UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
AIR AND RADIATION

September 30, 2021

Mr. Craig Eckberg
Petra Nova, LLC
1421 Mobil Oil Road
Vanderbilt, Texas 77991

Re: Monitoring, Reporting and Verification (MRV) Plan for West Ranch Field

Dear Mr. Eckberg:

The United States Environmental Protection Agency (EPA) has reviewed the Monitoring, Reporting and Verification (MRV) Plan submitted for the West Ranch Field as required by 40 CFR Part 98, Subpart RR of the Greenhouse Gas Reporting Program. The EPA is approving the MRV Plan submitted by Petra Nova, LLC for the West Ranch Field as the final MRV plan. The MRV Plan Approval Number is 1013810-1. This decision is effective October 5, 2021 and appealable to the EPA's Environmental Appeals Board under 40 CFR Part 78.

If you have any questions regarding this determination, please write to ghgreporting@epa.gov and a member of the Greenhouse Gas Reporting Program will respond.

Sincerely,

Julius Banks, Chief
Greenhouse Gas Reporting Branch

Technical Review of Subpart RR MRV Plan for Petra Nova West Ranch Unit

September 2021

Contents

<u>Appendices</u>

This document summarizes the U.S. Environmental Protection Agency's (EPA's) technical evaluation of the Greenhouse Gas Reporting Program (GHGRP) Subpart RR Monitoring, Reporting, and Verification (MRV) Plan submitted by Petra Nova LLC, a wholly owned subsidiary of Petra Nova Parish Holdings (PNPH), for the carbon dioxide (CO_2) - enhanced oil recovery (EOR) project in the West Ranch Unit (WRU).

1 Overview of Project

The Petra Nova project is a commercial scale post-combustion carbon capture project utilizing an advanced amine-based absorption technology to capture at least 90 percent of the carbon dioxide (CO_2) from a nominal 240 MW equivalent flue gas slipstream diverted from the coal-fired Unit 8 (Unit 8) at NRG Energy, Inc.'s W.A. Parish Electric Generating Station. The Carbon Capture Equipment (CCE) is located southwest of Houston, Texas, in rural Fort Bend County, in the town of Thompsons, Texas. The captured CO_2, up to 4,717 metric tons (5,200 short tons) per day, is being dried, compressed, and transported via an 81-mile pipeline to the West Ranch oil field in Jackson County, Texas (West Ranch), where it is used in CO_2 enhanced oil recovery (EOR) operations. The CCE has been capturing CO_2 since late 2016 and sending it to West Ranch. Hilcorp Energy Company (Hilcorp) is the designated operator of West Ranch. It uses CO_2 captured at and transported from the CCE (Fresh CO_2) and CO_2 produced during the oil production process (Recycled CO_2) for EOR floods at West Ranch. West Ranch is located in southeast Texas in Jackson County near the town of Vanderbilt as shown in Figure 2.1.1 of the MRV plan. The West Ranch Unit (WRU) boundary for the current CO_2 EOR operation that exists is delineated in Figure 2.1.2 of the MRV plan. The MRV plan states that the WRU was formed by consolidating portions of two Oligocene-age reservoirs, the 98-A and 41-A, within the Frio Formation. A stratigraphic column is provided in Figure 2.3.1 of the MRV plan.

The MRV plan states that CO_2 flooding was initiated in the 98-A reservoir in December 2016 and has been subsequently expanded horizontally. While the horizontal expansion of the 98-A reservoir is still ongoing, a vertical expansion into the 41-A reservoir, which lies immediately above the 98-A reservoir, began in 2018. The CO_2 EOR operations at West Ranch are planned to expand horizontally and vertically upward over time, including the CO_2 flooding of additional portions of the 98-A and 41-A reservoirs, and three additional reservoirs in the Frio Formation: Greta, Glasscock, and Ward. This MRV Plan anticipates the expansion into the entire interval between the base of the 98-A reservoir and the base of the Anahuac Shale, a regionally contiguous and impermeable shale immediately above the Frio Formation at West Ranch (Project Interval). The reservoirs in the Project Interval have similar geologic characteristics and PNPH will apply the same operational controls in each area of expansion. The MRV plan states all of the injection zones in the Project Interval share the following characteristics:

- four-way dip anticline trapping mechanisms;
- no faulting;

- presence of a primary confining interval above each injection zone within the Project Interval and a secondary confining interval (Anahuac Shale) that overlays the entire project area; and
- depleted reservoir pressure.

West Ranch is one of several oil fields located in the Gulf Coast Basin that share the same petroleum system. The MRV plan states that the West Ranch field is formed on a gentle four-way anticlinal structure on a rollover structure (Figures 2.2.1(a), 2.2.1(b), 2.2.2(a), and 2.2.2(b)) on the upthrown side of a northeast-southwest trending regional growth fault as shown in Figure 2.2.3.

The generalized stratigraphic section of geologic formations present at West Ranch is shown in Figure 2.3.1 of the MRV plan. The reservoir sandstones into which CO_2 is currently or planned to be injected at West Ranch include five reservoir sandstones in the Frio Formation: the 98-A, 41- A, Ward (not shown on Figure 2.3.1), Glasscock, and Greta, from the deepest (6,200 feet) to the shallowest (5,100 feet). Each reservoir sandstone is separated by locally continuous low permeability and individually confining mudstones (Figure 2.3.2). The Anahuac Shale is a low permeability confining layer that has served as a stratigraphic seal to prevent the upward migration of hydrocarbons throughout geologic time for many oil fields throughout the Gulf Coast region (Galloway and Cheng, 1985), and it serves as the secondary seal in addition to the individual confining layers overlaying each reservoir. Above the Anahuac Shale is a series of sandstones separated by shales collectively known regionally as the Oakville Formation, which are also referred to as the Miocene Sands.

West Ranch was discovered in 1938. The description of the discovery and the original conditions of the main producing reservoirs, and the oil field operations including hydrocarbon production and brine injection, are described in the MRV plan. The main reservoirs at West Ranch (Greta, Glasscock, Ward, 41-A, and 98-A) are porous and permeable. These reservoirs average more than 27 percent porosity and 400 millidarcy (mD) permeability. Besides the five main producing sands, 79 additional minor reservoirs have been classified as producing sands by the Texas Railroad Commission (TRRC). A primary gas cap in contact with the oil zone was present upon discovery in all main oil producing reservoirs, indicating vertical hydraulic isolation of each sand zone. These reservoirs were originally produced with a gas-cap expansion and/or a natural water drive. The Glasscock and Ward reservoirs were constituted from oil-rim reservoirs with gas caps as large as one-third of the volume, and 95 percent of the energy was attributable to the expansion of their gas caps (Galloway and Cheng, 1985). Greta, 41-A, and 98-A reservoirs are mainly energized by strong natural water drive.

The MRV plan states that the operational requirements that currently apply in the WRU will also apply in the expansion zones. They include rules for injection wells such as the confirmation of nearby well condition, periodic testing of casing integrity, adequate cementation to confine fluids in the injection reservoir, and monitoring and limitation of injection pressure. Based on these conditions, PNPH believes that all reservoirs within the Project Interval at West Ranch can be included under this MRV plan as they are utilized in the future. At reservoir conditions of West Ranch, the five main target reservoirs could hold about 919 billion standard cubic feet (Bscf) (48.06 million metric tons) of CO_2 based on the original oil and gas in place. PNPH forecasts that 20 years of CO_2 EOR operations would result in sequestered CO_2 occupying approximately 61 percent of the calculated storage capacity.

The MRV plan provides a description of the project, including the site setting, processes, and plans for injection operations. The description of the project is determined to be reasonable and provides information acceptable and in compliance with 40 CFR 98.448(a)(6). Any changes in wells including new wells and plugging and abandonment of existing wells would go through TRRC approval and be included in the annual report to EPA.

2 Evaluation of the Delineation of the Maximum Monitoring Area (MMA) and Active Monitoring Area (AMA)

As part of the MRV Plan, the reporter must identify both the maximum monitoring area (MMA) and active monitoring area (AMA), pursuant to 40 CFR 98.448(a)(1). Subpart RR defines maximum monitoring area as "the area that must be monitored under this regulation and is defined as equal to or greater than the area expected to contain the free phase CO_2 plume until the CO_2 plume has stabilized plus an all-around buffer zone of at least one-half mile." Subpart RR defines active monitoring area as "the area that will be monitored over a specific time interval from the first year of the period (n) to the last year in the period (t). The boundary of the active monitoring area is established by superimposing two areas: (1) the area projected to contain the free phase CO_2 plume at the end of year t, plus an all-around buffer zone of one-half mile or greater if known leakage pathways extend laterally more than one-half mile; (2) the area projected to contain the free phase CO_2 plume at the end of year t + 5." See 40 CFR 98.449.

Petra Nova has defined the AMA as the boundary of the WRU plus an additional 0.5-mile radius buffer. Petra Nova has also defined the MMA as the boundary of the WRU plus an additional 0.5-mile buffer as required by 40 CFR §98.448(a)(1). Factors considered include: the predicted extent of free-phase CO_2 within the WRU, fluid pressure and management strategies to retain injected CO_2 within the unit, and the geological structure of the unit.

Reservoir modelling was used as a predictive tool to determine the capacity of the subsurface to accept CO_2 injection. The simulation modelling shows that the injection pressures are expected to remain below formation parting pressure and gas saturation is expected to remain within the intended range. Petra Nova also conducted a long-term simulation forecast through 2040. The simulation shows that CO_2 accumulates at the crest of the formation structure and is within the MMA.

The MMA, as it is defined in the MRV plan, is consistent with subpart RR requirements because the defined MMA accounts for the expected free phase CO_2 plume, based on modeling results, and incorporates the additional 0.5-mile or greater buffer area. The rationale used to delineate the MMA, as described in Petra Nova's MRV plan, accounts for the existing operational and subsurface conditions at the site along with any potential changes in future operations. Therefore, the designation of the AMA as the WRU, plus the required 0.5-mile buffer and the designation of the MMA as the WRU, plus the required 0.5-mile buffer, is an acceptable approach. Since the AMA is defined to be the same as the MMA in the MRV plan, the AMA is also consistent with subpart RR requirements.

The MRV plan states there will be a subsidiary purpose of establishing the long-term containment of CO_2 in the WRU during the Specified Period. The plan states that the Specified Period will be shorter than the period of production from the WRU. At the conclusion of the Specified Period, Petra Nova intends to submit a request for discontinuation of reporting. This request will be submitted with a demonstration that the cumulative mass of CO_2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage.

The delineations of the MMA and AMA were determined to be acceptable and in compliance with 40 CFR 98.448(a)(1). The MMA and AMA described in the MRV plan are clearly and explicitly delineated and are consistent with the definitions in 40 CFR 98.449.

3 Identification of Potential Surface Leakage Pathways

As part of the MRV plan, the reporter must identify potential surface leakage pathways for CO_2 in the MMA and the likelihood, magnitude, and timing of surface leakage of CO_2 through these pathways pursuant to 40 CFR 98.448(a)(2). Petra Nova identified the following as potential leakage pathways in their MRV plan that required consideration:

- Diffuse leakage through the Anahuac Shale;
- Faults and fractures;
- Natural and induced seismic activity;
- Failure of zonal isolation in existing wells;
- Failure of zonal isolation in new well construction;
- Drilling through the CO_2 area;
- Lateral migration outside the West Ranch Oil Field; and
- Pipeline/surface equipment.

3.1 Diffuse Leakage through the Anahuac Shale

The Anahuac Shale is a low permeability confining layer that serves as the secondary seal in addition to the individual confining layers overlaying each reservoir. The Anahuac Shale is more than 120 feet thick in the West Ranch area. It is composed of silty clay (average 56 percent clay) and has permeability values of 0.0006 to 0.0026 mD. The MRV plan states that the Anahuac Shale is an effective seal based on gas chemistry showing that gas migration is limited by diffusion and adsorption. The Anahuac Shale is also widely used as a top seal for Class I disposal operations in the Gulf Coast area. Section 4.2 of the MRV plan states injection pressure is continuously monitored and unexplained changes in injection pressure would trigger investigation as to the cause. Furthermore, the MRV plan states that diffuse leakage through the individual seals that lie above the reservoirs in the Project Interval is highly unlikely. Each reservoir sandstone in the Project Interval is separated by a locally continuous low permeability and individually confining mudstone as indicated in Figure 2.3.2 of the MRV plan.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected through the Anahuac Shale and the confining units of each reservoir within the Project Interval.

3.2 Leakage through Faults and Fractures

According to section 4.3 of the MRV plan, Petra Nova asserts that leakage of CO_2 from reservoirs within the Project Interval through faults and fractures is not likely because West Ranch is a roll-over anticline formed between two major growth fault zones, and there is no major fault within the field (Figures 2.2.1, 2.2.2, and 2.2.3). Section 4.3 of the MRV plan states that because the overall section is dominated by mudstones, fault permeability is controlled by clay smear. Rather than fracturing, Gulf Coast sandstones and mudstones are typically not fractured but deform without rupture by bending and smearing. This sealing nature of faults is evident at many hydrocarbon fields that are fault bounded. Additionally, section 2.8.2 of the MRV plan states that all injection permits require that injected fluids be confined in the authorized reservoir, and that injection at pressure exceeding fracture pressure is not allowed.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected through faults and fractures.

3.3 Leakage through Natural and Induced Seismic Activity

The MRV plan states that although the Gulf Coast has been and is still locally undergoing deformation related to loading and continued subsidence of the Gulf Basin, the area is not seismically active, and deformation occurs without producing earthquakes. The MRV plan cites the United States Geological Survey (USGS) long-term seismic risk map, which puts the Gulf Coast area encompassing West Ranch in the lowest risk category.

Petra Nova asserts that the risk of induced seismicity at West Ranch is low for several reasons: 1) the magnitude of pressure increase and the area where pressure is elevated is aggressively managed by balancing injection and withdrawal rates, 2) the reservoirs have a lower pressure as a result of past production, 3) the high permeability and rapid fluid cycling through the reservoir create little risk of developing local overpressure, and 4) the operation is compliant with TRRC regulations limiting injection pressure. Additionally, the MRV plan states that application for a new injection well permit, or modification of an existing injection well permit, must include a survey of historical seismic events within 5.64 miles, as specified in TRRC regulations.[1] These regulations state that an historical seismic event of Magnitude 2.0 or greater triggers a seismicity review conducted by the TRRC to consider the necessity of a permit disposition. The MRV plan states that in the unlikely event that seismicity resulted

[1] See https://www.rrc.texas.gov/oil-and-gas/publications-and-notices/manuals/injection-disposal-well-manual/summary-of-standards-and-procedures/seismicity-review

in a pathway for material amounts of CO_2 to migrate from the injection zone, the monitoring provisions at other reservoir levels would lead to further investigation as described in section 5.1 of the MRV plan.

Thus, the MRV plan provides an acceptable characterization of the likelihood of leakage from natural and induced seismic activity.

3.4 Leakage through Failure of Zonal Isolation in Existing Wells

Section 4.5 of the MRV plan states that the risk of CO_2 leakage through existing wells is being mitigated through a monitoring and maintenance program that will provide early detection of problems that could materialize into a leakage event. This monitoring and maintenance program includes continuous monitoring devices tracking injection rate, pressure, and volume (as well as continuous monitoring of the annulus with a pressure gauge). All pressure gauges are connected to a real time reporting Supervisory Control and Data Acquisition (SCADA) system. The SCADA monitoring system uses set points to trigger an alarm if there is more than a 10 percent change in pressure. In addition, periodic injection profiles are performed on the injection wells including running temperature surveys. Reservoir pressure is also measured through the injection wells when workovers are performed. All the aforementioned monitoring tools conform to the TRRC requirements under TAC Title 16 Part 1 §5.305(1)(B). Petra Nova states they will conduct periodic Mechanical Integrity Testing (MIT) in accordance with TRRC rules.

Additionally, the TRRC requires an applicant for an injection well permit to examine the data of record for wells that penetrate the proposed injection reservoir within one-quarter mile radius of the proposed well to determine if all abandoned wells have been plugged in a manner that will prevent the movement of fluids into strata other than the authorized reservoir for injection. Hilcorp currently reviews all wells located within one-half mile radius of any proposed injection well.

Prior to CO_2 flooding, the MRV plan states that an exhaustive study of all existing wellbores at West Ranch was carried out to confirm well condition and integrity. All of the plugged and abandoned wells at West Ranch have plugs to prevent the upward migration of fluid, and most wells have multiple plugs in the Frio formation isolating the deeper zones. All shut-in and producing wells in West Ranch were also reviewed as part of the study, and numerous shut-in wells are used for Petra Nova's active pressure monitoring program throughout the field as described in section 5.1.1 of the MRV plan.

The MRV plan states that while the CO_2 EOR operation is conducted, injection profile logs are run to determine where injected fluid is going. An injection profile provides a comprehensive picture of what is going on down hole in an injector through numerous surveys including a radioactive tracer, spinner logs, temperature logs, caliper logs, and collar logs. Petra Nova asserts that these logs will allow them to look for anomalies which can indicate if there is fluid loss during injection, indicate channeling, help in quantifying the release of fluid if one is found, and indicate fluid losses and events occurring inside and outside the well bore. In addition, a Reservoir Saturation Tool (RST) can be run to measure hydrocarbon and water saturations behind casing. This tool could indicate if injected fluid is going out of the targeted interval and into another zone. Section 4.5 of the MRV plan states that a baseline RST has been run on six wells.

Thus, the MRV plan provides an acceptable characterization of the likelihood of leakage through failure of zonal isolation in existing wells.

3.5 Leakage through Failure of Zonal Isolation in New Well Construction

The MRV plan states that the risk of zonal isolation failure in new wells is low because all of the injection wells for the CO_2 EOR operation are newly drilled wells or conversion of existing wellbores and must adhere to TRRC requirements as described in section 2.8.2 of the MRV plan. New wells are constructed to provide zonal isolation and are tested prior to use to determine that the cement in the rock-casing annulus covers the required intervals and is of good quality. All of the injection wells have coated tubulars to withstand corrosion, and both the surface and production casing strings are cemented back to the surface with a confirmation through a cement bond log of a full column of cement behind the casing.

In addition, newly drilled producing wells for CO_2 EOR operations are drilled and completed in a manner that inhibits corrosion, including coated tubulars and corrosion inhibiting fluid in the annulus between the tubing and the long string casing to prevent corrosion. Both surface and production casings are cemented to the surface. Petra Nova asserts that in the event of CO_2 leakage, this leakage would be identified and quantified through the monitoring protocols in section 5.1 of the MRV plan.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected through failure of zonal isolation in new well construction.

3.6 Leakage from Drilling Operations

The MRV plan states that future drilling within the existing or future WRU or drilling into a deeper reservoir could occur and inadvertently create a leakage pathway. Petra Nova characterizes CO_2 leakage from drilling operations as very low risk because of TRRC regulatory requirements for drilling in the West Ranch Oil Field and multiple gas charged reservoirs within the West Ranch Oil Field that necessitate all drilling be done with proper preparation to contain gas in such reservoirs. The MRV plan states that all wells drilled in the West Ranch Oil Field are regulated by the TRRC under TAC Title 16 Part 1 §3.13, which includes (a) ensuring that the casing is securely anchored to effectively control the well at all times, (b) all usable-quality water zones be isolated and sealed off to effectively prevent contamination or harm, and (c) all productive zones, potential flow zones, and zones with corrosive formation fluids be isolated and sealed off to prevent vertical migration of fluids behind the casing, including gases. Lastly, Petra Nova states that in the unlikely event of a gas leakage from a reservoir flooded with CO_2, the methods to quantify the amount of leakage would use appropriate engineering variables and standard methods for the estimation of the volume of releases.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected from drilling through the CO_2 area.

3.7 Leakage from Lateral Migration

In section 4.8 of the MRV plan, Petra Nova asserts that it is highly unlikely that injected CO_2 will laterally migrate outside of the West Ranch Oil Field because it contains the highest elevation of both current and planned future reservoirs for CO_2 flooding within the surrounding area. Because CO_2 is less dense than oil and water in the reservoir, CO_2 tends to migrate and accumulate at the top of geological structure. The MRV plan asserts that this tendency makes it highly unlikely that CO_2 will migrate downdip and laterally outside of the existing and future WRU, based on the anticipated volume of CO_2 to be injected. The well-defined structural closure based on well logs and oil-water contact provides a strong control on the lateral extent of the CO_2 plume, and the volume of injected CO_2 will be less than the storage capacity of each reservoir. The MRV plan also states that CO_2-oil miscibility strongly minimizes possible lateral CO_2 transport distance.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected from lateral migration.

3.8 Leakage from Pipeline and Surface Equipment

The MRV plan states that surface infrastructure is under surveillance for leakage from pipelines and surface equipment on a daily basis. The past three years of surveillance show that the release volumes are less than one percent of the captured CO_2. Petra Nova states that confidence in their surveillance is high, because the release of even small amounts of CO_2 is highly noticeable, as dense CO_2 flashes result in noise and creates a cloud, ice, or condensed water. Any releases of CO_2 from either planned events or unplanned incidents are being quantified and reported following Subpart W requirements of EPA's GHGRP or based on appropriate engineering variables and standard estimation of releases as stated in section 5.2 of the MRV plan.

Thus, Petra Nova's procedural monitoring and quantification of CO_2 releases, both intentional and unintentional, described in the MRV plan provide acceptable characterization of the likelihood of a CO_2 leak that could be expected.

4 Strategy for Detecting and Quantifying Surface Leakage of CO_2 and for Establishing Expected Baselines for Monitoring

40 CFR 98.448(a)(3) requires that an MRV Plan contain a strategy for detecting and quantifying any surface leakage of CO_2, and 40 CFR 98.448(a)(4) requires that an MRV Plan include a strategy for establishing the expected baselines for monitoring CO_2 surface leakage. Sections 5 and 6 of the MRV plan outline Petra Nova's strategy for quantifying surface leakage of CO_2 and their strategy for establishing expected baselines to monitor against. Petra Nova's approach primarily includes monitoring

of injection, production, and shut-in wells, monitoring of surface infrastructure, and field inspections by personnel.

CO_2 is supplied to the WRU from one source and is metered at the metering station at West Ranch. The concentration of CO_2 is measured at the custody transfer meter located in the vicinity of the CCE. The MRV plan indicates that measurements are monitored by the SCADA system located onsite, which alarms operators of any abnormalities. As the CO_2 flood expands throughout the entire Project Interval, Petra Nova states that new injection areas will be tied into the SCADA system using the same or equivalent equipment. The MRV plan states that the SCADA monitoring system uses set points to trigger an alarm if there is more than a 10 percent change in pressure. Additionally, injection profiles are performed periodically on the injection wells, which includes temperature surveys on the injection wells. Reservoir pressure is also measured through the injection wells when workovers are performed.

CO_2 records will be determined quarterly to be consistent with requirements specified by 40 CFR §98.3(g). The MRV plan states that all data will be collected as generated and aggregated as required for reporting purposes and maintain records for at least three years.

4.1 Subsurface Infrastructure Leakage

The MRV plan states that detection and quantification of any losses of CO_2 in the subsurface through damaged or faulty well construction can be done directly in active wells and shut-in wells. According to the MRV plan, all permanently plugged and abandoned wells are plugged with cement and drilling mud with well tubulars cut off below the surface in accordance with regulatory requirements; however, as these wells are not equipped with pressure gauges, in the unlikely event of well leakage, the detection and quantification will be done indirectly from the pressure reading of surrounding wells that are perforated in the same or shallower reservoirs. In addition to the measures described in section 5.1 of the MRV plan, Petra Nova states they will use pressure gauges in active wells to monitor pressure in the tubing, the production casing, and the surface casing. Gas lift rate and pressure are also monitored for each well. Injection rates of water, CO_2, or a combination of both are metered for each injection well. In the unlikely event of well leakage, the detection and quantification will be done indirectly from the pressure reading of surrounding wells that are perforated in the same or shallower reservoirs. The MRV plan indicates that the detection of leakage in the subsurface will occur prior to release of CO_2 at the surface and will be used to prevent loss to the surface. The plan also notes that, in some cases, the leakage risk may be brine (not CO_2); in other cases, loss of CO_2 could be into shallower zones of the subsurface.

Pressure monitoring at active producing wells, active injection wells, and shut-in wells is done via installation of pressure gauges at the wellhead that access the tubing and casing with connections to the SCADA system. Pressure readings at the surface casing, production casing and tubing on these wells are captured multiple times each day. The MRV plan states that if pressure changes in a reservoir that is not intended to be energized, or if there are any CO_2 releases from the subsurface, then the necessary alarms are set up to be notified through SCADA into the control room. The MRV plan indicates that all the active alarms are investigated by the field personnel for further investigation and diagnostics. If a leakage is detected, Petra Nova will use an event-specific approach to quantify leaked amounts of CO_2. This might include the use of modeling, engineering estimates, or direct measurements, depending on the circumstance, to estimate the relevant parameters (e.g., flow rate, concentration, and duration of leakage) to quantify the leak volume.

4.2 Equipment Leaks and Vented Emissions of CO_2

The MRV plan states that any losses through surface infrastructure are either intentional releases for maintenance or unplanned releases, in the case of upsets or accidents. Operators will detect such events using the data streams and alarms that are reported to the control room and the observations from visual inspection of facilities. It is stated that the methods of quantification of losses use the appropriate engineering variables and standard estimates of releases. Further, the plan states that the operator will evaluate and estimate leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

4.3 Determination of Baselines for Monitoring CO_2 Surface Leakage

The MRV plan describes that the results from daily monitoring of field conditions by Hilcorp, operational data, and routine testing and maintenance information will be used to help establish expected baselines. Based on the data from those efforts, the data will be used to determine when further investigation of CO_2 leakage is warranted. Visual inspections are conducted daily and are stated to provide the opportunity to identify issues early and address them proactively, including issues that may preclude leaks from happening. If an identified issue cannot be addressed by the personnel who identified it, a work order is generated to resolve the issue. Each event is documented, which includes an estimate of the amount of CO_2 leaked and is included in the annual subpart RR report.

The MRV plan states that MITs are carried out in compliance with TRRC and done to ensure that there is no significant leakage within the injection tubing, casing, packer, or outside of the casing. All injection wells undergo MIT at various intervals before injection operations begin; at least once every five years, or more frequently if required by the permit; after any workover that disturbs the seal between the tubing, packer, and casing, or after any repair work on the casing; and when a request is made to suspend or reactivate the injection or disposal permit. In the event where a loss of mechanical integrity occurs, the injection well is immediately shut-in and an investigation begins to determine the cause of the loss in mechanical integrity. The MRV plan notes that the resulting documentation from the investigation that identifies the root cause will also contain an estimate of the volume of CO_2 leaked to be included in the annual subpart RR report.

As noted, production and shut-in well pressure surveillance is conducted by the operators. If surveillance discovers an event that is a 10 percent deviation in pressure outside the expected value, then an investigation occurs to determine if the variance poses a leakage threat. If investigation of an event identifies that a leak has occurred, those events will be documented, including an estimate of the volume of CO_2 leaked and inclusion in the annual Subpart RR report.

The MRV plan describes an acceptable strategy for detecting and quantifying any surface leakage of CO_2 based on the identification of potential leakage risks and for establishing expected baselines for monitoring. The strategy is, therefore, determined to be consistent with the requirements of 40 CFR 98.448(a)(3) and 40 CFR 98.448(a)(4)of subpart RR.

5 Considerations Used to Calculate Site-Specific Variables for the Mass Balance Equation

5.1 Calculation of Mass of CO_2 Received

Petra Nova proposes to use equation RR-2 per 40 CFR 98.443(a)(2) to calculate the amount of CO_2 received. The equation is:

$$CO_{2T,r} = \sum_{p=1}^{4} \left(\varrho_{r,p} - S_{r,p} \right) * D * C_{CO_{2p,r}}$$

Where:

$CO_{2T,r}$ = *CO_2 Received, the injected net annual mass of CO_2 received through flow meter r (metric tons).*

$Q_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).*

$S_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into your well in quarter p (standard cubic meters). Since all delivery to West Ranch is used within the oilfield, the quarterly flow redelivered, $S_{r,p}$ is zero ("0").*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,r}$ = *Quarterly CO_2 concentration measurement in flow for flow meter r in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

r = *Receiving flow meter (M_2, CO_2 concentration for M_2 is measured at M_1).*

Petra Nova provides an acceptable approach to calculating each of these variables in section 8.1 of the MRV Plan.

5.2 Calculation of Total Annual Mass of CO_2 Injected

Section 7.1 of the MRV plan states that the Mass of CO_2 Injected into the Subsurface at the WRU will be calculated as the sum of the Mass of CO_2 Received (calculated using equation RR-2) and the Mass of CO_2 Recycled (calculated using equation RR-5). Petra Nova explains in the MRV Plan that Mass of CO_2

Received is calculated at the terminus of the CO_2 pipeline leading from the CCE by multiplying the CO_2 concentration by the density of the CO_2 as measured at the custody transfer meter. The Mass of CO_2 Recycled is stated to be equal to the Mass of CO_2 Produced. Petra Nova indicates that using data at each injection well would give an inaccurate estimate of total injection volume due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

Petra Nova's approach for calculating the total mass injected is acceptable for the subpart RR requirements.

5.3 Calculation of Total Annual Mass of CO_2 Produced

Section 7.2 of the MRV plan states that Petra Nova will use Equation RR-8 to calculate the annual mass of CO_2 produced and Equation RR-9 to aggregate the mass of CO_2 produced net of the mass of CO_2 entrained in produced oil. The MRV plan states that produced fluids are separated between water, oil, and CO_2. The CO_2 may be sent through a flash gas compressor and recycle gas compressor before being reinjected. CO_2 entrained in produced oil is stated to be measured in accordance with the requirements under 40 CFR Part 98 subpart W.

Petra Nova's proposed approach for calculating the total annual mass produced is acceptable for the subpart RR requirements.

5.4 Calculation of Total Annual Mass of CO_2 Emitted by Surface Leakage

For reporting of the total annual CO_2 mass sequestered under subpart RR, potential surface leaks must be accounted for in the mass balance equation. Pursuant to 40 CFR 98.448(a)(2), an MRV Plan must describe the likelihood, magnitude, and timing of surface leakage of CO_2 through potential pathways. Subpart RR also requires that the MRV plan identify a strategy for establishing a baseline for monitoring CO_2 surface leakage, pursuant to 40 CFR 98.448(a)(4).

In the event surface emissions occur, Petra Nova will calculate and report the mass of CO_2 emitted by surface leakage using Equation RR-10 . The plan states that the total annual Mass of CO_2 Emitted by Surface Leakage will be calculated using various methodologies, including measurements, engineering estimates, and emission factors, used for the leakage originating from subsurface as described in Section 5.1. The plan's approach is acceptable for estimating potential emissions from surface leakage given the likelihood, magnitude and timing of surface leakage as described in the MRV plan.

5.5 Calculation of Mass of CO_2 Sequestered

Petra Nova will use equation RR-11 to calculate the Mass of CO_2 Sequestered in subsurface geologic formations in the reporting year at the WRU. A material balance envelope diagram is provided in Figure 7 of the MRV plan to detail how each element of the mass-balance equation will be calculated.

As part of the mass balance equation, Petra Nova will calculate the total annual CO_2 mass emitted from equipment leaks and vented emissions from surface equipment between the injection flow meter and the injection wellhead and the production wellhead and the separator flow meter using calculation methods in subpart W of the GHGRP.

Petra Nova proposes an acceptable approach for calculating the Mass of CO_2 Sequestered.

6 Summary of Findings

The subpart RR MRV plan for the Petra Nova West Ranch Unit facility meets the requirements of 40 CFR 98.238. The regulatory provisions of 40 CFR 98.238(a), which specifies the requirements for MRV plans, are summarized below along with a summary of relevant provisions in Petra Nova's MRV Plan.

Subpart RR MRV Plan Requirement	**Petra Nova West Ranch Unit MRV Plan**
40 CFR 98.448(a)(1): Delineation of the maximum monitoring area (MMA) and the active monitoring areas (AMA).	Section 3 of the MRV Plan describes the MMA and AMA. The MMA is delineated as equal to or greater than the boundary of the WRU, plus an all-around buffer zone of at least one-half mile and the AMA is defined as the same boundary as the MMA. The MMA and AMA delineations consider site characterization, the extent of free-phase CO_2 within the WRU, fluid pressure and management strategies to retain injected CO_2 within the unit, and reservoir modeling along with prior operating experience.
40 CFR 98.448(a)(2): Identification of potential surface leakage pathways for CO_2 in the MMA and the likelihood, magnitude, and timing, of surface leakage of CO_2 through these pathways.	Section 4 of the MRV Plan identifies and evaluates potential surface leakage pathways. The MRV Plan identifies the following potential pathways: diffuse leakage through the primary confining interval, faults and fractures, natural and induced seismicity, failure of zonal isolation in new and existing wells, drilling through the CO_2 area, lateral migration, and leakage through pipeline and surface equipment. The MRV Plan analyzes the likelihood, magnitude, and timing of surface leakage through these pathways. Petra Nova determined that these leakage pathways are highly unlikely at the WRU facility, and it is very unlikely that potential leakage conduits

	would result in significant loss of CO_2 to the atmosphere.
40 CFR 98.448(a)(3): A strategy for detecting and quantifying any surface leakage of CO_2.	Section 5 of the MRV Plan describes how the facility would detect CO_2 leakage to the surface, such as monitoring of existing wells, field inspections, and pressure monitoring. Sections 5 and 7 of the MRV Plan describe how surface leakage would be quantified.
40 CFR 98.448(a)(4): A strategy for establishing the expected baselines for monitoring CO_2 surface leakage.	Section 6 of the MRV Plan describes the baselines against which monitoring results will be compared to assess potential surface leakage.
40 CFR 98.448(a)(5): A summary of the considerations you intend to use to calculate site specific variables for the mass balance equation.	Section 7 of the MRV Plan describes Petra Nova's approach to determining the amount of CO_2 sequestered using the subpart RR mass balance equation, including as related to calculation of total annual mass emitted as equipment leakage.
40 CFR 98.448(a)(6): For each injection well, report the well identification number used for the UIC permit (or the permit application) and the UIC permit class.	Appendix 2 of the MRV Plan provides well identification numbers for each injection well. The MRV Plan specifies that all injection wells are permitted as UIC Class II wells.
40 CFR 98.448(a)(7): Proposed date to begin collecting data for calculating total amount sequestered according to equation RR-11 or RR12 of this subpart.	Section 8 of the MRV Plan states that the activities described in this MRV Plan are in place, and reporting is planned to start upon EPA approval.

Appendix A: Final MRV Plan

Petra Nova

West Ranch Oil Field CO_2 Monitoring, Reporting and Verification (MRV) Plan

July 2021

Table of Contents

Contents

Introduction

The Petra Nova project is a commercial scale post-combustion carbon capture project utilizing an advanced amine-based absorption technology to capture at least 90 percent of the carbon dioxide (CO_2) from a nominal 240 MW equivalent flue gas slipstream diverted from the coal-fired Unit 8 (Unit 8) at NRG Energy, Inc.'s W.A. Parish Electric Generating Station (Carbon Capture Equipment (CCE)). The CCE is located southwest of Houston, Texas, in rural Fort Bend County, in the town of Thompsons, Texas. The captured CO_2, up to 4,717 metric tons (5,200 short tons) per day, is being dried, compressed, and transported via an 81-mile pipeline to the West Ranch oil field in Jackson County, Texas (West Ranch), where it is used in CO_2 enhanced oil recovery (EOR) operations. Petra Nova Parish Holdings LLC (PNPH), through its wholly-owned subsidiary Petra Nova CCS I LLC, owns the CCE. PNPH is a joint venture between NRG Energy, Inc. (NRG) and JX Nippon Oil and Gas Exploration Corporation (JX).

The CCE uses the Kansai Mitsubishi Carbon Dioxide Recovery Process, also known as KM-CDR Process®, an advanced amine-based CO_2 absorption technology jointly developed by Mitsubishi Heavy Industries, Ltd. and the Kansai Electric Power Co. Inc. The CCE achieved commercial operation on December 29, 2016, and represents the largest commercial-scale deployment of post-combustion CO_2 capture technology at a coal power plant to date.

The CCE has been capturing CO_2 since late 2016 and sending it to West Ranch. The working interest and capital equipment of the West Ranch is owned by Texas Coastal Ventures, LLC (TCV), a joint venture between Petra Nova LLC (a wholly-owned subsidiary of PNPH) and Hilcorp Energy I LP. TCV, through its wholly-owned subsidiary, TCV Pipeline, LLC, owns the dedicated 81-mile CO_2 pipeline between the CCE and West Ranch. Figure 1 outlines the ownership structure of the CCE and TCV.

Hilcorp Energy Company (Hilcorp) is the designated operator of West Ranch. It uses CO_2 captured at and transported from the CCE (Fresh CO_2) and CO_2 produced during the oil production process (Recycled CO_2) for EOR floods at West Ranch.

Petra Nova LLC (PN), a wholly owned subsidiary of PNPH and the 50 percent direct owner of TCV, prepared this Monitoring, Reporting, and Verification Plan (MRV Plan). This MRV Plan and any related reporting will be managed by PNPH through PN on behalf of TCV, with the assistance of Hilcorp, as the operator of West Ranch, including the reporting to the U.S. Environmental Protection Agency (EPA) under its Greenhouse Gas Reporting Program (GHGRP), Subpart RR. The operator will continue to report to the EPA under the GHGRP, Subpart W.

As part of the U.S. Department of Energy (DOE) grant to PNPH, a Monitoring, Verification and Accounting Plan (MVA Plan) was required to be developed and managed by PNPH during a 3-year demonstration period (2017-2019) starting after the commercial operation date of the CCE. PNPH contracted with the Bureau of Economic Geology at the University of Texas at Austin to develop and support the management of the MVA Plan. The DOE approved MVA Plan was deployed a year prior to the beginning of CO_2 injection (to develop a pre-flood baseline) and was in operation until the end of the DOE demonstration period at the end of 2019. The MVA Plan and the knowledge gained from operating under that plan supported the development of the MRV Plan described herein.

The mass balance accounting for determining the quantity of CO_2 stored conforms to the requirements in Subpart RR and is consistent with the method used in the MVA Plan. The method, described in Section 7, uses metered volumes of CO_2 received, injected, and produced, as well as quantified volumes of other CO_2 emissions and losses, if any.

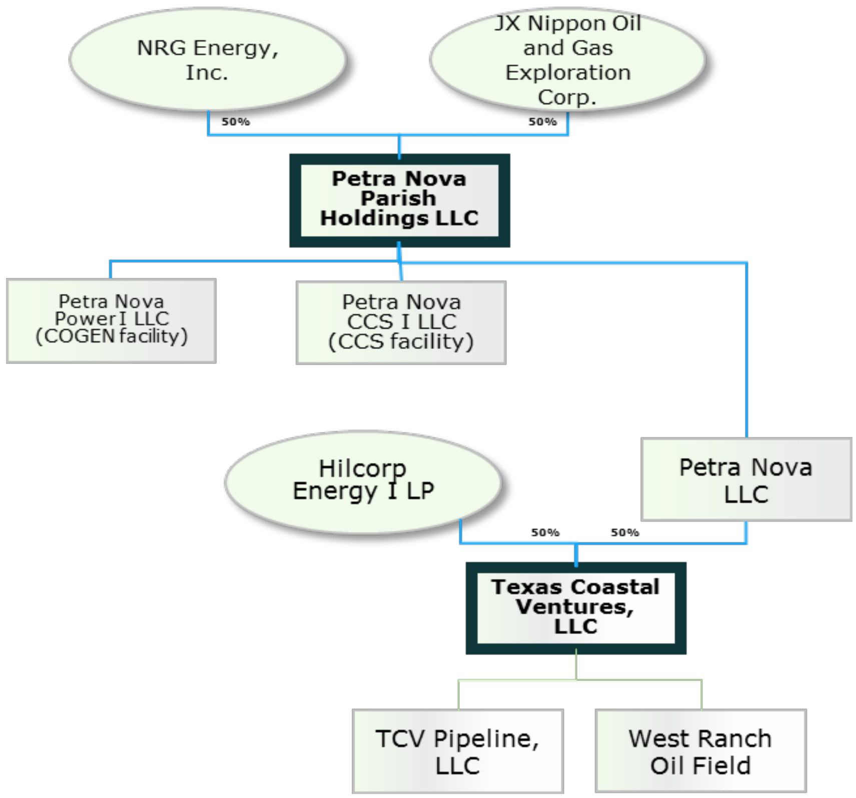

Figure 1 Ownership Structure

Current Status

The mass balance accounting under the MVA Plan started in March 2017, after the commissioning of the surface facilities at West Ranch. Through the end of 2020, the amount of CO_2 sequestered is listed below in metric tons. The difference between CO_2 delivered and CO_2 sequestered is the mass of CO_2 lost at the surface.

	CO_2 Delivered at West Ranch (Metric Tons)	CO_2 Sequestered at West Ranch (Metric Tons)
2017 (Mar-Dec)	909,419	904,757
2018	1,008,601	996,154
2019	1,386,987	1,373,958
2020	293,171	281,542
Total	**3,598,178**	**3,556,411**

MRV Plan Overview

This MRV plan contains twelve sections:

Section No.	Topic
1	Facility information
2	Project description. This section describes the overall project information; the geology, reservoir characterization and development history; the current operation and infrastructure including the CO_2 injection process; and the CO_2 storage capacity at West Ranch.
3	Delineation of monitoring area and timeframes
4	Evaluation of potential pathways for CO_2 leakage to the surface
5	Site-specific risk-based monitoring
6	Determination of baselines
7	Determination of sequestration volumes using mass balance equations
8	MRV Plan implementation schedule
9	Quality assurance program
10	Records retention
11	References
12	Appendices

1. Facility Information

a. Reporter number – 575661 Petra Nova West Ranch

b. The wells at West Ranch are permitted by the Texas Railroad Commission (TRRC), through TAC 16 Part 1 Chapter 3. The TRRC has primacy to implement the federal UIC Class II requirements and incorporated those provisions in TAC 16 Part 1 Chapter 3.

c. All wells at West Ranch are identified by name, API number, status, and type. A listing of the wells as of December 2020 is included in Appendix 2.

2. Project Description

2.1 Petra Nova Carbon Capture Facility and West Ranch Oil Field

When operating at 100 percent load, the CCE captures approximately 4,717 metric tons (5,200 short tons) per day from Unit 8 of NRG's W.A. Parish Power Station near Houston, Texas. The

captured CO_2 is compressed, dried, cooled, and transported to West Ranch via 81-mile long CO_2 pipeline. The CCE is the only source of CO_2 delivered for injection at West Ranch during the "Specified Period" as discussed below. West Ranch is located in southeast Texas in Jackson County near the town of Vanderbilt as shown in Figure 2.1.1.

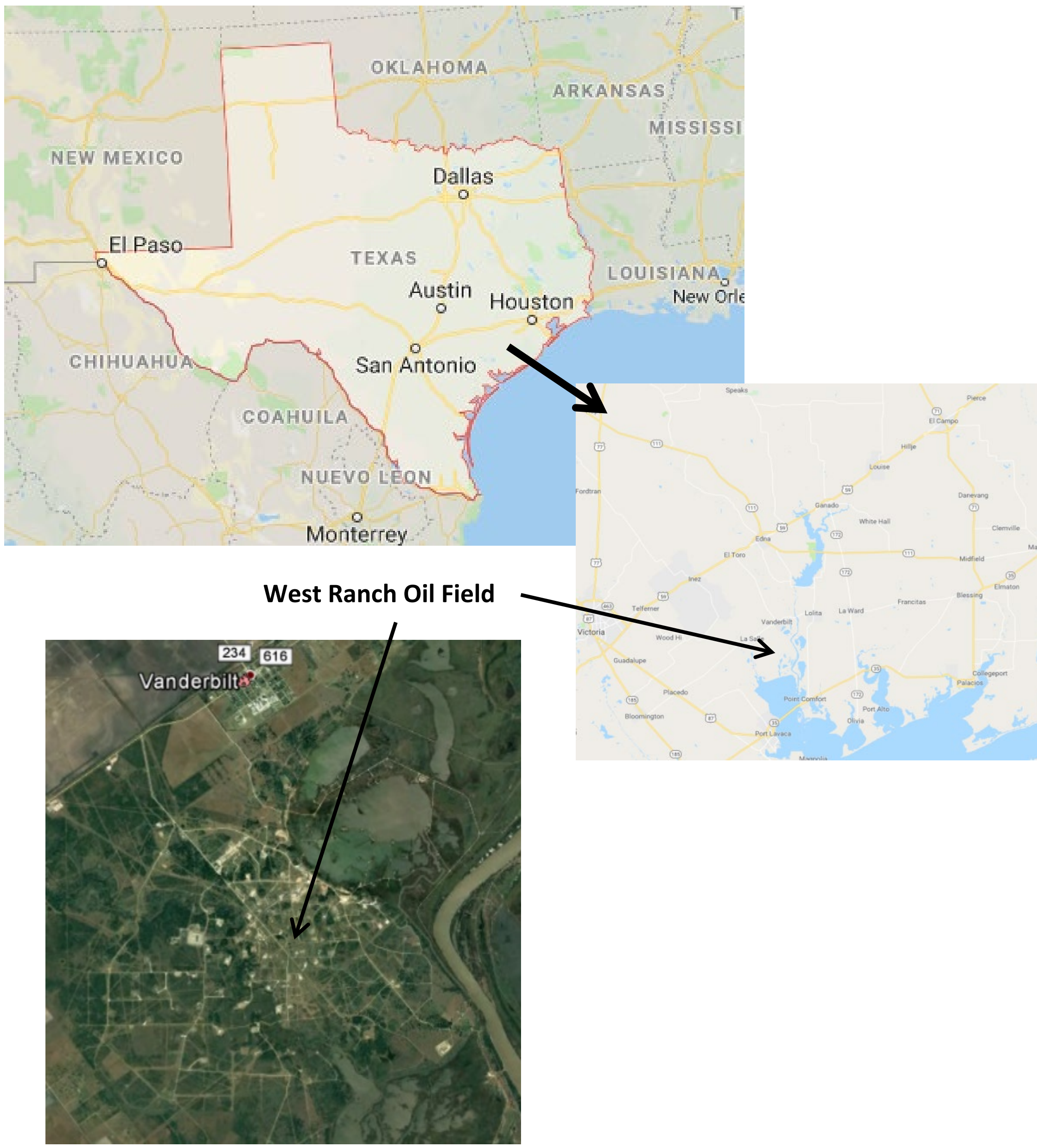

Figure 2.1.1 Location of West Ranch Oil Field

The West Ranch Unit (WRU) boundary for the current CO_2 EOR operation is delineated in Figure 2.1.2. The WRU was formed by consolidating portions of two Oligocene-age reservoirs, the 98-A and 41-A, within the Frio Formation.[1]

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[1] The 98-A and 41-A zones are unitized as West Ranch 41-A/98-A (Consolidated) Unit in 2016 (O & G Docket No. 02-0299798).

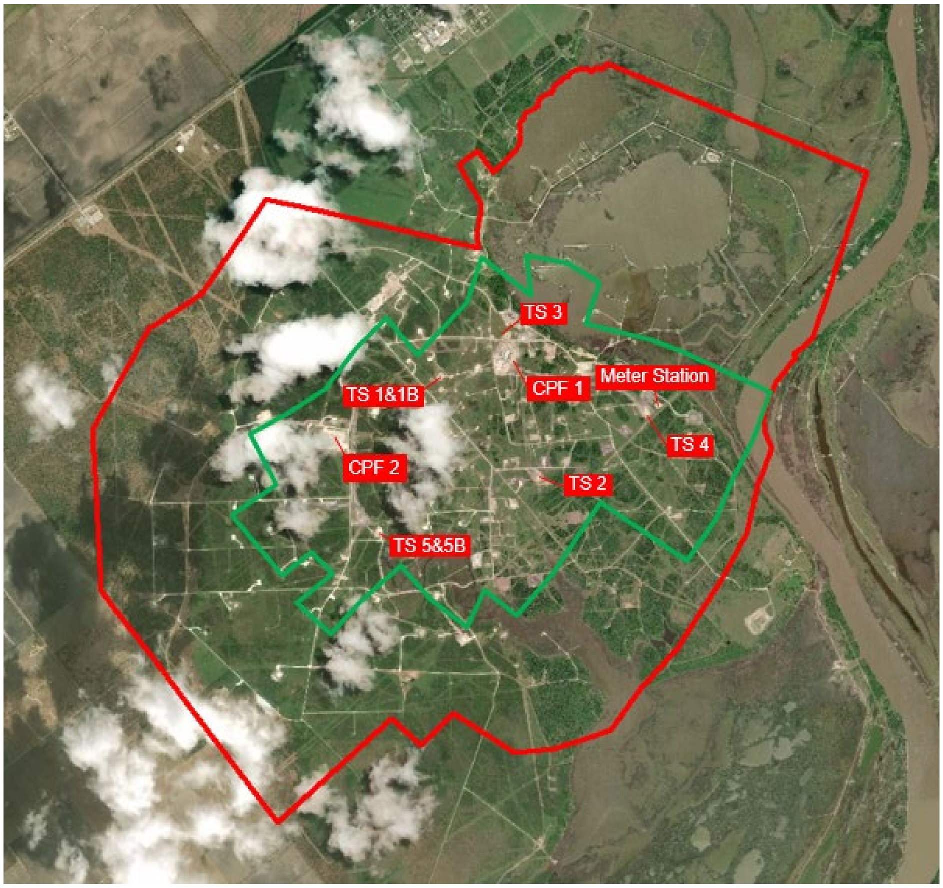


Figure 2.1.2 West Ranch Unit (41-A/98-A (Consolidated) Unit) Boundary (in Red)

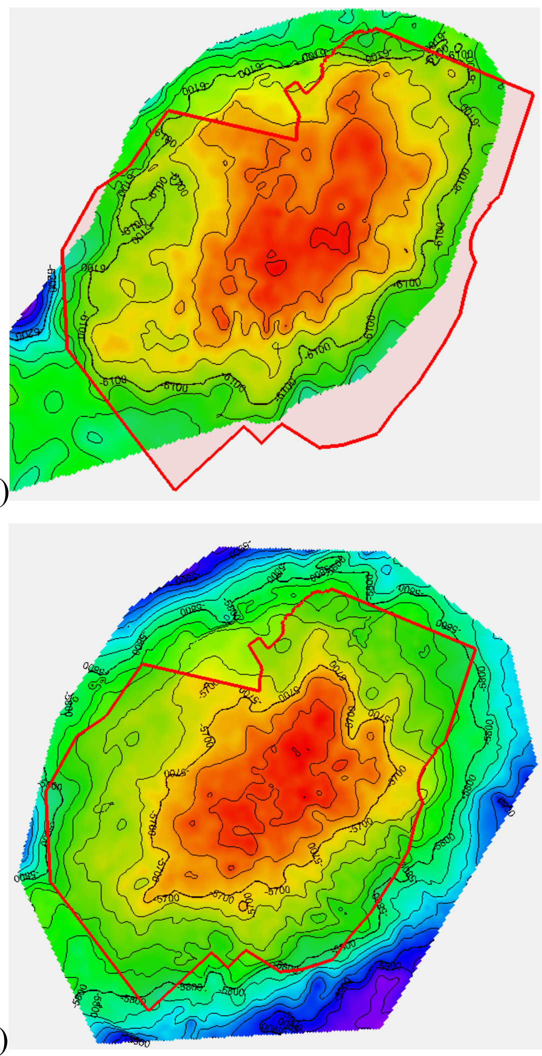
CO_2 flooding was initiated in the 98-A reservoir in December 2016 and has been subsequently expanded horizontally. While the horizontal expansion of the 98-A reservoir is still ongoing, a vertical expansion into the 41-A reservoir, which lies immediately above the 98-A reservoir, began in 2018. The CO_2 EOR operations at West Ranch are planned to expand horizontally and vertically upward over time, including the CO_2 flooding of additional portions of the 98-A and 41-A reservoirs, and three additional reservoirs in the Frio Formation: Greta, Glasscock, and Ward. This MRV Plan anticipates the expansion into the entire interval between the base of 98-A reservoir and the base of the Anahuac Shale, a regionally contiguous and impermeable shale immediately above Frio Formation at West Ranch (Project Interval). In order to expand into the full Project Interval, the operator will obtain TRRC approval for certifications as tertiary recovery projects, unitization agreements, and permits to conduct fluid injection operations in each area of expansion in the Project Interval. The reservoirs in the Project Interval have similar geologic characteristics and the operator will apply the same operational controls in each area of expansion. All injection zones in the Project Interval share the following characteristics:

- four-way dip anticline trapping mechanisms,
- no faulting,
- presence of a primary confining intervals above each injection zone within the Project Interval and a secondary confining interval (Anahuac Shale) that overlays the entire project area, and
- depleted reservoir pressure.

The operational requirements that currently apply in WRU will also apply in the expansion zones. They include rules for injection wells such as the confirmation of nearby well condition, the periodic testing of casing integrity, the adequate cementing to confine fluids in the injection reservoir, and the monitoring and limitation of injection pressure. Based on these conditions, PNPH believes that all reservoirs within the Project Interval at West Ranch can be included under this MRV Plan as they are brought online.

2.2 Petroleum Geology of West Ranch Oil Field

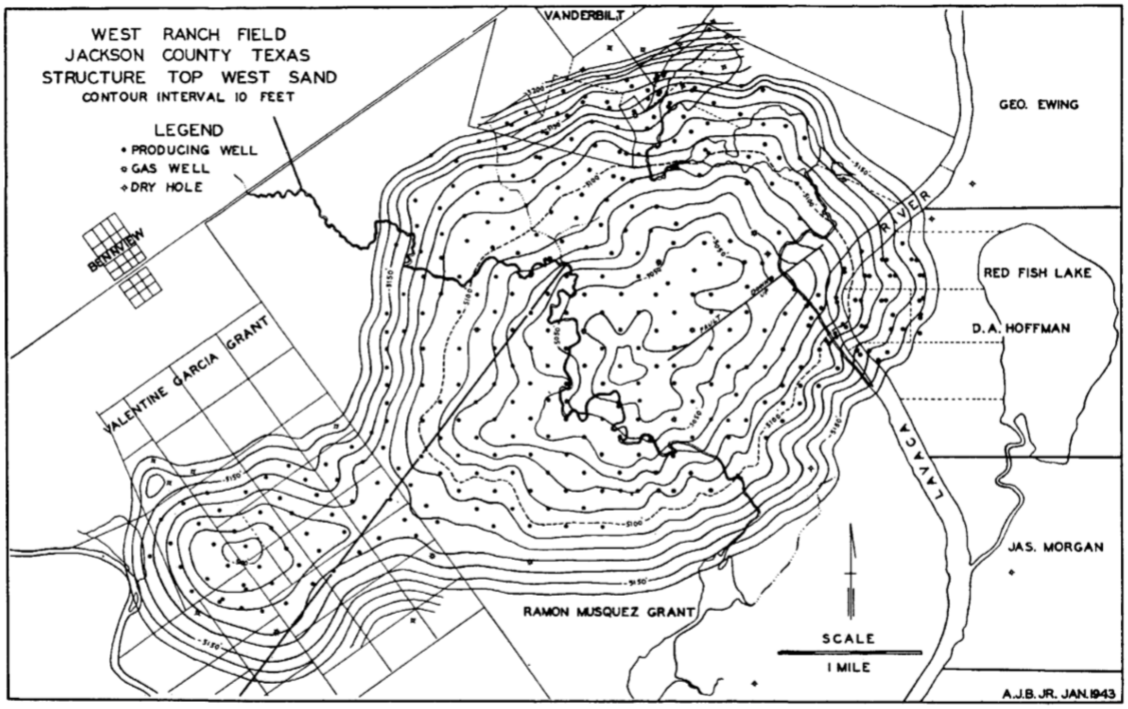
West Ranch is one of several oil fields located in the Gulf Coast Basin that shares the same petroleum system. West Ranch is formed on a gentle four-way anticlinal structure on a roll-over structure (Figures 2.2.1(a), 2.2.1(b), 2.2.2(a), and 2.2.2(b)) on the upthrown side of a northeast-southwest trending regional growth fault as shown in Figure 2.2.3.



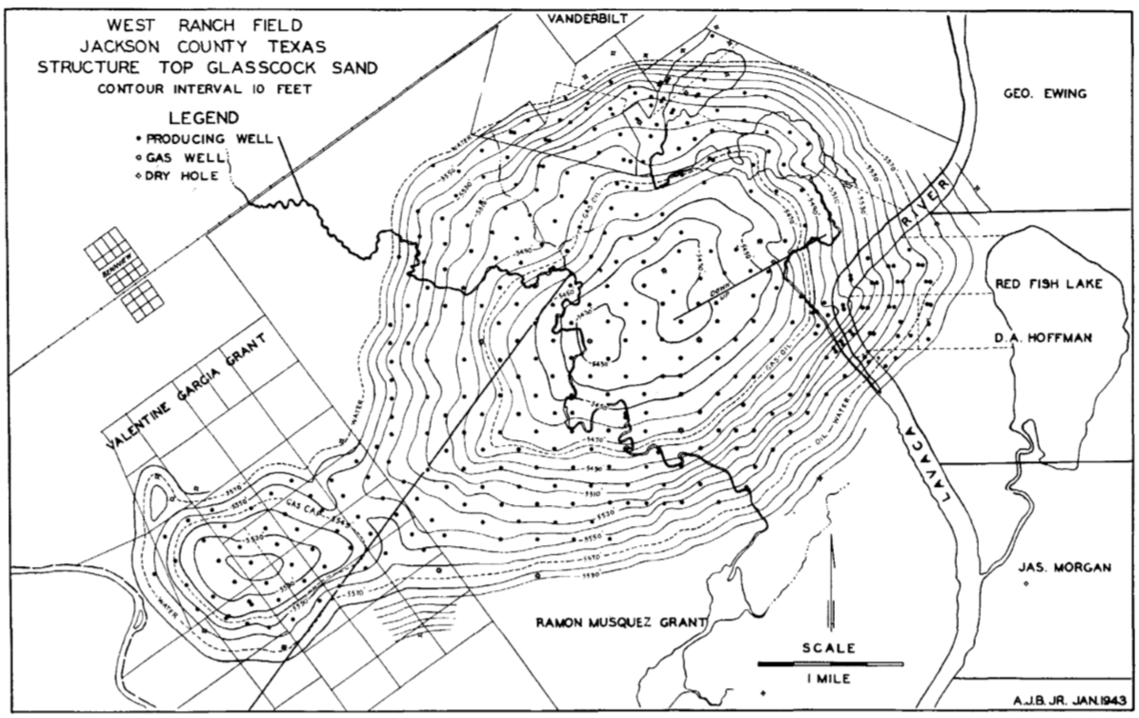
(a)

(b)

Figure 2.2.1 Structure-contour map of West Ranch Oil Field with the currently existing WRU boundary (41-A/98-A Consolidated) (red outline). Datum is the top of (a) 98-A and (b) 41-A reservoirs.



(a)



(b)

Figure 2.2.2 Structure-contour map of West Ranch Oil Field. Datum is the top of (a) the Greta and (b) the Glasscock reservoirs (Baurenschmidt, 1944).

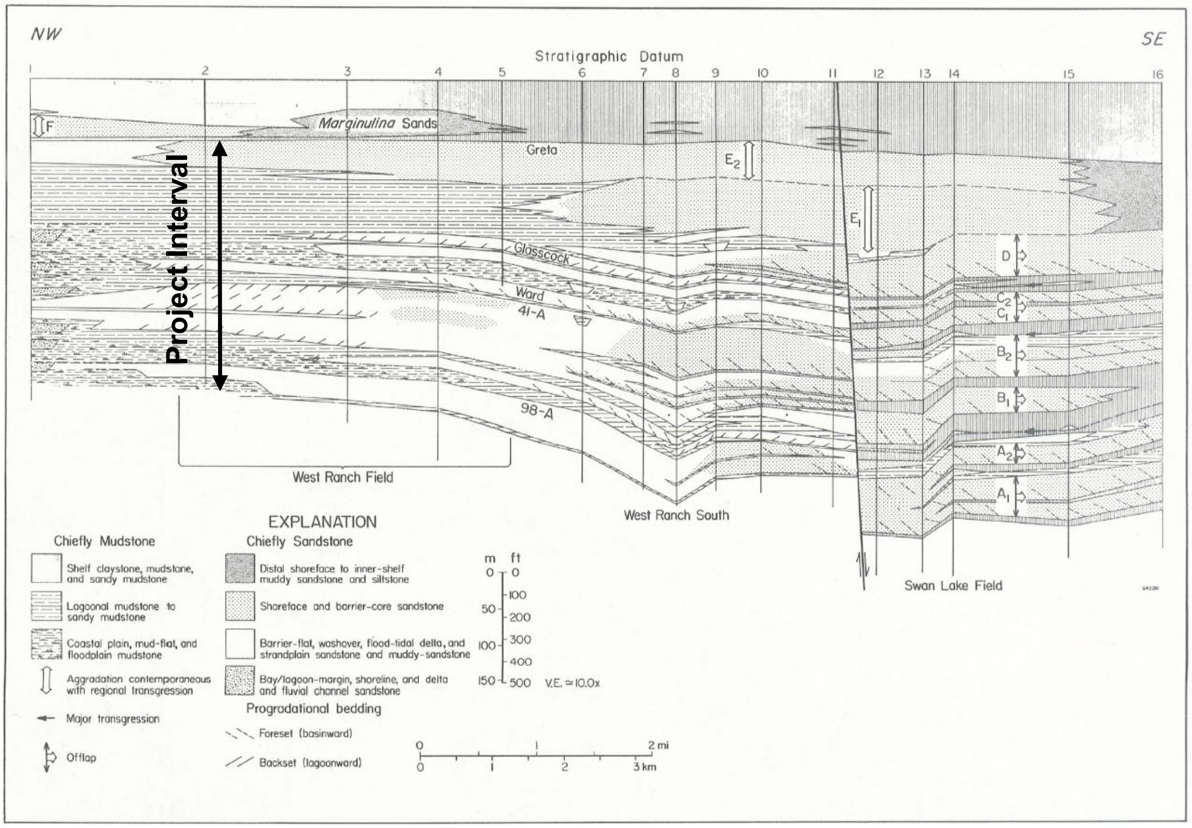


Figure 2.2.3 Regional cross section though West Ranch Oil Field showing non-faulted structure. From Galloway and Cheng, 1985

2.3 Stratigraphy of the West Ranch Oil Field Area

The generalized stratigraphic section illustration of geologic formations present at West Ranch is shown in Figure 2.3.1. The reservoir sandstones into which CO_2 is currently or planned to be injected at West Ranch include five reservoir sandstones in Frio Formation, being 98-A, 41-A, Ward, Glasscock, and Greta, from the deepest (6,200 feet) to the shallowest (5,100 feet). Each reservoir sandstone is separated by locally continuous low permeability and individually confining mudstones (Figure 2.3.2).

Anahuac Shale is a low-permeability confining layer that has served as a stratigraphic seal to prevent upward migration of hydrocarbon throughout geologic term for many oil fields throughout the Gulf Coast region (Galloway and Cheng, 1985), and it serves as the secondary seal in addition to the individual confining layers overlaying each reservoir.

Above Anahuac Shale is a series of sandstones separated by shales collectively known regionally as Oakville Formation, also referred to as Miocene Sands.

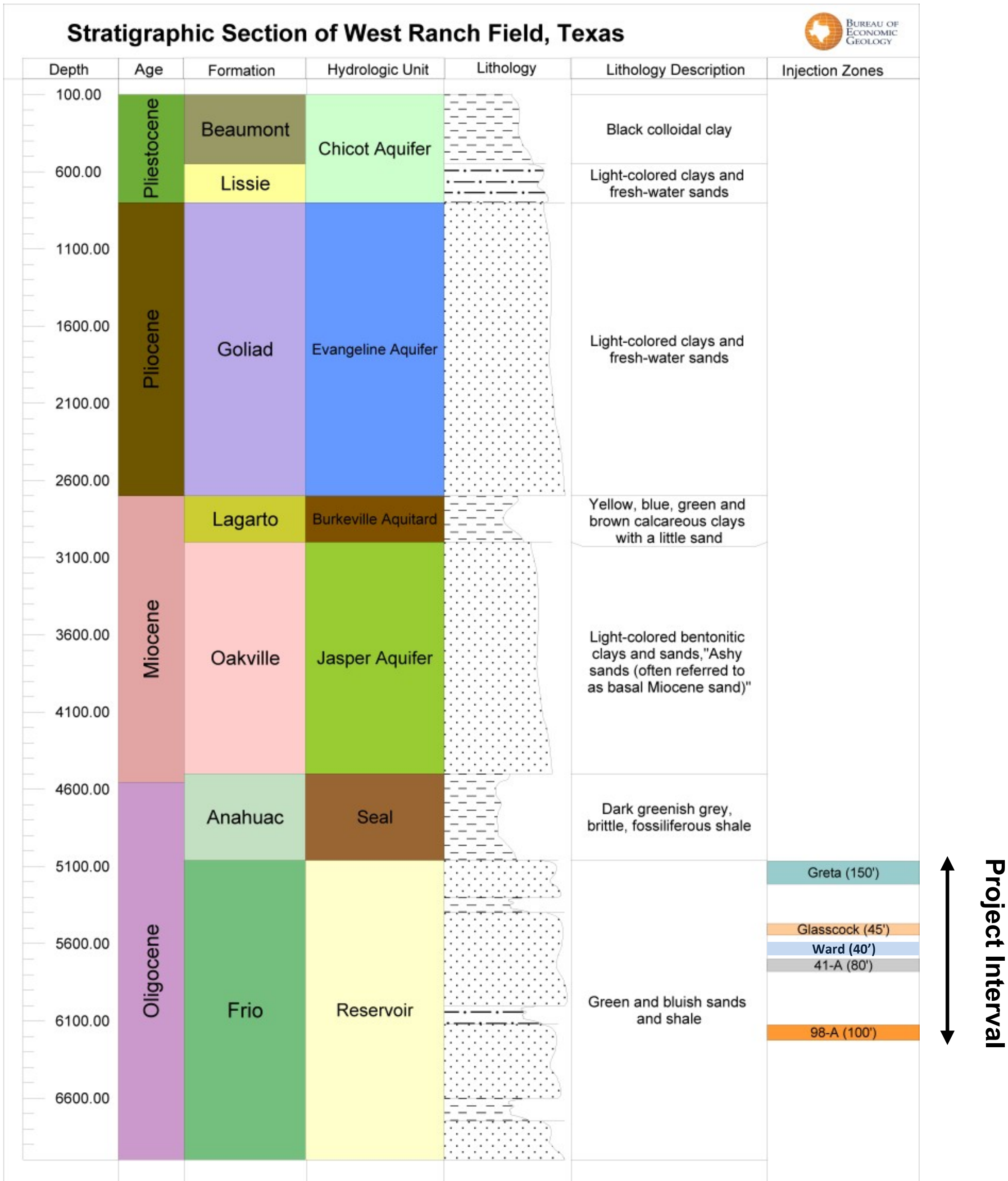


Figure 2.3.1 Generalized lithostratigraphic and hydrostratigraphic names for rocks/aquifers underlying West Ranch Oil Field. Depths shown correspond with those seen at West Ranch Oil Field. The Project Interval is indicated on the right.

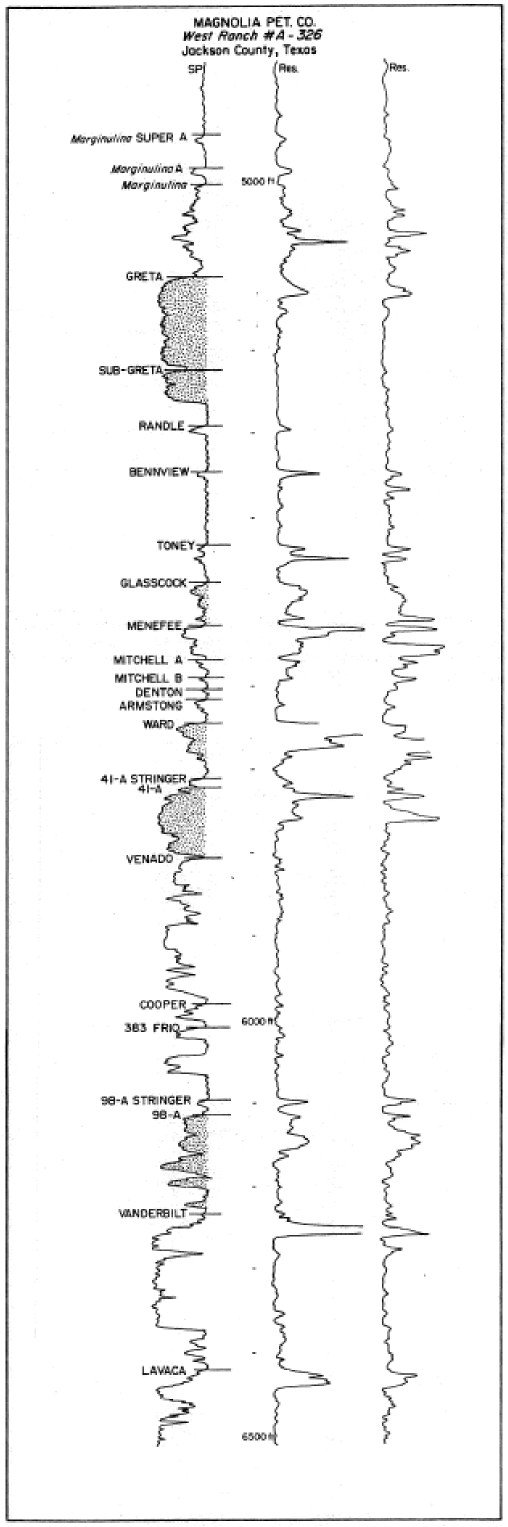


Figure 2.3.2 Type log for West Ranch Oil Field, modified from Galloway (1983), shows the entire injection zone for Project Interval. Current CO_2 EOR flooding is in the 98-A and 41-A, future expansion will be into the permeable zones (Ward, Glasscock, Greta). Each permeable zone is interspersed with non-permeable zones that serve as the primary confining layers. The secondary confining layer, the Anuhuac Shale is not marked on this Type log.

2.4 Depositional Environment of the West Ranch Oil Field Area

The reservoirs of West Ranch are part of the extensively characterized Oligocene-aged Frio Formation in the barrier/strandplain system, located between the Houston and Norias Delta Systems (Galloway et. al., 1983) (Figure 2.4). The barrier/strandplain system is composed of the northeast-southwest elongated bodies of laterally deposited shoreline sands, similar to the Padre-Mustang-St. Joseph-Matagorda island complex of today.

Within the barrier/strandplain system, the barrier island and shoreface deposits, such as the Greta reservoir, are well sorted, continuous, sandy, and internally homogeneous as a result of their high-energy, shallow-marine depositional origin. The Glasscock reservoir is one of the most widespread reservoirs in the field. It is a particularly thin barrier-island sand body that was deposited before a local transgression terminating the "C" cycle of strandplain progradation. The 41-A reservoir is a moderately thick sand body that occurs at the top of the widespread sand of the "B" cycle. Well-developed upward-coarsening sequences do not appear at the stratigraphic position of the 41-A reservoir for several miles farther basinward. Stratigraphic relationships suggest that much of the reservoir is overlain, and therefore sealed, by lagoonal mudstones deposited landward of a prograding barrier-sand complex. The 98-A and Ward reservoirs are both relatively thin progradational sand units (Galloway, 1986).

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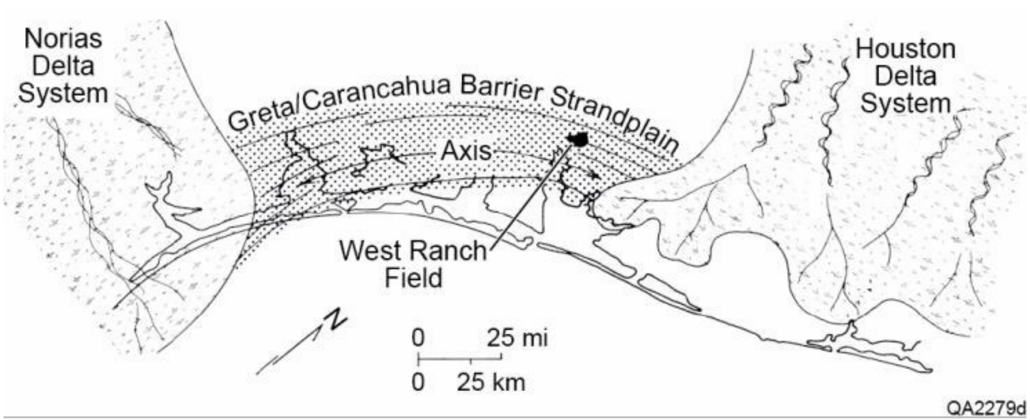


Figure 2.4 Oligocene (Frio) paleogeographic setting of Texas Gulf Coast, showing West Ranch Oil Field within Greta/Carancahua Barrier Strandplain System. Ambrose et al. (2008); modified from Galloway and Cheng (1985) and Galloway (1986).

2.5 Reservoir Characterization and Modeling

As previously discussed, PNPH, working with the BEG, developed and managed an MVA Plan that covered the three-year demonstration period that started on January 1, 2017 (aligned with the beginning of commercial operations of the CCE). As a part of the MVA Plan, reservoir modeling was used to characterize the currently existing WRU reservoirs, i.e., 98-A and 41-A, to develop a detailed understanding of each reservoir as well as the predictability of internal reservoir architecture, including the behavior of CO_2 in the course of CO_2 EOR operation. In general, the modeling was successful in demonstrating that the pressure elevation and the movement of CO_2 plume in the reservoirs are managed by the operational strategies, and the reservoirs have the capacity to permanently retain the injected CO_2 volume within the structural trap for prolonged period after the cessation of CO_2 EOR operation.

Reservoir modeling is the major predictive tool that determines the capacity of the subsurface to accept CO_2. Numerical simulation models are used to model the spatial extent of the CO_2 plume in the subsurface, which demonstrates that, under given assumptions and operational strategies, CO_2 is remaining within the targeted area. The numerical simulation modeling starts by building static reservoir models. The tops and bases of target sandstones and major seals are defined with well logs. The model is then constructed based on rock properties interpreted from Spontaneous Potential and Gamma-Ray logs, and to a limited extent, core sample studies at West Ranch. Rock properties were also assigned based on available data through literature review and historical field measurements.

A numerical simulation model of the 98-A and 41-A reservoirs was constructed based on the static geologic model as well as fluid properties (fluid compositions and PVT (pressure-volume-temperature) data) from the field, to develop a dynamic numerical model to history match the production and pressure data of the field, and to simulate the current and future performance of the field. The numerical model is developed using a compositional simulator. In compositional simulations, three phases (water, oil, and gas) with multiple components were defined. Relative permeability data, available through literature survey and special core analysis, was used as input in the simulations. Thermodynamic properties of the specific fluids in this field were tuned and modeled in a fluid characterization software.

The porosity and permeability maps of the model are shown in Figure 2.5.1 and 2.5.2.

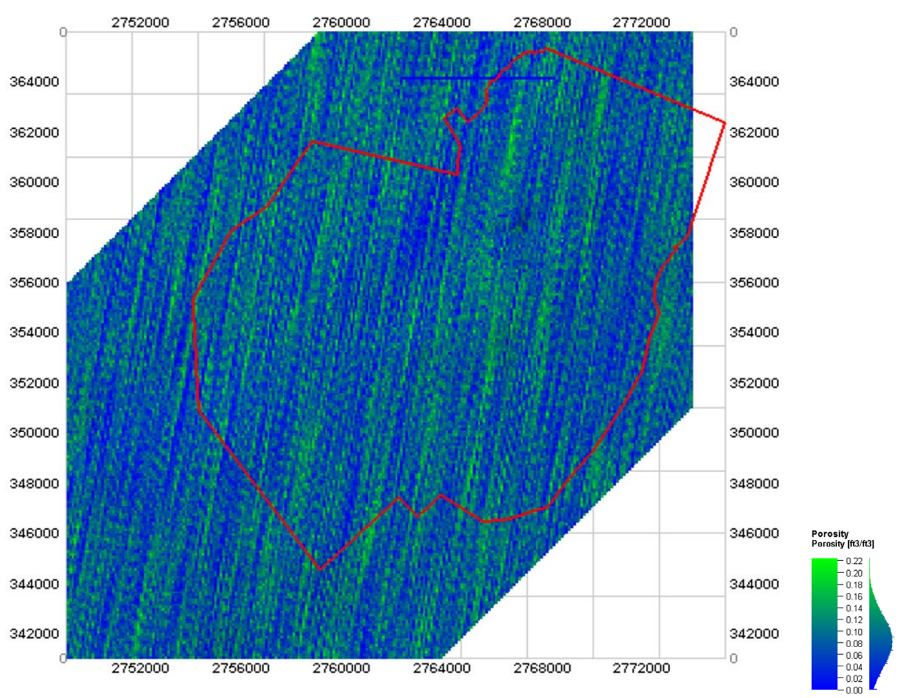


Figure 2.5.1 Porosity distribution of 98-A input into the numerical simulation model with 41-A/98-A Consolidated Unit (red)

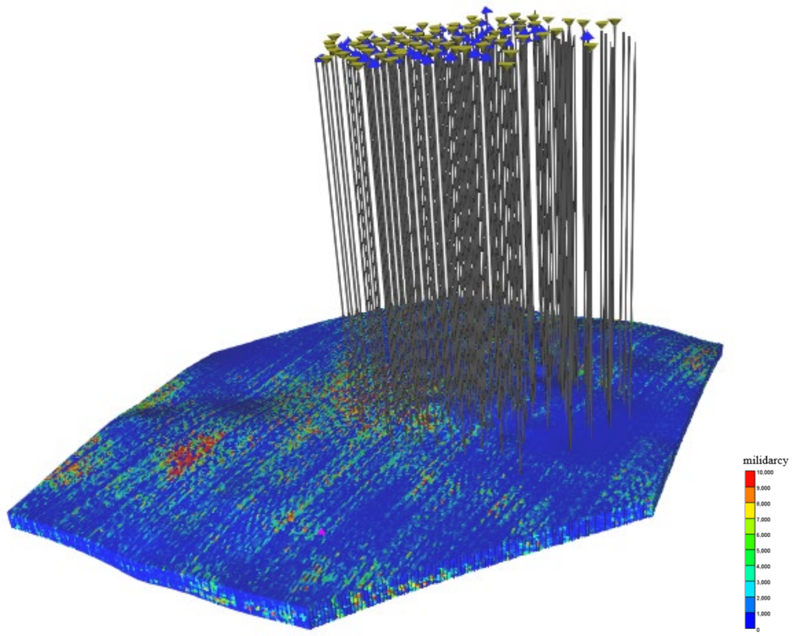


Figure 2.5.2 Location of EOR operation wells and horizontal permeability of 98-A input into the numerical simulation model.

The expected pressure and the gas saturation fields in the 98-A reservoir as of March 2020 based on the simulation model, with the best history match until September 2019, are shown below (Figure 2.5.3 and Figure 2.5.4). Overall results show that the pressure values remain within the intended range and below the fracturing pressure. Gas saturations are larger around the injection wells and mostly remain in the intended patterns.

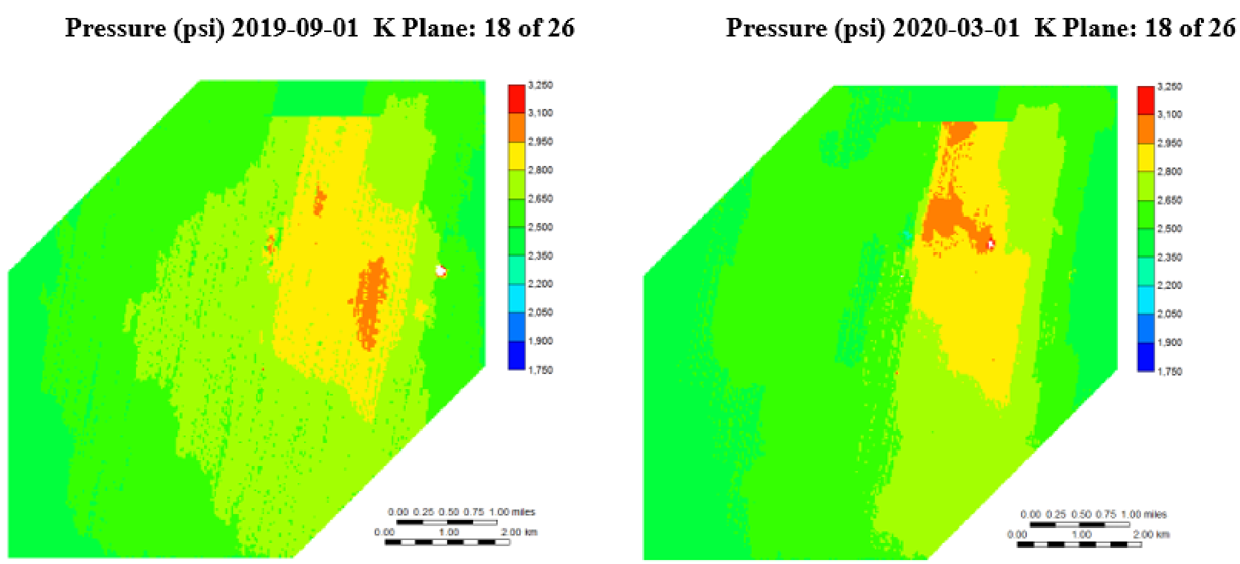


Figure 2.5.3 Pressure field at 98-A reservoir in (a) September 2019 and (b) March 2020.

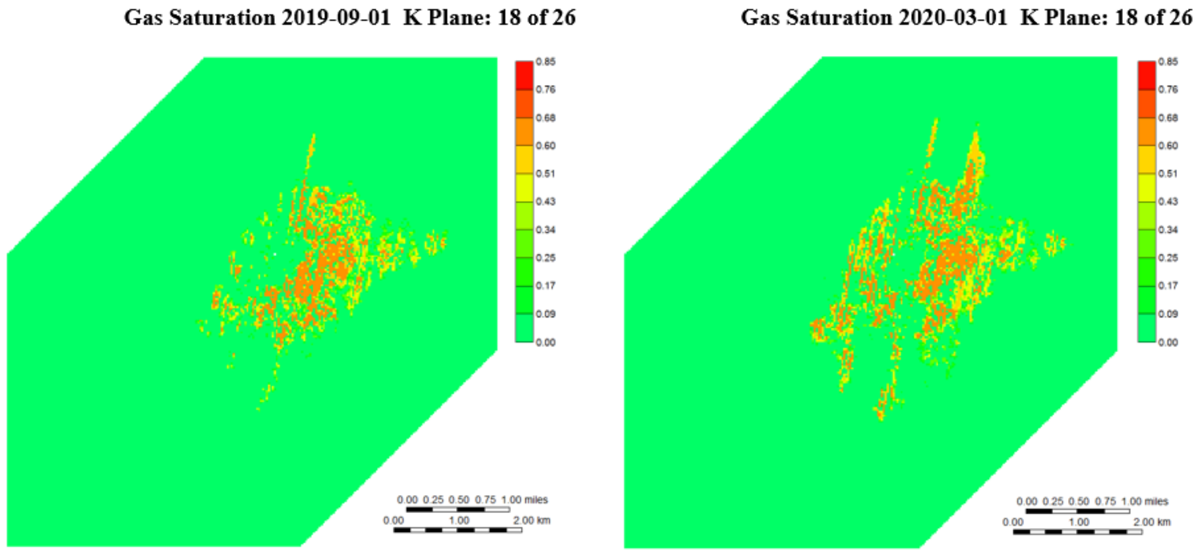
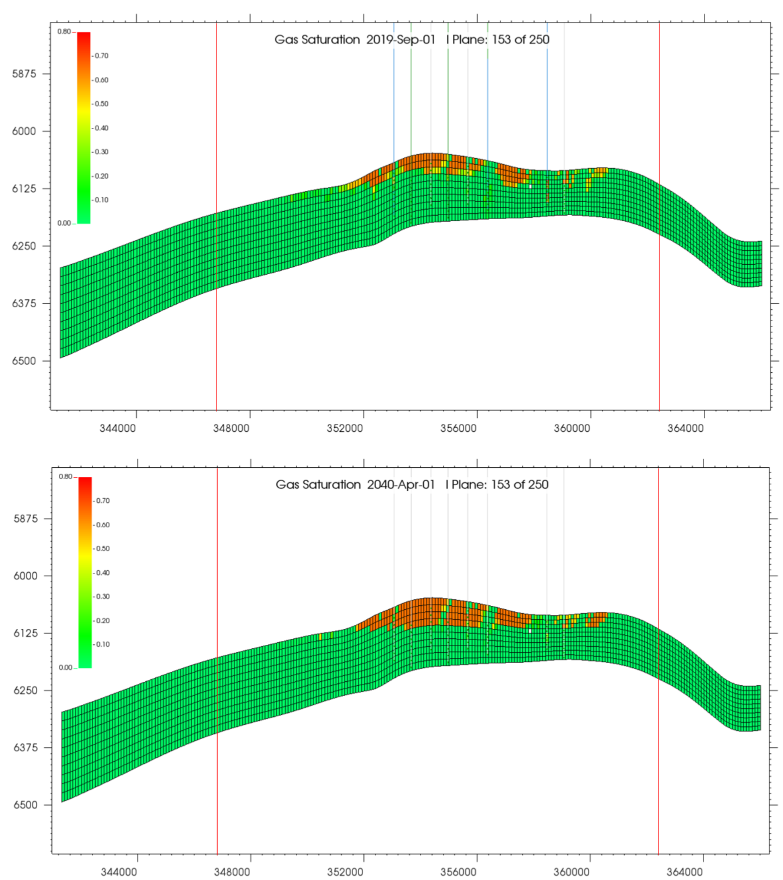


Figure 2.5.4 Gas saturation at 98-A reservoir in (a) September 2019 and (b) March 2020.

