5 PRE-OPERATIONAL TESTING PROGRAM

40 CFR 146.82(a)(8), 146.87

Polk Carbon Storage Complex (PCSC)

Facility Information

Facility (site) Name: Polk Carbon Storage Complex (PCSC)
Facility Operator: Tampa Electric Company (TEC)

Facility Contact: CLA MED AS CBI [redacted]

Well Location: Polk County, Florida

Well Name	Latitude (dms)	Longitude (dms)
PSC_IW1	CLAIMED AS CBI [redacted]	[redacted]
PSC_IW2	[redacted]	[redacted]
PSC_IW3	[redacted]	[redacted]

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List of Acronyms/Abbreviations

APHA	American Public Health Association
ASTM	American Society for Testing and Materials
CCS	Carbon Capture and Storage
CBL	Cement Bond Log
CFR	Code of Federal Regulations
DTS	Distributed Temperature Sensing
EPA	Environmental Protection Agency
FTS	Flow Through Sampler
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
ICP-OES	Inductively Coupled Plasma-Optical Emission Spectrometry
MICP	Mercury Intrusion Capillary Pressure
MIT	Mechanical Integrity Test
PCSC	Polk Carbon Storage Complex
QASP	Quality Assurance and Surveillance Plan
RSWC	Rotary Sidewall Core
SAPT	Standard Annular Pressure Test
TBD	To be determined
TEC	Tampa Electric Company
UCPZ-1	Upper Cretaceous Permeable Zone 1
USDW	Underground Source of Drinking Water
UV	Ultraviolet
XRD	X-ray Diffraction

5.1 Pre-Injection Testing Plan – Overview

This pre-operational testing plan was designed to obtain the necessary chemical and physical characteristics of the PCSC injection and confining zones required to meet the testing requirements of 40 CFR 146.87 and the well construction requirements of 40 CFR 146.86. This testing plan includes a combination of well logging, geologic coring, fluid sampling, and hydrogeologic testing which will generate datasets to determine and/or verify the depth, thickness, porosity, permeability, mineralogy, and geochemical profiles of the primary confining zone of the storage complex (Cedar Keys Anhydrite zone) and injection interval (UCPZ-1). Baseline data will also be collected from formations within and above the PCSC to obtain a baseline description of geology and fluid chemistry which will be later compared against data obtained during the injection phase. Due to the proximity of the three PCSC injection wells, TEC will optimize data collection from injection wells by collecting a comprehensive suite of logs, cores and other relevant datasets to support Class VI project design and operations while implementing a scaled down data collection strategy from the other two injection wells. However, TEC will ensure all regulatory data collection requirements are met for each injection well in compliance with UIC Class VI standards and any applicable state level requirements.

Three injection wells will be drilled for the PCSC project (**Table 5-1**). PSC_IW2 will be drilled first and will feature the pre-injection testing described in this plan. Twelve monitoring wells (7 shallow groundwater, 2 above-zone, and 3 in-zone) will be either constructed or converted for PCSC monitoring purposes. All PCSC well locations, relative to project elements (i.e., CO_2 plume footprint, AoR, etc.,) are shown in **Figure 5-1.** Locations of proposed injection and monitoring wells for the PCSC project Additional details on monitoring well construction, well conversion, and monitoring well testing may be found within the **Testing and Monitoring Plan** of this permit application (Chapter 7).

Table 5-1. Summary of all PCSC injection and monitoring wells.

Well Types	Well Acronym	CCS System Zone	Zone Formation	Zone Depth (ft MD* below ground level)	Quantity
Shallow Groundwater	PSC_GW1 PSC_GW2 PSC_GW3 PSC_GW4 PSC_GW5 PSC_GW6 PSC_GW7	Shallow USDW	Middle Floridan Aquifer	CLAIMED AS CBI [redacted]	7
Above-Zone Monitoring	PSC_AZ1 PSC_AZ2	1st Permeable Zone	Cedar Keys Ls/Dol	[redacted]	2
In-Zone Monitoring	PSC_IZ1 PSC_IZ2 PSC_IZ3	Reservoir	Upper Cretaceous Permeable Zone-1 (UCPZ-1)	[redacted]	3
Injection	PSC_IW1 PSC_IW2 PSC_IW3	Reservoir	Upper Cretaceous Permeable Zone-1 (UCPZ-1)	[redacted]	3

*MD = measured depth.
[1]All shallow groundwater wells are estimated to be completed to approximately 700 ft.

