ATTACHMENT D

PRE-OPERATIONAL TESTING AND LOGGING PLAN [40 CFR 146.87]

1. FACILITY INFORMATION

Facility Name: CarbonFrontier

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Well information:

Well Number	County, State	Latitude	Longitude
Injection Wells			
CI1-64Z-27N	Kern County, CA	35°33'9.4877"N	119°48'26.3702"W
CI2-64Z-35N	Kern County, CA	35°32'32.6713"N	119°47'37.0682"W
CI3-64Z-35N	Kern County, CA	35°32'11.6457"N	119°47'7.5912"W
CI4-64Z-35N	Kern County, CA	35°31'55.4154"N	119°46'51.7864"W
27R-27N	Kern County, CA	35°33'2.4280"N	119°48'28.6103"W
55-26N	Kern County, CA	35°32'43.2520"N	119°47'32.7755"W
64-35N	Kern County, CA	35°31'44.3600"N	119°46'44.9788"W
9-1N	Kern County, CA	35°31'31.6480"N	119°46'37.0154"W
64-27N	Kern County, CA	35°32'38.0979"N	119°47'54.6576"W
Monitoring Wells			
39-26N	Kern County, CA	35°32'54.8149"N	119°47'35.1082"W
1-28N	Kern County, CA	35°33'22.7757"N	119°48'51.4527"W
25-26N	Kern County, CA	35°33'1.2506"N	119°47'43.8785"W
27-1N	Kern County, CA	35°31'18.6498"N	119°46'21.0202"W
35X-27N	Kern County, CA	35°32'59.1538"N	119°48'06.3812"W

Version History

File Name	Version	Date	Description of Change
Attachment D – Aera CCS Pre-operational Testing Plan.pdf	1	January 19, 2023	Original document
Attachment D – CarbonFrontier Pre-operational Testing Plan V2 04182024.pdf	2	April 18, 2024	Revisions made based on EPA Technical Review comments from October 10, 2023

2. INTRODUCTION

Aera Energy LLC (Aera) plans to collect geologic and hydrogeologic data to demonstrate that the injection zone and confining layers are suitable for receiving and containing injected fluids. Aera will conduct logs, surveys, and tests to determine the depth, thickness, porosity, permeability, lithology, minerology, and heterogeneities of the injection and confining zones; measure the formation fluids; document conformance with the well construction requirements; and establish baseline data for time-lapse measurements, in accordance with 40 CFR 146.87. Because exploration and production activities in the 64 Zone Sandstones in the North Belridge oil field have been ongoing for the past 90 years, a substantial amount of relevant data has already been collected (**Section 2.4** of the **Application Narrative**). This document is the Pre-Operational Testing and Logging Plan for new, repurposed injection wells and monitoring wells. The activities described in this document will supplement existing data and confirm conditions at the injection well locations. Additional testing and monitoring prior to injection is also discussed in this document, related to establishing baseline information for leakage detection and geochemical assessment through formation fluid sampling in injection zone and permeable layers above the confining zone.

3. DRILLING AND INTEGRITY TESTS

3.1 Deviation Checks

Deviation measurements will be conducted for newly drilled wells at a minimum of approximately every 300 feet during well construction. More comprehensive deviation checks will be provided at the end of each hole section at depth intervals no greater than 100 feet between checks, including inclination and azimuth (note: this may be done with "measurement while drilling" while drilling the hole section). A gyroscopic survey of the completed well will be done following the installation of the long string casing for a final verification of the wellbore trajectory.

3.2 Cement Bond

Cement bond logs, variable density logs, and temperature logs will be performed on the newly drilled injection wells after the surface casing is cemented. Cement bond logs, variable density logs, and temperature logs will be performed on the repurposed injection wells after the long string inner casing is set and cemented.

