conditions
3. Data for field measurements (pH, SC, temperature, pressure)
4. Laboratory results, including QA of samples
5. Notes on any anomalous data

3 IN-ZONE MONITORING WELL PRE-OPERATION TESTING PLAN

GCS will convert an existing wellbore, Stream 34 Well No. 001 (SN 224951, Map Id 1) whose bottom hole location is approximately 0.75 miles north of the Minerva South Well Pad, into an in-zone monitoring well. The converted well will be named Minerva South In-Zone Well No. 001 (MS IZ 1) and will be used to track the CO₂ plume within the Injection Zone and conduct microseismic monitoring of the adjacent faults.

GCS will submit Form UIC-25 (or its replacement), Class V Well Application, to C&E to convert Stream 34 Well No. 001 to MS IZ 1. A conversion plan can be found in Appendix D-VII of the Testing and Monitoring Plan (Attachment D).

3.1 DEVIATION CHECKS

Deviation checks will not be required for Minerva South In-Zone Well No. 001 (MS IZ 1) as it will be converted from a legacy wellbore.

3.2 TESTS AND LOGS

Testing and logging will be completed in accordance with the applicable regulations set forth in LAC 43:XVII §3617. A detailed conversion plan along with a testing and logging plan will be submitted for approval with the Class V application.

3.2.1 Open Hole Logging and Testing

No open-hole logging/tests will be performed on MS IZ 1, as it will be a converted legacy well. Full details of the logging and testing plan can be found in Testing and Monitoring Plan (Attachment D, Appendix D-VII) and will be submitted for approval in the Class V UIC-25 application.

3.2.2 Cased Hole Logging

Full details of the logging and testing plan can be found in Testing and Monitoring Plan (Attachment D, Appendix D-VII) and will be submitted for approval in the Class V UIC-25 application.



3.2.3 Demonstration of Mechanical Integrity

The mechanical integrity demonstration for MS IZ 1 will be in accordance with the applicable requirements of 3617.B.1.d.i-iv and will be detailed in the conversion plan submitted for approval in the Class V UIC-25 application.

3.2.4 Reporting

Notification and the opportunity to witness these tests/logs shall be provided to C&E at least 72 hours in advance of a given test/log.

4 USDW AND ABOVE CONFINING ZONE (ACZ) MONITORING WELL PRE-OPERATION TESTING PLAN

To meet the requirements of LAC 43.XVII §3607.C.2.e, GCS will establish a baseline geochemical dataset of groundwater quality within the USDW and above the Confining Zone prior to injection.

4.1 BASELINE PRE-OPERATIONAL MONITORING PLAN

Table C.4.1-1 summarizes the planned monitoring methods, locations, and frequencies for baseline pre-operational groundwater quality and geochemical monitoring of the USDW and above the Confining Zone.

4.1.1 USDW Monitoring

Two existing freshwater wells that are completed within the USDW will be monitored prior to injection: Well Nos. 5891Z and 5893Z.

Well No. 5891Z is located within the AoR and is nearly 1,700 ft west-northwest of the Minerva South well pad. Well No. 5891Z is an active domestic well completed 400 ft below ground level and withdraws water from the “200-foot sand” of the Chicot aquifer within.

Well No. 5893Z is the nearest active water well outside of the AoR and is approximately 4,750 ft east-northeast of the Minerva South well pad and approximately 1,300 ft from the eastern edge of the delineated AoR. Well No. 5893Z is an active domestic well completed 235 ft below ground level and withdraws water from the “200-foot sand” of the Chicot Aquifer.

Well Nos. 5891Z and 5893Z are constructed of plastic “3x2” casing.

The wells will be used to establish baseline groundwater quality within the USDW before injection. GCS will have access to these wells for quarterly testing throughout the baseline monitoring period, aiming to collect samples over the year leading up to the injection. Baseline monitoring will conclude once injection commences. Unscheduled samples will be collected at the request of C&E.

4.1.2 ACZ Monitoring

Two (2) new above confining zone monitoring wells will be drilled prior to injection: Minerva South USDW Well No. 001 (MS USDW 1) and Minerva South USDW Well No. 002 (MS USDW 2). MS USDW 1 will be sited at the Minerva South Well Pad to monitor the only known



potential pathway for vertical fluid migration within the AoR. MS USDW 2 will be sited at the well pad of Stream 34 Well No. 001 (SN 224951, Map Id 1).