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Findings from planned testing activities discussed in this plan will be summarized in a report which will be submitted to the UIC Program Director within 60 days after drilling and testing operations are completed.

5.2 Pre-Injection Testing Plan – Injection Wells

The following testing and characterization activities will be conducted on the first PCSC injection well scheduled to be drilled to meet the testing and construction requirements pursuant to 40 CFR 146.87 and 40 CFR 146.86. Please refer to the **PCSC Injection Well Construction Plan** within this permit application (Chapter 4) for detailed specifications on injection well construction.

5.2.1 Deviation Checks

Deviation measurements will be conducted approximately every 100 to 300 feet during construction of the well.

5.2.2 Tests and Logs

5.2.2.1 Open-hole Logging

Open-hole well log data will be collected from the PCSC injection wells to obtain *in-situ* physical, chemical, geologic, and geomechanical information from the above-zone and in-zone intervals within the storage complex. Each open hole logging tool to be utilized within PCSC injection wells is briefly described below. A more detailed description of each specific tool/measurement theory and analysis protocols may be found in Bateman (2012)[1]. **Table 5-2** summarizes the open-hole logging plan for each wellbore section. The PCSC project plans to utilize the following open-hole logging tools:

- **Mud Log** - A continuous visual description of drill cuttings circulated to surface which yields the relative lithology of the formations the drilling rig has penetrated, in addition to any observations on the presence of hydrocarbons. Physical sample sets of drill cuttings will be collected and cataloged every 30 feet within the above zone, and every 10 feet within the PCSC.
- **Gamma Ray -** A logging tool which measures the natural radioactivity of geologic units. Data from this tool will be used for subsurface correlations, depth shifting/matching of other test data, and to approximate clay/shale volumes.
- **Spontaneous Potential -** A logging tool which measures the natural spontaneous electric potential generated due to variations of salinity between wellbore and formation fluids. Data from this tool will be used for subsurface correlations, salinity calculations, and to identify relative intervals of higher permeability.
- **Neutron porosity -** A logging tool which indirectly approximates porosity by measuring the presence of hydrogen (water). Data from this tool will be used in conjunction with others logs to identify lithology and estimate the volume of porosity (total and effective) within subsurface geologic units.

[1] Bateman, R. M. (2012). *Open hole Log analysis and Formation Evaluation* (2nd ed.). Society of Petroleum Engineers.

- **Formation Bulk Density -** A logging tool which indirectly approximates the bulk density of a geologic formation. Data from this tool will be used in conjunction with others to identify lithology and estimate the volume of porosity (total and effective) within subsurface geologic units.
- **Photoelectric Factor -** A logging tool which yields a relative indicator for lithology. This log will be used to determine mineralogy and lithology of geologic units.
- **Resistivity -** A logging tool which measures the electrical resistance of rocks. Data from this tool will be used to estimate fluid saturation, porosity, and estimate/confirm salinity.
- **Acoustic Sonic Logs (Monopole and Dipole)** - Acoustic sonic logs measure the travel time of sonic waves through rocks. Monopole sonic logs measure only the compressional wave velocity, while dipole sonic logs measure both compressional and shear wave velocities. Monopole sonic logs will be used to characterize porosity, lithology, and generate synthetic seismograms for seismic well ties. Dipole sonic log data will be used for geomechanical characterization (fracture and stress characterization).
- **Resistivity Borehole Image Log -** A tool which measures electrical resistivity radially across the wellbore. Measurements from this tool are then processed into images of the open wellbore colored by contrasts in resistivity values. Data from this tool will be interpreted for the presence of geologic bedding planes and associated contacts, fractures (open, healed, and induced), shows of porosity, and rock textures (sedimentary structures).
- **Caliper** - A tool which provides information on the shape (rugosity) and volume of the wellbore in addition to the quality of geophysical logging data acquired in borehole conditions. This log will be used to estimate the quality of well log data and estimate wellbore volumes.
- **Nuclear Magnetic Resonance** - A logging tool which manipulates the magnetic alignment of protons (hydrogen nuclei) within formation fluid to resolve information related to porosity, pore-body size, permeability, and fluid saturations, independent of the rock matrix. Data from this tool will be used to aid in calculating petrophysical properties of the storage complex.
- **Elemental Spectroscopy -** A logging tool which estimates the elemental concentration of a rock using characteristic gamma ray signatures emitted from an atomic nucleus during neutron bombardment. Data from this tool will be used to estimate petrophysical properties, fluid saturations, and volumetric proportions of minerals.

