UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 9

SAN FRANCISCO, CA 94105

February 12, 2025 Sent via email only

Brennan Ott
West Coast Permitting Lead
Chevron New Energies
9525 Camino Media
Bakersfield, CA 93311
BrennanOtt@Chevron.com

Re: Technical Review – Request for Additional Information
Chevron Kern River Eastridge CCS Project
Underground Injection Control (UIC) Permit Application
Class VI Permit Application No. R9UIC-CA6-FY24-1.1-1.4

Dear Brennan Ott:

The United States Environmental Protection Agency, Region 9 (EPA) has identified information or clarification needed for continued evaluation of the site characterization and the Area of Review (AoR) delineation of the Permit application for the Chevron Kern River Carbon Capture and Sequestration (CCS) Project submitted by Chevron U.S.A., Inc. (Chevron). The review summaries and comments are included in the Enclosure.

EPA reviewed the changes to Chevron's application submitted on December 23, 2024 to add a variety of CO_2 emission sources (e.g. Direct Air Capture) and delete the Eastridge Cogeneration Facility CO_2 source. EPA considered the changes related to the CO_2 source in the enclosed comments.

Please submit the information requested in the enclosed AoR delineation, Computational Modeling, and Site Characterization comments by March 14, 2025. If you have any questions about this letter and the Enclosure, please contact me at (415) 972-3971, or call Nancy Rumrill at (415) 972-3293.

Sincerely,

DAVID ALBRIGHT Digitally signed by DAVID ALBRIGHT Date: 2025.02.12 07:24:48 -08'00'

David Albright
Manager, Groundwater Protection Section

Enclosure

cc (via email): Chris Jones, CalGEM Inland District
Alex Olsen, Central Valley Regional Water Quality Control Board
Janice Zinky, CA State Water Resources Control Board
Jason Dunn, CA State Water Resources Control Board

ENCLOSURE
Request for Additional Information
Chevron Kern River Eastridge CCS Project
Underground Injection Control (UIC) Permit Application

AoR Delineation and Modeling Review Summary

EPA reviewed the AoR and Corrective Action Plan 40 CFR §146.84(b) part of the Permit application dated December 2024 ("AoR and Corrective Action Plan"). In this part of the application, Chevron ("applicant") provides a well-documented and credible description of the proposed site, the geological setting, the approach for forecasting, the response of the storage system to planned CO_2 injection, and the method used to estimate the area of review.

The tool used for dynamic reservoir simulation (INTERSECT®, a trademark of Schlumberger) is, with the capability to account for features, events, and processes, relevant to geologic carbon storage. Chevron uses INTERSECT® for CO_2 sequestration simulation to understand the CO_2 plume and pressure front migration through time, delineate the AoR, and optimize development scenarios. The INTERSECT® program can simulate multiphase flow of CO_2 and formation fluids, including equations of state for CO_2 and other chemical species of interest and phase transitions (temperature, pressure) for CO_2. The equation of state was developed using Chevron's internal phase behavior software (Chevron Phase Calculation Program) and the modified Peng-Robinson EOS model that was imported into INTERSECT® to model the mixture property changes due to dissolution.

The boundary conditions for dynamic flow simulations are clearly described and justified with no flow boundaries at the top of the storage interval (base of overlying Freeman-Jewett Silt (1,140') layer (upper confining zone)) and underlying confining interval separating the 5th Vedder from the Famoso. The lateral boundaries of the targeted Vedder sand intervals are set as open with pore volume modifiers assigned at various lateral boundaries according to the expected aquifer support in each direction.

The applicant utilized the TOUGHReact & TReactMech simulation model code to explore the potential geochemical effects of CO_2 injection and storage on flow behavior (distinct simulations from the flow simulations that serve as the basis for AoR estimation). The results from this study highlight that geochemical trapping is not expected to play a significant role in trapping CO_2 during the expected project timeframes and that geochemical reactions are not expected to degrade injectivity with negligible permeability and porosity changes (Sonnenthal et al, 2022).

The applicant provided a robust sensitivity analysis, considering the potential effects of uncertainty in porosity, permeability, fault transmissibility, and injection schemes. These sensitivities were considered in designing the Testing and Monitoring Plan, and monitoring data will be used as the basis for periodic concordance evaluation during the period of active injection and AoR reevaluation/injection scheme modification, as needed.

The applicant provides a detailed evaluation of plume stabilization, based on reservoir simulation. That analysis suggests that the CO_2 extent approaches stability after 20 years of injection, with a small amount of additional CO_2 plume growth continuing over the next 40-60 years of post-injection monitoring. A small amount of that CO_2 migrates up-dip and builds a column against the Canfield fault, with a smaller portion eventually overcoming the capillary threshold at the fault interface and reducing permeability of the fault zone.

