ATTACHMENT E: POST-INJECTION SITE CARE AND SITE CLOSURE PLAN
40 CFR 146.93(a)
CTV VI

Document Version History

Version	Revision Date	File Name	Description of Change
1	7/31/2024	Att E - CTV VI PISC_v1	Original Submittal

1. Facility Information

Facility name: CTV VI

Facility contact: Faisal Latif, Storage Development Manager
(661) 763-6274, faisal.latif@crc.com

Location: Claimed as PBI

This Post-Injection Site Care (PISC) and Site Closure Plan describes the activities that Carbon TerraVault Holdings, LLC (CTV) will perform to meet the requirements of 40 CFR 146.93. CTV will monitor groundwater quality and track the position of the carbon dioxide (CO_2) plume and pressure front during the post-injection period. CTV will not cease post-injection monitoring until a demonstration of non-endangerment of underground sources of drinking water (USDWs) has been approved by the U.S. Environmental Protection Agency (EPA) Underground Injection Control (UIC) Program Director pursuant to 40 CFR 146.93(b)(3). Following approval for site closure, CTV will plug all monitoring wells, restore the site to its original condition, and submit a site closure report and associated documentation.

2. Pre- and Post-Injection Pressure Differential [40 CFR 146.93(a)(2)(i)]

Based on the computational modeling, Injection Zone pressure in the injection area is expected to stabilize Claimed as PBI Injection limits will be based on the fracture pressure of the Injection Zone. Additional information on the projected post-injection pressure declines and differentials is presented in **Attachment A: Narrative Permit Application** (**Attachment A**), and **Attachment B: Area of Review (AoR) and Corrective Action Plan** (**Attachment B**).

Using the base case scenario of 100 percent CO_2 injectate, **Figures E-1 through E-3** show the modeled pressure and pressure increase at monitoring well locations Claimed as PBI and Claimed as PBI at middle perforation point (MPP) within Claimed as PBI during the injection period and Claimed as PBI post injection. Pressure decline trends are discussed further in Section 6.2.

The storage reservoir will be operated such that the bottom-hole injection pressures will not exceed the fracture pressure of the reservoir with a 10 percent safety factor. This operating

strategy is to minimize the potential for induced seismicity and to ensure confinement of the injectate.

3. Predicted Position of the CO_2 Plume and Associated Pressure Front at Site Closure [40 CFR 146.93(a)(2)(ii)]

Figure E-4 shows the predicted maximum extent of the plume (100 years) at the end of the PISC time frame (50 years), representing the maximum extent of the plume and pressure front (the pressure front area is contained with the plume, see **Appendix 9**). This map is based on the final AoR delineation modeling results submitted pursuant to 40 CFR 146.84 (**Attachment B**).

4. Post-Injection Monitoring Plan [40 CFR 146.93(b)(1)]

Monitoring during the post-injection phase will include pressure monitoring and fluid composition monitoring within the Injection Zone and above the Confining Zone. The monitoring plan described in the following sections meets the requirements of 40 CFR 146.93(b)(1). The results of all post-injection phase testing and monitoring will be submitted annually, within 90 days of the end of each year, as described under "Schedule for Submitting Post-Injection Monitoring Results."

Attachment C: Testing and Monitoring Plan (**Attachment C**) describes the monitoring strategies within the Injection Zone, above the Confining Zone, and within USDWs. A quality assurance and surveillance plan (QASP) for all testing and monitoring activities during the injection and post injection phases is provided in **Appendix 10**.

Injection Zone pressure monitoring will monitor for pressure stabilization. This is the best method to confirm confinement of the reservoir. If trends of pressure in the reservoir are inconsistent when compared to computational modeling results, CTV will assess for potential leakage. Throughout the AoR, there are USDWs in formations overlying the Confining Zone. As such, ongoing USDW groundwater monitoring will assess potential impacts. Groundwater samples will be analyzed annually for indicators of CO_2 movement into the USDWs.

CTV has obtained surface access rights for the duration of the project.

4.1 Monitoring Above the Confining Zone

Table E-1 presents the monitoring methods, locations, and frequencies for monitoring above the Confining Zone. **Table E-2** identifies the parameters to be monitored and the analytical methods CTV will employ. **Table E-3** presents sampling and recording frequencies for continuous monitoring.

4.2 Carbon Dioxide Plume and Pressure Front Tracking [40 CFR 146.93(a)(2)(iii)]

CTV will employ direct and indirect methods to track the extent of the CO_2 plume and the presence or absence of elevated pressure.

