ENCLOSURE
Request for Additional Information
Site Characterization
Carbon TerraVault (CTV) IV Carbon Capture and Storage (CCS) Project
Underground Injection Control (UIC) Permit Application
Class VI Pre-Construction Permit Application Nos. R9UIC-CA6-FY23-3.1 to 3.8

[redacted]

This Enclosure for the proposed CTV IV Class VI geologic sequestration project summarizes EPA's review of the site characterization developed by CTV as described in their permit application Narrative dated June 27, 2023 (Version 3) and Attachment B: Area of Review (AoR) and Corrective Action Plan (CAP) dated April 12, 2023 (Version 1). Clarifying questions or requests that require further work are provided below in ***bold, italic*** text. Text that is not ***bold, italic*** is provided to give context or is recommended for further work. [redacted]

Injection and Confining Zone Details [40 CFR 146.82(a)(3)(iii)]

1. All of the wells within the AoR are outside the predicted extent of the CO_2 plume, but inside the delineated AoR based on the extent of both the CO_2 plume and pressure front. Thus, there generally is limited site-specific data that represents the injection well locations.

Injection and Confining Zone Details [40 CFR 146.82(a)(3)(iii)]

2. In Table 2.4-5, formation thicknesses and depths are reported "within the project AoR." However, the reported high and low values are inconsistent with the maps provided in Figures 2.4-6 and 2.4-7. ***Please clarify this discrepancy and/or revise Table 2.4-5 and elsewhere in the narrative, e.g., Section 2.2.2, with thickness and depth values specific to the delineated AoR.***
3. Quantitative mineralogical data is stated to be unavailable from within the AoR, so the mineralogical data presented in the application is from multiple wells located outside the AoR. These core data are presented in Table 2.4-1. Formations, sample depths, and the quantities of minerals are provided in the table as derived from XRD and FTIR. However, site-specific data points for the injection and confining zones at the injection well locations are not provided. Cores collected during construction will need to confirm site-specific properties, including porosity, permeability, capillary pressure, pore pressure, mineralogy, etc.
4. The permeability was estimated by applying a core-based permeability transform that utilizes capillary pressure, porosity, and permeability with clay values. The permeability transform is based on 13 core data points from two wells, and an example transform is

provided in Figure 2.4-2. ***Please provide the location of the two wells that are the source of the core data used for the permeability transform***.

5. The transform was verified by comparing nuclear magnetic resonance (NMR) log-generated permeability values (calculated from the Timur-Coates method) from the well [redacted] to values calculated from the transform (Figure 2.4-3). Pre-operational testing data will need to confirm the transform estimations and reduce uncertainty.
6. No capillary pressure data are available for the injection or confining zones, and all calculations and modeling are estimated based on injection zone capillary pressure data from the well [redacted] The lack of site-specific capillary pressure data from within the AoR and at the injection well locations introduces uncertainty that will need to be addressed in updated modeling before injection may be authorized.
7. The variability in the thickness and depth of the injection and confining zones is stated to not affect containment, and that the [redacted] confining zone is generally uniform across the AoR. ***What site-specific evidence is available to support the statement that variability in the thickness and depth of the confining zones will not affect containment?***
8. ***Please confirm if there are core data from drilling any wells in the*** [redacted] ***or from any other research on geologic sequestration (GS) in the state of California that can provide porosity, permeability, capillary pressure, pore pressure, mineralogy, etc., data about the injection or confining zones to increase the number of data points on which the site characterization is based.***
9. [redacted]

Geomechanical and Petrophysical Information [40 CFR 146.82(a)(3)(iv)]

10. The ductility of the confining zones was assessed using existing oil and gas well data from within the AoR study area consisting of thousands of logging data points for each confining zone. ***Please clarify if the same grouping of oil and gas wells used for the [redacted] ductility calculations were also used to characterize the [redacted] and [redacted] zones***.
11. The overburden stress gradient in the injection and confining zones ranges from 0.87 to 0.90 psi/ft. ***Please explain how the overburden stress gradient was derived***.

Seismic History [40 CFR 146.82(a)(3)(v)]

12. Seismic research was focused on earthquake activity in the greater vicinity of the project from 1850 through modern day with events of a magnitude greater than 2.5. ***Please confirm how "the greater vicinity" is defined***. ***Please update the reported earthquake results to include earthquake occurrences within the search radius that are greater than 1.5 magnitude***.
13. The [redacted] earthquake event identified within Section 2.6.1 is listed as occurring in [redacted] in Table 2.6-1. ***Please correct the discrepancy***.
14. ***Please discuss the pressures that are predicted to be incurred along the normal fault and what evidence there is (e.g., based on modeling sensitivity analyses) that reservoir pressure increases due to injection will not activate or destabilize this fault***.

Hydrologic and Hydrogeologic Information [40 CFR 146.82(a)(3)(vi), 146.82(a)(5)]

15. The base of the lowermost underground source of drinking water (USDW) is determined to be at a depth between 2,000 and 3,000 ft across the AoR. The depth of the lowermost USDW was determined using salinity calculations based on geophysical logs from wells within the AoR. Site-specific fluid sampling at the locations of the injection wells will be needed to provide a more precise measurement of the total dissolved solids (TDS) content and water chemistry of the lowermost USDW and confirm that the lowermost USDW is within the [redacted] identified. ***Please confirm if there any physical sample results confirming the [redacted] TDS content of the lowermost USDW***.
16. Based on data collected from California Department of Water Resources (DWR), the California State Water Resources Control Board Groundwater Ambient Monitoring Assessment Program (GAMA), the California Statewide Groundwater Elevation Monitoring (CASGEM), and other public databases, over 160 wells were identified within a one-mile radius of the project AoR boundary. [redacted] or the

secondary confining zone [redacted]