3.3 Mechanical Integrity Tests (MIT) [40 CFR 146.87(a)(4)]

A series of mechanical integrity tests, listed below, will be performed in the final stages of well construction to demonstrate the internal and external mechanical integrity of the injection and monitoring wells. Detailed testing procedures can be found in the Testing and Monitoring Plan (**Attachment E**) and include the following:

- Annular pressure test
- Temperature, noise, or oxygen activation log

- Multi-finger caliper log
- Ultrasonic image log

4. FORMATION TESTING AND WELL LOGGING PLAN

This section describes the suite of formation testing and well logging activities associated with newly drilled injection wells, repurposed injection wells, and monitoring wells. A descriptive report will be prepared for each well summarizing observations from logs, core, fluid samples, and other measurements, including quality assurance information. These reports will address measurements and/or estimates of fracture pressure, as well as the physical and chemical characteristics of the injection and confining zones (including depth, thickness, porosity, permeability, heterogeneity, minerology, and lithology) and formation fluids (including temperature, salinity, and conductivity). These tests and logs will be used to corroborate or update geologic site information, such as thickness and depths of the injection and confining zones, and reservoir conditions, which are described in the **Application Narrative** and the Area of Review and Corrective Action Plan (**Attachment B**). The tests and logs will be used to confirm the temperature vs. depth and hydrostatic pressure profile, which are used to inform the Testing and Monitoring Plan (**Attachment E**).

4.1 Petrophysical Logging and Coring [40 CFR 146.87 (A)-(B)]

4.1.1 Logging of Newly Drilled Injection Wells

Prior to installing the surface casing, a “Triple Combo” open-hole logging suite consisting of formation density, neutron porosity, resistivity, gamma ray, and spontaneous potential logs will be run from the well’s present total depth (TD) to the ground surface (or base of conductor casing).

Additional logging runs will be performed after the surface casing is set but before the intermediate casing, long string casing, and injection liner are installed. These logs will span from the wells’ TD to the base of surface casing, providing a complete log of the stratigraphic section. At this time, additional open-hole logs will be collected across the 64 Zone (injection zone), Santos Shale (primary confining layer), and Agua Sandstone (first permeable zone above the primary confining layer). Combined, these logs will provide a comprehensive evaluation of the physical and chemical properties of the injection zone and primary confining layer at the injection well locations and will serve as baseline measurements against which future measurements may be compared. Finally, additional sets of cement bond logs, variable density logs, and temperature logs will be performed to cover the entire well, after the intermediate casing, long string casing, and injection liner have been set and cemented.

As described in **section 2.4.3** within the **Application Narrative**, there is an existing dataset from logs and cores that provide sufficient information to characterize porosity and permeability in the 64 Zone U and W Sandstones. Apart from the presence of a few calcite-cemented intervals with lower porosity and permeability, there appears to be a weak trend of porosity decreasing downward in the 64 Zone W Sandstone and similarly, an observable trend of permeability degradation at the base of the 64 Zone W Sandstone. These trends would be confirmed as new core and log data is planned to be acquired from the newly drilled injection wells. As noted in **Table 1**, NMR logs would be acquired to provide a vertically continuous estimate of porosity and permeability in the Area of Review (AoR), providing additional independent porosity and permeability measurements besides the core derived information, as noted in **section 4.1.3**. It is important to note that borehole conditions need to be suitable to acquire NMR log data because these logs have small radius of investigation and are extremely sensitive to borehole rugosity.

A summary of proposed open-hole logs and their objectives is provided in **Table 1.**

Table 1: Proposed Open-Hole Logging for Newly Drilled Injection Wells

Log	Purpose	Depth Range(s)
Triple Combo	Correlation of formation markers, porosity, lithology, and formation water salinity	Base of conductor to base of surface casing; base of surface casing to TD
Temperature	Temperature	Base of conductor to base of surface casing; base of surface casing to TD
Four-arm caliper	Borehole shape and rugosity	Base of conductor to base of surface casing; base of surface casing to TD
Dipole sonic	Compressional and shear velocity for mechanical properties and principal stress magnitude; Stoneley-wave processing for fracture identification	Base of surface casing to TD
Spectral gamma ray	Lithology	Base of surface casing to TD
Formation micro-resistivity image	Structural dip, rock texture, fracture identification, principal stress orientation	Base of surface casing to TD
NMR	Porosity, Permeability, Vertical Heterogeneity	Base of surface casing to TD