A long-term simulation was also run through 2040, and the result shows that CO_2 accumulates at the crest of structure and within the intended area (Figure 2.5.5).



(a)

(b)

Figure 2.5.5 Demonstration of gas migration after CO_2 flooding. Gas saturation at 98-A reservoir in (a) September 2019 and (b) April 2040 with 41-A/98-A Consolidated Unit (red)

2.6 Development of West Ranch Oil Field, Primary and Secondary Production

West Ranch was discovered in 1938. The main reservoirs at West Ranch (Greta, Glasscock, Ward, 41-A, and 98-A) are porous and permeable, averaging more than 27 percent porosity and 400 mD permeability. The discovery and original conditions of main producing reservoirs, and the oil field operations including hydrocarbon production and brine injection, are described in this section. Besides the five main producing sands, 79 additional minor reservoirs have been classified as producing sands by the TRRC.

At discovery, a primary gas cap was in contact with the oil zone in all main oil-producing reservoirs. This indicates vertical hydraulic isolation of each sand zone. These reservoirs were originally produced with a gas-cap expansion and/or a natural water drive. Glasscock and Ward reservoirs were constituted from oil-rim reservoirs with gas caps as large as one-third of the volume, and 95 percent of the energy thereof was attributable to the expansion of their gas caps (Galloway and Cheng, 1985). The Greta, 41-A, and 98-A reservoirs were mainly energized by strong natural water drive.

In most of the water-injection programs, water was injected into reservoirs along the periphery of their gas caps to maintain reservoir pressure and to prevent expansion of the gas cap into the oil-bearing zone (Galloway and Cheng, 1985).

Cumulative oil production in the main reservoirs as of 2010 is provided in Table 2.6.1.

Reservoir	Discovery Date	Cum. Prod. (MMSTB)
Greta	1938	101.3
41-A	1940	99.5
98-A	1940	59.2
Glasscock	1939	45.8
Ward	1939	30.4

Table 2.6.1 Cumulative oil production of major reservoirs at West Ranch Oil Field from TRRC (2010)

The original reservoir conditions, such as fluid contact depths, water saturation, and solution gas ratios, are listed in Table 2.6.2, along with average rock and fluid properties.

	Greta	Glasscock	Ward	41 A	98 A
Gas-Oil contact, ft ss	5,065	5,475	5,705	5,690	6,070
Oil-Water contact, ft ss	5,105	5,570	5,735	5,750	6,140
Average porosity, %	30	27	30	30	31
Average permeability, md	1,200+	400	1,200	1,700	500
Original pressure, psia	2,350	2,560	2,650	2,625	2,795
Reservoir temp, °F	160	166	171	171	178
Oil gravity, API	24.7	31.6	30.6	31.1	40.4
Solution gas ratio, scf/stb	306	440	451	500	671

Table 2.6.2 General reservoir data and original conditions of main sands at West Ranch Oil Field (Bauernschmidt, 1962)

Initial reservoir pressures found in West Ranch indicate an original hydrostatic pressure gradient of approximately 0.53 psi/ft (Figure 2.6.1). Kreitler and Akhter (1990) gathered and plotted nearly 17,400 pressure values from a commercial database to study the complex hydrologic regimes of the Texas Gulf Coast region. Two major gradients are observed: (1) a formation water hydrostatic regime (0.465 psi/ft) that reaches depths of 11,000 ft, and (2) a geopressured regime as shallow as 7,000 ft. Both have been extensively depleted by production, although the original profile can be identified by plotting the maximum pressures. The West Ranch pressure gradient is not geopressured but is slightly steeper than the average hydrostatic gradient for freshwater in the area (Figure 2.6.2(a)). A current pressure profile from the A-600 well in 2012, the injection location for a recent CO_2 injection test, is imposed over the Kreitler and Akhter (1990) Gulf Coast pressure profile for comparison (Figure 2.6.2(b)). The A-600 well profile shows strongly depleted zones, likely resulting from past production of reservoirs that lacked good connection to water drive. In contrast, the pressure of Greta, 41-A and 98-A reservoirs indicates the strong natural water drive as mentioned above.

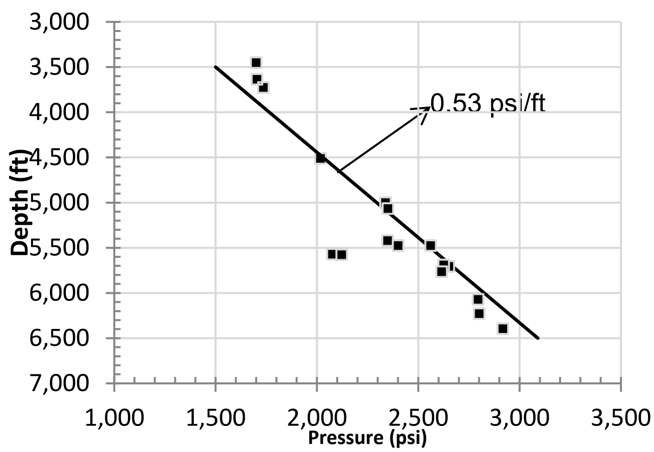


Figure 2.6.1 West Ranch hydrostatic pressure gradient. Adapted from Bauernschmidt (1962)

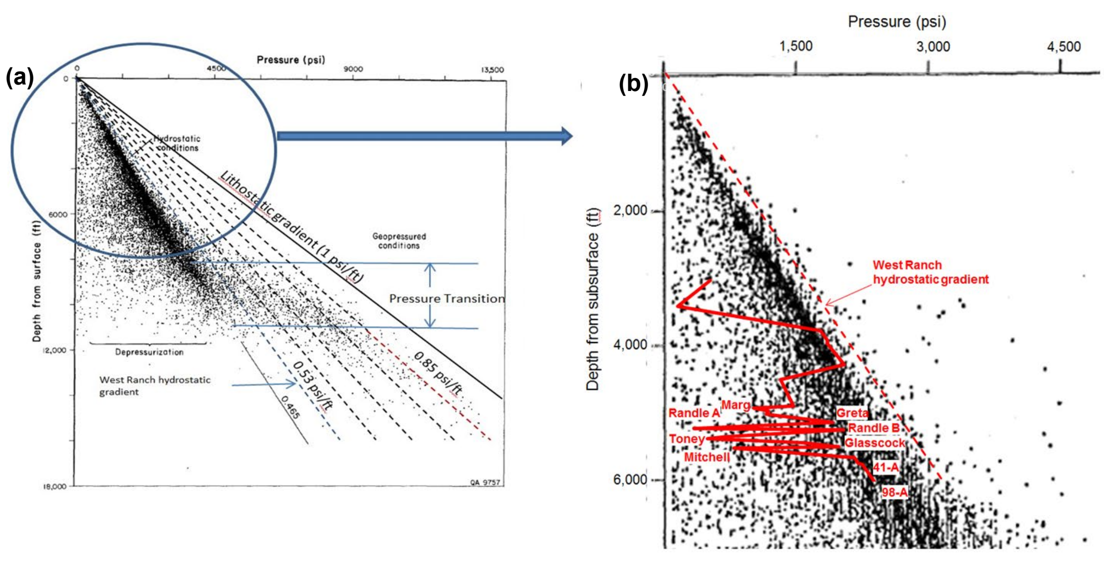


Figure 2.6.2 (a) Gulf Coast pressure profile. Pressure measurements from drill-stem tests (DST) and bottom-hole pressures, adapted from Kreitler and Akhter (1990), and (b) Current pressure profile at West Ranch Oil Field in red at A-600 well plotted against Gulf Coast pressure profile.

2.7 Regulatory Process

Prior to commencement of any underground injection of CO_2 for EOR, the operator must submit a permit application and obtain approval from the TRRC. Texas Administrative Code (TAC) Title 16 Part 1 §3.46 governs fluid injection into reservoirs for production of oil, gas, or geothermal resources. The information required in the application includes the data concerning the project, the subject reservoir, and the well(s); and the geographic description of area covered by the project. The technical requirements include: the isolation from usable-quality water by 250 feet of low permeability strata, the area of review (AoR) to determine if all abandoned wells within one-quarter (1/4) mile radius of the proposed well have been properly plugged, the cementing interval for surface and production casings, the packer setting depth, the injection pressures, and in certain areas, a seismicity review. Notice of application must be given to parties affected or who may be affected by implementation of the project along with notice to local regulatory bodies and the public. There is an opportunity for a hearing in the event of a protest. After permit approval, a mechanical integrity test is required to be performed for each well before injection and periodically thereafter, and the operator is obligated to file a completion report and annual injection report.

Unitization is necessary to conduct CO_2 EOR operations at reservoirs which straddle multiple tracts with separate and divergent ownership interests, primarily to determine the participation formula of interest owners. Unitization is subject to TRRC approval, and the information required and the procedure employed are similar to those applicable to the injection permitting process. The project must satisfy all of the requirements set out in Texas Natural Resources Code Title 3 Subtitle C Chapter 101, including (a) unit operations are necessary to increase ultimate recovery from the reservoir or prevent waste, (b) correlative rights of interest owners are protected, and (c) the additional cost involved does not exceed the additional recovery anticipated. The approval is also subject to receiving the injection permits.

There are also economic incentives to conduct CO_2 EOR operations in Texas, particularly those with anthropogenic CO_2. There is a severance tax on crude oil, and a 50 percent reduction in that severance tax rate by obtaining an EOR project certification under TAC Title 16 Part 1 §3.50, which is further lowered by additional 50 percent, to 25 percent of the original rate, if anthropogenic CO_2 is used and the certification under TAC Title 16 Part 1 Subchapter C is obtained. The TRRC must approve a measurement, monitoring and verification program for stored anthropogenic CO_2, and the certification is issued only if the TRRC finds that at least 99 percent of the CO_2 sequestered will remain sequestered for at least 1,000 years.

The current CO_2 EOR operations in the WRU for 98-A and 41-A reservoirs have gone through all regulatory processes as discussed in this section, and the same processes will be followed when the development area in West Ranch expands either horizontally outside of the existing WRU, or vertically upwards to Greta, Ward, Glasscock or other sub-layers.

2.8 Description of CO_2 EOR Project Facilities and the Injection Process

2.8.1 West Ranch Oil Field Facility Description

The following two figures illustrate the CO_2 EOR process at West Ranch. Figure 2.8.1 is a generalized facility flow diagram and Figure 2.8.2 shows the location of all facilities within the

WRU boundary.

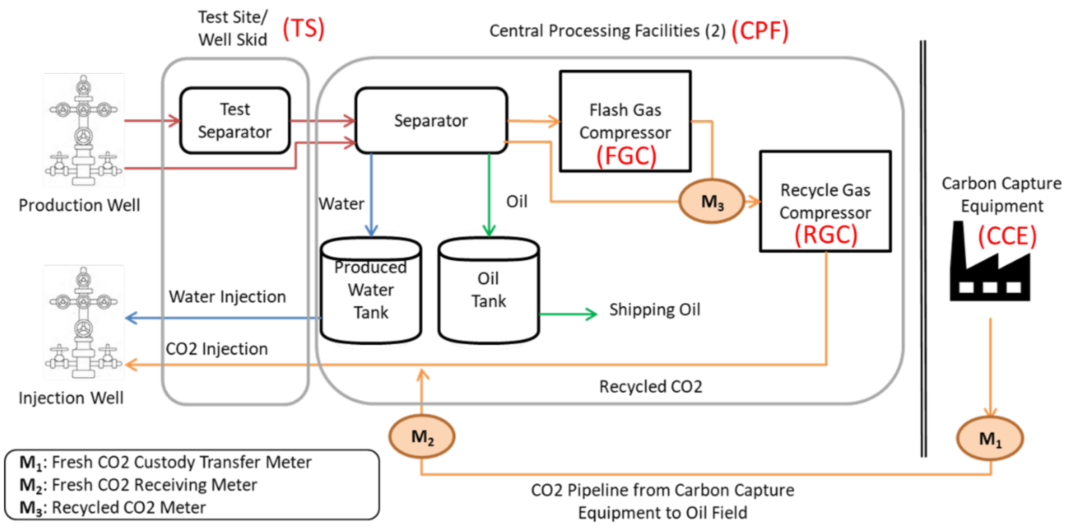


Figure 2.8.1 Facility Flow Diagram

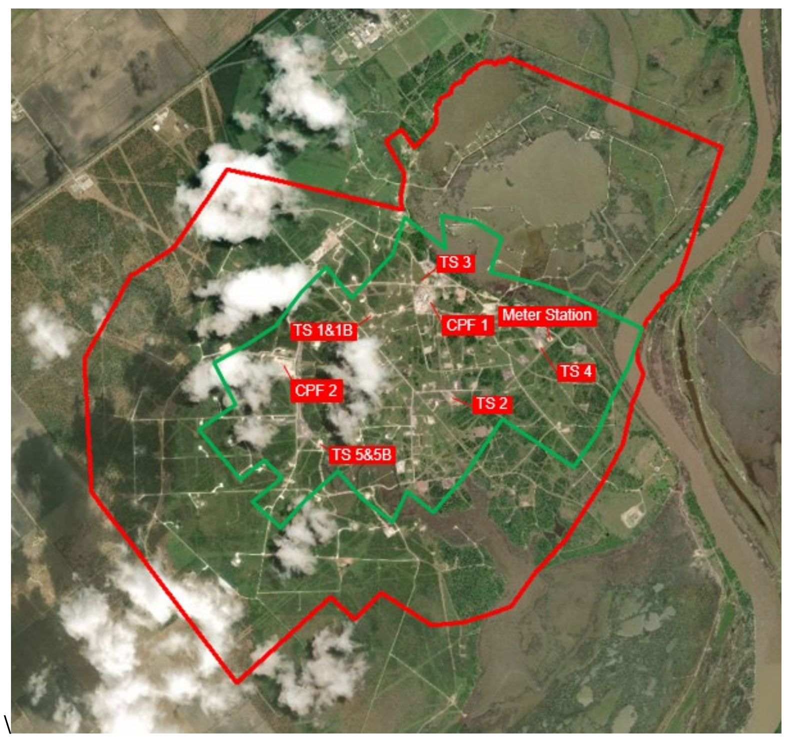


Figure 2.8.2 Locations of current Meter station, Central processing facilities (CPF1 and CPF2) and Test Sites (TS) at West Ranch Oil Field. Locations within this footprint may change over the life of the project. WRU boundary (red) and current flood area (green).

1. Central Processing Facility (CPF)

   There are two CPFs at West Ranch (shown as CPF1 and CPF 2 on Figure 2.8.2). Produced fluids (water, oil, and gas) are separated in the high/intermediate/low pressure water knock-out drums and separators located at the CPFs.

a) The water is mainly separated from gas and oil in the water knock-out drums, then reinjected into the field through injection wells with make-up water from water source wells.

b) The oil is separated from gas in the separators, settled in tanks for few days, then metered and sold.

c) The produced gas, which consists of CO_2 and reservoir hydrocarbon gas, is transferred to flash/recycle gas compressors (FGC/RGC). High and intermediate pressure gas is directly transferred to the RGC. Low pressure gas is compressed by the FGC then transferred to the RGC.

2. Test Site (TS)

There are five TSs (TS 1-5 on Figure 2.8.2) and two extended TSs (TS 1B and 5B on Figure 2.8.2) in the field. Produced fluids from the production wells are aggregated at one of the five TSs. Each TS consists of a three-phase test separator, which measures production rates of oil, water, and gas from each production well at least once per month. This data is not used in the mass balance accounting but is used to allocate produced fluid to wells and for production optimization. Produced fluid from the individual production wells gathered at the TSs is transferred to one of the two CPFs through high/intermediate/low pressure production lines.

3. CO_2 Injection Process

Fresh CO_2 is captured at the CCE and transported to West Ranch via the CO_2 pipeline, and the flow is metered at the metering station at West Ranch (M_2). The concentration of Fresh CO_2 applicable to calculate the mass of CO_2 received at West Ranch is measured at the custody transfer meter located in the vicinity of the CCE (M_1 on Figure 2.8.1). Fresh CO_2 received from the CO_2 pipeline and Recycled CO_2 from the RGCs at the CPFs, the volume and concentration of which is measured at M_3, are comingled and sent through the CO_2 distribution pipeline system to injection wells throughout the field.

All processes at West Ranch are monitored by the Supervisory Control and Data Acquisition (SCADA) system located on site and equipped with alarms to alert operators of any abnormalities. As the CO_2 flood expands into the entire Project Interval, new injection areas will be tied into this system using existing or new equivalent equipment.

2.8.2 Wells at West Ranch Oil Field

As of December 2020, there are 257 active wells at West Ranch; 155 are producing wells, 91 are injection wells, and 11 are water sourcing wells. Appendix 2 lists these wells with well identification numbers. Table 2.8.2 shows total well count at West Ranch by status.

Well Count	Active	Shut-in	Temporarily Abandoned	Plugged and Abandoned
TOTAL	257	277	2	389

Table 2.8.2 West Ranch Oil Field Well Count

TRRC rules govern well siting, construction, operation, maintenance, and closure for all oil field wells. The TRRC granted authority the operator to inject CO_2 in permitted wells after application, notice and hearings. TRRC requirements are found at TAC Title 16 Part 1 Chapter 3 and Chapter 5[2] and include:

- Fluids must be constrained in the strata in which they are encountered;
- Activities governed by the TRRC rules cannot result in the pollution of subsurface or surface water;
- Adherence to specified casing, cementing, drilling well control, and completion requirements designed to prevent fluids from moving from the strata encountered into strata with oil and gas, or into subsurface and surface waters;
- Filing of a well completion report including basic electric log (e.g., a density, sonic, or resistivity (except dip meter) log run over the entire wellbore);
- Equipping wells with a Bradenhead valve, measuring the pressure between casing strings using the Bradenhead gauge, and following procedures to report and address any instances where pressure on a Bradenhead is detected;
- Following plugging procedures that require advance approval from the TRRC and allow consideration of the suitability of the cement based on the use of the well, the location and setting of plugs;
- Corrosion monitoring under TAC Title 16 Part 1 §5.305(1) (D) is met by alternative monitoring through continuous SCADA monitoring in all wells;
- Using corrosion resistant alloy (CRA) for facilities which are exposed to CO_2; and
- Conducting Casing Integrity Tests annually as required under TAC Title 16 Part 1 §5.305(1)(C).

All changes in the status of wells must be in compliance with the TRRC rules and go through the TRRC approval process, and will be included in the annual report to EPA under GHGRP, Subpart RR.

2.9 Storage Capacity Calculation

During the injection of CO_2 and water for CO_2 EOR operations, fluids will move from injection wells toward the production wells following the pressure trends. At the end of CO_2 EOR operations, the reservoir fluids will be in equilibrium based on their gravity difference where lighter fluids, likely gases, will move toward the top of the formation below the seal of each reservoir (see Section 2.5, Reservoir Characterization and Modeling). The estimated total amount of the CO_2 that can be sequestered in these reservoirs is based on the available pore space at each of the reservoirs. Though the available pore space is considered to be the entire

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[2] TRRC rules can be found online at:
https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=3&rl=Y and
https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=5

pore space from top of the reservoir to the spill point, for purpose of this calculation, the original oil and gas in place of each reservoir is assumed as the available pore space, and further, only down to the shallower of spill point or oil water contact. The oil water contacts are above the spill points in the 41-A and Greta reservoirs; hence, the pore space accounted for these two reservoirs are only down to the oil water contact. The oil water contacts are below the spill points in 98-A, Ward, and Glasscock.

The following equation was used to estimate the storage capacity:

$$CO_2\ Storage\ Capacity = HCPV * E * \rho CO_2$$

where:

HCPV = *Hydrocarbon pore volume above oil water contact or a spill point of the south-west structure.*

E = *Efficiency factor.*

ρCO_2 = *CO_2 density at reservoir pressure and temperature.*

Based on the numerical simulations conducted by the BEG, the CO_2 occupancy of the pore space at the end of the CO_2 EOR operation is calculated. These calculations assume a 50 percent efficiency factor, and results are tabulated in Table 2.9.1.

Reservoir	Storage capacity (MM metric ton)
Greta	12.35
Glasscock	6.35
Ward	10.10
41-A	10.74
98-A	8.52
Total	**48.06**

Table 2.9.1 West Ranch Oil Field CO_2 storage capacity in different reservoirs (metric tons)

At reservoir conditions of West Ranch, the five main target reservoirs could hold about 919 Bscf (48.06 million metric tons) of CO_2 in the reservoir based on the original oil and gas in place. PNPH forecasts that 20 years of CO_2 EOR operations would result in sequestered CO_2 occupying approximately 61 percent of the calculated storage capacity.

3. Delineation of Monitoring Area and Timeframes

3.1 Active Monitoring Area

As discussed in Sections 2.1 through 2.4, the subsurface characteristics of the existing WRU for the 98-A and 41-A reservoirs are similar to the characteristics in the other reservoirs within the Project Interval at West Ranch. They all have four-way dip anticline trapping mechanisms, no faulting, primary confining layers over each injection zone, the existence of secondary confining interval (Anahuac Shale) in addition to individual confining layers overlying each reservoir, and depleted reservoir pressure. Expansion into the full Project Interval will require the operator to obtain approval for unitization and permits for injection from TRRC, as explained in Sections 2.7 and 2.8. In addition, the reservoir simulation effort carried out as part of DOE's MVA Plan, and the storage capacity calculation as illustrated in Sections 2.5 and 2.9 demonstrated the viability of the Project Interval for a long-term CO_2 retention. Because CO_2 is retained within the WRUs, the Active Monitoring Area (AMA) is the existing WRU boundary of 41-A/98-A (Consolidated) Unit, as depicted in Figure 2.1.2, plus the half mile buffer. When a new WRU for CO_2 EOR operation is established, either for the currently flooded reservoirs or for the other three reservoirs and sublayers within the Project Interval, the AMA will be expanded to cover the boundaries of those new WRUs, plus the half mile buffer. In addition to the aforementioned reason, the following factors are considered in defining this boundary:

- CO_2 injected into West Ranch reservoirs remains contained within the unit boundary because of the fluid and pressure management, which includes: the practice of targeting the maintenance of an injection-withdrawal ratio of 1.0, which assures a stable reservoir pressure, and the managed leaseline water injection and production wells that are used to retain CO_2 and fluids within the unit boundary. The effectiveness was demonstrated by the history matching and reservoir simulation effort in Section 2.5 as it demonstrated that the movement of CO_2 plume is largely contained within the intended patterns and the elevation of reservoir pressure is maintained within the intended range.
- Over geologic timeframes, sequestered CO_2 will remain in the respective unit boundaries, and will not migrate downdip, because of the higher elevations of the WRUs compared to other part of the corresponding reservoirs in the same structure as described in Figures 2.2.1 and 2.2.2.

3.2 Maximum Monitoring Area

Based on the potential future expansion of WRU to conduct CO_2 EOR operations in the currently flooded reservoirs and the other three reservoirs and sublayers within the Project Interval, the injection zone extends geologically along the outermost boundary of those reservoirs subject to CO_2 EOR operation, which is primarily determined by oil-water-contact and structures (Figure 3.2). In accordance with 40 CFR §98.448-449, the Maximum Monitoring Area (MMA) will extend for the half mile buffer beyond the boundary.

Figure 3.2 Areal extent of Maximum Monitoring Area (red dashed line) includes the outermost boundary of reservoirs at West Ranch Oil Field that could potentially be developed by utilizing CO_2 EOR operation, plus ½ mile buffer.

3.3 Monitoring Timeframes

The primary purpose for injecting CO_2 is to produce oil that would otherwise remain trapped in the reservoir. During the Specified Period, PNPH will have a secondary purpose of establishing the long-term containment of a measurable quantity of CO_2 at West Ranch. The Specified Period will be shorter than the period of production from West Ranch. This is in part because the purchase of Fresh CO_2 for injection is projected to taper off significantly before production ceases at West Ranch. At the conclusion of the Specified Period, PNPH will submit a request for discontinuation of reporting. This request will be submitted with a demonstration that the cumulative mass of CO_2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage. See 40 CFR §98.441(b)(2)(ii).

4. Evaluation of Potential Pathways for CO_2 Leakage to the Surface

4.1 Introduction

The subsurface characteristics at West Ranch are well known as a result of exploration, production, and continued reevaluation for optimization of production, including the recent reevaluation for CO_2 EOR and monitoring activities under the MVA Plan. The presence of thick oil and gas accumulations in the subsurface of West Ranch provides strong evidence that the mudstones that separate the sandstones are effective in isolating buoyant fluids and provides assurance that injected CO_2 will be effectivity trapped. Further evidence of effective confinement of fluids is the sustained pressure depletion of some zones after production.

This MRV Plan considered the following potential leakage pathways:

- Diffuse leakage through the Anahuac Shale
- Faults and fractures
- Natural and induced seismic activity
- Failure of zonal isolation in existing wells
- Failure of zonal isolation in new well construction
- Drilling through the CO_2 area
- Lateral migration outside the West Ranch Oil Field
- Pipeline/surface equipment

4.2 Diffuse leakage through the Anahuac Shale

Diffuse leakage through the seals that lie above the reservoirs in the Project Interval is highly unlikely. There are numerous sections above the sand reservoirs in the Project Interval that are impermeable and serve as reliable barriers to prevent fluids from moving upwards towards the surface. These barriers are referred to as seals because they effectively seal fluids into the formations beneath them. In addition, Anahuac Shale was deposited over much of the Gulf Coast during a major regional transgression. It serves as a major confining unit that traps hydrocarbons. It is also widely used as a top seal for Class I disposal operations in the Gulf Coast area. Anahuac Shale is more than 120 feet thick in the West Ranch area, and a 30-foot core collected at the A-600 well has been examined in detail to characterize the quality of this confining layer (Lu et al 2014). It is composed of silty clay (average 56 percent clay) and has permeabilities of 0.0006 to 0.0026 mD. Gas chemistry shows that gas migration is limited by diffusion and adsorption and confirms that Anahuac Shale is an effective seal which will not allow diffuse leakage of CO_2 above the Project Interval. Injection pressure is continuously monitored and unexplained changes in injection pressure that might indicate leakage would trigger investigation as to the cause.

4.3 Faults and Fractures

West Ranch is a roll-over anticline formed between two major growth fault zones (Figures 2.2.1,

2.2.2 and 2.2.3), and there is no major fault within the field (Baurenschmidt, 1962). The Gulf Coast region is faulted by systems of growth faults (active during sediment accumulation) and by structures associated with deep-seated and piercement salt structures, which have been extensively characterized by exploration. Because the overall section is dominated by mudstones, fault permeability is controlled by clay smear. The sealing nature of faults is evident at many hydrocarbon fields that are fault-bounded. Gulf Coast sandstones and mudstones are typically not fractured but deform without rupture by bending and smearing. As described in Section 2.8.2, all injection permits require that injected fluids be confined in the authorized reservoir, and injection at pressure exceeding fracture pressure is not allowed.

4.4 Natural and Induced Seismic Activity

Although the Gulf Coast has been and is still locally undergoing deformation related to loading and continued subsidence of the Gulf Basin, the area is not seismically active. Deformation occurs without producing earthquakes. The United States Geological Survey (USGS) long term seismic risk map puts the entire Gulf Coast area, including West Ranch, in the lowest risk category (United States Geological Survey, 2014).

Risk of induced seismicity at West Ranch is low for several reasons: 1) magnitude of pressure increase and the area where elevated pressure is aggressively managed by balancing injection and withdrawal rates, 2) the reservoirs have a lower pressure as a result of past production, 3) high permeability and rapid fluid cycling though the reservoir creates little risk of developing local overpressure, and 4) the operation is compliant with regulations limiting injection pressure.

In addition, the application for a new injection well permit or an amendment of an existing injection well permit for injection pressure, injection rate, or injection interval must include a survey of historical seismic events within 5.64 miles, the Area of Interest (AOI). A seismic event of 2.0 Magnitude (M) or greater from the USGS earthquake catalog or the TexNet earthquake catalog triggers seismicity review and requires additional geologic information across the AOI for the TRRC to consider the necessity of a permit disposition.

In the unlikely event that seismicity resulted in a pathway for material amounts of CO_2 to migrate from the injection zone, the monitoring provisions at other reservoir levels would lead to further investigation as elaborated in Section 5.1.

4.5 Failure of Zonal Isolation in Existing Wells

Wells are required to be constructed and either plugged and abandoned or maintained so the injection and production zones are isolated from other zones and from fresh groundwater (underground sources of drinking water or USDW). West Ranch contains many legacy wells; hence, the operator invests in well qualification and management. Well qualification and management are overseen by the TRRC.

TRRC rules call for periodic Mechanical Integrity Testing (MIT). Continuous monitoring devices tracking injection rate, pressure, and volume (as well as continuous monitoring of the annulus with a pressure gauge) are installed in line with the requirement. These monitoring tools conform to the TRRC requirements under TAC Title 16 Part 1 §5.305(1)(B) and used to protect against the high cost from loss of well control. All pressure gauges are hooked up to a real time reporting SCADA system. The SCADA monitoring system uses set points to trigger an alarm if there is more than a 10 percent change in pressure. In addition, periodic injection profiles are performed on the injection wells, and this will include running temperature surveys on the injection wells. Reservoir pressure is also measured through the injection wells when workovers are performed.

While the CO_2 EOR operation is conducted, injection profiles are performed to determine where the injected fluid is going and to understand the comprehensive picture of what is going on down hole in an injector well. An injection profile package is made up of numerous surveys. The tool used has several components such as a radioactive tracer, spinner logs, temperature logs, caliper logs, and collar logs. The temperature survey looks for anomalies which can indicate if there is fluid loss during injection. A tracer tool monitors the reduction in tracer material as it moves down the well and could indicate channeling and help in quantifying the amount of a release if one is found. A spinner gives the rate, and a shut-in temperature survey indicates fluid losses and events occurring inside and outside the well bore.

In addition, a Reservoir Saturation Tool (RST) is run to measure hydrocarbon and water saturations behind the casing. This tool could indicate if the injected fluid is going out of the targeted interval and into another zone. Baseline RST has been run on six wells.

An exhaustive study of all existing wellbores at West Ranch was carried out prior to the start of the CO_2 flood to confirm well condition and integrity. All of the plugged and abandoned wells at West Ranch have plugs to prevent the upward migration of fluids. Most wells have numerous plugs in the Frio Formation isolating the deeper zones. All shut-in and producing wells in West Ranch were also reviewed, and numerous shut-in wells are used for its active pressure monitoring program throughout the field as described in Section 5.1.1.

Additionally, the TRRC requires an applicant for an injection well permit to examine the data of record for wells that penetrate the proposed injection reservoir within one-quarter (1/4) mile radius of the proposed well to determine if all abandoned wells have been plugged in a manner that will prevent the movement of fluids into strata other than the authorized reservoir for injection (AoR). The operator currently reviews all wells located within one-half (1/2) mile radius of a proposed injection well.

Based on the measures above, the risk of CO_2 leakage through existing wells is being mitigated through a monitoring and maintenance program that will provide early detection of problems that could materialize into a leakage event. Any potential CO_2 leakage would be identified and quantified through the monitoring provisions in Section 5.1.

4.6 Failure of Zonal Isolation in New Well Construction

Well qualification and management are overseen by the TRRC. New wells are constructed to provide zonal isolation and are tested prior to use to confirm that cement in the rock-casing annulus covers the required intervals and is of good quality; hence, the risk of failure of zonal isolation in new wells is low. In the event CO_2 leakage were to occur, it would be identified and quantified through the monitoring provisions in Section 5.1.

All injection wells for the CO_2 EOR operation are newly drilled wells or conversion of existing wellbores and must adhere to the TRRC requirements as described elsewhere herein including

Section 2.8.2. All injection wells have coated tubulars to withstand corrosion. Both the surface and production casing strings are cemented back to the surface, with a confirmation through a cement bond log of a full column of cement behind the casing.

For producing wells for CO_2 EOR operation that are newly drilled, these wells are drilled and completed to deal with corrosion, including coated tubulars and corrosion inhibiting fluid in the annulus between the tubing and the long string casing to prevent corrosion. Both surface and production casings are cemented to the surface.

4.7 Drilling through the CO_2 Area

A future drilling initiative within the existing or future WRU to extend the current CO_2 flood area or to drill into a deeper reservoir creating an inadvertent leakage pathway is possible; however, such risk is considered to be very low. As previously stated, all wells drilled in the West Ranch Oil Field are regulated by the TRRC (specifically under TAC Title 16 Part 1 §3.13) which includes (a) ensuring that the casing is securely anchored to effectively control the well at all times, (b) all usable-quality water zones are isolated and sealed off to effectively prevent contamination or harm, and (c) all productive zones, potential flow zones, and zones with corrosive formation fluids are isolated and sealed off to prevent vertical migration of fluids behind the casing, including gases. Multiple reservoirs at West Ranch are gas charged, and all drilling to each reservoir must be done with proper preparation to contain gas within such reservoirs (e.g., using well control mechanisms such as dense drilling mud, blow out preventers, and completion to isolate zones). In the unlikely event of gas leakage from a reservoir flooded with CO_2, the methods to quantify the amount of leakage use appropriate engineering variables and standard estimation of releases.

4.8 Lateral Migration outside West Ranch Oil Field

As illustrated in Figures 2.2.1 and 2.2.2, West Ranch contains the highest elevation of both current and future reservoirs for CO_2 flooding within the surrounding area. It is highly unlikely that injected CO_2 will migrate downdip and laterally outside of the existing and future WRUs because CO_2 is less dense than oil and water in the reservoir. As a result, the CO_2 tends to migrate and accumulate at the top of geological structure. The well-defined structural closure based on well logs and oil-water contact provides a strong control on the lateral extent of the CO_2 plume, and the volume of injected CO_2 will be less than the storage capacity of each reservoir. CO_2-oil miscibility also strongly minimizes possible lateral CO_2 transport distance.

4.9 Pipeline/Surface Equipment

Surface infrastructure is under daily surveillance. Any releases of CO_2 from either planned events or unplanned incidents are being quantified and reported following the requirement of Subpart W of EPA's GHGRP or based on appropriate engineering variables and standard estimation of releases as stated in Section 5.2. The past three years of surveillance show that the release volumes are less than one percent of the captured CO_2. Confidence in surveillance is high, because release of even small amounts of CO_2 is highly noticeable as dense CO_2 flashes result in large volume increases and strong cooling, resulting in noise and a cloud, ice, or condensed water.

5. Site-specific Risk-based Monitoring

5.1 Losses through Subsurface Infrastructure

Detection of any losses of CO_2 in the subsurface through damaged or faulty well construction, or through any other potential pathways for CO_2 leakage to the surface as identified in Section 4, including faults and fractures, will be done based on the monitoring information obtained from both active and shut-in wells. Proactive pressure monitoring at active producing wells, active injection wells, and shut-in monitoring wells is done via installation of pressure gauges at the wellhead that access the tubing and casing with connections to the SCADA system. Pressure reading at the surface casing, production casing and tubing on these wells are captured multiple times each day. If CO_2 leaked from an active CO_2 EOR reservoir, which is carefully monitored with the active and shut-in monitoring wells and managed through the operating practice and further backstopped by the higher elevation of the field as explained in section 3.1, it would migrate upwards into another reservoir and increase that reservoir's pressure. As presented in Table 5.1.1, multiple reservoirs above and below the regional Anahuac Shale, each also immediately overlain by confining rocks, are equipped with shut-in monitoring wells to detect the abnormal reservoir pressure change. The shut-in monitoring wells are also horizontally scattered throughout the field, as shown on Figure 5.1.1, which helps with early leak detection. If pressure changes in a reservoir that is not intended to be energized or if there are any CO_2 releases from the subsurface, alarms are set up to be notified through the SCADA system into the control room. All active alarms are followed up by field personnel for further investigation and diagnostics. If a leakage is detected, PNPH will use an event-specific approach to quantify leaked amounts of CO_2. Depending on the circumstance, this might include the use of modeling, engineering estimates, or direct measurements to estimate the relevant parameters (e.g., flow rate, concentration, and duration of leakage) to quantify the leaked volume.

All permanently plugged and abandoned wells are plugged with cement and drilling mud with well tubulars cut off below the surface in accordance with regulatory requirements; however, as these wells are not equipped with pressure gauges, in the unlikely event of well leakage, the detection and quantification will be done indirectly from the pressure reading of surrounding wells that are perforated in the same or shallower reservoirs.

5.1.1 Inactive Well Monitoring

As of December 31, 2020, there are 255 inactive wells completed in the Frio Formation above the injection interval and in select zones above the impenetrable Anahuac Shale that are being used as pressure monitoring wells. These monitoring wells are outfitted with gauges on the tubings, the production casings, and the surface casings. All data is reported and monitored in real time through the SCADA system that reports information into the control room with back-up information fed into the operator's corporate offices. Figure 5.1.1 shows the location of the pressure monitoring wells throughout the field. Table 5.1.1 shows the zones of the inactive monitoring wells.

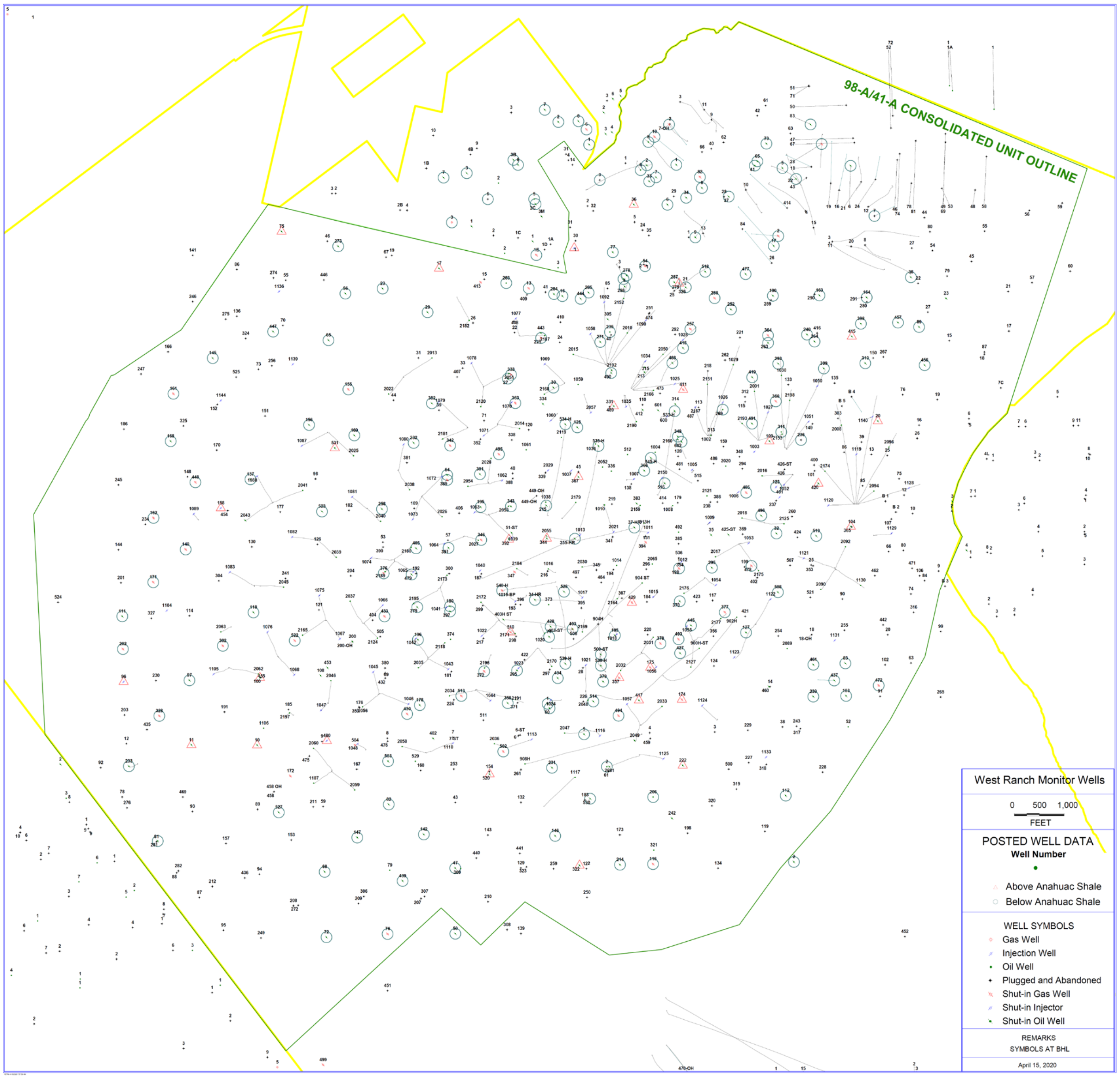

Figure 5.1.1 Location of inactive wells with pressure monitoring (wells above and below Anahuac Shale are shown as pink triangles and green circles, respectively)

#	Reservoir	Number of wells	Depth	
1	Shallow Gas	6		
2	80-A	4	2,940’	
3	Noble/Miocene	11		
4	3800	1	3,775’	
5	Catahoula	13		
6	Discorbis	4	4,555’	
7	Marg	31	4,960’	Below Anahuac Shale
8	Greta	83	5,065	
9	Randle	2	5,250’	
10	Benneview	1	5,320’	
11	Dixon	2	5,390’	
12	Toney	16	5,400’	
13	Glasscock	14	5,470’	
14	Menefee	3	5,550’	
15	Mitchell	10	5,580’	
16	Armstrong	1	5,600’	
17	Ward	33	5,630’	
18	41-A	7	5,700’	
19	Musquez	1	6,050’	
20	383 Frio	2	6,080’	
21	98-A	10	6,125’	

Table 5.1.1 Zones where pressure monitoring wells are located

5.1.2. Production Well Monitoring

Figure 5.1.2 depicts how a production well is monitored in the SCADA system. Pressure gauges monitor pressure in the tubing, the production casing, and the surface casing. Gas lift rate and pressure are also monitored for each well. The valves on the right side of the diagram are located at the TS manifold and allow the well to be directed into the high pressure (HP), intermediate pressure (IP), or low pressure (LP) system, or to the TS separator. Alarms are set to monitor any changes in the pressure from the normal pressure ranges. If abnormal pressures are noted, an alarm sounds and the well will be monitored for CO_2 leaks.

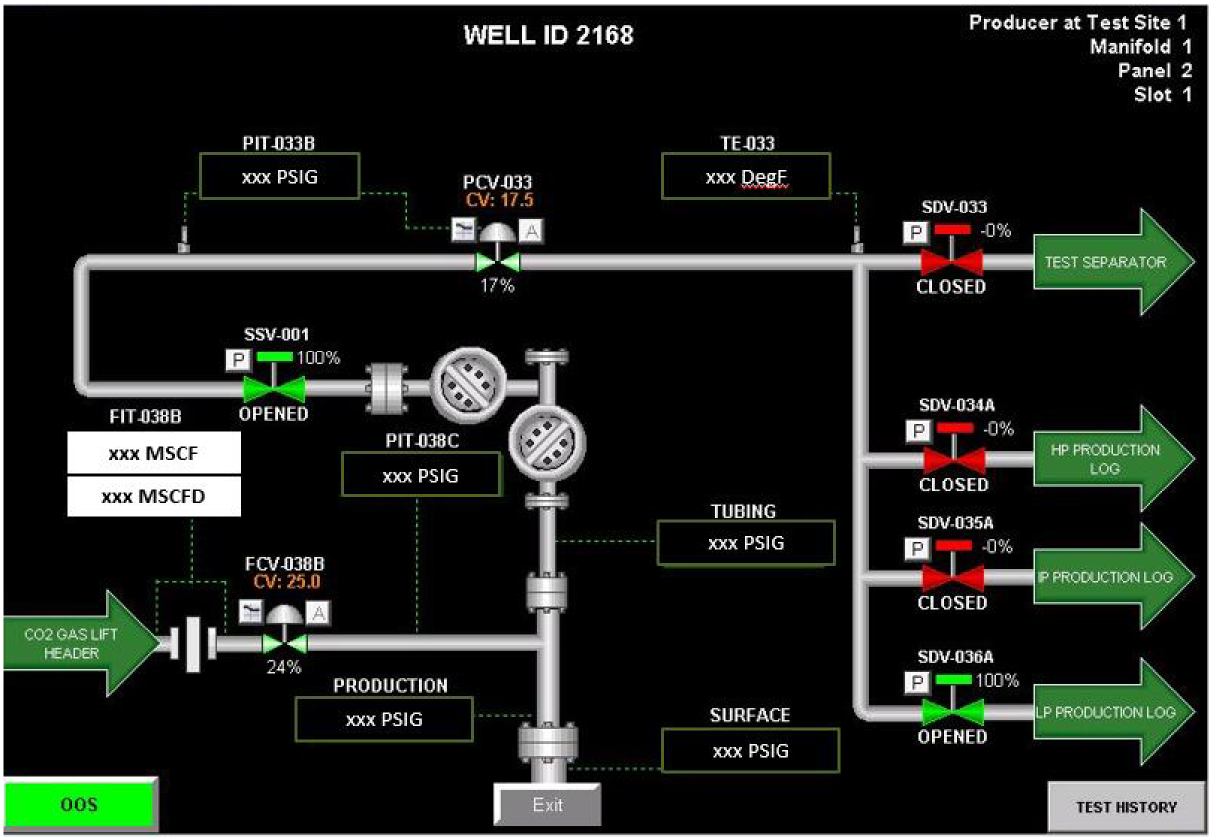

Figure 5.1.2 Monitoring of Production Wells

5.1.3. Injection Well Monitoring

Figure 5.1.3 depicts how an injection well is monitored in the SCADA system. Pressure gauges monitor pressure in the tubing, the production casing, and the surface casing. The valves on the right side of the diagram are located at the TS manifold and allow either CO_2 or water to be injected into the well, and in some cases both CO_2 and water at the same time. The injection rate is metered for each well. Alarms are set to monitor any changes in the pressure from the normal pressure ranges. If abnormal pressures are noted, an alarm sounds and the well will be monitored for CO_2 leaks.

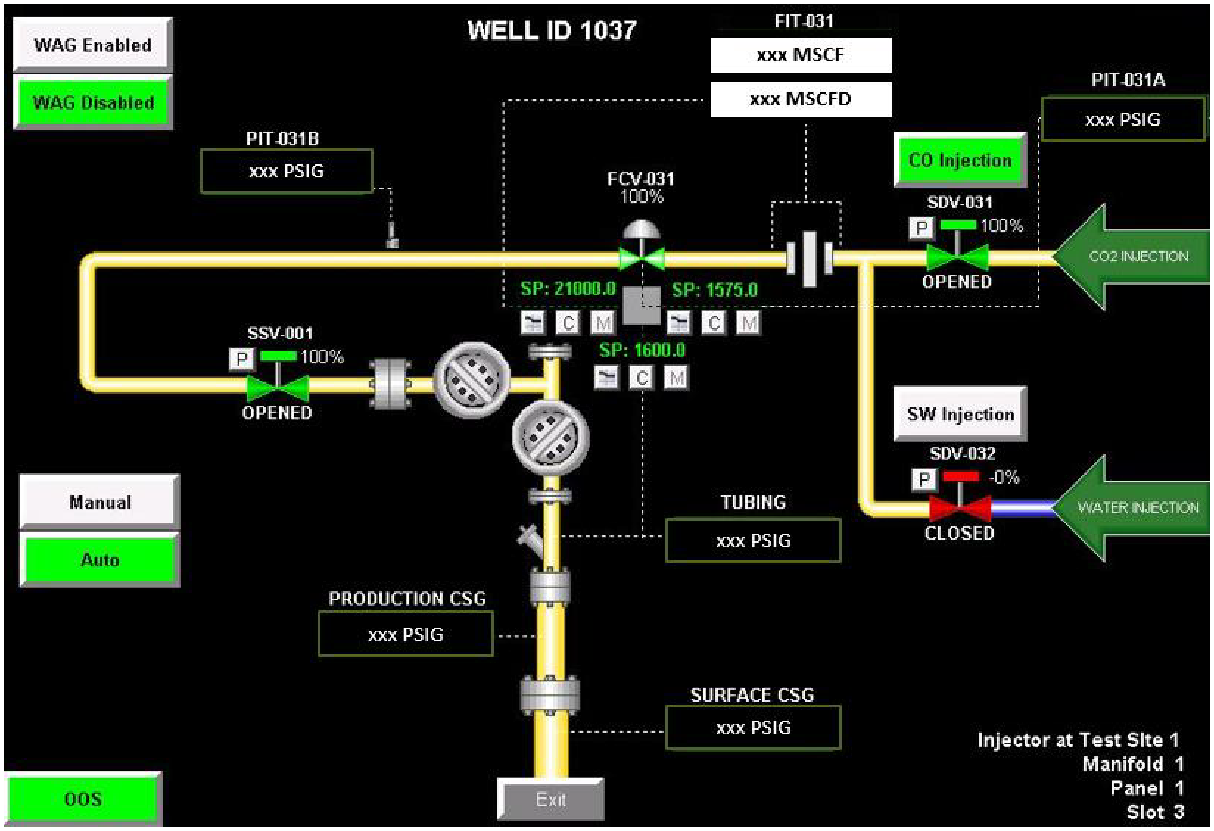

Figure 5.1.3 Monitoring of Injection Wells

5.2 Losses through Surface Infrastructure

Losses though surface infrastructure are either intentional releases for maintenance or unplanned releases, in the case of upsets or accidents. The method of detection is identified by the operator using both the data streams and alarms that are reported to the control room and visual inspection of facilities. The methods of quantification use appropriate engineering variables and standard estimation of releases.

PNPH ensures that the operator evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6. Determination of Baselines

PNPH will use the results from daily monitoring of field conditions by the operator and operational data, as well as routine testing and maintenance information to monitor for surface leakage. As indicated in Sections 4.5 and 5, the SCADA system is used to conduct the CO_2 EOR operations at West Ranch. The data from these efforts is used to identify and investigate variances from expected performance that could indicate CO_2 leakage. Below is a description of how this data will be used to determine when further investigation of potential CO_2 leakage is warranted.

- **Visual Inspections**: As mentioned in Section 4.9, operations personnel make daily rounds of the facilities, providing a visual inspection of equipment used in the operations (e.g., vessels, piping, valves, wellheads). These inspection rounds provide the opportunity to identify issues early and address them proactively, which may preclude leaks from happening and/or minimize any CO_2 leakage. If an identified issue cannot be resolved by the person who first observes it, a work order will be generated to resolve the matter. Each event will be documented, including an estimate of the amount of CO_2 leaked and included in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.
- **Mechanical Integrity Test (MIT)**: TRRC rules calls for operators to comply with MIT requirements, which are designed to ensure that there is no significant leakage within the injection tubing, casing, or packer, as well as no leakage outside of the casing. All active injection wells undergo MIT testing (referred to as "H-5 Testing") at the following intervals:
    - Before injection operations begin;
    - At least once every five years, or more frequently if required by the permit;
    - After any workover that disturbs the seal between the tubing, packer, and casing, or after any repair work on the casing; and
    - When a request is made to suspend or reactivate the injection or disposal permit.

  The TRRC requires that the operator notify the TRRC district office at least 48 hours prior to conducting the H-5 Testing. Operators are required to use a pressure recorder and pressure gauge for the test. Operators' field representative must sign the pressure recorder chart and submit it with Form H-5. Casing pressure must fall within 30-70% of the pressure recorder chart's full scale, and the pressure gauge must measure in increments that are no greater than 5% of the test pressure.

  In the event a loss of mechanical integrity occurs, the injection well is immediately shut-in and an investigation is initiated to determine what caused the loss of mechanical integrity. If investigation of an event identifies that a leak has occurred, those events will be documented, including an estimate of the amount of CO_2 leaked and included in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.
- **Production and Shut-in Well Pressure Surveillance**: All tubings and casings of production and shut-in wells are equipped with pressure gauges and connected to the SCADA system as described in Section 5. If a 10% deviation in pressure outside of the expected values occurs, the event is investigated to determine if the variance poses a leak threat. If investigation of an event identifies that a leak has occurred, those events will be documented, including an estimate of the amount of CO_2 leaked and included in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.

7. Determination of Sequestration Volumes Using Mass Balance Equations

PNPH will use equation RR-11 in 40 C.F.R. §98.443 to calculate the Mass of CO_2 Sequestered in Subsurface Geologic Formations in a reporting year as follows:

$$CO_2 = CO_{2I} - CO_{2P} - CO_{2E} - CO_{2FI} - CO_{2FP} \quad \text{(Eq. RR-11)}$$

where:

- CO_2 = *Total annual CO_2 mass sequestered in subsurface geologic formations (metric tons) at the facility in the reporting year.*
- CO_{2I} = *CO_2 Injected, the total annual CO_2 mass injected (metric tons) in the well or group of wells covered by this source category in the reporting year, includes both Received CO_2 (or Fresh CO_2, see discussion below) and Recycled CO_2.*
- CO_{2P} = *CO_2 Produced, the total annual CO_2 mass produced (metric tons) in the reporting year, includes Recycled CO_2 (see discussion below).*
- CO_{2E} = *CO_2 Emitted by Surface Leakage, total annual CO_2 mass emitted (metric tons) by surface leakage in the reporting year.*
- CO_{2FI} = *Total annual CO_2 mass emitted (metric tons) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead, for which a calculation procedure is provided in Subpart W.*
- CO_{2FP} = *Total annual CO_2 mass emitted (metric tons) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity, for which a calculation procedure is provided in Subpart W.*

To account for site-specific considerations, PNPH proposes the locations below for obtaining data to determine the CO_2 volumes used in the mass balance.

The first proposal addresses the propagation of error that would be created if volume data from meters at each injection well were utilized. This issue arises because each meter has a small but acceptable margin of calibration error, and this error could become significant if data were taken from the approximately 100 meters within West Ranch. As such, PNPH proposes to use the mass of Recycled CO_2 from commercial quality flow meters at the inlet of RGCs combined with mass of CO_2 Received (earlier referred to as Fresh CO_2 and further defined below) to determine the mass of CO_2 Injected into the subsurface (CO_{2I} in the formula above). The mass of CO_2 Produced (CO_{2P} in the formula above) will be the same as Recycled CO_2.

The second proposal addresses the concentration of CO_2 Received. Figure 7 shows the planned mass balance envelope overlaid as a blue square onto the facility flow diagram originally shown in Figure 2.7.1. The envelope contains all measurements relevant to the mass balance equation except for CO_2 Received, which is proposed to be measured at the custody transfer meter located in the vicinity of CCE (M_1) as shown in Section 2.8.1.

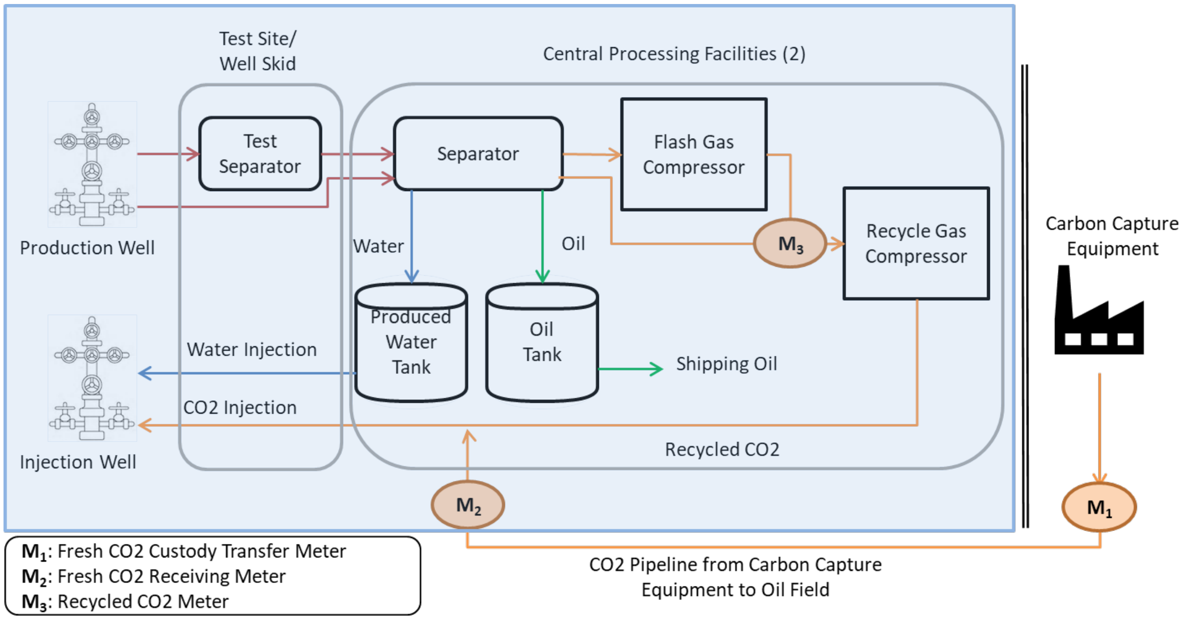

Figure 7 Material Balance Envelope (in blue)

The following sections describe how each element of the mass-balance equation will be calculated.

7.1 Mass of CO_2 Injected into the Subsurface

The equation for calculating the mass of CO_2 Injected into the Subsurface at West Ranch is equal to the sum of the mass of CO_2 Received (volumetric flow at M_2 using CO_2 concentration at M_1) and the mass of Recycled CO_2 measured at the inlet of the RGC (M_3).

$$\mathrm{CO}_{2I} = \mathrm{CO}_{2T,r} + \mathrm{CO}_{2,u}$$

where:

CO_{2I} = *CO_2 Injected, the total annual CO_2 mass injected (metric tons) in the well or group of wells covered by this source category in the reporting year*

$CO_{2T,r}$ = *CO_2 Received, the injected net annual mass of CO_2 received through flow meter r (metric tons).*

$CO_{2,u}$ = *CO_2 Recycled, the injected annual CO_2 mass injected (metric tons) as measured by flow meter u.*

Mass of CO_2 Received

PNPH will use equation RR-2 as indicated in 40 C.F.R. §98.443 to calculate the mass of CO_2. Received. The volumetric flow at standard conditions as defined in 9.1.2 is measured at the receiving meter at West Ranch at the terminus of CO_2 Pipeline from CCE (M_2), and will be multiplied by the CO_2 concentration measured at the custody transfer meter located in the

vicinity of CCE (M_1) as stated above, and the density of CO_2 at standard conditions to determine mass.

$$CO_{2T,r} = \sum_{p=1}^{4}(Q_{r,p} - S_{r,p}) * D * C_{CO_{2,p,r}} \quad \text{(Eq. RR-2)}$$

where:

$CO_{2T,r}$ = *CO_2 Received, the injected net annual mass of CO_2 received through flow meter r (metric tons).*

$Q_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).*

$S_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into your well in quarter p (standard cubic meters). Since all delivery to West Ranch is used within the oilfield, the quarterly flow redelivered, $S_{r,p}$ is zero ("0").*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,r}$ = *Quarterly CO_2 concentration measurement in flow for flow meter r in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

r = *Receiving flow meter (M_2, CO_2 concentration for M_2 is measured at M_1).*

Mass of CO_2 Recycled

PNPH will use equation RR-5 from 40 C.F.R. §98.443 to calculate the Mass of Recycled CO_2.

$$CO_{2,u} = \sum_{p=1}^{4} Q_{p,u} * D * C_{CO_{2,p,u}} \quad \text{(Eq. RR-5)}$$

where:

$CO_{2,u}$ = *CO_2 Recycled, the annual CO_2 mass injected (metric tons) as measured by flow meter u.*

$Q_{p,u}$ = *Quarterly volumetric flow rate measurement for flow meter u in quarter p at standard conditions (standard cubic meters per quarter).*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,u}$ = *CO_2 concentration measurement for flow meter u in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

u = Flow meter (M_3).

7.2 Mass of CO_2 Produced

As discussed above, the mass of CO_2 Produced equals the mass of Recycled CO_2 measured at the flow meters at inlet of RGCs (M_3). Equation RR-9 in 40 C.F.R. §98.443 will be used to

aggregate the mass of CO_2 produced net of the mass of CO_2 entrained in produced oil as follows:

$$\mathrm{CO}_{2P} = \sum_{w=1}^{W} \mathrm{CO}_{2,w} + X_{oil} \qquad \text{(Eq. RR-9)}$$

where:

CO_{2P} = *CO_2 Produced, the total annual CO_2 mass produced (metric tons) in the reporting year.*

$CO_{2,w}$ = *Annual CO_2 mass produced (metric tons) through flow meter w in the reporting year (further defined below).*

X_{oil} = *Mass of entrained CO_2 (metric tons) in oil in the reporting year calculated as per 40 C.F.R. Subpart W.*

w = *Flow meter (M_3)*

PNPH will use equation RR-8 as indicated in 40 C.F.R. §98.443 to calculate the annual mass of CO_2 produced.

$$\mathrm{CO}_{2,w} = \sum_{p=1}^{4} Q_{p,w} * D * C_{\mathrm{CO}_{2,p,w}} \qquad \text{(Eq. RR-8)}$$

where:

$CO_{2,w}$ = *Annual CO_2 mass produced (metric tons) through flow meter w.*

$Q_{p,w}$ = *Volumetric gas flow rate measurement for separator w in quarter p at standard conditions (standard cubic meters).*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,w}$ = *CO_2 concentration measurement for flow meter w in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

w = *Flow meter (M_3)*

7.3 Mass of CO_2 Emitted by Surface Leakage

The mass of CO_2 Emitted by Surface Leakage (term CO_{2E} in Eq. RR-11) is calculated based on various methodologies, including measurements, engineering estimates, and emission factors, used for the leakage originating from subsurface as described in Section 5.1. For releases from surface equipment and equipment venting (terms CO_{2FI} and CO_{2FP} in Eq. RR-11), 40 C.F.R. Subpart W reporting is relied upon as noted above.

Equation RR-10 in 40 C.F.R. §98.443 will be used to calculate and report the Mass of CO_2 Emitted by Surface Leakage:

$$\mathrm{CO}_{2E} = \sum_{x=1}^{X} \mathrm{CO}_{2,x} \qquad \text{(Eq. RR-10)}$$

where:

$CO_{2.}$ =	*Total annual CO_2 mass emitted by surface leakage (metric tons) in the reporting year.*
$CO_{2,x}$ =	*Annual CO_2 mass emitted (metric tons) at leakage pathway x in the reporting year.*
x =	*Leakage pathway*
X =	*Total number of leakage pathways.*

8. MRV Plan Implementation Schedule

The activities described in this MRV Plan are in place, and reporting is planned to start upon EPA approval. It is anticipated that the Annual Subpart RR Report will be filed on March 31 of the year after the reporting year. As described in Section 3.3 above, PNPH anticipates that the MRV Plan will be in effect during the Specified Period, during which time West Ranch is operated with the subsidiary purpose of establishing long-term containment of a measurable quantity of CO_2 in subsurface geological formations at West Ranch. PNPH anticipates establishing that a measurable portion of the CO_2 injected during the Specified Period will be sequestered in a manner not expected to migrate resulting in future surface leakage. At such time, PNPH will prepare a filing to support the long-term containment determination and submit a request to discontinue reporting under this MRV Plan. See 40 CFR § 98.441(b)(2)(ii).

9. Quality Assurance Program

9.1 Monitoring QA/QC

9.1.1 Flow Meter Provisions

The flow meters used to generate data for the mass balance equations in Section 7 are:

- Operated continuously except as necessary for maintenance and calibration.
- Operated using the calibration and accuracy requirements in 40 CFR §98.3(i).
- Operated in conformance with American Petroleum Institute (API) standards.
- National Institute of Standards and Technology (NIST) traceable.

9.1.2 Concentration of CO_2

CO_2 concentration is measured using an appropriate standard method consistent with 40 CFR §98.444(f)(1). Further, all measured volumes of CO_2 have been converted to standard cubic meters at a temperature of 60 degrees Fahrenheit and at an absolute pressure of 14.65 psi, including those used in Equations RR-2, RR-5, and RR-8 in Section 7.

9.2 Missing Data Procedures

In the event PNPH is unable to collect data needed for the mass balance calculations, procedures for estimating missing data will be used as follows:

- A quarterly flow rate of CO_2 received that is missing would be estimated using invoices or using a representative flow rate value from the nearest previous time period.
- A quarterly CO_2 concentration of a CO_2 stream received that is missing would be estimated using invoices or using a representative concentration value from the nearest previous time period.
- A quarterly quantity of CO_2 injected that is missing would be estimated using a representative quantity of CO_2 injected from the nearest previous period of time at a similar injection pressure.

For any values associated with CO_2 emissions from equipment leaks and vented emissions of CO_2 from surface equipment at the facility that are reported in this subpart, missing data estimation procedures will be followed.

9.3 MRV Plan Revisions

In the event there is a material change to the monitoring and/or operational parameters of the West Ranch CO_2 EOR operations that is not anticipated in this MRV Plan, the MRV Plan will be revised and submitted to the EPA Administrator within 180 days as required in 40 CFR §98.448(d). As stated earlier in Sections 2 and 3, the subsurface characteristics of the existing WRU for 98-A and 41-A reservoirs are found in the other reservoirs within the Project Interval at West Ranch. Any future expansion into the Project Interval will be subjected to the same regulatory and operational requirements as explained in Sections 2.7 and 2.8. In addition, the reservoir simulation effort carried out as part of DOE's MVA Plan and the storage capacity calculation as illustrated in Sections 2.5 and 2.9 demonstrated the viability of existing and future WRUs for long-term CO_2 retention. Therefore, any horizontal or upward vertical expansion at West Ranch will be managed by applying the same monitoring approach as identified in this MRV Plan and would not trigger a modification to this MRV Plan, as far as they are confined within the Project Interval and fall under the definition of AMA and/or MMA.

10. Records Retention

PNPH will follow the record retention requirements specified by 40 CFR §98.3(g). In addition, the requirements in 40 CFR §98.447 will be met by maintaining the following records for at least three years:

- Quarterly records of CO_2 received including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of this stream.
- Quarterly records of injected CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of this stream.
- Quarterly records of produced CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of this stream.

- Annual records of information used to calculate the CO_2 emitted by surface leakage from leakage pathways.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity.

All data will be collected as generated and aggregated as required for reporting purposes.

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12. Appendices

Appendix 1 Acronyms

AMA – Active Monitoring Area

AoR – Area of Review

API – American Petroleum Institute

Bscf – Billion Standard Cubic Feet

CO_2 – Carbon Dioxide

EOR – Enhanced Oil Recovery

EPA – U.S. Environmental Protection Agency

GHGRP – Greenhouse Gas Reporting Program

MIT – Mechanical Integrity Test

MMSTB – Million barrels

MRV – Monitoring, Reporting, and Verification

scf – Standard Cubic Feet

UIC – Underground Injection Control

USDW – Underground Source of Drinking Water

Appendix 2 Well Identification Numbers

The following table presents the well name, API number, status and type for the wells in the West Ranch as of December 2020. The table is subject to change over time as new wells are drilled, existing wells change status, or existing wells are repurposed.

Well Name	API Number	Well Status
DRUMMOND JH 1	422390233500	P&A
DRUMMOND JH 2	422390233600	P&A
DRUMMOND JH 3	422390233700	Monitor
DRUMMOND JH 4	422390233800	P&A
DRUMMOND JH 5	422390233900	Monitor
DRUMMOND JH 6	422390234000	Monitor
DRUMMOND JH 7	422390234100	Monitor
DRUMMOND JH 8	422390234200	Monitor
DRUMMOND JH 1A	422390234300	P&A
DRUMMOND JH 9	422390234400	P&A
DRUMMOND JH 1B	422390234500	P&A
DRUMMOND JH 2B	422390234600	P&A
DRUMMOND JH 3B	422390234700	Monitor
DRUMMOND JH 4B	422390234800	P&A
DRUMMOND JH 1C	422390234900	P&A
DRUMMOND JH 2C	422390235000	Monitor
DRUMMOND JH 1D	422390235100	P&A
WEST RANCH A 2	422390235600	P&A
WEST RANCH A 3	422390235700	P&A
WEST RANCH A 4	422390235800	P&A
WEST RANCH A 5	422390235900	Monitor
WEST RANCH A 6-ST	422390236001	P&A
WEST RANCH A 6	422390236099	P&A
WEST RANCH A 7-ST	422390236101	P&A
WEST RANCH A 8	422390236200	P&A
WEST RANCH A 9	422390236300	P&A
WEST RANCH A 10	422390236400	Monitor
WEST RANCH A 11	422390236500	Monitor
WEST RANCH A 12	422390236600	P&A
WEST RANCH A 13	422390236800	Monitor
WEST RANCH A 14	422390236900	P&A
WEST RANCH A 15	422390237000	P&A
WEST RANCH A 16	422390237100	Monitor
WEST RANCH A 17	422390237200	Monitor
WEST RANCH A 18-OH	422390237399	P&A
WEST RANCH A 19	422390237400	P&A
WEST RANCH A 20	422390237500	P&A
WEST RANCH A 21	422390237600	P&A
WEST RANCH A 22	422390237700	P&A
WEST RANCH A 23	422390237800	Monitor
WEST RANCH A 24	422390237900	P&A
WEST RANCH A 25	422390238000	P&A
WEST RANCH A 26	422390238100	P&A
WEST RANCH A 27	422390238200	Monitor

WEST RANCH A 28	422390238300	P&A
WEST RANCH A 29	422390238400	Monitor
WEST RANCH A 30	422390238500	Monitor
WEST RANCH A 31	422390238600	P&A
WEST RANCH A 32	422390238700	Monitor
WEST RANCH A 33	422390238800	P&A
WEST RANCH A 34-HR	422390238901	Monitor
WEST RANCH A 35	422390239000	OIL-Conventional
WEST RANCH A 36	422390239100	Monitor
WEST RANCH A 37-HR	422390239201	Monitor
WEST RANCH A 38	422390239300	P&A
WEST RANCH A 39	422390239400	P&A
WEST RANCH A 40	422390239500	P&A
WEST RANCH A 41	422390239600	P&A
WEST RANCH A 42	422390239700	WSW
WEST RANCH A 43	422390239800	P&A
WEST RANCH A 44	422390239900	P&A
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WEST RANCH A 46	422390240100	P&A
WEST RANCH A 47	422390240200	Monitor
WEST RANCH A 48	422390240300	P&A
WEST RANCH A 49	422390240400	Monitor
WEST RANCH A 50	422390240500	Monitor
WEST RANCH A 51-ST	422390240601	Monitor
WEST RANCH A 52	422390240700	OIL-Conventional
WEST RANCH A 53	422390240800	P&A
WEST RANCH A 54	422390240900	Monitor
WEST RANCH A 55	422390241000	P&A
WEST RANCH A 56	422390241100	Monitor
WEST RANCH A 57	422390241200	P&A
WEST RANCH A 58	422390241300	Monitor
WEST RANCH A 59	422390241400	P&A
WEST RANCH A 60	422390241500	Monitor
WEST RANCH A 61	422390241600	P&A
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WEST RANCH A 63	422390241800	P&A
WEST RANCH A 64	422390241900	Monitor
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WEST RANCH A 66	422390242100	P&A
WEST RANCH A 67	422390242200	P&A
WEST RANCH A 68	422390242300	Monitor
WEST RANCH A 69	422390242400	P&A
WEST RANCH A 70	422390242500	P&A
WEST RANCH A 71	422390242600	P&A
WEST RANCH A 72	422390242700	Monitor
WEST RANCH A 73	422390242800	P&A
WEST RANCH A 74	422390242900	P&A
WEST RANCH A 75	422390243000	Monitor
WEST RANCH A 76	422390243100	Monitor
WEST RANCH A 77	422390243200	Monitor
WEST RANCH A 78	422390243300	P&A
WEST RANCH A 79	422390243400	OIL-Conventional
WEST RANCH A 80	422390243500	P&A

WEST RANCH A 81	422390243600	P&A
WEST RANCH A 82	422390243700	Monitor
WEST RANCH A 83	422390243800	Monitor
WEST RANCH A 84	422390243900	P&A
WEST RANCH A 85	422390244000	P&A
WEST RANCH A 86	422390244100	P&A
WEST RANCH A 87	422390244200	P&A
WEST RANCH A 88	422390244300	P&A
WEST RANCH A 89	422390244400	P&A
WEST RANCH A 90	422390244500	P&A
WEST RANCH A 91	422390244600	P&A
WEST RANCH A 92	422390244700	P&A
WEST RANCH A 93	422390244800	P&A
WEST RANCH A 94	422390244900	P&A
WEST RANCH A 95	422390245000	P&A
WEST RANCH A 96	422390245100	Monitor
WEST RANCH A 97	422390245200	Monitor
WEST RANCH A 98	422390245300	P&A
WEST RANCH A 99	422390245400	P&A
WEST RANCH A 100	422390245500	P&A
WEST RANCH A 101	422390245600	P&A
WEST RANCH A 102	422390245700	P&A
WEST RANCH A 103	422390245800	Monitor
WEST RANCH A 104	422390245900	P&A
WEST RANCH A 105	422390246000	Monitor
WEST RANCH A 106	422390246100	P&A
WEST RANCH A 107	422390246200	P&A
WEST RANCH A 108	422390246300	OIL-Conventional
WEST RANCH A 109	422390246400	Monitor
WEST RANCH A 110	422390246500	P&A
WEST RANCH A 111	422390246600	Monitor
WEST RANCH A 112	422390246700	Monitor
WEST RANCH A 113	422390246800	P&A
WEST RANCH A 114	422390246900	P&A
WEST RANCH A 115	422390247000	P&A
WEST RANCH A 116	422390247100	Monitor
WEST RANCH A 117	422390247200	P&A
WEST RANCH A 118	422390247300	Monitor
WEST RANCH A 119	422390247400	P&A
WEST RANCH A 120	422390247500	P&A
WEST RANCH A 121	422390247600	P&A
WEST RANCH A 122	422390247700	P&A
WEST RANCH A 123	422390247800	Monitor
WEST RANCH A 124	422390247900	P&A
WEST RANCH A 125	422390248000	Monitor
WEST RANCH A 126	422390248100	P&A
WEST RANCH A 127	422390248200	OIL-Conventional
WEST RANCH A 128	422390248300	P&A
WEST RANCH A 129	422390248400	P&A
WEST RANCH A 130	422390248500	P&A
WEST RANCH A 131	422390248600	P&A
WEST RANCH A 132	422390248700	P&A
WEST RANCH A 133	422390248800	P&A

WEST RANCH A 134	422390248900	P&A
WEST RANCH A 135	422390249000	P&A
WEST RANCH A 136	422390249100	P&A
WEST RANCH A 137	422390249200	Monitor
WEST RANCH A 138	422390249300	P&A
WEST RANCH A 139	422390249400	P&A
WEST RANCH A 140	422390249500	Monitor
WEST RANCH A 141	422390249600	P&A
WEST RANCH A 142	422390249700	Monitor
WEST RANCH A 143	422390249800	P&A
WEST RANCH A 144	422390249900	P&A
WEST RANCH A 145	422390250000	Monitor
WEST RANCH A 146	422390250100	Monitor
WEST RANCH A 147	422390250200	Monitor
WEST RANCH A 148	422390250300	P&A
WEST RANCH A 149	422390250400	P&A
WEST RANCH A 150	422390250500	P&A
WEST RANCH A 151	422390250600	P&A
WEST RANCH A 152	422390250700	P&A
WEST RANCH A 153	422390250800	P&A
WEST RANCH A 154	422390250900	P&A
WEST RANCH A 155	422390251000	Monitor
WEST RANCH A 156	422390251100	Monitor
WEST RANCH A 157	422390251200	P&A
WEST RANCH A 158	422390251300	Monitor
WEST RANCH A 159	422390251400	P&A
WEST RANCH A 160	422390251500	P&A
WEST RANCH A 161	422390251600	Monitor
WEST RANCH A 162	422390251700	Monitor
WEST RANCH A 163	422390251800	Monitor
WEST RANCH A 164	422390251900	Monitor
WEST RANCH A 165	422390252000	Monitor
WEST RANCH A 166	422390252100	P&A
WEST RANCH A 167	422390252200	P&A
WEST RANCH A 168	422390252300	Monitor
WEST RANCH A 169	422390252400	Monitor
WEST RANCH A 170	422390252500	P&A
WEST RANCH A 171	422390252600	Monitor
WEST RANCH A 172	422390252700	OIL-Conventional
WEST RANCH A 173	422390252800	P&A
WEST RANCH A 174	422390252900	Monitor
WEST RANCH A 175	422390253000	Monitor
WEST RANCH A 176	422390253100	P&A
WEST RANCH A 177	422390253200	P&A
WEST RANCH A 178	422390253300	Monitor
WEST RANCH A 179	422390253400	P&A
WEST RANCH A 180	422390253500	Monitor
WEST RANCH A 181	422390253600	P&A
WEST RANCH A 182	422390253700	P&A
WEST RANCH A 183	422390253800	P&A
WEST RANCH A 184	422390253900	P&A
WEST RANCH A 185	422390254000	P&A
WEST RANCH A 186	422390254100	P&A

WEST RANCH A 187	422390254200	P&A
WEST RANCH A 188	422390254300	Monitor
WEST RANCH A 189	422390254400	P&A
WEST RANCH A 190	422390254500	Monitor
WEST RANCH A 191	422390254600	P&A
WEST RANCH A 192	422390254700	P&A
WEST RANCH A 193	422390254800	P&A
WEST RANCH A 194	422390254900	P&A
WEST RANCH A 195	422390255000	Monitor
WEST RANCH A 196	422390255100	Monitor
WEST RANCH A 197	422390255200	WSW
WEST RANCH A 198	422390255300	P&A
WEST RANCH A 199	422390255400	P&A
WEST RANCH A 200	422390255500	P&A
WEST RANCH A 201	422390255600	P&A
WEST RANCH A 202	422390255700	Monitor
WEST RANCH A 203	422390255800	P&A
WEST RANCH A 204	422390255900	P&A
WEST RANCH A 205	422390256000	Monitor
WEST RANCH A 206	422390256100	Monitor
WEST RANCH A 207	422390256200	P&A
WEST RANCH A 208	422390256300	P&A
WEST RANCH A 209	422390256400	P&A
WEST RANCH A 210	422390256500	P&A
WEST RANCH A 211	422390256600	P&A
WEST RANCH A 212	422390256700	P&A
WEST RANCH A 213	422390256800	OIL-Conventional
WEST RANCH A 214	422390256900	Monitor
WEST RANCH A 215	422390257000	Monitor
WEST RANCH A 216	422390257100	P&A
WEST RANCH A 217	422390257200	P&A
WEST RANCH A 218	422390257300	P&A
WEST RANCH A 219	422390257400	P&A
WEST RANCH A 220	422390257500	P&A
WEST RANCH A 221	422390257600	P&A
WEST RANCH A 222	422390257700	Monitor
WEST RANCH A 224	422390257900	P&A
WEST RANCH A 225	422390258000	Monitor
WEST RANCH A 226	422390258100	P&A
WEST RANCH A 227	422390258200	P&A
WEST RANCH A 228	422390258300	P&A
WEST RANCH A 229	422390258400	P&A
WEST RANCH A 230	422390258500	P&A
WEST RANCH A 231	422390258600	Monitor
WEST RANCH A 232	422390258700	Monitor
WEST RANCH A 234	422390258800	P&A
WEST RANCH A 235	422390258900	Monitor
WEST RANCH A 236	422390259000	Monitor
WEST RANCH A 237	422390259100	P&A
WEST RANCH A 238	422390259200	P&A
WEST RANCH A 239	422390259300	Monitor
WEST RANCH A 241	422390259400	P&A
WEST RANCH A 242	422390259500	OIL-Conventional

WEST RANCH A 243	422390259600	P&A
WEST RANCH A 246	422390259700	P&A
WEST RANCH A 245	422390259800	P&A
WEST RANCH A 247	422390259900	P&A
WEST RANCH A 248	422390260000	P&A
WEST RANCH A 249	422390260100	P&A
WEST RANCH A 250	422390260200	P&A
WEST RANCH A 251	422390260300	P&A
WEST RANCH A 254	422390260400	P&A
WEST RANCH A 255	422390260500	P&A
WEST RANCH A 256	422390260600	P&A
WEST RANCH A 257	422390260700	Monitor
WEST RANCH A 258	422390260800	Monitor
WEST RANCH A 252	422390260900	Monitor
WEST RANCH A 259	422390261000	P&A
WEST RANCH A 260	422390261100	P&A
WEST RANCH A 261	422390261200	P&A
WEST RANCH A 262	422390261300	P&A
WEST RANCH A 263	422390261400	Monitor
WEST RANCH A 264	422390261500	Monitor
WEST RANCH A 240	422390261600	Monitor
WEST RANCH A 265	422390261700	P&A
WEST RANCH A 267	422390261800	P&A
WEST RANCH A 269	422390261900	Monitor
WEST RANCH A 271	422390262000	Monitor
WEST RANCH A 272	422390262100	P&A
WEST RANCH A 273	422390262200	Monitor
WEST RANCH A 274	422390262300	P&A
WEST RANCH A 275	422390262400	P&A
WEST RANCH A 276	422390262500	P&A
WEST RANCH A 278	422390262600	Monitor
WEST RANCH A 279	422390262700	Monitor
WEST RANCH A 280	422390262800	P&A
WEST RANCH A 281	422390262900	Monitor
WEST RANCH A 282	422390263000	P&A
WEST RANCH A 283	422390263100	Monitor
WEST RANCH A 284	422390263200	Monitor
WEST RANCH A 285	422390263300	Monitor
WEST RANCH A 286	422390263400	Monitor
WEST RANCH A 287	422390263500	Monitor
WEST RANCH A 288	422390263600	Monitor
WEST RANCH A 289	422390263700	P&A
WEST RANCH A 290	422390263800	P&A
WEST RANCH A 291	422390263900	P&A
WEST RANCH A 292	422390264000	P&A
WEST RANCH A 293	422390264100	Monitor
WEST RANCH A 294	422390264200	P&A
WEST RANCH A 295	422390264300	Monitor
WEST RANCH A 296	422390264400	P&A
WEST RANCH A 297	422390264500	P&A
WEST RANCH A 298	422390264600	P&A
WEST RANCH A 299	422390264700	P&A
WEST RANCH A 300	422390264800	P&A

WEST RANCH A 301	422390264900	Monitor
WEST RANCH A 302	422390265000	Monitor
WEST RANCH A 303	422390265100	P&A
WEST RANCH A 304	422390265200	P&A
WEST RANCH A 305	422390265300	OIL-Conventional
WEST RANCH A 306	422390265400	P&A
WEST RANCH A 307	422390265500	P&A
WEST RANCH A 308	422390265600	P&A
WEST RANCH A 309	422390265700	OIL-Conventional
WEST RANCH A 310	422390265800	Monitor
WEST RANCH A 311	422390265900	Monitor
WEST RANCH A 312	422390266000	P&A
WEST RANCH A 313	422390266100	P&A
WEST RANCH A 314	422390266200	OIL-Conventional
WEST RANCH A 315	422390266300	OIL-Conventional
WEST RANCH A 316	422390266400	P&A
WEST RANCH A 317	422390266500	P&A
WEST RANCH A 318	422390266600	P&A
WEST RANCH A 319	422390266700	P&A
WEST RANCH A 320	422390266800	P&A
WEST RANCH A 321	422390266900	OIL-Conventional
WEST RANCH A 322	422390267000	Monitor
WEST RANCH A 323	422390267100	P&A
WEST RANCH A 324	422390267200	P&A
WEST RANCH A 325	422390267300	P&A
WEST RANCH A 326	422390267400	Monitor
WEST RANCH A 327	422390267500	P&A
WEST RANCH A 328	422390267600	Monitor
WEST RANCH A 330	422390267700	WSW
WEST RANCH A 331	422390267800	P&A
WEST RANCH A 332	422390267900	OIL-Conventional
WEST RANCH A 333	422390268000	Monitor
WEST RANCH A 334	422390268100	OIL-Conventional
WEST RANCH A 335	422390268200	WSW
WEST RANCH A 336	422390268300	OIL-Conventional
WEST RANCH A 337	422390268400	Monitor
WEST RANCH A 338	422390268500	P&A
WEST RANCH A 339	422390268600	P&A
WEST RANCH A 340	422390268700	WSW
WEST RANCH A 341	422390268800	P&A
WEST RANCH A 342	422390268900	Monitor
WEST RANCH A 343	422390269000	Monitor
WEST RANCH A 344	422390269100	Monitor
WEST RANCH A 345	422390269200	P&A
WEST RANCH A 346	422390269300	Monitor
WEST RANCH A 347	422390269400	OIL-Conventional
WEST RANCH A 348	422390269500	P&A
WEST RANCH A 349	422390269600	Monitor
WEST RANCH A 350	422390269700	WSW
WEST RANCH A 351	422390269800	WSW
WEST RANCH A 352	422390269900	P&A
WEST RANCH A 353	422390270000	P&A
WEST RANCH A 354	422390270100	P&A