Table E-4 presents the direct and indirect methods that CTV will use to monitor the CO_2 plume, including the activities, locations, and frequencies CTV will employ.

Table E-5 presents the direct and indirect methods that CTV will use to monitor pressure, including the activities, locations, and frequencies CTV will employ. Direct monitoring will include pressure gauges to monitor the pressure in the injection zone monitoring wells. Additionally, seismic monitoring via installed surface and/or shallow borehole seismometers will be used to detect micro-seismic events.

Using the base case scenario of 100% CO_2 injectate, **Figure E-4** shows the location of the injection wells and the predicted CO_2 plume development through time in plan view.

4.3 Schedule for Submitting Post-Injection Monitoring Results [40 CFR 146.93(a)(2)(iv)]

All post-injection site care monitoring data and monitoring results collected using the methods described above will be submitted to EPA in annual reports submitted within 90 days following the anniversary date on which injection ceases. The reports will contain information and data generated during the reporting period (i.e., well-based monitoring data, sample analysis, and the results from updated site models).

5. Alternative Post-Injection Site Care Timeframe

An alternative PISC time frame of 20 years (compared to the default of 50 years) is appropriate based on the results of the detailed geologic analyses and numerical plume and pressure-front modeling presented in **Attachment A** and **Attachment B**.

Injection well and monitoring well construction are presented in **Appendix 5**, and wells will be constructed and plugged for the case of the injection wells to maintain integrity and prevent fluid leakage.

5.1 Computational Modeling Results

AoR delineation modeling information, including methods, results, and sensitivity analyses, is presented in **Attachment B**. These results are used for discussion of plume and pressure front migration in the following subsections.

5.2 Predicted Time Frame for Pressure Decline

Figures E-1 through E-3 display simulated pressure at the locations of the Injection Zone monitoring wells and Figure 4.3 of **Attachment B** shows average pore volume pressure in the AoR region. In all cases, Claimed as PBI [redacted]

5.3 Predicted Rate of Plume Migration

Figure E-4 displays the location of the simulated injection zone CO_2 plumes at various times (outermost extent of CO_2 plume within each formation). The CO_2 plume is predicted to move slowly after the injection period, Claimed as PBI [redacted] As shown on **Figure E-4**, throughout most of its perimeter the plume is predicted to be stable and not migrate after injection ends.

EPA Class VI Well Plugging, PISC and Site Closure Guidance states that when the plume is migrating at a negligible rate compared to the location of sensitive receptors, the plume migration rate may be considered sufficiently minor so as to not pose an endangerment to USDWs. **Figure E-4** shows the locations of plugged wells relative to CO_2 plume development. Claimed as PBI [redacted]

5.4 Site-Specific Trapping Processes

At the CTV VI site, simulations indicate that trapping occurs primarily by capillary trapping and CO_2 dissolution in the brine. Equilibrium geochemical modeling presented in **Appendix 3** indicates minor CO_2 mineralization. **Attachment B** includes a detailed discussion of simulated CO_2 fate after injection (see Figure 4.4 of **Attachment B**). Most of the CO_2 is trapped as separate-phase CO_2 ("capillary trapping"), consistent with scientific understanding of key storage processes in saline reservoirs (e.g., Krevor et al., 2015[1]). As discussed below, the fraction of CO_2 predicted to be stored via capillary trapping in pore space remains relatively constant in the post-injection period, supporting a reduced PISC time frame.

Claimed as PBI [redacted]

[1] https://doi.org/10.1016/j.ijggc.2015.04.006

5.5 Confining Zone Characterization

Attachment A includes a detailed evaluation of the Claimed as PBI [redacted] that acts as the confining zone for the storage project. Claimed as PBI [redacted] The geometric average permeability of the upper confining zone is 1.62 nanodarcies (nD) (Section 2.4.2.2 of **Attachment A**). Geochemical modeling indicates that Claimed as PBI [redacted] will not be significantly reactive with CO_2 (**Appendix 3**). Claimed as PBI [redacted] These attributes indicate that the Confining Zone will restrict upward fluid movement and support a reduced PISC time frame.

5.6 Assessment of Fluid Movement Potential

Attachment B presents information on abandoned wells within the AoR. There are two wells within the AoR that penetrate the Confining Zone and Injection Zone, and both are planned for corrective action prior to injection.

5.7 Location of USDWs

Delineation of the depth to the top of the Injection Zone and the depth of the lowermost USDW are discussed in **Attachment A**. Figure 1 of **Appendix 9** presents a map of the thickness between the Injection Zone and the lowermost USDW. Minimum distance between the Injection Zone and the lowermost USDW within the AoR is approximately 700 feet. There is significant thickness that exists between the Injection Zone and lowermost USDW, which, as described in **Attachment A**, consists of Claimed as PBI [redacted] is another assurance of the limited risk to USDWs and supports a shorter PISC time frame.