Table 5-2. Open-hole well logging program for PCSC injection wells.

Zone	Logging Activity	*Purpose/Comments
Surface Hole		
USDW	Mud log	Monitor drilling process and ensure safe drilling conditions Provide lithologic information while drilling to identify formations penetrated
	Basic Wireline Logs: Spontaneous Potential, Resistivity, Gamma Ray, Caliper, Bulk Density, Photoelectric Factor, Neutron Porosity,	Characterize Geology Obtain baseline characteristics from shallow formations
	Monopole Sonic Log	Seismic Well Tie Sonic Porosity
Intermediate Hole		
Lowermost USDW & Above Zone	Mud log	Monitor drilling process and ensure safe drilling conditions Provide lithologic information while drilling to identify formations penetrated
	Basic Wireline Logs: Spontaneous Potential, Resistivity, Gamma Ray, Caliper, Bulk Density, Photoelectric Factor, Neutron Porosity	Characterize Geology and determine formation tops Obtain baseline characteristics from Above Zone formations
	Monopole Sonic Log	Seismic Well Tie Sonic Porosity
Injection Hole		
PCSC Storage complex	Mud log	Monitor drilling process and ensure safe drilling conditions Provide lithologic information while drilling to identify formations penetrated
	Basic Wireline Logs: Spontaneous Potential, Resistivity, Gamma Ray, Caliper, Bulk Density, Photoelectric Factor, Neutron Porosity	Characterize Geology and determine formation tops Baseline Formation Evaluation
	Elemental Spectroscopy Log	Baseline Mineral Model Baseline Formation Evaluation
	Dipole sonic Log	Seismic Well Tie Sonic Porosity Geomechanical Analysis Fracture Characterization
	Resistivity-based Borehole Image Log	Fracture Characterization Sedimentological/Geologic Interpretation
	Nuclear Magnetic Resonance Log	Baseline Formation Evaluation

*See text in section *5.2.2.1* for a more detailed explanation of applications of each well log.

5.2.2.2 Cased-Hole Well Logging

Cased-hole wireline well logs will be run in all PCSC injection wells to ensure conformance with the construction and testing requirements documented in 40 CFR 146.86 and 40 CFR 146.87, in addition to collecting pre-operational baseline profiles of critical geologic units for future comparison. A summary of the cased-hole wireline logging plan is detailed in **Table 5-3**. Each cased-hole logging tool to be utilized within PCSC injection wells is briefly described below:

- **Ultrasonic Imaging Tool** - This log provides estimates of well integrity and zonal isolation through the measurement of acoustic impedance within cement. Data from this tool will be used to create maps of the casing integrity and cement, determine if there is solid (cement), liquid, or gas in between the casing and formation, and identify corrosion or casing damage.

- **Cement Bond Log (CBL)** - CBL tools use sonic waves to estimate the integrity of a well's cement job. CBL tools use acoustic transmitters and receivers to measure signal attenuation to provide a measurement of how well the casing and the cement are bonded. CBLs provide an indication of the cement-to-formation bond in the form of a variable density log. This log will be used to interpret the integrity of wellbore cement.

- **Distributed Temperature Sensing (DTS) Fiber Optics** - DTS fiber optic systems utilize the physical properties of pulses of laser light as it moves down a fiber optic cable to derive continuous temperature measurements along the outside of the cable. The DTS fiber optic cable will be run along the outside of the long-string casing and will continuously measure temperature of wellbore elements (brine, cement) along the long-string casing/cement interface, at a sub-foot scale. DTS technology will be used to continuously monitor external integrity of wellbore cement and monitor for the presence of out-of-zone brine or CO_2 along the entirety of the wellbore.

- **Pulsed Neutron Log-** A logging tool which estimates fluid saturations through casing via neutron bombardment. This tool will be used to estimate brine and CO_2 saturations.

Table 5-3. Cased hole wireline logging to be performed on PCSC injection wells.