WEST RANCH A 355	422390270200	Monitor
WEST RANCH A 355-HR	422390270201	Monitor
WEST RANCH A 356	422390270300	P&A
WEST RANCH A 357	422390270400	Monitor
WEST RANCH A 358	422390270500	Monitor
WEST RANCH A 359	422390270600	P&A
WEST RANCH A 360	422390270700	Monitor
WEST RANCH A 361	422390270800	WSW
WEST RANCH A 362	422390270900	WSW
WEST RANCH A 363	422390271000	Monitor
WEST RANCH A 364	422390271100	Monitor
WEST RANCH A 365	422390271200	Monitor
WEST RANCH A 366	422390271300	Monitor
WEST RANCH A 367	422390271400	Monitor
WEST RANCH A 368	422390271500	Monitor
WEST RANCH A 369	422390271600	P&A
WEST RANCH A 370	422390271700	Monitor
WEST RANCH A 371	422390271800	P&A
WEST RANCH A 372	422390271900	Monitor
WEST RANCH A 373	422390272000	OIL-CO2
WEST RANCH A 374	422390272100	OIL-Conventional
WEST RANCH A 375	422390272200	Monitor
WEST RANCH A 376	422390272300	Monitor
WEST RANCH A 377	422390272400	Monitor
WEST RANCH A 378	422390272500	Monitor
WEST RANCH A 379	422390272600	Monitor
WEST RANCH A 380	422390272700	P&A
WEST RANCH A 381	422390272800	P&A
WEST RANCH A 382	422390272900	Monitor
WEST RANCH A 383	422390273000	OIL-Conventional
WEST RANCH A 384	422390273100	Monitor
WEST RANCH A 385	422390273200	P&A
WEST RANCH A 386	422390273300	P&A
WEST RANCH A 387	422390273400	P&A
WEST RANCH A 388	422390273500	P&A
WEST RANCH A 389	422390273600	Monitor
WEST RANCH A 390	422390273700	P&A
WEST RANCH A 391	422390273800	Monitor
WEST RANCH A 392	422390273900	Monitor
WEST RANCH A 393	422390274000	Monitor
WEST RANCH A 394	422390274100	OIL-Conventional
WEST RANCH A 395	422390274200	P&A
WEST RANCH A 396	422390274300	P&A
WEST RANCH A 397	422390274400	Monitor
WEST RANCH A 398	422390274500	Monitor
WEST RANCH A 399	422390274600	Monitor
WEST RANCH A 400	422390274700	P&A
WEST RANCH A 401	422390274800	INJ
WEST RANCH A 402	422390274900	P&A
WEST RANCH A 403	422390275000	OIL-Conventional
WEST RANCH A 404	422390275100	P&A
WEST RANCH A 405	422390275200	Monitor
WEST RANCH A 406	422390275300	P&A

WEST RANCH A 407	422390275400	P&A
WEST RANCH A 408	422390275500	P&A
WEST RANCH A 409	422390275600	P&A
WEST RANCH A 410	422390275700	P&A
WEST RANCH A 411	422390275800	Monitor
WEST RANCH A 412	422390275900	OIL-Conventional
WEST RANCH A 413	422390276000	OIL-Conventional
WEST RANCH A 414	422390276100	P&A
WEST RANCH A 415	422390276200	Monitor
WEST RANCH A 416	422390276300	P&A
WEST RANCH A 417	422390276400	Monitor
WEST RANCH A 418	422390276500	Monitor
WEST RANCH A 419	422390276600	Monitor
WEST RANCH A 420	422390276700	Monitor
WEST RANCH A 421	422390276800	P&A
WEST RANCH A 422	422390276900	P&A
WEST RANCH A 423	422390277000	P&A
WEST RANCH A 424	422390277100	P&A
WEST RANCH A 425-ST	422390277201	OIL-Conventional
WEST RANCH A 426-ST	422390277301	P&A
WEST RANCH A 427	422390277400	Monitor
WEST RANCH A 428	422390277500	Monitor
WEST RANCH A 429	422390277600	Monitor
WEST RANCH A 430	422390277700	Monitor
WEST RANCH A 431	422390277800	Monitor
WEST RANCH A 432	422390277900	P&A
WEST RANCH A 433	422390278000	Monitor
WEST RANCH A 434	422390278100	Monitor
WEST RANCH A 435	422390278200	P&A
WEST RANCH A 436	422390278300	P&A
WEST RANCH A 437	422390278400	Monitor
WEST RANCH A 439	422390278500	Monitor
WEST RANCH A 440	422390278600	P&A
WEST RANCH A 441	422390278700	P&A
WEST RANCH A 442	422390278800	P&A
WEST RANCH A 443	422390278900	OIL-Conventional
WEST RANCH A 444	422390279000	Monitor
WEST RANCH A 445	422390279100	Monitor
WEST RANCH A 446	422390279200	P&A
WEST RANCH A 447	422390279300	Monitor
WEST RANCH A 448	422390279400	Monitor
WEST RANCH A 449-OH	422390279599	P&A
WEST RANCH State 2	422390279700	Monitor
WEST RANCH A 233	422390279800	Monitor
DRUMMOND JH 1	422390280400	Monitor
DRUMMOND JH 2	422390280500	Monitor
DRUMMOND 3	422390280600	OIL-Conventional
DRUMMOND 4	422390280700	P&A
DRUMMOND 6	422390280800	Monitor
DRUMMOND 7	422390280900	Monitor
TONEY 1	422390281100	Monitor
TONEY 2	422390281200	P&A
TONEY 3	422390281300	Monitor

TONEY 4	422390281400	P&A
TONEY 5	422390281500	P&A
TONEY 6	422390281600	Monitor
TONEY 7	422390281700	Monitor
TONEY 8	422390281800	Monitor
TONEY 9	422390281900	P&A
TONEY 10 (aka WRGSU 310)	422390282000	P&A
TONEY 11	422390282100	P&A
TONEY 12	422390282200	P&A
TONEY 13	422390282300	P&A
TONEY 14	422390282400	P&A
TONEY 15	422390282500	P&A
TONEY 16	422390282600	P&A
TONEY 17	422390282700	P&A
TONEY 19	422390282900	P&A
TONEY 20	422390283000	Monitor
TONEY 21	422390283100	P&A
TONEY 22	422390283200	P&A
TONEY 24	422390283400	P&A
TONEY 26	422390283500	P&A
TONEY 28	422390283600	P&A
TONEY 27	422390283700	P&A
TONEY 28	422390283800	P&A
TONEY 29	422390283900	P&A
TONEY 30	422390284000	P&A
TONEY 31	422390284100	P&A
TONEY 32	422390284200	P&A
TONEY 33	422390284300	Monitor
TONEY 35	422390284400	P&A
TONEY 34	422390284500	Monitor
TONEY 36	422390284600	Monitor
TONEY 37	422390284700	Monitor
TONEY 38	422390284800	Monitor
TONEY 39	422390284900	P&A
TONEY 40	422390285000	P&A
TONEY 41	422390285100	Monitor
TONEY 42	422390285200	P&A
TONEY 43	422390285300	P&A
TONEY 44	422390285400	P&A
TONEY 45	422390285500	P&A
TONEY 46	422390285600	P&A
TONEY 47	422390285700	P&A
TONEY 49	422390285900	P&A
TONEY 50	422390286000	P&A
TONEY 51	422390286100	P&A
TONEY 52	422390286200	P&A
TONEY 53	422390286300	P&A
TONEY 54	422390286400	P&A
TONEY 55	422390286500	P&A
TONEY 56	422390286600	P&A
TONEY 57	422390286700	P&A
TONEY 58	422390286800	P&A
TONEY 61	422390287100	P&A

TONEY 62	422390287200	P&A
TONEY 63	422390287300	P&A
TONEY 65	422390287500	Monitor
TONEY 66	422390287600	P&A
TONEY 67	422390287700	P&A
TONEY 69	422390287800	P&A
TONEY 71	422390287900	P&A
TONEY 72	422390288000	P&A
TONEY 73	422390288100	Monitor
TONEY 74	422390288200	P&A
TONEY 75	422390288300	P&A
TONEY 76 (D & F) (aka WRGSU 376)	422390288400	P&A
TONEY 77	422390288500	Monitor
TONEY 78	422390288600	P&A
TONEY 79	422390288700	P&A
VANDERBILT STATE 1	422390288800	P&A
VANDERBILT STATE 5	422390288900	Monitor
VANDERBILT STATE 2	422390289000	Monitor
VANDERBILT STATE 3	422390289100	P&A
VANDERBILT STATE 6	422390289200	Monitor
VANDERBILT STATE 4	422390289300	P&A
VANDERBILT STATE 7	422390289400	Monitor
VANDERBILT STATE 8	422390289500	P&A
VANDERBILT STATE 9	422390289600	Monitor
VANDERBILT STATE B 10	422390289700	Monitor
VANDERBILT STATE 11	422390289800	P&A
VANDERBILT STATE 13	422390290000	P&A
VANDERBILT STATE 14 (aka WRGSU 414)	422390290100	P&A
VANDERBILT STATE 15	422390290200	P&A
VANDERBILT STATE 17	422390290400	Monitor
VANDERBILT STATE 19	422390290600	P&A
VANDERBILT STATE 20	422390290700	P&A
VANDERBILT STATE 21	422390290800	P&A
VANDERBILT STATE 22	422390290900	Monitor
VANDERBILT STATE 24	422390291000	P&A
VANDERBILT STATE B 1	422390291100	P&A
VANDERBILT STATE B 2	422390291200	P&A
VANDERBILT STATE B 3	422390291300	P&A
VANDERBILT STATE B 4	422390291400	P&A
VANDERBILT STATE B 5	422390291500	P&A
VANDERBILT STATE B 6	422390291600	Monitor
VANDERBILT STATE B 7 OH	422390291700	Monitor
VANDERBILT STATE B 8	422390291800	Monitor
VANDERBILT STATE B 9	422390291900	P&A
VANDERBILT STATE 10	422390292000	P&A
VANDERBILT STATE B 11	422390292100	P&A
MENEFEE BAYOU STATE 1	422390293500	P&A
MENEFEE BAYOU STATE 3	422390293600	P&A
MENEFEE BAYOU STATE 4	422390293700	Monitor
MENEFEE BAYOU STATE B 1	422390293800	P&A
MENEFEE BAYOU STATE B 2	422390293900	P&A
MENEFEE BAYOU STATE B 4	422390294100	P&A

MENEFEE BAYOU STATE 2	422390294300	P&A
WEST RANCH A 253	422390337700	P&A
TONEY 80	422390349700	P&A
TONEY 81	422390349800	P&A
TONEY 82	422390349900	Monitor
TONEY 84	422390362800	P&A
TONEY 83	422390365300	Monitor
WEST RANCH A 455	422390365400	Monitor
WEST RANCH A 462	422390365500	P&A
WEST RANCH A 460	422390366100	OIL-Conventional
WEST RANCH A 461	422390366200	Monitor
WEST RANCH A 458	422390366300	P&A
WEST RANCH A 458 OH	422390366399	P&A
VANDERBILT STATE 25	422390366700	P&A
VANDERBILT STATE 26	422390366800	P&A
MENEFEE BAYOU STATE B 5 (aka WRGSU 205F)	422390367900	P&A
WEST RANCH A 454	422390368000	P&A
WEST RANCH A 459	422390368300	P&A
WEST RANCH A 456	422390368400	Monitor
WEST RANCH A 457	422390368500	Monitor
TONEY 86 H	422390369700	P&A
TONEY 87	422390377800	P&A
WRSOGU 1-2	422390382800	Monitor
WRSOGU 2-2	422393282500	Monitor
WRSOGU 1-3	422390384400	P&A
WRSOGU 2-3	422393282400	Monitor
WRSOGU 1-4	422390384600	P&A
WRSOGU 1-5	422390386100	Monitor
STATE COBDEN 1	422390393300	Monitor
WEST RANCH A 453	422390393900	OIL-Conventional
STATE COBDEN 2	422390394200	Monitor
VANDERBILT STATE 27	422392028000	P&A
WRSOGU 1-6	422393000300	Monitor
WEST RANCH A 469	422393006100	P&A
WRSOGU 1-7	422393007100	Oil-Conventional
WRSOGU 1-8	422393009500	P&A
WRSOGU 2-1	422393010100	P&A
WRSOGU 1-10	422393011100	Monitor
WRASOGU 1-11	422393011300	P&A
WEST RANCH A 471	422393017500	P&A
WEST RANCH A 472	422393017600	Monitor
WEST RANCH A 473	422393020700	P&A
WEST RANCH A 474	422393022100	P&A
DRUMMOND JH 1E	422393033400	Monitor
VANDERBILT STATE 28	422393036500	Monitor
WEST RANCH A 476	422393038000	P&A
TONEY 89	422393038500	Monitor
WEST RANCH A 477	422393054200	Monitor
WEST RANCH A 482	422393082600	OIL-Conventional
WEST RANCH A 478	422393082800	Monitor
WEST RANCH A 479	422393082900	Monitor
WEST RANCH A 480	422393083000	Monitor
WEST RANCH A 484	422393118900	P&A

WEST RANCH A 483	422393119000	Monitor
WEST RANCH A 481	422393124000	P&A
WEST RANCH A 485	422393124100	Monitor
WEST RANCH A 488	422393124900	Monitor
WEST RANCH A 487	422393125000	P&A
WEST RANCH A 486	422393125100	P&A
WEST RANCH A 489	422393125200	Monitor
WEST RANCH A 491	422393125300	Monitor
WEST RANCH A 490	422393125400	Monitor
WEST RANCH A 492	422393125500	OIL-CO2
WEST RANCH A1 ERD	422393161500	P&A
WEST RANCH A 493	422393163300	Monitor
WEST RANCH A 496	422393168300	Monitor
WEST RANCH A 495	422393168400	Monitor
WEST RANCH A 497	422393197600	P&A
WEST RANCH A 494	422393200700	Monitor
WEST RANCH A 501	422393200800	Monitor
WEST RANCH A 502	422393200900	Monitor
WEST RANCH A 508	422393201000	Monitor
WEST RANCH A 505	422393201200	P&A
WEST RANCH A 504	422393201300	OIL-Conventional
WEST RANCH A 503	422393201400	Monitor
WEST RANCH A 507	422393201500	P&A
WEST RANCH A 506	422393201600	P&A
WEST RANCH A 510	422393213100	Monitor
WEST RANCH A 509J	422393213401	Monitor
WEST RANCH A 511	422393213600	P&A
WEST RANCH A 512	422393220900	OIL-CO2
WEST RANCH A 513	422393221500	Monitor
WEST RANCH A 514	422393221600	Monitor
WEST RANCH A 515	422393222400	P&A
WEST RANCH A 516	422393223000	Monitor
WEST RANCH A 517	422393224900	WSW
WEST RANCH A 520	422393228600	Monitor
WEST RANCH A 518	422393235400	Monitor
WEST RANCH A 523	422393236800	Monitor
WEST RANCH A 519	422393237000	Monitor
WEST RANCH A 521	422393237200	P&A
WEST RANCH A 522	422393237800	Monitor
WEST RANCH Unit 1-1	422393241600	Monitor
TONEY 91	422393244500	Monitor
WEST RANCH A 524	422393245900	P&A
WEST RANCH Unit 1-2	422393251300	Monitor
WEST RANCH A 525	422393256600	P&A
WEST RANCH A 526	422393257400	P&A
WEST RANCH A 527	422393258100	Monitor
WEST RANCH A 528	422393258300	Monitor
WEST RANCH A 529	422393260100	OIL-Conventional
WEST RANCH A 531	422393260200	Monitor
WEST RANCH A 530	422393260400	Monitor
WEST RANCH A 533 H	422393270000	Monitor
WRSOGU 1-15	422393273500	Monitor
WRSOGU 1-14	422393276000	Oil-Conventional

DRUMMOND-SUPERIOR 8 (aka 3M-8)	422393289500	Monitor
WEST RANCH A 534 H	422393290600	Monitor
WEST RANCH A 535 H	422393290700	Monitor
WEST RANCH A 539 H	422393296000	Monitor
WEST RANCH A 538 H	422393296100	Monitor
WEST RANCH A 536	422393296200	P&A
WEST RANCH A 537 H	422393296300	Monitor
WEST RANCH A 540 H	422393314800	Monitor
WEST RANCH A 541 H	422393318900	WSW
WEST RANCH A 545 H	422393320700	Monitor
WRSOGU 1-17	422393353800	Oil-Conventional
ASHLEY ANN 1	422393356100	OIL-Conventional
WRSOGU 1-18	422393356300	Oil-Conventional
WRSOGU 1-19	422393356400	Oil-Conventional
DRUMMOND JH 3M	422393356900	OIL-Conventional
ASHLEY ANN 2	422393357600	OIL-Conventional
WEST RANCH A 600	422393358000	INJ
WEST RANCH A 601	422393358100	OIL-Conventional
ASHLEY ANN 3	422393358500	OIL-Conventional
WEST RANCH A 602	422393358600	Monitor
3M-2	422393358900	OIL-Conventional
3M-3	422393359900	Monitor
WEST RANCH A 1129	422393362600	INJ
WEST RANCH A 1131	422393362700	INJ
WEST RANCH A 1133	422393363200	INJ
WEST RANCH A 1104	422393363400	SI-CO2
WEST RANCH A 1089	422393363600	INJ
WEST RANCH A 1059	422393365200	OIL-CO2
WEST RANCH A 2119	422393365300	OIL-CO2
WEST RANCH A 1035	422393365400	INJ
WEST RANCH A 2057	422393365500	INJ
WEST RANCH A 1002	422393365600	OIL-CO2
WEST RANCH A 1036	422393365700	INJ
WEST RANCH A 1060	422393365800	INJ
WEST RANCH A 1061	422393365900	OIL-CO2
WEST RANCH A 1003	422393366000	INJ
WEST RANCH A 1004	422393366100	INJ
WEST RANCH A 2020	422393366200	OIL-CO2
WEST RANCH A 2052	422393366300	OIL-CO2
WEST RANCH A 2029	422393366400	INJ
WEST RANCH A 1005	422393366500	INJ
WEST RANCH A 1037	422393366600	INJ
WEST RANCH A 1007	422393366700	INJ
WEST RANCH A 1062	422393366800	INJ
WEST RANCH A 1006	422393366900	INJ
WEST RANCH A 2121	422393367000	OIL-CO2
WEST RANCH A 1038	422393367100	OIL-CO2
WEST RANCH A 1009	422393367200	INJ
WEST RANCH A 1008	422393367300	OIL-CO2
WEST RANCH A 2065	422393367400	OIL-CO2
WEST RANCH A 2021	422393367500	OIL-CO2
WEST RANCH A 1010	422393367600	OIL-CO2
WEST RANCH A 1011	422393367700	INJ

WEST RANCH A 1012	422393367800	INJ
WEST RANCH A 1013	422393367900	INJ
WEST RANCH A 2150	422393368100	OIL-CO2
WEST RANCH A 1014	422393368300	INJ
WEST RANCH A 1015	422393368400	INJ
WEST RANCH A 1016	422393368500	OIL-CO2
WEST RANCH A 1017	422393368600	INJ
WEST RANCH A 1019	422393368700	INJ
WEST RANCH A 1018	422393368800	INJ
WEST RANCH A 2030	422393368900	OIL-CO2
WEST RANCH A 2053	422393369000	OIL-CO2
WEST RANCH A 2055	422393369100	OIL-CO2
WEST RANCH A 1020	422393369200	OIL-CO2
WEST RANCH A 1039	422393369300	INJ
WEST RANCH A 1040	422393369400	INJ
WEST RANCH A 1063	422393369500	INJ
WEST RANCH A 1042	422393369600	INJ
WEST RANCH A 2159	422393369700	OIL-CO2
WEST RANCH A 2160	422393369800	OIL-CO2
WEST RANCH A 2164	422393369900	OIL-CO2
WEST RANCH A 1022	422393370100	INJ
WEST RANCH A 1023	422393370200	INJ
WEST RANCH A 1021	422393370300	INJ
WEST RANCH A 1024	422393370400	INJ
WEST RANCH A 1064	422393370500	INJ
WEST RANCH A 1065	422393370600	INJ
WEST RANCH A 1069	422393370700	INJ
WEST RANCH A 1070	422393370800	INJ
WEST RANCH A 1071	422393370900	INJ
WEST RANCH A 1072	422393371000	INJ
WEST RANCH A 1073	422393371100	INJ
WEST RANCH A 2048	422393371200	OIL-CO2
WEST RANCH A 2170	422393371300	OIL-CO2
WEST RANCH A 1041	422393371400	INJ
WEST RANCH A 2027	422393371800	OIL-CO2
WEST RANCH A 1066	422393371900	INJ
WEST RANCH A 2034	422393372200	OIL-CO2
WEST RANCH A 1044	422393372300	INJ
WEST RANCH A 1043	422393372400	INJ
WEST RANCH A 1117	422393372500	OIL-Conventional
WEST RANCH A 1116	422393372600	INJ
WEST RANCH A 1055	422393372700	INJ
WEST RANCH A 1056	422393372800	INJ
WEST RANCH A 1057	422393372900	INJ
WEST RANCH A 1113	422393373000	INJ
WEST RANCH A 1054	422393373100	INJ
WEST RANCH A 1053	422393373200	INJ
WEST RANCH A 1052	422393373300	INJ
WEST RANCH A 2047	422393373400	OIL-CO2
WEST RANCH A 2036	422393373500	OIL-CO2
WEST RANCH A 2169	422393373600	OIL-CO2
WEST RANCH A 2179	422393373700	OIL-CO2
WEST RANCH A 2118	422393373800	OIL-CO2

WEST RANCH A 1074	422393373900	INJ
WEST RANCH A 2184	422393374000	OIL-CO2
WEST RANCH A 2014	422393374100	OIL-CO2
WEST RANCH A 2168	422393374200	OIL-CO2
WEST RANCH A 2026	422393374300	OIL-CO2
WEST RANCH A 2028	422393374400	OIL-CO2
WEST RANCH A 2054	422393374500	OIL-CO2
WEST RANCH A 2180	422393374600	OIL-CO2
WEST RANCH A 2035	422393374800	OIL-CO2
WEST RANCH A 2037	422393374900	OIL-CO2
WEST RANCH A 2124	422393375000	OIL-CO2
WEST RANCH A 1045	422393375100	OIL-CO2
WEST RANCH A 2056	422393375200	OIL-CO2
WEST RANCH A 1067	422393375300	INJ
WEST RANCH A 1046	422393375400	INJ
WEST RANCH A 1075	422393375500	INJ
WEST RANCH A 2165	422393375600	OIL-CO2
WEST RANCH A 1110	422393375700	INJ
WEST RANCH A 2058	422393375800	SI-CO2
WEST RANCH A 2171	422393375900	OIL-CO2
WEST RANCH A 2172	422393376000	OIL-CO2
WEST RANCH A 2173	422393376100	OIL-CO2
WEST RANCH A 1026	422393376200	INJ
WEST RANCH A 1029	422393376300	INJ
WEST RANCH A 2151	422393376400	OIL-CO2
WEST RANCH A 2167	422393376500	INJ
WEST RANCH A 1076	422393376600	INJ
WEST RANCH A 1068	422393376700	OIL-CO2
WEST RANCH A 2187	422393376800	OIL-CO2
WEST RANCH A 1077	422393376900	INJ
WEST RANCH A 2051	422393377000	OIL-CO2
WEST RANCH A 1078	422393377100	INJ
WEST RANCH A 2120	422393377200	OIL-CO2
WEST RANCH A 2181	422393377300	OIL-CO2
WEST RANCH A 1079	422393377400	INJ
WEST RANCH A 2038	422393377500	OIL-CO2
WEST RANCH A 2040	422393377600	OIL-CO2
WEST RANCH A 1081	422393377700	INJ
WEST RANCH A 2039	422393377800	OIL-CO2
WEST RANCH A 1082	422393377900	INJ
WEST RANCH A 2045	422393378000	OIL-CO2
WEST RANCH A 1083	422393378100	OIL-CO2
WEST RANCH A 1080	422393378200	INJ
WEST RANCH A 2189	422393378400	OIL-CO2
WEST RANCH A 2190	422393378700	OIL-CO2
WEST RANCH A 2063	422393378900	OIL-CO2
WEST RANCH A 2062	422393379000	OIL-CO2
WEST RANCH A 2046	422393379100	OIL-CO2
WEST RANCH A 1106	422393379200	OIL-CO2
WEST RANCH A 1105	422393379300	OIL-CO2
WEST RANCH A 1048	422393379400	INJ
WEST RANCH A 1047	422393379700	OIL-CO2
WEST RANCH A 2061	422393379800	SI-CO2

WEST RANCH A 1107	422393379900	OIL-CO2
WEST RANCH A 2059	422393380000	OIL-Conventional
WEST RANCH A 2060	422393380100	OIL-Conventional
WEST RANCH A 1111	422393380200	SI-CO2
WEST RANCH A 1112	422393380300	SI-CO2
WEST RANCH A 2075	422393380400	SI-CO2
WEST RANCH A 1025	422393380700	INJ
WEST RANCH A 1028	422393380800	INJ
WEST RANCH A 2050	422393380900	OIL-CO2
WEST RANCH A 2166	422393381000	OIL-CO2
WEST RANCH A 1027	422393381100	INJ
WEST RANCH A 2001	422393381200	OIL-CO2
WEST RANCH A 2153	422393381300	OIL-CO2
WEST RANCH A 1030	422393381400	INJ
WEST RANCH A 1051	422393381500	INJ
WEST RANCH A 1050	422393381600	INJ
WEST RANCH A 2152	422393381700	OIL-CO2
WEST RANCH A 2009	422393381800	TA
WEST RANCH A 2010	422393381900	OIL-CO2
WEST RANCH A 2015	422393382000	OIL-CO2
WEST RANCH A 1090	422393382100	INJ
WEST RANCH A 2096	422393382200	OIL-CO2
WEST RANCH A 1058	422393382300	INJ
WEST RANCH A 1119	422393382400	INJ
WEST RANCH A 1120	422393382500	INJ
WEST RANCH A 2008	422393382600	OIL-CO2
WEST RANCH A 1092	422393382700	INJ
WEST RANCH A 1140	422393382800	INJ
WEST RANCH A 2094	422393382900	OIL-CO2
WEST RANCH A 1128	422393383000	INJ
WEST RANCH A 2174	422393383100	OIL-CO2
WEST RANCH A 1034	422393383200	INJ
WEST RANCH A 2193	422393383300	OIL-CO2
WEST RANCH A 2192	422393383400	OIL-CO2
WEST RANCH A 2191	422393383500	OIL-CO2
WEST RANCH A 2016	422393383700	OIL-CO2
WEST RANCH A 2017	422393383800	OIL-CO2
WEST RANCH A 2175	422393383900	OIL-CO2
WEST RANCH A 2176	422393384000	OIL-CO2
WEST RANCH A 2177	422393384100	OIL-CO2
WEST RANCH A 2127	422393384200	OIL-CO2
WEST RANCH A 2031	422393384300	OIL-CO2
WEST RANCH A 2032	422393384400	OIL-CO2
WEST RANCH A 2033	422393384500	OIL-CO2
WEST RANCH A 2049	422393384600	OIL-CO2
WEST RANCH A 1087	422393385300	SI-CO2
WEST RANCH A 2025	422393385400	OIL-CO2
WEST RANCH A 2041	422393385500	OIL-CO2
WEST RANCH A 2043	422393385600	SI-CO2
WEST RANCH A 1088	422393386000	INJ
WEST RANCH A 2125	422393386100	OIL-CO2
WEST RANCH A 2018	422393386200	OIL-CO2
WEST RANCH A 2196	422393386300	OIL-CO2

WEST RANCH A 2195	422393386400	OIL-CO2
WEST RANCH A 1121	422393386800	INJ
WEST RANCH A 1130	422393386900	INJ
WEST RANCH A 2092	422393387000	OIL-CO2
WEST RANCH A 2090	422393387100	OIL-CO2
WEST RANCH A 2197	422393387600	OIL-CO2
WEST RANCH A 2198	422393387900	OIL-CO2
WEST RANCH A 2019	422393388100	SI-CO2
WEST RANCH A 2073	422393388300	SI-CO2
WEST RANCH A 1109	422393388700	SI-CO2
WEST RANCH A 1154	422393389100	SI-CO2
WEST RANCH A 2089	422393390100	OIL-CO2
WEST RANCH A 1122	422393390200	INJ
WEST RANCH A 1123	422393390300	INJ
WEST RANCH A 1124	422393390700	INJ
WEST RANCH A 1125	422393390800	INJ
WEST RANCH A 2081	422393390900	OIL-CO2
WEST RANCH A 900 ST	422393392300	OIL-Conventional
WEST RANCH A 902	422393392400	OIL-Conventional
WEST RANCH A 904	422393393400	OIL-Conventional
WEST RANCH A 908	422393393600	OIL-Conventional
WEST RANCH A 500	422398062200	P&A
DRUMMOND JH 10	422398062400	P&A
VANDERBILT STATE 18	422398062700	P&A
VANDERBILT STATE 16	422398066500	P&A
TONEY 18	422398082200	P&A
TONEY 48	422398112500	P&A
VANDERBILT STATE 12	422398127200	P&A
WEST RANCH A 475	422398146700	P&A
WEST RANCH A 913	422393393800	OIL-Conventional
WEST RANCH A 912	422393393900	TA
WRSOGU 1-12	TBD	P&A
WRSOGU 1-13	TBD	P&A
WRSOGU 1-16	TBD	P&A
WRSOGU 1-20	TBD	P&A

P&A: Plugged and Abandoned Well
INJ: Injection Well
SI: Shut-in Well
TA: Temporarily Abandoned Well
WSW: Water Source Well

Appendix B: Submissions and Responses to Requests for Additional Information

Petra Nova

West Ranch Oil Field CO_2 Monitoring, Reporting and Verification (MRV) Plan

July 2021

Table of Contents

Contents

Introduction

The Petra Nova project is a commercial scale post-combustion carbon capture project utilizing an advanced amine-based absorption technology to capture at least 90 percent of the carbon dioxide (CO_2) from a nominal 240 MW equivalent flue gas slipstream diverted from the coal-fired Unit 8 (Unit 8) at NRG Energy, Inc.'s W.A. Parish Electric Generating Station (Carbon Capture Equipment (CCE)). The CCE is located southwest of Houston, Texas, in rural Fort Bend County, in the town of Thompsons, Texas. The captured CO_2, up to 4,717 metric tons (5,200 short tons) per day, is being dried, compressed, and transported via an 81-mile pipeline to the West Ranch oil field in Jackson County, Texas (West Ranch), where it is used in CO_2 enhanced oil recovery (EOR) operations. Petra Nova Parish Holdings LLC (PNPH), through its wholly-owned subsidiary Petra Nova CCS I LLC, owns the CCE. PNPH is a joint venture between NRG Energy, Inc. (NRG) and JX Nippon Oil and Gas Exploration Corporation (JX).

The CCE uses the Kansai Mitsubishi Carbon Dioxide Recovery Process, also known as KM-CDR Process®, an advanced amine-based CO_2 absorption technology jointly developed by Mitsubishi Heavy Industries, Ltd. and the Kansai Electric Power Co. Inc. The CCE achieved commercial operation on December 29, 2016, and represents the largest commercial-scale deployment of post-combustion CO_2 capture technology at a coal power plant to date.

The CCE has been capturing CO_2 since late 2016 and sending it to West Ranch. The working interest and capital equipment of the West Ranch is owned by Texas Coastal Ventures, LLC (TCV), a joint venture between Petra Nova LLC (a wholly-owned subsidiary of PNPH) and Hilcorp Energy I LP. TCV, through its wholly-owned subsidiary, TCV Pipeline, LLC, owns the dedicated 81-mile CO_2 pipeline between the CCE and West Ranch. Figure 1 outlines the ownership structure of the CCE and TCV.

Hilcorp Energy Company (Hilcorp) is the designated operator of West Ranch. It uses CO_2 captured at and transported from the CCE (Fresh CO_2) and CO_2 produced during the oil production process (Recycled CO_2) for EOR floods at West Ranch.

Petra Nova LLC (PN), a wholly owned subsidiary of PNPH and the 50 percent direct owner of TCV, prepared this Monitoring, Reporting, and Verification Plan (MRV Plan). This MRV Plan and any related reporting will be managed by PNPH through PN on behalf of TCV, with the assistance of Hilcorp, as the operator of West Ranch, including the reporting to the U.S. Environmental Protection Agency (EPA) under its Greenhouse Gas Reporting Program (GHGRP), Subpart RR. The operator will continue to report to the EPA under the GHGRP, Subpart W.

As part of the U.S. Department of Energy (DOE) grant to PNPH, a Monitoring, Verification and Accounting Plan (MVA Plan) was required to be developed and managed by PNPH during a 3-year demonstration period (2017-2019) starting after the commercial operation date of the CCE. PNPH contracted with the Bureau of Economic Geology at the University of Texas at Austin to develop and support the management of the MVA Plan. The DOE approved MVA Plan was deployed a year prior to the beginning of CO_2 injection (to develop a pre-flood baseline) and was in operation until the end of the DOE demonstration period at the end of 2019. The MVA Plan and the knowledge gained from operating under that plan supported the development of the MRV Plan described herein.

The mass balance accounting for determining the quantity of CO_2 stored conforms to the requirements in Subpart RR and is consistent with the method used in the MVA Plan. The method, described in Section 7, uses metered volumes of CO_2 received, injected, and produced, as well as quantified volumes of other CO_2 emissions and losses, if any.

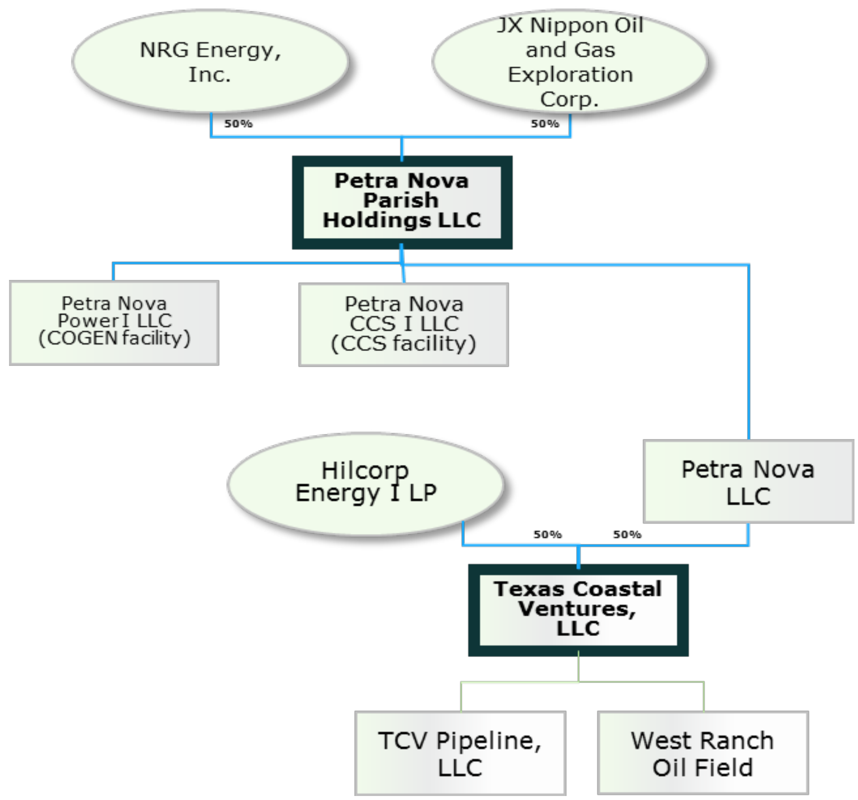


Figure 1 Ownership Structure

Current Status

The mass balance accounting under the MVA Plan started in March 2017, after the commissioning of the surface facilities at West Ranch. Through the end of 2020, the amount of CO_2 sequestered is listed below in metric tons. The difference between CO_2 delivered and CO_2 sequestered is the mass of CO_2 lost at the surface.

	CO_2 Delivered at West Ranch (Metric Tons)	**CO_2 Sequestered at West Ranch (Metric Tons)**
2017 (Mar-Dec)	909,419	904,757
2018	1,008,601	996,154
2019	1,386,987	1,373,958
2020	293,171	281,542
Total	**3,598,178**	**3,556,411**

MRV Plan Overview

This MRV plan contains twelve sections:

Section No.	Topic
1	Facility information
2	Project description. This section describes the overall project information; the geology, reservoir characterization and development history; the current operation and infrastructure including the CO_2 injection process; and the CO_2 storage capacity at West Ranch.
3	Delineation of monitoring area and timeframes
4	Evaluation of potential pathways for CO_2 leakage to the surface
5	Site-specific risk-based monitoring
6	Determination of baselines
7	Determination of sequestration volumes using mass balance equations
8	MRV Plan implementation schedule
9	Quality assurance program
10	Records retention
11	References
12	Appendices

1. Facility Information

a. Reporter number – 575661 Petra Nova West Ranch

b. The wells at West Ranch are permitted by the Texas Railroad Commission (TRRC), through TAC 16 Part 1 Chapter 3. The TRRC has primacy to implement the federal UIC Class II requirements and incorporated those provisions in TAC 16 Part 1 Chapter 3.

c. All wells at West Ranch are identified by name, API number, status, and type. A listing of the wells as of December 2020 is included in Appendix 2.

2. Project Description

2.1 Petra Nova Carbon Capture Facility and West Ranch Oil Field

When operating at 100 percent load, the CCE captures approximately 4,717 metric tons (5,200 short tons) per day from Unit 8 of NRG’s W.A. Parish Power Station near Houston, Texas. The

captured CO_2 is compressed, dried, cooled, and transported to West Ranch via 81-mile long CO_2 pipeline. The CCE is the only source of CO_2 delivered for injection at West Ranch during the "Specified Period" as discussed below. West Ranch is located in southeast Texas in Jackson County near the town of Vanderbilt as shown in Figure 2.1.1.

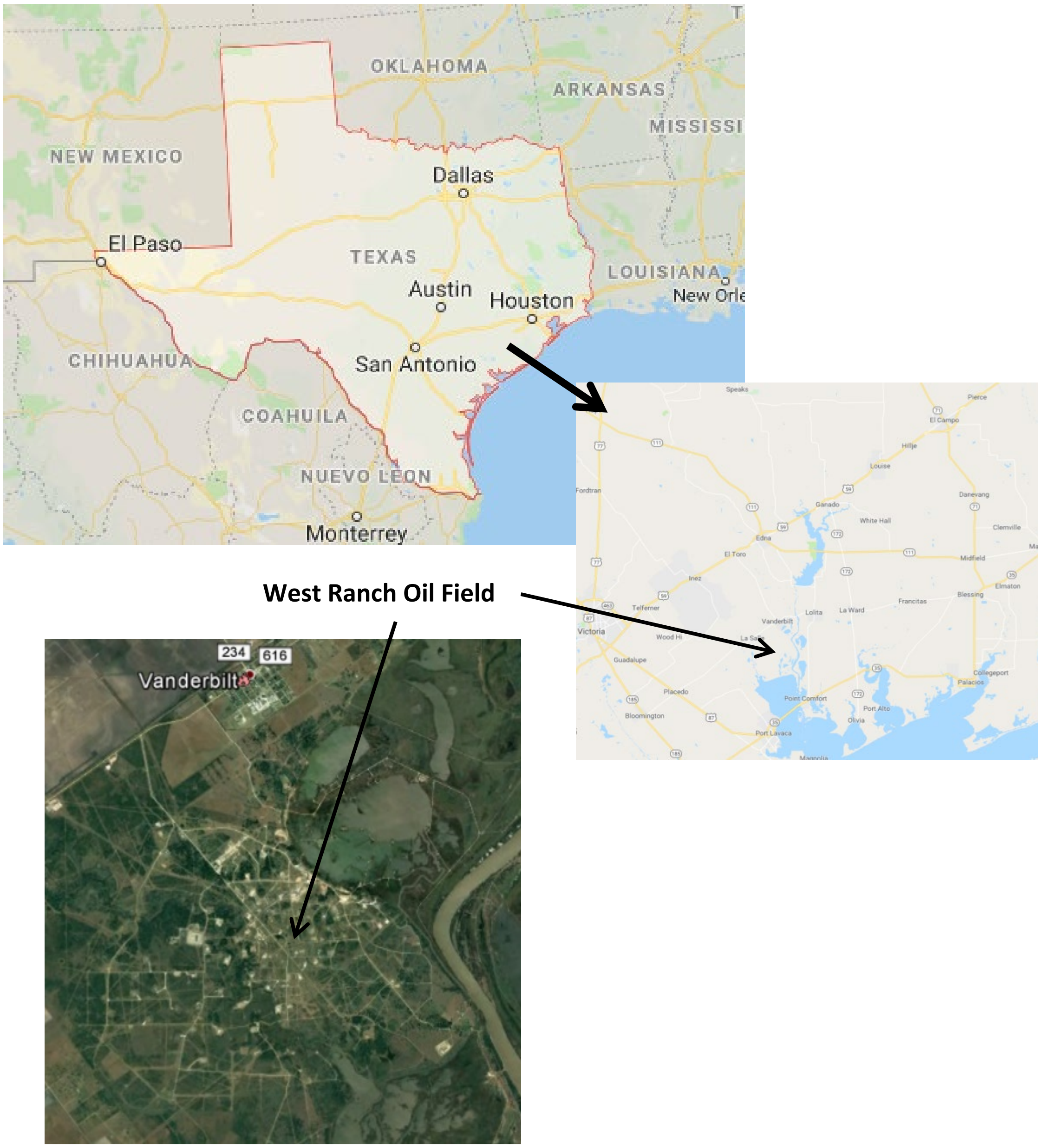


Figure 2.1.1 Location of West Ranch Oil Field

The West Ranch Unit (WRU) boundary for the current CO_2 EOR operation is delineated in Figure 2.1.2. The WRU was formed by consolidating portions of two Oligocene-age reservoirs, the 98-A and 41-A, within the Frio Formation.[1]

[1] The 98-A and 41-A zones are unitized as West Ranch 41-A/98-A (Consolidated) Unit in 2016 (O & G Docket No. 02-0299798).

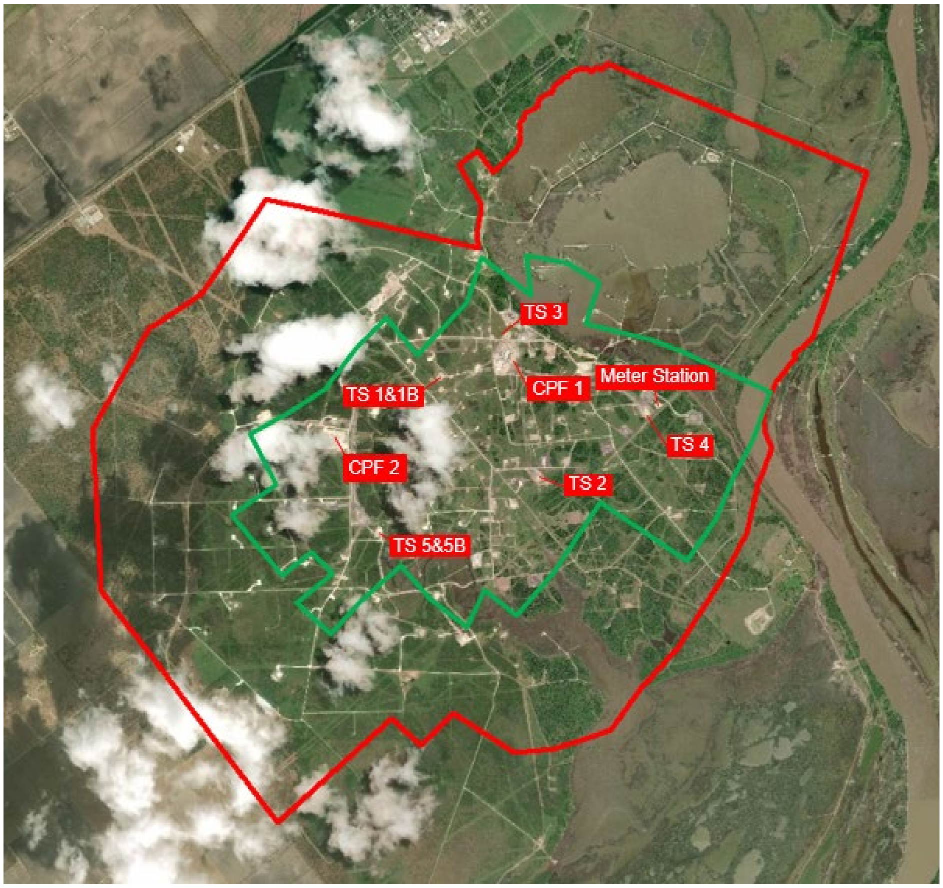


Figure 2.1.2 West Ranch Unit (41-A/98-A (Consolidated) Unit) Boundary (in Red)

CO_2 flooding was initiated in the 98-A reservoir in December 2016 and has been subsequently expanded horizontally. While the horizontal expansion of the 98-A reservoir is still ongoing, a vertical expansion into the 41-A reservoir, which lies immediately above the 98-A reservoir, began in 2018. The CO_2 EOR operations at West Ranch are planned to expand horizontally and vertically upward over time, including the CO_2 flooding of additional portions of the 98-A and 41-A reservoirs, and three additional reservoirs in the Frio Formation: Greta, Glasscock, and Ward. This MRV Plan anticipates the expansion into the entire interval between the base of 98-A reservoir and the base of the Anahuac Shale, a regionally contiguous and impermeable shale immediately above Frio Formation at West Ranch (Project Interval). In order to expand into the full Project Interval, the operator will obtain TRRC approval for certifications as tertiary recovery projects, unitization agreements, and permits to conduct fluid injection operations in each area of expansion in the Project Interval. The reservoirs in the Project Interval have similar geologic characteristics and the operator will apply the same operational controls in each area of expansion. All injection zones in the Project Interval share the following characteristics:

- four-way dip anticline trapping mechanisms,
- no faulting,
- presence of a primary confining intervals above each injection zone within the Project Interval and a secondary confining interval (Anahuac Shale) that overlays the entire project area, and
- depleted reservoir pressure.

The operational requirements that currently apply in WRU will also apply in the expansion zones. They include rules for injection wells such as the confirmation of nearby well condition, the periodic testing of casing integrity, the adequate cementing to confine fluids in the injection reservoir, and the monitoring and limitation of injection pressure. Based on these conditions, PNPH believes that all reservoirs within the Project Interval at West Ranch can be included under this MRV Plan as they are brought online.

2.2 Petroleum Geology of West Ranch Oil Field

West Ranch is one of several oil fields located in the Gulf Coast Basin that shares the same petroleum system. West Ranch is formed on a gentle four-way anticlinal structure on a roll-over structure (Figures 2.2.1(a), 2.2.1(b), 2.2.2(a), and 2.2.2(b)) on the upthrown side of a northeast-southwest trending regional growth fault as shown in Figure 2.2.3.

(a)

(b)

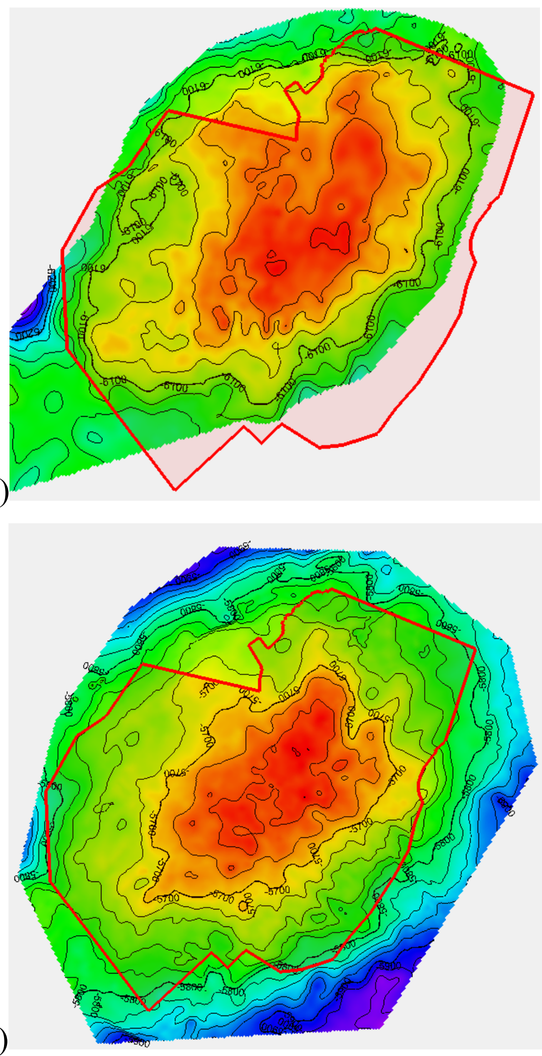
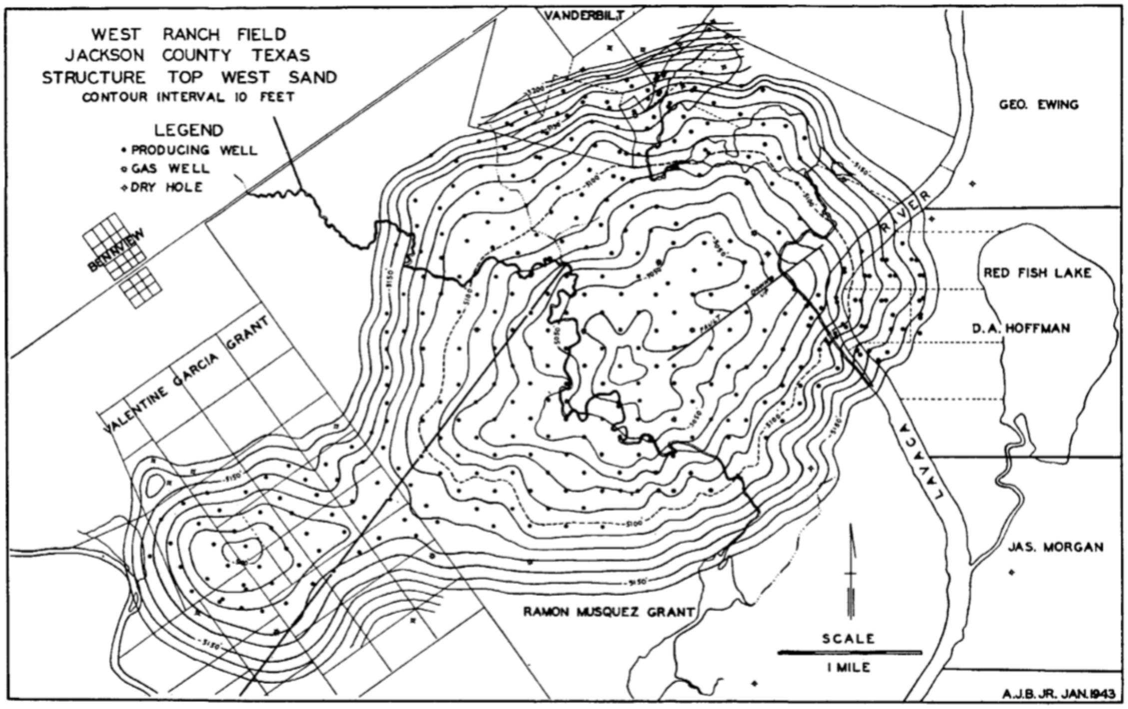


Figure 2.2.1 Structure-contour map of West Ranch Oil Field with the currently existing WRU boundary (41-A/98-A Consolidated) (red outline). Datum is the top of (a) 98-A and (b) 41-A reservoirs.

(a)


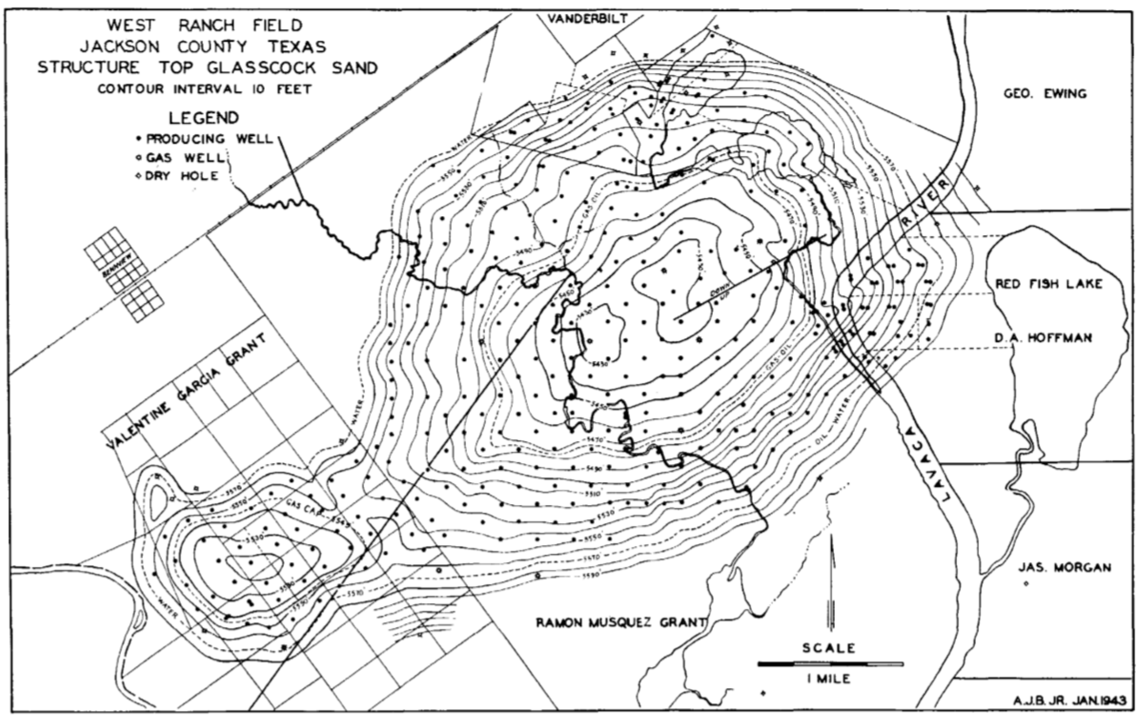
(b)


Figure 2.2.2 Structure-contour map of West Ranch Oil Field. Datum is the top of (a) the Greta and (b) the Glasscock reservoirs (Baurenschmidt, 1944).

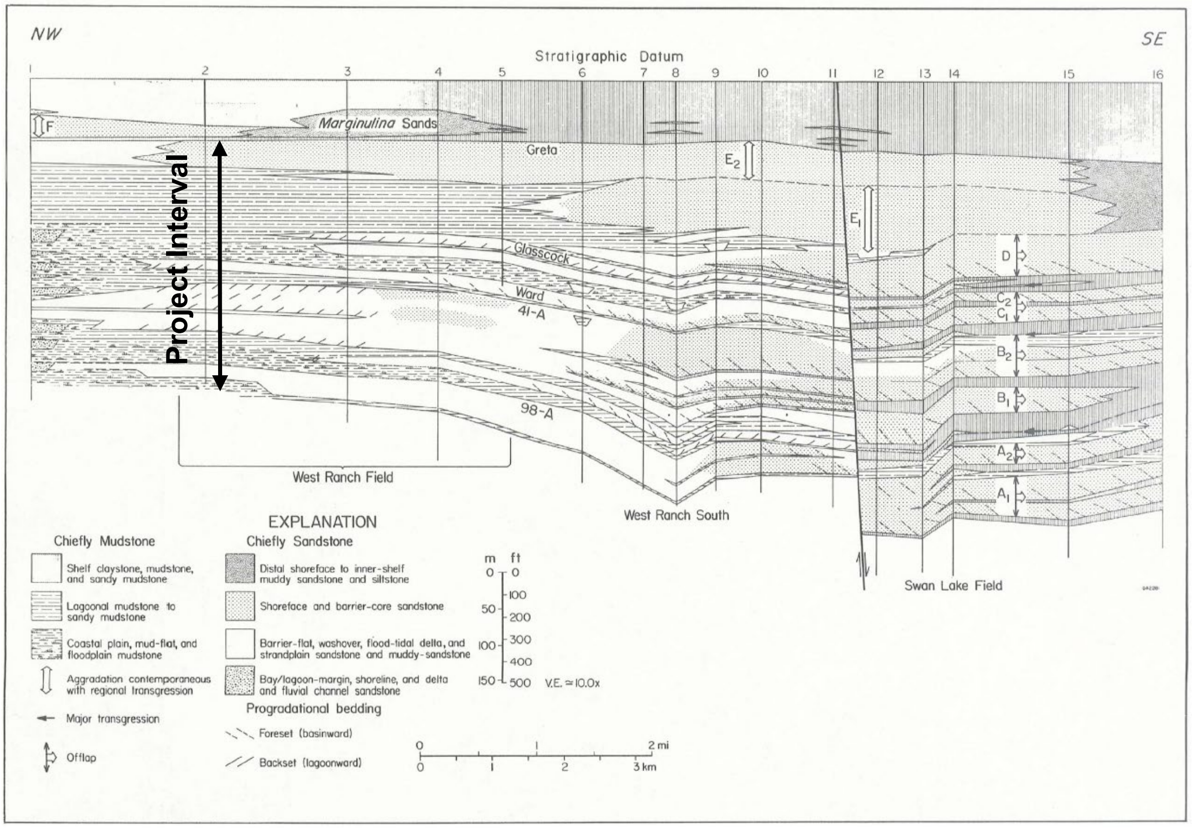


Figure 2.2.3 Regional cross section though West Ranch Oil Field showing non-faulted structure.
From Galloway and Cheng, 1985

2.3 Stratigraphy of the West Ranch Oil Field Area

The generalized stratigraphic section illustration of geologic formations present at West Ranch is shown in Figure 2.3.1. The reservoir sandstones into which CO_2 is currently or planned to be injected at West Ranch include five reservoir sandstones in Frio Formation, being 98-A, 41-A, Ward, Glasscock, and Greta, from the deepest (6,200 feet) to the shallowest (5,100 feet). Each reservoir sandstone is separated by locally continuous low permeability and individually confining mudstones (Figure 2.3.2).

Anahuac Shale is a low-permeability confining layer that has served as a stratigraphic seal to prevent upward migration of hydrocarbon throughout geologic term for many oil fields throughout the Gulf Coast region (Galloway and Cheng, 1985), and it serves as the secondary seal in addition to the individual confining layers overlaying each reservoir.

Above Anahuac Shale is a series of sandstones separated by shales collectively known regionally as Oakville Formation, also referred to as Miocene Sands.

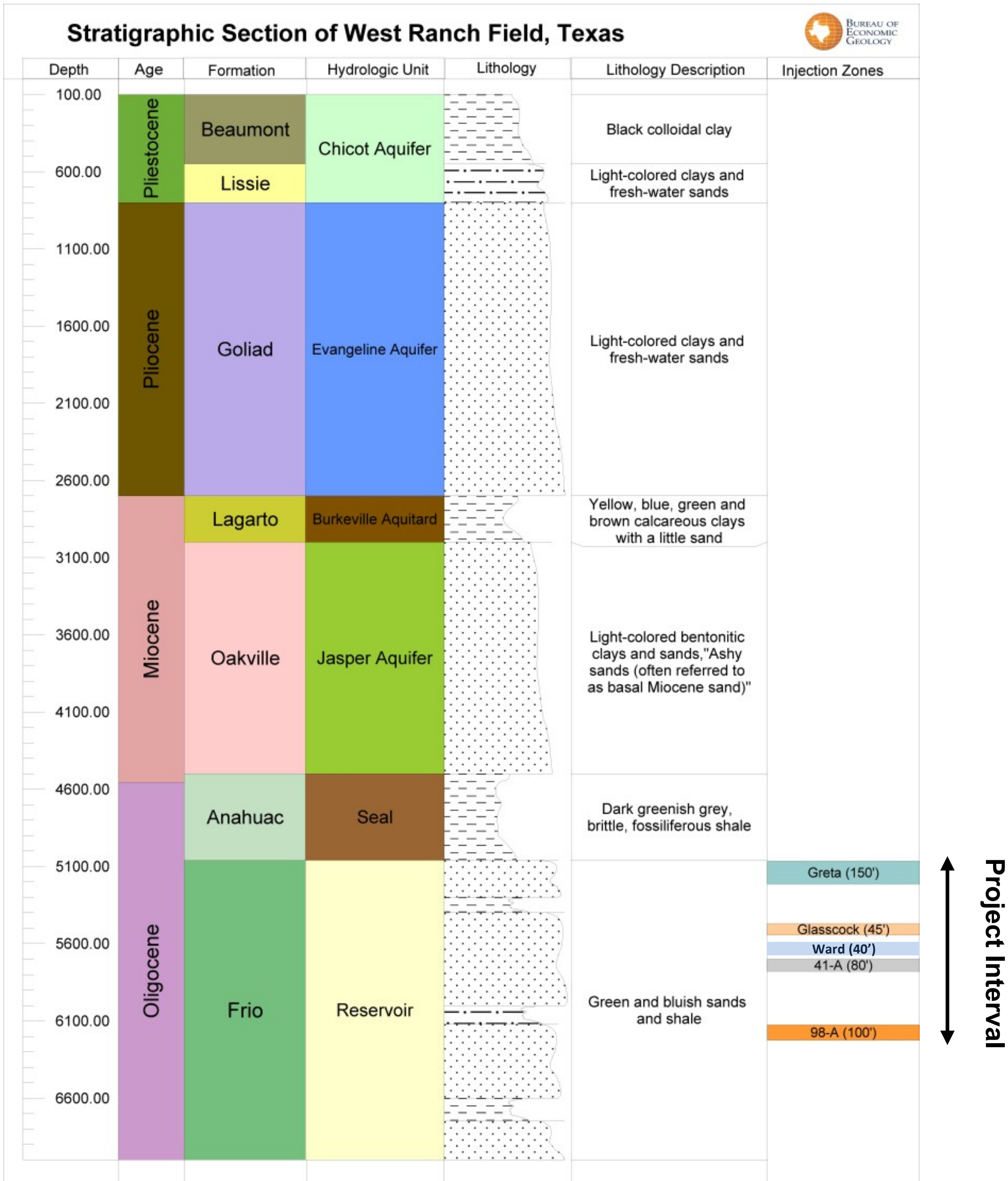


Figure 2.3.1 Generalized lithostratigraphic and hydrostratigraphic names for rocks/aquifers underlying West Ranch Oil Field. Depths shown correspond with those seen at West Ranch Oil Field. The Project Interval is indicated on the right.

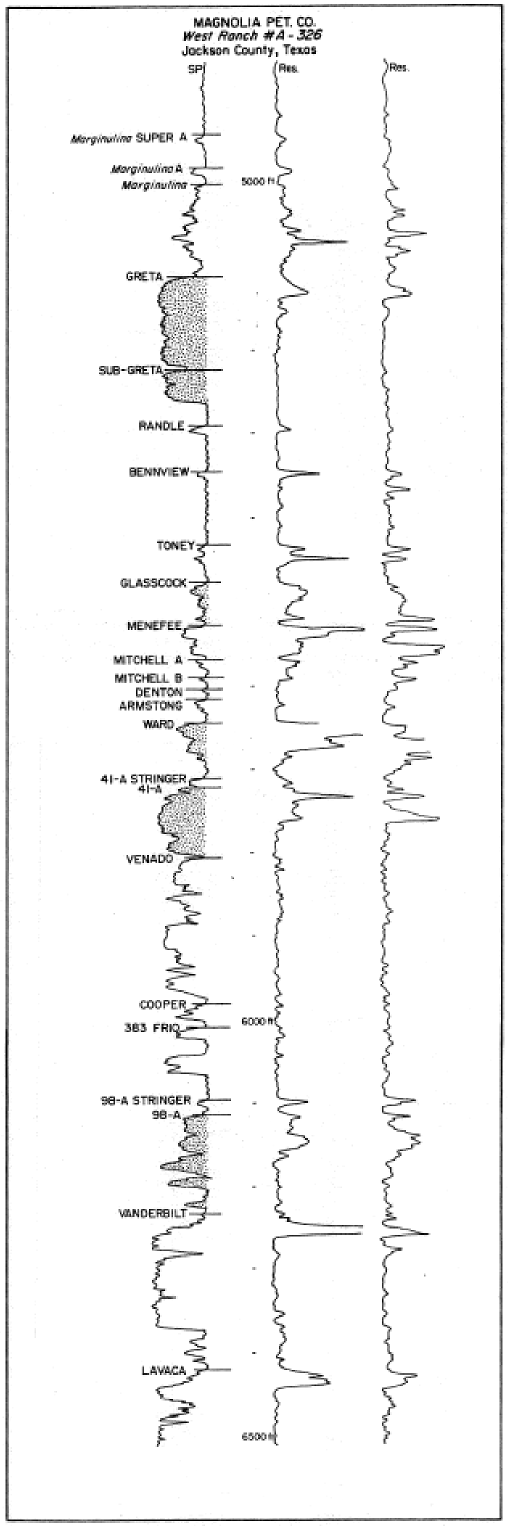


Figure 2.3.2 Type log for West Ranch Oil Field, modified from Galloway (1983), shows the entire injection zone for Project Interval. Current CO_2 EOR flooding is in the 98-A and 41-A, future expansion will be into the permeable zones (Ward, Glasscock, Greta). Each permeable zone is interspersed with non-permeable zones that serve as the primary confining layers. The secondary confining layer, the Anuhuac Shale is not marked on this Type log.

2.4 Depositional Environment of the West Ranch Oil Field Area

The reservoirs of West Ranch are part of the extensively characterized Oligocene-aged Frio Formation in the barrier/strandplain system, located between the Houston and Norias Delta Systems (Galloway et. al., 1983) (Figure 2.4). The barrier/strandplain system is composed of the northeast-southwest elongated bodies of laterally deposited shoreline sands, similar to the Padre-Mustang-St. Joseph-Matagorda island complex of today.

Within the barrier/strandplain system, the barrier island and shoreface deposits, such as the Greta reservoir, are well sorted, continuous, sandy, and internally homogeneous as a result of their high-energy, shallow-marine depositional origin. The Glasscock reservoir is one of the most widespread reservoirs in the field. It is a particularly thin barrier-island sand body that was deposited before a local transgression terminating the "C" cycle of strandplain progradation. The 41-A reservoir is a moderately thick sand body that occurs at the top of the widespread sand of the "B" cycle. Well-developed upward-coarsening sequences do not appear at the stratigraphic position of the 41-A reservoir for several miles farther basinward. Stratigraphic relationships suggest that much of the reservoir is overlain, and therefore sealed, by lagoonal mudstones deposited landward of a prograding barrier-sand complex. The 98-A and Ward reservoirs are both relatively thin progradational sand units (Galloway, 1986).

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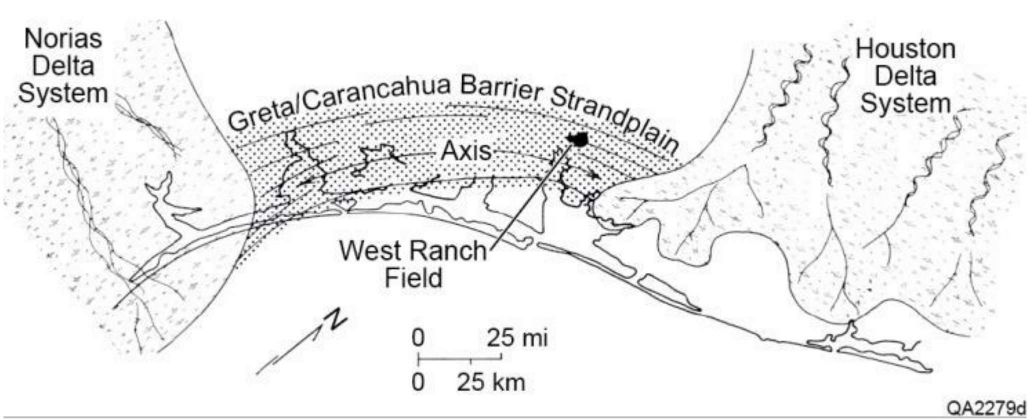

Figure 2.4 Oligocene (Frio) paleogeographic setting of Texas Gulf Coast, showing West Ranch Oil Field within Greta/Carancahua Barrier Strandplain System. Ambrose et al. (2008); modified from Galloway and Cheng (1985) and Galloway (1986).

2.5 Reservoir Characterization and Modeling

As previously discussed, PNPH, working with the BEG, developed and managed an MVA Plan that covered the three-year demonstration period that started on January 1, 2017 (aligned with the beginning of commercial operations of the CCE). As a part of the MVA Plan, reservoir modeling was used to characterize the currently existing WRU reservoirs, i.e., 98-A and 41-A, to develop a detailed understanding of each reservoir as well as the predictability of internal reservoir architecture, including the behavior of CO_2 in the course of CO_2 EOR operation. In general, the modeling was successful in demonstrating that the pressure elevation and the movement of CO_2 plume in the reservoirs are managed by the operational strategies, and the reservoirs have the capacity to permanently retain the injected CO_2 volume within the structural trap for prolonged period after the cessation of CO_2 EOR operation.

Reservoir modeling is the major predictive tool that determines the capacity of the subsurface to accept CO_2. Numerical simulation models are used to model the spatial extent of the CO_2 plume in the subsurface, which demonstrates that, under given assumptions and operational strategies, CO_2 is remaining within the targeted area. The numerical simulation modeling starts by building static reservoir models. The tops and bases of target sandstones and major seals are defined with well logs. The model is then constructed based on rock properties interpreted from Spontaneous Potential and Gamma-Ray logs, and to a limited extent, core sample studies at West Ranch. Rock properties were also assigned based on available data through literature review and historical field measurements.

A numerical simulation model of the 98-A and 41-A reservoirs was constructed based on the static geologic model as well as fluid properties (fluid compositions and PVT (pressure-volume-temperature) data) from the field, to develop a dynamic numerical model to history match the production and pressure data of the field, and to simulate the current and future performance of the field. The numerical model is developed using a compositional simulator. In compositional simulations, three phases (water, oil, and gas) with multiple components were defined. Relative permeability data, available through literature survey and special core analysis, was used as input in the simulations. Thermodynamic properties of the specific fluids in this field were tuned and modeled in a fluid characterization software.

The porosity and permeability maps of the model are shown in Figure 2.5.1 and 2.5.2.

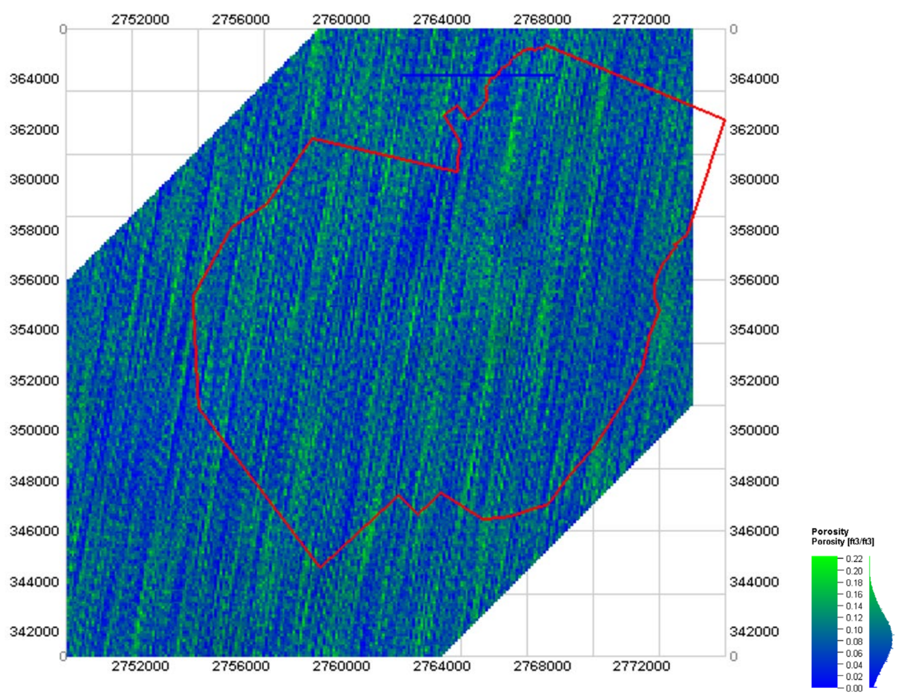

Figure 2.5.1 Porosity distribution of 98-A input into the numerical simulation model with 41-A/98-A Consolidated Unit (red)

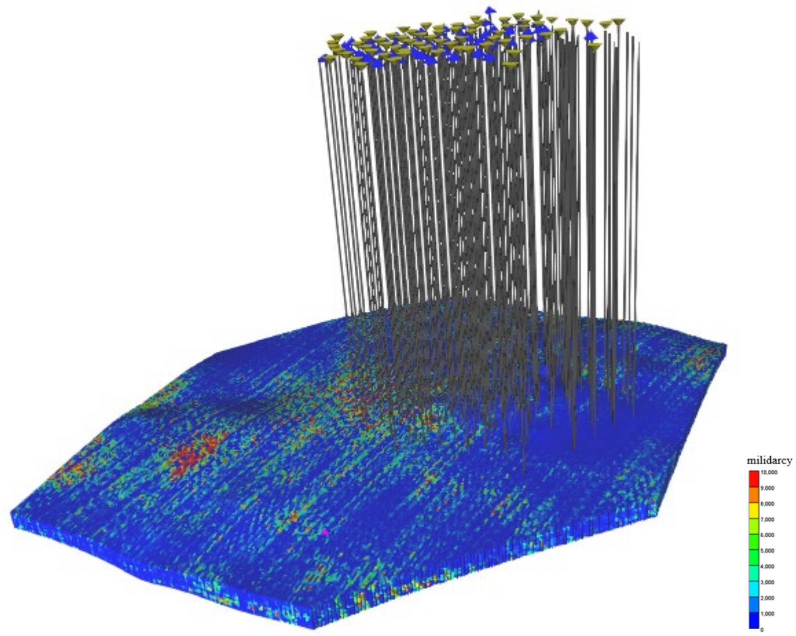

Figure 2.5.2 Location of EOR operation wells and horizontal permeability of 98-A input into the numerical simulation model.

The expected pressure and the gas saturation fields in the 98-A reservoir as of March 2020 based on the simulation model, with the best history match until September 2019, are shown below (Figure 2.5.3 and Figure 2.5.4). Overall results show that the pressure values remain within the intended range and below the fracturing pressure. Gas saturations are larger around the injection wells and mostly remain in the intended patterns.

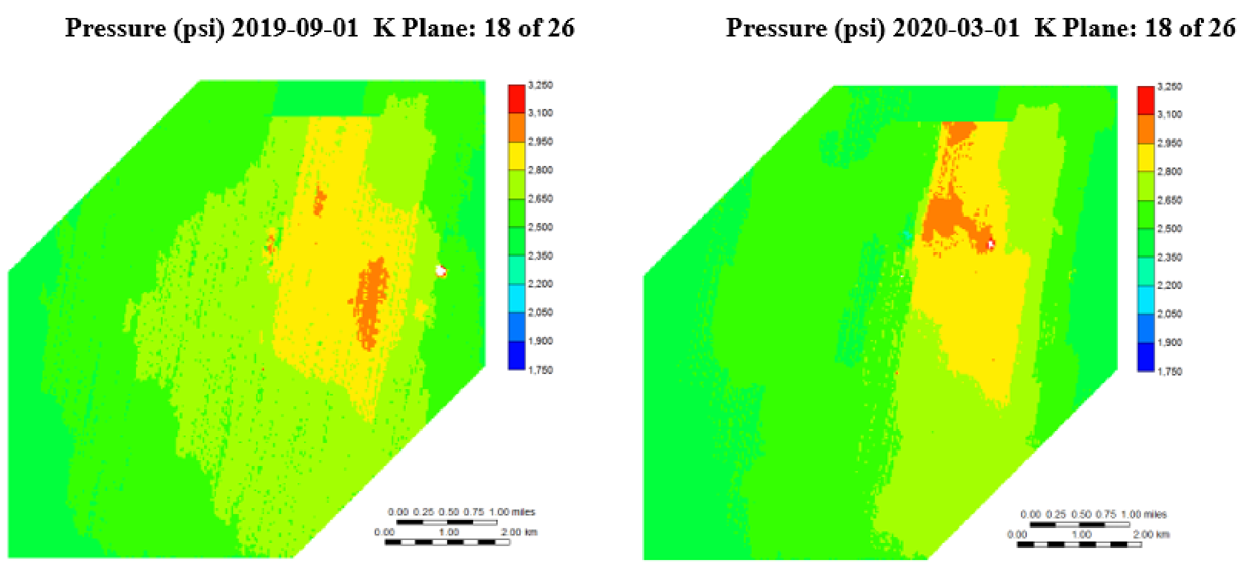

Figure 2.5.3 Pressure field at 98-A reservoir in (a) September 2019 and (b) March 2020.

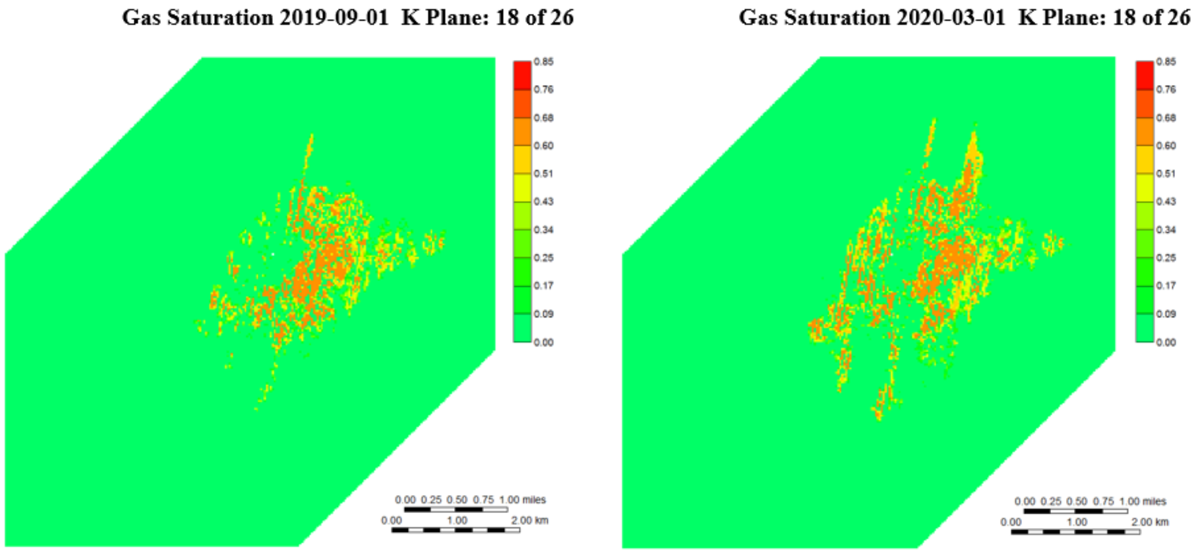

Figure 2.5.4 Gas saturation at 98-A reservoir in (a) September 2019 and (b) March 2020.

A long-term simulation was also run through 2040, and the result shows that CO_2 accumulates at the crest of structure and within the intended area (Figure 2.5.5).

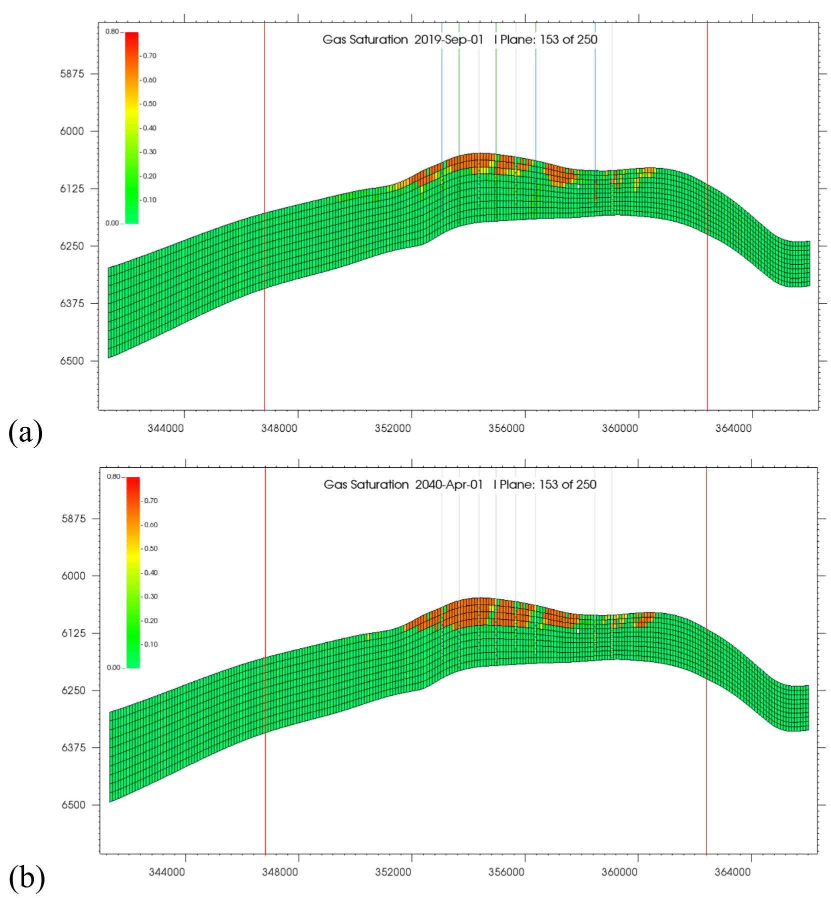

Figure 2.5.5 Demonstration of gas migration after CO_2 flooding. Gas saturation at 98-A reservoir in (a) September 2019 and (b) April 2040 with 41-A/98-A Consolidated Unit (red)

2.6 Development of West Ranch Oil Field, Primary and Secondary Production

West Ranch was discovered in 1938. The main reservoirs at West Ranch (Greta, Glasscock, Ward, 41-A, and 98-A) are porous and permeable, averaging more than 27 percent porosity and 400 mD permeability. The discovery and original conditions of main producing reservoirs, and the oil field operations including hydrocarbon production and brine injection, are described in this section. Besides the five main producing sands, 79 additional minor reservoirs have been classified as producing sands by the TRRC.

At discovery, a primary gas cap was in contact with the oil zone in all main oil-producing reservoirs. This indicates vertical hydraulic isolation of each sand zone. These reservoirs were originally produced with a gas-cap expansion and/or a natural water drive. Glasscock and Ward reservoirs were constituted from oil-rim reservoirs with gas caps as large as one-third of the volume, and 95 percent of the energy thereof was attributable to the expansion of their gas caps (Galloway and Cheng, 1985). The Greta, 41-A, and 98-A reservoirs were mainly energized by strong natural water drive.

In most of the water-injection programs, water was injected into reservoirs along the periphery of their gas caps to maintain reservoir pressure and to prevent expansion of the gas cap into the oil-bearing zone (Galloway and Cheng, 1985).

Cumulative oil production in the main reservoirs as of 2010 is provided in Table 2.6.1.

Reservoir	Discovery Date	Cum. Prod. (MMSTB)
Greta	1938	101.3
41-A	1940	99.5
98-A	1940	59.2
Glasscock	1939	45.8
Ward	1939	30.4

Table 2.6.1 Cumulative oil production of major reservoirs at West Ranch Oil Field from TRRC (2010)

The original reservoir conditions, such as fluid contact depths, water saturation, and solution gas ratios, are listed in Table 2.6.2, along with average rock and fluid properties.

	Greta	Glasscock	Ward	41 A	98 A
Gas-Oil contact, ft ss	5,065	5,475	5,705	5,690	6,070
Oil-Water contact, ft ss	5,105	5,570	5,735	5,750	6,140
Average porosity, %	30	27	30	30	31
Average permeability, md	1,200+	400	1,200	1,700	500
Original pressure, psia	2,350	2,560	2,650	2,625	2,795
Reservoir temp, °F	160	166	171	171	178
Oil gravity, API	24.7	31.6	30.6	31.1	40.4
Solution gas ratio, scf/stb	306	440	451	500	671

Table 2.6.2 General reservoir data and original conditions of main sands at West Ranch Oil Field (Bauernschmidt, 1962)

Initial reservoir pressures found in West Ranch indicate an original hydrostatic pressure gradient of approximately 0.53 psi/ft (Figure 2.6.1). Kreitler and Akhter (1990) gathered and plotted nearly 17,400 pressure values from a commercial database to study the complex hydrologic regimes of the Texas Gulf Coast region. Two major gradients are observed: (1) a formation water hydrostatic regime (0.465 psi/ft) that reaches depths of 11,000 ft, and (2) a geopressured regime as shallow as 7,000 ft. Both have been extensively depleted by production, although the original profile can be identified by plotting the maximum pressures. The West Ranch pressure gradient is not geopressured but is slightly steeper than the average hydrostatic gradient for freshwater in the area (Figure 2.6.2(a)). A current pressure profile from the A-600 well in 2012, the injection location for a recent CO_2 injection test, is imposed over the Kreitler and Akhter (1990) Gulf Coast pressure profile for comparison (Figure 2.6.2(b)). The A-600 well profile shows strongly depleted zones, likely resulting from past production of reservoirs that lacked good connection to water drive. In contrast, the pressure of Greta, 41-A and 98-A reservoirs indicates the strong natural water drive as mentioned above.