A third ACZ monitoring well, Minerva South USDW Well No. 003 (MS USDW 3), will be drilled within the AoR after injection commences and once the direction of the plume and pressure fronts have been established.

These wells will be utilized to establish a baseline prior to injection and monitor ground water quality and geochemical changes above the confining zone(s). Drilling and Logging procedure for MS USDW 1 and MS USDW 2 can be found in Appendix D-III of the Testing and Monitoring Plan (Attachment D).

GCS will submit Form UIC-25 (or its replacement), Class V Well Applications, to C&E to drill and operate MS USDW 1 and MS USDW 2. A detailed drilling, testing and logging plan will be submitted for approval with the Class V application. GCS will submit the same application for MS USDW 3 at the appropriate time.

MS USDW 1 and 2 will be drilled once construction of the injection wells is complete, but prior to commencement of injection. After operation commences, GCS will consult with C&E to evaluate the location and installation of MS USDW 3 in the AoR. Deviation checks will not be required for MS USDW 1, MS USDW 2, and MS USDW 3 as they will be vertical wells completed at a depth less than 2,000' below ground level.

4.2 BASELINE SAMPLING AND TESTING

Once GCS receives authorization to drill MS CCS 1 and MS CCS 2, baseline monitoring of the USDW will commence and quarterly samples will be collected from Well Nos. 5891Z and 5893Z until injection commences.

After MS USDW 1 and MS USDW 2 are drilled, baseline monitoring above the Confining Zone will commence, and quarterly samples will be collected from each of the ACZ monitoring wells. Once MS USDW 3 is drilled, groundwater sampling will follow the same schedule. After injection commences, groundwater samples will be collected through the operational life of the project.

The following subsections outline the parameters, methods, and chain of custody that will be employed during the baseline monitoring.

4.2.1 Analytical Parameters

Table C.4.2-1 outlines the parameters for establishing a baseline dataset and their continued use in groundwater monitoring, along with the analytical methods that GCS will employ.

The list of parameters may be reduced over the operational period, should it be determined during baseline sampling and/or the operational period that parameters listed in Table C.4.2-1 are no longer constituents of concern.

4.2.2 Sampling Methods

Samples will be collected using the following procedures:



- Water Level depth and elevation measurements will be taken.
- Wells will be purged such that existing water in the well is removed and fresh formation water is sampled.
- Downhole measurements of static fluid level, temperature, pH, conductance, dissolved oxygen, and pressure will be collected.
- Samples will be collected by lowering clean equipment downhole.
- Field measurements taken for density, pH, conductance, temperature, and dissolved oxygen will be collected from the samples at the surface.
- Samples will be preserved and sent to lab as per chain-of-custody procedure.

Groundwater samples will be collected following the procedures outlined in the project's Quality Assurance Surveillance Plan (QASP) (Attachment D, Appendix D-I) during the operational and post-operational periods.

4.2.3 Accredited Laboratory/Chain of Custody and Analysis Procedures

Final laboratory selection has not been made at this time. The laboratory selected will be LELAP accredited and will meet all requirements set forth in the Testing and Monitoring Plan and the QASP (Appendix D-I). The Chain-of-Custody procedures will follow the requirements of the QASP.

The selected LELAP accredited laboratory will have all the necessary equipment, experience, and certifications to complete the analysis. Once selected, the LELAP accredited laboratory will have a chain of custody procedures that will be similar to the following:

- Sample date
- Sample description
- Sample type
- Relinquished by and received by signature
- Sampler name
- Location information

4.2.4 Demonstration of Mechanical Integrity

A demonstration of Mechanical Integrity is not required above confining zone monitoring wells. Well Nos. 5891Z and 5893Z and the ACZ monitoring wells will strictly be used for shallower groundwater sampling purposes. The wells will not be completed with tubing or packer nor will they have wellheads.

4.2.5 Reporting

Notification and the opportunity to witness these tests/logs shall be provided to C&E at least 72 hours in advance of a given test/log.



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5 REFERENCES

Swanson, S. M., & Karlsen, A. (2009). PS USGS Assessment of Undiscovered Oil and Gas Resources for the Oligocene Frio and Anahuac Formations, Onshore Gulf of Mexico Basin, USA. *AAPG Annual Convention*. San Antonio, Texas: AAPG.