6. Non-Endangerment Demonstration Criteria

Prior to authorization of site closure, CTV will submit a demonstration of non-endangerment of USDWs to the Director per 40 CFR 143.93(b)(2) or (3).

CTV will provide a report to the Director that demonstrates USDW non-endangerment based on the evaluation of site monitoring data. The report will detail how the non-endangerment determination is based on site-specific conditions, supported with the computational model. All relevant monitoring data and interpretations will be provided.

6.1 Summary of Monitoring Data

A summary of the site monitoring data will be provided, pursuant to the Testing and Monitoring Plan (**Attachment C**) and this PISC and Site Closure Plan, including data collected during the injection and PISC phases of the project. Data submittal will be in a format acceptable to the Director and will include:

- A narrative that explains the monitoring activities.
- Dates of all monitoring events.
- Changes to the monitoring program over time.
- An explanation of all monitoring information that has existed at the site.
- Explanation of how the monitoring data from injection and PISC has varied from the baseline data during site characterization.
- Summary of any emergencies that occurred during the injection and post-injection phases of the project. Included will be a description of how any issues have been resolved and assurance that there is no endangerment to the USDW.

6.2 Evaluation of the CO_2 Plume and the AoR

Computational modeling results (**Attachment B**) calibrated with monitoring data (e.g., pressure) will be used to support that the plume has stabilized and that the pressure change is negligible (less than 10 pounds per square inch [psi] per year) and poses no risk for potential vertical migration. Computational modeling results calibrated with monitoring data from storage reservoir, USDW, and above the Confining Zone will be used to demonstrate the following:

- The lack of CO_2 leakage over the project time frame
- The accuracy of the model to predict and represent the storage reservoir
- The adequacy of the computational model in defining the AoR

6.3 Evaluation of Reservoir Pressure

Monitoring data will be reviewed to ensure that the CO_2 plume has stabilized post-injection and that the reservoir pressure change is negligible (less than 10 psi per year). This demonstration will be supported by the computational model that has been calibrated with the most recent monitoring data. Plume migration is minimal; as such, pressure stabilization will be used for non-endangerment assessment.

6.4 Evaluation of Potential Conduits for Fluid Movement

Wells that require corrective action will be reviewed and assessed prior to PISC and site closure, including monitoring wells, injection wells, and other wells that penetrate within the AoR and the confining layer. Final demonstration will be made that natural and artificial conduits will not allow fluid migration from the storage reservoir.

6.5 Evaluation of Seismicity Monitoring

It will be demonstrated that the plume has stabilized and the pressure change is negligible (less than 10 psi per year), minimizing the risk for induced seismicity after site closure. Final review will be made with the seismicity monitoring to demonstrate seal integrity and to ensure that there is no further endangerment to the USDW.

7. Site Closure Plan

CTV will conduct site closure activities to meet the requirements of 40 CFR 146.93(e), with notification to the permitting agencies at least 120 days prior to its intent to close the site. Upon approval of the permitting agencies, CTV will plug the injection and monitoring wells, restore the site, and submit a site closure plan to EPA.

A site closure report will be prepared and submitted within 90 days following site closure supported by the following:

- Verification of injector and monitoring well plugging
- Notifications to state and local authorities per 40 CFR 146.93 (f)(2)
- Composition and volume of the injected CO_2
- Post-injection monitoring records

CTV will record a notation to the property's deed that will indicate the following:

- The property was used for CO_2 sequestration, the period of injection, and the volume of CO_2 injected.
- The formation into which the fluid was injected.
- The name of the local agency to which a plat of survey with injection well locations was submitted.

Figures

Figure E-1. Modeled Pressure and Pressure Increase at Monitoring Well Locations Within Claimed as PBI
Figure shows monitoring wells Claimed as PBI (blue line) and Claimed as PBI (orange line) at MPP within the Claimed as PBI during the injection period and until 100 years post injection. Horizontal dashed line indicates initial pressure. Stars denote the 20-year post-injection time.

Figure E-2. Modeled Pressure and Pressure Increase at Monitoring Well Locations Within Claimed as PBI
Figure shows monitoring wells Claimed as PBI (blue line) and Claimed as PBI (orange line) at MPP within the Claimed as PBI during the injection period and until 100 years post injection. Horizontal dashed line indicates initial pressure. Stars denote the 20-year post-injection time.