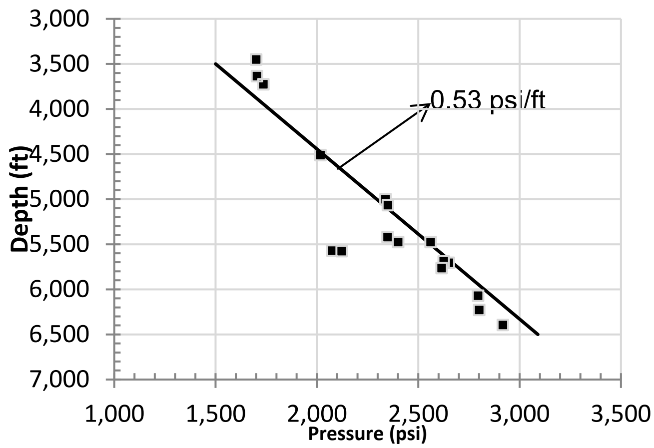

Figure 2.6.1 West Ranch hydrostatic pressure gradient. Adapted from Bauernschmidt (1962)

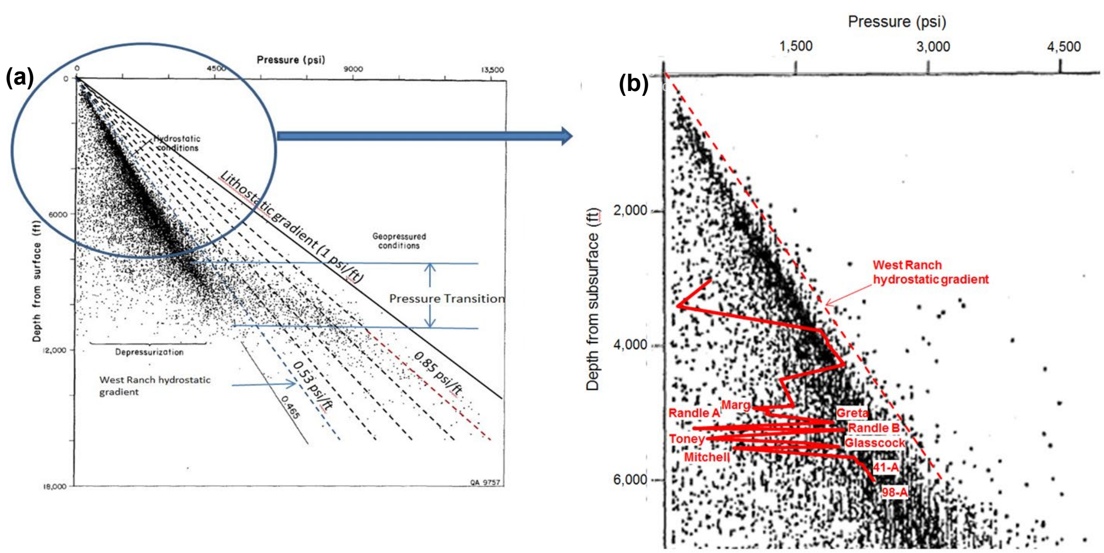

Figure 2.6.2 (a) Gulf Coast pressure profile. Pressure measurements from drill-stem tests (DST) and bottom-hole pressures, adapted from Kreitler and Akhter (1990), and (b) Current pressure profile at West Ranch Oil Field in red at A-600 well plotted against Gulf Coast pressure profile.

2.7 Regulatory Process

Prior to commencement of any underground injection of CO_2 for EOR, the operator must submit a permit application and obtain approval from the TRRC. Texas Administrative Code (TAC) Title 16 Part 1 §3.46 governs fluid injection into reservoirs for production of oil, gas, or geothermal resources. The information required in the application includes the data concerning the project, the subject reservoir, and the well(s); and the geographic description of area covered by the project. The technical requirements include: the isolation from usable-quality water by 250 feet of low permeability strata, the area of review (AoR) to determine if all abandoned wells within one-quarter (1/4) mile radius of the proposed well have been properly plugged, the cementing interval for surface and production casings, the packer setting depth, the injection pressures, and in certain areas, a seismicity review. Notice of application must be given to parties affected or who may be affected by implementation of the project along with notice to local regulatory bodies and the public. There is an opportunity for a hearing in the event of a protest. After permit approval, a mechanical integrity test is required to be performed for each well before injection and periodically thereafter, and the operator is obligated to file a completion report and annual injection report.

Unitization is necessary to conduct CO_2 EOR operations at reservoirs which straddle multiple tracts with separate and divergent ownership interests, primarily to determine the participation formula of interest owners. Unitization is subject to TRRC approval, and the information required and the procedure employed are similar to those applicable to the injection permitting process. The project must satisfy all of the requirements set out in Texas Natural Resources Code Title 3 Subtitle C Chapter 101, including (a) unit operations are necessary to increase ultimate recovery from the reservoir or prevent waste, (b) correlative rights of interest owners are protected, and (c) the additional cost involved does not exceed the additional recovery anticipated. The approval is also subject to receiving the injection permits.

There are also economic incentives to conduct CO_2 EOR operations in Texas, particularly those with anthropogenic CO_2. There is a severance tax on crude oil, and a 50 percent reduction in that severance tax rate by obtaining an EOR project certification under TAC Title 16 Part 1 §3.50, which is further lowered by additional 50 percent, to 25 percent of the original rate, if anthropogenic CO_2 is used and the certification under TAC Title 16 Part 1 Subchapter C is obtained. The TRRC must approve a measurement, monitoring and verification program for stored anthropogenic CO_2, and the certification is issued only if the TRRC finds that at least 99 percent of the CO_2 sequestered will remain sequestered for at least 1,000 years.

The current CO_2 EOR operations in the WRU for 98-A and 41-A reservoirs have gone through all regulatory processes as discussed in this section, and the same processes will be followed when the development area in West Ranch expands either horizontally outside of the existing WRU, or vertically upwards to Greta, Ward, Glasscock or other sub-layers.

2.8 Description of CO_2 EOR Project Facilities and the Injection Process

2.8.1 West Ranch Oil Field Facility Description

The following two figures illustrate the CO_2 EOR process at West Ranch. Figure 2.8.1 is a generalized facility flow diagram and Figure 2.8.2 shows the location of all facilities within the

WRU boundary.

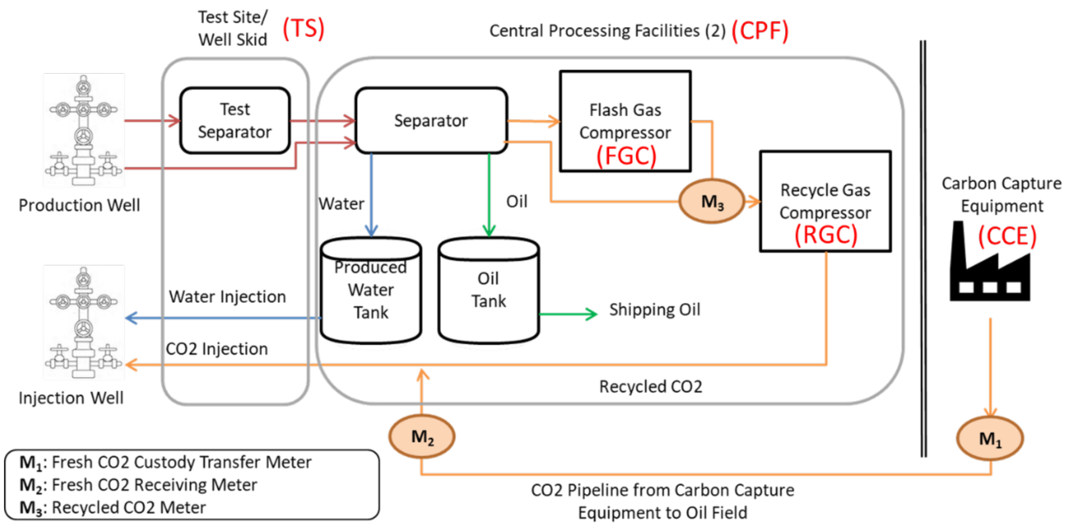

Figure 2.8.1 Facility Flow Diagram

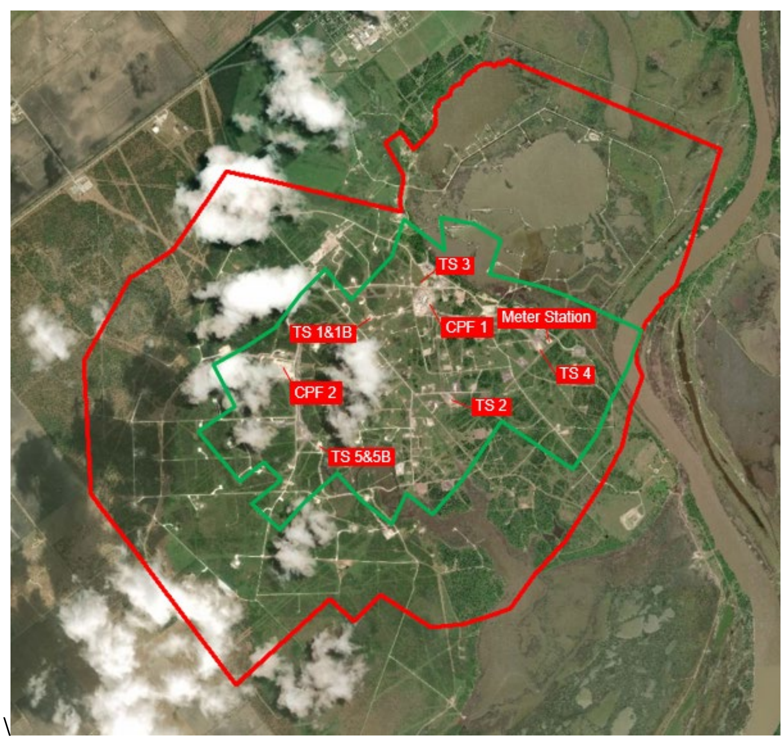

Figure 2.8.2 Locations of current Meter station, Central processing facilities (CPF1 and CPF2) and Test Sites (TS) at West Ranch Oil Field. Locations within this footprint may change over the life of the project. WRU boundary (red) and current flood area (green).

1. Central Processing Facility (CPF)

   There are two CPFs at West Ranch (shown as CPF1 and CPF 2 on Figure 2.8.2). Produced fluids (water, oil, and gas) are separated in the high/intermediate/low pressure water knock-out drums and separators located at the CPFs.

a) The water is mainly separated from gas and oil in the water knock-out drums, then reinjected into the field through injection wells with make-up water from water source wells.

b) The oil is separated from gas in the separators, settled in tanks for few days, then metered and sold.

c) The produced gas, which consists of CO_2 and reservoir hydrocarbon gas, is transferred to flash/recycle gas compressors (FGC/RGC). High and intermediate pressure gas is directly transferred to the RGC. Low pressure gas is compressed by the FGC then transferred to the RGC.

2. Test Site (TS)

There are five TSs (TS 1-5 on Figure 2.8.2) and two extended TSs (TS 1B and 5B on Figure 2.8.2) in the field. Produced fluids from the production wells are aggregated at one of the five TSs. Each TS consists of a three-phase test separator, which measures production rates of oil, water, and gas from each production well at least once per month. This data is not used in the mass balance accounting but is used to allocate produced fluid to wells and for production optimization. Produced fluid from the individual production wells gathered at the TSs is transferred to one of the two CPFs through high/intermediate/low pressure production lines.

3. CO_2 Injection Process

Fresh CO_2 is captured at the CCE and transported to West Ranch via the CO_2 pipeline, and the flow is metered at the metering station at West Ranch (M_2). The concentration of Fresh CO_2 applicable to calculate the mass of CO_2 received at West Ranch is measured at the custody transfer meter located in the vicinity of the CCE (M_1 on Figure 2.8.1). Fresh CO_2 received from the CO_2 pipeline and Recycled CO_2 from the RGCs at the CPFs, the volume and concentration of which is measured at M_3, are comingled and sent through the CO_2 distribution pipeline system to injection wells throughout the field.

All processes at West Ranch are monitored by the Supervisory Control and Data Acquisition (SCADA) system located on site and equipped with alarms to alert operators of any abnormalities. As the CO_2 flood expands into the entire Project Interval, new injection areas will be tied into this system using existing or new equivalent equipment.

2.8.2 Wells at West Ranch Oil Field

As of December 2020, there are 257 active wells at West Ranch; 155 are producing wells, 91 are injection wells, and 11 are water sourcing wells. Appendix 2 lists these wells with well identification numbers. Table 2.8.2 shows total well count at West Ranch by status.

Well Count	Active	Shut-in	Temporarily Abandoned	Plugged and Abandoned
TOTAL	257	277	2	389

Table 2.8.2 West Ranch Oil Field Well Count

TRRC rules govern well siting, construction, operation, maintenance, and closure for all oil field wells. The TRRC granted authority the operator to inject CO_2 in permitted wells after application, notice and hearings. TRRC requirements are found at TAC Title 16 Part 1 Chapter 3 and Chapter 5[2] and include:

- Fluids must be constrained in the strata in which they are encountered;
- Activities governed by the TRRC rules cannot result in the pollution of subsurface or surface water;
- Adherence to specified casing, cementing, drilling well control, and completion requirements designed to prevent fluids from moving from the strata encountered into strata with oil and gas, or into subsurface and surface waters;
- Filing of a well completion report including basic electric log (e.g., a density, sonic, or resistivity (except dip meter) log run over the entire wellbore);
- Equipping wells with a Bradenhead valve, measuring the pressure between casing strings using the Bradenhead gauge, and following procedures to report and address any instances where pressure on a Bradenhead is detected;
- Following plugging procedures that require advance approval from the TRRC and allow consideration of the suitability of the cement based on the use of the well, the location and setting of plugs;
- Corrosion monitoring under TAC Title 16 Part 1 §5.305(1) (D) is met by alternative monitoring through continuous SCADA monitoring in all wells;
- Using corrosion resistant alloy (CRA) for facilities which are exposed to CO_2; and
- Conducting Casing Integrity Tests annually as required under TAC Title 16 Part 1 §5.305(1)(C).

All changes in the status of wells must be in compliance with the TRRC rules and go through the TRRC approval process, and will be included in the annual report to EPA under GHGRP, Subpart RR.

2.9 Storage Capacity Calculation

During the injection of CO_2 and water for CO_2 EOR operations, fluids will move from injection wells toward the production wells following the pressure trends. At the end of CO_2 EOR operations, the reservoir fluids will be in equilibrium based on their gravity difference where lighter fluids, likely gases, will move toward the top of the formation below the seal of each reservoir (see Section 2.5, Reservoir Characterization and Modeling). The estimated total amount of the CO_2 that can be sequestered in these reservoirs is based on the available pore space at each of the reservoirs. Though the available pore space is considered to be the entire

[2] TRRC rules can be found online at:
https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=3&rl=Y and
https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=5

pore space from top of the reservoir to the spill point, for purpose of this calculation, the original oil and gas in place of each reservoir is assumed as the available pore space, and further, only down to the shallower of spill point or oil water contact. The oil water contacts are above the spill points in the 41-A and Greta reservoirs; hence, the pore space accounted for these two reservoirs are only down to the oil water contact. The oil water contacts are below the spill points in 98-A, Ward, and Glasscock.

The following equation was used to estimate the storage capacity:

$$CO_2\ Storage\ Capacity = HCPV * E * \rho CO_2$$

where:

HCPV = *Hydrocarbon pore volume above oil water contact or a spill point of the south-west structure.*

E = *Efficiency factor.*

ρCO_2 = *CO_2 density at reservoir pressure and temperature.*

Based on the numerical simulations conducted by the BEG, the CO_2 occupancy of the pore space at the end of the CO_2 EOR operation is calculated. These calculations assume a 50 percent efficiency factor, and results are tabulated in Table 2.9.1.

Reservoir	Storage capacity (MM metric ton)
Greta	12.35
Glasscock	6.35
Ward	10.10
41-A	10.74
98-A	8.52
Total	**48.06**

Table 2.9.1 West Ranch Oil Field CO_2 storage capacity in different reservoirs (metric tons)

At reservoir conditions of West Ranch, the five main target reservoirs could hold about 919 Bscf (48.06 million metric tons) of CO_2 in the reservoir based on the original oil and gas in place. PNPH forecasts that 20 years of CO_2 EOR operations would result in sequestered CO_2 occupying approximately 61 percent of the calculated storage capacity.

3. Delineation of Monitoring Area and Timeframes

3.1 Active Monitoring Area

As discussed in Sections 2.1 through 2.4, the subsurface characteristics of the existing WRU for the 98-A and 41-A reservoirs are similar to the characteristics in the other reservoirs within the Project Interval at West Ranch. They all have four-way dip anticline trapping mechanisms, no faulting, primary confining layers over each injection zone, the existence of secondary confining interval (Anahuac Shale) in addition to individual confining layers overlying each reservoir, and depleted reservoir pressure. Expansion into the full Project Interval will require the operator to obtain approval for unitization and permits for injection from TRRC, as explained in Sections 2.7 and 2.8. In addition, the reservoir simulation effort carried out as part of DOE's MVA Plan, and the storage capacity calculation as illustrated in Sections 2.5 and 2.9 demonstrated the viability of the Project Interval for a long-term CO_2 retention. Because CO_2 is retained within the WRUs, the Active Monitoring Area (AMA) is the existing WRU boundary of 41-A/98-A (Consolidated) Unit, as depicted in Figure 2.1.2, plus the half mile buffer. When a new WRU for CO_2 EOR operation is established, either for the currently flooded reservoirs or for the other three reservoirs and sublayers within the Project Interval, the AMA will be expanded to cover the boundaries of those new WRUs, plus the half mile buffer. In addition to the aforementioned reason, the following factors are considered in defining this boundary:

- CO_2 injected into West Ranch reservoirs remains contained within the unit boundary because of the fluid and pressure management, which includes: the practice of targeting the maintenance of an injection-withdrawal ratio of 1.0, which assures a stable reservoir pressure, and the managed leaseline water injection and production wells that are used to retain CO_2 and fluids within the unit boundary. The effectiveness was demonstrated by the history matching and reservoir simulation effort in Section 2.5 as it demonstrated that the movement of CO_2 plume is largely contained within the intended patterns and the elevation of reservoir pressure is maintained within the intended range.
- Over geologic timeframes, sequestered CO_2 will remain in the respective unit boundaries, and will not migrate downdip, because of the higher elevations of the WRUs compared to other part of the corresponding reservoirs in the same structure as described in Figures 2.2.1 and 2.2.2.

3.2 Maximum Monitoring Area

Based on the potential future expansion of WRU to conduct CO_2 EOR operations in the currently flooded reservoirs and the other three reservoirs and sublayers within the Project Interval, the injection zone extends geologically along the outermost boundary of those reservoirs subject to CO_2 EOR operation, which is primarily determined by oil-water-contact and structures (Figure 3.2). In accordance with 40 CFR §98.448-449, the Maximum Monitoring Area (MMA) will extend for the half mile buffer beyond the boundary.

Figure 3.2 Areal extent of Maximum Monitoring Area (red dashed line) includes the outermost boundary of reservoirs at West Ranch Oil Field that could potentially be developed by utilizing CO_2 EOR operation, plus ½ mile buffer.

3.3 Monitoring Timeframes

The primary purpose for injecting CO_2 is to produce oil that would otherwise remain trapped in the reservoir. During the Specified Period, PNPH will have a secondary purpose of establishing the long-term containment of a measurable quantity of CO_2 at West Ranch. The Specified Period will be shorter than the period of production from West Ranch. This is in part because the purchase of Fresh CO_2 for injection is projected to taper off significantly before production ceases at West Ranch. At the conclusion of the Specified Period, PNPH will submit a request for discontinuation of reporting. This request will be submitted with a demonstration that the cumulative mass of CO_2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage. See 40 CFR §98.441(b)(2)(ii).

4. Evaluation of Potential Pathways for CO_2 Leakage to the Surface

4.1 Introduction

The subsurface characteristics at West Ranch are well known as a result of exploration, production, and continued reevaluation for optimization of production, including the recent reevaluation for CO_2 EOR and monitoring activities under the MVA Plan. The presence of thick oil and gas accumulations in the subsurface of West Ranch provides strong evidence that the mudstones that separate the sandstones are effective in isolating buoyant fluids and provides assurance that injected CO_2 will be effectivity trapped. Further evidence of effective confinement of fluids is the sustained pressure depletion of some zones after production.

This MRV Plan considered the following potential leakage pathways:

- Diffuse leakage through the Anahuac Shale
- Faults and fractures
- Natural and induced seismic activity
- Failure of zonal isolation in existing wells
- Failure of zonal isolation in new well construction
- Drilling through the CO_2 area
- Lateral migration outside the West Ranch Oil Field
- Pipeline/surface equipment

4.2 Diffuse leakage through the Anahuac Shale

Diffuse leakage through the seals that lie above the reservoirs in the Project Interval is highly unlikely. There are numerous sections above the sand reservoirs in the Project Interval that are impermeable and serve as reliable barriers to prevent fluids from moving upwards towards the surface. These barriers are referred to as seals because they effectively seal fluids into the formations beneath them. In addition, Anahuac Shale was deposited over much of the Gulf Coast during a major regional transgression. It serves as a major confining unit that traps hydrocarbons. It is also widely used as a top seal for Class I disposal operations in the Gulf Coast area. Anahuac Shale is more than 120 feet thick in the West Ranch area, and a 30-foot core collected at the A-600 well has been examined in detail to characterize the quality of this confining layer (Lu et al 2014). It is composed of silty clay (average 56 percent clay) and has permeabilities of 0.0006 to 0.0026 mD. Gas chemistry shows that gas migration is limited by diffusion and adsorption and confirms that Anahuac Shale is an effective seal which will not allow diffuse leakage of CO_2 above the Project Interval. Injection pressure is continuously monitored and unexplained changes in injection pressure that might indicate leakage would trigger investigation as to the cause.

4.3 Faults and Fractures

West Ranch is a roll-over anticline formed between two major growth fault zones (Figures 2.2.1,

2.2.2 and 2.2.3), and there is no major fault within the field (Baurenschmidt, 1962). The Gulf Coast region is faulted by systems of growth faults (active during sediment accumulation) and by structures associated with deep-seated and piercement salt structures, which have been extensively characterized by exploration. Because the overall section is dominated by mudstones, fault permeability is controlled by clay smear. The sealing nature of faults is evident at many hydrocarbon fields that are fault-bounded. Gulf Coast sandstones and mudstones are typically not fractured but deform without rupture by bending and smearing. As described in Section 2.8.2, all injection permits require that injected fluids be confined in the authorized reservoir, and injection at pressure exceeding fracture pressure is not allowed.

4.4 Natural and Induced Seismic Activity

Although the Gulf Coast has been and is still locally undergoing deformation related to loading and continued subsidence of the Gulf Basin, the area is not seismically active. Deformation occurs without producing earthquakes. The United States Geological Survey (USGS) long term seismic risk map puts the entire Gulf Coast area, including West Ranch, in the lowest risk category (United States Geological Survey, 2014).

Risk of induced seismicity at West Ranch is low for several reasons: 1) magnitude of pressure increase and the area where elevated pressure is aggressively managed by balancing injection and withdrawal rates, 2) the reservoirs have a lower pressure as a result of past production, 3) high permeability and rapid fluid cycling though the reservoir creates little risk of developing local overpressure, and 4) the operation is compliant with regulations limiting injection pressure.

In addition, the application for a new injection well permit or an amendment of an existing injection well permit for injection pressure, injection rate, or injection interval must include a survey of historical seismic events within 5.64 miles, the Area of Interest (AOI). A seismic event of 2.0 Magnitude (M) or greater from the USGS earthquake catalog or the TexNet earthquake catalog triggers seismicity review and requires additional geologic information across the AOI for the TRRC to consider the necessity of a permit disposition.

In the unlikely event that seismicity resulted in a pathway for material amounts of CO_2 to migrate from the injection zone, the monitoring provisions at other reservoir levels would lead to further investigation as elaborated in Section 5.1.

4.5 Failure of Zonal Isolation in Existing Wells

Wells are required to be constructed and either plugged and abandoned or maintained so the injection and production zones are isolated from other zones and from fresh groundwater (underground sources of drinking water or USDW). West Ranch contains many legacy wells; hence, the operator invests in well qualification and management. Well qualification and management are overseen by the TRRC.

TRRC rules call for periodic Mechanical Integrity Testing (MIT). Continuous monitoring devices tracking injection rate, pressure, and volume (as well as continuous monitoring of the annulus with a pressure gauge) are installed in line with the requirement. These monitoring tools conform to the TRRC requirements under TAC Title 16 Part 1 §5.305(1)(B) and used to protect against the high cost from loss of well control. All pressure gauges are hooked up to a real time reporting SCADA system. The SCADA monitoring system uses set points to trigger an alarm if there is more than a 10 percent change in pressure. In addition, periodic injection profiles are performed on the injection wells, and this will include running temperature surveys on the injection wells. Reservoir pressure is also measured through the injection wells when workovers are performed.

While the CO_2 EOR operation is conducted, injection profiles are performed to determine where the injected fluid is going and to understand the comprehensive picture of what is going on down hole in an injector well. An injection profile package is made up of numerous surveys. The tool used has several components such as a radioactive tracer, spinner logs, temperature logs, caliper logs, and collar logs. The temperature survey looks for anomalies which can indicate if there is fluid loss during injection. A tracer tool monitors the reduction in tracer material as it moves down the well and could indicate channeling and help in quantifying the amount of a release if one is found. A spinner gives the rate, and a shut-in temperature survey indicates fluid losses and events occurring inside and outside the well bore.

In addition, a Reservoir Saturation Tool (RST) is run to measure hydrocarbon and water saturations behind the casing. This tool could indicate if the injected fluid is going out of the targeted interval and into another zone. Baseline RST has been run on six wells.

An exhaustive study of all existing wellbores at West Ranch was carried out prior to the start of the CO_2 flood to confirm well condition and integrity. All of the plugged and abandoned wells at West Ranch have plugs to prevent the upward migration of fluids. Most wells have numerous plugs in the Frio Formation isolating the deeper zones. All shut-in and producing wells in West Ranch were also reviewed, and numerous shut-in wells are used for its active pressure monitoring program throughout the field as described in Section 5.1.1.

Additionally, the TRRC requires an applicant for an injection well permit to examine the data of record for wells that penetrate the proposed injection reservoir within one-quarter (1/4) mile radius of the proposed well to determine if all abandoned wells have been plugged in a manner that will prevent the movement of fluids into strata other than the authorized reservoir for injection (AoR). The operator currently reviews all wells located within one-half (1/2) mile radius of a proposed injection well.

Based on the measures above, the risk of CO_2 leakage through existing wells is being mitigated through a monitoring and maintenance program that will provide early detection of problems that could materialize into a leakage event. Any potential CO_2 leakage would be identified and quantified through the monitoring provisions in Section 5.1.

4.6 Failure of Zonal Isolation in New Well Construction

Well qualification and management are overseen by the TRRC. New wells are constructed to provide zonal isolation and are tested prior to use to confirm that cement in the rock-casing annulus covers the required intervals and is of good quality; hence, the risk of failure of zonal isolation in new wells is low. In the event CO_2 leakage were to occur, it would be identified and quantified through the monitoring provisions in Section 5.1.

All injection wells for the CO_2 EOR operation are newly drilled wells or conversion of existing wellbores and must adhere to the TRRC requirements as described elsewhere herein including

Section 2.8.2. All injection wells have coated tubulars to withstand corrosion. Both the surface and production casing strings are cemented back to the surface, with a confirmation through a cement bond log of a full column of cement behind the casing.

For producing wells for CO_2 EOR operation that are newly drilled, these wells are drilled and completed to deal with corrosion, including coated tubulars and corrosion inhibiting fluid in the annulus between the tubing and the long string casing to prevent corrosion. Both surface and production casings are cemented to the surface.

4.7 Drilling through the CO_2 Area

A future drilling initiative within the existing or future WRU to extend the current CO_2 flood area or to drill into a deeper reservoir creating an inadvertent leakage pathway is possible; however, such risk is considered to be very low. As previously stated, all wells drilled in the West Ranch Oil Field are regulated by the TRRC (specifically under TAC Title 16 Part 1 §3.13) which includes (a) ensuring that the casing is securely anchored to effectively control the well at all times, (b) all usable-quality water zones are isolated and sealed off to effectively prevent contamination or harm, and (c) all productive zones, potential flow zones, and zones with corrosive formation fluids are isolated and sealed off to prevent vertical migration of fluids behind the casing, including gases. Multiple reservoirs at West Ranch are gas charged, and all drilling to each reservoir must be done with proper preparation to contain gas within such reservoirs (e.g., using well control mechanisms such as dense drilling mud, blow out preventers, and completion to isolate zones). In the unlikely event of gas leakage from a reservoir flooded with CO_2, the methods to quantify the amount of leakage use appropriate engineering variables and standard estimation of releases.

4.8 Lateral Migration outside West Ranch Oil Field

As illustrated in Figures 2.2.1 and 2.2.2, West Ranch contains the highest elevation of both current and future reservoirs for CO_2 flooding within the surrounding area. It is highly unlikely that injected CO_2 will migrate downdip and laterally outside of the existing and future WRUs because CO_2 is less dense than oil and water in the reservoir. As a result, the CO_2 tends to migrate and accumulate at the top of geological structure. The well-defined structural closure based on well logs and oil-water contact provides a strong control on the lateral extent of the CO_2 plume, and the volume of injected CO_2 will be less than the storage capacity of each reservoir. CO_2-oil miscibility also strongly minimizes possible lateral CO_2 transport distance.

4.9 Pipeline/Surface Equipment

Surface infrastructure is under daily surveillance. Any releases of CO_2 from either planned events or unplanned incidents are being quantified and reported following the requirement of Subpart W of EPA's GHGRP or based on appropriate engineering variables and standard estimation of releases as stated in Section 5.2. The past three years of surveillance show that the release volumes are less than one percent of the captured CO_2. Confidence in surveillance is high, because release of even small amounts of CO_2 is highly noticeable as dense CO_2 flashes result in large volume increases and strong cooling, resulting in noise and a cloud, ice, or condensed water.

5. Site-specific Risk-based Monitoring

5.1 Losses through Subsurface Infrastructure

Detection of any losses of CO_2 in the subsurface through damaged or faulty well construction, or through any other potential pathways for CO_2 leakage to the surface as identified in Section 4, including faults and fractures, will be done based on the monitoring information obtained from both active and shut-in wells. Proactive pressure monitoring at active producing wells, active injection wells, and shut-in monitoring wells is done via installation of pressure gauges at the wellhead that access the tubing and casing with connections to the SCADA system. Pressure reading at the surface casing, production casing and tubing on these wells are captured multiple times each day. If CO_2 leaked from an active CO_2 EOR reservoir, which is carefully monitored with the active and shut-in monitoring wells and managed through the operating practice and further backstopped by the higher elevation of the field as explained in section 3.1, it would migrate upwards into another reservoir and increase that reservoir's pressure. As presented in Table 5.1.1, multiple reservoirs above and below the regional Anahuac Shale, each also immediately overlain by confining rocks, are equipped with shut-in monitoring wells to detect the abnormal reservoir pressure change. The shut-in monitoring wells are also horizontally scattered throughout the field, as shown on Figure 5.1.1, which helps with early leak detection. If pressure changes in a reservoir that is not intended to be energized or if there are any CO_2 releases from the subsurface, alarms are set up to be notified through the SCADA system into the control room. All active alarms are followed up by field personnel for further investigation and diagnostics. If a leakage is detected, PNPH will use an event-specific approach to quantify leaked amounts of CO_2. Depending on the circumstance, this might include the use of modeling, engineering estimates, or direct measurements to estimate the relevant parameters (e.g., flow rate, concentration, and duration of leakage) to quantify the leaked volume.

All permanently plugged and abandoned wells are plugged with cement and drilling mud with well tubulars cut off below the surface in accordance with regulatory requirements; however, as these wells are not equipped with pressure gauges, in the unlikely event of well leakage, the detection and quantification will be done indirectly from the pressure reading of surrounding wells that are perforated in the same or shallower reservoirs.

5.1.1 Inactive Well Monitoring

As of December 31, 2020, there are 255 inactive wells completed in the Frio Formation above the injection interval and in select zones above the impenetrable Anahuac Shale that are being used as pressure monitoring wells. These monitoring wells are outfitted with gauges on the tubings, the production casings, and the surface casings. All data is reported and monitored in real time through the SCADA system that reports information into the control room with back-up information fed into the operator's corporate offices. Figure 5.1.1 shows the location of the pressure monitoring wells throughout the field. Table 5.1.1 shows the zones of the inactive monitoring wells.

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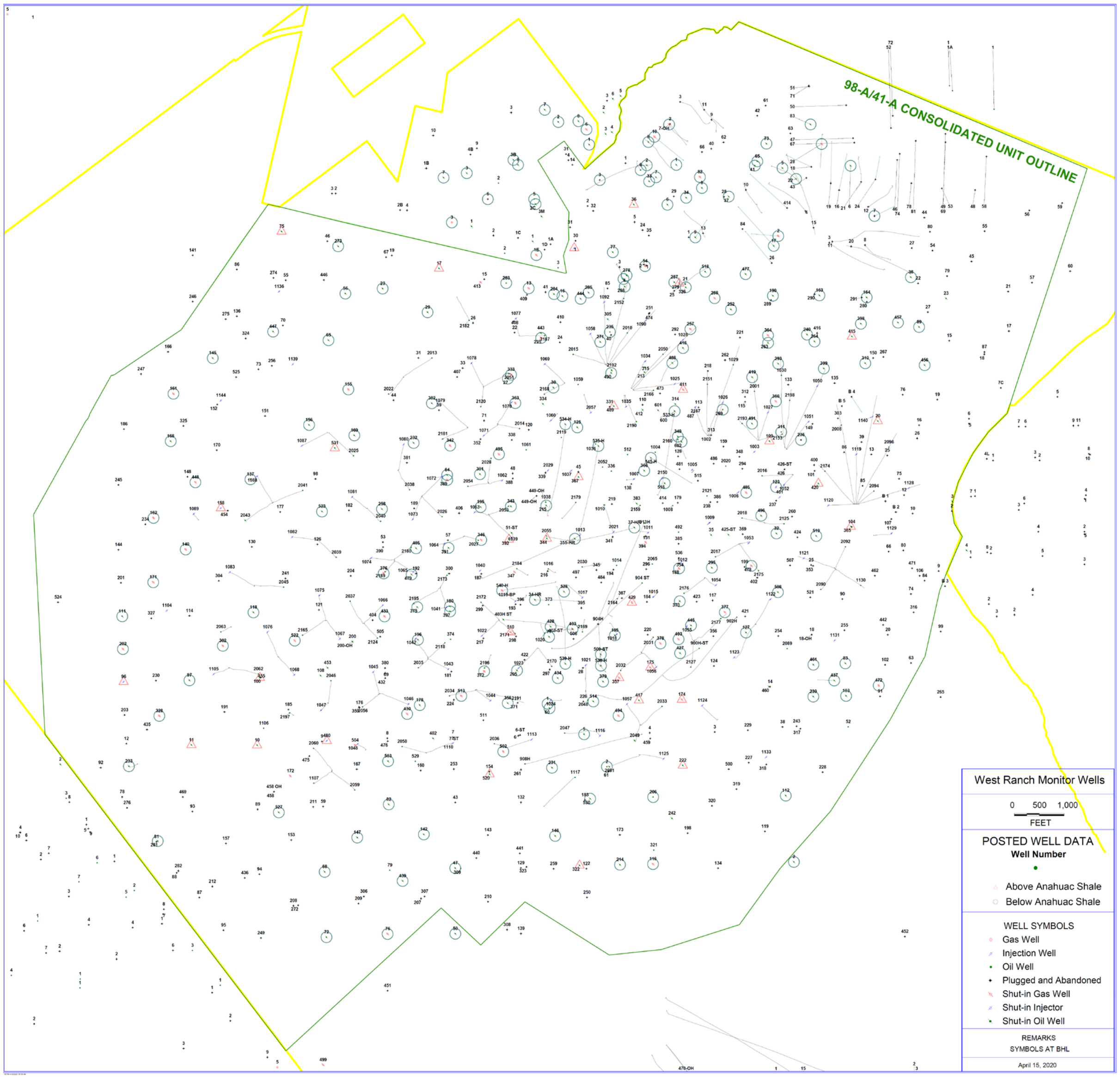

Figure 5.1.1 Location of inactive wells with pressure monitoring (wells above and below Anahuac Shale are shown as pink triangles and green circles, respectively)

#	Reservoir	Number of wells	Depth	
1	Shallow Gas	6		
2	80-A	4	2,940’	
3	Noble/Miocene	11		
4	3800	1	3,775’	
5	Catahoula	13		
6	Discorbis	4	4,555’	
7	Marg	31	4,960’	Below Anahuac Shale
8	Greta	83	5,065	
9	Randle	2	5,250’	
10	Benneview	1	5,320’	
11	Dixon	2	5,390’	
12	Toney	16	5,400’	
13	Glasscock	14	5,470’	
14	Menefee	3	5,550’	
15	Mitchell	10	5,580’	
16	Armstrong	1	5,600’	
17	Ward	33	5,630’	
18	41-A	7	5,700’	
19	Musquez	1	6,050’	
20	383 Frio	2	6,080’	
21	98-A	10	6,125’	

Table 5.1.1 Zones where pressure monitoring wells are located

5.1.2. Production Well Monitoring

Figure 5.1.2 depicts how a production well is monitored in the SCADA system. Pressure gauges monitor pressure in the tubing, the production casing, and the surface casing. Gas lift rate and pressure are also monitored for each well. The valves on the right side of the diagram are located at the TS manifold and allow the well to be directed into the high pressure (HP), intermediate pressure (IP), or low pressure (LP) system, or to the TS separator. Alarms are set to monitor any changes in the pressure from the normal pressure ranges. If abnormal pressures are noted, an alarm sounds and the well will be monitored for CO_2 leaks.

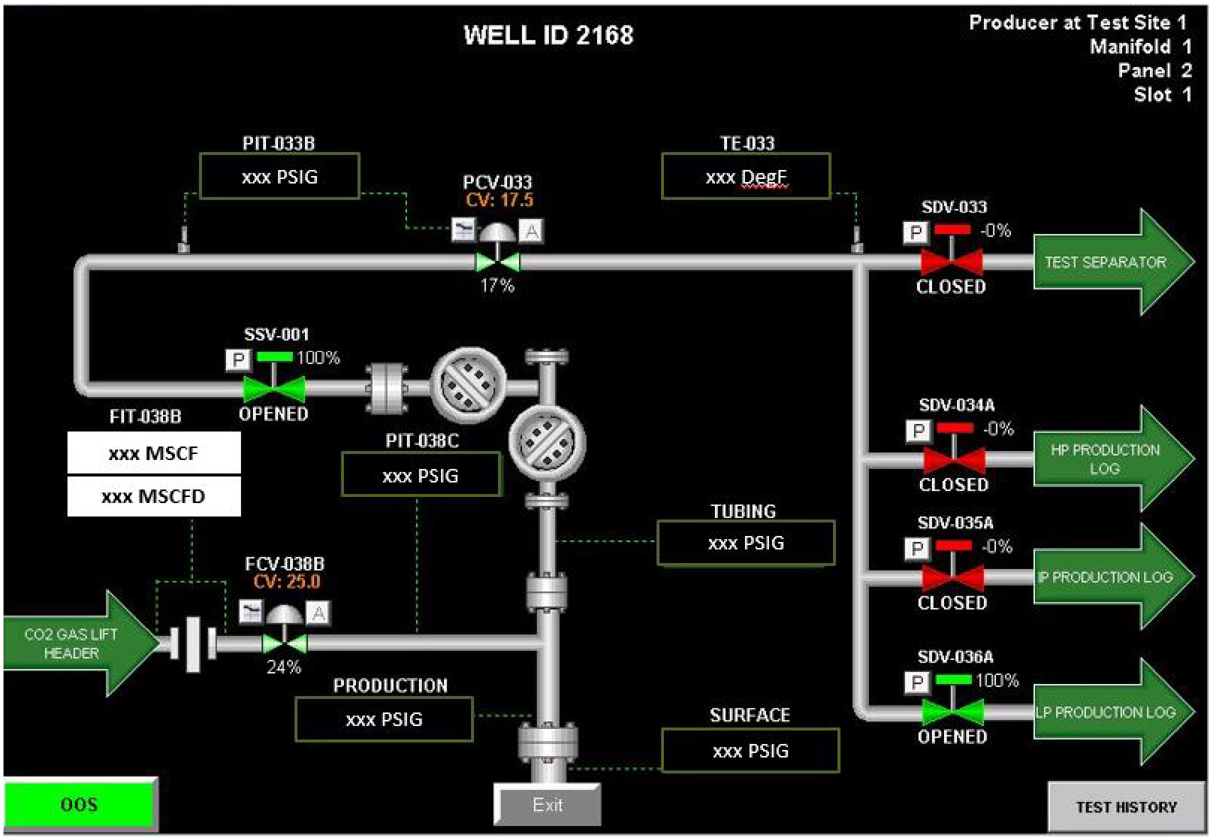

Figure 5.1.2 Monitoring of Production Wells

5.1.3. Injection Well Monitoring

Figure 5.1.3 depicts how an injection well is monitored in the SCADA system. Pressure gauges monitor pressure in the tubing, the production casing, and the surface casing. The valves on the right side of the diagram are located at the TS manifold and allow either CO_2 or water to be injected into the well, and in some cases both CO_2 and water at the same time. The injection rate is metered for each well. Alarms are set to monitor any changes in the pressure from the normal pressure ranges. If abnormal pressures are noted, an alarm sounds and the well will be monitored for CO_2 leaks.

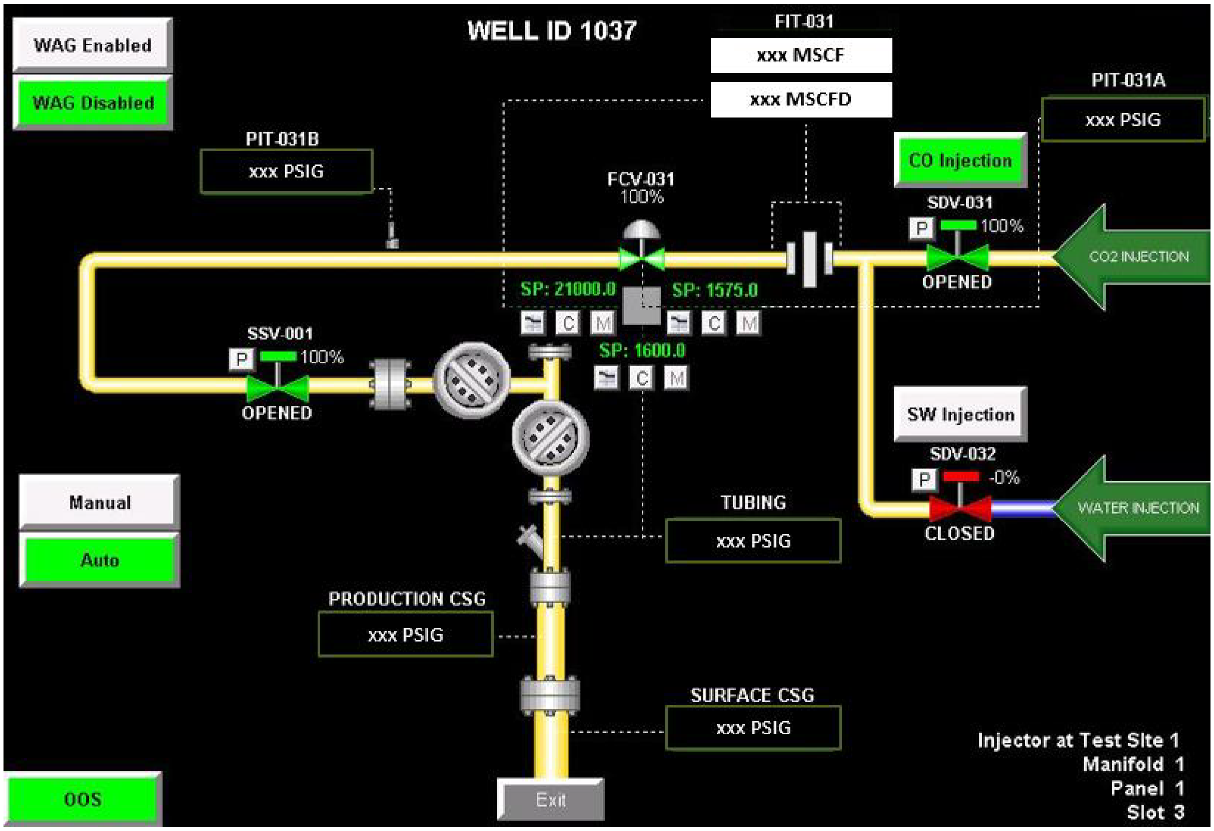

Figure 5.1.3 Monitoring of Injection Wells

5.2 Losses through Surface Infrastructure

Losses though surface infrastructure are either intentional releases for maintenance or unplanned releases, in the case of upsets or accidents. The method of detection is identified by the operator using both the data streams and alarms that are reported to the control room and visual inspection of facilities. The methods of quantification use appropriate engineering variables and standard estimation of releases.

PNPH ensures that the operator evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6. Determination of Baselines

PNPH will use the results from daily monitoring of field conditions by the operator and operational data, as well as routine testing and maintenance information to monitor for surface leakage. As indicated in Sections 4.5 and 5, the SCADA system is used to conduct the CO_2 EOR operations at West Ranch. The data from these efforts is used to identify and investigate variances from expected performance that could indicate CO_2 leakage. Below is a description of how this data will be used to determine when further investigation of potential CO_2 leakage is warranted.

- **Visual Inspections**: As mentioned in Section 4.9, operations personnel make daily rounds of the facilities, providing a visual inspection of equipment used in the operations (e.g., vessels, piping, valves, wellheads). These inspection rounds provide the opportunity to identify issues early and address them proactively, which may preclude leaks from happening and/or minimize any CO_2 leakage. If an identified issue cannot be resolved by the person who first observes it, a work order will be generated to resolve the matter. Each event will be documented, including an estimate of the amount of CO_2 leaked and included in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.
- **Mechanical Integrity Test (MIT)**: TRRC rules calls for operators to comply with MIT requirements, which are designed to ensure that there is no significant leakage within the injection tubing, casing, or packer, as well as no leakage outside of the casing. All active injection wells undergo MIT testing (referred to as "H-5 Testing") at the following intervals:
    - Before injection operations begin;
    - At least once every five years, or more frequently if required by the permit;
    - After any workover that disturbs the seal between the tubing, packer, and casing, or after any repair work on the casing; and
    - When a request is made to suspend or reactivate the injection or disposal permit.

  The TRRC requires that the operator notify the TRRC district office at least 48 hours prior to conducting the H-5 Testing. Operators are required to use a pressure recorder and pressure gauge for the test. Operators' field representative must sign the pressure recorder chart and submit it with Form H-5. Casing pressure must fall within 30-70% of the pressure recorder chart's full scale, and the pressure gauge must measure in increments that are no greater than 5% of the test pressure.

  In the event a loss of mechanical integrity occurs, the injection well is immediately shut-in and an investigation is initiated to determine what caused the loss of mechanical integrity. If investigation of an event identifies that a leak has occurred, those events will be documented, including an estimate of the amount of CO_2 leaked and included in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.
- **Production and Shut-in Well Pressure Surveillance**: All tubings and casings of production and shut-in wells are equipped with pressure gauges and connected to the SCADA system as described in Section 5. If a 10% deviation in pressure outside of the expected values occurs, the event is investigated to determine if the variance poses a leak threat. If investigation of an event identifies that a leak has occurred, those events will be documented, including an estimate of the amount of CO_2 leaked and included in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.

7. Determination of Sequestration Volumes Using Mass Balance Equations

PNPH will use equation RR-11 in 40 C.F.R. §98.443 to calculate the Mass of CO_2 Sequestered in Subsurface Geologic Formations in a reporting year as follows:

$$CO_2 = CO_{2I} - CO_{2P} - CO_{2E} - CO_{2FI} - CO_{2FP} \quad \text{(Eq. RR-11)}$$

where:

CO_2 = *Total annual CO_2 mass sequestered in subsurface geologic formations (metric tons) at the facility in the reporting year.*

CO_{2I} = *CO_2 Injected, the total annual CO_2 mass injected (metric tons) in the well or group of wells covered by this source category in the reporting year, includes both Received CO_2 (or Fresh CO_2, see discussion below) and Recycled CO_2.*

CO_{2P} = *CO_2 Produced, the total annual CO_2 mass produced (metric tons) in the reporting year, includes Recycled CO_2 (see discussion below).*

CO_{2E} = *CO_2 Emitted by Surface Leakage, total annual CO_2 mass emitted (metric tons) by surface leakage in the reporting year.*

CO_{2FI} = *Total annual CO_2 mass emitted (metric tons) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead, for which a calculation procedure is provided in Subpart W.*

CO_{2FP} = *Total annual CO_2 mass emitted (metric tons) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity, for which a calculation procedure is provided in Subpart W.*

To account for site-specific considerations, PNPH proposes the locations below for obtaining data to determine the CO_2 volumes used in the mass balance.

The first proposal addresses the propagation of error that would be created if volume data from meters at each injection well were utilized. This issue arises because each meter has a small but acceptable margin of calibration error, and this error could become significant if data were taken from the approximately 100 meters within West Ranch. As such, PNPH proposes to use the mass of Recycled CO_2 from commercial quality flow meters at the inlet of RGCs combined with mass of CO_2 Received (earlier referred to as Fresh CO_2 and further defined below) to determine the mass of CO_2 Injected into the subsurface (CO_{2I} in the formula above). The mass of CO_2 Produced (CO_{2P} in the formula above) will be the same as Recycled CO_2.

The second proposal addresses the concentration of CO_2 Received. Figure 7 shows the planned mass balance envelope overlaid as a blue square onto the facility flow diagram originally shown in Figure 2.7.1. The envelope contains all measurements relevant to the mass balance equation except for CO_2 Received, which is proposed to be measured at the custody transfer meter located in the vicinity of CCE (M_1) as shown in Section 2.8.1.

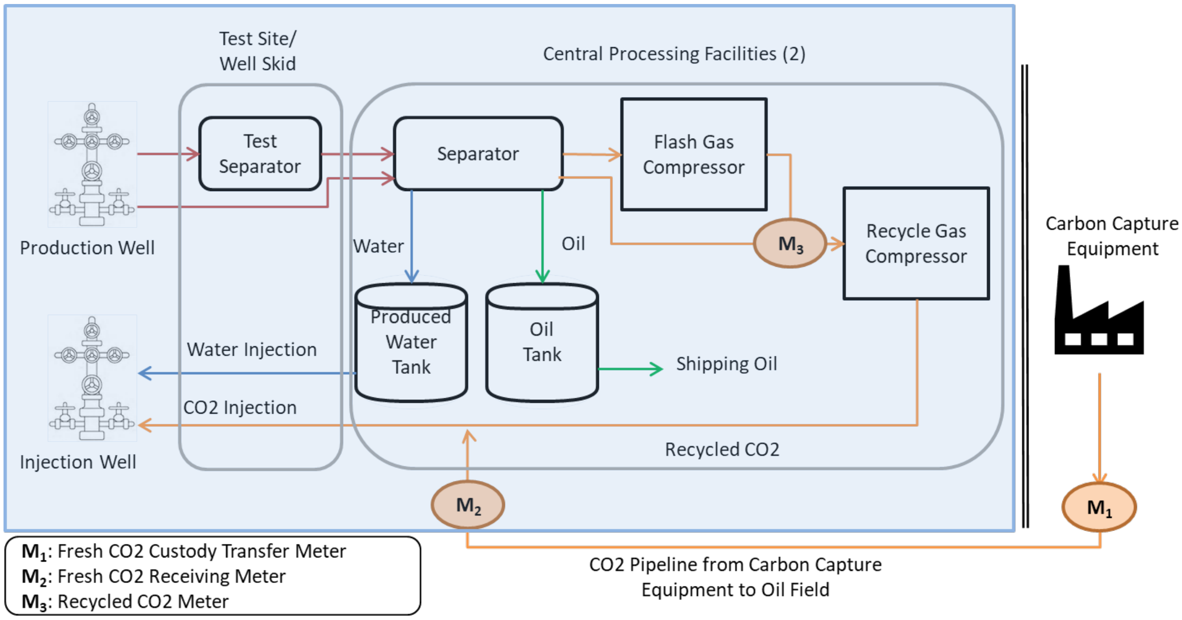

Figure 7 Material Balance Envelope (in blue)

The following sections describe how each element of the mass-balance equation will be calculated.

7.1 Mass of CO_2 Injected into the Subsurface

The equation for calculating the mass of CO_2 Injected into the Subsurface at West Ranch is equal to the sum of the mass of CO_2 Received (volumetric flow at M_2 using CO_2 concentration at M_1) and the mass of Recycled CO_2 measured at the inlet of the RGC (M_3).

$$CO_{2I} = CO_{2T,r} + CO_{2,u}$$

where:

CO_{2I} = *CO_2 Injected, the total annual CO_2 mass injected (metric tons) in the well or group of wells covered by this source category in the reporting year*

$CO_{2T,r}$ = *CO_2 Received, the injected net annual mass of CO_2 received through flow meter r (metric tons).*

$CO_{2,u}$ = *CO_2 Recycled, the injected annual CO_2 mass injected (metric tons) as measured by flow meter u.*

Mass of CO_2 Received

PNPH will use equation RR-2 as indicated in 40 C.F.R. §98.443 to calculate the mass of CO_2. Received. The volumetric flow at standard conditions as defined in 9.1.2 is measured at the receiving meter at West Ranch at the terminus of CO_2 Pipeline from CCE (M_2), and will be multiplied by the CO_2 concentration measured at the custody transfer meter located in the

vicinity of CCE (M_1) as stated above, and the density of CO_2 at standard conditions to determine mass.

$$\mathrm{CO}_{2T,r} = \sum_{p=1}^{4}(Q_{r,p} - S_{r,p}) * D * C_{\mathrm{CO}_{2,p,r}} \quad \text{(Eq. RR-2)}$$

where:

$CO_{2T,r}$ = *CO_2 Received, the injected net annual mass of CO_2 received through flow meter r (metric tons).*

$Q_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).*

$S_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into your well in quarter p (standard cubic meters). Since all delivery to West Ranch is used within the oilfield, the quarterly flow redelivered, $S_{r,p}$ is zero ("0").*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,r}$ = *Quarterly CO_2 concentration measurement in flow for flow meter r in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

r = *Receiving flow meter (M_2, CO_2 concentration for M_2 is measured at M_1).*

Mass of CO_2 Recycled

PNPH will use equation RR-5 from 40 C.F.R. §98.443 to calculate the Mass of Recycled CO_2.

$$\mathrm{CO}_{2,u} = \sum_{p=1}^{4} Q_{p,u} * D * C_{\mathrm{CO}_{2,p,u}} \quad \text{(Eq. RR-5)}$$

where:

$CO_{2,u}$ = *CO_2 Recycled, the annual CO_2 mass injected (metric tons) as measured by flow meter u.*

$Q_{p,u}$ = *Quarterly volumetric flow rate measurement for flow meter u in quarter p at standard conditions (standard cubic meters per quarter).*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,u}$ = *CO_2 concentration measurement for flow meter u in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

u = Flow meter (M_3).

7.2 Mass of CO_2 Produced

As discussed above, the mass of CO_2 Produced equals the mass of Recycled CO_2 measured at the flow meters at inlet of RGCs (M_3). Equation RR-9 in 40 C.F.R. §98.443 will be used to

aggregate the mass of CO_2 produced net of the mass of CO_2 entrained in produced oil as follows:

$$\mathrm{CO}_{2P} = \sum_{w=1}^{W} \mathrm{CO}_{2,w} + X_{oil} \qquad \text{(Eq. RR-9)}$$

where:

CO_{2P} = *CO_2 Produced, the total annual CO_2 mass produced (metric tons) in the reporting year.*

$CO_{2,w}$ = *Annual CO_2 mass produced (metric tons) through flow meter w in the reporting year (further defined below).*

X_{oil} = *Mass of entrained CO_2 (metric tons) in oil in the reporting year calculated as per 40 C.F.R. Subpart W.*

w = *Flow meter (M_3)*

PNPH will use equation RR-8 as indicated in 40 C.F.R. §98.443 to calculate the annual mass of CO_2 produced.

$$\mathrm{CO}_{2,w} = \sum_{p=1}^{4} Q_{p,w} * D * C_{\mathrm{CO}_{2,p,w}} \qquad \text{(Eq. RR-8)}$$

where:

$CO_{2,w}$ = *Annual CO_2 mass produced (metric tons) through flow meter w.*

$Q_{p,w}$ = *Volumetric gas flow rate measurement for separator w in quarter p at standard conditions (standard cubic meters).*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,w}$ = *CO_2 concentration measurement for flow meter w in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

w = *Flow meter (M_3)*

7.3 Mass of CO_2 Emitted by Surface Leakage

The mass of CO_2 Emitted by Surface Leakage (term CO_{2E} in Eq. RR-11) is calculated based on various methodologies, including measurements, engineering estimates, and emission factors, used for the leakage originating from subsurface as described in Section 5.1. For releases from surface equipment and equipment venting (terms CO_{2FI} and CO_{2FP} in Eq. RR-11), 40 C.F.R. Subpart W reporting is relied upon as noted above.

Equation RR-10 in 40 C.F.R. §98.443 will be used to calculate and report the Mass of CO_2 Emitted by Surface Leakage:

$$\mathrm{CO}_{2E} = \sum_{x=1}^{X} \mathrm{CO}_{2,x} \qquad \text{(Eq. RR-10)}$$

where:

CO_2. =	*Total annual CO_2 mass emitted by surface leakage (metric tons) in the reporting year.*
$CO_{2,x}$ =	*Annual CO_2 mass emitted (metric tons) at leakage pathway x in the reporting year.*
x =	*Leakage pathway*
X =	*Total number of leakage pathways.*

8. MRV Plan Implementation Schedule

The activities described in this MRV Plan are in place, and reporting is planned to start upon EPA approval. It is anticipated that the Annual Subpart RR Report will be filed on March 31 of the year after the reporting year. As described in Section 3.3 above, PNPH anticipates that the MRV Plan will be in effect during the Specified Period, during which time West Ranch is operated with the subsidiary purpose of establishing long-term containment of a measurable quantity of CO_2 in subsurface geological formations at West Ranch. PNPH anticipates establishing that a measurable portion of the CO_2 injected during the Specified Period will be sequestered in a manner not expected to migrate resulting in future surface leakage. At such time, PNPH will prepare a filing to support the long-term containment determination and submit a request to discontinue reporting under this MRV Plan. See 40 CFR § 98.441(b)(2)(ii).

9. Quality Assurance Program

9.1 Monitoring QA/QC

9.1.1 Flow Meter Provisions

The flow meters used to generate data for the mass balance equations in Section 7 are:

- Operated continuously except as necessary for maintenance and calibration.
- Operated using the calibration and accuracy requirements in 40 CFR §98.3(i).
- Operated in conformance with American Petroleum Institute (API) standards.
- National Institute of Standards and Technology (NIST) traceable.

9.1.2 Concentration of CO_2

CO_2 concentration is measured using an appropriate standard method consistent with 40 CFR §98.444(f)(1). Further, all measured volumes of CO_2 have been converted to standard cubic meters at a temperature of 60 degrees Fahrenheit and at an absolute pressure of 14.65 psi, including those used in Equations RR-2, RR-5, and RR-8 in Section 7.

9.2 Missing Data Procedures

In the event PNPH is unable to collect data needed for the mass balance calculations, procedures for estimating missing data will be used as follows:

- A quarterly flow rate of CO_2 received that is missing would be estimated using invoices or using a representative flow rate value from the nearest previous time period.
- A quarterly CO_2 concentration of a CO_2 stream received that is missing would be estimated using invoices or using a representative concentration value from the nearest previous time period.
- A quarterly quantity of CO_2 injected that is missing would be estimated using a representative quantity of CO_2 injected from the nearest previous period of time at a similar injection pressure.

For any values associated with CO_2 emissions from equipment leaks and vented emissions of CO_2 from surface equipment at the facility that are reported in this subpart, missing data estimation procedures will be followed.

9.3 MRV Plan Revisions

In the event there is a material change to the monitoring and/or operational parameters of the West Ranch CO_2 EOR operations that is not anticipated in this MRV Plan, the MRV Plan will be revised and submitted to the EPA Administrator within 180 days as required in 40 CFR §98.448(d). As stated earlier in Sections 2 and 3, the subsurface characteristics of the existing WRU for 98-A and 41-A reservoirs are found in the other reservoirs within the Project Interval at West Ranch. Any future expansion into the Project Interval will be subjected to the same regulatory and operational requirements as explained in Sections 2.7 and 2.8. In addition, the reservoir simulation effort carried out as part of DOE's MVA Plan and the storage capacity calculation as illustrated in Sections 2.5 and 2.9 demonstrated the viability of existing and future WRUs for long-term CO_2 retention. Therefore, any horizontal or upward vertical expansion at West Ranch will be managed by applying the same monitoring approach as identified in this MRV Plan and would not trigger a modification to this MRV Plan, as far as they are confined within the Project Interval and fall under the definition of AMA and/or MMA.

10. Records Retention

PNPH will follow the record retention requirements specified by 40 CFR §98.3(g). In addition, the requirements in 40 CFR §98.447 will be met by maintaining the following records for at least three years:

- Quarterly records of CO_2 received including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of this stream.
- Quarterly records of injected CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of this stream.
- Quarterly records of produced CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of this stream.

- Annual records of information used to calculate the CO_2 emitted by surface leakage from leakage pathways.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity.

All data will be collected as generated and aggregated as required for reporting purposes.

11. References

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12. Appendices

Appendix 1 Acronyms

AMA – Active Monitoring Area

AoR – Area of Review

API – American Petroleum Institute

Bscf – Billion Standard Cubic Feet

CO_2 – Carbon Dioxide

EOR – Enhanced Oil Recovery

EPA – U.S. Environmental Protection Agency

GHGRP – Greenhouse Gas Reporting Program

MIT – Mechanical Integrity Test

MMSTB – Million barrels

MRV – Monitoring, Reporting, and Verification

scf – Standard Cubic Feet

UIC – Underground Injection Control

USDW – Underground Source of Drinking Water

Appendix 2 Well Identification Numbers

The following table presents the well name, API number, status and type for the wells in the West Ranch as of December 2020. The table is subject to change over time as new wells are drilled, existing wells change status, or existing wells are repurposed.

Well Name	API Number	Well Status
DRUMMOND JH 1	422390233500	P&A
DRUMMOND JH 2	422390233600	P&A
DRUMMOND JH 3	422390233700	Monitor
DRUMMOND JH 4	422390233800	P&A
DRUMMOND JH 5	422390233900	Monitor
DRUMMOND JH 6	422390234000	Monitor
DRUMMOND JH 7	422390234100	Monitor
DRUMMOND JH 8	422390234200	Monitor
DRUMMOND JH 1A	422390234300	P&A
DRUMMOND JH 9	422390234400	P&A
DRUMMOND JH 1B	422390234500	P&A
DRUMMOND JH 2B	422390234600	P&A
DRUMMOND JH 3B	422390234700	Monitor
DRUMMOND JH 4B	422390234800	P&A
DRUMMOND JH 1C	422390234900	P&A
DRUMMOND JH 2C	422390235000	Monitor
DRUMMOND JH 1D	422390235100	P&A
WEST RANCH A 2	422390235600	P&A
WEST RANCH A 3	422390235700	P&A
WEST RANCH A 4	422390235800	P&A
WEST RANCH A 5	422390235900	Monitor
WEST RANCH A 6-ST	422390236001	P&A
WEST RANCH A 6	422390236099	P&A
WEST RANCH A 7-ST	422390236101	P&A
WEST RANCH A 8	422390236200	P&A
WEST RANCH A 9	422390236300	P&A
WEST RANCH A 10	422390236400	Monitor
WEST RANCH A 11	422390236500	Monitor
WEST RANCH A 12	422390236600	P&A
WEST RANCH A 13	422390236800	Monitor
WEST RANCH A 14	422390236900	P&A
WEST RANCH A 15	422390237000	P&A
WEST RANCH A 16	422390237100	Monitor
WEST RANCH A 17	422390237200	Monitor
WEST RANCH A 18-OH	422390237399	P&A
WEST RANCH A 19	422390237400	P&A
WEST RANCH A 20	422390237500	P&A
WEST RANCH A 21	422390237600	P&A
WEST RANCH A 22	422390237700	P&A
WEST RANCH A 23	422390237800	Monitor
WEST RANCH A 24	422390237900	P&A
WEST RANCH A 25	422390238000	P&A
WEST RANCH A 26	422390238100	P&A
WEST RANCH A 27	422390238200	Monitor

WEST RANCH A 28	422390238300	P&A
WEST RANCH A 29	422390238400	Monitor
WEST RANCH A 30	422390238500	Monitor
WEST RANCH A 31	422390238600	P&A
WEST RANCH A 32	422390238700	Monitor
WEST RANCH A 33	422390238800	P&A
WEST RANCH A 34-HR	422390238901	Monitor
WEST RANCH A 35	422390239000	OIL-Conventional
WEST RANCH A 36	422390239100	Monitor
WEST RANCH A 37-HR	422390239201	Monitor
WEST RANCH A 38	422390239300	P&A
WEST RANCH A 39	422390239400	P&A
WEST RANCH A 40	422390239500	P&A
WEST RANCH A 41	422390239600	P&A
WEST RANCH A 42	422390239700	WSW
WEST RANCH A 43	422390239800	P&A
WEST RANCH A 44	422390239900	P&A
WEST RANCH A 45	422390240000	P&A
WEST RANCH A 46	422390240100	P&A
WEST RANCH A 47	422390240200	Monitor
WEST RANCH A 48	422390240300	P&A
WEST RANCH A 49	422390240400	Monitor
WEST RANCH A 50	422390240500	Monitor
WEST RANCH A 51-ST	422390240601	Monitor
WEST RANCH A 52	422390240700	OIL-Conventional
WEST RANCH A 53	422390240800	P&A
WEST RANCH A 54	422390240900	Monitor
WEST RANCH A 55	422390241000	P&A
WEST RANCH A 56	422390241100	Monitor
WEST RANCH A 57	422390241200	P&A
WEST RANCH A 58	422390241300	Monitor
WEST RANCH A 59	422390241400	P&A
WEST RANCH A 60	422390241500	Monitor
WEST RANCH A 61	422390241600	P&A
WEST RANCH A 62	422390241700	Monitor
WEST RANCH A 63	422390241800	P&A
WEST RANCH A 64	422390241900	Monitor
WEST RANCH A 65	422390242000	Monitor
WEST RANCH A 66	422390242100	P&A
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WEST RANCH A 68	422390242300	Monitor
WEST RANCH A 69	422390242400	P&A
WEST RANCH A 70	422390242500	P&A
WEST RANCH A 71	422390242600	P&A
WEST RANCH A 72	422390242700	Monitor
WEST RANCH A 73	422390242800	P&A
WEST RANCH A 74	422390242900	P&A
WEST RANCH A 75	422390243000	Monitor
WEST RANCH A 76	422390243100	Monitor
WEST RANCH A 77	422390243200	Monitor
WEST RANCH A 78	422390243300	P&A
WEST RANCH A 79	422390243400	OIL-Conventional
WEST RANCH A 80	422390243500	P&A

WEST RANCH A 81	422390243600	P&A
WEST RANCH A 82	422390243700	Monitor
WEST RANCH A 83	422390243800	Monitor
WEST RANCH A 84	422390243900	P&A
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WEST RANCH A 97	422390245200	Monitor
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WEST RANCH A 258	422390260800	Monitor
WEST RANCH A 252	422390260900	Monitor
WEST RANCH A 259	422390261000	P&A
WEST RANCH A 260	422390261100	P&A
WEST RANCH A 261	422390261200	P&A
WEST RANCH A 262	422390261300	P&A
WEST RANCH A 263	422390261400	Monitor
WEST RANCH A 264	422390261500	Monitor
WEST RANCH A 240	422390261600	Monitor
WEST RANCH A 265	422390261700	P&A
WEST RANCH A 267	422390261800	P&A
WEST RANCH A 269	422390261900	Monitor
WEST RANCH A 271	422390262000	Monitor
WEST RANCH A 272	422390262100	P&A
WEST RANCH A 273	422390262200	Monitor
WEST RANCH A 274	422390262300	P&A
WEST RANCH A 275	422390262400	P&A
WEST RANCH A 276	422390262500	P&A
WEST RANCH A 278	422390262600	Monitor
WEST RANCH A 279	422390262700	Monitor
WEST RANCH A 280	422390262800	P&A
WEST RANCH A 281	422390262900	Monitor
WEST RANCH A 282	422390263000	P&A
WEST RANCH A 283	422390263100	Monitor
WEST RANCH A 284	422390263200	Monitor
WEST RANCH A 285	422390263300	Monitor
WEST RANCH A 286	422390263400	Monitor
WEST RANCH A 287	422390263500	Monitor
WEST RANCH A 288	422390263600	Monitor
WEST RANCH A 289	422390263700	P&A
WEST RANCH A 290	422390263800	P&A
WEST RANCH A 291	422390263900	P&A
WEST RANCH A 292	422390264000	P&A
WEST RANCH A 293	422390264100	Monitor
WEST RANCH A 294	422390264200	P&A
WEST RANCH A 295	422390264300	Monitor
WEST RANCH A 296	422390264400	P&A
WEST RANCH A 297	422390264500	P&A
WEST RANCH A 298	422390264600	P&A
WEST RANCH A 299	422390264700	P&A
WEST RANCH A 300	422390264800	P&A

WEST RANCH A 301	422390264900	Monitor
WEST RANCH A 302	422390265000	Monitor
WEST RANCH A 303	422390265100	P&A
WEST RANCH A 304	422390265200	P&A
WEST RANCH A 305	422390265300	OIL-Conventional
WEST RANCH A 306	422390265400	P&A
WEST RANCH A 307	422390265500	P&A
WEST RANCH A 308	422390265600	P&A
WEST RANCH A 309	422390265700	OIL-Conventional
WEST RANCH A 310	422390265800	Monitor
WEST RANCH A 311	422390265900	Monitor
WEST RANCH A 312	422390266000	P&A
WEST RANCH A 313	422390266100	P&A
WEST RANCH A 314	422390266200	OIL-Conventional
WEST RANCH A 315	422390266300	OIL-Conventional
WEST RANCH A 316	422390266400	P&A
WEST RANCH A 317	422390266500	P&A
WEST RANCH A 318	422390266600	P&A
WEST RANCH A 319	422390266700	P&A
WEST RANCH A 320	422390266800	P&A
WEST RANCH A 321	422390266900	OIL-Conventional
WEST RANCH A 322	422390267000	Monitor
WEST RANCH A 323	422390267100	P&A
WEST RANCH A 324	422390267200	P&A
WEST RANCH A 325	422390267300	P&A
WEST RANCH A 326	422390267400	Monitor
WEST RANCH A 327	422390267500	P&A
WEST RANCH A 328	422390267600	Monitor
WEST RANCH A 330	422390267700	WSW
WEST RANCH A 331	422390267800	P&A
WEST RANCH A 332	422390267900	OIL-Conventional
WEST RANCH A 333	422390268000	Monitor
WEST RANCH A 334	422390268100	OIL-Conventional
WEST RANCH A 335	422390268200	WSW
WEST RANCH A 336	422390268300	OIL-Conventional
WEST RANCH A 337	422390268400	Monitor
WEST RANCH A 338	422390268500	P&A
WEST RANCH A 339	422390268600	P&A
WEST RANCH A 340	422390268700	WSW
WEST RANCH A 341	422390268800	P&A
WEST RANCH A 342	422390268900	Monitor
WEST RANCH A 343	422390269000	Monitor
WEST RANCH A 344	422390269100	Monitor
WEST RANCH A 345	422390269200	P&A
WEST RANCH A 346	422390269300	Monitor
WEST RANCH A 347	422390269400	OIL-Conventional
WEST RANCH A 348	422390269500	P&A
WEST RANCH A 349	422390269600	Monitor
WEST RANCH A 350	422390269700	WSW
WEST RANCH A 351	422390269800	WSW
WEST RANCH A 352	422390269900	P&A
WEST RANCH A 353	422390270000	P&A
WEST RANCH A 354	422390270100	P&A

WEST RANCH A 355	422390270200	Monitor
WEST RANCH A 355-HR	422390270201	Monitor
WEST RANCH A 356	422390270300	P&A
WEST RANCH A 357	422390270400	Monitor
WEST RANCH A 358	422390270500	Monitor
WEST RANCH A 359	422390270600	P&A
WEST RANCH A 360	422390270700	Monitor
WEST RANCH A 361	422390270800	WSW
WEST RANCH A 362	422390270900	WSW
WEST RANCH A 363	422390271000	Monitor
WEST RANCH A 364	422390271100	Monitor
WEST RANCH A 365	422390271200	Monitor
WEST RANCH A 366	422390271300	Monitor
WEST RANCH A 367	422390271400	Monitor
WEST RANCH A 368	422390271500	Monitor
WEST RANCH A 369	422390271600	P&A
WEST RANCH A 370	422390271700	Monitor
WEST RANCH A 371	422390271800	P&A
WEST RANCH A 372	422390271900	Monitor
WEST RANCH A 373	422390272000	OIL-CO2
WEST RANCH A 374	422390272100	OIL-Conventional
WEST RANCH A 375	422390272200	Monitor
WEST RANCH A 376	422390272300	Monitor
WEST RANCH A 377	422390272400	Monitor
WEST RANCH A 378	422390272500	Monitor
WEST RANCH A 379	422390272600	Monitor
WEST RANCH A 380	422390272700	P&A
WEST RANCH A 381	422390272800	P&A
WEST RANCH A 382	422390272900	Monitor
WEST RANCH A 383	422390273000	OIL-Conventional
WEST RANCH A 384	422390273100	Monitor
WEST RANCH A 385	422390273200	P&A
WEST RANCH A 386	422390273300	P&A
WEST RANCH A 387	422390273400	P&A
WEST RANCH A 388	422390273500	P&A
WEST RANCH A 389	422390273600	Monitor
WEST RANCH A 390	422390273700	P&A
WEST RANCH A 391	422390273800	Monitor
WEST RANCH A 392	422390273900	Monitor
WEST RANCH A 393	422390274000	Monitor
WEST RANCH A 394	422390274100	OIL-Conventional
WEST RANCH A 395	422390274200	P&A
WEST RANCH A 396	422390274300	P&A
WEST RANCH A 397	422390274400	Monitor
WEST RANCH A 398	422390274500	Monitor
WEST RANCH A 399	422390274600	Monitor
WEST RANCH A 400	422390274700	P&A
WEST RANCH A 401	422390274800	INJ
WEST RANCH A 402	422390274900	P&A
WEST RANCH A 403	422390275000	OIL-Conventional
WEST RANCH A 404	422390275100	P&A
WEST RANCH A 405	422390275200	Monitor
WEST RANCH A 406	422390275300	P&A

WEST RANCH A 407	422390275400	P&A
WEST RANCH A 408	422390275500	P&A
WEST RANCH A 409	422390275600	P&A
WEST RANCH A 410	422390275700	P&A
WEST RANCH A 411	422390275800	Monitor
WEST RANCH A 412	422390275900	OIL-Conventional
WEST RANCH A 413	422390276000	OIL-Conventional
WEST RANCH A 414	422390276100	P&A
WEST RANCH A 415	422390276200	Monitor
WEST RANCH A 416	422390276300	P&A
WEST RANCH A 417	422390276400	Monitor
WEST RANCH A 418	422390276500	Monitor
WEST RANCH A 419	422390276600	Monitor
WEST RANCH A 420	422390276700	Monitor
WEST RANCH A 421	422390276800	P&A
WEST RANCH A 422	422390276900	P&A
WEST RANCH A 423	422390277000	P&A
WEST RANCH A 424	422390277100	P&A
WEST RANCH A 425-ST	422390277201	OIL-Conventional
WEST RANCH A 426-ST	422390277301	P&A
WEST RANCH A 427	422390277400	Monitor
WEST RANCH A 428	422390277500	Monitor
WEST RANCH A 429	422390277600	Monitor
WEST RANCH A 430	422390277700	Monitor
WEST RANCH A 431	422390277800	Monitor
WEST RANCH A 432	422390277900	P&A
WEST RANCH A 433	422390278000	Monitor
WEST RANCH A 434	422390278100	Monitor
WEST RANCH A 435	422390278200	P&A
WEST RANCH A 436	422390278300	P&A
WEST RANCH A 437	422390278400	Monitor
WEST RANCH A 439	422390278500	Monitor
WEST RANCH A 440	422390278600	P&A
WEST RANCH A 441	422390278700	P&A
WEST RANCH A 442	422390278800	P&A
WEST RANCH A 443	422390278900	OIL-Conventional
WEST RANCH A 444	422390279000	Monitor
WEST RANCH A 445	422390279100	Monitor
WEST RANCH A 446	422390279200	P&A
WEST RANCH A 447	422390279300	Monitor
WEST RANCH A 448	422390279400	Monitor
WEST RANCH A 449-OH	422390279599	P&A
WEST RANCH State 2	422390279700	Monitor
WEST RANCH A 233	422390279800	Monitor
DRUMMOND JH 1	422390280400	Monitor
DRUMMOND JH 2	422390280500	Monitor
DRUMMOND 3	422390280600	OIL-Conventional
DRUMMOND 4	422390280700	P&A
DRUMMOND 6	422390280800	Monitor
DRUMMOND 7	422390280900	Monitor
TONEY 1	422390281100	Monitor
TONEY 2	422390281200	P&A
TONEY 3	422390281300	Monitor

TONEY 4	422390281400	P&A
TONEY 5	422390281500	P&A
TONEY 6	422390281600	Monitor
TONEY 7	422390281700	Monitor
TONEY 8	422390281800	Monitor
TONEY 9	422390281900	P&A
TONEY 10 (aka WRGSU 310)	422390282000	P&A
TONEY 11	422390282100	P&A
TONEY 12	422390282200	P&A
TONEY 13	422390282300	P&A
TONEY 14	422390282400	P&A
TONEY 15	422390282500	P&A
TONEY 16	422390282600	P&A
TONEY 17	422390282700	P&A
TONEY 19	422390282900	P&A
TONEY 20	422390283000	Monitor
TONEY 21	422390283100	P&A
TONEY 22	422390283200	P&A
TONEY 24	422390283400	P&A
TONEY 26	422390283500	P&A
TONEY 28	422390283600	P&A
TONEY 27	422390283700	P&A
TONEY 28	422390283800	P&A
TONEY 29	422390283900	P&A
TONEY 30	422390284000	P&A
TONEY 31	422390284100	P&A
TONEY 32	422390284200	P&A
TONEY 33	422390284300	Monitor
TONEY 35	422390284400	P&A
TONEY 34	422390284500	Monitor
TONEY 36	422390284600	Monitor
TONEY 37	422390284700	Monitor
TONEY 38	422390284800	Monitor
TONEY 39	422390284900	P&A
TONEY 40	422390285000	P&A
TONEY 41	422390285100	Monitor
TONEY 42	422390285200	P&A
TONEY 43	422390285300	P&A
TONEY 44	422390285400	P&A
TONEY 45	422390285500	P&A
TONEY 46	422390285600	P&A
TONEY 47	422390285700	P&A
TONEY 49	422390285900	P&A
TONEY 50	422390286000	P&A
TONEY 51	422390286100	P&A
TONEY 52	422390286200	P&A
TONEY 53	422390286300	P&A
TONEY 54	422390286400	P&A
TONEY 55	422390286500	P&A
TONEY 56	422390286600	P&A
TONEY 57	422390286700	P&A
TONEY 58	422390286800	P&A
TONEY 61	422390287100	P&A

TONEY 62	422390287200	P&A
TONEY 63	422390287300	P&A
TONEY 65	422390287500	Monitor
TONEY 66	422390287600	P&A
TONEY 67	422390287700	P&A
TONEY 69	422390287800	P&A
TONEY 71	422390287900	P&A
TONEY 72	422390288000	P&A
TONEY 73	422390288100	Monitor
TONEY 74	422390288200	P&A
TONEY 75	422390288300	P&A
TONEY 76 (D & F) (aka WRGSU 376)	422390288400	P&A
TONEY 77	422390288500	Monitor
TONEY 78	422390288600	P&A
TONEY 79	422390288700	P&A
VANDERBILT STATE 1	422390288800	P&A
VANDERBILT STATE 5	422390288900	Monitor
VANDERBILT STATE 2	422390289000	Monitor
VANDERBILT STATE 3	422390289100	P&A
VANDERBILT STATE 6	422390289200	Monitor
VANDERBILT STATE 4	422390289300	P&A
VANDERBILT STATE 7	422390289400	Monitor
VANDERBILT STATE 8	422390289500	P&A
VANDERBILT STATE 9	422390289600	Monitor
VANDERBILT STATE B 10	422390289700	Monitor
VANDERBILT STATE 11	422390289800	P&A
VANDERBILT STATE 13	422390290000	P&A
VANDERBILT STATE 14 (aka WRGSU 414)	422390290100	P&A
VANDERBILT STATE 15	422390290200	P&A
VANDERBILT STATE 17	422390290400	Monitor
VANDERBILT STATE 19	422390290600	P&A
VANDERBILT STATE 20	422390290700	P&A
VANDERBILT STATE 21	422390290800	P&A
VANDERBILT STATE 22	422390290900	Monitor
VANDERBILT STATE 24	422390291000	P&A
VANDERBILT STATE B 1	422390291100	P&A
VANDERBILT STATE B 2	422390291200	P&A
VANDERBILT STATE B 3	422390291300	P&A
VANDERBILT STATE B 4	422390291400	P&A
VANDERBILT STATE B 5	422390291500	P&A
VANDERBILT STATE B 6	422390291600	Monitor
VANDERBILT STATE B 7 OH	422390291700	Monitor
VANDERBILT STATE B 8	422390291800	Monitor
VANDERBILT STATE B 9	422390291900	P&A
VANDERBILT STATE 10	422390292000	P&A
VANDERBILT STATE B 11	422390292100	P&A
MENEFEE BAYOU STATE 1	422390293500	P&A
MENEFEE BAYOU STATE 3	422390293600	P&A
MENEFEE BAYOU STATE 4	422390293700	Monitor
MENEFEE BAYOU STATE B 1	422390293800	P&A
MENEFEE BAYOU STATE B 2	422390293900	P&A
MENEFEE BAYOU STATE B 4	422390294100	P&A

MENEFEE BAYOU STATE 2	422390294300	P&A
WEST RANCH A 253	422390337700	P&A
TONEY 80	422390349700	P&A
TONEY 81	422390349800	P&A
TONEY 82	422390349900	Monitor
TONEY 84	422390362800	P&A
TONEY 83	422390365300	Monitor
WEST RANCH A 455	422390365400	Monitor
WEST RANCH A 462	422390365500	P&A
WEST RANCH A 460	422390366100	OIL-Conventional
WEST RANCH A 461	422390366200	Monitor
WEST RANCH A 458	422390366300	P&A
WEST RANCH A 458 OH	422390366399	P&A
VANDERBILT STATE 25	422390366700	P&A
VANDERBILT STATE 26	422390366800	P&A
MENEFEE BAYOU STATE B 5 (aka WRGSU 205F)	422390367900	P&A
WEST RANCH A 454	422390368000	P&A
WEST RANCH A 459	422390368300	P&A
WEST RANCH A 456	422390368400	Monitor
WEST RANCH A 457	422390368500	Monitor
TONEY 86 H	422390369700	P&A
TONEY 87	422390377800	P&A
WRSOGU 1-2	422390382800	Monitor
WRSOGU 2-2	422393282500	Monitor
WRSOGU 1-3	422390384400	P&A
WRSOGU 2-3	422393282400	Monitor
WRSOGU 1-4	422390384600	P&A
WRSOGU 1-5	422390386100	Monitor
STATE COBDEN 1	422390393300	Monitor
WEST RANCH A 453	422390393900	OIL-Conventional
STATE COBDEN 2	422390394200	Monitor
VANDERBILT STATE 27	422392028000	P&A
WRSOGU 1-6	422393000300	Monitor
WEST RANCH A 469	422393006100	P&A
WRSOGU 1-7	422393007100	Oil-Conventional
WRSOGU 1-8	422393009500	P&A
WRSOGU 2-1	422393010100	P&A
WRSOGU 1-10	422393011100	Monitor
WRASOGU 1-11	422393011300	P&A
WEST RANCH A 471	422393017500	P&A
WEST RANCH A 472	422393017600	Monitor
WEST RANCH A 473	422393020700	P&A
WEST RANCH A 474	422393022100	P&A
DRUMMOND JH 1E	422393033400	Monitor
VANDERBILT STATE 28	422393036500	Monitor
WEST RANCH A 476	422393038000	P&A
TONEY 89	422393038500	Monitor
WEST RANCH A 477	422393054200	Monitor
WEST RANCH A 482	422393082600	OIL-Conventional
WEST RANCH A 478	422393082800	Monitor
WEST RANCH A 479	422393082900	Monitor
WEST RANCH A 480	422393083000	Monitor
WEST RANCH A 484	422393118900	P&A