4.1.2 Logging of Repurposed Injection Wells and Monitoring Wells

Four of the five wells proposed to be repurposed as injectors were logged when originally drilled with a suite consisting of deviation surveys, resistivity, and spontaneous potential measuring tools. There are no records of open-hole logs for well 64-27N (API: 0402935068), which is currently completed with an uncemented liner. Aera intends to remove the liner and attempt to run open-hole wireline logs from the casing shoe (in the Lower Santos) to the well's TD (covering the U and W Sandstone intervals). Log measurements will include resistivity, spontaneous potential, porosity, caliper, gamma ray, and image logs (depending on borehole condition). Additionally, well 9-1N (API: 0402935107), originally drilled in 1940, was re-logged in 1986 (when the production liner was pulled) with gamma ray, formation density, thermal neutron, spontaneous potential and laterolog resistivity tools over the 64 Zone W section.

The proposed monitoring well network consists of five preexisting wells, screened to different depths in the 64 Zone sandstone, the Agua sandstone, and the Lower Carneros sandstone. These wells were logged when originally drilled with a differing suite of tools. Wells 1-28N, 39-26N, and 25-26N were each logged using resistivity and spontaneous potential measuring tools. Well 27-1N was logged with the triple combo tool and well 35X-27N was logged with the triple combo and sonic tools.

To supplement the suite of existing open-hole logs, a cased-hole logging program is proposed for repurposed wells and monitoring wells, which will be used to validate petrophysical and mechanical properties at the injection well locations. These logs will span an interval starting below the injection zone to a depth above the Agua Sandstone. **Table 2** lists the log measurements which are proposed in the cased-hole logging program for repurposed injection wells and **Table 3** lists the log measurements which are proposed in the cased-hole logging program for monitoring wells.

Table 2: Proposed Cased-Hole Logging for Repurposed Injection Wells

<table>
<tr><th>Log</th><th>Purpose</th><th>Depth Range(s)</th></tr>
<tr><td>Gamma ray</td><td>Correlation of formation markers</td><td rowspan="4">Below 64 Zone to above Agua Sandstone</td></tr>
<tr><td>Temperature</td><td>Temperature</td></tr>
<tr><td>Dipole sonic</td><td>Compressional and shear velocity for mechanical properties</td></tr>
<tr><td>Pulsed neutron</td><td>Baseline porosity, saturation, and lithology to compare against in future carbon dioxide (CO_2) saturation monitoring; permeability will be calculated from correlations with porosity and lithology</td></tr>
<tr><td>Gyroscopic survey</td><td>Wellbore path</td><td>Surface to TD</td></tr>
</table>

Table 3: Proposed Cased-Hole Logging for Monitoring Wells

<table>
<tr><th>Log</th><th>Purpose</th><th>Depth Range(s)</th></tr>
<tr><td>Gamma ray</td><td>Correlation of formation markers</td><td rowspan="3">Below 64 Zone to above Lower Carneros Sandstone</td></tr>
<tr><td>Temperature</td><td>Temperature</td></tr>
<tr><td>Pulsed neutron</td><td>Baseline porosity, saturation, and lithology to compare against in future CO_2 saturation monitoring; permeability will be calculated from correlations with porosity and lithology</td></tr>
<tr><td>Gyroscopic survey</td><td>Wellbore path</td><td>Surface to TD</td></tr>
</table>

The cased-hole environment is not conducive to downhole measurements for fracture identification; therefore, image logs are not feasible in repurposed wells and monitoring wells. Observations made from nearby wells on fracturing trends, however, are representative of the proposed repurposed well locations. Comparison of lithology measurements from logs will be made to validate this assumption.

4.1.3 Core from Newly Drilled Wells

Pressure depletion in the 64 Zone Sandstones poses challenges to successful recovery of conventional cores, as experienced with the cores acquired in the 1980s. For this reason, the acquisition of rotary sidewall cores will be attempted from the injection and confining zones. Core samples will be shipped to a laboratory and analyzed for required parameters. The existing catalog of conventional core data from seven legacy wells (**Section 2.4** of the **Application Narrative**) will be used to supplement and validate sidewall core measurements, where needed. Core data includes petrology and mineralogy, petrophysical properties, and geomechanical properties, including relative permeability, capillary pressure, fluid compatibility, wettability, and pore volume compressibility. Core data also includes lithology, thickness, grain size, sedimentary structures, diagenetic features, geologic contacts, textural maturity, oil staining, fracturing, and porosity.