Zone	Logging Activity	*Purpose/Comments
Surface Hole		
USDW	Cement Bond Log Tool (CBL)	External Wellbore Integrity
	Temperature Log	External Wellbore Integrity Baseline Temperature Data
Intermediate Hole		
Above-Zone	Cement Bond Log Tool (CBL)	External Wellbore Integrity
	Temperature Log	External Wellbore Integrity Baseline Temperature Data
	Ultrasonic Imaging Tool	External Wellbore Integrity
Injection Hole		
PCSC Caprock and Reservoir	Ultrasonic Imaging Tool	External Wellbore Integrity
	Pulsed Neutron Log	Baseline Fluid Saturations
	DTS Fiber Optics	External wellbore integrity

5.2.2.3 Rock Coring and Core Testing

Pursuant to the requirements of 40 CFR 146.87(b), rock cores will be collected in the form of whole core or sidewall cores to support core analysis studies. The preliminary plan for core acquisition and testing for the first PCSC injection well is detailed in **Table 5-4**, **Table 5-5**, and **Table 5-6.** Core data (sidewall and whole core) from the confining and reservoir zones will be collected, preserve samples onsite, and ship them to a commercial core testing facility for analysis. Analysis conducted on select core samples will include routine core analysis (porosity, permeability, grain density, lithology, fluid saturation), geologic/mineralogic analysis (core/thin section descriptions and X-ray diffraction), and special core analysis (geomechanics, geochemical compatibility testing, mercury intrusion capillary pressure (MICP), relative permeability, and threshold entry pressure). Core data (whole core and/or sidewall core) will be collected from subsequent PCSC injection wells and the confining and injection zones to meet the minimum Class VI testing requirements.

Table 5-4. Whole core acquisition plan for PCSC injection wells.

Core Run	Core Length	Cored Zone	Purpose/Comments
1	60’	Anhydrite Caprock Zone	PCSC Caprock Characterization
2	60’	UCPZ-1	PCSC Reservoir Characterization

Table 5-5. Whole core testing plan for PCSC injection wells.

Whole Core Testing Activity	Description	Zone
General processing	Core Slabbing, Photography (UV/white light)	PCSC Caprock and Reservoir
Routine Core Plug Analysis	Porosity, Grain Density, Permeability, Lithology, Fluorescence	
Geologic and Mineralogical Analysis	Thin Section Petrography X-ray Diffraction (XRD) Geological/Sedimentological Description	
Special Core Analysis	Geomechanics: triaxial compressive testing, triaxial ultrasonic testing, brazil testing, pore volume compressibility Mercury Intrusion Capillary Pressure (MICP) Relative Permeability Threshold Entry Pressure Geochemical Compatibility Testing: scaling tendencies, co-injection of CO_2/brine to assess effluent and rock mineralogy alterations	

Table 5-6. Summary of sidewall acquisition and analysis plan for the PCSC project.

	Sample Selection	Acquisition Zone	Analysis
Side Wall Coring	The number of/location of RSWC intervals will be selected based on reservoir and caprock rock shows interpreted from well logs, formation tests and mud logs	PCSC Caprock and Reservoir	Routine porosity, grain density, permeability, lithology, fluorescence

5.2.2.4 Fluid Sampling

Pursuant to 40 CFR 146.87(c), fluid samples will be collected from the first PCSC injection well to provide baseline profile data for the UCPZ-1 reservoir. Fluid samples will be collected in open-hole conditions using wireline-based formation testing tools. If representative samples cannot be obtained from open-hole conditions, fluid samples will be collected after the well is completed via techniques such as swabbing or pumping through tubing. Fluid sampling methods will sample reservoir pressure and static fluid levels. Fluid samples will be collected, stored, and transported using protocols discussed in the **QASP** (**Attachment A of Chapter 7, Testing and Monitoring Plan**). Any fluids introduced into the wellbore environment during drilling, conditioning, cementing, stimulation, or testing will be removed prior to fluid sampling to ensure samples are representative of the subsurface system. The preliminary analysis plan for fluid samples collected from PCSC injection wells is detailed in **Table 5-7**. For further details on baseline sampling in the shallow groundwater wells, please see section **7.1 Overall Strategy, Approach, and Conceptual Design for Testing and Monitoring** of the **Testing and Monitoring Plan**.

Table 5-7. PCSC injection well fluid analysis plan summary.