WEST RANCH A 483	422393119000	Monitor
WEST RANCH A 481	422393124000	P&A
WEST RANCH A 485	422393124100	Monitor
WEST RANCH A 488	422393124900	Monitor
WEST RANCH A 487	422393125000	P&A
WEST RANCH A 486	422393125100	P&A
WEST RANCH A 489	422393125200	Monitor
WEST RANCH A 491	422393125300	Monitor
WEST RANCH A 490	422393125400	Monitor
WEST RANCH A 492	422393125500	OIL-CO2
WEST RANCH A1 ERD	422393161500	P&A
WEST RANCH A 493	422393163300	Monitor
WEST RANCH A 496	422393168300	Monitor
WEST RANCH A 495	422393168400	Monitor
WEST RANCH A 497	422393197600	P&A
WEST RANCH A 494	422393200700	Monitor
WEST RANCH A 501	422393200800	Monitor
WEST RANCH A 502	422393200900	Monitor
WEST RANCH A 508	422393201000	Monitor
WEST RANCH A 505	422393201200	P&A
WEST RANCH A 504	422393201300	OIL-Conventional
WEST RANCH A 503	422393201400	Monitor
WEST RANCH A 507	422393201500	P&A
WEST RANCH A 506	422393201600	P&A
WEST RANCH A 510	422393213100	Monitor
WEST RANCH A 509J	422393213401	Monitor
WEST RANCH A 511	422393213600	P&A
WEST RANCH A 512	422393220900	OIL-CO2
WEST RANCH A 513	422393221500	Monitor
WEST RANCH A 514	422393221600	Monitor
WEST RANCH A 515	422393222400	P&A
WEST RANCH A 516	422393223000	Monitor
WEST RANCH A 517	422393224900	WSW
WEST RANCH A 520	422393228600	Monitor
WEST RANCH A 518	422393235400	Monitor
WEST RANCH A 523	422393236800	Monitor
WEST RANCH A 519	422393237000	Monitor
WEST RANCH A 521	422393237200	P&A
WEST RANCH A 522	422393237800	Monitor
WEST RANCH Unit 1-1	422393241600	Monitor
TONEY 91	422393244500	Monitor
WEST RANCH A 524	422393245900	P&A
WEST RANCH Unit 1-2	422393251300	Monitor
WEST RANCH A 525	422393256600	P&A
WEST RANCH A 526	422393257400	P&A
WEST RANCH A 527	422393258100	Monitor
WEST RANCH A 528	422393258300	Monitor
WEST RANCH A 529	422393260100	OIL-Conventional
WEST RANCH A 531	422393260200	Monitor
WEST RANCH A 530	422393260400	Monitor
WEST RANCH A 533 H	422393270000	Monitor
WRSOGU 1-15	422393273500	Monitor
WRSOGU 1-14	422393276000	Oil-Conventional

DRUMMOND-SUPERIOR 8 (aka 3M-8)	422393289500	Monitor
WEST RANCH A 534 H	422393290600	Monitor
WEST RANCH A 535 H	422393290700	Monitor
WEST RANCH A 539 H	422393296000	Monitor
WEST RANCH A 538 H	422393296100	Monitor
WEST RANCH A 536	422393296200	P&A
WEST RANCH A 537 H	422393296300	Monitor
WEST RANCH A 540 H	422393314800	Monitor
WEST RANCH A 541 H	422393318900	WSW
WEST RANCH A 545 H	422393320700	Monitor
WRSOGU 1-17	422393353800	Oil-Conventional
ASHLEY ANN 1	422393356100	OIL-Conventional
WRSOGU 1-18	422393356300	Oil-Conventional
WRSOGU 1-19	422393356400	Oil-Conventional
DRUMMOND JH 3M	422393356900	OIL-Conventional
ASHLEY ANN 2	422393357600	OIL-Conventional
WEST RANCH A 600	422393358000	INJ
WEST RANCH A 601	422393358100	OIL-Conventional
ASHLEY ANN 3	422393358500	OIL-Conventional
WEST RANCH A 602	422393358600	Monitor
3M-2	422393358900	OIL-Conventional
3M-3	422393359900	Monitor
WEST RANCH A 1129	422393362600	INJ
WEST RANCH A 1131	422393362700	INJ
WEST RANCH A 1133	422393363200	INJ
WEST RANCH A 1104	422393363400	SI-CO2
WEST RANCH A 1089	422393363600	INJ
WEST RANCH A 1059	422393365200	OIL-CO2
WEST RANCH A 2119	422393365300	OIL-CO2
WEST RANCH A 1035	422393365400	INJ
WEST RANCH A 2057	422393365500	INJ
WEST RANCH A 1002	422393365600	OIL-CO2
WEST RANCH A 1036	422393365700	INJ
WEST RANCH A 1060	422393365800	INJ
WEST RANCH A 1061	422393365900	OIL-CO2
WEST RANCH A 1003	422393366000	INJ
WEST RANCH A 1004	422393366100	INJ
WEST RANCH A 2020	422393366200	OIL-CO2
WEST RANCH A 2052	422393366300	OIL-CO2
WEST RANCH A 2029	422393366400	INJ
WEST RANCH A 1005	422393366500	INJ
WEST RANCH A 1037	422393366600	INJ
WEST RANCH A 1007	422393366700	INJ
WEST RANCH A 1062	422393366800	INJ
WEST RANCH A 1006	422393366900	INJ
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WEST RANCH A 1009	422393367200	INJ
WEST RANCH A 1008	422393367300	OIL-CO2
WEST RANCH A 2065	422393367400	OIL-CO2
WEST RANCH A 2021	422393367500	OIL-CO2
WEST RANCH A 1010	422393367600	OIL-CO2
WEST RANCH A 1011	422393367700	INJ

WEST RANCH A 1012	422393367800	INJ
WEST RANCH A 1013	422393367900	INJ
WEST RANCH A 2150	422393368100	OIL-CO2
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WEST RANCH A 1016	422393368500	OIL-CO2
WEST RANCH A 1017	422393368600	INJ
WEST RANCH A 1019	422393368700	INJ
WEST RANCH A 1018	422393368800	INJ
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WEST RANCH A 2053	422393369000	OIL-CO2
WEST RANCH A 2055	422393369100	OIL-CO2
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WEST RANCH A 1039	422393369300	INJ
WEST RANCH A 1040	422393369400	INJ
WEST RANCH A 1063	422393369500	INJ
WEST RANCH A 1042	422393369600	INJ
WEST RANCH A 2159	422393369700	OIL-CO2
WEST RANCH A 2160	422393369800	OIL-CO2
WEST RANCH A 2164	422393369900	OIL-CO2
WEST RANCH A 1022	422393370100	INJ
WEST RANCH A 1023	422393370200	INJ
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WEST RANCH A 1024	422393370400	INJ
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WEST RANCH A 1071	422393370900	INJ
WEST RANCH A 1072	422393371000	INJ
WEST RANCH A 1073	422393371100	INJ
WEST RANCH A 2048	422393371200	OIL-CO2
WEST RANCH A 2170	422393371300	OIL-CO2
WEST RANCH A 1041	422393371400	INJ
WEST RANCH A 2027	422393371800	OIL-CO2
WEST RANCH A 1066	422393371900	INJ
WEST RANCH A 2034	422393372200	OIL-CO2
WEST RANCH A 1044	422393372300	INJ
WEST RANCH A 1043	422393372400	INJ
WEST RANCH A 1117	422393372500	OIL-Conventional
WEST RANCH A 1116	422393372600	INJ
WEST RANCH A 1055	422393372700	INJ
WEST RANCH A 1056	422393372800	INJ
WEST RANCH A 1057	422393372900	INJ
WEST RANCH A 1113	422393373000	INJ
WEST RANCH A 1054	422393373100	INJ
WEST RANCH A 1053	422393373200	INJ
WEST RANCH A 1052	422393373300	INJ
WEST RANCH A 2047	422393373400	OIL-CO2
WEST RANCH A 2036	422393373500	OIL-CO2
WEST RANCH A 2169	422393373600	OIL-CO2
WEST RANCH A 2179	422393373700	OIL-CO2
WEST RANCH A 2118	422393373800	OIL-CO2

WEST RANCH A 1074	422393373900	INJ
WEST RANCH A 2184	422393374000	OIL-CO2
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WEST RANCH A 2168	422393374200	OIL-CO2
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WEST RANCH A 2028	422393374400	OIL-CO2
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WEST RANCH A 2180	422393374600	OIL-CO2
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WEST RANCH A 2037	422393374900	OIL-CO2
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WEST RANCH A 2056	422393375200	OIL-CO2
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WEST RANCH A 1075	422393375500	INJ
WEST RANCH A 2165	422393375600	OIL-CO2
WEST RANCH A 1110	422393375700	INJ
WEST RANCH A 2058	422393375800	SI-CO2
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WEST RANCH A 2173	422393376100	OIL-CO2
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WEST RANCH A 2151	422393376400	OIL-CO2
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WEST RANCH A 1076	422393376600	INJ
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WEST RANCH A 1077	422393376900	INJ
WEST RANCH A 2051	422393377000	OIL-CO2
WEST RANCH A 1078	422393377100	INJ
WEST RANCH A 2120	422393377200	OIL-CO2
WEST RANCH A 2181	422393377300	OIL-CO2
WEST RANCH A 1079	422393377400	INJ
WEST RANCH A 2038	422393377500	OIL-CO2
WEST RANCH A 2040	422393377600	OIL-CO2
WEST RANCH A 1081	422393377700	INJ
WEST RANCH A 2039	422393377800	OIL-CO2
WEST RANCH A 1082	422393377900	INJ
WEST RANCH A 2045	422393378000	OIL-CO2
WEST RANCH A 1083	422393378100	OIL-CO2
WEST RANCH A 1080	422393378200	INJ
WEST RANCH A 2189	422393378400	OIL-CO2
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WEST RANCH A 2063	422393378900	OIL-CO2
WEST RANCH A 2062	422393379000	OIL-CO2
WEST RANCH A 2046	422393379100	OIL-CO2
WEST RANCH A 1106	422393379200	OIL-CO2
WEST RANCH A 1105	422393379300	OIL-CO2
WEST RANCH A 1048	422393379400	INJ
WEST RANCH A 1047	422393379700	OIL-CO2
WEST RANCH A 2061	422393379800	SI-CO2

WEST RANCH A 1107	422393379900	OIL-CO2
WEST RANCH A 2059	422393380000	OIL-Conventional
WEST RANCH A 2060	422393380100	OIL-Conventional
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WEST RANCH A 1112	422393380300	SI-CO2
WEST RANCH A 2075	422393380400	SI-CO2
WEST RANCH A 1025	422393380700	INJ
WEST RANCH A 1028	422393380800	INJ
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WEST RANCH A 1051	422393381500	INJ
WEST RANCH A 1050	422393381600	INJ
WEST RANCH A 2152	422393381700	OIL-CO2
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WEST RANCH A 2010	422393381900	OIL-CO2
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WEST RANCH A 2096	422393382200	OIL-CO2
WEST RANCH A 1058	422393382300	INJ
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WEST RANCH A 2008	422393382600	OIL-CO2
WEST RANCH A 1092	422393382700	INJ
WEST RANCH A 1140	422393382800	INJ
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WEST RANCH A 2193	422393383300	OIL-CO2
WEST RANCH A 2192	422393383400	OIL-CO2
WEST RANCH A 2191	422393383500	OIL-CO2
WEST RANCH A 2016	422393383700	OIL-CO2
WEST RANCH A 2017	422393383800	OIL-CO2
WEST RANCH A 2175	422393383900	OIL-CO2
WEST RANCH A 2176	422393384000	OIL-CO2
WEST RANCH A 2177	422393384100	OIL-CO2
WEST RANCH A 2127	422393384200	OIL-CO2
WEST RANCH A 2031	422393384300	OIL-CO2
WEST RANCH A 2032	422393384400	OIL-CO2
WEST RANCH A 2033	422393384500	OIL-CO2
WEST RANCH A 2049	422393384600	OIL-CO2
WEST RANCH A 1087	422393385300	SI-CO2
WEST RANCH A 2025	422393385400	OIL-CO2
WEST RANCH A 2041	422393385500	OIL-CO2
WEST RANCH A 2043	422393385600	SI-CO2
WEST RANCH A 1088	422393386000	INJ
WEST RANCH A 2125	422393386100	OIL-CO2
WEST RANCH A 2018	422393386200	OIL-CO2
WEST RANCH A 2196	422393386300	OIL-CO2

WEST RANCH A 2195	422393386400	OIL-CO2
WEST RANCH A 1121	422393386800	INJ
WEST RANCH A 1130	422393386900	INJ
WEST RANCH A 2092	422393387000	OIL-CO2
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WEST RANCH A 2198	422393387900	OIL-CO2
WEST RANCH A 2019	422393388100	SI-CO2
WEST RANCH A 2073	422393388300	SI-CO2
WEST RANCH A 1109	422393388700	SI-CO2
WEST RANCH A 1154	422393389100	SI-CO2
WEST RANCH A 2089	422393390100	OIL-CO2
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WEST RANCH A 1124	422393390700	INJ
WEST RANCH A 1125	422393390800	INJ
WEST RANCH A 2081	422393390900	OIL-CO2
WEST RANCH A 900 ST	422393392300	OIL-Conventional
WEST RANCH A 902	422393392400	OIL-Conventional
WEST RANCH A 904	422393393400	OIL-Conventional
WEST RANCH A 908	422393393600	OIL-Conventional
WEST RANCH A 500	422398062200	P&A
DRUMMOND JH 10	422398062400	P&A
VANDERBILT STATE 18	422398062700	P&A
VANDERBILT STATE 16	422398066500	P&A
TONEY 18	422398082200	P&A
TONEY 48	422398112500	P&A
VANDERBILT STATE 12	422398127200	P&A
WEST RANCH A 475	422398146700	P&A
WEST RANCH A 913	422393393800	OIL-Conventional
WEST RANCH A 912	422393393900	TA
WRSOGU 1-12	TBD	P&A
WRSOGU 1-13	TBD	P&A
WRSOGU 1-16	TBD	P&A
WRSOGU 1-20	TBD	P&A

P&A: Plugged and Abandoned Well
INJ: Injection Well
SI: Shut-in Well
TA: Temporarily Abandoned Well
WSW: Water Source Well

Request for Additional Information: Petra Nova West Ranch Field
June 16, 2021

Instructions: Please enter responses into this table. Any long responses, references, or supplemental information may be attached to the end of the table as an appendix. Supplemental information may also be provided in a resubmitted MRV plan.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
1.	N/A	N/A	There are editorial issues (e.g., spelling, grammar) in many places in the MRV plan. We recommend performing an additional review of the document for any substantiative grammatical or spelling issues to improve the overall quality of the resubmission. You may wish to consider using the built-in spelling and grammar error identification features in Microsoft Word to help these identify these issues.	The MRV plan is corrected and updated accordingly.
2.	N/A	Cover Page	The cover page date should be updated to the current month and year of official resubmission.	The MRV plan is corrected and updated accordingly.
3.	N/A	N/A	The Table of Contents should be updated to account for any changes to the document. There are several occurrences that use the incorrect page number when referring to specific sections.	The MRV plan is corrected and updated accordingly.
4.	6	36	"Mechanical Integration Test (MIT):" This abbreviation for MIT is inconsistent with other sections of the MRV plan (see Appendix 1 Acronyms). It is our understanding that MIT should be Mechanical Integrity Test. Please address this issue or provide further explanation.	It should be stated as "Mechanical Integrity Test". The MRV plan is corrected and updated accordingly.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
5.	10	42	The MRV plan states that Petra Nova Parish Holdings LLC will retain the following records for 3 years: information for CO_2 received, CO_2 injected, and the calculation of surface leakage and emissions/leaks from surface equipment. However, all data used to calculate CO_2 sequestered must be retained. Please review the Subpart A and Subpart RR requirements (40 CFR 98.3 and 40 CFR 98.447) to ensure that the MRV plan reflects proper records retention, and update the plan accordingly.	Section 10 is modified to state as follows: "PNPH will follow the record retention requirements specified by 40 CFR §98.3(g). In addition, the requirements in 40 CFR §98.447 will be met by maintaining the following records for at least three years: • Quarterly records of CO_2 received including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of this stream. • Quarterly records of injected CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of this stream. • Quarterly records of produced CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of this stream. • Annual records of information used to calculate the CO_2 emitted by surface leakage from leakage pathways. • Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead. • Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity. All data will be collected as generated and aggregated as required for reporting purposes."

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
6.	7	37	"To account for specific conditions, PNPH proposes to modify the locations for obtaining volume data for the equations in 40 C.F.R. §98.443 as indicated below." Modification of equations in regulatory text is not allowed under the GHGRP. In your previous RFAI response, you indicated that you are not actually modifying any equations but rather using site-specific considerations. Please revise the MRV plan text itself accordingly.	We modified the language as follows: "To account for site-specific considerations, PNPH proposes the locations below for obtaining data to determine the CO2 volumes used in the mass balance." Additionally, the word "modification" used in two paragraphs below are modified as "proposal".

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
7.	5	31-35	"Detection of any losses of CO_2 in the subsurface through damaged or faulty well construction, or through any other potential pathways for CO_2 leakage to the surface as identified in Section 4, will be done based on the monitoring information obtained from active wells and shut-in wells." The discussion in Section 5 focuses on well monitoring as a way to detect and quantify leakage through all potential pathways identified in Section 4. In the MRV plan, please elaborate on how surface leakage from non-well pathways (such as faults and fractures) would be detected/quantified by well monitoring and whether it would differ from the detection/quantification methods for leakage pathways related to well infrastructure. In general, please ensure that all leakage pathways identified in Section 4 have a surface leakage detection and quantification strategy.	CO_2 leakage through all potential pathways, including those non-well related such as faults and fractures, would be detected and quantified by well monitoring. When CO_2 is leaking from an active CO_2 EOR reservoir; which is carefully monitored with the active and shut-in monitoring wells, managed through the operating practice, and further backstopped by the higher elevation of the field as explained in section 3.1; it would migrate upwards into another reservoir and increase the reservoir pressure thereof. As presented in Table 5.1.1, multiple reservoirs above and below the regional Anahuac Shale, each also immediately overlain by confining rocks, are equipped with shut-in monitoring wells to detect the abnormal reservoir pressure change therein. The shut-in monitoring wells are also horizontally scattered throughout the field, as shown on Figure 5.1.1, which helps the early detection of leakage. Once the CO_2 leakage is detected, Petra Nova will use an event-specific approach to quantify leaked amounts of CO_2, which could include the use of modeling, engineering estimates, or direct measurements, depending on the circumstance, to estimate the relevant parameters (e.g., flow rate, concentration, and duration of leakage) to quantify the leak volume. The language in the MRV plan is modified to illustrate the additional points made above.

Petra Nova

West Ranch Field CO_2 Monitoring, Reporting and Verification (MRV) Plan

February 2021

Table of Contents

Contents

Introduction

The Petra Nova project is a commercial scale post-combustion carbon capture project utilizing an advanced amine-based absorption technology to capture at least 90 percent of the carbon dioxide (CO_2) from a nominal 240 MW equivalent flue gas slipstream diverted from the coal-fired Unit 8 (Unit 8) at NRG Energy, Inc.'s W.A. Parish Electric Generating Station (Carbon Capture Equipment (CCE)). The CCE is located southwest of Houston, Texas, in rural Fort Bend County, in the town of Thompsons, Texas. The captured CO_2, up to 4,717 metric tonnes (5,200 short tons) per day, is being dried, compressed, and transported via an 81-mile pipeline to the West Ranch oil field in Jackson County, Texas (West Ranch), where it is used in CO_2 enhanced oil recovery (EOR) operations. Petra Nova Parish Holdings LLC (PNPH), through its wholly-owned subsidiary Petra Nova CCS I LLC, owns the CCE. PNPH is a joint venture between NRG Energy, Inc. (NRG) and JX Nippon Oil and Gas Exploration Corporation (JX).

The CCE uses the Kansai Mitsubishi Carbon Dioxide Recovery Process, also known as KM-CDR Process®, an advanced amine-based CO_2 absorption technology jointly developed by Mitsubishi Heavy Industries, Ltd. and the Kansai Electric Power Co. Inc. The CCE achieved commercial operation on December 29, 2016 and represents the largest commercial-scale deployment of post-combustion CO_2 capture technology at a coal power plant to date.

The CCE has been capturing CO_2 since late 2016 and sending it to West Ranch. The working interest and capital equipment of the West Ranch is owned by Texas Coastal Ventures, LLC (TCV), a joint venture between Petra Nova LLC (a wholly-owned subsidiary of PNPH) and Hilcorp Energy I LP. TCV, through its wholly-owned subsidiary, TCV Pipeline, LLC, owns the dedicated 81-mile CO_2 pipeline between the CCE and West Ranch. Figure 1 outlines the ownership structure of the CCE and TCV.

Hilcorp Energy Company (Hilcorp) is the designated operator of West Ranch. It uses CO_2 captured at and transported from the CCE (Fresh CO_2) and CO_2 produced during the oil production process (Recycled CO_2) for EOR floods at West Ranch.

Petra Nova LLC (PN), a wholly owned subsidiary of PNPH and the 50 percent direct owner of TCV, and the indirect owner of West Ranch prepared this Monitoring, Reporting, and Verification Plan (MRV Plan). This MRV Plan and any related reporting will be managed by PNPH through PN on behalf of TCV, with the assistance of Hilcorp, as the operator of West Ranch, including the reporting to the U.S. Environmental Protection Agency (EPA) under its Greenhouse Gas Reporting Program (GHGRP), Subpart RR. Hilcorp will continue to report to the EPA under the GHGRP, Subpart W.

As part of the U.S. Department of Energy (DOE) grant to the CCE, a Monitoring, Verification and Accounting Plan (MVA Plan) was required to be developed and managed by PNPH during a 3-year demonstration period (2017-2019) starting after the commercial operation date of the CCE. PNPH contracted with the Bureau of Economic Geology at the University of Texas at Austin to develop and support the management of the MVA Plan. The DOE approved MVA Plan was deployed a year prior to the beginning of CO_2 injection (to develop a pre-flood baseline) and was in operation until the end of the DOE demonstration period at the end of 2019. The MVA Plan and the knowledge gained from operating under that plan supported the development of the MRV Plan described herein.

The mass balance accounting for determining the quantity of CO_2 stored conforms to the requirements in Subpart RR, and is consistent with the method used in the MVA Plan. The method, described in Section 7, uses metered volumes of CO_2 received, injected, and produced as well as quantified volumes of other CO_2 emissions and losses, if any.

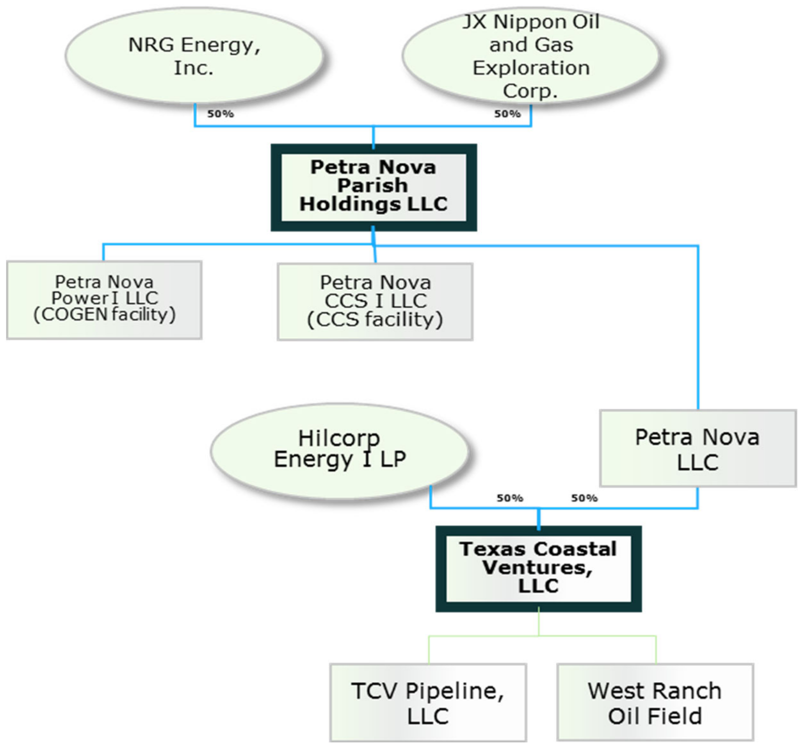


Figure 1 Ownership Structure

Current Status

The mass balance accounting under the MVA Plan started in March 2017, after the commissioning of the surface facilities at West Ranch. Through the end of 2020, the amount of CO_2 sequestered is listed below in metric tons. The difference between CO_2 delivered and CO_2 sequestered is the mass of CO_2 lost at the surface.

	CO_2 Delivered at West Ranch Metric Tons	**CO_2 Sequestered at West Ranch Metric Tons**
2017 (Mar-Dec)	909,419	904,757
2018	1,008,601	996,154
2019	1,386,987	1,373,958
2020	293,171	281,542
Total	**3,598,178**	**3,556,411**

MRV Plan Overview

This MRV plan contains twelve sections:

Section No.	Topic
1	Facility information
2	Project description. This section describes the overall project information; the geology, reservoir characterization and development history; the current operation and infrastructure including the CO_2 injection process; and the CO_2 storage capacity at West Ranch
3	Delineation of monitoring area and timeframes
4	Evaluation of potential pathways for CO_2 leakage to the surface
5	Site-specific risk-based monitoring
6	Determination of baselines
7	Determination of sequestration volumes using mass balance equations
8	MRV Plan implementation schedule
9	Monitoring QA/QC
10	Record retention
11	References
12	Appendices

1. Facility Information

a. Reporter number – 575661 Petra Nova West Ranch

b. The wells at West Ranch are permitted by the Texas Railroad Commission (TRRC), through TAC 16 Part 1 Chapter 3. The TRRC has primacy to implement the federal UIC Class II requirements and incorporated those provisions in TAC 16 Part 1 Chapter 3.

c. All wells at West Ranch are identified by name, API number, status, and type. A listing of the wells as of December 2020 is included in Appendix 2.

2. Project Description

2.1 Petra Nova Carbon Capture Facility and West Ranch Oil Field

When operating at 100 percent load, the CCE captures approximately 4,717 metric tons (5,200 short tons) per day from Unit 8 of NRG’s W.A. Parish Power Station near Houston, Texas. The

captured CO_2 is compressed, dried, cooled, and transported to West Ranch via 81-mile long CO_2 pipeline. The CCE is the only source of CO_2 delivered for injection at West Ranch during the "Specified Period" as discussed below. West Ranch is located in southeast Texas in Jackson County near the town of Vanderbilt as shown in Figure 2.1.1.

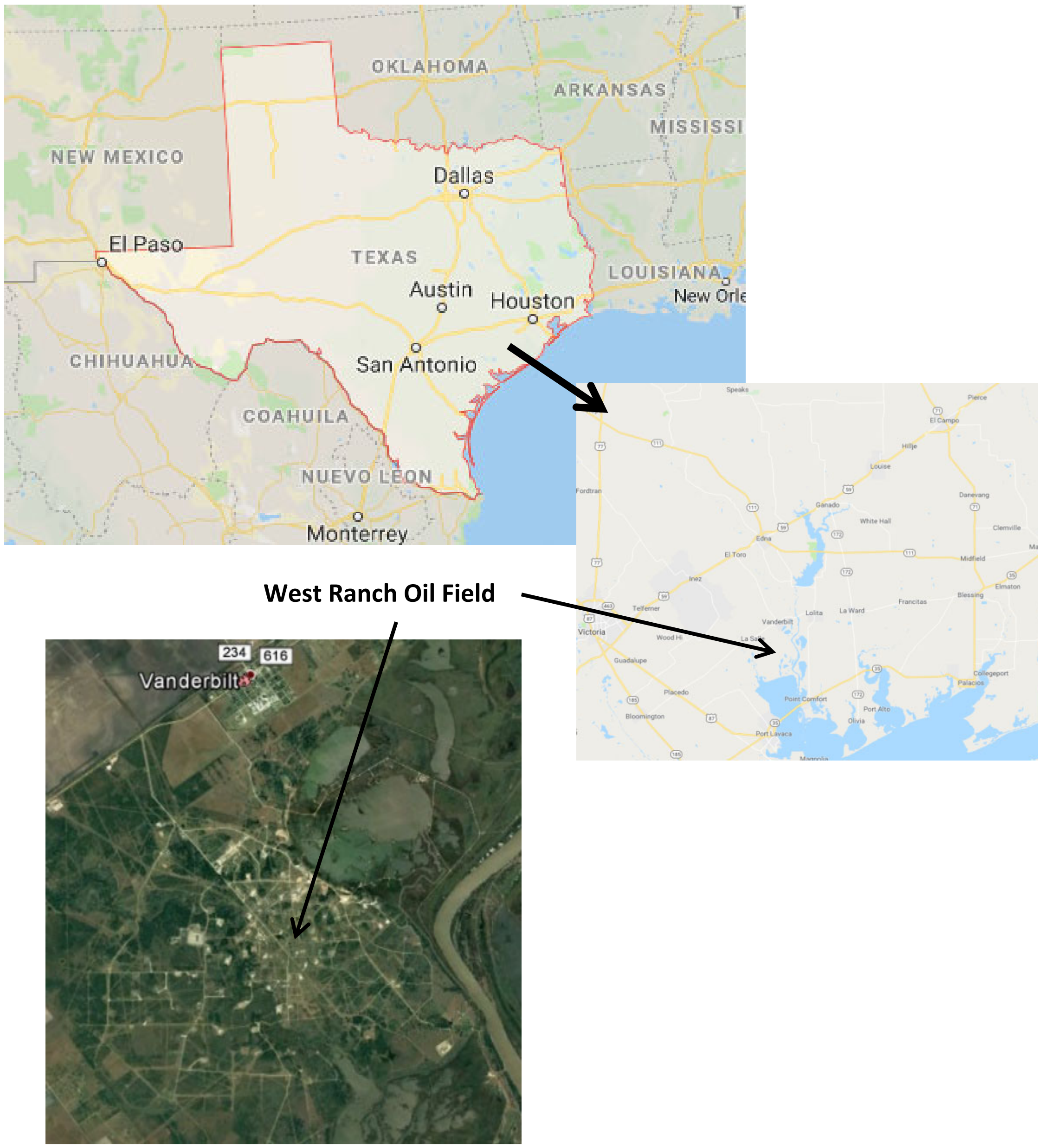


Figure 2.1.1 Location of the West Ranch Oil Field

The West Ranch Unit (WRU) boundary for the current CO_2 EOR operation that currently exists is delineated in Figure 2.1.2. The WRU was formed by consolidating portions of two Oligocene-age reservoirs, the 98-A and 41-A, within the Frio Formation.[1]

[1] The 98-A and 41-A zones are unitized as West Ranch 41-A/98-A (Consolidated) Unit in 2016 (O & G Docket No. 02-0299798).

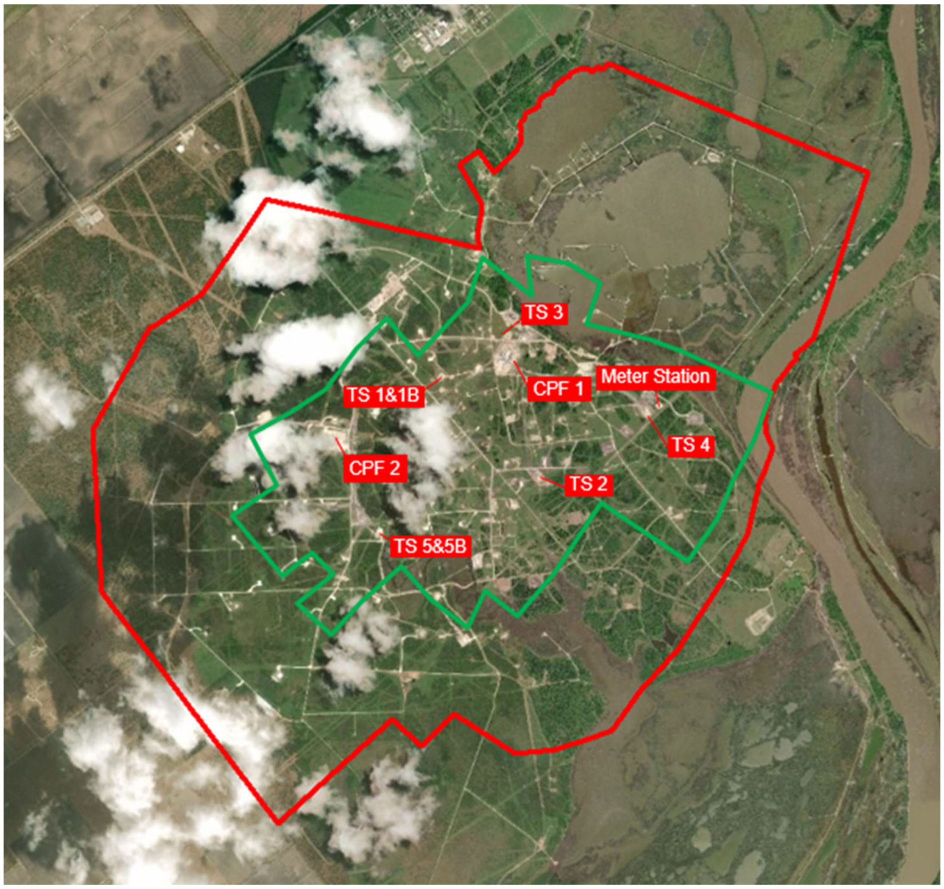


Figure 2.1.2 West Ranch Unit (41-A/98-A (Consolidated) Unit) Boundary (in Red)

CO_2 flooding was initiated in the 98-A reservoir in December 2016 and has been subsequently expanded horizontally. While the horizontal expansion of the 98-A reservoir is still ongoing, a vertical expansion into the 41-A reservoir, which lies immediately above the 98-A reservoir, began in 2018. The CO_2 EOR operations at West Ranch are planned to expand horizontally and vertically upward over time, including the CO_2 flooding of additional portions of the 98-A and 41-A reservoirs, and three additional reservoirs in the Frio Formation: Greta, Glasscock, and Ward. This MRV Plan anticipates the expansion into the entire interval between the base of 98-A reservoir and the base of the Anahuac Shale, a regionally contiguous and impermeable shale immediately above Frio Formation at West Ranch (Project Interval). In order to expand into the full Project Interval, Hilcorp, on the behalf of TCV, will obtain TRRC approval for certifications as tertiary recovery projects, unitization agreements, and permits to conduct fluid injection operations in each area of expansion in the Project Interval. The reservoirs in the Project Interval have similar geologic characteristics and PNPH will apply the same operational controls in each area of expansion. All of the injection zones in the Project Interval share the following characteristics:

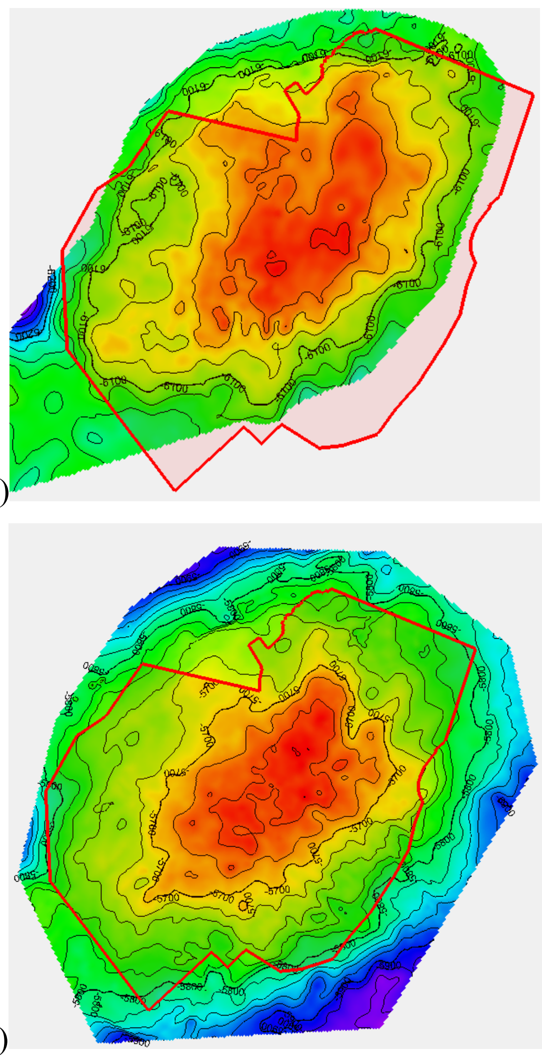
- four-way dip anticline trapping mechanisms,
- no faulting,
- presence of a primary confining intervals above each injection zone within the Project Interval and a secondary confining interval (Anahuac Shale) that overlays the entire project area, and

- depleted reservoir pressure.

The operational requirements that currently apply in WRU will also apply in the expansion zones. They include rules for injection wells such as the confirmation of nearby well condition, the periodic testing of casing integrity, the adequate cementing to confine fluids in the injection reservoir, and the monitoring and limitation of injection pressure. Based on these conditions, PNPH believes that all reservoirs within the Project Interval at West Ranch can be included under this MRV Plan as they are brought online.

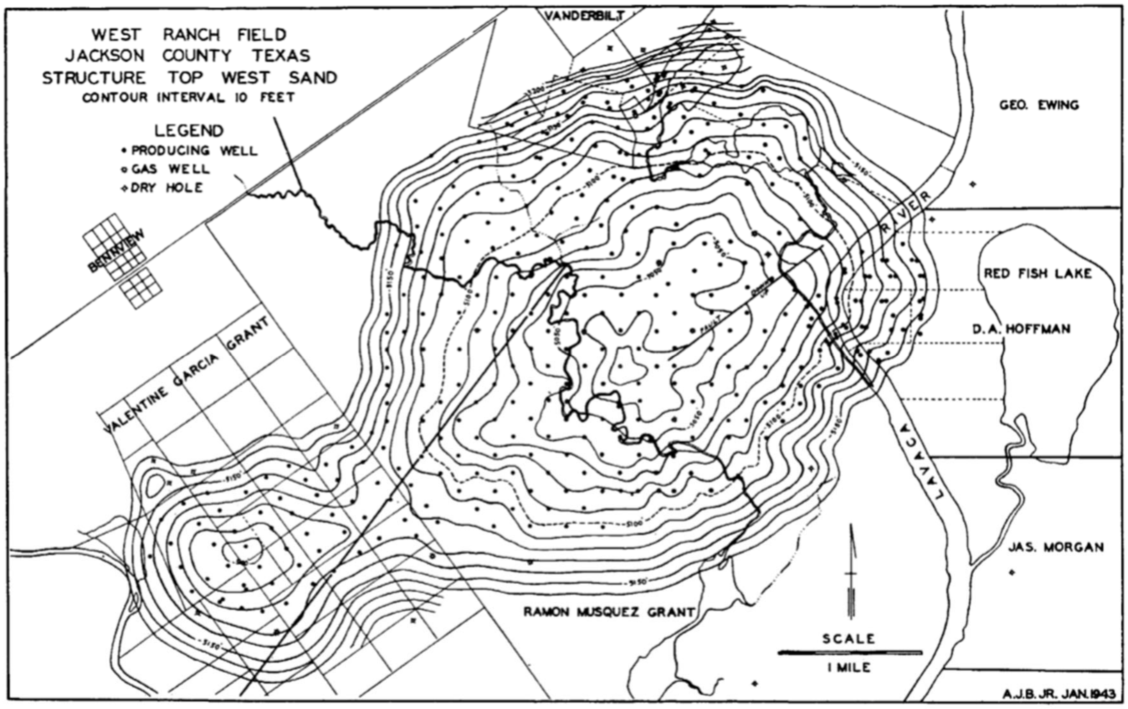
2.2 Petroleum Geology of West Ranch

West Ranch is one of several oil fields located in the Gulf Coast Basin that shares the same petroleum system. West Ranch is formed on a gentle four-way anticlinal structure on a roll-over structure (Figures 2.2.1(a), 2.2.1(b), 2.2.2(a), and 2.2.2(b)) on the upthrown side of a northeast-southwest trending regional growth fault as shown in Figure 2.2.3.

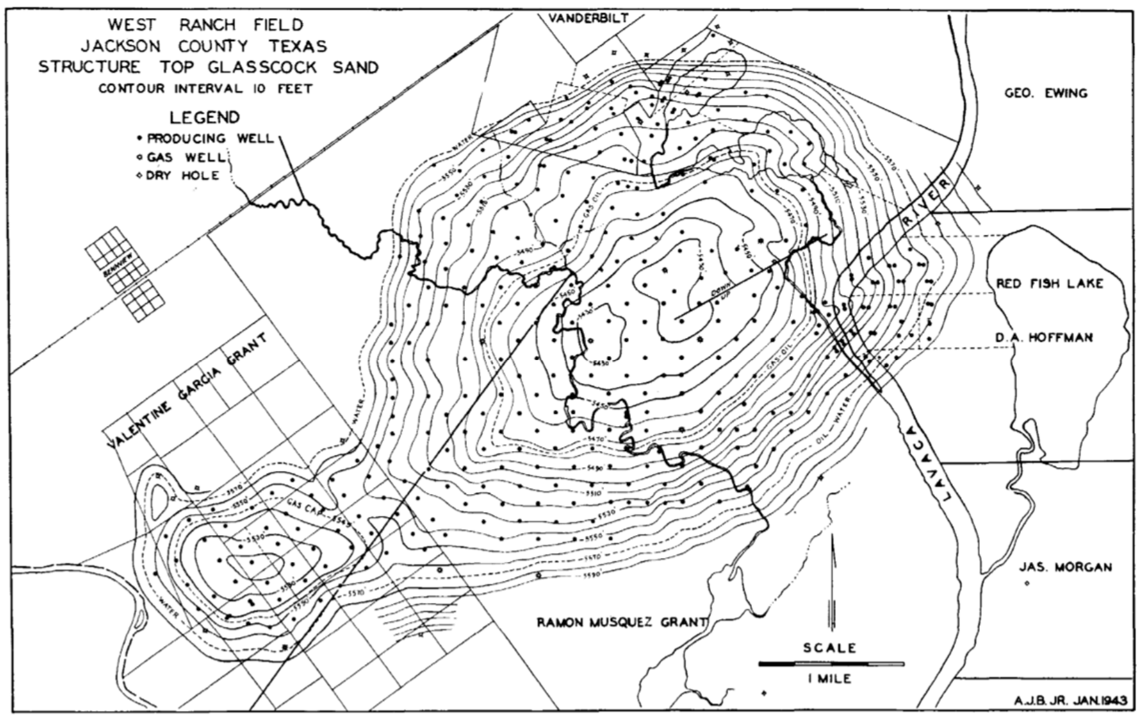


(a) (b)

Figure 2.2.1 Structure-contour map of West Ranch with the currently existing WRU boundary (41-A/98-A Consolidated) (red outline). Datum is the top of (a) 98-A and (b) 41-A reservoirs.



(a)



(b)

Figure 2.2.2 Structure-contour map of West Ranch. Datum is the top of (a) the Greta and (b) the Glasscock reservoirs (Baurenschmidt, 1944).

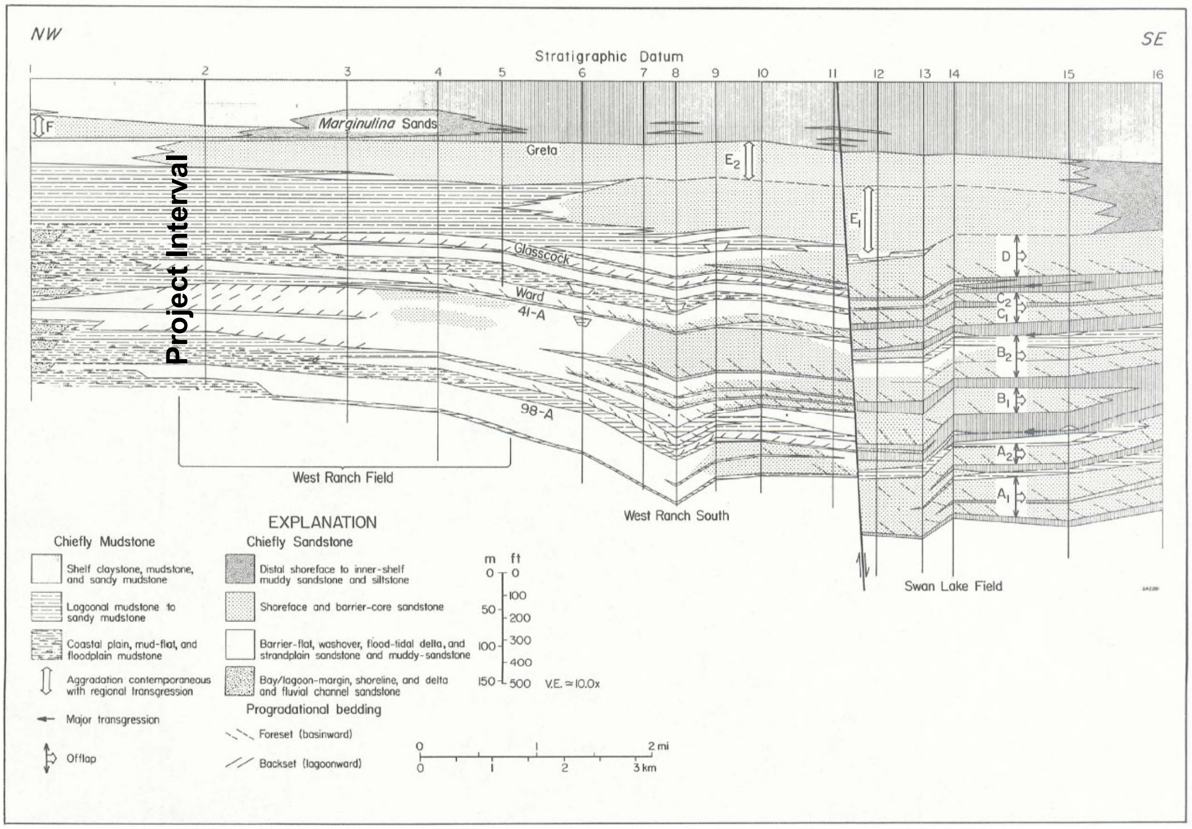


Figure 2.2.3 Regional cross section though West Ranch showing unfaulted structure. From Galloway and Cheng, 1985

2.3 Stratigraphy of the West Ranch Oil Field Area

The generalized stratigraphic section illustration of geologic formations present at West Ranch is shown in Figure 2.3.1. The reservoir sandstones into which CO_2 is currently or planned to be injected at West Ranch include five reservoir sandstones in Frio Formation being the 98-A, 41-A, Ward (not shown on Figure 2.3.1), Glasscock, and Greta, from the deepest (6,200 feet) to the shallowest (5,100 feet). Each reservoir sandstone is separated by locally continuous low permeability and individually confining mudstones (Figure 2.3.2).

Anahuac Shale is a low-permeability confining layer that has served as a stratigraphic seal to prevent upward migration of hydrocarbon throughout geologic term for many oil fields throughout the Gulf Coast region (Galloway and Cheng, 1985), and it serves as the secondary seal in addition to the individual confining layers overlaying each reservoir.

Above Anahuac Shale is a series of sandstones separated by shales collectively known regionally as Oakville Formation, and are also referred to as the Miocene Sands.

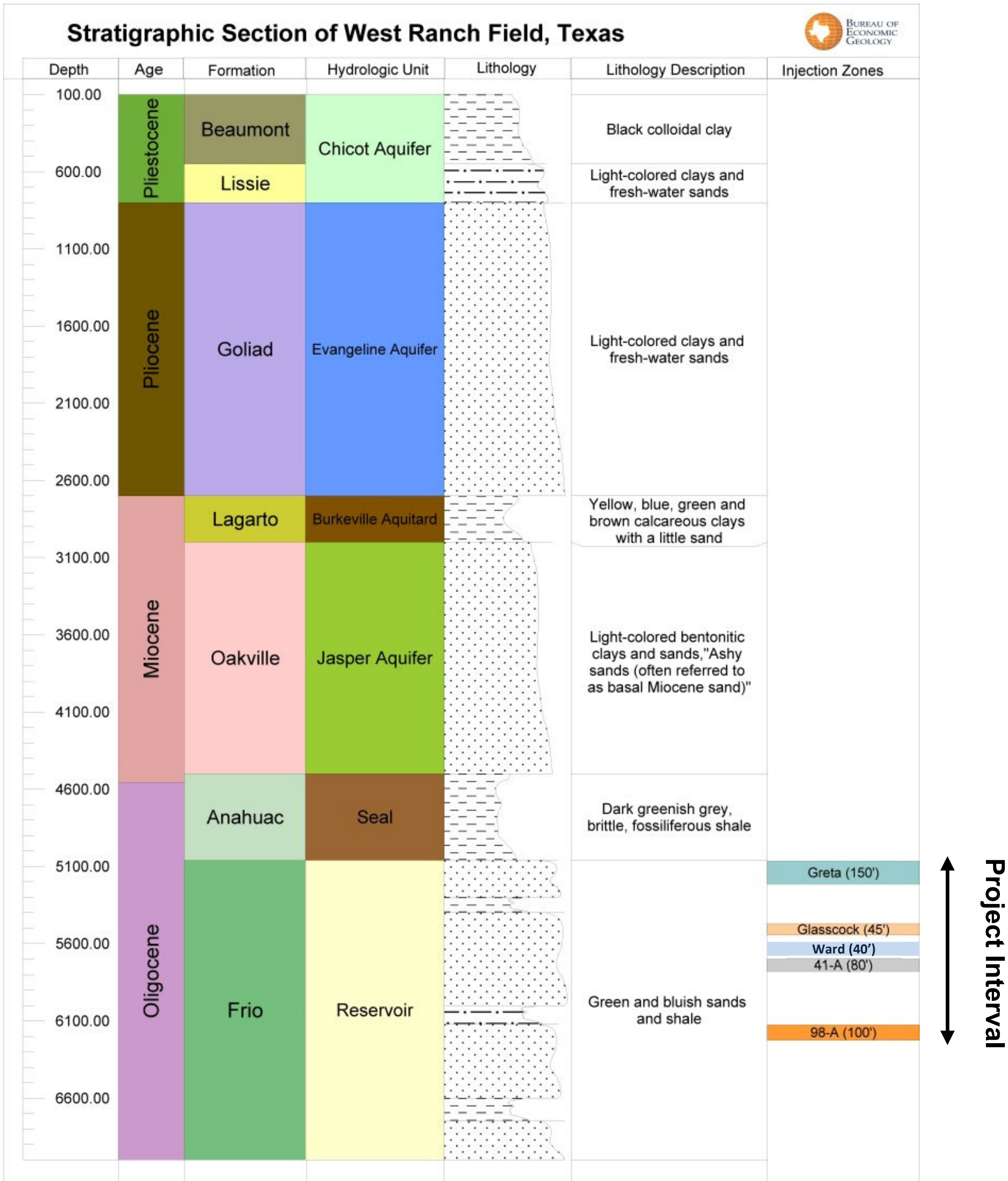


Figure 2.3.1 Generalized lithostratigraphic and hydrostratigraphic names for rocks/aquifers underlying West Ranch Oil Field. Depths shown correspond with those seen at West Ranch Oil Field.

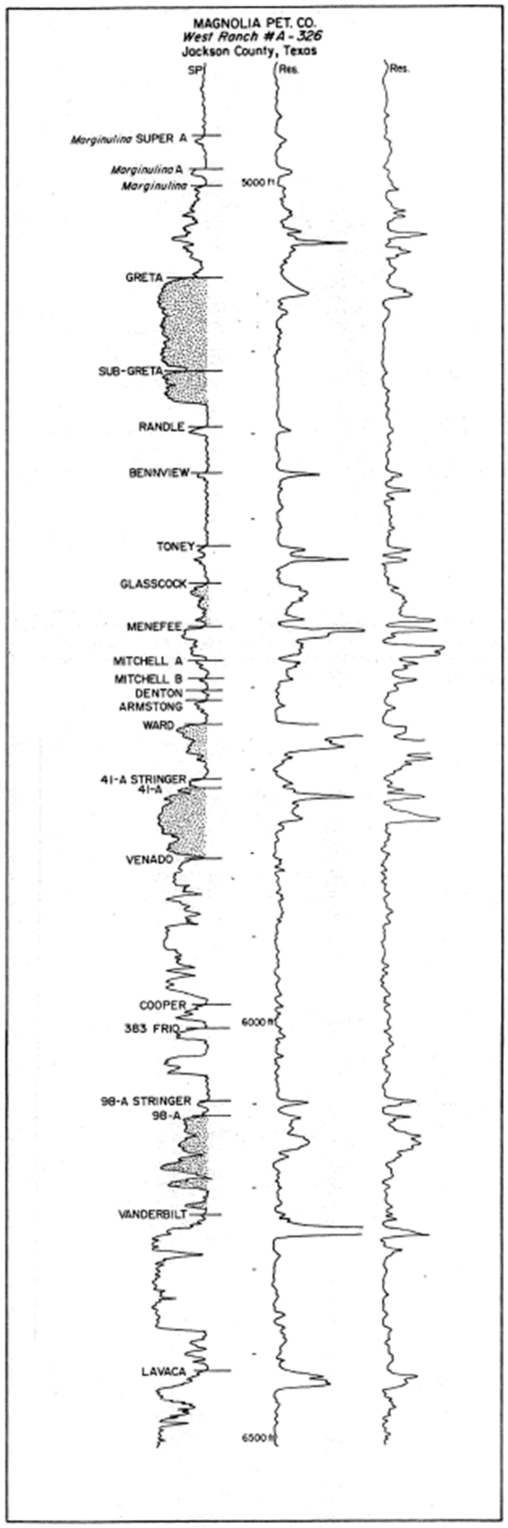


Figure 2.3.2 Type log for West Ranch Oil Field. After Galloway (1981) shows the entire injection zone for Project Interval. Current CO_2 EOR flooding is in the 98-A and 41-A, future expansion will be into the permeable zones (Ward, Glasscock, Greta). Each permeable zone is interspersed with non-permeable zones that serve as the primary confining layers. The secondary confining layer, the Anuhuac Shale is not marked on this Type Log.

2.4 Depositional Environment of the West Ranch Oil Field Area

The reservoirs of West Ranch are part of the extensively characterized Oligocene-aged Frio Formation in the barrier/strandplain system, located between the Houston and Norias Delta Systems (Galloway et. al., 1983) (Figure 2.4). The barrier/strandplain system is composed of the northeast-southwest elongated bodies of laterally deposited shoreline sands, similar to the Padre-Mustang-St. Joseph-Matagorda island complex of today.

Within the barrier/strandplain system, the barrier island and shoreface deposits, such as the Greta reservoir, are well sorted, continuous, sandy, and internally homogeneous as a result of their high-energy, shallow-marine depositional origin. The Glasscock reservoir is one of the most widespread reservoirs in the field. It is a particularly thin barrier-island sand body that was deposited before a local transgression terminating the "C" cycle of strandplain progradation. The 41-A reservoir is a moderately thick sand body that occurs at the top of the widespread sand of the "B" cycle. Well-developed upward-coarsening sequences do not appear at the stratigraphic position of the 41-A reservoir for several miles farther basinward. Stratigraphic relationships suggest that much of the reservoir is overlain, and therefore sealed, by lagoonal mudstones deposited landward of a prograding barrier-sand complex. The 98-A and Ward reservoirs are both relatively thin progradational sand units (Galloway, 1986).

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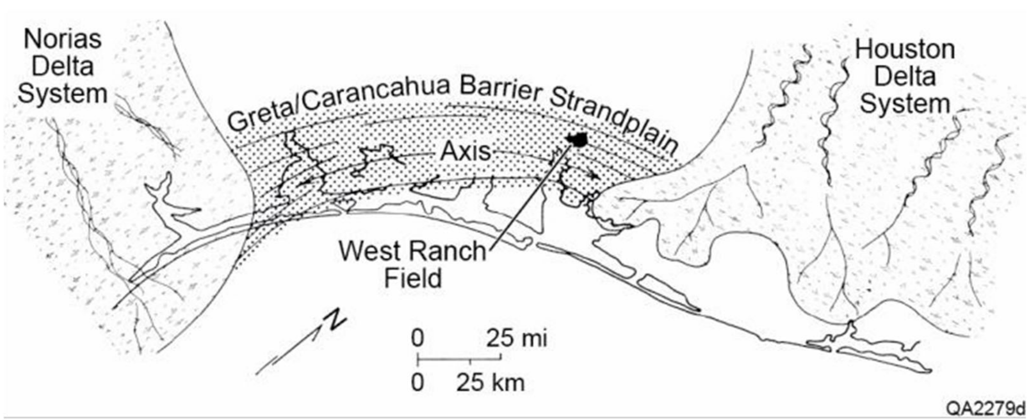

Figure 2.4 Oligocene (Frio) paleogeographic setting of Texas Gulf Coast, showing West Ranch Oil Field within Greta/Carancahua Barrier Strandplain System. Ambrose et al. (2008); modified from Galloway and Cheng (1985) and Galloway (1986).

2.5 Reservoir Characterization and Modeling

As previously discussed, PNPH, working with the BEG, developed and managed an MVA Plan that covered the three-year demonstration period that started on January 1, 2017 (aligned with the beginning of commercial operations of the CCE). As a part of the MVA Plan, reservoir modeling was used to characterize the currently existing WRU reservoirs, 98-A and 41-A, to develop a detailed understanding of each reservoir as well as the predictability of internal reservoir architecture including the behavior of CO_2 in the course of CO_2 EOR operation. In general, the modeling was successful in demonstrating that the pressure elevation and the movement of CO_2 plume in the reservoirs are managed by the operational strategies, and the reservoirs have the capacity to permanently retain the injected CO_2 volume within the structural trap for prolonged period after the cessation of CO_2 EOR operation. Going forward, PNPH does not plan to develop detailed models for additional reservoirs, but will draw on a set of transferable principles from this modeling effort.

Reservoir modeling is the major predictive tool that determines the capacity of the subsurface to accept CO_2. Numerical simulation models are used to model the spatial extent of the CO_2 plume in the subsurface, which demonstrates that, under given assumptions and operational strategies, CO_2 is remaining within the targeted area. The numerical simulation modeling starts by building static reservoir models. The tops and bases of target sandstones and major seals are defined with well logs. The model is then constructed based on rock properties interpreted from Spontaneous Potential and Gamma-Ray logs, and to a limited extent, core sample studies at West Ranch. Rock properties (including permeability, porosity, rock, and fluid saturations) were also assigned based on available data through literature review and historical field measurements. This allowed us to populate the static reservoir model with appropriate rock type, porosity, and permeability distributions.

A numerical simulation model of the 98-A and 41-A reservoirs was constructed based on the static geologic model as well as fluid properties (fluid compositions and PVT (pressure-volume-temperature) data) from the field, to develop a dynamic numerical model to history match the production and pressure data of the field, and to simulate the current and future performance of the field. The numerical model is developed using a compositional simulator. In compositional simulations, three phases (water, oil and gas) with multiple components were defined. Relative permeability data, available through literature survey and special core analysis, was used as input in the simulations. Thermodynamic properties of the specific fluids in this field were tuned and modeled in a fluid characterization software.

The porosity and permeability maps of the model are shown in Figure 2.5.1 and 2.5.2.

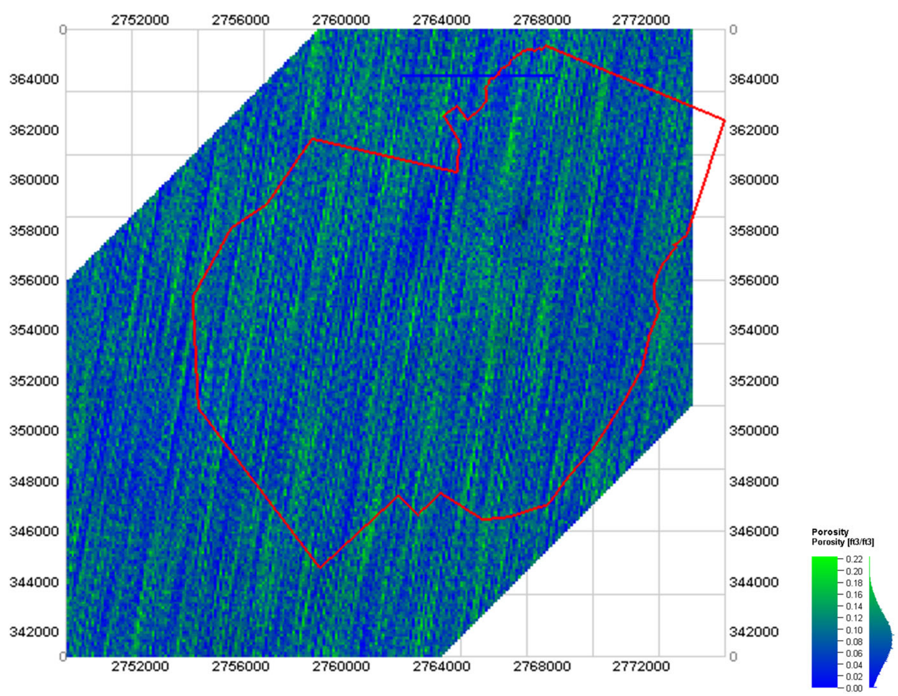

Figure 2.5.1 Porosity distribution of 98-A input into the numerical simulation model with 41-A/98-A Consolidated Unit (red)

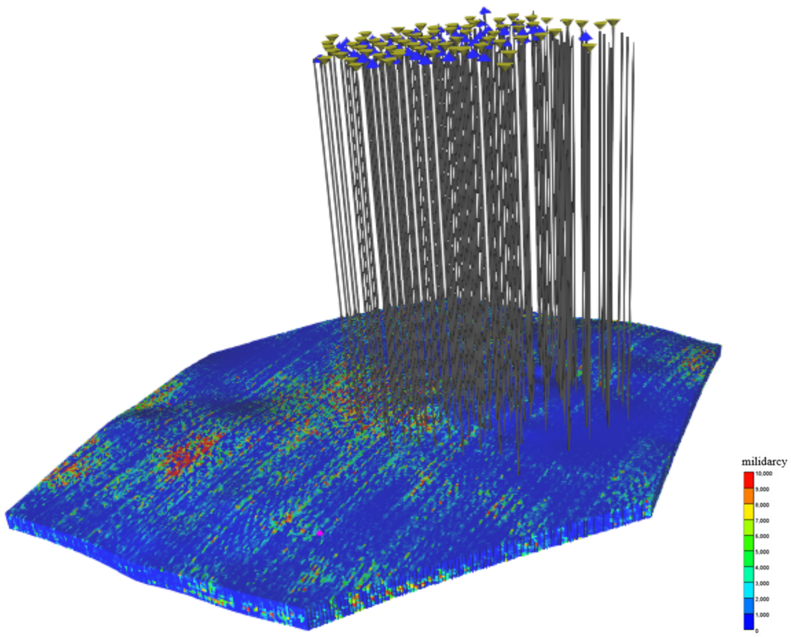

Figure 2.5.2 Location of EOR operation wells and horizontal permeability of 98-A input into the numerical simulation model.

The expected pressure and the gas saturation fields in 98-A reservoir as of March 2020 based on the simulation model, with the best history match until September 2019 and porosity and permeability fields above, are shown below (Figure 2.5.3 to Figure 2.5.4). Overall results show that the pressure values remain within the intended range and below the fracturing pressure. Gas saturations are larger around the injection wells and mostly remained in the intended patterns.

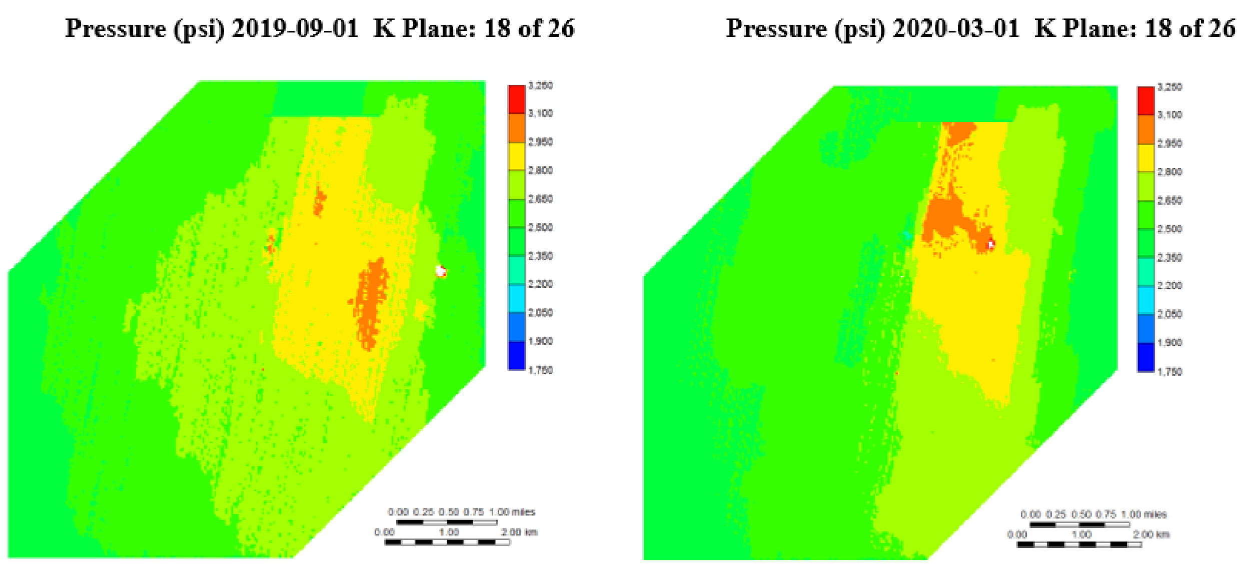

Figure 2.5.3 Pressure field at 98-A reservoir in (a) September 2019 and (b) March 2020.

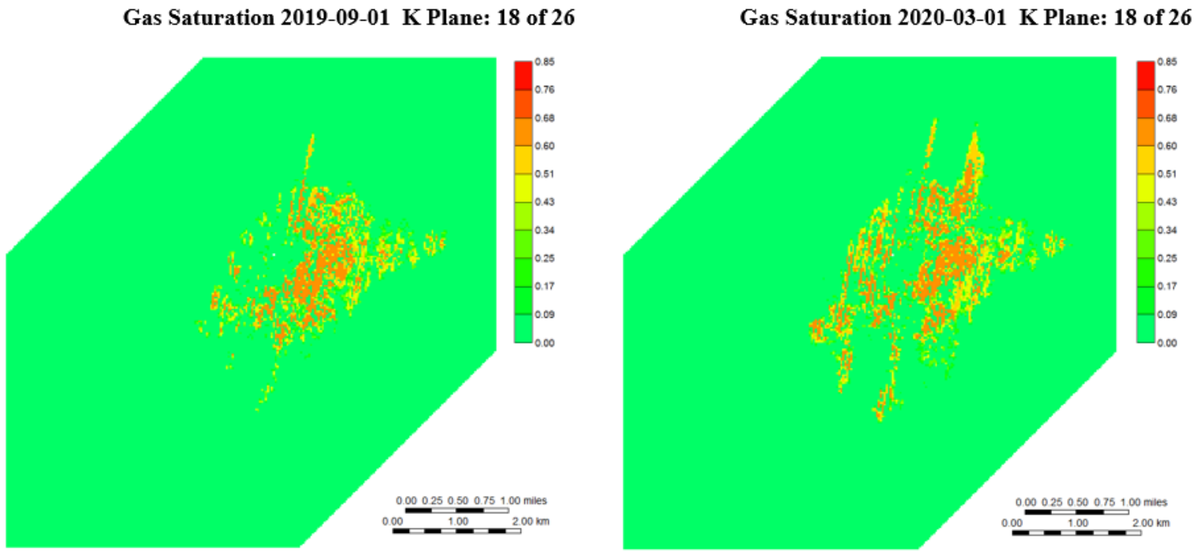

Figure 2.5.4 Gas saturation at 98-A reservoir in (a) September 2019 and (b) March 2020.

The long-term simulation was also run through 2040, and the result shows that CO_2 was accumulated at the crest of structure and within the intended area (Figure 2.5.5).

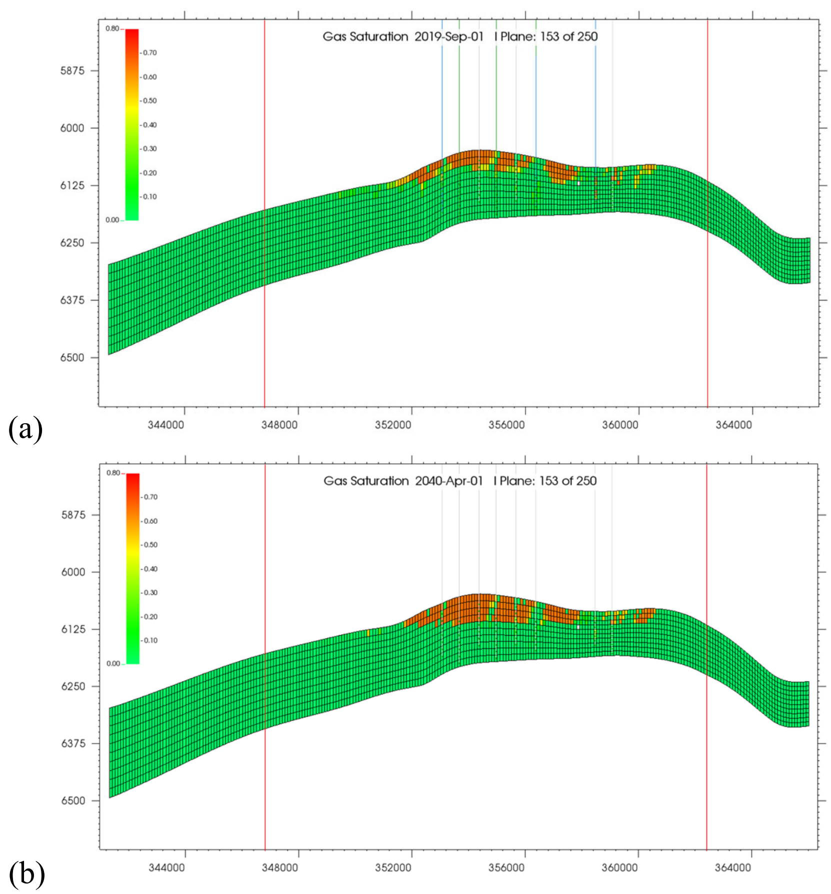

Figure 2.5.5 Demonstration of gas migration after CO_2 flooding. Gas saturation at 98-A reservoir in (a) September 2019 and (b) April 2040 with 41-A/98-A Consolidated Unit (red)

2.6 Development of West Ranch Oil Field, Primary and Secondary Production

West Ranch was discovered in 1938. The main reservoirs at West Ranch (Greta, Glasscock, Ward, 41-A, and 98-A) are porous and permeable, averaging more than 27 percent porosity and 400 mD permeability. The description of the discovery and the original conditions of main producing reservoirs, and the oil field operations including hydrocarbon production and brine injection, are described in this section. Besides the five main producing sands, 79 additional minor reservoirs have been classified as producing sands by the TRRC.

A primary gas cap in contact with the oil zone was present upon discovery in all main oil-producing reservoirs, indicating vertical hydraulic isolation of each sand zone. These reservoirs were originally produced with a gas-cap expansion and/or a natural water drive. Glasscock and Ward reservoirs were constituted from oil-rim reservoirs with gas caps as large as one-third of the volume, and 95 percent of the energy was attributable to the expansion of their gas caps (Galloway and Cheng, 1985). On the other hand, Greta, 41-A, and 98-A reservoirs are mainly energized by strong natural water drive.

In most of the water-injection programs, water was injected into reservoirs along the periphery of their gas caps to maintain reservoir pressure and to prevent expansion of the gas cap into the oil-bearing zone (Galloway and Cheng, 1985).

Cumulative oil production in the main reservoirs as of 2010 is provided in Table 2.6.1.

Reservoir	Discovery Date	Cum. Prod. (MMSTB)
Greta	1938	101.3
41-A	1940	99.5
98-A	1940	59.2
Glasscock	1939	45.8
Ward	1939	30.4

Table 2.6.1 Cumulative oil production of major West Ranch reservoirs from TRRC (2010)

Original conditions, such as fluid contact depths, water saturation, and solution gas ratio are listed in Table 2.6.2, along with average rock and fluid properties.

	Greta	Glasscock	Ward	41-A	98-A
Gas-Oil contact, ft ss	5,065	5,475	5,705	5,690	6,070
Oil-Water contact, ft ss	5,105	5,570	5,735	5,750	6,140
Average porosity, %	30	27	30	30	31
Average permeability, md	1,200+	400	1,200	1,700	500
Original pressure, psia	2,350	2,560	2,650	2,625	2,795
Reservoir temp, °F	160	166	171	171	178
Oil gravity, API	24.7	31.6	30.6	31.1	40.4
Solution gas ratio, scf/stb	306	440	451	500	671

Table 2.6.2 General reservoir data and original conditions of main West Ranch sands (Bauernschmidt, 1962)

Initial pressures found in West Ranch indicate an original hydrostatic pressure gradient of approximately 0.53 psi/ft (Figure 2.6.1). Kreitler and Akhter (1990) gathered and plotted nearly 17,400 pressure values from a commercial database to study the complex hydrologic regimes of the Texas Gulf Coast region. Two major gradients are observed: (1) a formation water hydrostatic regime (0.465 psi/ft) that reaches depths of 11,000 ft, and (2) a geopressured regime as shallow as 7,000 ft. Both have been extensively depleted by production, although the original profile can be identified by plotting the maximum pressures. The West Ranch pressure gradient is not geopressured but is slightly steeper than the average hydrostatic gradient for freshwater in the area (Figure 2.6.2(a)). A current pressure profile from the A-600 well in 2012, the injection location for a recent CO_2 injection test, is imposed over the Kreitler and Akhter (1990) Gulf Coast pressure profile for comparison (Figure 2.6.2(b)). The A-600 well profile shows strongly depleted zones, likely resulting from past production of reservoirs that lacked good connection to water drive. In contrast, the pressure of Greta, 41-A and 98-A reservoirs indicates the strong natural water drive as mentioned above.

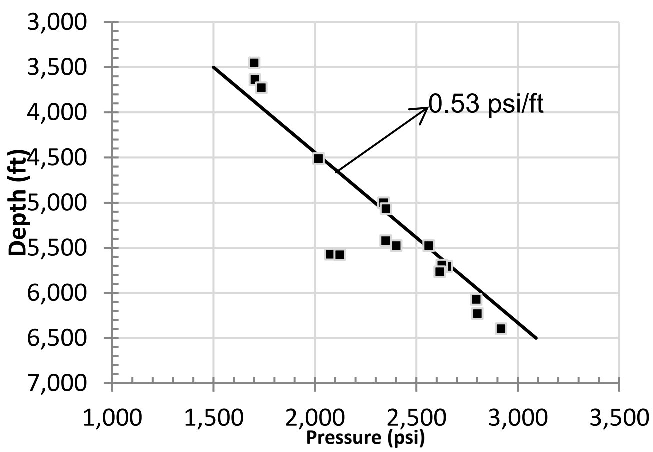

Figure 2.6.1 West Ranch hydrostatic pressure gradient. Adapted from Bauernschmidt (1962)

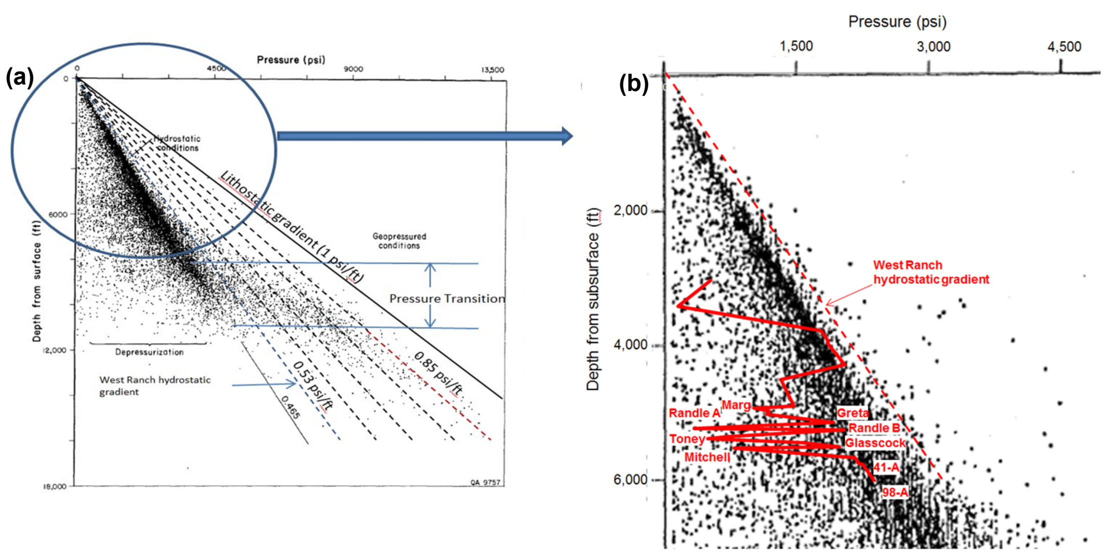

Figure 2.6.2 (a) Gulf Coast pressure profile. Pressure measurements from drill-stem tests (DST) and bottom-hole pressures, adapted from Kreitler and Akhter (1990), and (b) Current West Ranch pressure profile in red at A-600 well plotted against Gulf Coast pressure profile

2.7 Regulatory Process

Prior to commencement of any underground injection for CO_2 EOR purpose, TCV must submit a permit application and obtain approval from the TRRC. Texas Administrative Code (TAC) Title 16 Part 1 §3.46 governs fluid injection into reservoirs productive of oil, gas, or geothermal resources. The information required in the application include the data concerning the project, the subject reservoir and the well(s); and the geographic description of area covered by the project. The technical requirements include: the isolation from usable-quality water by 250 feet of low permeability strata, the area of review (AoR) to determine if all abandoned wells within one-quarter (1/4) mile radius of the proposed well have been properly plugged, the cementing interval for surface and production casings, the packer setting depth, the injection pressures, and in certain areas, a seismicity review. Notice of application must be given to parties affected or who may be affected by implementation of the project and local regulatory bodies, and public notice is also made. There is an opportunity for hearing should there be a protest. After the approval of permit, it is required to perform a mechanical integrity test before injection, and periodically thereafter; and to file a completion report and an annual injection report.

Unitization is necessary to conduct CO_2 EOR operation at reservoirs which straddle multiple tracts with separate and divergent ownership interests, primarily to determine the participation formula of interest owners. Unitization is subject the TRRC approval; similar information is required and a similar procedure is employed as with the injection permitting. The project must satisfy all of the requirements set out in Texas Natural Resources Code Title 3 Subtitle C Chapter 101, including that unit operations are necessary to increase ultimate recovery from the reservoir or prevent waste, that correlative rights of interest owners are protected, and that the additional cost involved does not exceed the additional recovery anticipated. The approval is also made subject to receiving the injection permits.

There are also economic incentives to conduct CO_2 EOR operations in Texas, particularly those with anthropogenic CO_2. There is a severance tax on crude oil, and using CO_2 grants a 50 percent reduction in that severance tax rate by obtaining a project certification under TAC Title 16 Part 1 §3.50, and it is further lowered by additional 50 percent, to 25 percent of the original rate, if anthropogenic CO_2 is used and the certification under TAC Title 16 Part 1 Subchapter C is obtained. The TRRC must approve a measurement, monitoring and verification program for stored anthropogenic CO_2, and the certification is issued only if the TRRC finds that at least 99 percent of the CO_2 sequestered will remain sequestered for at least 1,000 years.

The current CO_2 EOR operations in the WRU for 98-A and 41-A reservoirs have gone through all the regulatory process as stated in this section, and the same process will be followed when the development area in West Ranch expands either horizontally outside of the existing WRU, or vertically upwards to Greta, Ward, Glasscock or other sub-layers.

2.8 Description of CO_2 EOR Project Facilities and the Injection Process

2.8.1 West Ranch Facility Description

The following two figures illustrate the CO_2 EOR process at West Ranch. Figure 2.8.1 is a generalized facility flow diagram and Figure 2.8.2 shows the location of all facilities within the WRU boundary.

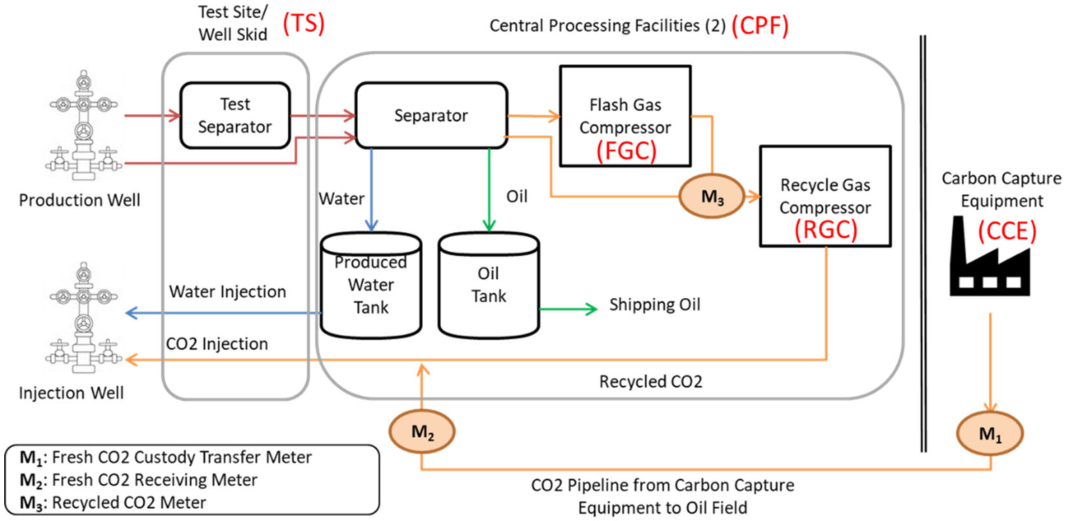

Figure 2.8.1 Facility Flow Diagram

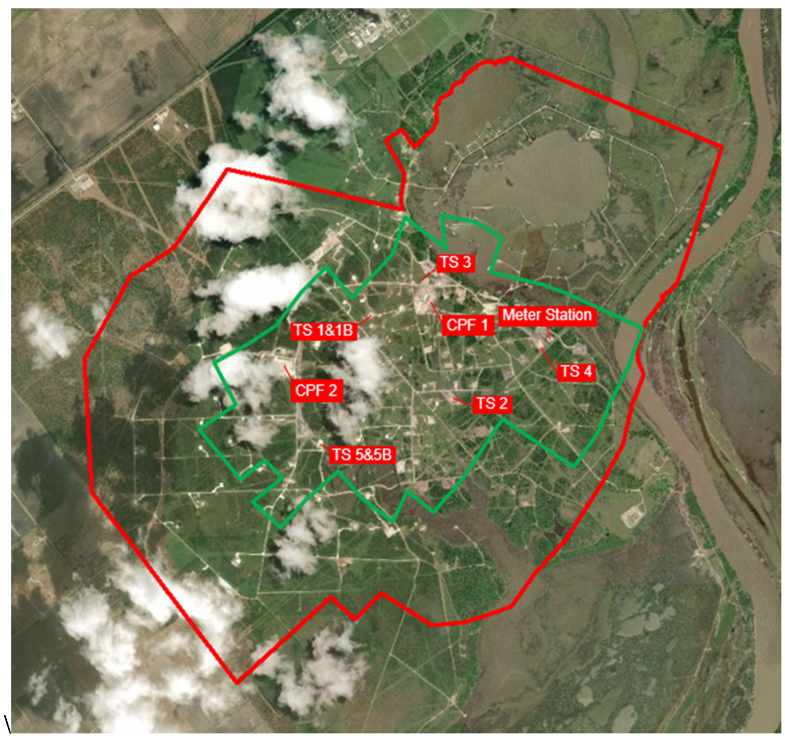

Figure 2.8.2 Locations of current Meter station, Central processing facilities (CPF1 and CPF2) and Test Sites (TS) at West Ranch. Locations within this footprint may change over the life of the project. WRU boundary (red) and current flood area (green)

1. Central Processing Facility (CPF)

   There are two CPFs at West Ranch (CPF1 and CPF 2 on Figure 2.8.2). Produced fluids (water, oil, and gas) are separated in the high/intermediate/low pressure water knock-out drums and separators in the CPFs.

   a) The water is mainly separated from gas and oil in the water knock-out drums, then reinjected into the field through injection wells with make-up water from water source wells.

b) The oil is separated from gas in the separators, settled in tanks for few days, then metered and sold.

c) The produced gas, which consists of CO_2 and reservoir hydrocarbon gas, is transferred to flash/recycle gas compressors (FGC/RGC). High and intermediate pressure gas is directly transferred to the RGC. Low pressure gas is compressed by the FGC then transferred to RGC.

2. Test Site (TS)

There are five TSs (TS 1-5 on Figure 2.8.2) and two extended TSs (TS 1B and 5B on Figure 2.8.2) in the field as of year-end 2020. Produced fluids from the production wells are aggregated at one of the five TSs. Each TS consists of a three-phase test separator, which measures production rates of oil, water and gas from each production well at least once per month. This data is not used in the mass balance accounting, but is used to allocate produced fluid to wells and for production optimization. Produced fluid from the individual production wells gathered at the TSs is transferred to one of the two CPFs through high/intermediate/low pressure production lines.

3. CO_2 Injection Process

Fresh CO_2 is captured at the CCE and transported to West Ranch via the CO_2 pipeline, and the flow is metered at the metering station at West Ranch (M_2). The concentration of Fresh CO_2 applicable to calculate the mass of CO_2 received at West Ranch is measured at the custody transfer meter located in the vicinity of CCE (M_1 on Figure 2.8.1). Fresh CO_2 received from the CO_2 pipeline and Recycled CO_2 from the RGCs at the CPFs, the volume and concentration of which is measured at M_3, are comingled and sent through the CO_2 distribution pipeline system to injection wells throughout the field.