Details of Injection and Confining Zones [40 CFR 146.82(a)(6)]

17. The narrative indicates that no mineralogical data or fluid sample analytical data were available from wells within the AoR boundary. As such, mineralogical data was interpolated using core data from wells outside of the AoR within the region, and fluid samples from [redacted] were used to characterize geochemistry of the project site. The geochemistry data will be collected during pre-operational testing to compare and correlate against the regional data used for characterization.
18. The narrative indicates that there is a low risk of any adverse reactions to the CO_2 stream such as calcification of pore spaces or salting out effects. Given the time since the samples from which these conclusions were taken, pre-operational collection of site-specific baseline geochemical data for the upper and lower injection zones will be necessary to confirm assumptions of site parameters and reduce uncertainty in modeling inputs.
19. No fluid geochemistry data was available for the upper confining zone or the internal barrier. The narrative claims that fluid for analysis will only be extracted from the shales if stimulation is performed. However, no impacts are anticipated from the CO_2 injectate to the confining zones given their low permeability and carbonate content. Stimulating the confining zone is not recommended, as it affects the integrity, but instead comprehensive mineralogy data about the confining zone should be collected to serve as model inputs. ***Please elaborate on the statement that the confining zones will only provide formation fluid samples if stimulated.***

Site Suitability [40 CFR 146.83]

20. No concerns about potential facies changes that could affect the project were noted. However, as noted elsewhere, some assertions are based on data collected outside the AoR and no data in the direct vicinity of the injection wells is provided; data collected during pre-operational testing should be evaluated to confirm these assertions and reduce uncertainties in the characterization of facies changes and before final approval of the AoR.
21. Given the limited amount of geochemical and mineralogic data on the injection and confining zones from within the AoR, geochemical modeling inputs will need to be updated with site-specific data collected within the AoR during pre-operational testing to reduce uncertainty about the geologic characterization of the site and ultimately approve the AoR delineation, before injection of CO_2 is authorized.
22. The total storage volume for the project area was estimated as [redacted] million tonnes of CO_2, which was arrived at through the AoR computational modeling, as described in Attachment B. Due to the unconfined nature of the injection zones' boundaries, there

are no concerns for total storage capacity. ***Please provide information and calculations regarding how the storage capacity of the injection zones was determined, and how site-specific properties of the injection zones and operational conditions were factored into this evaluation***.

Site Geomodel

23. The AoR/CA document describes the static geomodel created for the AoR delineation. The geomodel appears to accurately represent the site characterization data as described in the narrative document, and there are no initial concerns with the methodologies used to construct the geomodel. All concerns regarding the geomodel reflect the concerns about the deficiencies in site-specific characterization data as described in this evaluation. Details of the geomodel are discussed below:
    a. The model domain is described in Table 3.1. Figure 3.3 displays the geomodel boundary and geo-cellular grid used to define the CO_2 plume extent and delineated AoR. Separate model layers are described for the upper and lower injection zones. This approach is consistent with the characterization of the [redacted] internal barrier, assuming the integrity of this shale is confirmed via pre-operational data collection.
    b. As data are collected from near the injection wells during pre-operational testing, the inputs at the finer grids should be revised as necessary to reflect any heterogeneities identified.
    c. No site-specific capillary pressure data is available, so data from the [redacted] was used, which is acceptable pending collection of site-specific data during the pre-injection phase.
    d. An injection zone fracture pressure gradient was assumed to be 0.76 psi/ft based on formation integrity tests conducted on nine wells in the [redacted]. The assumed fracture pressure gradient is consistent with the narrative, pending the plan to confirm this fracture pressure gradient by conducting step rate tests in the injection zones as part of pre-operational testing. The fracture gradient information is unavailable for the [redacted] upper confining zone, so a step rate test for the [redacted] will be conducted as part of the pre-operational testing. ***Please clarify the location of the nine wells that are the source of the fracture pressure gradient used in the model***.
24. Figure 3.4 (Static model grid layering of the Injection Zones) appears to be mislabeled as Figure 3.2. ***Please correct this discrepancy***.
25. ***For clarity, please expand the data source column on Table 3.3 in the AoR/CA Plan to include the specific logs and/or offset field production areas used to gather data for the initial condition values, and describe how the formation initial conditions were determined***.

Summarized Objectives for Pre-Operational Testing

26. The formation logging and testing to be performed during drilling of the injection wells is described in the pre-operational testing plan (POTP), Attachment I. Testing activities should address the following:
    a. Identify site-specific porosity, permeability, mineral composition, and petrophysical characteristics of the injection and confining zones at the location of each injection well.
    b. Clarify formation ductility, principal stresses, pore pressure, fracture gradient, and other petrophysical parameters to confirm assumptions used in geomechanical modeling.
    c. Determine static fluid levels (per 40 CFR 146.87(c)).
    d. Characterize the hydrogeologic characteristics of the injection zones using a pump test or injectivity test (per 146.87(e)).
    e. Confirm the uniformity in confining zone thickness and the absence of transecting faults or fractures.
    f. Determine precise injection zone storage capacity based on site-specific injection zone characteristics and operational data.
27. ***Please update Attachment I to include the following***:
    a. Detailed procedures for all planned testing noted above.
    b. Core sampling in each of the injection wells to provide a distribution of site-specific porosity, permeability, capillary pressure, pore pressure, mineralogy data, which will aid in accuracy.
    c. A pump test or injectivity test.
    d. Triaxial load testing to determine compressive strength and ductility in the upper confining zone.
    e. Testing to characterize the geomechanical and petrophysical characteristics of the lower confining zone units.