Parameters	Analytical Methods
PCSC Injection Reservoir (UCPZ-1)	
Cations: **Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl**	ICP-MS, EPA Method 6020
Cations: **Ca, Fe, K, Mg, Na, and Si**	ICP-OES, EPA Method 6010B
Anions: **Br, Cl, F, NO_3 and SO_4** **Dissolved CO_2**	Ion Chromatography, EPA Method 300.0 Coulometric titration, ASTM D513-11
Total Dissolved Solids **Water Density** **Alkalinity** **pH (field)** **Specific conductance (field)** **Temperature (field)**	Gravimetry, APHA 2540C Oscillating body method APHA 2320B EPA 150.1 APHA 2510 Thermocouple

5.2.2.5 Mechanical Integrity Testing

Pursuant to 40 CFR 146.87(a)(4), TEC will conduct tests and run logs as needed to demonstrate the internal and external mechanical integrity of all injection wells prior to initiating CO_2 injection. Internal mechanical integrity testing involves identifying any potential leaks internally within the well which includes within the tubing, packer, and casing above the packer. External mechanical integrity testing will identify any potential fluid movement/leakage pathways through channels adjacent to the injection wellbore which could result in fluid migration into an USDW.

A summary of internal and external mechanical integrity tests to be performed on PCSC injection wells is shown in **Table 5-8**. Internal mechanical integrity within each PCSC injection well will be demonstrated by conducting a casing pressure test immediately after running casing into each wellbore segment (surface, intermediate, long string) prior to drilling out the plug on each casing string. Additionally, after each injection well is completed, a standard annular pressure test (SAPT) will be conducted to verify internal MIT prior to injection. The procedure for annular pressure testing is discussed in the **Testing and Monitoring Plan**.

External MIT will be verified within PCSC injection wells using cement bond, ultrasonic, and temperature cased-hole logs and/or distributed temperature sensing (DTS) fiber optic technology.

DTS will be run along the outside of the long string casing to continuously measure temperature from surface to total depth. Additional information on the cased-hole logging tools and DTS technology is discussed within the cased-hole logging section *5.2.2.2* of this plan as well as section **7.6 Mechanical Integrity of the Testing and Monitoring Plan**; tool-specific specifications and quality control procedures are available in the **QASP**.

TEC will notify EPA at least 30 days prior to conducting the test and provide a detailed description of the testing procedure. Notice and the opportunity to witness these tests/logs shall be provided to EPA at least 48 hours in advance of a given test/log.

Table 5-8. Summary of PCSC mechanical integrity testing.

Mechanical Integrity Test Type	Test Name	Tested Interval	Test Timeframe
Internal	Casing Pressure Test	Entire casing section (surface, intermediate, long string)	Before drilling next wellbore section
Internal	Annular Pressure Test	Long string/tubing	After completion, prior to injection
External	Cement Bond, Ultrasonic, and Temperature logs	Entire casing section (surface, intermediate, long string)	After casing installation, before well completion.
External	DTS Technology	Long string casing	Continuous, one analysis before injection

5.2.2.6 Hydrogeologic Testing

Pursuant to 40 CFR 146.87, PCSC injection wells will undergo hydrogeologic testing to determine: (1) fracture pressure; (2) chemical characteristics; (3) formation pressure; (4) feasibility of large-scale injectivity and identification of nearby hydrogeologic boundaries. TEC will utilize a wireline formation testing tool to determine fracture pressure within the confining and reservoir zones via micro-frac tests on select intervals. Micro-frac testing conducted via wireline formation testing tools provide an opportunity to measure fracture-pressure *in-situ* by locally pressing up a small interval along the wellbore that has been isolated using two micro-packers, thus limiting damage to the formation. Micro-frac measurements will be used to verify, calibrate, and supplement well-log-based estimates of fracture pressure obtained via dipole sonic log analysis. Wireline-formation testing tools will also be used to obtain *in-situ* measurements of formation pressure and to collect fluid samples from the reservoir and confining zones (see **subsection 5.2.2.4** for fluid analysis plan). After completion, TEC will perform step rate testing and pressure fall-off testing within PCSC injection wells to verify large-scale injectivity and identify the presence of flow boundaries. Best practices will be followed during hydrogeologic testing; more information regarding testing procedures is available in the **Testing and Monitoring Plan** (Chapter 7 of this permit application).

Table 5-9. Summary of hydrogeologic testing to be performed on PCSC injection wells.

Hydrogeologic Test	Zone	Depth Interval	Application/Comment
Wireline Formation Tester (MDT)	Anhydrite Caprock zone & UCPZ-1	*TBD based on interpreted reservoir and caprock shows from well logs and mud log*	Reservoir/Caprock Fracture Pressure Reservoir Fluid Sampling Reservoir/Caprock *In-situ* Formation Pressure
Step Rate Test & Pressure Fall off Testing	UCPZ-1	*TBD based on interpreted reservoir and caprock shows from well logs and mud log*	Identification of hydrogeologic Boundaries Injectivity Testing