All of the processes at West Ranch are monitored by the Supervisory Control and Data Acquisition (SCADA) system located on site, which is staffed 24 hours and alarmed to alert operators of any abnormalities. As the CO2 flood expands into the entire Project Interval, new injection areas will be tied into this system using the same or equivalent equipment.

2.8.2 Wells at West Ranch Oil Field

As of December 2020, there are 257 active wells at West Ranch; 155 are producing wells, 91 are injection wells, and 11 are water sourcing wells. Appendix 2 lists these wells with well identification numbers. All of the wells in the field are operated by Hilcorp. Table 2.8.2 shows these well counts at West Ranch by status.

Well Count	Active	Shut-in	Temporarily Abandoned	Plugged and Abandoned
TOTAL	257	277	2	389

Table 2.8.2 West Ranch Well Count

TRRC rules govern well siting, construction, operation, maintenance, and closure for all oil field wells. The TRRC granted authority to inject CO_2 in permitted wells after application, notice and hearings. TRRC requirements are found at TAC Title 16 Part 1 Chapter 3 and Chapter 5[2] and include:

- Fluids must be constrained in the strata in which they are encountered;
- Activities governed by the TRRC rules cannot result in the pollution of subsurface or surface water;
- Adherance to specified casing, cementing, drilling well control, and completion requirements designed to prevent fluids from moving from the strata encountered into strata with oil and gas, or into subsurface and surface waters;
- Filing of a well completion report including basic electric log (e.g., a density, sonic, or resistivity (except dip meter) log run over the entire wellbore);
- Equipping wells with a Bradenhead valve, measuring the pressure between casing strings using the Bradenhead gauge, and following procedures to report and address any instances where pressure on a Bradenhead is detected;
- Following plugging procedures that require advance approval from the TRRC and allow consideration of the suitability of the cement based on the use of the well, the location and setting of plugs;
- Corrosion monitoring under TAC Title 16 Part 1 §5.305(1) (D) is met by alternative monitoring through continuous SCADA monitoring in all wells;
- Using corrosion resistant alloy (CRA) for facilities which are exposed to CO_2; and
- Conducting Casing Integrity Tests annually as required under TAC Title 16 Part 1 §5.305(1)(C).

All changes in status of wells are in compliance with TRRC rules and all new changes in status of facility equipment are in compliance with TRRC rules. Any changes in wells including new wells and plug & abandonment would go through TRRC approval and be included in the annual report to EPA.

2.9 Storage Capacity Calculation

During the injection of CO_2 and water for CO_2 EOR operations, fluids will move from injection wells toward the production wells following the pressure trends. At the end of CO_2 EOR operations, the reservoir fluids will be in equilibrium based on their gravity difference where lighter fluids, likely gases, will move toward the top of the formation below the seal of each reservoir (see Section 2.5, Reservoir Characterization and Modeling). The estimated total amount of the CO_2 that can be sequestered in these reservoirs is based on the available pore

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[2] TRRC rules can be found online at:
https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=3&rl=Y and https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=5

space at each of the reservoirs. Though the available pore space is considered to be the entire pore space from top of the reservoir to the spill point, for purpose of this calculation, the original oil and gas in place of each reservoir is assumed as the available pore space, and further, only down to the shallower of spill point or oil water contact. The oil water contacts are above the spill points in 41-A and Greta reservoirs; hence, the pore space accounted for those two reservoirs are only down to the oil water contact. The oil water contacts are below the spill points in 98-A, Ward, and Glasscock.

The following equation was used to estimate the storage capacity:

$$CO_2\,Storage\ Capacity = HCPV * E * \rho CO_2$$

where:

HCPV = *Hydrocarbon pore volume above oil water contact or a spill point of the south-west structure.*

E = *Efficiency factor.*

ρCO_2 = *CO_2 density at reservoir pressure and temperature.*

Based on the numerical simulations conducted by BEG, the CO_2 occupancy of the pore space at the end of the CO_2 EOR operation is calculated. These calculations assume a 50 percent efficiency factor, and results are tabulated in Table 2.9.1.

Reservoir	Storage capacity (MM metric ton)
Greta	12.35
Glasscock	6.35
Ward	10.10
41-A	10.74
98-A	8.52
Total	**48.06**

Table 2.9.1 West Ranch field CO_2 storage capacity in different reservoirs (metric tons)

At reservoir conditions of West Ranch, the five main target reservoirs could hold about 919 Bscf (48.06 million metric tonnes) of CO_2 in the reservoir based on the original oil and gas in place. PNPH forecasts that 20 years of CO_2 EOR operations would result in sequestered CO_2 occupying approximately 61 percent of the calculated storage capacity.

3. Delineation of Monitoring Area and Timeframes

3.1 Active Monitoring Area

As discussed in sections 2.1 through 2.4, the subsurface characteristics of the existing WRU for 98-A and 41-A reservoirs are similar to the characteristics in the other reservoirs within the Project Interval at West Ranch. They all have four-way dip anticline trapping mechanism; no faulting; primary confining layers over each injection zone; the existence of secondary confining interval (Anahuac Shale) in addition to individual confining layers overlying each reservoir; and, depleted reservoir pressure. Expansion into the full Project Interval will require the operator to obtain approval for unitzation and permits for injection from TRRC, as explained in sections 2.7 and 2.8. In addition, the reservoir simulation effort carried out as part of DOE's MVA Plan and the storage capacity calculation as illustrated in sections 2.5 and 2.9 demonstrated the viability of the Project Interval for a long-term CO_2 retention. Because CO_2 is retained within the WRUs, the Active Monitoring Area (AMA) is the existing WRU boundary of 41-A/98-A (Consolidated) Unit, as depicted in Figure 2.1.2, plus the half mile buffer. When a new WRU for CO_2 EOR operation is established, either for the currently flooded reservoirs or for the other three reservoirs and sublayers within the Project Interval, AMA will be expanded to cover the boundaries of those new WRUs, plus the half mile buffer. In addition to the aforementioned reason, the following factors are considered in defining this boundary:

- CO_2 injected into West Ranch reservoirs remains contained within the unit boundary because of the fluid and pressure management, which includes: the practice of targeting the maintenance of an injection and withdrawal ratio (IWR) of 1.0, which assures a stable reservoir pressure; and the managed leaseline water injection and production wells that are used to retain CO_2 and fluids within the unit boundary. The effectiveness was demonstrated by the history matching and reservoir simulation effort in section 2.5 as it demonstrated that the movement of CO_2 plume was largely contained within the intended patterns and the elevation of reservoir pressure was maintained within the intended range.
- Over geologic timeframes, sequestered CO_2 will remain in the respective unit boundaries, and will not migrate downdip, because of the higher elevations of the WRUs compared to other part of the corresponding reservoirs in the same structure as described in Figure 2.2.1 and 2.2.2.

3.2 Maximum Monitoring Area

Based on the potential future expansion of WRU to conduct CO_2 EOR operations in the currently flooded reservoirs and the other three reservoirs and sublayers within the Project Interval, the injection zone extends geologically along the outermost boundary of those reservoirs subject to CO_2 EOR operation, which is primarily determined by oil-water-contact and structures (Figure 3.2). In accordance with 40 CFR §98.448-449, the Maximum Monitoring Area (MMA) will extend for the half mile buffer beyond the boundary.

Figure 3.2 Areal extent of Maximum Monitoring Area (red dashed line) includes the outermost boundary of reservers at West Ranch that could potentially be developed by utilizing CO_2 EOR operation, plus ½ mile buffer.

3.3 Monitoring Timeframes

The primary purpose for injecting CO_2 is to produce oil that would otherwise remain trapped in the reservoir. During the Specified Period, PNPH will have a subsidiary purpose of establishing the long-term containment of a measurable quantity of CO_2 at West Ranch. The Specified Period will be shorter than the period of production from West Ranch. This is in part because the purchase of Fresh CO_2 for injection is projected to taper off significantly before production ceases at West Ranch. At the conclusion of the Specified Period, PNPH will submit a request for discontinuation of reporting. This request will be submitted with a demonstration that the cumulative mass of CO_2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage. See 40 CFR §98.441(b)(2)(ii).

4. Evaluation of Potential Pathways for CO_2 Leakage to the Surface

4.1 Introduction

The subsurface characteristics at West Ranch are very well known as a result of exploration, production, and recurrent reevaluation for optimization of production, including the recent reevaluation for CO_2 EOR and monitoring activities under the MVA Plan. The presence of thick oil and gas accumulations in the subsurface of West Ranch provides strong evidence that the mudstones that separate the sandstones are effective in isolating buoyant fluids, and provides assurance that injected CO_2 will be effectivity trapped. Further evidence of effective confinement of fluids is the sustained pressure depletion of some zones after production.

This MRV Plan considered the following potential leakage pathways:

- Diffuse leakage through the Anahuac Shale
- Faults and fractures
- Natural and induced seismic activity
- Failure of zonal isolation in existing wells
- Failure of zonal isolation in new well construction
- Drilling through the CO_2 area
- Lateral migration outside the West Ranch Oil Field
- Pipeline/surface equipment

4.2 Diffuse leakage through the Anahuac Shale

Diffuse leakage through the seals that lie above the reservoirs in the Project Interval is highly unlikely. There are a number of sections above the sand reservoirs in the Project Interval that are impermeable and serve as reliable barriers to prevent fluids from moving upwards towards the surface. These barriers are referred to as seals because they effectively seal fluids into the formations beneath them. In addition, Anahuac Shale was deposited over much of the Gulf Coast during a major regional transgression. It serves as a major confining unit that traps hydrocarbons. It is also widely used as a top seal for Class I disposal operations in the Gulf Coast area. Anahuac Shale is more than 120 feet thick in the West Ranch area, and a 30-foot core collected at the A-600 well has been examined in detail to characterize the quality of this confining layer (Lu et al 2014). It is composed of silty clay (average 56 percent clay) and has permeabilities of 0.0006 to 0.0026 mD. Gas chemistry shows that gas migration is limited by diffusion and adsorption, and confirms that Anahuac Shale is an effective seal which will not allow diffuse leakage of CO_2 above the Project Interval. Injection pressure is continuously monitored and unexplained changes in injection pressure that might indicate leakage would trigger investigation as to the cause.

4.3 Faults and Fractures

West Ranch is a roll-over anticline formed between two major growth fault zones (Figures 2.2.1,

2.2.2 and 2.2.3), and there is no major fault within the field (Baurenschmidt, 1962). The Gulf Coast region is faulted by systems of growth faults (active during sediment accumulation) and by structures associated with deep-seated and piercement salt structures, which have been extensively characterized by exploration. Because the overall section is dominated by mudstones, fault permeability is controlled by clay smear. The sealing nature of faults is evident at many hydrocarbon fields that are fault-bounded. Gulf Coast sandstones and mudstones are typically not fractured but deform without rupture by bending and smearing. As described in Section 2.8.2, all injection permits require that injected fluids be confined in the authorized reservoir, and injection at pressure exceeding fracture pressure is not allowed.

4.4 Natural and Induced Seismic Activity

Although the Gulf Coast has been and is still locally undergoing deformation related to loading and continued subsidence of the Gulf Basin, the area is not seismically active. Deformation occurs without producing earthquakes. The United States Geological Survey (USGS) long term seismic risk map puts the entire Gulf Coast area, including West Ranch, in the lowest risk category (United States Geological Survey, 2014).

Risk of induced seismicity at West Ranch is low for several reasons: 1) magnitude of pressure increase and the area where pressure elevated is aggressively managed by balancing injection and withdrawal rates, 2) the reservoirs are underpressured as a result of past production, 3) high permeability and rapid fluid cycling though the reservoir create little risk of developing local overpressure, and 4) the operation is compliant with regulations limiting injection pressure.

In addition, the application for a new injection well permit or an amendment of an existing injection well permit for injection pressure, injection rate, or injection interval must include a survey of historical seismic events within 5.64 miles, the Area of Interest (AOI). A seismic event of 2.0 Magnitude (M) or greater from the USGS earthquake catalog or the TexNet earthquake catalog triggers seismicity review and requires additional geologic information across the AOI for the TRRC to consider the necessity of a permit disposition.

In the unlikely event that seismicity resulted in a pathway for material amounts of CO_2 to migrate from the injection zone, the monitoring provisions at other reservoir levels would lead to further investigation as elaborated in Section 5.1.

4.5 Failure of Zonal Isolation in Existing Wells

Wells are required to be constructed and either plugged and abandoned or maintained so the injection and production zones are isolated from other zones and from fresh groundwater (underground sources of drinking water or USDW). West Ranch contains many legacy wells; hence, the operator invests in well qualification and management. Well qualification and management are overseen by the TRRC.

TRRC rules call for periodic Mechanical Integrity Testing (MIT). Continuous monitoring devices tracking injection rate, pressure, and volume (as well as continuous monitoring of the annulus with a pressure gauge) are installed in line with the requirement. These monitoring tools conform to the TRRC requirements under TAC Title 16 Part 1 §5.305(1)(B) and used to protect against the high cost from loss of well control. All pressure gauges are hooked up to a real time reporting SCADA system. The SCADA monitoring system uses set points to trigger an alarm if there is more than a 10 percent change in pressure. In addition, periodic injection profiles are performed on the injection wells, and this will include running temperature surveys on the injection wells. Reservoir pressure is also measured through the injection wells when workovers are performed.

While the CO_2 EOR operation is conducted, injection profile logs are run to determine where the injected fluid is going. A profile provides a comprehensive picture of what is going on down hole in an injector. An injection profile package is made up of numerous surveys. The tool used is made up of numerous components such as a radioactive tracer, spinner logs, temperature logs, caliper logs, and collar logs. The temperature survey looks for anomalies which can indicate if there is fluid loss during injection. A tracer tool monitors the reduction in tracer material as it moves down the well and could indicate channeling and help in quantifying the amount of a release if one is found. A spinner gives the rate and a shut-in temperature survey indicates fluid losses and events occurring inside and outside the well bore.

In addition, a Reservoir Saturation Tool (RST) is run to measure hydrocarbon and water saturations behind casing. This tool could indicate if the injected fluid is going out of the targeted interval and into another zone. Baseline RST has been run on six wells.

An exhaustive study of all existing wellbores at West Ranch was carried out prior to CO_2 flood to confirm well condition and integrity. All of the plugged and abandoned wells at West Ranch have plugs to prevent the upward migration of fluids. Most wells have numerous plugs in the Frio formation isolating the deeper zones. All shut-in and producing wells in West Ranch were also reviewed, and numerous shut-in wells are used for its active pressure monitoring program throughout the field as described in Section 5.1.1.

Additionally, the TRRC requires an applicant for an injection well permit to examine the data of record for wells that penetrate the proposed injection reservoir within one-quarter (1/4) mile radius of the proposed well to determine if all abandoned wells have been plugged in a manner that will prevent the movement of fluids into strata other than the authorized reservoir for injection (AoR). Hilcorp currently reviews all wells located within one-half (1/2) mile radius of a proposed injection well.

Based on the measures above, the risk of CO_2 leakage through existing wells is being mitigated through a monitoring and maintenance program that will provide early detection of problems that could materialize into a leakage event. Any potential CO_2 leakage would be identified and quantified through the monitoring provisions in Section 5.1.

4.6 Failure of Zonal Isolation in New Well Construction

Well qualification and management are overseen by the TRRC. New wells are constructed to provide zonal isolation and are tested prior to use to determine that cement in the rock-casing annulus covers the required intervals and is of good quality; hence, the risk of failure of zonal isolation in new wells is low. In the event CO_2 leakage were to occur, it would be identified and quantified through the monitoring provisions in Section 5.1.

All of the injection wells for the CO_2 EOR operation are newly drilled wells or conversion of existing wellbores and must adhere to the TRRC requirements as described elsewhere herein including Section 2.8.2. All of the injection wells have coated tubulars to withstand corrosion.

Both the surface and production casing strings are cemented back to the surface, with a confirmation through a cement bond log of a full column of cement behind the casing.

For producing wells for CO_2 EOR operation that are newly drilled, these wells are drilled and completed to deal with corrosion, including coated tubulars and corrosion inhibiting fluid in the annulus between the tubing and the long string casing to prevent corrosion. Both surface and production casings are cemented to surface.

4.7 Drilling through the CO_2 Area

A future drilling initiative within the existing or future WRU to extend the current CO_2 flood area or to drill into a deeper reservoir creating an inadvertent leakage pathway is possible; however, such risk is considered to be very low. As previously stated , all wells drilled in the West Ranch Oil Field are regulated by the TRRC (specifically under TAC Title 16 Part 1 §3.13) which includes (a) ensuring that the casing is securely anchored to effectively control the well at all times, (b) all usable-quality water zones be isolated and sealed off to effectively prevent contamination or harm, and (c) all productive zones, potential flow zones, and zones with corrosive formation fluids be isolated and sealed off to prevent vertical migration of fluids behind the casing, including gases. Multiple reservoirs at West Ranch Oil Field are gas charged, and all drilling to each reservoirs must be done with proper preparation to contain gas within such reservoirs (e.g., using well control mechanisms such as dense drilling mud, blow out preventers, and completion to isolate zones). In the unlikely event of gas leakage from a reservoir flooded with CO_2, the methods to quantify the amount of leakage use appropriate engineering variables and standard estimation of releases.

4.8 Lateral Migration outside West Ranch Oil Field

As illustrated in Figures 2.2.1 and 2.2.2, the West Ranch Oil Field contains the highest elevation of both current and future reservoirs for CO_2 flooding within the surrounding area. It is highly unlikely that injected CO_2 will migrate downdip and laterally outside of the existing and future WRUs because CO_2 is less dense than oil and water in the reservoir. As a result, the CO_2 tends to migrate and accumurate at the top of geological structure. The well-defined structural closure based on well logs and oil-water contact provides a strong control on the lateral extent of the CO_2 plume, and the volume of injected CO_2 will be less than the storage capacity of each reservoir. CO_2-oil miscibility also strongly minimizes possible lateral CO_2 transport distance.

4.9 Pipeline/Surface Equipment

Surface infrastructure is under surveillance on daily basis. Any releases of CO_2 from either planned events or unplanned incidents is being quantified and reported following the requirement of Subpart W of EPA's GHGRP or based on appropriate engineering variables and standard estimation of releases as stated in Section 5.2. The past three years of surveillance show that the release volumes less than one percent of the captured CO_2. Confidence in surveillance is high, because release of even small amounts of CO_2 leakage is highly noticeable, as dense CO_2 flashes result in large volume increases and strong cooling, resulting in noise and a cloud, ice, or condensed water.

5. Site-specific Risk-based Monitoring

5.1 Losses through Subsurface Infrastructure

Detection of any losses of CO_2 in the subsurface through damaged or faulty well construction, or through any other potential pathways for CO_2 leakage to the surface as identified in Section 4, will be done based on the monitoring information obtained from active wells and shut-in wells. Proactive pressure monitoring at active producing wells, active injection wells, and shut-in wells is done via installation of pressure gauges at the wellhead that access the tubing and casing with connections to the SCADA system. Pressure reading at the surface casing, production casing and tubing on these wells are captured multiple times each day. If pressure changes in a reservoir that is not intended to be energized or if there are any CO_2 releases from the subsurface, alarms are set up to be notified through SCADA into the control room. All the active alarms are followed up by the field personnel for further investigation and diagnostics. If a leakage is detected, Petra Nova will use an event-specific approach to quantify leaked amounts of CO_2. This might include the use of modeling, engineering estimates, or direct measurements, depending on the circumstance, to estimate the relevant parameters (e.g. flow rate, concentration, and duration of leakage) to quantify the leak volume.

All permanently plugged and abandoned wells are plugged with cement and drilling mud with well tubulars cut off below the surface in accordance with regulatory requirements; however, as these wells are not equipped with pressure gauges, in the unlikely event of well leakage, the detection and quantification will be done indirectly from the pressure reading of surrounding wells that are perforated in the same or shallower reservoirs.

In either case, detection of leakage in the subsurface will occur prior to release of CO_2 at the surface and will be used to prevent loss to the surface. In some cases, the leakage risk may be brine (not CO_2); in other cases, loss of CO_2 is into shallower zones of the subsurface.

5.1.1 Inactive Well Monitoring

As of December 31, 2020, there are 255 inactive wells completed in the Frio formation above the injection interval and in select zones above the impenetrable Anahuac Shale that are being used as pressure monitoring wells. These monitoring wells are outfitted with gauges on the tubings, the production casings, and the surface casings. All data is reported and monitored in real time through the SCADA system that reports information into the control room with back-up information fed into Hilcorp's corporate offices. Figure 5.1.1 shows the location of the pressure monitoring wells throughout the field. Table 5.1.1 shows the zones of the inactive monitoring wells.

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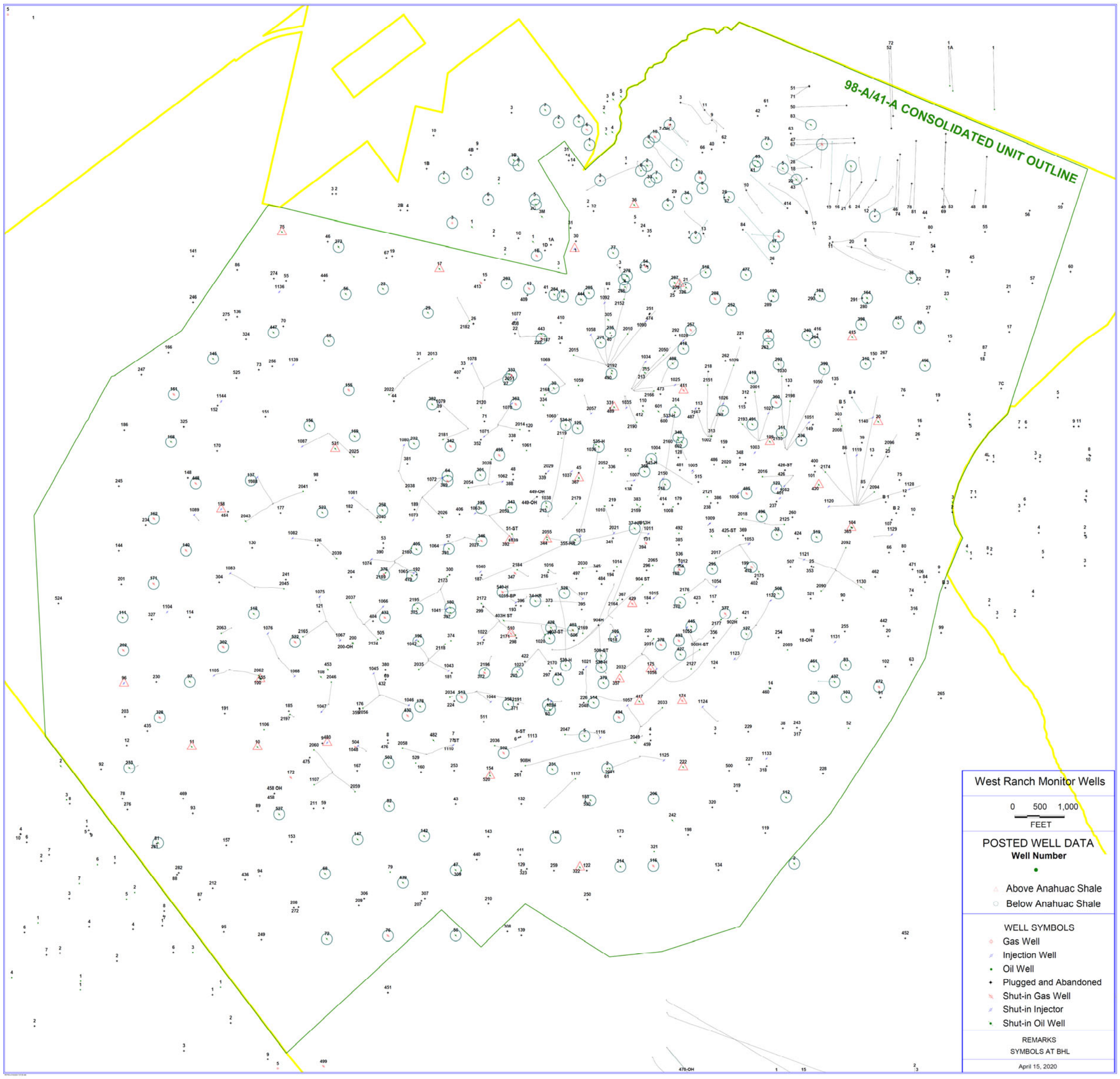

Figure 5.1.1 Location of inactive wells with pressure monitoring (wells above and below Anahuac Shale are shown as pink triangles and green circles, respectively)

#	Reservoir	Number of well	Depth	
1				
2	80-A	4	2,940’	
3		11		
4	3800	1	3,775’	
5	Catahoula	13		
6	Discorbis	4	4,555’	
7	Marg	31	4,960’	Below Anahuac Shale
8	Greta	83	5,065	
9	Randle	2	5,250’	
10	Benneview	1	5,320’	
11	Dixon	2	5,390’	
12	Toney	16	5,400’	
13	Glasscock	14	5,470’	
14	Menefee	3	5,550’	
15	Mitchell	10	5,580’	
16	Armstrong	1	5,600’	
17	Ward	33	5,630’	
18	41-A	7	5,700’	
19	Musquez	1	6,050’	
20	383 Frio	2	6,080’	
21	98-A	10	6,125’	

Table 5.1.1 Zones where pressure monitoring wells are located

5.1.2. Production Well Monitoring

Figure 5.1.2 depicts how a production well is monitored in the SCADA system. Pressure gauges monitor pressure in the tubing, the production casing, and the surface casing. Gas lift rate and pressure are also monitored for each well. The valves on the right side of the diagram are located at the TS manifold and allow the well to be directed into the high pressure (HP), intermediate pressure (IP), or low pressure (LP) system, or to the TS separator. Alarms are set to monitor any changes in the pressure from the normal pressure ranges. If abnormal pressures are noted, an alarm sounds and the particular well will be monitored for CO_2 leaks.

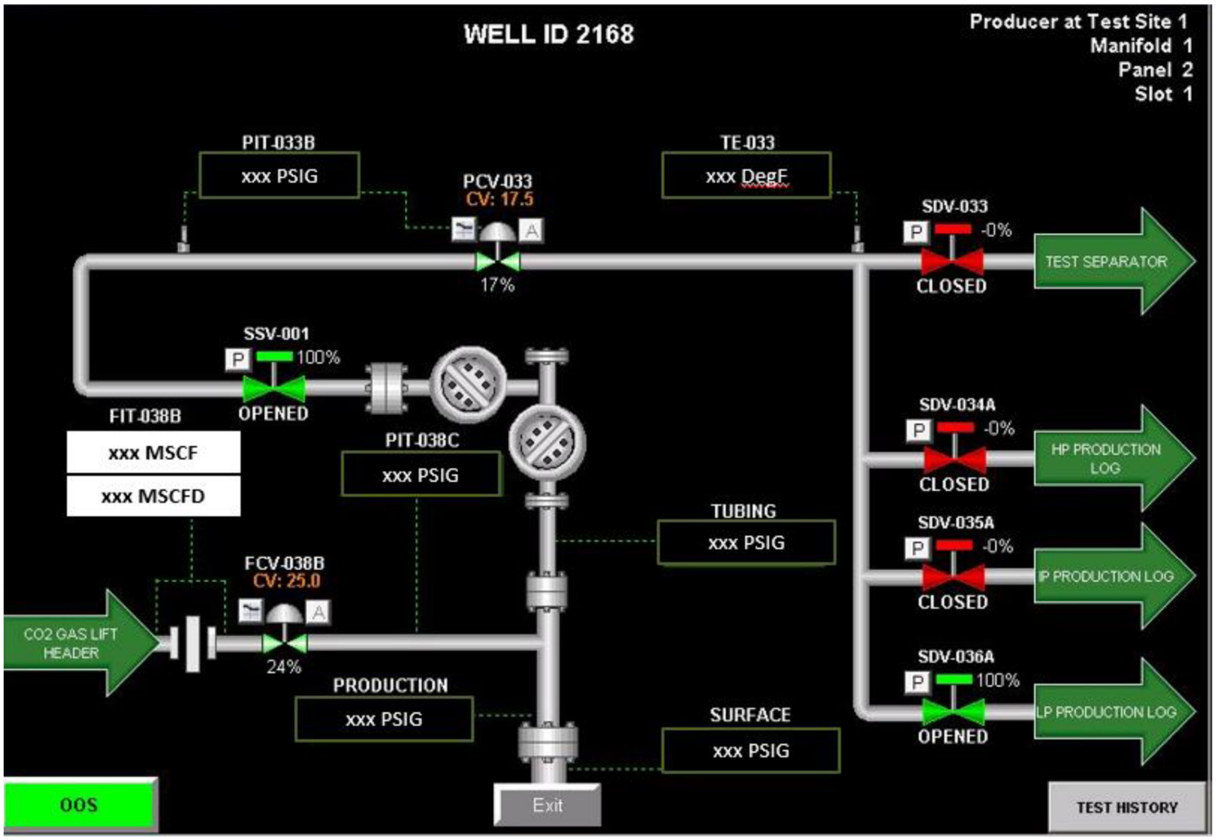

Figure 5.1.2 Monitoring of Production Wells

5.1.3. Injection Well Monitoring

Figure 5.1.3 depicts how an injection well is monitored in the SCADA system. Pressure gauges monitor pressure in the tubing, the production casing, and the surface casing. The valves on the right side of the diagram are located at the TS manifold and allow either CO_2 or water to be injected into the well, and in some cases both CO_2 and water at the same time. The injection rate is metered for each well. Alarms are set to monitor any changes in the pressure from the normal pressure ranges. If abnormal pressures are noted, an alarm sounds and the particular well will be monitored for CO_2 leaks.

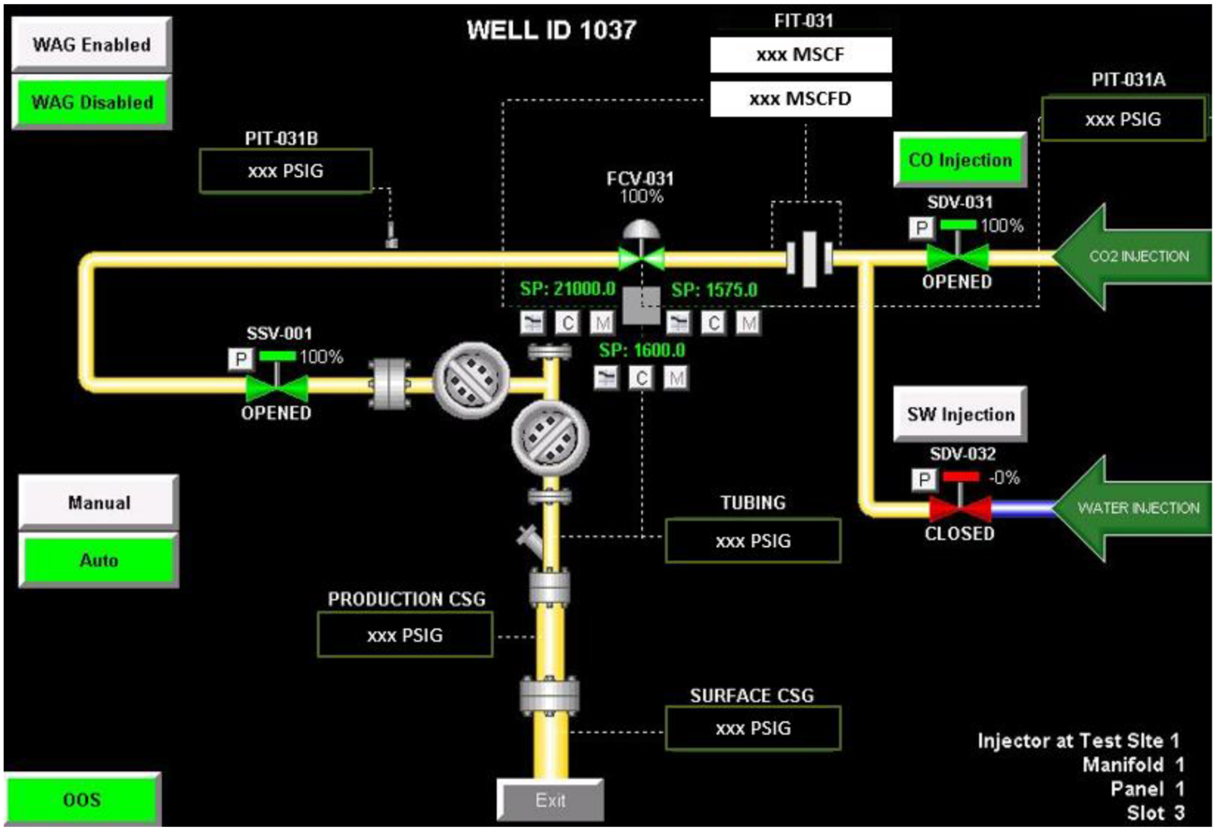

Figure 5.1.3 Monitoring of Injection Wells

5.2 Losses through Surface Infrastructure

Losses though surface infrastructure are either intentional releases for maintenance or unplanned releases, in the case of upsets or accidents. The method of detection is identified by the operator using both the data streams and alarms that are reported to the control room and visual inspection of facilities. The methods of quantification use appropriate engineering variables and standard estimation of releases.

PNPH ensures that the operator evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6. Determination of Baselines

PNPH will use the results from daily monitoring of field conditions by Hilcorp and operational data, as well as routine testing and maintenance information to monitor for surface leakage. As indicated in Sections 4.5 and 5, the SCADA system is used to conduct the CO_2 EOR operations at West Ranch. The data from these efforts is used to identify and investigate variances from expected performance that could indicate CO_2 leakage. Below is a description of how this data will be used to determine when further investigation of potential CO_2 leakage is warranted.

- **Visual Inspections**: As mentioned in Section 4.9, operations personnel make daily rounds of the facilities, providing a visual inspection of equipment used in the operations (e.g., vessels, piping, valves, wellheads). These inspection rounds provide the opportunity to identify issues early and address them proactively, which may preclude leaks from happening and/or minimize any CO_2 leakage. If an identified issue cannot be resolved by the person who first observes it, a work order will be generated to resolve the matter. Each event will be documented, include an estimate of the amount of CO_2 leaked and included in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.
- **Mechanical Integration Test (MIT)**: TRRC rules calls for operators to comply with MIT requirements, which are designed to ensure that there is no significant leakage within the injection tubing, casing, or packer, as well as no leakage outside of the casing. All active injection wells undergo MIT testing (referred to as "H-5 Testing") at the following intervals:
    - Before injection operations begin;
    - At least once every five years, or more frequently if required by the permit;
    - After any workover that disturbs the seal between the tubing, packer, and casing, or after any repair work on the casing; and
    - When a request is made to suspend or reactivate the injection or disposal permit.

  The TRRC requires that the operator notify the TRRC district office at least 48 hours prior to conducting the H-5 Testing. Operators are required to use a pressure recorder and pressure gauge for the test. Operators' field representative must sign the pressure recorder chart and submit it with Form H-5. Casing pressure must fall within 30-70% of the pressure recorder chart's full scale, and the pressure gauge must measure in increments that are no greater than 5% of the test pressure.

  In the event a loss of mechanical integrity occurs, the injection well is immediately shut-in and an investigation is initiated to determine what caused the loss of mechanical integrity. If investigation of an event identifies that a leak has occurred, those events will be documented, including an estimate of the amount of CO_2 leaked and inclusion in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.
- **Production and Shut-in Well Pressure Surveillance**: All tubings and casings of production and shut-in wells are equipped with pressure gauges and connected to the SCADA system as described in Section 5. If a 10 percent deviation in pressure outside of the expected values occurs, the event is investigated to determine if the variance poses a leak threat. If investigation of an event identifies that a leak has occurred, those events will be documented, including an estimate of the amount of CO_2 leaked and inclusion in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.

7. Determination of Sequestration Volumes Using Mass Balance Equations

PNPH will use equation RR-11 in 40 C.F.R. §98.443 to calculate the Mass of CO_2 Sequestered in Subsurface Geologic Formations in a reporting year as follows:

$$CO_2 = CO_{2I} - CO_{2P} - CO_{2E} - CO_{2FI} - CO_{2FP} \quad \text{(Eq. RR-11)}$$

where:

CO_2 = *Total annual CO_2 mass sequestered in subsurface geologic formations (metric tonnes) at the facility in the reporting year.*

CO_{2I} = *CO_2 Injected, the total annual CO_2 mass injected (metric tonnes) in the well or group of wells covered by this source category in the reporting year, includes both Received CO_2 (or Fresh CO_2, see discussion below) and Recycled CO_2.*

CO_{2P} = *CO_2 Produced, the total annual CO_2 mass produced (metric tonnes) in the reporting year, includes Recycled CO_2 (see discussion below).*

CO_{2E} = *CO_2 Emitted by Surface Leakage, total annual CO_2 mass emitted (metric tonnes) by surface leakage in the reporting year.*

CO_{2FI} = *Total annual CO_2 mass emitted (metric tonnes) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead, for which a calculation procedure is provided in Subpart W.*

CO_{2FP} = *Total annual CO_2 mass emitted (metric tonnes) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity, for which a calculation procedure is provided in Subpart W.*

To account for site-specific considerations, PNPH proposes to modify the locations for obtaining volume data for the equations in 40 C.F.R. §98.443 as indicated below.

The first modification addresses the propagation of error that would be created if volume data from meters at each injection well were utilized. This issue arises because each meter has a small but acceptable margin of calibration error, and this error could become significant if data were taken from the approximately 100 meters within West Ranch. As such, PNPH proposes to use the mass of Recycled CO_2 from commercial quality flow meters at the inlet of RGCs combined with mass of CO_2 Received (earlier referred to as Fresh CO_2 and further defined below) to determine the mass of CO_2 Injected into the subsurface (CO_{2I} in the formula above). The mass of CO_2 Produced (CO_{2P} in the formula above) will be the same as Recycled CO_2.

The second modification addresses the concentration of CO_2 Received. Figure 7 shows the planned mass balance envelope overlaid as a blue square onto the facility flow diagram originally shown in Figure 2.7.1. The envelope contains all of the measurements relevant to the mass balance equation except for CO_2 Received, which is proposed to be measured at the custody transfer meter located in the vicinity of CCE (M_1) as shown in Section 2.8.1.

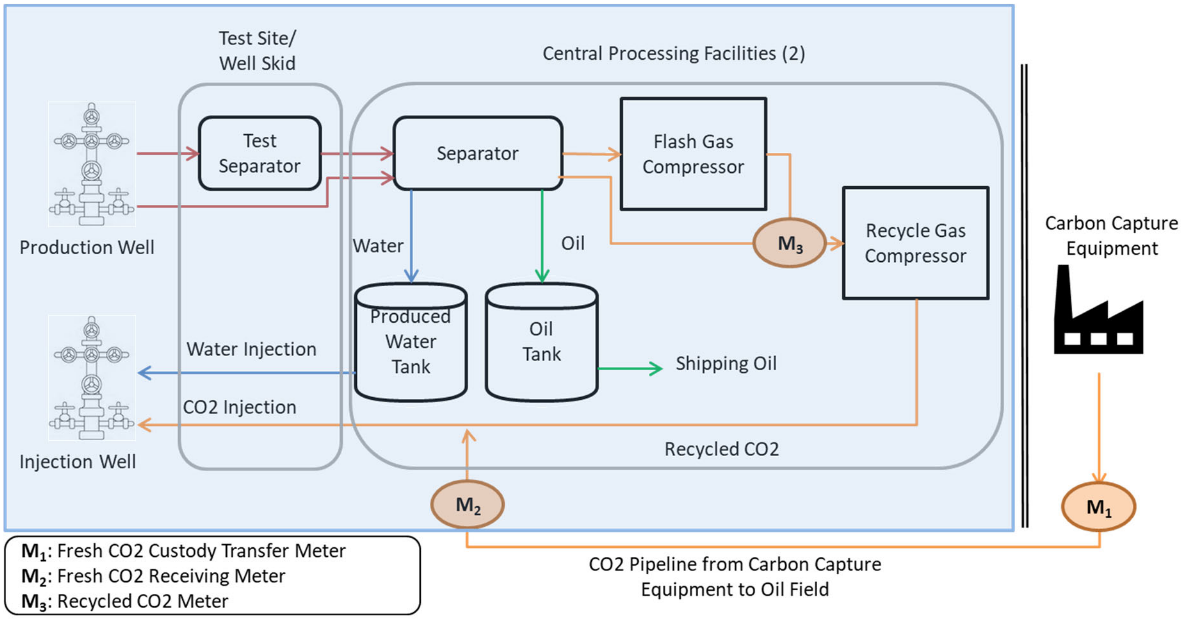

Figure 7 Material Balance Envelope (in blue)

The following sections describe how each element of the mass-balance equation will be calculated.

7.1 Mass of CO_2 Injected into the Subsurface

The equation for calculating the mass of CO_2 Injected into the Subsurface at West Ranch is equal to the sum of the mass of CO_2 Received (volumetric flow at M_2 using CO_2 concentration at M_1) and the mass of Recycled CO_2 measured at the inlet of the RGC (M_3).

$$CO_{2I} = CO_{2T,r} + CO_{2,u}$$

where:

- CO_{2I} = *CO_2 Injected, the total annual CO_2 mass injected (metric tonnes) in the well or group of wells covered by this source category in the reporting year*
- $CO_{2T,r}$ = *CO_2 Received, the injected net annual mass of CO_2 received through flow meter r (metric tons).*
- $CO_{2,u}$ = *CO_2 Recycled, the injected annual CO_2 mass injected (metric tons) as measured by flow meter u.*

Mass of CO_2 Received

PNPH will use equation RR-2 as indicated in 40 C.F.R. §98.443 to calculate the mass of CO_2. Received. The volumetric flow at standard conditions as defined in 9.1.2 is measured at the receiving meter at West Ranch at the terminus of CO_2 Pipeline from CCE (M_2), and will be multiplied by the CO_2 concentration measured at the custody transfer meter located in the

vicinity of CCE (M_1) as stated above, and the density of CO_2 at standard conditions to determine mass.

$$CO_{2T,r} = \sum_{p=1}^{4}(Q_{r,p} - S_{r,p}) * D * C_{CO_{2,p,r}} \text{ (Eq. RR-2)}$$

where:

$CO_{2T,r}$ = *CO_2 Received, the injected net annual mass of CO_2 received through flow meter r (metric tons).*

$Q_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).*

$S_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into your well in quarter p (standard cubic meters). Since all delivery to West Ranch is used within the oilfield, the quarterly flow redelivered, $S_{r,p}$ is zero ("0").*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter)= 0.0018682.*

$C_{CO2,p,r}$ = *Quarterly CO_2 concentration measurement in flow for flow meter r in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

r = *Receiving flow meter (M_2, CO_2 concentration for M_2 is measured at M_1).*

Mass of CO_2 Recycled

PNPH will use equation RR-5 from 40 C.F.R. §98.443 to calculate the Mass of Recycled CO_2.

$$CO_{2,u} = \sum_{p=1}^{4} Q_{p,u} * D * C_{CO_{2,p,u}} \text{ (Eq. RR-5)}$$

where:

$CO_{2,u}$ = *CO_2 Recycled, the annual CO_2 mass injected (metric tons) as measured by flow meter u.*

$Q_{p,u}$ = *Quarterly volumetric flow rate measurement for flow meter u in quarter p at standard conditions (standard cubic meters per quarter).*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,u}$ = *CO_2 concentration measurement for flow meter u in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

u = Flow meter (M_3).

7.2 Mass of CO_2 Produced

As discussed above, the mass of CO_2 Produced equals the mass of Recycled CO_2 measured at the flow meters at inlet of RGCs (M_3). Equation RR-9 in 40 C.F.R. §98.443 will be used to

aggregate the mass of CO_2 produced net of the mass of CO_2 entrained in produced oil as follows:

$$CO_{2P} = \sum_{w=1}^{W} CO_{2,w} + X_{oil} \qquad \text{(Eq. RR-9)}$$

where:

CO_{2P} = *CO_2 Produced, the total annual CO_2 mass produced (metric tonnes) in the reporting year.*

$CO_{2,w}$ = *Annual CO_2 mass produced (metric tons) through flow meter w in the reporting year (further defined below).*

X_{oil} = *Mass of entrained CO_2 (metric tons) in oil in the reporting year calculated as per 40 C.F.R. Subpart W.*

w = *Flow meter (M_3)*

PNPH will use equation RR-8 as indicated in 40 C.F.R. §98.443 to calculate the annual mass of CO_2 produced.

$$CO_{2,w} = \sum_{p=1}^{4} Q_{p,w} * D * C_{CO_{2,p,w}} \qquad \text{(Eq. RR-8)}$$

where:

$CO_{2,w}$ = *Annual CO_2 mass produced (metric tons) through flow meter w.*

$Q_{p,w}$ = *Volumetric gas flow rate measurement for separator w in quarter p at standard conditions (standard cubic meters).*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,w}$ = *CO_2 concentration measurement for flow meter w in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

w = *Flow meter (M_3)*

7.3 Mass of CO_2 Emitted by Surface Leakage

The mass of CO_2 Emitted by Surface Leakage (term CO_{2E} in Eq. RR-11) is calculated based on various methodologies, including measurements, engineering estimates, and emission factors, used for the leakage originating from subsurface as described in Section 5.1. For releases from surface equipment and equipment venting (terms CO_{2FI} and CO_{2FP} in Eq. RR-11), 40 C.F.R. Subpart W reporting is relied upon as noted above.

Equation RR-10 in 40 C.F.R. §98.443 will be used to calculate and report the Mass of CO_2 Emitted by Surface Leakage:

$$CO_{2E} = \sum_{x=1}^{X} CO_{2,x} \quad \text{(Eq. RR-10)}$$

where:

CO_2. =	*Total annual CO_2 mass emitted by surface leakage (metric tons) in the reporting year.*
$CO_{2,x}$ =	*Annual CO_2 mass emitted (metric tons) at leakage pathway x in the reporting year.*
x =	*Leakage pathway*
X =	*Total number of leakage pathways.*

8. MRV Plan Implementation Schedule

The activities described in this MRV Plan are in place; therefore reporting is planned to start as of January 1, 2021, upon EPA approval. It is anticipated that the Annual Subpart RR Report will be filed on March 31 of the year after the reporting year. As described in Section 3.3 above, PNPH anticipates that the MRV Plan will be in effect during the Specified Period, during which time West Ranch is operated with the subsidiary purpose of establishing long-term containment of a measurable quantity of CO_2 in subsurface geological formations at West Ranch. PNPH anticipates establishing that a measurable portion of the CO_2 injected during the Specified Period will be sequestered in a manner not expected to migrate resulting in future surface leakage. At such time, PNPH will prepare a filing to support the long-term containment determination and submit a request to discontinue reporting under this MRV Plan. See 40 CFR § 98.441(b)(2)(ii).

9. Quality Assurance Program

9.1 Monitoring QA/QC

9.1.1 Flow Meter Provisions

The flow meters used to generate date for the mass balance equations in Section 7 are:

- Operated continuously except as necessary for maintenance and calibration.
- Operated using the calibration and accuracy requirements in 40 CFR §98.3(i).
- Operated in conformance with American Petroleum Institute (API) standards.
- National Institute of Standards and Technology (NIST) traceable.

9.1.2 Concentration of CO_2

CO_2 concentration is measured using an appropriate standard method consistent with 40 CFR §98.444(f)(1). Further, all measured volumes of CO_2 have been converted to standard cubic meters at a temperature of 60 degrees Fahrenheit and at an absolute pressure of 14.65 psi, including those used in Equations RR-2, RR-5 and RR-8 in Section 7.

9.2 Missing Data Procedures

In the event PNPH is unable to collect data needed for the mass balance calculations, procedures for estimating missing data will be used as follows:

- A quarterly flow rate of CO_2 received that is missing would be estimated using invoices or using a representative flow rate value from the nearest previous time period.
- A quarterly CO_2 concentration of a CO_2 stream received that is missing would be estimated using invoices or using a representative concentration value from the nearest previous time period.
- A quarterly quantity of CO_2 injected that is missing would be estimated using a representative quantity of CO_2injected from the nearest previous period of time at a similar injection pressure.

For any values associated with CO_2 emissions from equipment leaks and vented emissions of CO_2 from surface equipment at the facility that are reported in this subpart, missing data estimation procedures will be followed.

9.3 MRV Plan Revisions

In the event there is a material change to the monitoring and/or operational parameters of the West Ranch CO_2 EOR operations that is not anticipated in this MRV Plan, the MRV Plan will be revised and submitted to the EPA Administrator within 180 days as required in 40 CFR §98.448(d). As stated earlier in Sections 2 and 3, the subsurface characteristics of the existing WRU for 98-A and 41-A reservoirs are found in the other reservoirs within the Project Interval at West Ranch. Any future expansion into the Project Interval will be subjected to the same regulatory and operational requirements as explained in Sections 2.7 and 2.8. In addition, the reservoir simulation effort carried out as part of DOE's MVA Plan and the storage capacity calculation as illustrated in Sections 2.5 and 2.9 demonstrated the viability of existing and future WRUs for long-term CO_2 retention. Therefore, any horizontal or upward vertical expansion at West Ranch can be managed by applying the same monitoring approach as alluded to in this MRV Plan and does not trigger the modification to this MRV Plan, as far as they are confined within the Project Interval and fall under the definition of AMA and/or MMA.

10. Records Retention

PNPH will follow the record retention requirements specified by 40 CFR §98.3(g) and maintain the following records for at least three years:

- Quarterly records of CO_2 delivered to West Ranch at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of injected CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Annual records of information used to calculate the CO_2 emitted by surface leakage from leakage pathways, if any.

- Annual records of information used to calculate the CO_2 emitted from equipment leaks or vented emissions of CO_2 from equipment located on the surface, if any.

All data will be collected as generated and aggregated as required for reporting purposes.

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Journal of Greenhouse Gas Control 19 (2013) 49–62

12. Appendices

Appendix 1 Acronyms

AMA – Active Monitoring Area

AoR – Area of Review

API – American Petroleum Institute

Bscf – billion standard cubic feet

B/D – barrels per day

bopd – barrels of oil per day

cf – cubic feet

CH_4 – Methane

CO_2 – Carbon Dioxide

EOR – Enhanced Oil Recovery

EPA – US Environmental Protection Agency

GHG – Greenhouse Gas

GHGRP – Greenhouse Gas Reporting Program

IWR -- Injection to Withdrawal Ratio

MIT – Mechanical Integrity Test

MMB – Million barrels

Mscf – Thousand standard cubic feet

MMscf – Million standard cubic feet

MMT – Million metric tonnes

MRV – Monitoring, Reporting, and Verification

MT -- Metric Tonne

ST – Short Ton

UIC – Underground Injection Control

USEPA – U.S. Environmental Protection Agency

USDW – Underground Source of Drinking Water

WAG – Water Alternating Gas

Appendix 2 Well Identification Numbers

The following table presents the well name, API number, status and type for the wells in the West Ranch field as of December 2020. The table is subject to change over time as new wells are drilled, existing wells change status, or existing wells are repurposed.

Well Name	API Number	Well Status
DRUMMOND JH 1	422390233500	P&A
DRUMMOND JH 2	422390233600	P&A
DRUMMOND JH 3	422390233700	Monitor
DRUMMOND JH 4	422390233800	P&A
DRUMMOND JH 5	422390233900	Monitor
DRUMMOND JH 6	422390234000	Monitor
DRUMMOND JH 7	422390234100	Monitor
DRUMMOND JH 8	422390234200	Monitor
DRUMMOND JH 1A	422390234300	P&A
DRUMMOND JH 9	422390234400	P&A
DRUMMOND JH 1B	422390234500	P&A
DRUMMOND JH 2B	422390234600	P&A
DRUMMOND JH 3B	422390234700	Monitor
DRUMMOND JH 4B	422390234800	P&A
DRUMMOND JH 1C	422390234900	P&A
DRUMMOND JH 2C	422390235000	Monitor
DRUMMOND JH 1D	422390235100	P&A
WEST RANCH A 2	422390235600	P&A
WEST RANCH A 3	422390235700	P&A
WEST RANCH A 4	422390235800	P&A
WEST RANCH A 5	422390235900	Monitor
WEST RANCH A 6-ST	422390236001	P&A
WEST RANCH A 6	422390236099	P&A
WEST RANCH A 7-ST	422390236101	P&A
WEST RANCH A 8	422390236200	P&A
WEST RANCH A 9	422390236300	P&A
WEST RANCH A 10	422390236400	Monitor
WEST RANCH A 11	422390236500	Monitor
WEST RANCH A 12	422390236600	P&A
WEST RANCH A 13	422390236800	Monitor
WEST RANCH A 14	422390236900	P&A
WEST RANCH A 15	422390237000	P&A
WEST RANCH A 16	422390237100	Monitor
WEST RANCH A 17	422390237200	Monitor
WEST RANCH A 18-OH	422390237399	P&A
WEST RANCH A 19	422390237400	P&A
WEST RANCH A 20	422390237500	P&A
WEST RANCH A 21	422390237600	P&A
WEST RANCH A 22	422390237700	P&A
WEST RANCH A 23	422390237800	Monitor
WEST RANCH A 24	422390237900	P&A
WEST RANCH A 25	422390238000	P&A
WEST RANCH A 26	422390238100	P&A
WEST RANCH A 27	422390238200	Monitor

WEST RANCH A	422390238300	P&A
WEST RANCH A	422390238400	Monitor
WEST RANCH A	422390238500	Monitor
WEST RANCH A	422390238600	P&A
WEST RANCH A	422390238700	Monitor
WEST RANCH A	422390238800	P&A
WEST RANCH A -HR	422390238901	Monitor
WEST RANCH A	422390239000	OIL-Conventional
WEST RANCH A	422390239100	Monitor
WEST RANCH A -HR	422390239201	Monitor
WEST RANCH A	422390239300	P&A
WEST RANCH A	422390239400	P&A
WEST RANCH A	422390239500	P&A
WEST RANCH A	422390239600	P&A
WEST RANCH A	422390239700	WSW
WEST RANCH A	422390239800	P&A
WEST RANCH A	422390239900	P&A
WEST RANCH A	422390240000	P&A
WEST RANCH A	422390240100	P&A
WEST RANCH A	422390240200	Monitor
WEST RANCH A	422390240300	P&A
WEST RANCH A	422390240400	Monitor
WEST RANCH A	422390240500	Monitor
WEST RANCH A -ST	422390240601	Monitor
WEST RANCH A	422390240700	OIL-Conventional
WEST RANCH A	422390240800	P&A
WEST RANCH A	422390240900	Monitor
WEST RANCH A	422390241000	P&A
WEST RANCH A	422390241100	Monitor
WEST RANCH A	422390241200	P&A
WEST RANCH A	422390241300	Monitor
WEST RANCH A	422390241400	P&A
WEST RANCH A	422390241500	Monitor
WEST RANCH A	422390241600	P&A
WEST RANCH A	422390241700	Monitor
WEST RANCH A	422390241800	P&A
WEST RANCH A	422390241900	Monitor
WEST RANCH A	422390242000	Monitor
WEST RANCH A	422390242100	P&A
WEST RANCH A	422390242200	P&A
WEST RANCH A	422390242300	Monitor
WEST RANCH A	422390242400	P&A
WEST RANCH A	422390242500	P&A
WEST RANCH A	422390242600	P&A
WEST RANCH A	422390242700	Monitor
WEST RANCH A	422390242800	P&A
WEST RANCH A	422390242900	P&A
WEST RANCH A	422390243000	Monitor
WEST RANCH A	422390243100	Monitor
WEST RANCH A	422390243200	Monitor
WEST RANCH A	422390243300	P&A
WEST RANCH A	422390243400	OIL-Conventional
WEST RANCH A	422390243500	P&A

WEST RANCH A	422390243600	P&A
WEST RANCH A	422390243700	Monitor
WEST RANCH A	422390243800	Monitor
WEST RANCH A	422390243900	P&A
WEST RANCH A	422390244000	P&A
WEST RANCH A	422390244100	P&A
WEST RANCH A	422390244200	P&A
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WEST RANCH A	422390244400	P&A
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WEST RANCH A	422390244700	P&A
WEST RANCH A	422390244800	P&A
WEST RANCH A	422390244900	P&A
WEST RANCH A	422390245000	P&A
WEST RANCH A	422390245100	Monitor
WEST RANCH A	422390245200	Monitor
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WEST RANCH A	422390245500	P&A
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WEST RANCH A	422390245900	P&A
WEST RANCH A	422390246000	Monitor
WEST RANCH A	422390246100	P&A
WEST RANCH A	422390246200	P&A
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WEST RANCH A	422390246400	Monitor
WEST RANCH A	422390246500	P&A
WEST RANCH A	422390246600	Monitor
WEST RANCH A	422390246700	Monitor
WEST RANCH A	422390246800	P&A
WEST RANCH A	422390246900	P&A
WEST RANCH A	422390247000	P&A
WEST RANCH A	422390247100	Monitor
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WEST RANCH A	422390247800	Monitor
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WEST RANCH A	422390248000	Monitor
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WEST RANCH A 262	422390261300	P&A
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WEST RANCH A 269	422390261900	Monitor
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WEST RANCH A 273	422390262200	Monitor
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WEST RANCH A 275	422390262400	P&A
WEST RANCH A 276	422390262500	P&A
WEST RANCH A 278	422390262600	Monitor
WEST RANCH A 279	422390262700	Monitor
WEST RANCH A 280	422390262800	P&A
WEST RANCH A 281	422390262900	Monitor
WEST RANCH A 282	422390263000	P&A
WEST RANCH A 283	422390263100	Monitor
WEST RANCH A 284	422390263200	Monitor
WEST RANCH A 285	422390263300	Monitor
WEST RANCH A 286	422390263400	Monitor
WEST RANCH A 287	422390263500	Monitor
WEST RANCH A 288	422390263600	Monitor
WEST RANCH A 289	422390263700	P&A
WEST RANCH A 290	422390263800	P&A
WEST RANCH A 291	422390263900	P&A
WEST RANCH A 292	422390264000	P&A
WEST RANCH A 293	422390264100	Monitor
WEST RANCH A 294	422390264200	P&A
WEST RANCH A 295	422390264300	Monitor
WEST RANCH A 296	422390264400	P&A
WEST RANCH A 297	422390264500	P&A
WEST RANCH A 298	422390264600	P&A
WEST RANCH A 299	422390264700	P&A
WEST RANCH A 300	422390264800	P&A

WEST RANCH A 301	422390264900	Monitor
WEST RANCH A 302	422390265000	Monitor
WEST RANCH A 303	422390265100	P&A
WEST RANCH A 304	422390265200	P&A
WEST RANCH A	422390265300	OIL-Conventional
WEST RANCH A 306	422390265400	P&A
WEST RANCH A 307	422390265500	P&A
WEST RANCH A 308	422390265600	P&A
WEST RANCH A 309	422390265700	OIL-Conventional
WEST RANCH A	422390265800	Monitor
WEST RANCH A 311	422390265900	Monitor
WEST RANCH A 312	422390266000	P&A
WEST RANCH A 313	422390266100	P&A
WEST RANCH A 314	422390266200	OIL-Conventional
WEST RANCH A	422390266300	OIL-Conventional
WEST RANCH A 316	422390266400	P&A
WEST RANCH A 317	422390266500	P&A
WEST RANCH A 318	422390266600	P&A
WEST RANCH A 319	422390266700	P&A
WEST RANCH A	422390266800	P&A
WEST RANCH A 321	422390266900	OIL-Conventional
WEST RANCH A 322	422390267000	Monitor
WEST RANCH A 323	422390267100	P&A
WEST RANCH A 324	422390267200	P&A
WEST RANCH A	422390267300	P&A
WEST RANCH A 326	422390267400	Monitor
WEST RANCH A 327	422390267500	P&A
WEST RANCH A 328	422390267600	Monitor
WEST RANCH A	422390267700	WSW
WEST RANCH A 331	422390267800	P&A
WEST RANCH A 332	422390267900	OIL-Conventional
WEST RANCH A 333	422390268000	Monitor
WEST RANCH A 334	422390268100	OIL-Conventional
WEST RANCH A	422390268200	WSW
WEST RANCH A 336	422390268300	OIL-Conventional
WEST RANCH A 337	422390268400	Monitor
WEST RANCH A 338	422390268500	P&A
WEST RANCH A 339	422390268600	P&A
WEST RANCH A	422390268700	WSW
WEST RANCH A 341	422390268800	P&A
WEST RANCH A 342	422390268900	Monitor
WEST RANCH A 343	422390269000	Monitor
WEST RANCH A 344	422390269100	Monitor
WEST RANCH A	422390269200	P&A
WEST RANCH A 346	422390269300	Monitor
WEST RANCH A 347	422390269400	OIL-Conventional
WEST RANCH A 348	422390269500	P&A
WEST RANCH A 349	422390269600	Monitor
WEST RANCH A	422390269700	WSW
WEST RANCH A 351	422390269800	WSW
WEST RANCH A 352	422390269900	P&A
WEST RANCH A 353	422390270000	P&A
WEST RANCH A 354	422390270100	P&A

WEST RANCH A	422390270200	Monitor
WEST RANCH A 355-HR	422390270201	Monitor
WEST RANCH A 356	422390270300	P&A
WEST RANCH A 357	422390270400	Monitor
WEST RANCH A 358	422390270500	Monitor
WEST RANCH A 359	422390270600	P&A
WEST RANCH A	422390270700	Monitor
WEST RANCH A 361	422390270800	WSW
WEST RANCH A 362	422390270900	WSW
WEST RANCH A 363	422390271000	Monitor
WEST RANCH A 364	422390271100	Monitor
WEST RANCH A	422390271200	Monitor
WEST RANCH A 366	422390271300	Monitor
WEST RANCH A 367	422390271400	Monitor
WEST RANCH A 368	422390271500	Monitor
WEST RANCH A 369	422390271600	P&A
WEST RANCH A	422390271700	Monitor
WEST RANCH A 371	422390271800	P&A
WEST RANCH A 372	422390271900	Monitor
WEST RANCH A 373	422390272000	OIL-CO2
WEST RANCH A 374	422390272100	OIL-Conventional
WEST RANCH A	422390272200	Monitor
WEST RANCH A 376	422390272300	Monitor
WEST RANCH A 377	422390272400	Monitor
WEST RANCH A 378	422390272500	Monitor
WEST RANCH A 379	422390272600	Monitor
WEST RANCH A	422390272700	P&A
WEST RANCH A 381	422390272800	P&A
WEST RANCH A 382	422390272900	Monitor
WEST RANCH A 383	422390273000	OIL-Conventional
WEST RANCH A 384	422390273100	Monitor
WEST RANCH A	422390273200	P&A
WEST RANCH A 386	422390273300	P&A
WEST RANCH A 387	422390273400	P&A
WEST RANCH A 388	422390273500	P&A
WEST RANCH A 389	422390273600	Monitor
WEST RANCH A	422390273700	P&A
WEST RANCH A 391	422390273800	Monitor
WEST RANCH A 392	422390273900	Monitor
WEST RANCH A 393	422390274000	Monitor
WEST RANCH A 394	422390274100	OIL-Conventional
WEST RANCH A	422390274200	P&A
WEST RANCH A 396	422390274300	P&A
WEST RANCH A 397	422390274400	Monitor
WEST RANCH A 398	422390274500	Monitor
WEST RANCH A 399	422390274600	Monitor
WEST RANCH A	422390274700	P&A
WEST RANCH A 401	422390274800	INJ
WEST RANCH A 402	422390274900	P&A
WEST RANCH A 403	422390275000	OIL-Conventional
WEST RANCH A 404	422390275100	P&A
WEST RANCH A	422390275200	Monitor
WEST RANCH A 406	422390275300	P&A

WEST RANCH A 407	422390275400	P&A
WEST RANCH A 408	422390275500	P&A
WEST RANCH A 409	422390275600	P&A
WEST RANCH A 410	422390275700	P&A
WEST RANCH A 411	422390275800	Monitor
WEST RANCH A 412	422390275900	OIL-Conventional
WEST RANCH A 413	422390276000	OIL-Conventional
WEST RANCH A 414	422390276100	P&A
WEST RANCH A 415	422390276200	Monitor
WEST RANCH A 416	422390276300	P&A
WEST RANCH A 417	422390276400	Monitor
WEST RANCH A 418	422390276500	Monitor
WEST RANCH A 419	422390276600	Monitor
WEST RANCH A 420	422390276700	Monitor
WEST RANCH A 421	422390276800	P&A
WEST RANCH A 422	422390276900	P&A
WEST RANCH A 423	422390277000	P&A
WEST RANCH A 424	422390277100	P&A
WEST RANCH A 425-ST	422390277201	OIL-Conventional
WEST RANCH A 426-ST	422390277301	P&A
WEST RANCH A 427	422390277400	Monitor
WEST RANCH A 428	422390277500	Monitor
WEST RANCH A 429	422390277600	Monitor
WEST RANCH A 430	422390277700	Monitor
WEST RANCH A 431	422390277800	Monitor
WEST RANCH A 432	422390277900	P&A
WEST RANCH A 433	422390278000	Monitor
WEST RANCH A 434	422390278100	Monitor
WEST RANCH A 435	422390278200	P&A
WEST RANCH A 436	422390278300	P&A
WEST RANCH A 437	422390278400	Monitor
WEST RANCH A 439	422390278500	Monitor
WEST RANCH A 440	422390278600	P&A
WEST RANCH A 441	422390278700	P&A
WEST RANCH A 442	422390278800	P&A
WEST RANCH A 443	422390278900	OIL-Conventional
WEST RANCH A 444	422390279000	Monitor
WEST RANCH A 445	422390279100	Monitor
WEST RANCH A 446	422390279200	P&A
WEST RANCH A 447	422390279300	Monitor
WEST RANCH A 448	422390279400	Monitor
WEST RANCH A 449-OH	422390279599	P&A
WEST RANCH State 2	422390279700	Monitor
WEST RANCH A 233	422390279800	Monitor
DRUMMOND JH 1	422390280400	Monitor
DRUMMOND JH 2	422390280500	Monitor
DRUMMOND 3	422390280600	OIL-Conventional
DRUMMOND 4	422390280700	P&A
DRUMMOND 6	422390280800	Monitor
DRUMMOND 7	422390280900	Monitor
TONEY 1	422390281100	Monitor
TONEY 2	422390281200	P&A
TONEY 3	422390281300	Monitor

TONEY 4	422390281400	P&A
TONEY 5	422390281500	P&A
TONEY 6	422390281600	Monitor
TONEY 7	422390281700	Monitor
TONEY 8	422390281800	Monitor
TONEY 9	422390281900	P&A
TONEY 10 (aka WRGSU 310)	422390282000	P&A
TONEY 11	422390282100	P&A
TONEY 12	422390282200	P&A
TONEY 13	422390282300	P&A
TONEY 14	422390282400	P&A
TONEY 15	422390282500	P&A
TONEY 16	422390282600	P&A
TONEY 17	422390282700	P&A
TONEY 19	422390282900	P&A
TONEY 20	422390283000	Monitor
TONEY 21	422390283100	P&A
TONEY 22	422390283200	P&A
TONEY 24	422390283400	P&A
TONEY 26	422390283500	P&A
TONEY 28	422390283600	P&A
TONEY 27	422390283700	P&A
TONEY 28	422390283800	P&A
TONEY 29	422390283900	P&A
TONEY 30	422390284000	P&A
TONEY 31	422390284100	P&A
TONEY 32	422390284200	P&A
TONEY 33	422390284300	Monitor
TONEY 35	422390284400	P&A
TONEY 34	422390284500	Monitor
TONEY 36	422390284600	Monitor
TONEY 37	422390284700	Monitor
TONEY 38	422390284800	Monitor
TONEY 39	422390284900	P&A
TONEY 40	422390285000	P&A
TONEY 41	422390285100	Monitor
TONEY 42	422390285200	P&A
TONEY 43	422390285300	P&A
TONEY 44	422390285400	P&A
TONEY 45	422390285500	P&A
TONEY 46	422390285600	P&A
TONEY 47	422390285700	P&A
TONEY 49	422390285900	P&A
TONEY 50	422390286000	P&A
TONEY 51	422390286100	P&A
TONEY 52	422390286200	P&A
TONEY 53	422390286300	P&A
TONEY 54	422390286400	P&A
TONEY 55	422390286500	P&A
TONEY 56	422390286600	P&A
TONEY 57	422390286700	P&A
TONEY 58	422390286800	P&A
TONEY 61	422390287100	P&A

TONEY 62	422390287200	P&A
TONEY 63	422390287300	P&A
TONEY 65	422390287500	Monitor
TONEY 66	422390287600	P&A
TONEY 67	422390287700	P&A
TONEY 69	422390287800	P&A
TONEY 71	422390287900	P&A
TONEY 72	422390288000	P&A
TONEY 73	422390288100	Monitor
TONEY 74	422390288200	P&A
TONEY 75	422390288300	P&A
TONEY 76 (D & F) (aka WRGSU 376)	422390288400	P&A
TONEY 77	422390288500	Monitor
TONEY 78	422390288600	P&A
TONEY 79	422390288700	P&A
VANDERBILT STATE 1	422390288800	P&A
VANDERBILT STATE 5	422390288900	Monitor
VANDERBILT STATE 2	422390289000	Monitor
VANDERBILT STATE 3	422390289100	P&A
VANDERBILT STATE 6	422390289200	Monitor
VANDERBILT STATE 4	422390289300	P&A
VANDERBILT STATE 7	422390289400	Monitor
VANDERBILT STATE 8	422390289500	P&A
VANDERBILT STATE 9	422390289600	Monitor
VANDERBILT STATE B 10	422390289700	Monitor
VANDERBILT STATE 11	422390289800	P&A
VANDERBILT STATE 13	422390290000	P&A
VANDERBILT STATE 14 (aka WRGSU 414)	422390290100	P&A
VANDERBILT STATE 15	422390290200	P&A
VANDERBILT STATE 17	422390290400	Monitor
VANDERBILT STATE 19	422390290600	P&A
VANDERBILT STATE 20	422390290700	P&A
VANDERBILT STATE 21	422390290800	P&A
VANDERBILT STATE 22	422390290900	Monitor
VANDERBILT STATE 24	422390291000	P&A
VANDERBILT STATE B 1	422390291100	P&A
VANDERBILT STATE B 2	422390291200	P&A
VANDERBILT STATE B 3	422390291300	P&A
VANDERBILT STATE B 4	422390291400	P&A
VANDERBILT STATE B 5	422390291500	P&A
VANDERBILT STATE B 6	422390291600	Monitor
VANDERBILT STATE B 7 OH	422390291700	Monitor
VANDERBILT STATE B 8	422390291800	Monitor
VANDERBILT STATE B 9	422390291900	P&A
VANDERBILT STATE 10	422390292000	P&A
VANDERBILT STATE B 11	422390292100	P&A
MENEFEE BAYOU STATE 1	422390293500	P&A
MENEFEE BAYOU STATE 3	422390293600	P&A
MENEFEE BAYOU STATE 4	422390293700	Monitor
MENEFEE BAYOU STATE B 1	422390293800	P&A
MENEFEE BAYOU STATE B 2	422390293900	P&A
MENEFEE BAYOU STATE B 4	422390294100	P&A

MENEFEE BAYOU STATE 2	422390294300	P&A
WEST RANCH A 253	422390337700	P&A
TONEY 80	422390349700	P&A
TONEY 81	422390349800	P&A
TONEY 82	422390349900	Monitor
TONEY 84	422390362800	P&A
TONEY 83	422390365300	Monitor
WEST RANCH A 455	422390365400	Monitor
WEST RANCH A 462	422390365500	P&A
WEST RANCH A 460	422390366100	OIL-Conventional
WEST RANCH A 461	422390366200	Monitor
WEST RANCH A 458	422390366300	P&A
WEST RANCH A 458 OH	422390366399	P&A
VANDERBILT STATE 25	422390366700	P&A
VANDERBILT STATE 26	422390366800	P&A
MENEFEE BAYOU STATE B 5 (aka WRGSU 205F)	422390367900	P&A
WEST RANCH A 454	422390368000	P&A
WEST RANCH A 459	422390368300	P&A
WEST RANCH A 456	422390368400	Monitor
WEST RANCH A 457	422390368500	Monitor
TONEY 86 H	422390369700	P&A
TONEY 87	422390377800	P&A
WRSOGU 1-2	422390382800	Monitor
WRSOGU 2-2	422393282500	Monitor
WRSOGU 1-3	422390384400	P&A
WRSOGU 2-3	422393282400	Monitor
WRSOGU 1-4	422390384600	P&A
WRSOGU 1-5	422390386100	Monitor
STATE COBDEN 1	422390393300	Monitor
WEST RANCH A 453	422390393900	OIL-Conventional
STATE COBDEN 2	422390394200	Monitor
VANDERBILT STATE 27	422392028000	P&A
WRSOGU 1-6	422393000300	Monitor
WEST RANCH A 469	422393006100	P&A
WRSOGU 1-7	422393007100	Oil-Conventional
WRSOGU 1-8	422393009500	P&A
WRSOGU 2-1	422393010100	P&A
WRSOGU 1-10	422393011100	Monitor
WRASOGU 1-11	422393011300	P&A
WEST RANCH A 471	422393017500	P&A
WEST RANCH A 472	422393017600	Monitor
WEST RANCH A 473	422393020700	P&A
WEST RANCH A 474	422393022100	P&A
DRUMMOND JH 1E	422393033400	Monitor
VANDERBILT STATE 28	422393036500	Monitor
WEST RANCH A 476	422393038000	P&A
TONEY 89	422393038500	Monitor
WEST RANCH A 477	422393054200	Monitor
WEST RANCH A 482	422393082600	OIL-Conventional
WEST RANCH A 478	422393082800	Monitor
WEST RANCH A 479	422393082900	Monitor
WEST RANCH A 480	422393083000	Monitor
WEST RANCH A 484	422393118900	P&A

WEST RANCH A 483	422393119000	Monitor
WEST RANCH A 481	422393124000	P&A
WEST RANCH A 485	422393124100	Monitor
WEST RANCH A 488	422393124900	Monitor
WEST RANCH A 487	422393125000	P&A
WEST RANCH A 486	422393125100	P&A
WEST RANCH A 489	422393125200	Monitor
WEST RANCH A 491	422393125300	Monitor
WEST RANCH A 490	422393125400	Monitor
WEST RANCH A 492	422393125500	OIL-CO2
WEST RANCH A1 ERD	422393161500	P&A
WEST RANCH A 493	422393163300	Monitor
WEST RANCH A 496	422393168300	Monitor
WEST RANCH A 495	422393168400	Monitor
WEST RANCH A 497	422393197600	P&A
WEST RANCH A 494	422393200700	Monitor
WEST RANCH A 501	422393200800	Monitor
WEST RANCH A 502	422393200900	Monitor
WEST RANCH A 508	422393201000	Monitor
WEST RANCH A 505	422393201200	P&A
WEST RANCH A 504	422393201300	OIL-Conventional
WEST RANCH A 503	422393201400	Monitor
WEST RANCH A 507	422393201500	P&A
WEST RANCH A 506	422393201600	P&A
WEST RANCH A 510	422393213100	Monitor
WEST RANCH A 509J	422393213401	Monitor
WEST RANCH A 511	422393213600	P&A
WEST RANCH A 512	422393220900	OIL-CO2
WEST RANCH A 513	422393221500	Monitor
WEST RANCH A 514	422393221600	Monitor
WEST RANCH A 515	422393222400	P&A
WEST RANCH A 516	422393223000	Monitor
WEST RANCH A 517	422393224900	WSW
WEST RANCH A 520	422393228600	Monitor
WEST RANCH A 518	422393235400	Monitor
WEST RANCH A 523	422393236800	Monitor
WEST RANCH A 519	422393237000	Monitor
WEST RANCH A 521	422393237200	P&A
WEST RANCH A 522	422393237800	Monitor
WEST RANCH Unit 1-1	422393241600	Monitor
TONEY 91	422393244500	Monitor
WEST RANCH A 524	422393245900	P&A
WEST RANCH Unit 1-2	422393251300	Monitor
WEST RANCH A 525	422393256600	P&A
WEST RANCH A 526	422393257400	P&A
WEST RANCH A 527	422393258100	Monitor
WEST RANCH A 528	422393258300	Monitor
WEST RANCH A 529	422393260100	OIL-Conventional
WEST RANCH A 531	422393260200	Monitor
WEST RANCH A 530	422393260400	Monitor
WEST RANCH A 533 H	422393270000	Monitor
WRSOGU 1-15	422393273500	Monitor
WRSOGU 1-14	422393276000	Oil-Conventional

DRUMMOND-SUPERIOR 8 (aka 3M-8)	422393289500	Monitor
WEST RANCH A 534 H	422393290600	Monitor
WEST RANCH A 535 H	422393290700	Monitor
WEST RANCH A 539 H	422393296000	Monitor
WEST RANCH A 538 H	422393296100	Monitor
WEST RANCH A 536	422393296200	P&A
WEST RANCH A 537 H	422393296300	Monitor
WEST RANCH A 540 H	422393314800	Monitor
WEST RANCH A 541 H	422393318900	WSW
WEST RANCH A 545 H	422393320700	Monitor
WRSOGU 1-17	422393353800	Oil-Conventional
ASHLEY ANN 1	422393356100	OIL-Conventional
WRSOGU 1-18	422393356300	Oil-Conventional
WRSOGU 1-19	422393356400	Oil-Conventional
DRUMMOND JH 3M	422393356900	OIL-Conventional
ASHLEY ANN 2	422393357600	OIL-Conventional
WEST RANCH A 600	422393358000	INJ
WEST RANCH A 601	422393358100	OIL-Conventional
ASHLEY ANN 3	422393358500	OIL-Conventional
WEST RANCH A 602	422393358600	Monitor
3M-2	422393358900	OIL-Conventional
3M-3	422393359900	Monitor
WEST RANCH A 1129	422393362600	INJ
WEST RANCH A 1131	422393362700	INJ
WEST RANCH A 1133	422393363200	INJ
WEST RANCH A 1104	422393363400	SI-CO2
WEST RANCH A 1089	422393363600	INJ
WEST RANCH A 1059	422393365200	OIL-CO2
WEST RANCH A 2119	422393365300	OIL-CO2
WEST RANCH A 1035	422393365400	INJ
WEST RANCH A 2057	422393365500	INJ
WEST RANCH A 1002	422393365600	OIL-CO2
WEST RANCH A 1036	422393365700	INJ
WEST RANCH A 1060	422393365800	INJ
WEST RANCH A 1061	422393365900	OIL-CO2
WEST RANCH A 1003	422393366000	INJ
WEST RANCH A 1004	422393366100	INJ
WEST RANCH A 2020	422393366200	OIL-CO2
WEST RANCH A 2052	422393366300	OIL-CO2
WEST RANCH A 2029	422393366400	INJ
WEST RANCH A 1005	422393366500	INJ
WEST RANCH A 1037	422393366600	INJ
WEST RANCH A 1007	422393366700	INJ
WEST RANCH A 1062	422393366800	INJ
WEST RANCH A 1006	422393366900	INJ
WEST RANCH A 2121	422393367000	OIL-CO2
WEST RANCH A 1038	422393367100	OIL-CO2
WEST RANCH A 1009	422393367200	INJ
WEST RANCH A 1008	422393367300	OIL-CO2
WEST RANCH A 2065	422393367400	OIL-CO2
WEST RANCH A 2021	422393367500	OIL-CO2
WEST RANCH A 1010	422393367600	OIL-CO2
WEST RANCH A 1011	422393367700	INJ

WEST RANCH A 1012	422393367800	INJ
WEST RANCH A 1013	422393367900	INJ
WEST RANCH A 2150	422393368100	OIL-CO2
WEST RANCH A 1014	422393368300	INJ
WEST RANCH A 1015	422393368400	INJ
WEST RANCH A 1016	422393368500	OIL-CO2
WEST RANCH A 1017	422393368600	INJ
WEST RANCH A 1019	422393368700	INJ
WEST RANCH A 1018	422393368800	INJ
WEST RANCH A 2030	422393368900	OIL-CO2
WEST RANCH A 2053	422393369000	OIL-CO2
WEST RANCH A 2055	422393369100	OIL-CO2
WEST RANCH A 1020	422393369200	OIL-CO2
WEST RANCH A 1039	422393369300	INJ
WEST RANCH A 1040	422393369400	INJ
WEST RANCH A 1063	422393369500	INJ
WEST RANCH A 1042	422393369600	INJ
WEST RANCH A 2159	422393369700	OIL-CO2
WEST RANCH A 2160	422393369800	OIL-CO2
WEST RANCH A 2164	422393369900	OIL-CO2
WEST RANCH A 1022	422393370100	INJ
WEST RANCH A 1023	422393370200	INJ
WEST RANCH A 1021	422393370300	INJ
WEST RANCH A 1024	422393370400	INJ
WEST RANCH A 1064	422393370500	INJ
WEST RANCH A 1065	422393370600	INJ
WEST RANCH A 1069	422393370700	INJ
WEST RANCH A 1070	422393370800	INJ
WEST RANCH A 1071	422393370900	INJ
WEST RANCH A 1072	422393371000	INJ
WEST RANCH A 1073	422393371100	INJ
WEST RANCH A 2048	422393371200	OIL-CO2
WEST RANCH A 2170	422393371300	OIL-CO2
WEST RANCH A 1041	422393371400	INJ
WEST RANCH A 2027	422393371800	OIL-CO2
WEST RANCH A 1066	422393371900	INJ
WEST RANCH A 2034	422393372200	OIL-CO2
WEST RANCH A 1044	422393372300	INJ
WEST RANCH A 1043	422393372400	INJ
WEST RANCH A 1117	422393372500	OIL-Conventional
WEST RANCH A 1116	422393372600	INJ
WEST RANCH A 1055	422393372700	INJ
WEST RANCH A 1056	422393372800	INJ
WEST RANCH A 1057	422393372900	INJ
WEST RANCH A 1113	422393373000	INJ
WEST RANCH A 1054	422393373100	INJ
WEST RANCH A 1053	422393373200	INJ
WEST RANCH A 1052	422393373300	INJ
WEST RANCH A 2047	422393373400	OIL-CO2
WEST RANCH A 2036	422393373500	OIL-CO2
WEST RANCH A 2169	422393373600	OIL-CO2
WEST RANCH A 2179	422393373700	OIL-CO2
WEST RANCH A 2118	422393373800	OIL-CO2

WEST RANCH A 1074	422393373900	INJ
WEST RANCH A 2184	422393374000	OIL-CO2
WEST RANCH A 2014	422393374100	OIL-CO2
WEST RANCH A 2168	422393374200	OIL-CO2
WEST RANCH A 2026	422393374300	OIL-CO2
WEST RANCH A 2028	422393374400	OIL-CO2
WEST RANCH A 2054	422393374500	OIL-CO2
WEST RANCH A 2180	422393374600	OIL-CO2
WEST RANCH A 2035	422393374800	OIL-CO2
WEST RANCH A 2037	422393374900	OIL-CO2
WEST RANCH A 2124	422393375000	OIL-CO2
WEST RANCH A 1045	422393375100	OIL-CO2
WEST RANCH A 2056	422393375200	OIL-CO2
WEST RANCH A 1067	422393375300	INJ
WEST RANCH A 1046	422393375400	INJ
WEST RANCH A 1075	422393375500	INJ
WEST RANCH A 2165	422393375600	OIL-CO2
WEST RANCH A 1110	422393375700	INJ
WEST RANCH A 2058	422393375800	SI-CO2
WEST RANCH A 2171	422393375900	OIL-CO2
WEST RANCH A 2172	422393376000	OIL-CO2
WEST RANCH A 2173	422393376100	OIL-CO2
WEST RANCH A 1026	422393376200	INJ
WEST RANCH A 1029	422393376300	INJ
WEST RANCH A 2151	422393376400	OIL-CO2
WEST RANCH A 2167	422393376500	INJ
WEST RANCH A 1076	422393376600	INJ
WEST RANCH A 1068	422393376700	OIL-CO2
WEST RANCH A 2187	422393376800	OIL-CO2
WEST RANCH A 1077	422393376900	INJ
WEST RANCH A 2051	422393377000	OIL-CO2
WEST RANCH A 1078	422393377100	INJ
WEST RANCH A 2120	422393377200	OIL-CO2
WEST RANCH A 2181	422393377300	OIL-CO2
WEST RANCH A 1079	422393377400	INJ
WEST RANCH A 2038	422393377500	OIL-CO2
WEST RANCH A 2040	422393377600	OIL-CO2
WEST RANCH A 1081	422393377700	INJ
WEST RANCH A 2039	422393377800	OIL-CO2
WEST RANCH A 1082	422393377900	INJ
WEST RANCH A 2045	422393378000	OIL-CO2
WEST RANCH A 1083	422393378100	OIL-CO2
WEST RANCH A 1080	422393378200	INJ
WEST RANCH A 2189	422393378400	OIL-CO2
WEST RANCH A 2190	422393378700	OIL-CO2
WEST RANCH A 2063	422393378900	OIL-CO2
WEST RANCH A 2062	422393379000	OIL-CO2
WEST RANCH A 2046	422393379100	OIL-CO2
WEST RANCH A 1106	422393379200	OIL-CO2
WEST RANCH A 1105	422393379300	OIL-CO2
WEST RANCH A 1048	422393379400	INJ
WEST RANCH A 1047	422393379700	OIL-CO2
WEST RANCH A 2061	422393379800	SI-CO2

WEST RANCH A 1107	422393379900	OIL-CO2
WEST RANCH A 2059	422393380000	OIL-Conventional
WEST RANCH A 2060	422393380100	OIL-Conventional
WEST RANCH A 1111	422393380200	SI-CO2
WEST RANCH A 1112	422393380300	SI-CO2
WEST RANCH A 2075	422393380400	SI-CO2
WEST RANCH A 1025	422393380700	INJ
WEST RANCH A 1028	422393380800	INJ
WEST RANCH A 2050	422393380900	OIL-CO2
WEST RANCH A 2166	422393381000	OIL-CO2
WEST RANCH A 1027	422393381100	INJ
WEST RANCH A 2001	422393381200	OIL-CO2
WEST RANCH A 2153	422393381300	OIL-CO2
WEST RANCH A 1030	422393381400	INJ
WEST RANCH A 1051	422393381500	INJ
WEST RANCH A 1050	422393381600	INJ
WEST RANCH A 2152	422393381700	OIL-CO2
WEST RANCH A 2009	422393381800	TA
WEST RANCH A 2010	422393381900	OIL-CO2
WEST RANCH A 2015	422393382000	OIL-CO2
WEST RANCH A 1090	422393382100	INJ
WEST RANCH A 2096	422393382200	OIL-CO2
WEST RANCH A 1058	422393382300	INJ
WEST RANCH A 1119	422393382400	INJ
WEST RANCH A 1120	422393382500	INJ
WEST RANCH A 2008	422393382600	OIL-CO2
WEST RANCH A 1092	422393382700	INJ
WEST RANCH A 1140	422393382800	INJ
WEST RANCH A 2094	422393382900	OIL-CO2
WEST RANCH A 1128	422393383000	INJ
WEST RANCH A 2174	422393383100	OIL-CO2
WEST RANCH A 1034	422393383200	INJ
WEST RANCH A 2193	422393383300	OIL-CO2
WEST RANCH A 2192	422393383400	OIL-CO2
WEST RANCH A 2191	422393383500	OIL-CO2
WEST RANCH A 2016	422393383700	OIL-CO2
WEST RANCH A 2017	422393383800	OIL-CO2
WEST RANCH A 2175	422393383900	OIL-CO2
WEST RANCH A 2176	422393384000	OIL-CO2
WEST RANCH A 2177	422393384100	OIL-CO2
WEST RANCH A 2127	422393384200	OIL-CO2
WEST RANCH A 2031	422393384300	OIL-CO2
WEST RANCH A 2032	422393384400	OIL-CO2
WEST RANCH A 2033	422393384500	OIL-CO2
WEST RANCH A 2049	422393384600	OIL-CO2
WEST RANCH A 1087	422393385300	SI-CO2
WEST RANCH A 2025	422393385400	OIL-CO2
WEST RANCH A 2041	422393385500	OIL-CO2
WEST RANCH A 2043	422393385600	SI-CO2
WEST RANCH A 1088	422393386000	INJ
WEST RANCH A 2125	422393386100	OIL-CO2
WEST RANCH A 2018	422393386200	OIL-CO2
WEST RANCH A 2196	422393386300	OIL-CO2

WEST RANCH A 2195	422393386400	OIL-CO2
WEST RANCH A 1121	422393386800	INJ
WEST RANCH A 1130	422393386900	INJ
WEST RANCH A 2092	422393387000	OIL-CO2
WEST RANCH A 2090	422393387100	OIL-CO2
WEST RANCH A 2197	422393387600	OIL-CO2
WEST RANCH A 2198	422393387900	OIL-CO2
WEST RANCH A 2019	422393388100	SI-CO2
WEST RANCH A 2073	422393388300	SI-CO2
WEST RANCH A 1109	422393388700	SI-CO2
WEST RANCH A 1154	422393389100	SI-CO2
WEST RANCH A 2089	422393390100	OIL-CO2
WEST RANCH A 1122	422393390200	INJ
WEST RANCH A 1123	422393390300	INJ
WEST RANCH A 1124	422393390700	INJ
WEST RANCH A 1125	422393390800	INJ
WEST RANCH A 2081	422393390900	OIL-CO2
WEST RANCH A 900 ST	422393392300	OIL-Conventional
WEST RANCH A 902	422393392400	OIL-Conventional
WEST RANCH A 904	422393393400	OIL-Conventional
WEST RANCH A 908	422393393600	OIL-Conventional
WEST RANCH A 500	422398062200	P&A
DRUMMOND JH 10	422398062400	P&A
VANDERBILT STATE 18	422398062700	P&A
VANDERBILT STATE 16	422398066500	P&A
TONEY 18	422398082200	P&A
TONEY 48	422398112500	P&A
VANDERBILT STATE 12	422398127200	P&A
WEST RANCH A 475	422398146700	P&A
WEST RANCH A 913	422393393800	OIL-Conventional
WEST RANCH A 912	422393393900	TA
WRSOGU 1-12	TBD	P&A
WRSOGU 1-13	TBD	P&A
WRSOGU 1-16	TBD	P&A
WRSOGU 1-20	TBD	P&A

Request for Additional Information: Petra Nova West Ranch Field
April 22, 2021

Instructions: Please enter responses into this table. Any long responses, references, or supplemental information may be attached to the end of the table as an appendix. Supplemental information may also be provided in a resubmitted MRV plan.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
1.	2.1	9	"Based on these conditions, PNPH believes that all reservoirs within the Project Interval at West Ranch can included under this MRV Plan as they are brought online." Please address grammatical issue. Should this read "can **be** included…"?	The sentence was corrected accordingly.
2.	2.3	11	"Anahuac Shale is a low-permeability confining layer that has served as a stratigraphic seal to upward migration of hydrocarbon throughout geologic term for many oil fields throughout the Gulf Coast region (Galloway and Cheng, 1985), and it serves as the secondary seal in addition to the individual confining layers overlaying each reservoir." Please address grammatical issue. Should this read "to **prevent** upward migration of hydrocarbons throughout geologic time…"?	The sentence was corrected accordingly.
3.	2.4	14	"It is particularly thin barrier-island sand body that was deposited before a local transgression terminating the "C" cycle of strandplain progradation." Please address grammatical issue. Should it read "It is **a** particularly…"?	The sentence was corrected accordingly.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
4.	2.4	14	"Well-developed upward-coarsening sequences in the 41-A reservoir at the West Ranch location, and sealed by lagoonal mudstones." This sentence is unclear. Please address.	The sentence was redrafted based on the original language in Galloway 1986: "Well-developed upward-coarsening sequences do not appear at the stratigraphic position of the 41-A reservoir for several miles farther basinward. Stratigraphic relationships suggest that much of the reservoir is overlain, and therefore sealed, by lagoonal mudstones deposited landward of a prograding barrier-sand complex."
5.	3.1	19	"They all have four-way dip anticline trapping mechanism;no faulting; primary confining layers over each injection zone; the existence of secondary confining interval (Anahuac Shale) in addition to individual confining layers overlying each reservoir; and, depleted reservoir pressure." Spacing issue identified. Please address.	The sentence was corrected accordingly.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
6.	3.2	25	"The Maximum Monitoring Area (MMA) includes both the AMA, the existing WRU plus the half mile buffer, and any future WRUs to be established at West Ranch for the purpose of CO2-EOR operation plus the half mile buffer." This description of the MMA with regard to future operations is not well-defined. If the intent is to develop the WRU into additional units, then we would anticipate that the MMA would include any areas expected to contain the free phase CO2 plume until the CO2 plume has stabilized plus an all-around buffer zone of at least one-half mile. Please clarify or amend the MRV plan to address this.	Although the actual future extent of WRU is unknown at this point, it should be confined within the boundary determined primarily by the oil-water-contact and structure of all reservoirs that could potentially be developed with CO2-EOR operation. The boundary plus ½ mile buffer was added as Figure 3.2 to show the MMA, and the description of Section 3.2 was changed as follows: "Based on the potential future expansion of WRU to conduct CO2 EOR operations in the currently flooded reservoirs and the other three reservoirs and sublayers within the Project Interval, the injection zone extends geologically along the outermost boundary of those reservoirs subject to CO2 EOR operation, which is primarily determined by oil-water-contact and structures (Figure 3.2). In accordance with 40 CFR §98.448-449, the Maximum Monitoring Area (MMA) will extend for the half mile buffer beyond the boundary."