Site Characterization Review Summary

EPA reviewed the geologic evaluation and data submitted by Chevron in the Pre-Operation Narrative of the Permit application (Version 3, dated December 2024) ("Narrative") per 40 CFR §146.82(a). Chevron used available well logs, core data, and seismic surveys from within and around the project Area of Review (AoR) to characterize the proposed injection site. Additional regional data and literature review were used to supplement lacking data in deeper formations.

Formation Properties

Formation properties are summarized in Table 1 below. Formation depths, apparent thicknesses, porosities, and permeabilities were calculated using averaged log data from wells across the AoR. (See Table 7 and the "Geomechanical and Petrophysical Information [40 CFR 146.82(a)(3)(iv)]" in the Narrative.)

Table 1. Formation Summary

Unit	Depth (ft MD)	Mean Thickness (ft)	Total Dissolved Solids (mg/l)	Average Porosity (%)	Average Permeability (millidarcies, mD)
Santa Margarita (Base of Lowermost USDW)	1,588 ft	392 ft	1,000	31	400
Freeman-Jewett Silt (Upper Confining Zone)	2,610	1,140 ft	-	21	0.001147
Vd1 (Injection Zone Subunit)	3,910 ft	270 ft	10,000	29	3,580
Vd2 (Injection Zone Subunit)	4,180 ft	140 ft	10,000	27	3,120
Vd3 (Injection Zone Subunit)	4,320 ft	260 ft	10,000	28	470
Vd4 (Injection Zone Subunit)	4,580 ft	270 ft	10,000	29	4,990
Vd5 (Lower Confining Zone)	4,860 ft	110 ft	-	-	-

Unit	Depth (ft MD)	Mean Thickness (ft)	Total Dissolved Solids (mg/l)	Average Porosity (%)	Average Permeability (millidarcies, mD)
Famoso Sand (Lower Confining Zone)	4,970 ft	-	-	-	-

Note: - Data was not available for the Upper and Lower Confining Zones. As noted below, the Pre-Operational Testing will determine this data.

Pre-Operational Testing Objectives

While the application provides some site-specific data points for the injection and confining zones, additional data collection (logging and testing proposed by Chevron) is needed to reduce uncertainty in the site characterization and modeling inputs that will be needed prior to final authorization to inject. Chevron's pre-operational testing will include coring programs and additional geophysical analysis of the injection zone, confining zone, and lowermost Underground Source of Drinking Water (USDW) within the AoR. In the Pre-Operational Logging and Testing section of the Narrative, Chevron describes the testing that it proposes to perform to meet the requirements of 40 CFR §146.87, specifically to characterize the depth, thickness, minerology, lithology, porosity, permeability, and geomechanical properties of the injection zone and the upper and lower confining zones.

Based on the data gaps identified in the evaluation, EPA has identified additional pre-operational testing objectives (listed below) that will help address the uncertainties. These objectives should be addressed via the testing that Chevron proposes to perform.

- Identify site-specific porosity, permeability, mineral composition, and petrophysical characteristics of the injection and upper/lower confining zones at the location of each injection well.
- Determine the fracture gradient of the injection zone and confining zones.
- Calibrate the sealing capacity of the faults located within the AoR and confirm there are no other faults or fractures in the injection zone and confining zones.
- Enhance characterization of the geomechanical properties of the injection and confining zones.
- Characterize the baseline geochemistry (including Total Dissolved Solids (TDS)) of the injection and confining zones and the Olcese Sand and Santa Margarita Formations and provide information to demonstrate compatibility of the formation fluids and rock with injected CO_2. The Olcese Sand Formation is immediately above the Freeman-Jewett Silt Formation (i.e., the upper confining zone).
- Confirm initial reservoir conditions assumed in the geomodel, e.g., formation pressure and temperature.

AoR Delineation and Computational Modeling Comments

1. The reviewers could find no explicit reference to the Geologic Model Development tool used for static geocellular modeling, but it is assumed that geologic parameters used in the dynamic flow model were drawn from Petrel by Schlumberger. **Please clarify the origin of the geologic parameters used in the dynamic flow model.** Regardless, the applicant provides a detailed explanation of how geologic characteristics are used to characterize the geologic system.