Rotary sidewall cores are preferred over percussion sidewall cores because of their suitability for porosity and permeability measurements. However, recovery of rotary sidewall cores can be challenging, especially considering the extent of pressure depletion in the 64 Zone Sandstones. Aera plans to collect up to 50 plug samples per well, which would be evenly distributed through the Lower Santos Shale (primary confining unit) and the 64 Zone Sandstone (injection zone) intervals to confirm observations on vertical heterogeneity. A percussion sidewall coring tool will be available as back-up to collect up to 30 samples if rotary sidewall recovery is not satisfactory. Percussion sidewall cores are not suitable for porosity and permeability measurements, but mineralogy and lithology analyses can be performed. A subset of the samples collected (5 to 8 samples from the Lower Santos Shale and a similar number from the 64 Zone Sandstones) will be selected in each new well to perform mineralogy and petrology analyses. The specific depths of the samples for mineralogy and petrology analyses will be selected using well logs and will be located to capture vertical heterogeneity.

Routine core analysis will be performed on all rotary sidewall core samples of sufficient dimensions, which includes porosity measurements via the Boyle's Helium expansion method. A subset of the samples collected from the injection zone (up to 5) will be selected in each new well to perform stressed porosity and permeability measurements. A similar number of samples will be selected from the confining layer to perform Tight Rock Analysis (TRA) measurements, including crushed-rock porosity and permeability measurements. In case rotary sidewall core recovery is not satisfactory, bulk and grain density measurements will be conducted on percussion core plugs or recovered rotary sidewall core material. The specific depths of the samples selected for the special core analysis (SCAL) described above will be selected using well logs with the intent to capture vertical heterogeneity. With regards to the capillary pressure measurements, those performed in core samples from the 64 Zone Sandstones in wells 4-1N and 17-2N are within the AoR, whereas the measurements from the Santos Shale are from core acquired in well 888N-12, located approximately a mile south of the AoR. If sufficient rotary sidewall core material is recovered, it is expected that additional capillary pressure measurements will be performed in a subset of the samples, especially those from the primary confining unit (Lower Santos Shale).

As previously noted in the **section 4.1.1**, NMR logs would be acquired from the newly drilled wells, if borehole condition is suitable, to continuously estimate porosity and permeability in the AoR. Besides the routine core analysis to estimate porosity and permeability, NMR porosity is also planned to be acquired from the rotary sidewall cores from these new wells. If the attempts to acquire rotary sidewall cores and modern log suites (including NMR) in new injection wells (preferably same well) are successful, newly acquired data will be used to first validate the permeability prediction algorithm described in the **Appendix 2B** of the **Application Narrative** and if significant discrepancies are observed, the algorithm will be refined with the newly acquired data. In this way, besides providing independent porosity and permeability measurements, the core-based NMR measurements will be used for the calibration of log-derived NMR assessments of porosity and permeability.

4.1.4 Core from Repurposed Injection Wells and Monitoring Wells

Sidewall core samples were acquired from the injection zone and described in logs from one of the five proposed repurposed wells, well 9-1N. While it is not feasible to collect new core samples in the remaining four repurposed injection or five monitoring wells, a robust core analysis database is available from nearby wells and can be interpolated to the repurposed well locations by comparing log response to that of cored wells.