7.	4	26-29	Subpart RR specifies that the MRV Plan address "Potential surface leakage pathways for CO2 in the MMA, and the likelihood, magnitude, and timing, of surface leakage of CO2 through these pathways." Although the MRV plan describes several leakage pathways, the discussion in Section 4 for some of the pathways does not describe likelihood or magnitude of surface leakage. Please revise the discussion throughout Section 4 to characterize potential surface leakage through the identified pathways and explain how the information presented supports these characterizations/conclusions.	The sections below were restated to address the comment. 4.2 Diffuse leakage through the Anahuac Shale The following sentence was added at the beginning and end of this section: (Beginning) "Diffuse leakage through the seals that lie above the reservoirs in the Project Interval is highly unlikely." (End) "Injection pressure is continuously monitored and unexplained changes in injection pressure that might indicate leakage would trigger investigation as to the cause." 4.3 Faults and Fractures The section was reconfigured by bringing the following statement at the top to clarify the characterization: "West Ranch is a roll-over anticline formed between two major growth fault zones (Figures 2.2.1, 2.2.2 and 2.2.3), and there is no major fault within the field (Baurenschmidt, 1962)." Additionally, the following statement was added at the end of this section: "As described in Section 2.8.2, all injection permits require that injected fluids be confined in the authorized reservoir, and injection at pressure exceeding fracture pressure is not allowed." 4.4 Natural and Induced Seismic Activity The following new paragraph was added at the end of section:

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
				"In the unlikely event that seismicity resulted in a pathway for material amounts of CO_2 to migrate from the injection zone, the monitoring provisions at other reservoir level would lead to further investigation as elaborated in Section 5.1." 4.5 Failure of Zonal Isolation in Existing Wells The following new paragraph was added at the end of section: "Based on the measures above, the risk of CO_2 leakage through existing wells is being mitigated through a monitoring and maintenance program that will provide early by detection ng of problems early that could materialize into a leakage event. Any potential CO_2 leakage would be identified and quantified through the monitoring provisions in Section 5.1." 4.6 Failure of Zonal Isolation in New Well Construction The first paragraph is reconfigured with additional wording to state as follows: "Well qualification and management are overseen by the TRRC. New wells are constructed to provide zonal isolation and are tested prior to use to determine that cement in the rock-casing annulus covers the required intervals and is of good quality; hence, the risk of failure of zonal isolation in new wells is low. In the event CO_2 leakage were to occur, it would be identified and quantified through the monitoring provisions in Section 5.1."

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
8.	4.7	29	"In the unlikely event of gas leakage from a reservoir flooded with CO2, the methods to quantify the amount of leakage usea appropriate engineering variables and standard estimation of releases." Spelling issue identified. Please change "usea" to "use".	The sentence was corrected accordingly.
9.	5	29-34	Subpart RR specifies that the MRV plan address "Strategies for detecting and quantifying potential CO2 leakages, and responding should leakages occur." The discussion in Section 5 should highlight how monitoring and quantification strategies correspond to the likelihood and risks identified in Section 4. The discussion in Section 5 provides little discussion concerning leakage from the subsurface and focuses mostly only on leakage through infrastructure. Are there additional pathways, beyond wells (such as faults and fractures), that will have corresponding strategies to detect and quantify leakage? Please revise and/or expand Section 5 to discuss strategies for detecting and quantifying leakages through all types of identified pathways.	The monitoring provision in Section 5 was meant to address all CO2 leakage through the potential pathways identified in Section 4. The first sentence in Section 5.1 was modified as below by adding the underlined wording: "Detection and quantification of any losses of CO2 in the subsurface through damaged or faulty well construction, or through any other potential pathways for CO2 leakage to the surface as identified in Section 4, can be done directly in active wells and shut-in wells."
10.	5.1	29	"To prevent upward mitigation of fluids" Should "mitigation" be replaced with "migration"?	The sentence was corrected accordingly.
11.	5.1.1	30	"As of December 31, 2020, there are 255 inactive wells completed in the Frio formation above the injection interval and in select zones above the impenetrable Anahuac Shale that are being used a pressure monitoring wells." Please fix grammatical issue to clear up concept. Should it be "used as"?	The sentence was corrected accordingly.

12.	5.1	30	"If pressure changes in a reservoir that is not intended to be energized or if there are any CO_2 releases from the subsurface, alarms are set up to be notified through SCADA into the control room. All the active alarms are followed up by the field personnel for further investigation and diagnostics." It is not clear how the volumes of CO_2 would be quantified in the case of such an event. Please elaborate.	The quantification methodology is added, and the section is reconstructed as follows: "Detection of any losses of CO_2 in the subsurface through damaged or faulty well construction, or through any other potential pathways for CO_2 leakage to the surface as identified in Section 4, will be done based on the monitoring information obtained from active wells and shut-in wells. Proactive pressure monitoring at active producing wells, active injection wells, and shut-in wells is done via installation of pressure gauges at the wellhead that access the tubing and casing with connections to the SCADA system. Pressure reading at the surface casing, production casing and tubing on these wells are captured multiple times each day. If pressure changes in a reservoir that is not intended to be energized or if there are any CO_2 releases from the subsurface, alarms are set up to be notified through SCADA into the control room. All the active alarms are followed up by the field personnel for further investigation and diagnostics. If a leakage is detected, Petra Nova will use an event-specific approach to quantify leaked amounts of CO_2. This might include the use of modeling, engineering estimates, or direct measurements, depending on the circumstance, to estimate the relevant parameters (e.g. flow rate, concentration, and duration of leakage) to quantify the leak volume. All permanently plugged and abandoned wells are plugged with cement and drilling mud with well tubulars cut off below the surface in accordance with regulatory requirements; however, as these wells are not equipped with pressure gauges, in the unlikely event of well leakage, the detection and quantification will be done indirectly from the pressure reading of surrounding wells that are perforated in the same or shallower reservoirs. In either case, detection of leakage in the subsurface will occur prior to release of CO_2 at the surface and will be

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
				used to prevent loss to the surface. In some cases, the leakage risk may be brine (not CO2); in other cases, loss of CO2 is into shallower zones of the subsurface."
13.	5.1.1	31	The legend in Figure 5.1.1 is difficult to read. Please address, for example, by enlarging.	The figure was corrected accordingly.
14.	6	35	"These inspection rounds provides the opportunity to identify issues early and address them proactively…" Grammatical issue identified. Please change "provides" to "provide".	The sentence was corrected accordingly.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
15.	7	36	"To account for specific conditions, PNPH proposes to modify the locations for obtaining volume data for the equations in 40 C.F.R. §98.443 as indicated below." Modification of equations in regulatory text is not allowed under the GHGRP. Is your plan to modify certain equations, or is your plan to use site-specific considerations? Please clarify.	Equations are not modified; our plan was to use site-specific consideration as stated in the paragraphs below. "The first modification addresses the propagation of error that would be created if volume data from meters at each injection well were utilized. This issue arises because each meter has a small but acceptable margin of calibration error, and this error could become significant if data were taken from the approximately 100 meters within West Ranch. As such, PNPH proposes to use the mass of Recycled CO2 from commercial quality flow meters at the inlet of RGCs combined with mass of CO2 Received (earlier referred to as Fresh CO2 and further defined below) to determine the mass of CO2 Injected into the subsurface (CO2I in the formula above). The mass of CO2 Produced (CO2P in the formula above) will be the same as Recycled CO2. The second modification addresses the concentration of CO2 Received. Figure 7 shows the planned mass balance envelope overlaid as a blue square onto the facility flow diagram originally shown in Figure 2.7.1. The envelope contains all of the measurements relevant to the mass balance equation except for CO2 Received, which is proposed to be measured at the custody transfer meter located in the vicinity of CCE (M1) as shown in Section 2.8.1."
16.	7.3	39	"7.3 Mass of CO2 Emitted by SurfaceLeakage" Spacing issue identified. Please address.	The title was corrected accordingly.
17.	9.3	41	"As stated earlier in Sections 2 and 3, the subsurface characteristics of the existing WRU for 98-A and 41-A reservoirs are are found in the other reservoirs…" Please remove second "are".	The sentence was corrected accordingly.

Petra Nova

West Ranch Field CO_2 Monitoring, Reporting and Verification (MRV) Plan

February 2021

Table of Contents

Contents

Introduction

The Petra Nova project is a commercial scale post-combustion carbon capture project utilizing an advanced amine-based absorption technology to capture at least 90 percent of the carbon dioxide (CO_2) from a nominal 240 MW equivalent flue gas slipstream diverted from the coal-fired Unit 8 (Unit 8) at NRG Energy, Inc.'s W.A. Parish Electric Generating Station (Carbon Capture Equipment (CCE)). The CCE is located southwest of Houston, Texas, in rural Fort Bend County, in the town of Thompsons, Texas. The captured CO_2, up to 4,717 metric tonnes (5,200 short tons) per day, is being dried, compressed, and transported via an 81-mile pipeline to the West Ranch oil field in Jackson County, Texas (West Ranch), where it is used in CO_2 enhanced oil recovery (EOR) operations. Petra Nova Parish Holdings LLC (PNPH), through its wholly-owned subsidiary Petra Nova CCS I LLC, owns the CCE. PNPH is a joint venture between NRG Energy, Inc. (NRG) and JX Nippon Oil and Gas Exploration Corporation (JX).

The CCE uses the Kansai Mitsubishi Carbon Dioxide Recovery Process, also known as KM-CDR Process®, an advanced amine-based CO_2 absorption technology jointly developed by Mitsubishi Heavy Industries, Ltd. and the Kansai Electric Power Co. Inc. The CCE achieved commercial operation on December 29, 2016 and represents the largest commercial-scale deployment of post-combustion CO_2 capture technology at a coal power plant to date.

The CCE has been capturing CO_2 since late 2016 and sending it to West Ranch. The working interest and capital equipment of the West Ranch is owned by Texas Coastal Ventures, LLC (TCV), a joint venture between Petra Nova LLC (a wholly-owned subsidiary of PNPH) and Hilcorp Energy I LP. TCV, through its wholly-owned subsidiary, TCV Pipeline, LLC, owns the dedicated 81-mile CO_2 pipeline between the CCE and West Ranch. Figure 1 outlines the ownership structure of the CCE and TCV.

Hilcorp Energy Company (Hilcorp) is the designated operator of West Ranch. It uses CO_2 captured at and transported from the CCE (Fresh CO_2) and CO_2 produced during the oil production process (Recycled CO_2) for EOR floods at West Ranch.

Petra Nova LLC (PN), a wholly owned subsidiary of PNPH and the 50 percent direct owner of TCV, and the indirect owner of West Ranch prepared this Monitoring, Reporting, and Verification Plan (MRV Plan). This MRV Plan and any related reporting will be managed by PNPH through PN on behalf of TCV, with the assistance of Hilcorp, as the operator of West Ranch, including the reporting to the U.S. Environmental Protection Agency (EPA) under its Greenhouse Gas Reporting Program (GHGRP), Subpart RR. Hilcorp will continue to report to the EPA under the GHGRP, Subpart W.

As part of the U.S. Department of Energy (DOE) grant to the CCE, a Monitoring, Verification and Accounting Plan (MVA Plan) was required to be developed and managed by PNPH during a 3-year demonstration period (2017-2019) starting after the commercial operation date of the CCE. PNPH contracted with the Bureau of Economic Geology at the University of Texas at Austin to develop and support the management of the MVA Plan. The DOE approved MVA Plan was deployed a year prior to the beginning of CO_2 injection (to develop a pre-flood baseline) and was in operation until the end of the DOE demonstration period at the end of 2019. The MVA Plan and the knowledge gained from operating under that plan supported the development of the MRV Plan described herein.

The mass balance accounting for determining the quantity of CO_2 stored conforms to the requirements in Subpart RR, and is consistent with the method used in the MVA Plan. The method, described in Section 7, uses metered volumes of CO_2 received, injected, and produced as well as quantified volumes of other CO_2 emissions and losses, if any.

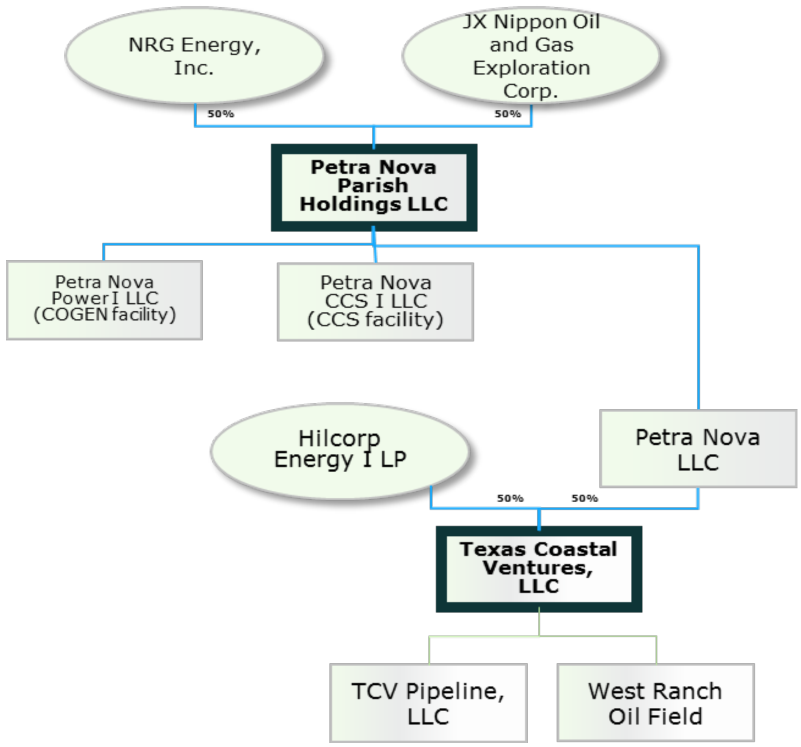


Figure 1 Ownership Structure

Current Status

The mass balance accounting under the MVA Plan started in March 2017, after the commissioning of the surface facilities at West Ranch. Through the end of 2020, the amount of CO_2 sequestered is listed below in metric tons. The difference between CO_2 delivered and CO_2 sequestered is the mass of CO_2 lost at the surface.

	CO_2 Delivered at West Ranch Metric Tons	**CO_2 Sequestered at West Ranch Metric Tons**
2017 (Mar-Dec)	909,419	904,757
2018	1,008,601	996,154
2019	1,386,987	1,373,958
2020	293,171	281,542
Total	**3,598,178**	**3,556,411**

MRV Plan Overview

This MRV plan contains twelve sections:

Section No.	Topic
1	Facility information
2	Project description. This section describes the overall project information; the geology, reservoir characterization and development history; the current operation and infrastructure including the CO_2 injection process; and the CO_2 storage capacity at West Ranch
3	Delineation of monitoring area and timeframes
4	Evaluation of potential pathways for CO_2 leakage to the surface
5	Site-specific risk-based monitoring
6	Determination of baselines
7	Determination of sequestration volumes using mass balance equations
8	MRV Plan implementation schedule
9	Monitoring QA/QC
10	Record retention
11	References
12	Appendices

1. Facility Information

a. Reporter number – 575661 Petra Nova West Ranch

b. The wells at West Ranch are permitted by the Texas Railroad Commission (TRRC), through TAC 16 Part 1 Chapter 3. The TRRC has primacy to implement the federal UIC Class II requirements and incorporated those provisions in TAC 16 Part 1 Chapter 3.

c. All wells at West Ranch are identified by name, API number, status, and type. A listing of the wells as of December 2020 is included in Appendix 2.

2. Project Description

2.1 Petra Nova Carbon Capture Facility and West Ranch Oil Field

When operating at 100 percent load, the CCE captures approximately 4,717 metric tons (5,200 short tons) per day from Unit 8 of NRG's W.A. Parish Power Station near Houston, Texas. The

captured CO_2 is compressed, dried, cooled, and transported to West Ranch via 81-mile long CO_2 pipeline. The CCE is the only source of CO_2 delivered for injection at West Ranch during the "Specified Period" as discussed below. West Ranch is located in southeast Texas in Jackson County near the town of Vanderbilt as shown in Figure 2.1.1.

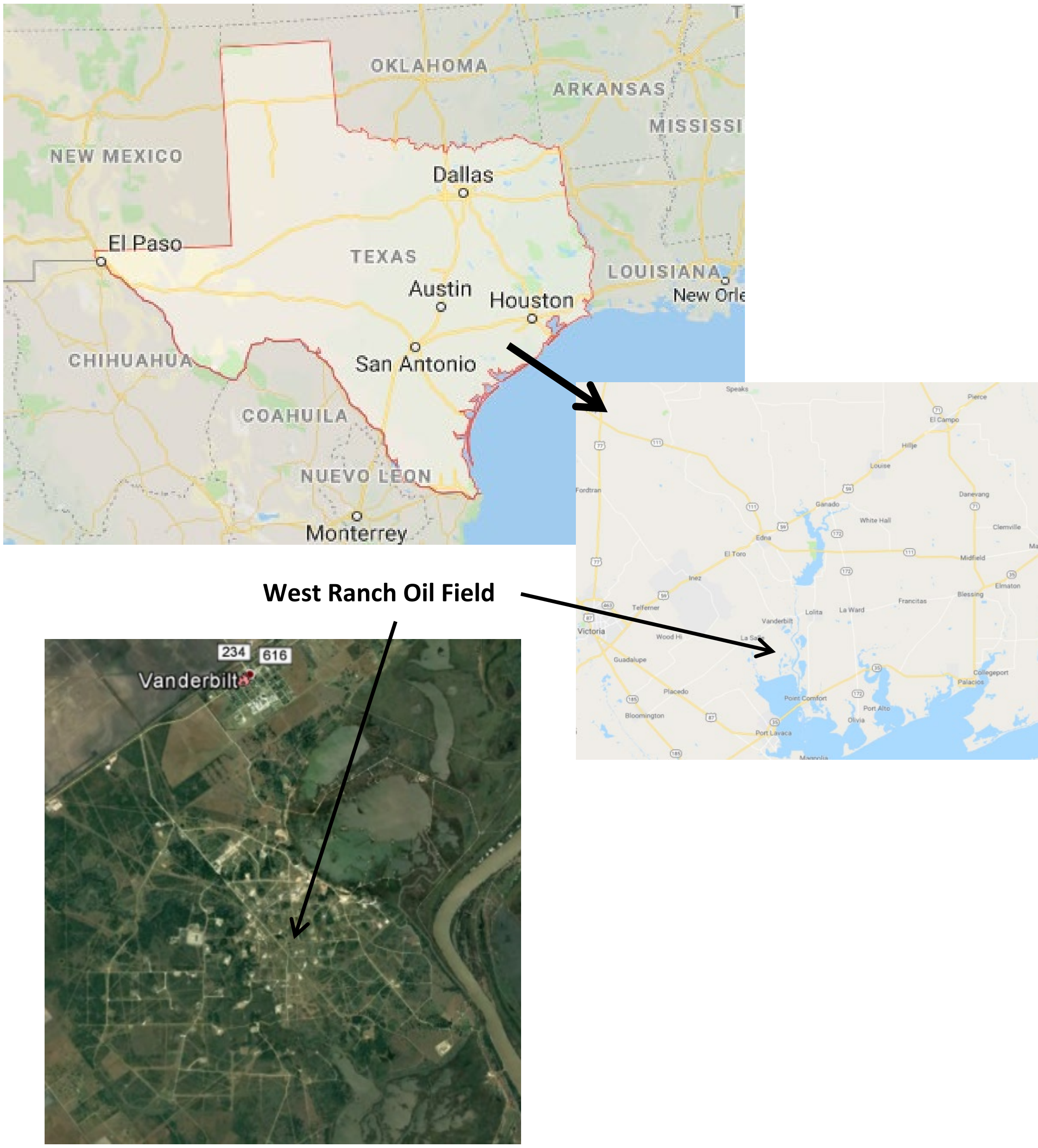


Figure 2.1.1 Location of the West Ranch Oil Field

The West Ranch Unit (WRU) boundary for the current CO_2 EOR operation that currently exists is delineated in Figure 2.1.2. The WRU was formed by consolidating portions of two Oligocene-age reservoirs, the 98-A and 41-A, within the Frio Formation.[1]

[1] The 98-A and 41-A zones are unitized as West Ranch 41-A/98-A (Consolidated) Unit in 2016 (O & G Docket No. 02-0299798).

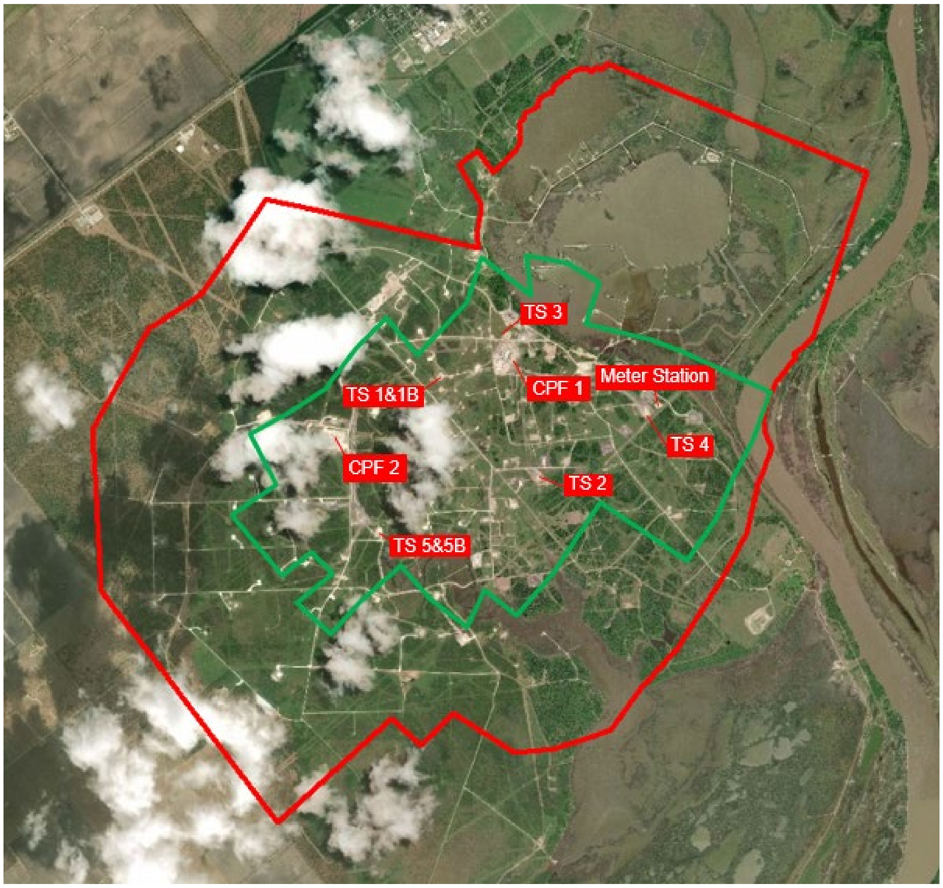


Figure 2.1.2 West Ranch Unit (41-A/98-A (Consolidated) Unit) Boundary (in Red)

CO_2 flooding was initiated in the 98-A reservoir in December 2016 and has been subsequently expanded horizontally. While the horizontal expansion of the 98-A reservoir is still ongoing, a vertical expansion into the 41-A reservoir, which lies immediately above the 98-A reservoir, began in 2018. The CO_2 EOR operations at West Ranch are planned to expand horizontally and vertically upward over time, including the CO_2 flooding of additional portions of the 98-A and 41-A reservoirs, and three additional reservoirs in the Frio Formation: Greta, Glasscock, and Ward. This MRV Plan anticipates the expansion into the entire interval between the base of 98-A reservoir and the base of the Anahuac Shale, a regionally contiguous and impermeable shale immediately above Frio Formation at West Ranch (Project Interval). In order to expand into the full Project Interval, Hilcorp, on the behalf of TCV, will obtain TRRC approval for certifications as tertiary recovery projects, unitization agreements, and permits to conduct fluid injection operations in each area of expansion in the Project Interval. The reservoirs in the Project Interval have similar geologic characteristics and PNPH will apply the same operational controls in each area of expansion. All of the injection zones in the Project Interval share the following characteristics:

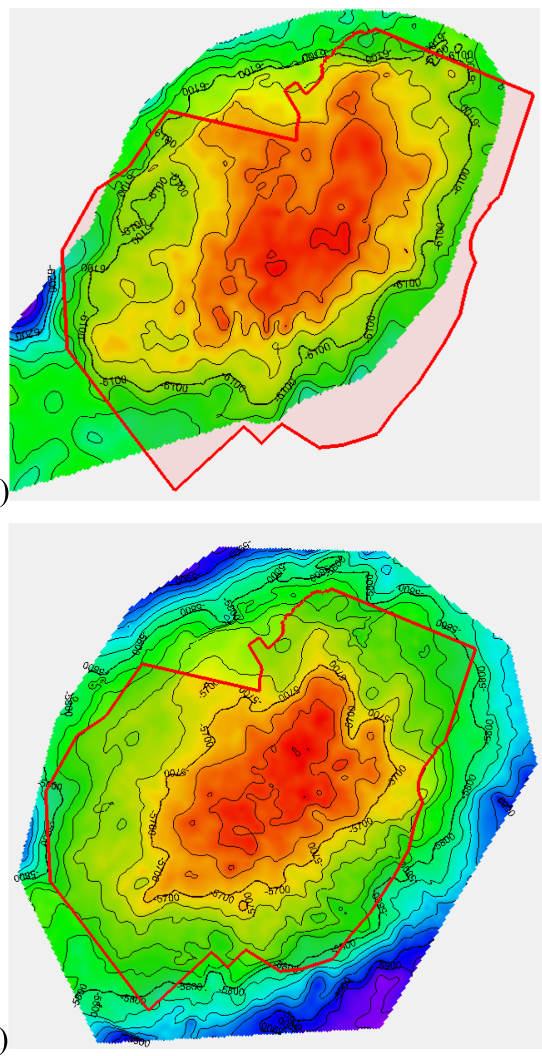
- four-way dip anticline trapping mechanisms,
- no faulting,
- presence of a primary confining intervals above each injection zone within the Project Interval and a secondary confining interval (Anahuac Shale) that overlays the entire project area, and

- depleted reservoir pressure.

The operational requirements that currently apply in WRU will also apply in the expansion zones. They include rules for injection wells such as the confirmation of nearby well condition, the periodic testing of casing integrity, the adequate cementing to confine fluids in the injection reservoir, and the monitoring and limitation of injection pressure. Based on these conditions, PNPH believes that all reservoirs within the Project Interval at West Ranch can included under this MRV Plan as they are brought online.

2.2 Petroleum Geology of West Ranch

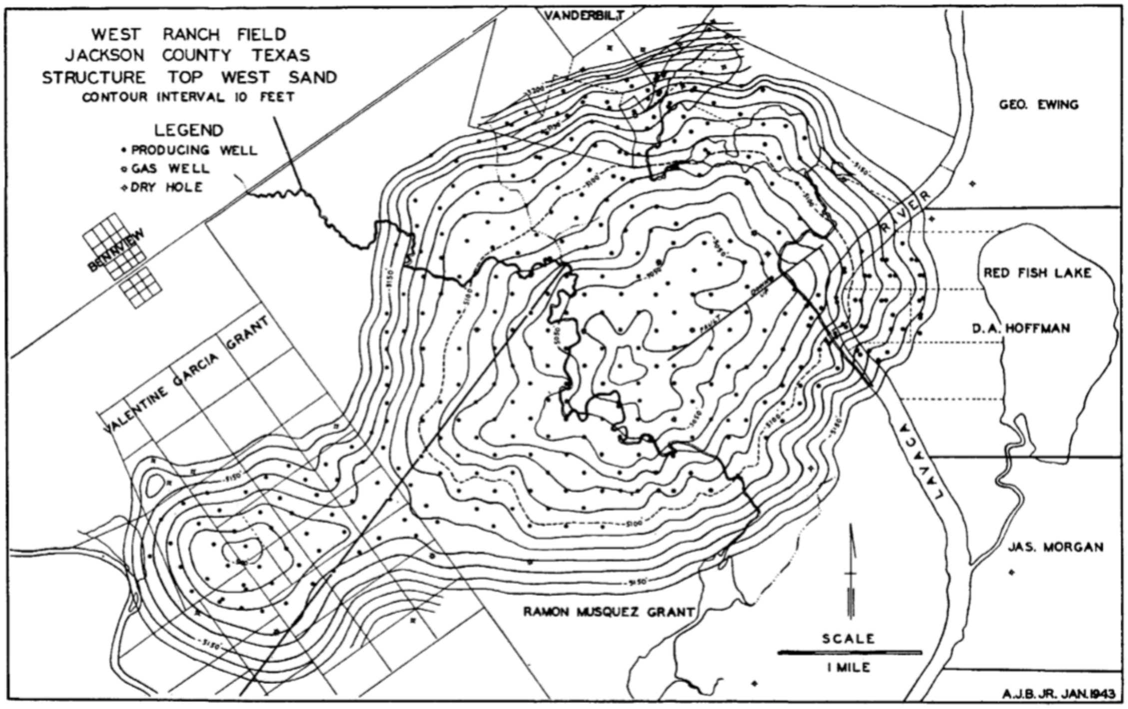
West Ranch is one of several oil fields located in the Gulf Coast Basin that shares the same petroleum system. West Ranch is formed on a gentle four-way anticlinal structure on a roll-over structure (Figures 2.2.1(a), 2.2.1(b), 2.2.2(a), and 2.2.2(b)) on the upthrown side of a northeast-southwest trending regional growth fault as shown in Figure 2.2.3.



(a)

(b)

Figure 2.2.1 Structure-contour map of West Ranch with the currently existing WRU boundary (41-A/98-A Consolidated) (red outline). Datum is the top of (a) 98-A and (b) 41-A reservoirs.

(a)


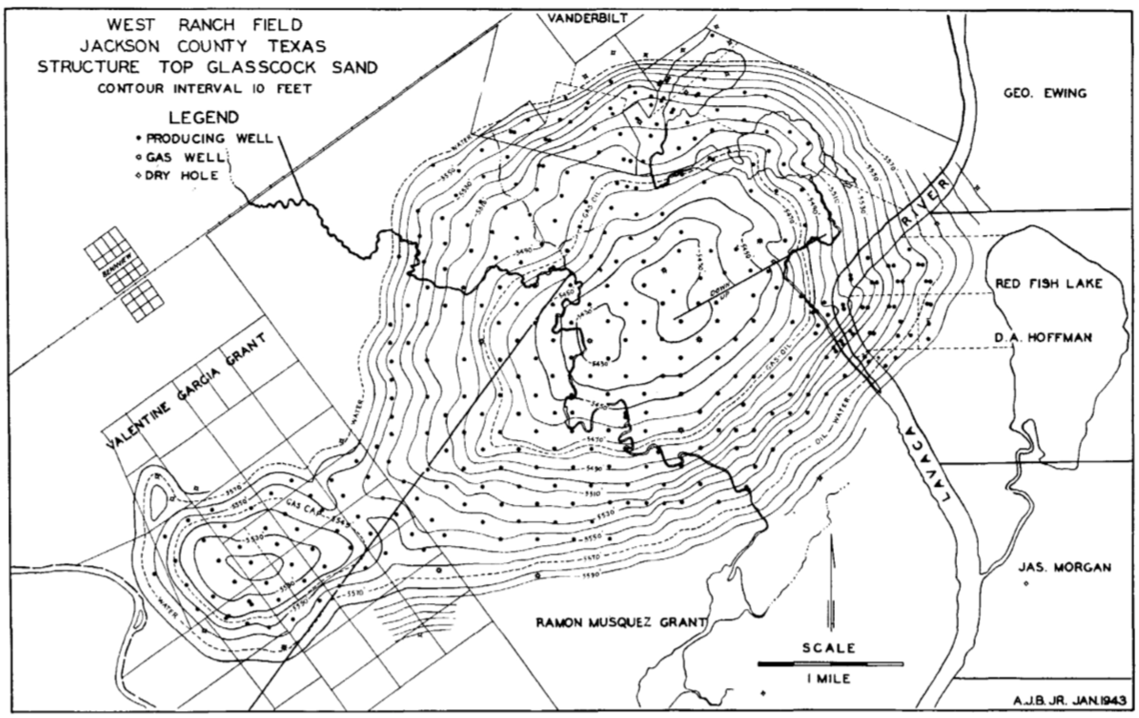
(b)


Figure 2.2.2 Structure-contour map of West Ranch. Datum is the top of (a) the Greta and (b) the Glasscock reservoirs (Baurenschmidt, 1944).

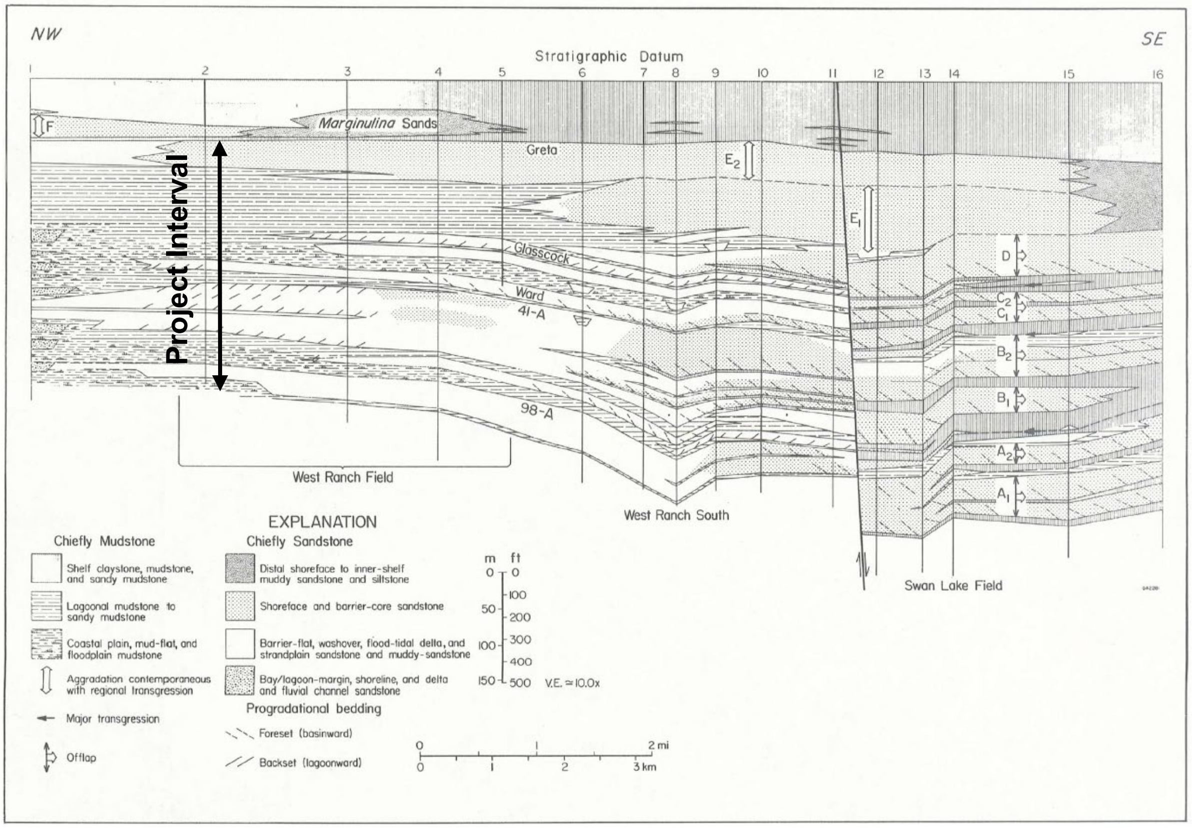


Figure 2.2.3 Regional cross section though West Ranch showing unfaulted structure.
From Galloway and Cheng, 1985

2.3 Stratigraphy of the West Ranch Oil Field Area

The generalized stratigraphic section illustration of geologic formations present at West Ranch is shown in Figure 2.3.1. The reservoir sandstones into which CO_2 is currently or planned to be injected at West Ranch include five reservoir sandstones in Frio Formation being the 98-A, 41-A, Ward (not shown on Figure 2.3.1), Glasscock, and Greta, from the deepest (6,200 feet) to the shallowest (5,100 feet). Each reservoir sandstone is separated by locally continuous low permeability and individually confining mudstones (Figure 2.3.2).

Anahuac Shale is a low-permeability confining layer that has served as a stratigraphic seal to upward migration of hydrocarbon throughout geologic term for many oil fields throughout the Gulf Coast region (Galloway and Cheng, 1985), and it serves as the secondary seal in addition to the individual confining layers overlaying each reservoir.

Above Anahuac Shale is a series of sandstones separated by shales collectively known regionally as Oakville Formation, and are also referred to as the Miocene Sands.

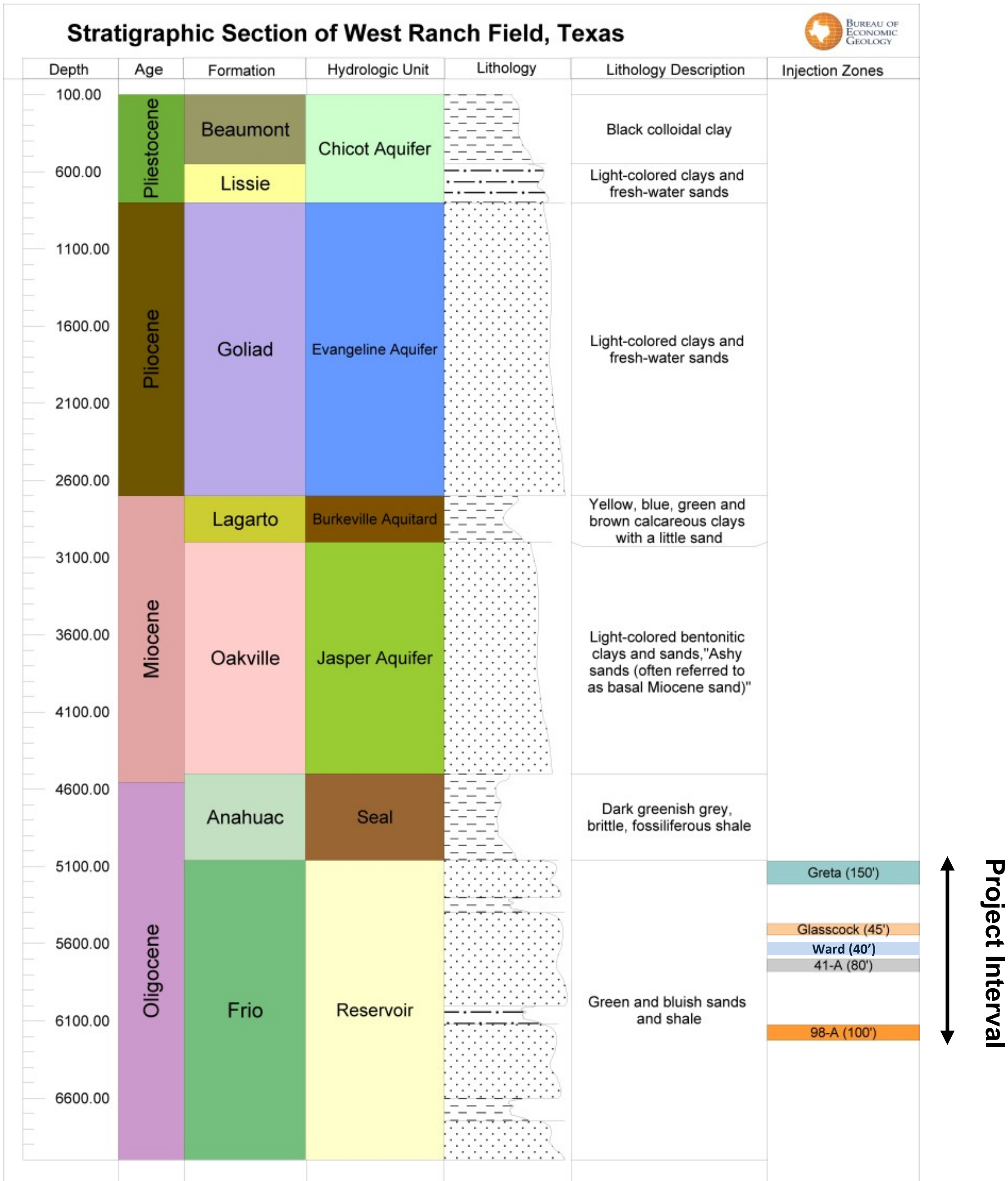


Figure 2.3.1 Generalized lithostratigraphic and hydrostratigraphic names for rocks/aquifers underlying West Ranch Oil Field. Depths shown correspond with those seen at West Ranch Oil Field.

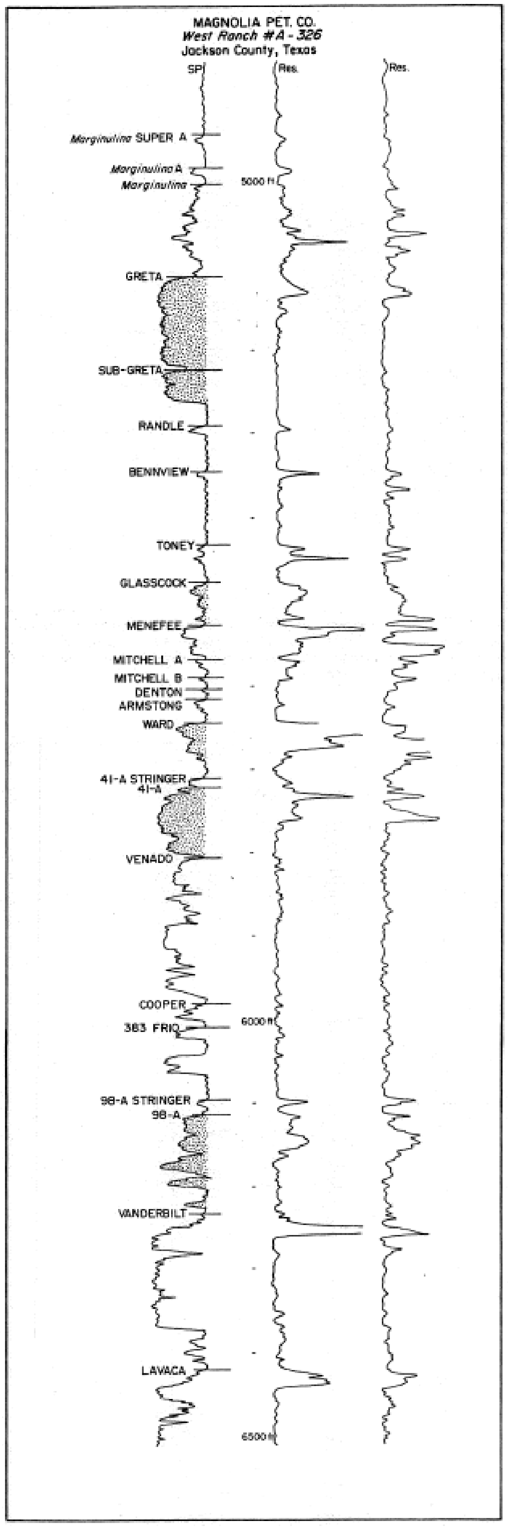


Figure 2.3.2 Type log for West Ranch Oil Field. After Galloway (1981) shows the entire injection zone for Project Interval. Current CO_2 EOR flooding is in the 98-A and 41-A, future expansion will be into the permeable zones (Ward, Glasscock, Greta). Each permeable zone is interspersed with non-permeable zones that serve as the primary confining layers. The secondary confining layer, the Anuhuac Shale is not marked on this Type Log.

2.4 Depositional Environment of the West Ranch Oil Field Area

The reservoirs of West Ranch are part of the extensively characterized Oligocene-aged Frio Formation in the barrier/strandplain system, located between the Houston and Norias Delta Systems (Galloway et. al., 1983) (Figure 2.4). The barrier/strandplain system is composed of the northeast-southwest elongated bodies of laterally deposited shoreline sands, similar to the Padre-Mustang-St. Joseph-Matagorda island complex of today.

Within the barrier/strandplain system, the barrier island and shoreface deposits, such as the Greta reservoir, are well sorted, continuous, sandy, and internally homogeneous as a result of their high-energy, shallow-marine depositional origin. The Glasscock reservoir is one of the most widespread reservoirs in the field. It is particularly thin barrier-island sand body that was deposited before a local transgression terminating the "C" cycle of strandplain progradation. The 41-A reservoir is a moderately thick sand body that occurs at the top of the widespread sand of the "B" cycle. Well-developed upward-coarsening sequences in the 41-A reservoir at the West Ranch location, and sealed by lagoonal mudstones. The 98-A and Ward reservoirs are both relatively thin progradational sand units (Galloway, 1986).

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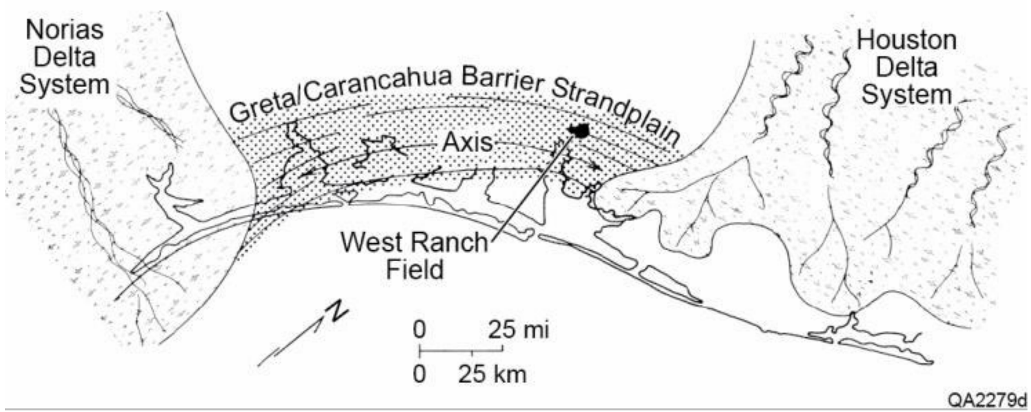

Figure 2.4 Oligocene (Frio) paleogeographic setting of Texas Gulf Coast, showing West Ranch Oil Field within Greta/Carancahua Barrier Strandplain System. Ambrose et al. (2008); modified from Galloway and Cheng (1985) and Galloway (1986).

2.5 Reservoir Characterization and Modeling

As previously discussed, PNPH, working with the BEG, developed and managed an MVA Plan that covered the three-year demonstration period that started on January 1, 2017 (aligned with the beginning of commercial operations of the CCE). As a part of the MVA Plan, reservoir modeling was used to characterize the currently existing WRU reservoirs, 98-A and 41-A, to develop a detailed understanding of each reservoir as well as the predictability of internal reservoir architecture including the behavior of CO_2 in the course of CO_2 EOR operation. In general, the modeling was successful in demonstrating that the pressure elevation and the movement of CO_2 plume in the reservoirs are managed by the operational strategies, and the reservoirs have the capacity to permanently retain the injected CO_2 volume within the structural trap for prolonged period after the cessation of CO_2 EOR operation. Going forward, PNPH does not plan to develop detailed models for additional reservoirs, but will draw on a set of transferable principles from this modeling effort.

Reservoir modeling is the major predictive tool that determines the capacity of the subsurface to accept CO_2. Numerical simulation models are used to model the spatial extent of the CO_2 plume in the subsurface, which demonstrates that, under given assumptions and operational strategies, CO_2 is remaining within the targeted area. The numerical simulation modeling starts by building static reservoir models. The tops and bases of target sandstones and major seals are defined with well logs. The model is then constructed based on rock properties interpreted from Spontaneous Potential and Gamma-Ray logs, and to a limited extent, core sample studies at West Ranch. Rock properties (including permeability, porosity, rock, and fluid saturations) were also assigned based on available data through literature review and historical field measurements. This allowed us to populate the static reservoir model with appropriate rock type, porosity, and permeability distributions.

A numerical simulation model of the 98-A and 41-A reservoirs was constructed based on the static geologic model as well as fluid properties (fluid compositions and PVT (pressure-volume-temperature) data) from the field, to develop a dynamic numerical model to history match the production and pressure data of the field, and to simulate the current and future performance of the field. The numerical model is developed using a compositional simulator. In compositional simulations, three phases (water, oil and gas) with multiple components were defined. Relative permeability data, available through literature survey and special core analysis, was used as input in the simulations. Thermodynamic properties of the specific fluids in this field were tuned and modeled in a fluid characterization software.

The porosity and permeability maps of the model are shown in Figure 2.5.1 and 2.5.2.

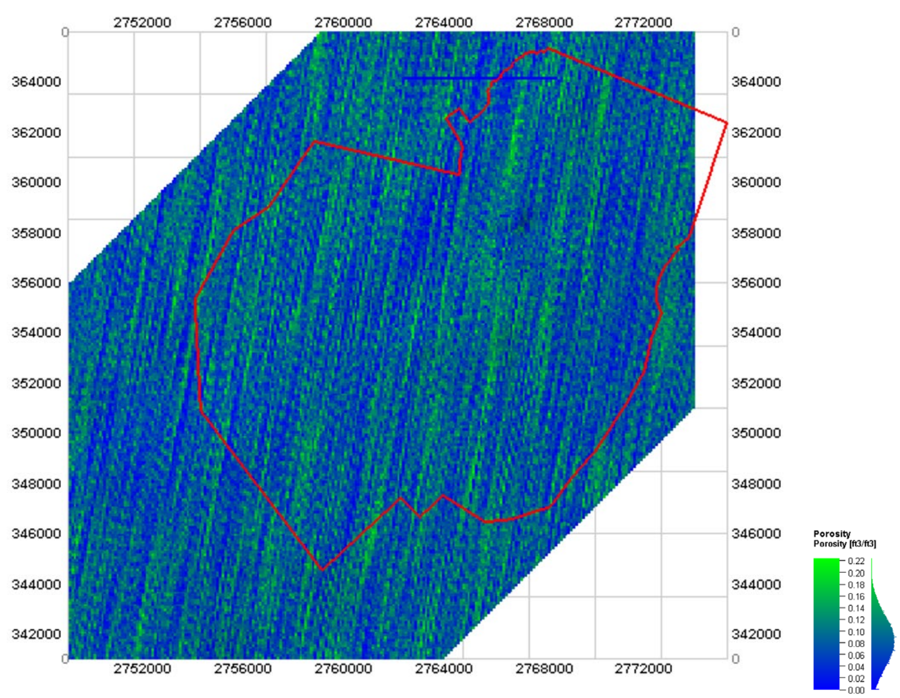

Figure 2.5.1 Porosity distribution of 98-A input into the numerical simulation model with 41-A/98-A Consolidated Unit (red)

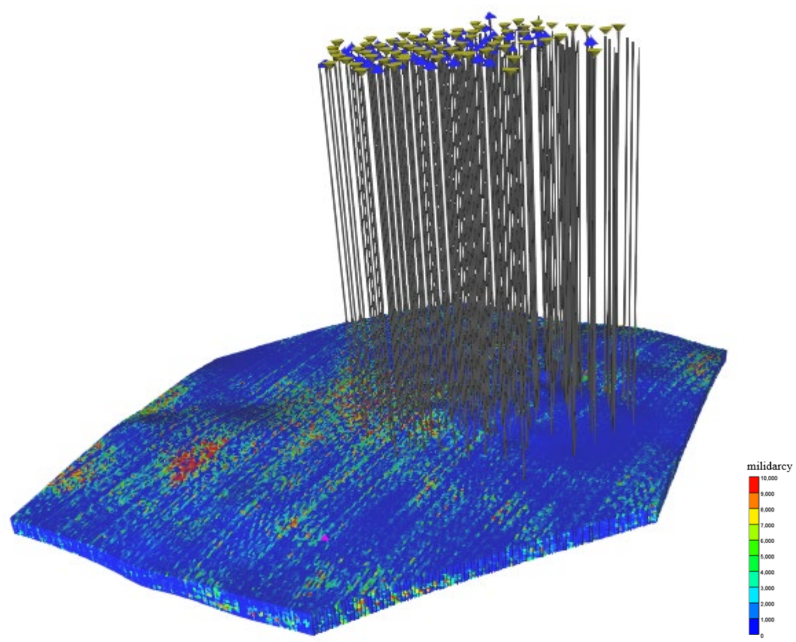

Figure 2.5.2 Location of EOR operation wells and horizontal permeability of 98-A input into the numerical simulation model.

The expected pressure and the gas saturation fields in 98-A reservoir as of March 2020 based on the simulation model, with the best history match until September 2019 and porosity and permeability fields above, are shown below (Figure 2.5.3 to Figure 2.5.4). Overall results show that the pressure values remain within the intended range and below the fracturing pressure. Gas saturations are larger around the injection wells and mostly remained in the intended patterns.

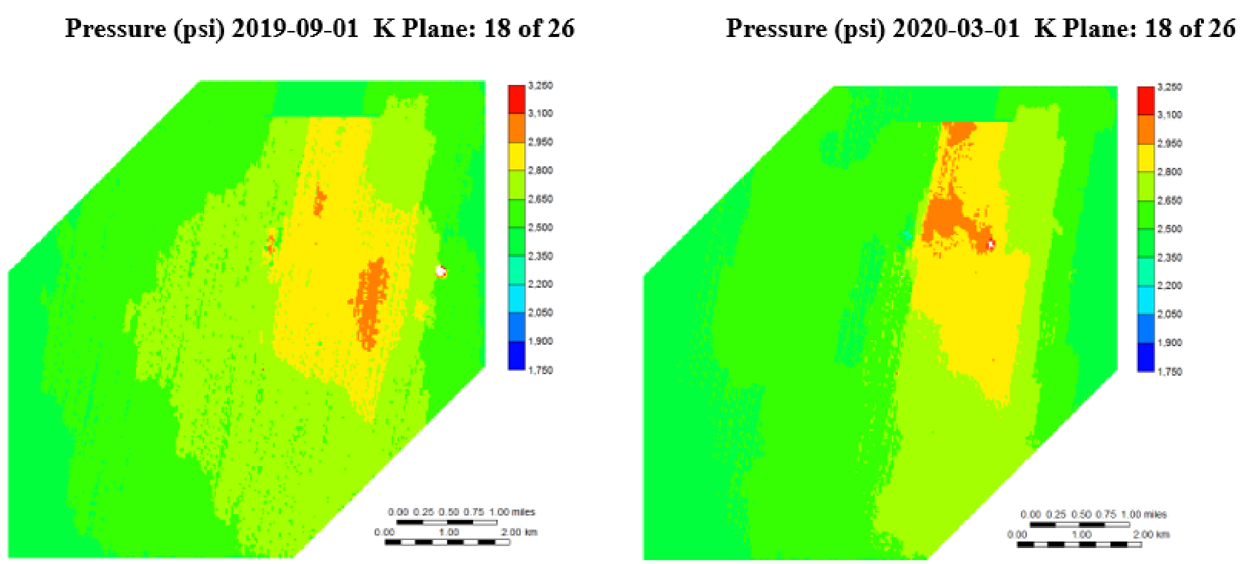

Figure 2.5.3 Pressure field at 98-A reservoir in (a) September 2019 and (b) March 2020.

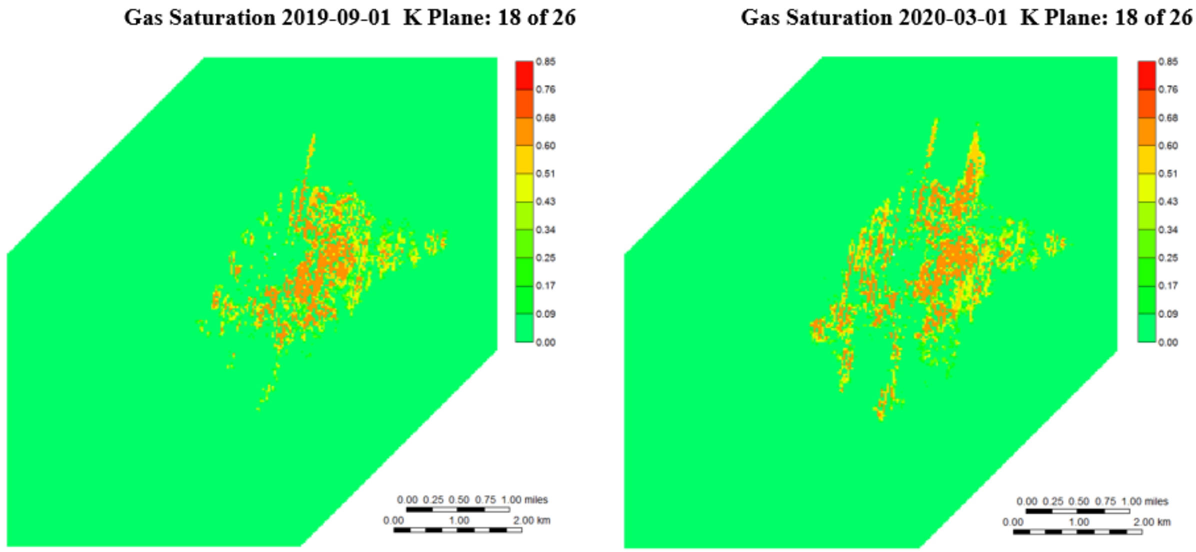

Figure 2.5.4 Gas saturation at 98-A reservoir in (a) September 2019 and (b) March 2020.

The long-term simulation was also run through 2040, and the result shows that CO_2 was accumulated at the crest of structure and within the intended area (Figure 2.5.5).

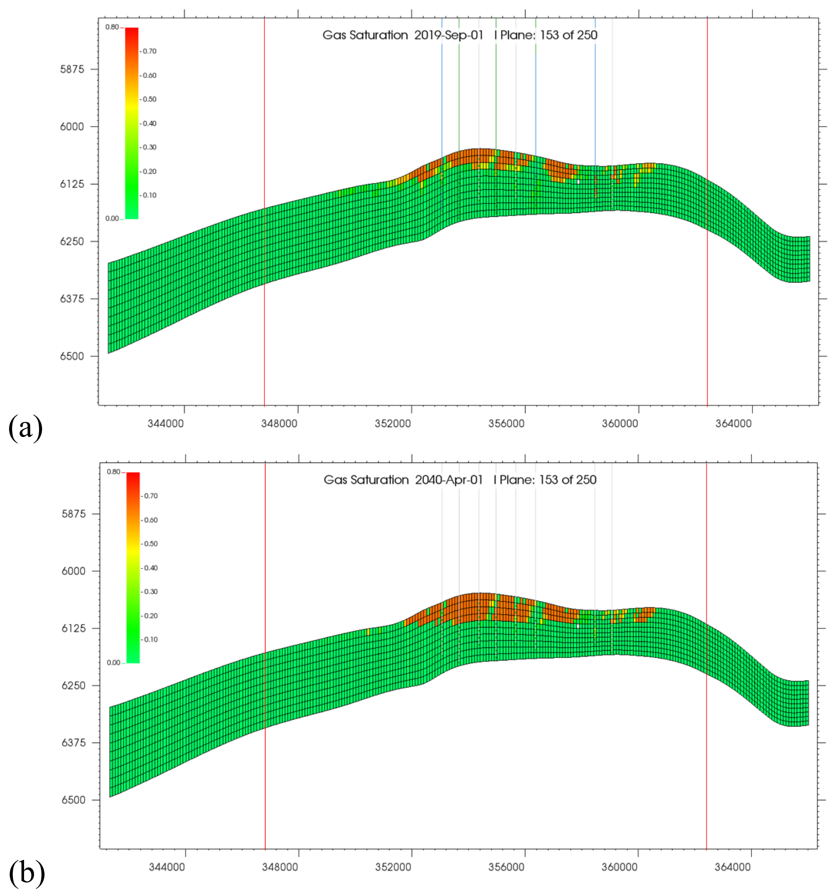

Figure 2.5.5 Demonstration of gas migration after CO_2 flooding. Gas saturation at 98-A reservoir in (a) September 2019 and (b) April 2040 with 41-A/98-A Consolidated Unit (red)

2.6 Development of West Ranch Oil Field, Primary and Secondary Production

West Ranch was discovered in 1938. The main reservoirs at West Ranch (Greta, Glasscock, Ward, 41-A, and 98-A) are porous and permeable, averaging more than 27 percent porosity and 400 mD permeability. The description of the discovery and the original conditions of main producing reservoirs, and the oil field operations including hydrocarbon production and brine injection, are described in this section. Besides the five main producing sands, 79 additional minor reservoirs have been classified as producing sands by the TRRC.

A primary gas cap in contact with the oil zone was present upon discovery in all main oil-producing reservoirs, indicating vertical hydraulic isolation of each sand zone. These reservoirs were originally produced with a gas-cap expansion and/or a natural water drive. Glasscock and Ward reservoirs were constituted from oil-rim reservoirs with gas caps as large as one-third of the volume, and 95 percent of the energy was attributable to the expansion of their gas caps (Galloway and Cheng, 1985). On the other hand, Greta, 41-A, and 98-A reservoirs are mainly energized by strong natural water drive.

In most of the water-injection programs, water was injected into reservoirs along the periphery of their gas caps to maintain reservoir pressure and to prevent expansion of the gas cap into the oil-bearing zone (Galloway and Cheng, 1985).

Cumulative oil production in the main reservoirs as of 2010 is provided in Table 2.6.1.

Reservoir	Discovery Date	Cum. Prod. (MMSTB)
Greta	1938	101.3
41-A	1940	99.5
98-A	1940	59.2
Glasscock	1939	45.8
Ward	1939	30.4

Table 2.6.1 Cumulative oil production of major West Ranch reservoirs from TRRC (2010)

Original conditions, such as fluid contact depths, water saturation, and solution gas ratio are listed in Table 2.6.2, along with average rock and fluid properties.

	Greta	Glasscock	Ward	41 A	98 A
Gas-Oil contact, ft ss	5,065	5,475	5,705	5,690	6,070
Oil-Water contact, ft ss	5,105	5,570	5,735	5,750	6,140
Average porosity, %	30	27	30	30	31
Average permeability, md	1,200+	400	1,200	1,700	500
Original pressure, psia	2,350	2,560	2,650	2,625	2,795
Reservoir temp, °F	160	166	171	171	178
Oil gravity, API	24.7	31.6	30.6	31.1	40.4
Solution gas ratio, scf/stb	306	440	451	500	671

Table 2.6.2 General reservoir data and original conditions of main West Ranch sands (Bauernschmidt, 1962)

Initial pressures found in West Ranch indicate an original hydrostatic pressure gradient of approximately 0.53 psi/ft (Figure 2.6.1). Kreitler and Akhter (1990) gathered and plotted nearly 17,400 pressure values from a commercial database to study the complex hydrologic regimes of the Texas Gulf Coast region. Two major gradients are observed: (1) a formation water hydrostatic regime (0.465 psi/ft) that reaches depths of 11,000 ft, and (2) a geopressured regime as shallow as 7,000 ft. Both have been extensively depleted by production, although the original profile can be identified by plotting the maximum pressures. The West Ranch pressure gradient is not geopressured but is slightly steeper than the average hydrostatic gradient for freshwater in the area (Figure 2.6.2(a)). A current pressure profile from the A-600 well in 2012, the injection location for a recent CO_2 injection test, is imposed over the Kreitler and Akhter (1990) Gulf Coast pressure profile for comparison (Figure 2.6.2(b)). The A-600 well profile shows strongly depleted zones, likely resulting from past production of reservoirs that lacked good connection to water drive. In contrast, the pressure of Greta, 41-A and 98-A reservoirs indicates the strong natural water drive as mentioned above.

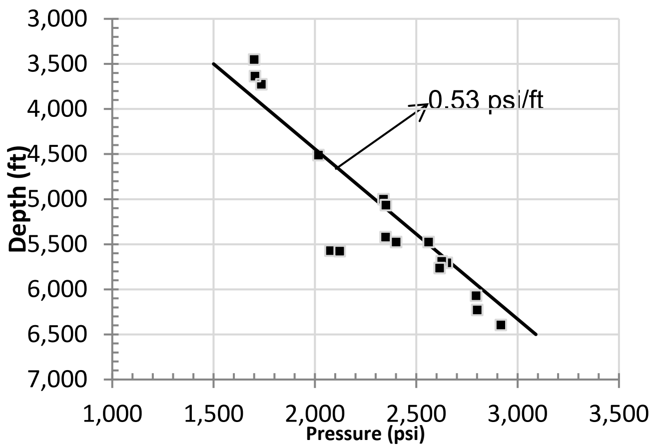

Figure 2.6.1 West Ranch hydrostatic pressure gradient. Adapted from Bauernschmidt (1962)

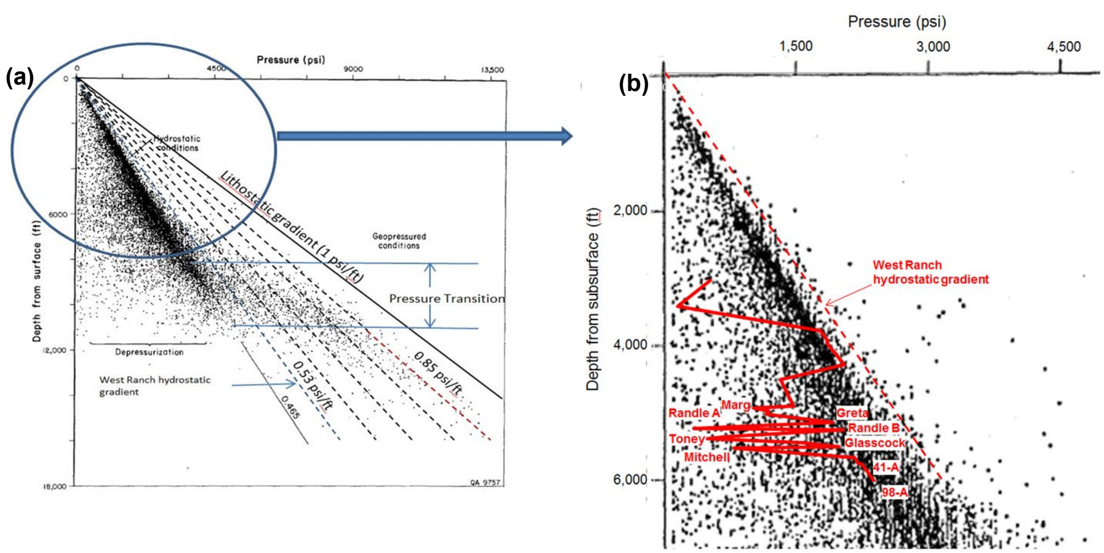

Figure 2.6.2 (a) Gulf Coast pressure profile. Pressure measurements from drill-stem tests (DST) and bottom-hole pressures, adapted from Kreitler and Akhter (1990), and (b) Current West Ranch pressure profile in red at A-600 well plotted against Gulf Coast pressure profile

2.7 Regulatory Process

Prior to commencement of any underground injection for CO_2 EOR purpose, TCV must submit a permit application and obtain approval from the TRRC. Texas Administrative Code (TAC) Title 16 Part 1 §3.46 governs fluid injection into reservoirs productive of oil, gas, or geothermal resources. The information required in the application include the data concerning the project, the subject reservoir and the well(s); and the geographic description of area covered by the project. The technical requirements include: the isolation from usable-quality water by 250 feet of low permeability strata, the area of review (AoR) to determine if all abandoned wells within one-quarter (1/4) mile radius of the proposed well have been properly plugged, the cementing interval for surface and production casings, the packer setting depth, the injection pressures, and in certain areas, a seismicity review. Notice of application must be given to parties affected or who may be affected by implementation of the project and local regulatory bodies, and public notice is also made. There is an opportunity for hearing should there be a protest. After the approval of permit, it is required to perform a mechanical integrity test before injection, and periodically thereafter; and to file a completion report and an annual injection report.

Unitization is necessary to conduct CO_2 EOR operation at reservoirs which straddle multiple tracts with separate and divergent ownership interests, primarily to determine the participation formula of interest owners. Unitization is subject the TRRC approval; similar information is required and a similar procedure is employed as with the injection permitting. The project must satisfy all of the requirements set out in Texas Natural Resources Code Title 3 Subtitle C Chapter 101, including that unit operations are necessary to increase ultimate recovery from the reservoir or prevent waste, that correlative rights of interest owners are protected, and that the additional cost involved does not exceed the additional recovery anticipated. The approval is also made subject to receiving the injection permits.

There are also economic incentives to conduct CO_2 EOR operations in Texas, particularly those with anthropogenic CO_2. There is a severance tax on crude oil, and using CO_2 grants a 50 percent reduction in that severance tax rate by obtaining a project certification under TAC Title 16 Part 1 §3.50, and it is further lowered by additional 50 percent, to 25 percent of the original rate, if anthropogenic CO_2 is used and the certification under TAC Title 16 Part 1 Subchapter C is obtained. The TRRC must approve a measurement, monitoring and verification program for stored anthropogenic CO_2, and the certification is issued only if the TRRC finds that at least 99 percent of the CO_2 sequestered will remain sequestered for at least 1,000 years.

The current CO_2 EOR operations in the WRU for 98-A and 41-A reservoirs have gone through all the regulatory process as stated in this section, and the same process will be followed when the development area in West Ranch expands either horizontally outside of the existing WRU, or vertically upwards to Greta, Ward, Glasscock or other sub-layers.

2.8 Description of CO_2 EOR Project Facilities and the Injection Process

2.8.1 West Ranch Facility Description

The following two figures illustrate the CO_2 EOR process at West Ranch. Figure 2.8.1 is a generalized facility flow diagram and Figure 2.8.2 shows the location of all facilities within the WRU boundary.

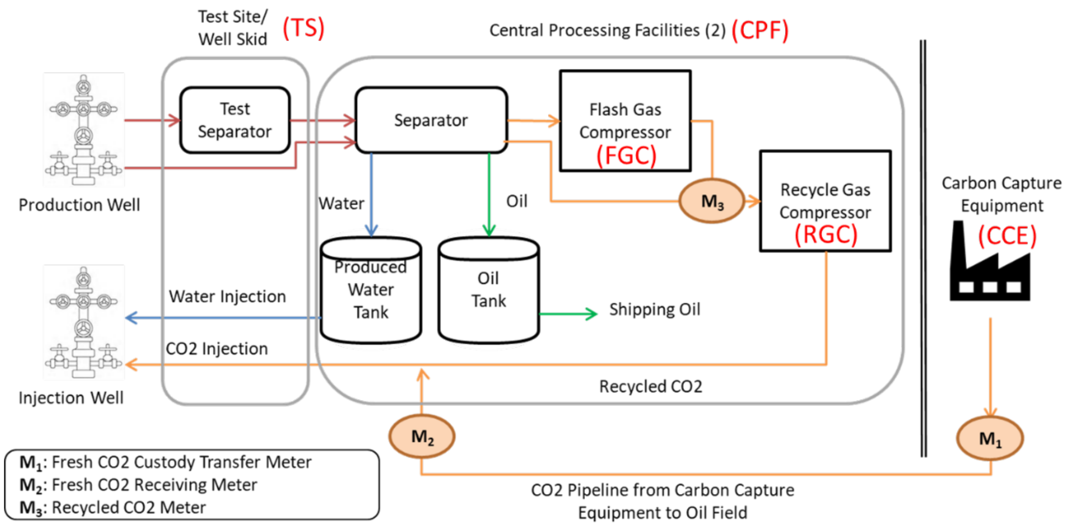

Figure 2.8.1 Facility Flow Diagram

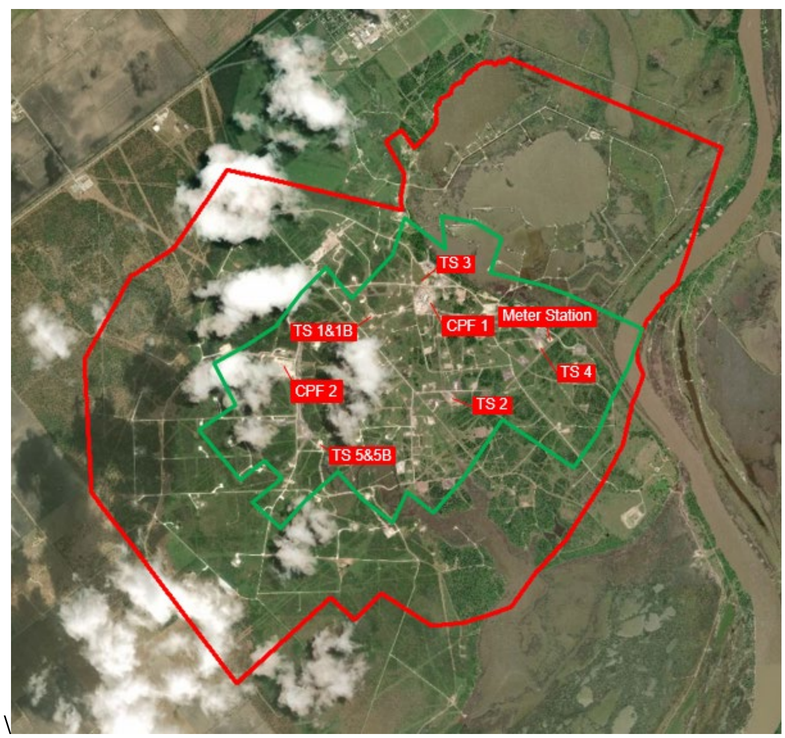

Figure 2.8.2 Locations of current Meter station, Central processing facilities (CPF1 and CPF2) and Test Sites (TS) at West Ranch. Locations within this footprint may change over the life of the project. WRU boundary (red) and current flood area (green)

1. Central Processing Facility (CPF)

   There are two CPFs at West Ranch (CPF1 and CPF 2 on Figure 2.8.2). Produced fluids (water, oil, and gas) are separated in the high/intermediate/low pressure water knock-out drums and separators in the CPFs.

   a) The water is mainly separated from gas and oil in the water knock-out drums, then reinjected into the field through injection wells with make-up water from water source wells.

b) The oil is separated from gas in the separators, settled in tanks for few days, then metered and sold.

c) The produced gas, which consists of CO_2 and reservoir hydrocarbon gas, is transferred to flash/recycle gas compressors (FGC/RGC). High and intermediate pressure gas is directly transferred to the RGC. Low pressure gas is compressed by the FGC then transferred to RGC.

2. Test Site (TS)

There are five TSs (TS 1-5 on Figure 2.8.2) and two extended TSs (TS 1B and 5B on Figure 2.8.2) in the field as of year-end 2020. Produced fluids from the production wells are aggregated at one of the five TSs. Each TS consists of a three-phase test separator, which measures production rates of oil, water and gas from each production well at least once per month. This data is not used in the mass balance accounting, but is used to allocate produced fluid to wells and for production optimization. Produced fluid from the individual production wells gathered at the TSs is transferred to one of the two CPFs through high/intermediate/low pressure production lines.

3. CO_2 Injection Process

Fresh CO_2 is captured at the CCE and transported to West Ranch via the CO_2 pipeline, and the flow is metered at the metering station at West Ranch (M_2). The concentration of Fresh CO_2 applicable to calculate the mass of CO_2 received at West Ranch is measured at the custody transfer meter located in the vicinity of CCE (M_1 on Figure 2.8.1). Fresh CO_2 received from the CO_2 pipeline and Recycled CO_2 from the RGCs at the CPFs, the volume and concentration of which is measured at M_3, are comingled and sent through the CO_2 distribution pipeline system to injection wells throughout the field.

All of the processes at West Ranch are monitored by the Supervisory Control and Data Acquisition (SCADA) system located on site, which is staffed 24 hours and alarmed to alert operators of any abnormalities. As the CO2 flood expands into the entire Project Interval, new injection areas will be tied into this system using the same or equivalent equipment.

2.8.2 Wells at West Ranch Oil Field

As of December 2020, there are 257 active wells at West Ranch; 155 are producing wells, 91 are injection wells, and 11 are water sourcing wells. Appendix 2 lists these wells with well identification numbers. All of the wells in the field are operated by Hilcorp. Table 2.8.2 shows these well counts at West Ranch by status.

Well Count	Active	Shut-in	Temporarily Abandoned	Plugged and Abandoned
TOTAL	257	277	2	389

Table 2.8.2 West Ranch Well Count

TRRC rules govern well siting, construction, operation, maintenance, and closure for all oil field wells. The TRRC granted authority to inject CO_2 in permitted wells after application, notice and hearings. TRRC requirements are found at TAC Title 16 Part 1 Chapter 3 and Chapter 5[2] and include:

- Fluids must be constrained in the strata in which they are encountered;
- Activities governed by the TRRC rules cannot result in the pollution of subsurface or surface water;
- Adherance to specified casing, cementing, drilling well control, and completion requirements designed to prevent fluids from moving from the strata encountered into strata with oil and gas, or into subsurface and surface waters;
- Filing of a well completion report including basic electric log (e.g., a density, sonic, or resistivity (except dip meter) log run over the entire wellbore);
- Equipping wells with a Bradenhead valve, measuring the pressure between casing strings using the Bradenhead gauge, and following procedures to report and address any instances where pressure on a Bradenhead is detected;
- Following plugging procedures that require advance approval from the TRRC and allow consideration of the suitability of the cement based on the use of the well, the location and setting of plugs;
- Corrosion monitoring under TAC Title 16 Part 1 §5.305(1) (D) is met by alternative monitoring through continuous SCADA monitoring in all wells;
- Using corrosion resistant alloy (CRA) for facilities which are exposed to CO_2; and
- Conducting Casing Integrity Tests annually as required under TAC Title 16 Part 1 §5.305(1)(C).

All changes in status of wells are in compliance with TRRC rules and all new changes in status of facility equipment are in compliance with TRRC rules. Any changes in wells including new wells and plug & abandonment would go through TRRC approval and be included in the annual report to EPA.