2. The applicant provides details of a step rate test that they performed in 2022 within the Area of Interest (AoI) in the target Vedder Sand (storage interval) using well KCL20050X (API #040304874500) with details on how it was used to estimate the site-specific fracture gradient. The applicant used a general fracture gradient of 0.642 psi/ft from the step rate test executed in 2022. This value is indicated by the applicant to be consistent with a nearby publicly available observed fracture gradients within the Vedder Sand (0.682 psi/ft).

   Table 10 in the AoR and Corrective Action Plan lists the maximum bottom-hole pressure details at each zone (based on site specific step-rate test based fracture gradient, depth below surface, and using 90% of the fracture pressure) as well as the maximum expected pressure at the top of each zone to verify that fracturing does not occur due to injection in the Vedder Sand. However, no specific integrity analysis has been performed by the applicant on the confining zone (Freeman-Jewett Silt). **Please provide additional justification for this choice and describe the proposed site-specific integrity analysis of the confining zone.**

3. From the Narrative of the application, the cumulative amount of sequestered CO_2 is expected to total 6.82 million tonnes over the life of the Project. **Please clarify the total planned injection volume over the proposed life of the project and how the total volume is determined. Please clarify the amount of CO_2 planned for injection in the years 2041-2042 (when the additional CO_2 source comes online) and any other durations of time that CO_2 injection fluid physical and chemical characteristics may change. Please modify the Figures and the text if the language should change based on the December 23, 2024 changes to the application.**

4. Figure 95 in the Narrative provides a schematic diagram of Chevron's monitoring plan. **For consistency with your December 23, 2024 change, please modify the Figure's Cogen & Pipeline reference and illustration.**

Numerical Simulator Capabilities

5. No results are shown from the model related to evaporation and salt deposition in multiphase flow of formation fluids and related to salt precipitation in salinity interaction. **Please illustrate these results or provide justification why the results are not shown.**

6. For residual phase trapping, capillarity effects do not appear to be explicitly considered in storage interval flow simulations, though threshold pressures are assigned to represent

transmissibility across fault grid blocks. **Please provide a discussion of consideration of capillarity effects in the simulations of the model and the possible impacts on model predictions.**

Computational Model Design

7. The grid resolution of 200x200x4 ft within the AoR and 400x400x4 ft outside the AoR is fine enough in the model to capture the localized heterogeneities that could affect fluid movement. The application does not consider sensitivity of pressure/saturation response in the reservoir and related AoR on these gridding assumptions which would be useful supporting information. **Please provide a discussion of these sensitivity considerations from simulations of the model.**

8. It is not stated in the application how the time steps were determined in the model to evaluate if the time steps are appropriate to provide an understanding of the plume and pressure front behavior throughout the injection and post-injection phases. However, the reviewers understand that INTERSECT selects the time steps based on convergence criteria to minimize numerical artifacts, which is typical with using an industry-standard reservoir simulation code. **For completeness, please provide a description of how the dynamic simulation time stepping choices are handled by the simulation tool and, ideally, specify the resulting time steps used in the simulations.**

9. Variations in hydrogeologic properties of permeability and porosity were considered in the model. The variability in porosity and permeability were characterized based on petrophysical and core analysis data associated with 30 wells (listed in Table 3 of the AoR and Corrective Action Plan). Additional reservoir properties including volume of shale (Vshale), total and effective porosity (PHIT and PHIE, respectively), total water saturation (Swt), and effective shale-corrected water saturation (Swe) were calculated using triple combo borehole geophysical logs and core data for sandstones. See Table 4 in the AoR and Corrective Action Plan (and Table 1 in these comments) for a summary of available data for depth, thickness, porosity, and permeability ranges in the Freeman-Jewett Silt, Vedder Sand, and Famoso sand formations.

   Reliable electric log data were utilized for calculating volume of shale (Vsh), porosity, permeability, and saturation within the Vedder Sand, in addition to 7 wells with quantitative whole-core data and logs, yielding a total of 260 individual routine core analysis data points for calibration. Figures 9-13 in the AoR and Corrective Action Plan provide net porosity and net permeability maps for each Vedder subunit. However, there is no indication of accounting for heterogeneities/variations within the formations of capillary pressure in the model. **Please provide a clarification and discussion of accounting for capillary pressure variability in the model.**

Descriptions of the Model Outcomes

10. The applicant describes how the buoyant supercritical CO_2 migrates vertically until it encounters barriers. However, the value for the highest pressure at each barrier is not

reported. **Please provide the value of the highest pressure at each barrier (caprock, faults, etc.).**