4.2 Reservoir Testing [40 CFR 146.87(C)-(E)]

4.2.1 Reservoir Pressure and Formation Fluid Measurements

Fluid temperature, pH, conductivity, reservoir pressure, and static fluid levels of the injection zone and relevant permeable zones above the primary confining layer, including the U and W sandstones, Agua Sandstone, and Lower Carneros Sandstone, will be measured and recorded during and/or after construction of new, repurposed injection wells and monitoring wells. Formation fluid samples will be collected from the injection zone and relevant permeable zones using a bottom-hole sampler or by swabbing the well. Where possible, downhole sampling will be used to characterize vertical variability in fluid properties by acquiring samples from approximately five representative depths within the U and W Sandstones at each newly drilled injection well. The sampling depths will be determined using wireline logs to ensure proper vertical coverage while sampling from sufficiently permeable intervals. These samples will be analyzed by a laboratory for salinity, pH, conductivity, TDS, and other potential properties of interest to determine physical and chemical characteristics of the formation fluids. An attempt will also be made to estimate TDS from logging within the target injection intervals of the new and repurposed wells. These data will be used along with historical information to develop baseline conditions for leakage detection during future monitoring. The details of such deep subsurface formation fluid testing are presented below.

Historical chemical data collected from solid, aqueous, and gaseous phases were evaluated to characterize geochemistry of the injection and confining zones and to inform the geochemical compatibility modeling of injectate with the target injection zone (the 64 Zone Sandstones) and fluids. This baseline chemical data, along with a further description of geologic, hydrologic, and geochemical characteristics and modeling of the injection and confining zones, is presented in the **Application Narrative**.

Following construction but prior to injection, baseline fluid sampling will be conducted from monitoring wells in two permeable zones above the primary confining layer: the Agua Sandstone and Lower Carneros Sandstone. Sampling will be conducted 1 year prior to injection to adequately capture baseline conditions at the site and to capture seasonal variability when applicable. Planned monitoring methods and frequencies for fluid sampling and geochemical monitoring above the confining zone are summarized for the baseline monitoring phase in **Table 4** and discussed in detail in the TMP (**Attachment E**).

The monitoring wells are located to allow for early detection of potential leakage from the injection zone into the permeable Agua and Lower Carneros Sandstones, which directly overlie the primary and secondary confining layers, respectively. Additional information on the modeling of the Area of Review that has led to selecting monitoring wells is given in the **Application Narrative** and Area of Review and Corrective Action Plan (**Attachment B**).

Table 4: Monitoring of Geochemical Changes Above the Confining Zone

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Baseline Frequency
Agua Sandstone (approximately 7,500 – 7,800 ft MD)	Fluid sampling	Installed monitoring wells 1-28N and 25-26N	Northern half of injection area	Once prior to injection
	Temperature and pressure monitoring	Installed monitoring wells 1-28N and 25-26N	Vertical distribution within well casings (based upon geophysical data indicating most transmissive interval within the perforation)	Continuous period prior to injection
	Pulsed neutron logging	Installed monitoring wells 1-28N and 25-26N	Along wellbore	Once prior to injection
Lower Carneros (approximately 6,550–7,150 ft MD)	Pressure	Installed monitoring well 35X-27N	Above secondary confining layer	Continuous period prior to injection
	Fluid sampling	Installed monitoring well 35X-27N	Above secondary confining layer	Once prior to injection

ft: feet
MD: measured depth

Prior to injection, fluid sampling is planned to include an extensive set of chemical parameters to establish aqueous geochemical baseline data. Parameters will include selected constituents that (1) have primary and secondary United States Environmental Protection Agency drinking water maximum contaminant levels, (2) are the most responsive to interaction with CO_2 or brine, (3) are needed for QC, and (4) may be needed for geochemical modeling. The full set of parameters is presented in **Table 5**.