Figure E-3. Modeled Pressure and Pressure Increase at Monitoring Well Locations Within Claimed as PBI
Figure shows Claimed as PBI (blue line) and Claimed as PBI (orange line) at MPP within Claimed as PBI during the injection period and until 100 years post injection. Horizontal dashed line indicates initial pressure. Stars denote the 20-year post-injection time.

Figure E-4. Injection Zone Plume Development Through Time. Figure shows 1-year, 5-year, 10-year, 30-year (end of injection), 50-year (end of PISC), and 100-year post-injection.

Tables

Table E-1. Monitoring of Groundwater Quality and Geochemical Changes above the Confining Zone

Target Formation	Monitoring Activity	Device	Data Collection Location(s)	Spatial Coverage or Depth	Frequency (Post-Injection Phase)
USDW	Fluid Sampling	Pump	Claimed as PBI	[redacted]	Annual
	Pressure	Pressure Gauge	Claimed as PBI	[redacted]	Continuous (12-hr)
	Temperature	Temperature Sensor	Claimed as PBI	[redacted]	Continuous (12-hr)
	Temperature	Fiberoptic cable (DTS)	Claimed as PBI	[redacted]	Continuous
[redacted]	Pressure	External Pressure Gauge	Claimed as PBI	[redacted]	Continuous
	Temperature	External Temperature Sensor	Claimed as PBI	[redacted]	Continuous
	Temperature	Fiberoptic cable (DTS)	Claimed as PBI	[redacted]	Continuous

Table E-2. Analytical and Field Parameters for Groundwater Samples

Parameters	Analytical Methods
Cations (Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Se, Zn, Tl)	EPA 200.7 Rev 4.4, EPA 200.8 Rev 5.4
Cations (Ca, Fe, K, Mg, Na, Si)	EPA 200.7 Rev 4.4
Anions (Br, Cl, F, NO3, SO4)	EPA Method 300.0 Rev 2.1
Dissolved CO_2	EPA 1631; SM 4500 CO2 D
$\delta^{13}C$	Isotope ratio mass spectrometry
Hydrogen sulfide	EA-IRMS
Oxygen, argon, and hydrogen	Chromatographic analysis
Total dissolved solids	Gravimetry; Method 2540 C
Alkalinity	SM 2320 B
pH (field)	EPA 150.1
Specific conductance (field)	SM 2510 B
Temperature (field)	Thermocouple
Dissolved oxygen (field)	Electrode, 4500-O G-2016

Table E-3. Sampling and Recording Frequencies for Continuous Monitoring

Parameter	Device(s)	Location	Min. Sampling Frequency	Min. Recording Frequency
During active injection	Pressure gauge	USDW Monitoring Well	5 hours	5 hours
Post injection	Pressure gauge	USDW Monitoring Well	12 hours	12 hours

Sampling frequency refers to how often the monitoring device obtains data from the well for a particular parameter. For example, a recording device might sample a pressure transducer monitoring injection pressure once every two seconds and save this value in memory.

Recording frequency refers to how often the sampled information gets recorded to digital format (such as a computer hard drive). For example, the data from the injection pressure transducer might be recorded to a hard drive once every minute.

Table E-4. Post-Injection Phase Plume Monitoring

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage or Depth	Frequency (Injection Phase)
Plume Monitoring [40 CFR 146.90(g)] Direct Monitoring	Claimed as PBI	Pressure	Claimed as PBI	Claimed as PBI	Continuous
		Temperature		Claimed as PBI	Continuous
	Claimed as PBI	Pressure	Claimed as PBI	Claimed as PBI	Continuous
		Temperature		Claimed as PBI	Continuous
Plume Monitoring [40 CFR 146.90(g)] Indirect Monitoring	Claimed as PBI	Pulsed Neutron Log	Claimed as PBI	Claimed as PBI	Every 5 years
			Claimed as PBI	Claimed as PBI	

Table E-5. Post-Injection Phase Pressure-Front Monitoring

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage or Depth	Frequency (Baseline)	Frequency (Post-Injection)
Pressure-Front Monitoring [40 CFR 146.90(g)] Direct Monitoring	Claimed as PBI [redacted]	Pressure	Claimed as PBI	Claimed as PBI	Baseline	Continuous
		Temperature			Baseline	Continuous
	Claimed as PBI [redacted]	Pressure	Claimed as PBI	Claimed as PBI	Baseline	Continuous
		Temperature			Baseline	Continuous
Pressure-Front Monitoring Indirect Monitoring	All Formations	Seismicity	Seismic Monitoring Network	Full AOR	Baseline	Continuous