11. Figure 41 in the AoR and Corrective Action Plan depicts the maximum lateral extent of the CO_2 plume for all Vedder Sand target zones in the year 2150, illustrating its migration 120 years after the initial injection. Figures 25 and 26 in the AoR and Corrective Action Plan illustrate the evolution of the pressure front throughout the project's 120-years (20-years injection and 100-years) duration. However, the maximum vertical extent of the CO_2 plume and pressure front is not shown. **Please provide illustrations of the maximum vertical extent of the CO_2 plume and pressure front.**

12. Figure 23 and Figure 24 in the AoR and Corrective Action Plan display the maximum lateral extent of the CO_2 plume at various time steps throughout the project life. **Please provide illustrations of the vertical extent of the CO_2 plume at various time steps throughout the project life.**

13. The CO_2 plume behavior is represented and discussed in the AoR and Corrective Action Plan using 2D views. **Please incorporate more illustrative visualizations, as 3D illustrations, to better capture and represent the vertical behavior of the CO_2 plume.**

Model Sensitivity Analyses and Approach

14. The model outputs, specifically the maximum lateral extent of the CO_2 plume or the associated pressure front, were most sensitive to variations in relative permeability, permeability, porosity, the injection scheme, fault threshold pressure, and fault transmissibility. The sensitivity analysis showed that these parameters significantly impacted the AoR, with some conditions leading to expanded or reduced AoRs. Figure 56 in the AoR and Corrective Action Plan shows cases that result in an expanded AoR, while Figure 57 of the Plan shows cases that result in a reduced AoR. The applicants did not include the sensitivities impact on the vertical extent of the CO_2 plume. **Please provide a discussion and illustrations of the sensitivities impact on the vertical extent of the CO_2 plume.**

15. No sensitivity study was performed on the grid block size (i.e., mesh) refinement. **Please provide a description of a sensitivity study on mesh refinement effects in the simulations of the model and provide a discussion on the uncertainties of the mesh size and the impacts on the model results.**

16. The applicant also does not discuss the choices of the finite-difference methods, sensitivity to those choices, or their effects on the results. **Please identify where the modeling uses finite-difference methods and provide a discussion of the choices of the method, sensitivity to those choices, and their effects on the uncertainties of the modeling approach on the results.**

Site Characterization Comments

Regional Geology, Hydrogeology, and Local Structural Geology [146.82(a)(3)(vi)]

17. Chevron utilized multiple geophysical well logs from around the AoR with data including spontaneous potential, gamma ray, resistivity, porosity, and nuclear magnetic resonance (NMR) permeability to characterize the project site. Figure 5 in the Narrative depicts the locations of 70 wells penetrating the injection zone with log data. The AoI is an area of approximately 25 square miles, and the delineated AoR is an area of approximately 3.5 square miles. **Please indicate which of the 70 wells described as within the AoI that penetrate the Vedder Sand are located within the delineated AoR.**

18. **Please clarify whether Table 7 in the Narrative was derived from the logs of the 70 wells.**

Depictions of the Area of Review [40 CFR §146.82(a)(3)(i)]

19. Figure 5 in the Narrative depicts the proposed injection wells, AoR and AoI boundaries, the extent of Chevron's 3D seismic survey, 70 wells penetrating the Vedder Sand, seismic well ties, faults within the AoI, and township boundaries. Several elements required at 40 CFR §146.82(a)(2), including deep stratigraphic boreholes, State- or EPA-approved subsurface cleanup sites, surface bodies of water, springs, mines (surface and subsurface), quarries, water wells, roads, and structures intended for human occupancy within the AoR are missing. **Please revise Figure 5 or create a new figure to include all of the information required at 40 CFR §146.82(a)(2) or indicate in the Narrative that these features are not present in the AoR.**

20. **Please include the delineated AoR on all figures as appropriate such as Figure 49 and Figure 81 in the Narrative.**

21. **Please provide higher resolution versions of Figures such as the Geologic Cross Section and map legend in Figure 10 in the Narrative.**

Faults and Fractures [40 CFR 146.82(a)(3)(ii)]

22. Minor faults occurring outside the AoR but within the AoI include the China Grade fault zone, a system of east-striking normal faults located near the southern boundary of the AoI, and the Kern Front fault, a south-striking normal fault located near the western boundary of the AoI. The Kern Front fault is a south-striking, west-dipping normal fault that displaces Quaternary alluvium and borders the western side of the AoI. Chevron describes the Kern Front fault as Holocene-active (according to the state of California) but currently aseismic, creeping to the north at a rate of 3 to 12 mm annually based on data collected by the National Oceanographic Survey between 1968 and 1974.