Table 5: Summary of Analytical and Field Parameters for Fluid Sampling

Parameters	Analytical Methods(1)
Cations/metals (aluminum, barium, manganese, arsenic, cadmium, chromium, copper, lead, selenium, titanium, zinc)	EPA Method 200.7/200.8 or similar by inductively coupled plasma optical emission spectroscopy (ICP-OES) or mass spectroscopy (ICP-MS)
Cations/metals (calcium, sodium, potassium, iron, magnesium, silica)	
Anions (chloride, sulfate, sulfide, bromide, fluoride, nitrate)	EPA Method 300.0/300.1 or similar by ion chromatography; SM 4500 for sulfide by colorimetry
Dissolved CO_2	Coulometric titration or RSK-175M by gas chromatography/flame ionization detector (GC/FID)
Dissolved CH_4	RSK-175M by GC/FID
Dissolved O_2	SM 4500 OG by Membrane Electrode Method or RSK-175M by GC/FID
Dissolved H_2S (field)	Field Test Kit
Total dissolved solids (TDS)	EPA Method 160.1/SM 2540 C by gravimetry
Alkalinity	SM 2320 B/EPA Method 310.1 by titration
pH (field)	EPA Method 150.1/SM4500-H+B electrometrically
Specific conductance (field)	EPA Method 120.1 by conductivity meter
Temperature (field)	Thermocouple
Hardness	SM 2340C by titration
Turbidity	SM 2130B by nephelometry
Specific gravity	SM 2710F by calculation
Water density	SM 2710F by calculation
Dissolved inorganic carbon isotopes ($\delta^{13}C$)	Mass spectrometry

1: An equivalent method may be employed with the prior approval of the UIC Program Director.
2: Detection limits and precision (laboratory control limits) are typical for these analytical methods and were provided by Eurofins Environment Testing.
H_2S: hydrogen sulfide

Sampling methods, laboratory protocol, and QC procedures are detailed in Testing and Monitoring Plan (**Attachment E**).

To assess the presence of USDW's within the non-exempted portions of the Tulare Fm. in the AoR, Aera will develop a plan for the collection of additional groundwater samples in these areas. A groundwater sampling plan for the Tulare Fm. will be submitted to EPA for approval as an addendum to the Pre-Operation Testing Plan, prior to implementing the sampling activities.

4.2.2 Fracture Pressure

Fracture pressure will be evaluated using step rate tests (SRTs). Before injection, Aera plans to conduct SRTs in a representative selection of two to three existing wells in the North Belridge oil field, scheduled to be either abandoned or repurposed as observation wells. The use of existing wells is preferred to reduce the risk of compromising the mechanical integrity of the storage complex at the injection well locations. Additionally, in combination with SRTs, Aera will attempt to acquire dipole sonic logs behind casing with the objective of calibrating a log-based calculation of the fracture gradient of the injection layer and the primary confining zone.

Aera plans to conduct the SRTs following a generally accepted procedure[1] in which the well is shut-in long enough so that the bottom-hole pressure is representative of static formation pressure. Subsequently, the test consists of a series of increasing constant-rate injection periods. Each step will last at least 30 minutes (as a function of formation permeability). Injection rates, volumes, and surface and bottom-hole pressures are recorded for each step to determine the formation parting pressure.

4.2.3 Hydrogeologic Characteristics of the Injection Zone

Pressure fall-off tests and pump or injectivity tests will be performed on each injection well after construction but prior to operation. Pressure fall-off tests will be used to determine hydrogeologic parameters, including the transmissibility of the injection zone, the static injection zone pressure, the skin factor, and to identify faults or fractures adjacent to the wellbore. Details on the test procedures are included in **Attachment I**.

Injectivity for the sequestration zone is estimated based on historic production and injection in the 64 Zone Sandstones and described in **the Application Narrative**. Results from transient analysis tests will be used with historical data to confirm the injectivity of the sequestration zone and set operating limits for carbon dioxide (CO_2) injection rates and volumes.

5. WITNESSING OF PRE-OPERATIONAL WELL TESTING [40 CFR 146.87(F)]

Aera will submit a schedule of the proposed tests and logs at least 30 days prior to conducting the first test to allow the Underground Injection Control (UIC) Program Director the opportunity to witness these tests. Changes to the testing schedule will be submitted at least 30 days prior to the next scheduled test.

6. QUALITY ASSURANCE AND SURVEILLANCE PLAN (QASP)

The quality Assurance and Surveillance Plan is presented in the appendix of the Testing and Monitoring Plan (**Attachment E**).

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[1] Singh, P.K., R.G. Agarwal, and L.D. Krase, "Systematic design and analysis of step-rate tests to determine formation parting pressure," (paper, SPE Annual Technical Conference and Exhibition, Dallas, Texas, September 1987).