    Please provide more recent data, if available, to describe the creep of the Kern Front Fault.

23. Chevron references oil columns in the Vedder Sand subunits as physical evidence of sealing in the Apollo Sr and Jr Faults (Figure 53 in the Narrative). Further physical evidence was collected by a pressure fall-off test conducted on well KC20050X, around 3.5 miles from the AoR, and summarized in Table 5 and Figure 56 in the Narrative. Additional evidence of fault sealing was provided using geochemical gas chromatographic analysis of oils in the injection zone subunits. Figures 57 and 58 in the Narrative show the lack of vertical fluid communication through the faults or intraformational shales in wells KC20050X, REV0004X, and S3_0819X.

    Please provide the locations of the wells KC20050X, REV0004X, and S3_0819X and highlight/identify them on all maps indicating that they are used as data points.

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

24. Chevron utilized legacy well logs, whole core, and sidewall core data (from wells mapped in Figures 5, 59, and 60 and provided in Appendices A, B, and C in the Narrative) in addition to mapping from 3D seismic data to characterize the depth, thickness, porosity, and permeability of the injection and confining zones. These values were summarized in Table 7 in the Narrative.

    Please indicate which wells on Figures 59 and 60 in the Narrative have core data, logs, or both.

25. **Please clarify if all of the wells in Figures 5, 59, and 60 in the Narrative penetrate to the lower confining zone. If not, please indicate on which formations they provide data.**

26. Permeability for the Freeman-Jewett Silt is based on nuclear magnetic resonance (NMR) data taken from Chevron's KH_WDVI reference well (located within 1.1 miles of the project site), showing horizontal and vertical permeability averages 0.784 mD and 0.001147 mD, respectively. Average porosity over the Freeman-Jewett Silt at the reference well is 21%. Chevron proposes to collect additional information to refine the Freeman-Jewett Silt porosity and permeability as outlined in their Pre-Operational Testing Plan. **For clarity, when referencing a well, please describe its distance from the AoR.**

27. Page 97 of the Narrative references well AP_0051X and 33_0028X as within the AoR and OM_0044X as within the AoI. In Figure 5 in the Narrative, this appears to be the opposite. **Please clarify the discrepancy.**

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

28. No geomechanical characterization of the Freeman-Jewett Silt was provided. **Please provide a summary of geomechanical information on fractures, stress, ductility, rock strength, and in situ fluid pressures within the Freeman-Jewett Silt as required in 40 CFR §146.82(a)(3)(iv).**

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

29. The Santa Margarita is the lowermost USDW in the AoR and consists of marine sandstone interbedded with shale. More than 2,500 ft of overburden exists between the top of the Vedder Sand injection zone and the base of the Santa Margarita. The Santa Margarita has an average porosity of 31% and an average permeability of 400 mD. Chevron states that "historical records" indicate a TDS ranging from 490 to 1,584 mg/L for the Santa Margarita within the AoI. The source of this information is unclear. **Please identify the source of the TDS data for the Santa Margarita formation.**

Site Suitability [40 CFR 146.83]

30. The total storage capacity of the Vedder Sand injection zone is between 0.9 to 3.6 billion tons of CO2 across the San Joaquin basin according to a study by Lawrence Berkeley National Laboratory (LBNL). However, specific storage capacity at the project site is not described in the Narrative. **Please describe the total storage capacity of the injection zone at the project site, and how this was estimated, e.g., via modeling.**

31. As noted in the summary above, Chevron partnered with LBNL to compile their site-specific data into the TOUGHREACT geochemical simulator with the ECO2n V2.0 equation-of-state module. Input parameters and data are provided in Tables 16-18 in the Narrative. The distribution of porosity and permeability values input to the model is provided in Figure 91 in the Narrative. Using TOUGHREACT, a 2D radial model was created to simulate CO2 movement, pH changes, and dry out during CO2 injection over the course of the 20-year injection period with a minimum timestep of 1 second. The study concludes that little to no significant geochemical reaction will occur between the rock formations, the injected CO2, injected impurities, and the in-situ brine. The geochemical modeling does not consider the 50-year post-injection site care (PISC) period. **Please provide the results of the geochemical modeling over the PISC period.**

Site Geomodel [40 CFR 146.84(c)(1)]

The AoR and Corrective Action Plan refers to wells S3_0819X_ST1 (API #040297371201) and KCL20050X (API #040304874500); however, these wells do not appear elsewhere in the application. EPA believes these may be S3_0819X or S3_0819XRD1 and KC20050X. **Please clarify the names of these wells and add them to all appropriate figures and tables**