2.9 Storage Capacity Calculation

During the injection of CO_2 and water for CO_2 EOR operations, fluids will move from injection wells toward the production wells following the pressure trends. At the end of CO_2 EOR operations, the reservoir fluids will be in equilibrium based on their gravity difference where lighter fluids, likely gases, will move toward the top of the formation below the seal of each reservoir (see Section 2.5, Reservoir Characterization and Modeling). The estimated total amount of the CO_2 that can be sequestered in these reservoirs is based on the available pore

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[2] TRRC rules can be found online at:
https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=3&rl=Y and https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=5

space at each of the reservoirs. Though the available pore space is considered to be the entire pore space from top of the reservoir to the spill point, for purpose of this calculation, the original oil and gas in place of each reservoir is assumed as the available pore space, and further, only down to the shallower of spill point or oil water contact. The oil water contacts are above the spill points in 41-A and Greta reservoirs; hence, the pore space accounted for those two reservoirs are only down to the oil water contact. The oil water contacts are below the spill points in 98-A, Ward, and Glasscock.

The following equation was used to estimate the storage capacity:

$$CO_2\ Storage\ Capacity = HCPV * E * \rho CO_2$$

where:

HCPV = *Hydrocarbon pore volume above oil water contact or a spill point of the south-west structure.*

E = *Efficiency factor.*

ρCO_2 = *CO_2 density at reservoir pressure and temperature.*

Based on the numerical simulations conducted by BEG, the CO_2 occupancy of the pore space at the end of the CO_2 EOR operation is calculated. These calculations assume a 50 percent efficiency factor, and results are tabulated in Table 2.9.1.

Reservoir	Storage capacity (MM metric ton)
Greta	12.35
Glasscock	6.35
Ward	10.10
41-A	10.74
98-A	8.52
Total	**48.06**

Table 2.9.1 West Ranch field CO_2 storage capacity in different reservoirs (metric tons)

At reservoir conditions of West Ranch, the five main target reservoirs could hold about 919 Bscf (48.06 million metric tonnes) of CO_2 in the reservoir based on the original oil and gas in place. PNPH forecasts that 20 years of CO_2 EOR operations would result in sequestered CO_2 occupying approximately 61 percent of the calculated storage capacity.

3. Delineation of Monitoring Area and Timeframes

3.1 Active Monitoring Area

As discussed in sections 2.1 through 2.4, the subsurface characteristics of the existing WRU for 98-A and 41-A reservoirs are similar to the characteristics in the other reservoirs within the Project Interval at West Ranch. They all have four-way dip anticline trapping mechanism;no faulting; primary confining layers over each injection zone; the existence of secondary confining interval (Anahuac Shale) in addition to individual confining layers overlying each reservoir; and, depleted reservoir pressure. Expansion into the full Project Interval will require PNPH to obtain approval for unitzation and permits for injection from TRRC, as explained in sections 2.7 and 2.8. In addition, the reservoir simulation effort carried out as part of DOE's MVA Plan and the storage capacity calculation as illustrated in sections 2.5 and 2.9 demonstrated the viability of the Project Interval for a long-term CO_2 retention. Because CO_2 is retained within the WRUs, the Active Monitoring Area (AMA) is the existing WRU boundary of 41-A/98-A (Consolidated) Unit, as depicted in Figure 2.1.2, plus the half mile buffer. When a new WRU for CO_2-EOR operation is established, either for the currently flooded reservoirs or for the other three reservoirs and sublayers within the Project Interval, AMA will be expanded to cover the boundaries of those new WRUs, plus the half mile buffer. In addition to the aforementioned reason, the following factors are considered in defining this boundary:

- CO_2 injected into West Ranch reservoirs remains contained within the unit boundary because of the fluid and pressure management, which includes: the practice of targeting the maintenance of an injection and withdrawal ratio (IWR) of 1.0, which assures a stable reservoir pressure; and the managed leaseline water injection and production wells that are used to retain CO_2 and fluids within the unit boundary. The effectiveness was demonstrated by the history matching and reservoir simulation effort in section 2.5 as it demonstrated that the movement of CO_2 plume was largely contained within the intended patterns and the elevation of reservoir pressure was maintained within the intended range.
- Over geologic timeframes, sequestered CO_2 will remain in the respective unit boundaries, and will not migrate downdip, because of the higher elevations of the WRUs compared to other part of the corresponding reservoirs in the same structure as described in Figure 2.2.1 and 2.2.2.

3.2 Maximum Monitoring Area

The Maximum Monitoring Area (MMA) includes both the AMA, the existing WRU plus the half mile buffer, and any future WRUs to be established at West Ranch for the purpose of CO_2-EOR operation plus the half mile buffer.

3.3 Monitoring Timeframes

The primary purpose for injecting CO_2 is to produce oil that would otherwise remain trapped in the reservoir. During the Specified Period, PNPH will have a subsidiary purpose of establishing the long-term containment of a measurable quantity of CO_2 at West Ranch. The Specified Period will be shorter than the period of production from West Ranch. This is in part because the purchase of Fresh CO_2 for injection is projected to taper off significantly before production ceases at West Ranch. At the conclusion of the Specified Period, PNPH will submit a request for discontinuation of reporting. This request will be submitted with a demonstration that the cumulative mass of CO_2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage. See 40 CFR §98.441(b)(2)(ii).

4. Evaluation of Potential Pathways for CO_2 Leakage to the Surface

4.1 Introduction

The subsurface characteristics at West Ranch are very well known as a result of exploration, production, and recurrent reevaluation for optimization of production, including the recent reevaluation for CO_2 EOR and monitoring activities under the MVA Plan. The presence of thick oil and gas accumulations in the subsurface of West Ranch provides strong evidence that the mudstones that separate the sandstones are effective in isolating buoyant fluids, and provides assurance that injected CO_2 will be effectivity trapped. Further evidence of effective confinement of fluids is the sustained pressure depletion of some zones after production.

This MRV Plan considered the following potential leakage pathways:

- Diffuse leakage through the Anahuac Shale
- Faults and fractures
- Natural and induced seismic activity
- Failure of zonal isolation in existing wells
- Failure of zonal isolation in new well construction
- Drilling through the CO_2 area
- Lateral migration outside the West Ranch Oil Field
- Pipeline/surface equipment

4.2 Diffuse leakage through the Anahuac Shale

There are a number of sections above the sand reservoirs in the Project Interval that are impermeable and serve as reliable barriers to prevent fluids from moving upwards towards the surface. These barriers are referred to as seals because they effectively seal fluids into the formations beneath them. In addition, Anahuac Shale was deposited over much of the Gulf Coast during a major regional transgression. It serves as a major confining unit that traps hydrocarbons. It is also widely used as a top seal for Class I disposal operations in the Gulf Coast area. Anahuac Shale is more than 120 feet thick in the West Ranch area, and a 30-foot core collected at the A-600 well has been examined in detail to characterize the quality of this confining layer (Lu et al 2014). It is composed of silty clay (average 56 percent clay) and has permeabilities of 0.0006 to 0.0026 mD. Gas chemistry shows that gas migration is limited by diffusion and adsorption, and confirms that Anahuac Shale is an effective seal which will not allow diffuse leakage of CO_2 above the Project Interval.

4.3 Faults and Fractures

The Gulf Coast region is faulted by systems of growth faults (active during sediment accumulation) and by structures associated with deep-seated and piercement salt structures, which have been extensively characterized by exploration. Because the overall section is dominated by mudstones, fault permeability is controlled by clay smear. The sealing nature of faults is evident at many hydrocarbon fields that are fault-bounded. However, West Ranch is a roll-over anticline formed between two major growth fault zones (Figures 2.2.1, 2.2.2 and 2.2.3). There is no major fault in the field (Baurenschmidt, 1962). Gulf Coast sandstones and mudstones are typically not fractured but deform without rupture by bending and smearing.

4.4 Natural and Induced Seismic Activity

Although the Gulf Coast has been and is still locally undergoing deformation related to loading and continued subsidence of the Gulf Basin, the area is not seismically active. Deformation occurs without producing earthquakes. The United States Geological Survey (USGS) long term seismic risk map puts the entire Gulf Coast area, including West Ranch, in the lowest risk category (United States Geological Survey, 2014).

Risk of induced seismicity at West Ranch is low for several reasons: 1) magnitude of pressure increase and the area where pressure elevated is aggressively managed by balancing injection and withdrawal rates, 2) the reservoirs are underpressured as a result of past production, 3) high permeability and rapid fluid cycling though the reservoir create little risk of developing local overpressure, and 4) the operation is compliant with regulations limiting injection pressure.

In addition, the application for a new injection well permit or an amendment of an existing injection well permit for injection pressure, injection rate, or injection interval must include a survey of historical seismic events within 5.64 miles, the Area of Interest (AOI). A seismic event of 2.0 Magnitude (M) or greater from the USGS earthquake catalog or the TexNet earthquake catalog triggers seismicity review and requires additional geologic information across the AOI for the TRRC to consider the necessity of a permit disposition.

4.5 Failure of Zonal Isolation in Existing Wells

Wells are required to be constructed and either plugged and abandoned or maintained so the injection and production zones are isolated from other zones and from fresh groundwater (underground sources of drinking water or USDW). West Ranch contains many legacy wells; hence, the operator invests in well qualification and management. Well qualification and management are overseen by the TRRC.

TRRC rules call for periodic Mechanical Integrity Testing (MIT). Continuous monitoring devices tracking injection rate, pressure, and volume (as well as continuous monitoring of the annulus with a pressure gauge) are installed in line with the requirement. These monitoring tools conform to the TRRC requirements under TAC Title 16 Part 1 §5.305(1)(B) and used to protect against the high cost from loss of well control. All pressure gauges are hooked up to a real time reporting SCADA system. The SCADA monitoring system uses set points to trigger an alarm if there is more than a 10 percent change in pressure. In addition, periodic injection profiles are performed on the injection wells, and this will include running temperature surveys on the injection wells. Reservoir pressure is also measured through the injection wells when workovers are performed.

While the CO_2 EOR operation is conducted, injection profile logs are run to determine where the injected fluid is going. A profile provides a comprehensive picture of what is going on down hole in an injector. An injection profile package is made up of numerous surveys. The tool used is made up of numerous components such as a radioactive tracer, spinner logs, temperature logs, caliper logs, and collar logs. The temperature survey looks for anomalies which can indicate if there is fluid loss during injection. A tracer tool monitors the reduction in tracer material as it moves down the well and could indicate channeling and help in quantifying the amount of a release if one is found. A spinner gives the rate and a shut-in temperature survey indicates fluid losses and events occurring inside and outside the well bore.

In addition, a Reservoir Saturation Tool (RST) is run to measure hydrocarbon and water saturations behind casing. This tool could indicate if the injected fluid is going out of the targeted interval and into another zone. Baseline RST has been run on six wells.

An exhaustive study of all existing wellbores at West Ranch was carried out prior to CO_2 flood to confirm well condition and integrity. All of the plugged and abandoned wells at West Ranch have plugs to prevent the upward migration of fluids. Most wells have numerous plugs in the Frio formation isolating the deeper zones. All shut-in and producing wells in West Ranch were also reviewed, and numerous shut-in wells are used for its active pressure monitoring program throughout the field as described in Section 5.1.1.

Additionally, the TRRC requires an applicant for an injection well permit to examine the data of record for wells that penetrate the proposed injection reservoir within one-quarter (1/4) mile radius of the proposed well to determine if all abandoned wells have been plugged in a manner that will prevent the movement of fluids into strata other than the authorized reservoir for injection (AoR). Hilcorp currently reviews all wells located within one-half (1/2) mile radius of a proposed injection well.

4.6 Failure of Zonal Isolation in New Well Construction

New wells are constructed to provide zonal isolation and are tested prior to use to determine that cement in the rock-casing annulus covers the required intervals and is of good quality. Risk of failure of zonal isolation in new wells is therefore low. Well qualification and management are overseen by the TRRC.

All of the injection wells for the CO_2 EOR operation are newly drilled wells or conversion of existing wellbores and must adhere to the TRRC requirements as described elsewhere herein including Section 2.8.2. All of the injection wells have coated tubulars to withstand corrosion. Both the surface and production casing strings are cemented back to the surface, with a confirmation through a cement bond log of a full column of cement behind the casing.

For producing wells for CO_2 EOR operation that are newly drilled, these wells are drilled and completed to deal with corrosion, including coated tubulars and corrosion inhibiting fluid in the annulus between the tubing and the long string casing to prevent corrosion. Both surface and production casings are cemented to surface.

4.7 Drilling through the CO_2 Area

A future drilling initiative within the existing or future WRU to extend the current CO_2 flood area or to drill into a deeper reservoir creating an inadvertent leakage pathway is possible; however, such risk is considered to be very low. As previously stated , all wells drilled in the West Ranch Oil Field are regulated by the TRRC (specifically under TAC Title 16 Part 1 §3.13) which includes (a) ensuring that the casing is securely anchored to effectively control the well at all times, (b) all usable-quality water zones be isolated and sealed off to effectively prevent contamination or harm, and (c) all productive zones, potential flow zones, and zones with corrosive formation fluids be isolated and sealed off to prevent vertical migration of fluids behind the casing, including gases. Multiple reservoirs at West Ranch Oil Field are gas charged, and all drilling to each reservoirs must be done with proper preparation to contain gas within such reservoirs (e.g., using well control mechanisms such as dense drilling mud, blow out preventers, and completion to isolate zones). In the unlikely event of gas leakage from a reservoir flooded with CO_2, the methods to quantify the amount of leakage usea appropriate engineering variables and standard estimation of releases.

4.8 Lateral Migration outside West Ranch Oil Field

As illustrated in Figures 2.2.1 and 2.2.2, the West Ranch Oil Field contains the highest elevation of both current and future reservoirs for CO_2 flooding within the surrounding area. It is highly unlikely that injected CO_2 will migrate downdip and laterally outside of the existing and future WRUs because CO_2 is less dense than oil and water in the reservoir. As a result, the CO_2 tends to migrate and accumurate at the top of geological structure. The well-defined structural closure based on well logs and oil-water contact provides a strong control on the lateral extent of the CO_2 plume, and the volume of injected CO_2 will be less than the storage capacity of each reservoir. CO_2-oil miscibility also strongly minimizes possible lateral CO_2 transport distance.

4.9 Pipeline/Surface Equipment

Surface infrastructure is under surveillance on daily basis. Any releases of CO_2 from either planned events or unplanned incidents is being quantified and reported following the requirement of Subpart W of EPA's GHGRP or based on appropriate engineering variables and standard estimation of releases as stated in Section 5.2. The past three years of surveillance show that the release volumes less than one percent of the captured CO_2. Confidence in surveillance is high, because release of even small amounts of CO_2 leakage is highly noticeable, as dense CO_2 flashes result in large volume increases and strong cooling, resulting in noise and a cloud, ice, or condensed water.

5. Site-specific Risk-based Monitoring

5.1 Losses through Subsurface Infrastructure

Detection and quantification of any losses of CO_2 in the subsurface through damaged or faulty well construction can be done directly in active wells and shut-in wells. To prevent upward mitigation of fluids, all permanently plugged and abandoned wells are plugged with cement and drilling mud with well tubulars cut off below the surface in accordance with regulatory requirements; however, as these wells are not equipped with pressure gauges, in the unlikely event of well leakage, the detection and quantification will be done indirectly from the pressure reading of surrounding wells that are perforated in the same or shallower reservoirs. In either case, detection of leakage in the subsurface will occur prior to release of CO_2 at the surface and will be used to prevent loss to the surface. In some cases, the leakage risk may be brine (not CO_2); in other cases, loss of CO_2 is into shallower zones of the subsurface.

Proactive pressure monitoring at active producing wells, active injection wells, and shut-in wells is done via installation of pressure gauges at the wellhead that access the tubing and casing with connections to the SCADA system. Pressure reading at the surface casing, production casing and tubing on these wells are captured multiple times each day. If pressure changes in a reservoir that is not intended to be energized or if there are any CO_2 releases from the subsurface, alarms are set up to be notified through SCADA into the control room. All the active alarms are followed up by the field personnel for further investigation and diagnostics.

5.1.1 Inactive Well Monitoring

As of December 31, 2020, there are 255 inactive wells completed in the Frio formation above the injection interval and in select zones above the impenetrable Anahuac Shale that are being used a pressure monitoring wells. These monitoring wells are outfitted with gauges on the tubings, the production casings, and the surface casings. All data is reported and monitored in real time through the SCADA system that reports information into the control room with back-up information fed into Hilcorp's corporate offices. Figure 5.1.1 shows the location of the pressure monitoring wells throughout the field. Table 5.1.1 shows the zones of the inactive monitoring wells.

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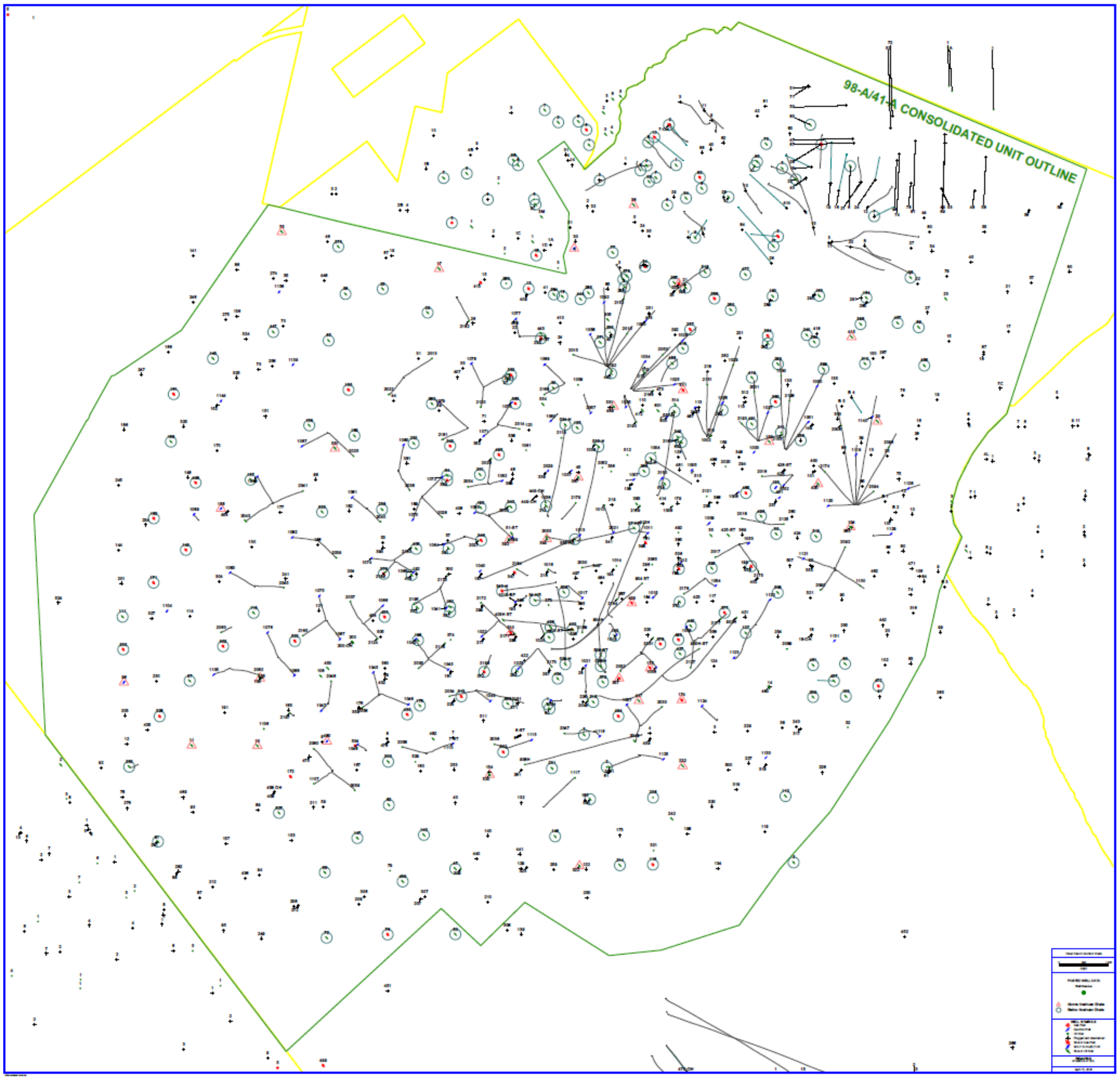

Figure 5.1.1 Location of inactive wells with pressure monitoring (wells above and below Anahuac Shale are shown as pink triangles and green circles, respectively)

#	Reservoir	Number of well	Depth	
1				
2	80-A	4	2,940’	
3		11		
4	3800	1	3,775’	
5	Catahoula	13		
6	Discorbis	4	4,555’	
7	Marg	31	4,960’	Below Anahuac Shale
8	Greta	83	5,065	
9	Randle	2	5,250’	
10	Benneview	1	5,320’	
11	Dixon	2	5,390’	
12	Toney	16	5,400’	
13	Glasscock	14	5,470’	
14	Menefee	3	5,550’	
15	Mitchell	10	5,580’	
16	Armstrong	1	5,600’	
17	Ward	33	5,630’	
18	41-A	7	5,700’	
19	Musquez	1	6,050’	
20	383 Frio	2	6,080’	
21	98-A	10	6,125’	

Table 5.1.1 Zones where pressure monitoring wells are located

5.1.2. Production Well Monitoring

Figure 5.1.2 depicts how a production well is monitored in the SCADA system. Pressure gauges monitor pressure in the tubing, the production casing, and the surface casing. Gas lift rate and pressure are also monitored for each well. The valves on the right side of the diagram are located at the TS manifold and allow the well to be directed into the high pressure (HP), intermediate pressure (IP), or low pressure (LP) system, or to the TS separator. Alarms are set to monitor any changes in the pressure from the normal pressure ranges. If abnormal pressures are noted, an alarm sounds and the particular well will be monitored for CO_2 leaks.

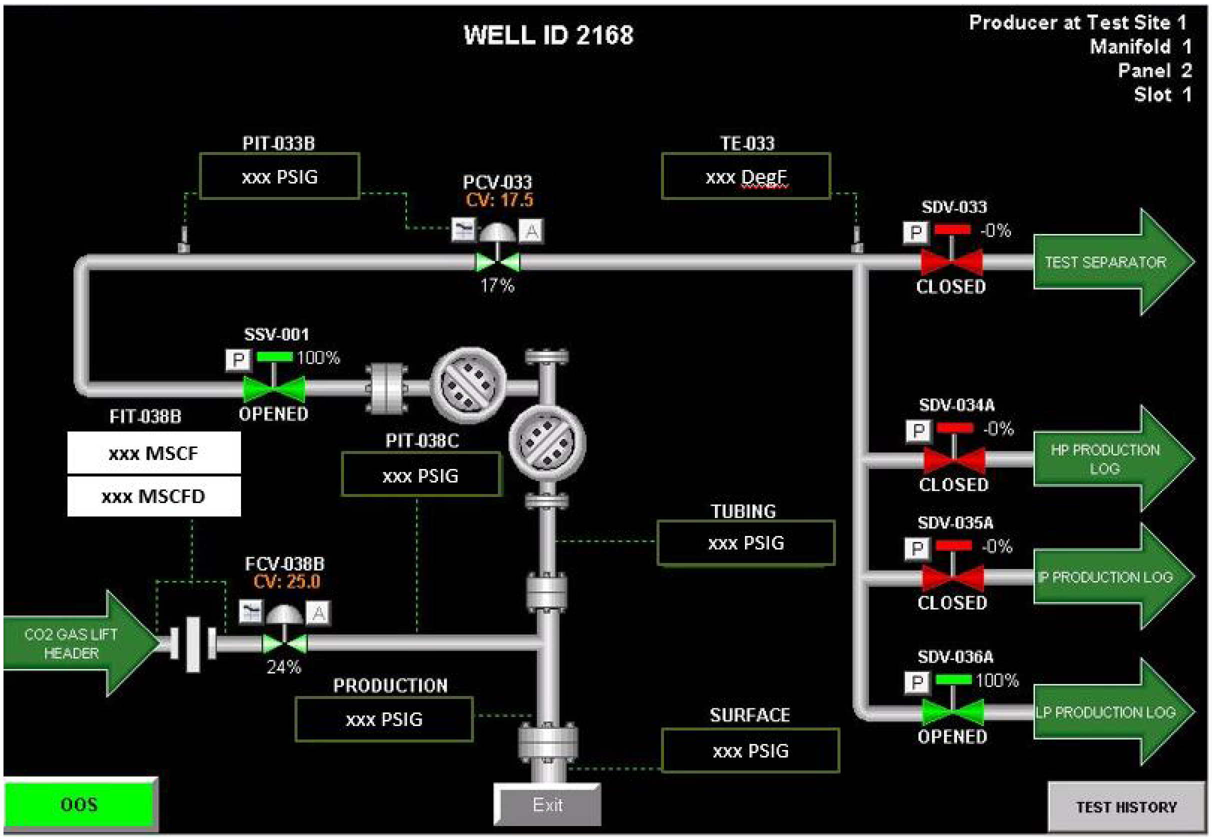

Figure 5.1.2 Monitoring of Production Wells

5.1.3. Injection Well Monitoring

Figure 5.1.3 depicts how an injection well is monitored in the SCADA system. Pressure gauges monitor pressure in the tubing, the production casing, and the surface casing. The valves on the right side of the diagram are located at the TS manifold and allow either CO_2 or water to be injected into the well, and in some cases both CO_2 and water at the same time. The injection rate is metered for each well. Alarms are set to monitor any changes in the pressure from the normal pressure ranges. If abnormal pressures are noted, an alarm sounds and the particular well will be monitored for CO_2 leaks.

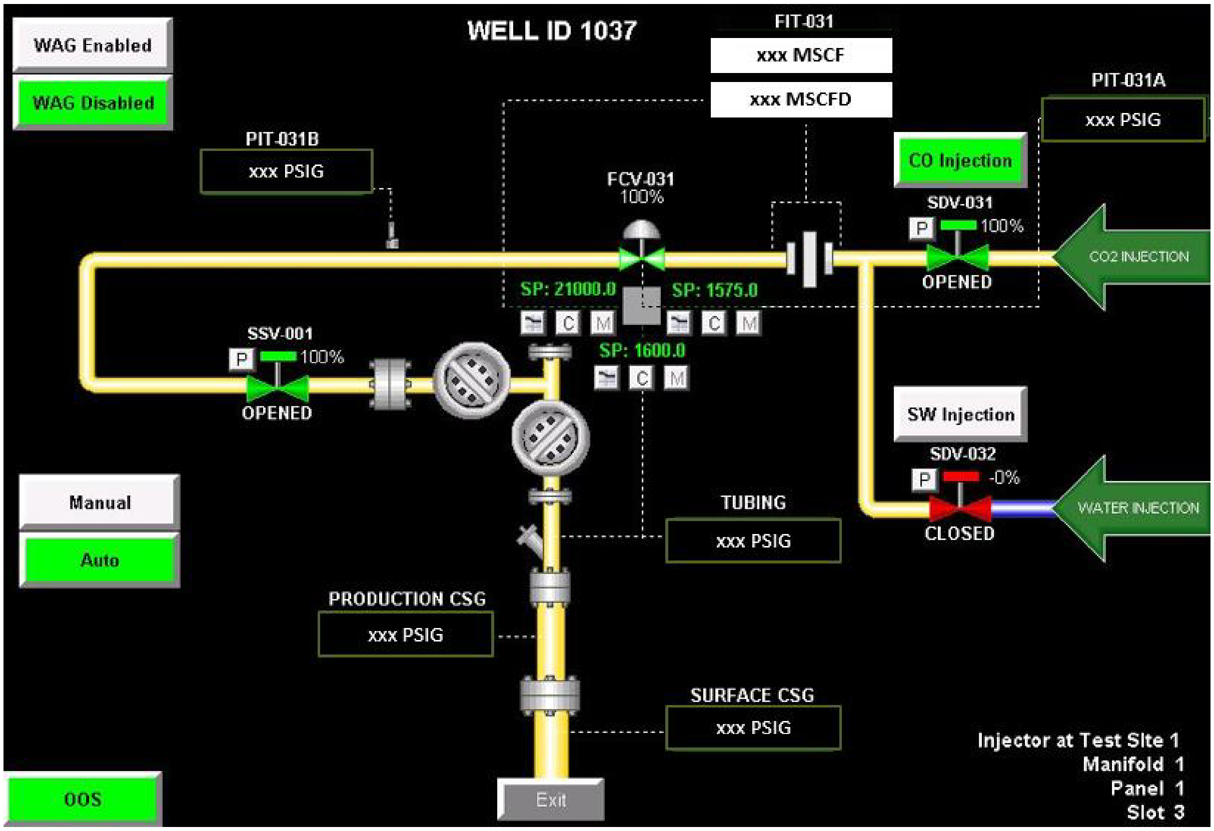

Figure 5.1.3 Monitoring of Injection Wells

5.2 Losses through Surface Infrastructure

Losses though surface infrastructure are either intentional releases for maintenance or unplanned releases, in the case of upsets or accidents. The method of detection is identified by the operator using both the data streams and alarms that are reported to the control room and visual inspection of facilities. The methods of quantification use appropriate engineering variables and standard estimation of releases.

PNPH ensures that the operator evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6. Determination of Baselines

PNPH will use the results from daily monitoring of field conditions by Hilcorp and operational data, as well as routine testing and maintenance information to monitor for surface leakage. As indicated in Sections 4.5 and 5, the SCADA system is used to conduct the CO_2 EOR operations at West Ranch. The data from these efforts is used to identify and investigate variances from expected performance that could indicate CO_2 leakage. Below is a description of how this data will be used to determine when further investigation of potential CO_2 leakage is warranted.

- **Visual Inspections**: As mentioned in Section 4.9, operations personnel make daily rounds of the facilities, providing a visual inspection of equipment used in the operations (e.g., vessels, piping, valves, wellheads). These inspection rounds provides the opportunity to identify issues early and address them proactively, which may preclude leaks from happening and/or minimize any CO_2 leakage. If an identified issue cannot be resolved by the person who first observes it, a work order will be generated to resolve the matter. Each event will be documented, include an estimate of the amount of CO_2 leaked and included in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.
- **Mechanical Integration Test (MIT)**: TRRC rules calls for operators to comply with MIT requirements, which are designed to ensure that there is no significant leakage within the injection tubing, casing, or packer, as well as no leakage outside of the casing. All active injection wells undergo MIT testing (referred to as "H-5 Testing") at the following intervals:
    - Before injection operations begin;
    - At least once every five years, or more frequently if required by the permit;
    - After any workover that disturbs the seal between the tubing, packer, and casing, or after any repair work on the casing; and
    - When a request is made to suspend or reactivate the injection or disposal permit.

  The TRRC requires that the operator notify the TRRC district office at least 48 hours prior to conducting the H-5 Testing. Operators are required to use a pressure recorder and pressure gauge for the test. Operators' field representative must sign the pressure recorder chart and submit it with Form H-5. Casing pressure must fall within 30-70% of the pressure recorder chart's full scale, and the pressure gauge must measure in increments that are no greater than 5% of the test pressure.

  In the event a loss of mechanical integrity occurs, the injection well is immediately shut-in and an investigation is initiated to determine what caused the loss of mechanical integrity. If investigation of an event identifies that a leak has occurred, those events will be documented, including an estimate of the amount of CO_2 leaked and inclusion in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.
- **Production and Shut-in Well Pressure Surveillance**: All tubings and casings of production and shut-in wells are equipped with pressure gauges and connected to the SCADA system as described in Section 5. If a 10 percent deviation in pressure outside of the expected values occurs, the event is investigated to determine if the variance poses a leak threat. If investigation of an event identifies that a leak has occurred, those events will be documented, including an estimate of the amount of CO_2 leaked and inclusion in the annual Subpart RR reporting. Records for such events will be kept on file for a minimum of three years.

7. Determination of Sequestration Volumes Using Mass Balance Equations

PNPH will use equation RR-11 in 40 C.F.R. §98.443 to calculate the Mass of CO_2 Sequestered in Subsurface Geologic Formations in a reporting year as follows:

$$CO_2 = CO_{2I} - CO_{2P} - CO_{2E} - CO_{2FI} - CO_{2FP} \quad \text{(Eq. RR-11)}$$

where:

CO_2 = *Total annual CO_2 mass sequestered in subsurface geologic formations (metric tonnes) at the facility in the reporting year.*

CO_{2I} = *CO_2 Injected, the total annual CO_2 mass injected (metric tonnes) in the well or group of wells covered by this source category in the reporting year, includes both Received CO_2 (or Fresh CO_2, see discussion below) and Recycled CO_2.*

CO_{2P} = *CO_2 Produced, the total annual CO_2 mass produced (metric tonnes) in the reporting year, includes Recycled CO_2 (see discussion below).*

CO_{2E} = *CO_2 Emitted by Surface Leakage, total annual CO_2 mass emitted (metric tonnes) by surface leakage in the reporting year.*

CO_{2FI} = *Total annual CO_2 mass emitted (metric tonnes) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead, for which a calculation procedure is provided in Subpart W.*

CO_{2FP} = *Total annual CO_2 mass emitted (metric tonnes) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity, for which a calculation procedure is provided in Subpart W.*

To account for specific conditions, PNPH proposes to modify the locations for obtaining volume data for the equations in 40 C.F.R. §98.443 as indicated below.

The first modification addresses the propagation of error that would be created if volume data from meters at each injection well were utilized. This issue arises because each meter has a small but acceptable margin of calibration error, and this error could become significant if data were taken from the approximately 100 meters within West Ranch. As such, PNPH proposes to use the mass of Recycled CO_2 from commercial quality flow meters at the inlet of RGCs combined with mass of CO_2 Received (earlier referred to as Fresh CO_2 and further defined below) to determine the mass of CO_2 Injected into the subsurface (CO_{2I} in the formula above). The mass of CO_2 Produced (CO_{2P} in the formula above) will be the same as Recycled CO_2.

The second modification addresses the concentration of CO_2 Received. Figure 7 shows the planned mass balance envelope overlaid as a blue square onto the facility flow diagram originally shown in Figure 2.7.1. The envelope contains all of the measurements relevant to the mass balance equation except for CO_2 Received, which is proposed to be measured at the custody transfer meter located in the vicinity of CCE (M_1) as shown in Section 2.8.1.

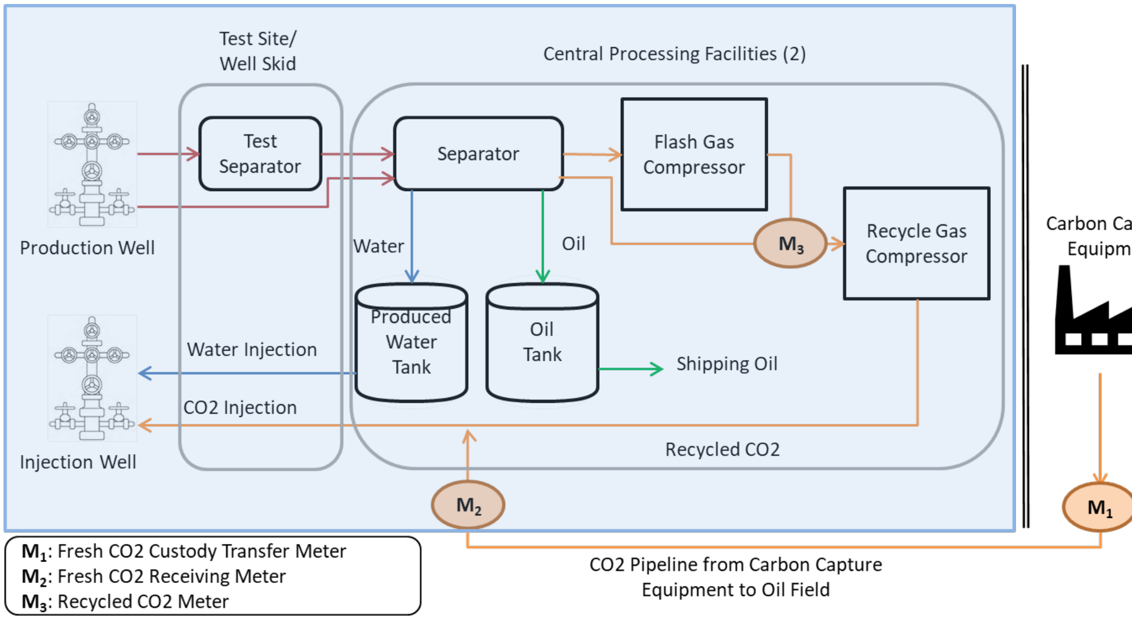

Figure 7 Material Balance Envelope (in blue)

The following sections describe how each element of the mass-balance equation will be calculated.

7.1 Mass of CO_2 Injected into the Subsurface

The equation for calculating the mass of CO_2 Injected into the Subsurface at West Ranch is equal to the sum of the mass of CO_2 Received (volumetric flow at M_2 using CO_2 concentration at M_1) and the mass of Recycled CO_2 measured at the inlet of the RGC (M_3).

$$CO_{2I} = CO_{2T,r} + CO_{2,u}$$

where:

CO_{2I} = *CO_2 Injected, the total annual CO_2 mass injected (metric tonnes) in the well or group of wells covered by this source category in the reporting year*

$CO_{2T,r}$ = *CO_2 Received, the injected net annual mass of CO_2 received through flow meter r (metric tons).*

$CO_{2,u}$ = *CO_2 Recycled, the injected annual CO_2 mass injected (metric tons) as measured by flow meter u.*

Mass of CO_2 Received

PNPH will use equation RR-2 as indicated in 40 C.F.R. §98.443 to calculate the mass of CO_2. Received. The volumetric flow at standard conditions as defined in 9.1.2 is measured at the receiving meter at West Ranch at the terminus of CO_2 Pipeline from CCE (M_2), and will be multiplied by the CO_2 concentration measured at the custody transfer meter located in the

vicinity of CCE (M_1) as stated above, and the density of CO_2 at standard conditions to determine mass.

$$CO_{2T,r} = \sum_{p=1}^{4}(Q_{r,p} - S_{r,p}) * D * C_{CO_{2,p,r}} \quad \text{(Eq. RR-2)}$$

where:

$CO_{2T,r}$ = *CO_2 Received, the injected net annual mass of CO_2 received through flow meter r (metric tons).*

$Q_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).*

$S_{r,p}$ = *Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into your well in quarter p (standard cubic meters). Since all delivery to West Ranch is used within the oilfield, the quarterly flow redelivered, $S_{r,p}$ is zero ("0").*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter)= 0.0018682.*

$C_{CO2,p,r}$ = *Quarterly CO_2 concentration measurement in flow for flow meter r in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

r = *Receiving flow meter (M_2, CO_2 concentration for M_2 is measured at M_1).*

Mass of CO_2 Recycled

PNPH will use equation RR-5 from 40 C.F.R. §98.443 to calculate the Mass of Recycled CO_2.

$$CO_{2,u} = \sum_{p=1}^{4} Q_{p,u} * D * C_{CO_{2,p,u}} \quad \text{(Eq. RR-5)}$$

where:

$CO_{2,u}$ = *CO_2 Recycled, the annual CO_2 mass injected (metric tons) as measured by flow meter u.*

$Q_{p,u}$ = *Quarterly volumetric flow rate measurement for flow meter u in quarter p at standard conditions (standard cubic meters per quarter).*

D = *Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.*

$C_{CO2,p,u}$ = *CO_2 concentration measurement for flow meter u in quarter p (volume percent CO_2, expressed as a decimal fraction).*

p = *Quarter of the year.*

u = Flow meter (M_3).

7.2 Mass of CO_2 Produced

As discussed above, the mass of CO_2 Produced equals the mass of Recycled CO_2 measured at the flow meters at inlet of RGCs (M_3). Equation RR-9 in 40 C.F.R. §98.443 will be used to

aggregate the mass of CO_2 produced net of the mass of CO_2 entrained in produced oil as follows:

$$CO_{2P} = \sum_{w=1}^{W} CO_{2,w} + X_{oil} \qquad \text{(Eq. RR-9)}$$

where:

CO_{2P} = CO_2 Produced, the total annual CO_2 mass produced (metric tonnes) in the reporting year.

$CO_{2,w}$ = Annual CO_2 mass produced (metric tons) through flow meter w in the reporting year (further defined below).

X_{oil} = Mass of entrained CO_2 (metric tons) in oil in the reporting year calculated as per 40 C.F.R. Subpart W.

w = Flow meter (M_3)

PNPH will use equation RR-8 as indicated in 40 C.F.R. §98.443 to calculate the annual mass of CO_2 produced.

$$CO_{2,w} = \sum_{p=1}^{4} Q_{p,w} * D * C_{CO_{2,p,w}} \qquad \text{(Eq. RR-8)}$$

where:

$CO_{2,w}$ = Annual CO_2 mass produced (metric tons) through flow meter w.

$Q_{p,w}$ = Volumetric gas flow rate measurement for separator w in quarter p at standard conditions (standard cubic meters).

D = Density of CO_2 at standard conditions (metric tons per standard cubic meter) = 0.0018682.

$C_{CO2,p,w}$ = CO_2 concentration measurement for flow meter w in quarter p (volume percent CO_2, expressed as a decimal fraction).

p = Quarter of the year.

w = Flow meter (M_3)

7.3 Mass of CO_2 Emitted by SurfaceLeakage

The mass of CO_2 Emitted by Surface Leakage (term CO_{2E} in Eq. RR-11) is calculated based on various methodologies, including measurements, engineering estimates, and emission factors, used for the leakage originating from subsurface as described in Section 5.1. For releases from surface equipment and equipment venting (terms CO_{2FI} and CO_{2FP} in Eq. RR-11), 40 C.F.R. Subpart W reporting is relied upon as noted above.

Equation RR-10 in 40 C.F.R. §98.443 will be used to calculate and report the Mass of CO_2 Emitted by Surface Leakage:

$$CO_{2E} = \sum_{x=1}^{X} CO_{2,x} \qquad \text{(Eq. RR-10)}$$

where:

CO_2. = *Total annual CO_2 mass emitted by surface leakage (metric tons) in the reporting year.*

$CO_{2,x}$ = *Annual CO_2 mass emitted (metric tons) at leakage pathway x in the reporting year.*

x = *Leakage pathway*

X = *Total number of leakage pathways.*

8. MRV Plan Implementation Schedule

The activities described in this MRV Plan are in place; therefore reporting is planned to start as of January 1, 2021, upon EPA approval. It is anticipated that the Annual Subpart RR Report will be filed on March 31 of the year after the reporting year. As described in Section 3.3 above, PNPH anticipates that the MRV Plan will be in effect during the Specified Period, during which time West Ranch is operated with the subsidiary purpose of establishing long-term containment of a measurable quantity of CO_2 in subsurface geological formations at West Ranch. PNPH anticipates establishing that a measurable portion of the CO_2 injected during the Specified Period will be sequestered in a manner not expected to migrate resulting in future surface leakage. At such time, PNPH will prepare a filing to support the long-term containment determination and submit a request to discontinue reporting under this MRV Plan. See 40 CFR § 98.441(b)(2)(ii).

9. Quality Assurance Program

9.1 Monitoring QA/QC

9.1.1 Flow Meter Provisions

The flow meters used to generate date for the mass balance equations in Section 7 are:

- Operated continuously except as necessary for maintenance and calibration.
- Operated using the calibration and accuracy requirements in 40 CFR §98.3(i).
- Operated in conformance with American Petroleum Institute (API) standards.
- National Institute of Standards and Technology (NIST) traceable.

9.1.2 Concentration of CO_2

CO_2 concentration is measured using an appropriate standard method consistent with 40 CFR §98.444(f)(1). Further, all measured volumes of CO_2 have been converted to standard cubic meters at a temperature of 60 degrees Fahrenheit and at an absolute pressure of 14.65 psi, including those used in Equations RR-2, RR-5 and RR-8 in Section 7.

9.2 Missing Data Procedures

In the event PNPH is unable to collect data needed for the mass balance calculations, procedures for estimating missing data will be used as follows:

- A quarterly flow rate of CO_2 received that is missing would be estimated using invoices or using a representative flow rate value from the nearest previous time period.
- A quarterly CO_2 concentration of a CO_2 stream received that is missing would be estimated using invoices or using a representative concentration value from the nearest previous time period.
- A quarterly quantity of CO_2 injected that is missing would be estimated using a representative quantity of CO_2injected from the nearest previous period of time at a similar injection pressure.

For any values associated with CO_2 emissions from equipment leaks and vented emissions of CO_2 from surface equipment at the facility that are reported in this subpart, missing data estimation procedures will be followed.

9.3 MRV Plan Revisions

In the event there is a material change to the monitoring and/or operational parameters of the West Ranch CO_2 EOR operations that is not anticipated in this MRV Plan, the MRV Plan will be revised and submitted to the EPA Administrator within 180 days as required in 40 CFR §98.448(d). As stated earlier in Sections 2 and 3, the subsurface characteristics of the existing WRU for 98-A and 41-A reservoirs are are found in the other reservoirs within the Project Interval at West Ranch. Any future expansion into the Project Interval will be subjected to the same regulatory and operational requirements as explained in Sections 2.7 and 2.8. In addition, the reservoir simulation effort carried out as part of DOE's MVA Plan and the storage capacity calculation as illustrated in Sections 2.5 and 2.9 demonstrated the viability of existing and future WRUs for long-term CO_2 retention. Therefore, any horizontal or upward vertical expansion at West Ranch can be managed by applying the same monitoring approach as alluded to in this MRV Plan and does not trigger the modification to this MRV Plan, as far as they are confined within the Project Interval and fall under the definition of AMA and/or MMA.

10. Records Retention

PNPH will follow the record retention requirements specified by 40 CFR §98.3(g) and maintain the following records for at least three years:

- Quarterly records of CO_2 delivered to West Ranch at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of injected CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Annual records of information used to calculate the CO_2 emitted by surface leakage from leakage pathways, if any.

- Annual records of information used to calculate the CO_2 emitted from equipment leaks or vented emissions of CO_2 from equipment located on the surface, if any.

All data will be collected as generated and aggregated as required for reporting purposes.

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Journal of Greenhouse Gas Control 19 (2013) 49–62

12. Appendices

Appendix 1 Acronyms

AMA – Active Monitoring Area

AoR – Area of Review

API – American Petroleum Institute

Bscf – billion standard cubic feet

B/D – barrels per day

bopd – barrels of oil per day

cf – cubic feet

CH_4 – Methane

CO_2 – Carbon Dioxide

EOR – Enhanced Oil Recovery

EPA – US Environmental Protection Agency

GHG – Greenhouse Gas

GHGRP – Greenhouse Gas Reporting Program

IWR -- Injection to Withdrawal Ratio

MIT – Mechanical Integrity Test

MMB – Million barrels

Mscf – Thousand standard cubic feet

MMscf – Million standard cubic feet

MMT – Million metric tonnes

MRV – Monitoring, Reporting, and Verification

MT -- Metric Tonne

ST – Short Ton

UIC – Underground Injection Control

USEPA – U.S. Environmental Protection Agency

USDW – Underground Source of Drinking Water

WAG – Water Alternating Gas

Appendix 2 Well Identification Numbers

The following table presents the well name, API number, status and type for the wells in the West Ranch field as of December 2020. The table is subject to change over time as new wells are drilled, existing wells change status, or existing wells are repurposed.

Well Name	API Number	Well Status
DRUMMOND JH 1	422390233500	P&A
DRUMMOND JH 2	422390233600	P&A
DRUMMOND JH 3	422390233700	Monitor
DRUMMOND JH 4	422390233800	P&A
DRUMMOND JH 5	422390233900	Monitor
DRUMMOND JH 6	422390234000	Monitor
DRUMMOND JH 7	422390234100	Monitor
DRUMMOND JH 8	422390234200	Monitor
DRUMMOND JH 1A	422390234300	P&A
DRUMMOND JH 9	422390234400	P&A
DRUMMOND JH 1B	422390234500	P&A
DRUMMOND JH 2B	422390234600	P&A
DRUMMOND JH 3B	422390234700	Monitor
DRUMMOND JH 4B	422390234800	P&A
DRUMMOND JH 1C	422390234900	P&A
DRUMMOND JH 2C	422390235000	Monitor
DRUMMOND JH 1D	422390235100	P&A
WEST RANCH A 2	422390235600	P&A
WEST RANCH A 3	422390235700	P&A
WEST RANCH A 4	422390235800	P&A
WEST RANCH A 5	422390235900	Monitor
WEST RANCH A 6-ST	422390236001	P&A
WEST RANCH A 6	422390236099	P&A
WEST RANCH A 7-ST	422390236101	P&A
WEST RANCH A 8	422390236200	P&A
WEST RANCH A 9	422390236300	P&A
WEST RANCH A 10	422390236400	Monitor
WEST RANCH A 11	422390236500	Monitor
WEST RANCH A 12	422390236600	P&A
WEST RANCH A 13	422390236800	Monitor
WEST RANCH A 14	422390236900	P&A
WEST RANCH A 15	422390237000	P&A
WEST RANCH A 16	422390237100	Monitor
WEST RANCH A 17	422390237200	Monitor
WEST RANCH A 18-OH	422390237399	P&A
WEST RANCH A 19	422390237400	P&A
WEST RANCH A 20	422390237500	P&A
WEST RANCH A 21	422390237600	P&A
WEST RANCH A 22	422390237700	P&A
WEST RANCH A 23	422390237800	Monitor
WEST RANCH A 24	422390237900	P&A
WEST RANCH A 25	422390238000	P&A
WEST RANCH A 26	422390238100	P&A
WEST RANCH A 27	422390238200	Monitor

WEST RANCH A 28	422390238300	P&A
WEST RANCH A 29	422390238400	Monitor
WEST RANCH A 30	422390238500	Monitor
WEST RANCH A 31	422390238600	P&A
WEST RANCH A 32	422390238700	Monitor
WEST RANCH A 33	422390238800	P&A
WEST RANCH A 34-HR	422390238901	Monitor
WEST RANCH A 35	422390239000	OIL-Conventional
WEST RANCH A 36	422390239100	Monitor
WEST RANCH A 37-HR	422390239201	Monitor
WEST RANCH A 38	422390239300	P&A
WEST RANCH A 39	422390239400	P&A
WEST RANCH A 40	422390239500	P&A
WEST RANCH A 41	422390239600	P&A
WEST RANCH A 42	422390239700	WSW
WEST RANCH A 43	422390239800	P&A
WEST RANCH A 44	422390239900	P&A
WEST RANCH A 45	422390240000	P&A
WEST RANCH A 46	422390240100	P&A
WEST RANCH A 47	422390240200	Monitor
WEST RANCH A 48	422390240300	P&A
WEST RANCH A 49	422390240400	Monitor
WEST RANCH A 50	422390240500	Monitor
WEST RANCH A 51-ST	422390240601	Monitor
WEST RANCH A 52	422390240700	OIL-Conventional
WEST RANCH A 53	422390240800	P&A
WEST RANCH A 54	422390240900	Monitor
WEST RANCH A 55	422390241000	P&A
WEST RANCH A 56	422390241100	Monitor
WEST RANCH A 57	422390241200	P&A
WEST RANCH A 58	422390241300	Monitor
WEST RANCH A 59	422390241400	P&A
WEST RANCH A 60	422390241500	Monitor
WEST RANCH A 61	422390241600	P&A
WEST RANCH A 62	422390241700	Monitor
WEST RANCH A 63	422390241800	P&A
WEST RANCH A 64	422390241900	Monitor
WEST RANCH A 65	422390242000	Monitor
WEST RANCH A 66	422390242100	P&A
WEST RANCH A 67	422390242200	P&A
WEST RANCH A 68	422390242300	Monitor
WEST RANCH A 69	422390242400	P&A
WEST RANCH A 70	422390242500	P&A
WEST RANCH A 71	422390242600	P&A
WEST RANCH A 72	422390242700	Monitor
WEST RANCH A 73	422390242800	P&A
WEST RANCH A 74	422390242900	P&A
WEST RANCH A 75	422390243000	Monitor
WEST RANCH A 76	422390243100	Monitor
WEST RANCH A 77	422390243200	Monitor
WEST RANCH A 78	422390243300	P&A
WEST RANCH A 79	422390243400	OIL-Conventional
WEST RANCH A 80	422390243500	P&A

WEST RANCH A 81	422390243600	P&A
WEST RANCH A 82	422390243700	Monitor
WEST RANCH A 83	422390243800	Monitor
WEST RANCH A 84	422390243900	P&A
WEST RANCH A 85	422390244000	P&A
WEST RANCH A 86	422390244100	P&A
WEST RANCH A 87	422390244200	P&A
WEST RANCH A 88	422390244300	P&A
WEST RANCH A 89	422390244400	P&A
WEST RANCH A 90	422390244500	P&A
WEST RANCH A 91	422390244600	P&A
WEST RANCH A 92	422390244700	P&A
WEST RANCH A 93	422390244800	P&A
WEST RANCH A 94	422390244900	P&A
WEST RANCH A 95	422390245000	P&A
WEST RANCH A 96	422390245100	Monitor
WEST RANCH A 97	422390245200	Monitor
WEST RANCH A 98	422390245300	P&A
WEST RANCH A 99	422390245400	P&A
WEST RANCH A 100	422390245500	P&A
WEST RANCH A 101	422390245600	P&A
WEST RANCH A 102	422390245700	P&A
WEST RANCH A 103	422390245800	Monitor
WEST RANCH A 104	422390245900	P&A
WEST RANCH A 105	422390246000	Monitor
WEST RANCH A 106	422390246100	P&A
WEST RANCH A 107	422390246200	P&A
WEST RANCH A 108	422390246300	OIL-Conventional
WEST RANCH A 109	422390246400	Monitor
WEST RANCH A 110	422390246500	P&A
WEST RANCH A 111	422390246600	Monitor
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WEST RANCH A 113	422390246800	P&A
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WEST RANCH A 115	422390247000	P&A
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WEST RANCH A 119	422390247400	P&A
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WEST RANCH A 122	422390247700	P&A
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WEST RANCH A 235	422390258900	Monitor
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WEST RANCH A 237	422390259100	P&A
WEST RANCH A 238	422390259200	P&A
WEST RANCH A 239	422390259300	Monitor
WEST RANCH A 241	422390259400	P&A
WEST RANCH A 242	422390259500	OIL-Conventional

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WEST RANCH A 258	422390260800	Monitor
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WEST RANCH A 261	422390261200	P&A
WEST RANCH A 262	422390261300	P&A
WEST RANCH A 263	422390261400	Monitor
WEST RANCH A 264	422390261500	Monitor
WEST RANCH A 240	422390261600	Monitor
WEST RANCH A 265	422390261700	P&A
WEST RANCH A 267	422390261800	P&A
WEST RANCH A 269	422390261900	Monitor
WEST RANCH A 271	422390262000	Monitor
WEST RANCH A 272	422390262100	P&A
WEST RANCH A 273	422390262200	Monitor
WEST RANCH A 274	422390262300	P&A
WEST RANCH A 275	422390262400	P&A
WEST RANCH A 276	422390262500	P&A
WEST RANCH A 278	422390262600	Monitor
WEST RANCH A 279	422390262700	Monitor
WEST RANCH A 280	422390262800	P&A
WEST RANCH A 281	422390262900	Monitor
WEST RANCH A 282	422390263000	P&A
WEST RANCH A 283	422390263100	Monitor
WEST RANCH A 284	422390263200	Monitor
WEST RANCH A 285	422390263300	Monitor
WEST RANCH A 286	422390263400	Monitor
WEST RANCH A 287	422390263500	Monitor
WEST RANCH A 288	422390263600	Monitor
WEST RANCH A 289	422390263700	P&A
WEST RANCH A 290	422390263800	P&A
WEST RANCH A 291	422390263900	P&A
WEST RANCH A 292	422390264000	P&A
WEST RANCH A 293	422390264100	Monitor
WEST RANCH A 294	422390264200	P&A
WEST RANCH A 295	422390264300	Monitor
WEST RANCH A 296	422390264400	P&A
WEST RANCH A 297	422390264500	P&A
WEST RANCH A 298	422390264600	P&A
WEST RANCH A 299	422390264700	P&A
WEST RANCH A 300	422390264800	P&A

WEST RANCH A 301	422390264900	Monitor
WEST RANCH A 302	422390265000	Monitor
WEST RANCH A 303	422390265100	P&A
WEST RANCH A 304	422390265200	P&A
WEST RANCH A 305	422390265300	OIL-Conventional
WEST RANCH A 306	422390265400	P&A
WEST RANCH A 307	422390265500	P&A
WEST RANCH A 308	422390265600	P&A
WEST RANCH A 309	422390265700	OIL-Conventional
WEST RANCH A 310	422390265800	Monitor
WEST RANCH A 311	422390265900	Monitor
WEST RANCH A 312	422390266000	P&A
WEST RANCH A 313	422390266100	P&A
WEST RANCH A 314	422390266200	OIL-Conventional
WEST RANCH A 315	422390266300	OIL-Conventional
WEST RANCH A 316	422390266400	P&A
WEST RANCH A 317	422390266500	P&A
WEST RANCH A 318	422390266600	P&A
WEST RANCH A 319	422390266700	P&A
WEST RANCH A 320	422390266800	P&A
WEST RANCH A 321	422390266900	OIL-Conventional
WEST RANCH A 322	422390267000	Monitor
WEST RANCH A 323	422390267100	P&A
WEST RANCH A 324	422390267200	P&A
WEST RANCH A 325	422390267300	P&A
WEST RANCH A 326	422390267400	Monitor
WEST RANCH A 327	422390267500	P&A
WEST RANCH A 328	422390267600	Monitor
WEST RANCH A 330	422390267700	WSW
WEST RANCH A 331	422390267800	P&A
WEST RANCH A 332	422390267900	OIL-Conventional
WEST RANCH A 333	422390268000	Monitor
WEST RANCH A 334	422390268100	OIL-Conventional
WEST RANCH A 335	422390268200	WSW
WEST RANCH A 336	422390268300	OIL-Conventional
WEST RANCH A 337	422390268400	Monitor
WEST RANCH A 338	422390268500	P&A
WEST RANCH A 339	422390268600	P&A
WEST RANCH A 340	422390268700	WSW
WEST RANCH A 341	422390268800	P&A
WEST RANCH A 342	422390268900	Monitor
WEST RANCH A 343	422390269000	Monitor
WEST RANCH A 344	422390269100	Monitor
WEST RANCH A 345	422390269200	P&A
WEST RANCH A 346	422390269300	Monitor
WEST RANCH A 347	422390269400	OIL-Conventional
WEST RANCH A 348	422390269500	P&A
WEST RANCH A 349	422390269600	Monitor
WEST RANCH A 350	422390269700	WSW
WEST RANCH A 351	422390269800	WSW
WEST RANCH A 352	422390269900	P&A
WEST RANCH A 353	422390270000	P&A
WEST RANCH A 354	422390270100	P&A

WEST RANCH A 355	422390270200	Monitor
WEST RANCH A 355-HR	422390270201	Monitor
WEST RANCH A 356	422390270300	P&A
WEST RANCH A 357	422390270400	Monitor
WEST RANCH A 358	422390270500	Monitor
WEST RANCH A 359	422390270600	P&A
WEST RANCH A 360	422390270700	Monitor
WEST RANCH A 361	422390270800	WSW
WEST RANCH A 362	422390270900	WSW
WEST RANCH A 363	422390271000	Monitor
WEST RANCH A 364	422390271100	Monitor
WEST RANCH A 365	422390271200	Monitor
WEST RANCH A 366	422390271300	Monitor
WEST RANCH A 367	422390271400	Monitor
WEST RANCH A 368	422390271500	Monitor
WEST RANCH A 369	422390271600	P&A
WEST RANCH A 370	422390271700	Monitor
WEST RANCH A 371	422390271800	P&A
WEST RANCH A 372	422390271900	Monitor
WEST RANCH A 373	422390272000	OIL-CO2
WEST RANCH A 374	422390272100	OIL-Conventional
WEST RANCH A 375	422390272200	Monitor
WEST RANCH A 376	422390272300	Monitor
WEST RANCH A 377	422390272400	Monitor
WEST RANCH A 378	422390272500	Monitor
WEST RANCH A 379	422390272600	Monitor
WEST RANCH A 380	422390272700	P&A
WEST RANCH A 381	422390272800	P&A
WEST RANCH A 382	422390272900	Monitor
WEST RANCH A 383	422390273000	OIL-Conventional
WEST RANCH A 384	422390273100	Monitor
WEST RANCH A 385	422390273200	P&A
WEST RANCH A 386	422390273300	P&A
WEST RANCH A 387	422390273400	P&A
WEST RANCH A 388	422390273500	P&A
WEST RANCH A 389	422390273600	Monitor
WEST RANCH A 390	422390273700	P&A
WEST RANCH A 391	422390273800	Monitor
WEST RANCH A 392	422390273900	Monitor
WEST RANCH A 393	422390274000	Monitor
WEST RANCH A 394	422390274100	OIL-Conventional
WEST RANCH A 395	422390274200	P&A
WEST RANCH A 396	422390274300	P&A
WEST RANCH A 397	422390274400	Monitor
WEST RANCH A 398	422390274500	Monitor
WEST RANCH A 399	422390274600	Monitor
WEST RANCH A 400	422390274700	P&A
WEST RANCH A 401	422390274800	INJ
WEST RANCH A 402	422390274900	P&A
WEST RANCH A 403	422390275000	OIL-Conventional
WEST RANCH A 404	422390275100	P&A
WEST RANCH A 405	422390275200	Monitor
WEST RANCH A 406	422390275300	P&A

WEST RANCH A 407	422390275400	P&A
WEST RANCH A 408	422390275500	P&A
WEST RANCH A 409	422390275600	P&A
WEST RANCH A 410	422390275700	P&A
WEST RANCH A 411	422390275800	Monitor
WEST RANCH A 412	422390275900	OIL-Conventional
WEST RANCH A 413	422390276000	OIL-Conventional
WEST RANCH A 414	422390276100	P&A
WEST RANCH A 415	422390276200	Monitor
WEST RANCH A 416	422390276300	P&A
WEST RANCH A 417	422390276400	Monitor
WEST RANCH A 418	422390276500	Monitor
WEST RANCH A 419	422390276600	Monitor
WEST RANCH A 420	422390276700	Monitor
WEST RANCH A 421	422390276800	P&A
WEST RANCH A 422	422390276900	P&A
WEST RANCH A 423	422390277000	P&A
WEST RANCH A 424	422390277100	P&A
WEST RANCH A 425-ST	422390277201	OIL-Conventional
WEST RANCH A 426-ST	422390277301	P&A
WEST RANCH A 427	422390277400	Monitor
WEST RANCH A 428	422390277500	Monitor
WEST RANCH A 429	422390277600	Monitor
WEST RANCH A 430	422390277700	Monitor
WEST RANCH A 431	422390277800	Monitor
WEST RANCH A 432	422390277900	P&A
WEST RANCH A 433	422390278000	Monitor
WEST RANCH A 434	422390278100	Monitor
WEST RANCH A 435	422390278200	P&A
WEST RANCH A 436	422390278300	P&A
WEST RANCH A 437	422390278400	Monitor
WEST RANCH A 439	422390278500	Monitor
WEST RANCH A 440	422390278600	P&A
WEST RANCH A 441	422390278700	P&A
WEST RANCH A 442	422390278800	P&A
WEST RANCH A 443	422390278900	OIL-Conventional
WEST RANCH A 444	422390279000	Monitor
WEST RANCH A 445	422390279100	Monitor
WEST RANCH A 446	422390279200	P&A
WEST RANCH A 447	422390279300	Monitor
WEST RANCH A 448	422390279400	Monitor
WEST RANCH A 449-OH	422390279599	P&A
WEST RANCH State 2	422390279700	Monitor
WEST RANCH A 233	422390279800	Monitor
DRUMMOND JH 1	422390280400	Monitor
DRUMMOND JH 2	422390280500	Monitor
DRUMMOND 3	422390280600	OIL-Conventional
DRUMMOND 4	422390280700	P&A
DRUMMOND 6	422390280800	Monitor
DRUMMOND 7	422390280900	Monitor
TONEY 1	422390281100	Monitor
TONEY 2	422390281200	P&A
TONEY 3	422390281300	Monitor

TONEY 4	422390281400	P&A
TONEY 5	422390281500	P&A
TONEY 6	422390281600	Monitor
TONEY 7	422390281700	Monitor
TONEY 8	422390281800	Monitor
TONEY 9	422390281900	P&A
TONEY 10 (aka WRGSU 310)	422390282000	P&A
TONEY 11	422390282100	P&A
TONEY 12	422390282200	P&A
TONEY 13	422390282300	P&A
TONEY 14	422390282400	P&A
TONEY 15	422390282500	P&A
TONEY 16	422390282600	P&A
TONEY 17	422390282700	P&A
TONEY 19	422390282900	P&A
TONEY 20	422390283000	Monitor
TONEY 21	422390283100	P&A
TONEY 22	422390283200	P&A
TONEY 24	422390283400	P&A
TONEY 26	422390283500	P&A
TONEY 28	422390283600	P&A
TONEY 27	422390283700	P&A
TONEY 28	422390283800	P&A
TONEY 29	422390283900	P&A
TONEY 30	422390284000	P&A
TONEY 31	422390284100	P&A
TONEY 32	422390284200	P&A
TONEY 33	422390284300	Monitor
TONEY 35	422390284400	P&A
TONEY 34	422390284500	Monitor
TONEY 36	422390284600	Monitor
TONEY 37	422390284700	Monitor
TONEY 38	422390284800	Monitor
TONEY 39	422390284900	P&A
TONEY 40	422390285000	P&A
TONEY 41	422390285100	Monitor
TONEY 42	422390285200	P&A
TONEY 43	422390285300	P&A
TONEY 44	422390285400	P&A
TONEY 45	422390285500	P&A
TONEY 46	422390285600	P&A
TONEY 47	422390285700	P&A
TONEY 49	422390285900	P&A
TONEY 50	422390286000	P&A
TONEY 51	422390286100	P&A
TONEY 52	422390286200	P&A
TONEY 53	422390286300	P&A
TONEY 54	422390286400	P&A
TONEY 55	422390286500	P&A
TONEY 56	422390286600	P&A
TONEY 57	422390286700	P&A
TONEY 58	422390286800	P&A
TONEY 61	422390287100	P&A

TONEY 62	422390287200	P&A
TONEY 63	422390287300	P&A
TONEY 65	422390287500	Monitor
TONEY 66	422390287600	P&A
TONEY 67	422390287700	P&A
TONEY 69	422390287800	P&A
TONEY 71	422390287900	P&A
TONEY 72	422390288000	P&A
TONEY 73	422390288100	Monitor
TONEY 74	422390288200	P&A
TONEY 75	422390288300	P&A
TONEY 76 (D & F) (aka WRGSU 376)	422390288400	P&A
TONEY 77	422390288500	Monitor
TONEY 78	422390288600	P&A
TONEY 79	422390288700	P&A
VANDERBILT STATE 1	422390288800	P&A
VANDERBILT STATE 5	422390288900	Monitor
VANDERBILT STATE 2	422390289000	Monitor
VANDERBILT STATE 3	422390289100	P&A
VANDERBILT STATE 6	422390289200	Monitor
VANDERBILT STATE 4	422390289300	P&A
VANDERBILT STATE 7	422390289400	Monitor
VANDERBILT STATE 8	422390289500	P&A
VANDERBILT STATE 9	422390289600	Monitor
VANDERBILT STATE B 10	422390289700	Monitor
VANDERBILT STATE 11	422390289800	P&A
VANDERBILT STATE 13	422390290000	P&A
VANDERBILT STATE 14 (aka WRGSU 414)	422390290100	P&A
VANDERBILT STATE 15	422390290200	P&A
VANDERBILT STATE 17	422390290400	Monitor
VANDERBILT STATE 19	422390290600	P&A
VANDERBILT STATE 20	422390290700	P&A
VANDERBILT STATE 21	422390290800	P&A
VANDERBILT STATE 22	422390290900	Monitor
VANDERBILT STATE 24	422390291000	P&A
VANDERBILT STATE B 1	422390291100	P&A
VANDERBILT STATE B 2	422390291200	P&A
VANDERBILT STATE B 3	422390291300	P&A
VANDERBILT STATE B 4	422390291400	P&A
VANDERBILT STATE B 5	422390291500	P&A
VANDERBILT STATE B 6	422390291600	Monitor
VANDERBILT STATE B 7 OH	422390291700	Monitor
VANDERBILT STATE B 8	422390291800	Monitor
VANDERBILT STATE B 9	422390291900	P&A
VANDERBILT STATE 10	422390292000	P&A
VANDERBILT STATE B 11	422390292100	P&A
MENEFEE BAYOU STATE 1	422390293500	P&A
MENEFEE BAYOU STATE 3	422390293600	P&A
MENEFEE BAYOU STATE 4	422390293700	Monitor
MENEFEE BAYOU STATE B 1	422390293800	P&A
MENEFEE BAYOU STATE B 2	422390293900	P&A
MENEFEE BAYOU STATE B 4	422390294100	P&A

MENEFEE BAYOU STATE 2	422390294300	P&A
WEST RANCH A 253	422390337700	P&A
TONEY 80	422390349700	P&A
TONEY 81	422390349800	P&A
TONEY 82	422390349900	Monitor
TONEY 84	422390362800	P&A
TONEY 83	422390365300	Monitor
WEST RANCH A 455	422390365400	Monitor
WEST RANCH A 462	422390365500	P&A
WEST RANCH A 460	422390366100	OIL-Conventional
WEST RANCH A 461	422390366200	Monitor
WEST RANCH A 458	422390366300	P&A
WEST RANCH A 458 OH	422390366399	P&A
VANDERBILT STATE 25	422390366700	P&A
VANDERBILT STATE 26	422390366800	P&A
MENEFEE BAYOU STATE B 5 (aka WRGSU 205F)	422390367900	P&A
WEST RANCH A 454	422390368000	P&A
WEST RANCH A 459	422390368300	P&A
WEST RANCH A 456	422390368400	Monitor
WEST RANCH A 457	422390368500	Monitor
TONEY 86 H	422390369700	P&A
TONEY 87	422390377800	P&A
WRSOGU 1-2	422390382800	Monitor
WRSOGU 2-2	422393282500	Monitor
WRSOGU 1-3	422390384400	P&A
WRSOGU 2-3	422393282400	Monitor
WRSOGU 1-4	422390384600	P&A
WRSOGU 1-5	422390386100	Monitor
STATE COBDEN 1	422390393300	Monitor
WEST RANCH A 453	422390393900	OIL-Conventional
STATE COBDEN 2	422390394200	Monitor
VANDERBILT STATE 27	422392028000	P&A
WRSOGU 1-6	422393000300	Monitor
WEST RANCH A 469	422393006100	P&A
WRSOGU 1-7	422393007100	Oil-Conventional
WRSOGU 1-8	422393009500	P&A
WRSOGU 2-1	422393010100	P&A
WRSOGU 1-10	422393011100	Monitor
WRASOGU 1-11	422393011300	P&A
WEST RANCH A 471	422393017500	P&A
WEST RANCH A 472	422393017600	Monitor
WEST RANCH A 473	422393020700	P&A
WEST RANCH A 474	422393022100	P&A
DRUMMOND JH 1E	422393033400	Monitor
VANDERBILT STATE 28	422393036500	Monitor
WEST RANCH A 476	422393038000	P&A
TONEY 89	422393038500	Monitor
WEST RANCH A 477	422393054200	Monitor
WEST RANCH A 482	422393082600	OIL-Conventional
WEST RANCH A 478	422393082800	Monitor
WEST RANCH A 479	422393082900	Monitor
WEST RANCH A 480	422393083000	Monitor
WEST RANCH A 484	422393118900	P&A

WEST RANCH A 483	422393119000	Monitor
WEST RANCH A 481	422393124000	P&A
WEST RANCH A 485	422393124100	Monitor
WEST RANCH A 488	422393124900	Monitor
WEST RANCH A 487	422393125000	P&A
WEST RANCH A 486	422393125100	P&A
WEST RANCH A 489	422393125200	Monitor
WEST RANCH A 491	422393125300	Monitor
WEST RANCH A 490	422393125400	Monitor
WEST RANCH A 492	422393125500	OIL-CO2
WEST RANCH A1 ERD	422393161500	P&A
WEST RANCH A 493	422393163300	Monitor
WEST RANCH A 496	422393168300	Monitor
WEST RANCH A 495	422393168400	Monitor
WEST RANCH A 497	422393197600	P&A
WEST RANCH A 494	422393200700	Monitor
WEST RANCH A 501	422393200800	Monitor
WEST RANCH A 502	422393200900	Monitor
WEST RANCH A 508	422393201000	Monitor
WEST RANCH A 505	422393201200	P&A
WEST RANCH A 504	422393201300	OIL-Conventional
WEST RANCH A 503	422393201400	Monitor
WEST RANCH A 507	422393201500	P&A
WEST RANCH A 506	422393201600	P&A
WEST RANCH A 510	422393213100	Monitor
WEST RANCH A 509J	422393213401	Monitor
WEST RANCH A 511	422393213600	P&A
WEST RANCH A 512	422393220900	OIL-CO2
WEST RANCH A 513	422393221500	Monitor
WEST RANCH A 514	422393221600	Monitor
WEST RANCH A 515	422393222400	P&A
WEST RANCH A 516	422393223000	Monitor
WEST RANCH A 517	422393224900	WSW
WEST RANCH A 520	422393228600	Monitor
WEST RANCH A 518	422393235400	Monitor
WEST RANCH A 523	422393236800	Monitor
WEST RANCH A 519	422393237000	Monitor
WEST RANCH A 521	422393237200	P&A
WEST RANCH A 522	422393237800	Monitor
WEST RANCH Unit 1-1	422393241600	Monitor
TONEY 91	422393244500	Monitor
WEST RANCH A 524	422393245900	P&A
WEST RANCH Unit 1-2	422393251300	Monitor
WEST RANCH A 525	422393256600	P&A
WEST RANCH A 526	422393257400	P&A
WEST RANCH A 527	422393258100	Monitor
WEST RANCH A 528	422393258300	Monitor
WEST RANCH A 529	422393260100	OIL-Conventional
WEST RANCH A 531	422393260200	Monitor
WEST RANCH A 530	422393260400	Monitor
WEST RANCH A 533 H	422393270000	Monitor
WRSOGU 1-15	422393273500	Monitor
WRSOGU 1-14	422393276000	Oil-Conventional

DRUMMOND-SUPERIOR 8 (aka 3M-8)	422393289500	Monitor
WEST RANCH A 534 H	422393290600	Monitor
WEST RANCH A 535 H	422393290700	Monitor
WEST RANCH A 539 H	422393296000	Monitor
WEST RANCH A 538 H	422393296100	Monitor
WEST RANCH A 536	422393296200	P&A
WEST RANCH A 537 H	422393296300	Monitor
WEST RANCH A 540 H	422393314800	Monitor
WEST RANCH A 541 H	422393318900	WSW
WEST RANCH A 545 H	422393320700	Monitor
WRSOGU 1-17	422393353800	Oil-Conventional
ASHLEY ANN 1	422393356100	OIL-Conventional
WRSOGU 1-18	422393356300	Oil-Conventional
WRSOGU 1-19	422393356400	Oil-Conventional
DRUMMOND JH 3M	422393356900	OIL-Conventional
ASHLEY ANN 2	422393357600	OIL-Conventional
WEST RANCH A 600	422393358000	INJ
WEST RANCH A 601	422393358100	OIL-Conventional
ASHLEY ANN 3	422393358500	OIL-Conventional
WEST RANCH A 602	422393358600	Monitor
3M-2	422393358900	OIL-Conventional
3M-3	422393359900	Monitor
WEST RANCH A 1129	422393362600	INJ
WEST RANCH A 1131	422393362700	INJ
WEST RANCH A 1133	422393363200	INJ
WEST RANCH A 1104	422393363400	SI-CO2
WEST RANCH A 1089	422393363600	INJ
WEST RANCH A 1059	422393365200	OIL-CO2
WEST RANCH A 2119	422393365300	OIL-CO2
WEST RANCH A 1035	422393365400	INJ
WEST RANCH A 2057	422393365500	INJ
WEST RANCH A 1002	422393365600	OIL-CO2
WEST RANCH A 1036	422393365700	INJ
WEST RANCH A 1060	422393365800	INJ
WEST RANCH A 1061	422393365900	OIL-CO2
WEST RANCH A 1003	422393366000	INJ
WEST RANCH A 1004	422393366100	INJ
WEST RANCH A 2020	422393366200	OIL-CO2
WEST RANCH A 2052	422393366300	OIL-CO2
WEST RANCH A 2029	422393366400	INJ
WEST RANCH A 1005	422393366500	INJ
WEST RANCH A 1037	422393366600	INJ
WEST RANCH A 1007	422393366700	INJ
WEST RANCH A 1062	422393366800	INJ
WEST RANCH A 1006	422393366900	INJ
WEST RANCH A 2121	422393367000	OIL-CO2
WEST RANCH A 1038	422393367100	OIL-CO2
WEST RANCH A 1009	422393367200	INJ
WEST RANCH A 1008	422393367300	OIL-CO2
WEST RANCH A 2065	422393367400	OIL-CO2
WEST RANCH A 2021	422393367500	OIL-CO2
WEST RANCH A 1010	422393367600	OIL-CO2
WEST RANCH A 1011	422393367700	INJ

WEST RANCH A 1012	422393367800	INJ
WEST RANCH A 1013	422393367900	INJ
WEST RANCH A 2150	422393368100	OIL-CO2
WEST RANCH A 1014	422393368300	INJ
WEST RANCH A 1015	422393368400	INJ
WEST RANCH A 1016	422393368500	OIL-CO2
WEST RANCH A 1017	422393368600	INJ
WEST RANCH A 1019	422393368700	INJ
WEST RANCH A 1018	422393368800	INJ
WEST RANCH A 2030	422393368900	OIL-CO2
WEST RANCH A 2053	422393369000	OIL-CO2
WEST RANCH A 2055	422393369100	OIL-CO2
WEST RANCH A 1020	422393369200	OIL-CO2
WEST RANCH A 1039	422393369300	INJ
WEST RANCH A 1040	422393369400	INJ
WEST RANCH A 1063	422393369500	INJ
WEST RANCH A 1042	422393369600	INJ
WEST RANCH A 2159	422393369700	OIL-CO2
WEST RANCH A 2160	422393369800	OIL-CO2
WEST RANCH A 2164	422393369900	OIL-CO2
WEST RANCH A 1022	422393370100	INJ
WEST RANCH A 1023	422393370200	INJ
WEST RANCH A 1021	422393370300	INJ
WEST RANCH A 1024	422393370400	INJ
WEST RANCH A 1064	422393370500	INJ
WEST RANCH A 1065	422393370600	INJ
WEST RANCH A 1069	422393370700	INJ
WEST RANCH A 1070	422393370800	INJ
WEST RANCH A 1071	422393370900	INJ
WEST RANCH A 1072	422393371000	INJ
WEST RANCH A 1073	422393371100	INJ
WEST RANCH A 2048	422393371200	OIL-CO2
WEST RANCH A 2170	422393371300	OIL-CO2
WEST RANCH A 1041	422393371400	INJ
WEST RANCH A 2027	422393371800	OIL-CO2
WEST RANCH A 1066	422393371900	INJ
WEST RANCH A 2034	422393372200	OIL-CO2
WEST RANCH A 1044	422393372300	INJ
WEST RANCH A 1043	422393372400	INJ
WEST RANCH A 1117	422393372500	OIL-Conventional
WEST RANCH A 1116	422393372600	INJ
WEST RANCH A 1055	422393372700	INJ
WEST RANCH A 1056	422393372800	INJ
WEST RANCH A 1057	422393372900	INJ
WEST RANCH A 1113	422393373000	INJ
WEST RANCH A 1054	422393373100	INJ
WEST RANCH A 1053	422393373200	INJ
WEST RANCH A 1052	422393373300	INJ
WEST RANCH A 2047	422393373400	OIL-CO2
WEST RANCH A 2036	422393373500	OIL-CO2
WEST RANCH A 2169	422393373600	OIL-CO2
WEST RANCH A 2179	422393373700	OIL-CO2
WEST RANCH A 2118	422393373800	OIL-CO2

WEST RANCH A 1074	422393373900	INJ
WEST RANCH A 2184	422393374000	OIL-CO2
WEST RANCH A 2014	422393374100	OIL-CO2
WEST RANCH A 2168	422393374200	OIL-CO2
WEST RANCH A 2026	422393374300	OIL-CO2
WEST RANCH A 2028	422393374400	OIL-CO2
WEST RANCH A 2054	422393374500	OIL-CO2
WEST RANCH A 2180	422393374600	OIL-CO2
WEST RANCH A 2035	422393374800	OIL-CO2
WEST RANCH A 2037	422393374900	OIL-CO2
WEST RANCH A 2124	422393375000	OIL-CO2
WEST RANCH A 1045	422393375100	OIL-CO2
WEST RANCH A 2056	422393375200	OIL-CO2
WEST RANCH A 1067	422393375300	INJ
WEST RANCH A 1046	422393375400	INJ
WEST RANCH A 1075	422393375500	INJ
WEST RANCH A 2165	422393375600	OIL-CO2
WEST RANCH A 1110	422393375700	INJ
WEST RANCH A 2058	422393375800	SI-CO2
WEST RANCH A 2171	422393375900	OIL-CO2
WEST RANCH A 2172	422393376000	OIL-CO2
WEST RANCH A 2173	422393376100	OIL-CO2
WEST RANCH A 1026	422393376200	INJ
WEST RANCH A 1029	422393376300	INJ
WEST RANCH A 2151	422393376400	OIL-CO2
WEST RANCH A 2167	422393376500	INJ
WEST RANCH A 1076	422393376600	INJ
WEST RANCH A 1068	422393376700	OIL-CO2
WEST RANCH A 2187	422393376800	OIL-CO2
WEST RANCH A 1077	422393376900	INJ
WEST RANCH A 2051	422393377000	OIL-CO2
WEST RANCH A 1078	422393377100	INJ
WEST RANCH A 2120	422393377200	OIL-CO2
WEST RANCH A 2181	422393377300	OIL-CO2
WEST RANCH A 1079	422393377400	INJ
WEST RANCH A 2038	422393377500	OIL-CO2
WEST RANCH A 2040	422393377600	OIL-CO2
WEST RANCH A 1081	422393377700	INJ
WEST RANCH A 2039	422393377800	OIL-CO2
WEST RANCH A 1082	422393377900	INJ
WEST RANCH A 2045	422393378000	OIL-CO2
WEST RANCH A 1083	422393378100	OIL-CO2
WEST RANCH A 1080	422393378200	INJ
WEST RANCH A 2189	422393378400	OIL-CO2
WEST RANCH A 2190	422393378700	OIL-CO2
WEST RANCH A 2063	422393378900	OIL-CO2
WEST RANCH A 2062	422393379000	OIL-CO2
WEST RANCH A 2046	422393379100	OIL-CO2
WEST RANCH A 1106	422393379200	OIL-CO2
WEST RANCH A 1105	422393379300	OIL-CO2
WEST RANCH A 1048	422393379400	INJ
WEST RANCH A 1047	422393379700	OIL-CO2
WEST RANCH A 2061	422393379800	SI-CO2

WEST RANCH A 1107	422393379900	OIL-CO2
WEST RANCH A 2059	422393380000	OIL-Conventional
WEST RANCH A 2060	422393380100	OIL-Conventional
WEST RANCH A 1111	422393380200	SI-CO2
WEST RANCH A 1112	422393380300	SI-CO2
WEST RANCH A 2075	422393380400	SI-CO2
WEST RANCH A 1025	422393380700	INJ
WEST RANCH A 1028	422393380800	INJ
WEST RANCH A 2050	422393380900	OIL-CO2
WEST RANCH A 2166	422393381000	OIL-CO2
WEST RANCH A 1027	422393381100	INJ
WEST RANCH A 2001	422393381200	OIL-CO2
WEST RANCH A 2153	422393381300	OIL-CO2
WEST RANCH A 1030	422393381400	INJ
WEST RANCH A 1051	422393381500	INJ
WEST RANCH A 1050	422393381600	INJ
WEST RANCH A 2152	422393381700	OIL-CO2
WEST RANCH A 2009	422393381800	TA
WEST RANCH A 2010	422393381900	OIL-CO2
WEST RANCH A 2015	422393382000	OIL-CO2
WEST RANCH A 1090	422393382100	INJ
WEST RANCH A 2096	422393382200	OIL-CO2
WEST RANCH A 1058	422393382300	INJ
WEST RANCH A 1119	422393382400	INJ
WEST RANCH A 1120	422393382500	INJ
WEST RANCH A 2008	422393382600	OIL-CO2
WEST RANCH A 1092	422393382700	INJ
WEST RANCH A 1140	422393382800	INJ
WEST RANCH A 2094	422393382900	OIL-CO2
WEST RANCH A 1128	422393383000	INJ
WEST RANCH A 2174	422393383100	OIL-CO2
WEST RANCH A 1034	422393383200	INJ
WEST RANCH A 2193	422393383300	OIL-CO2
WEST RANCH A 2192	422393383400	OIL-CO2
WEST RANCH A 2191	422393383500	OIL-CO2
WEST RANCH A 2016	422393383700	OIL-CO2
WEST RANCH A 2017	422393383800	OIL-CO2
WEST RANCH A 2175	422393383900	OIL-CO2
WEST RANCH A 2176	422393384000	OIL-CO2
WEST RANCH A 2177	422393384100	OIL-CO2
WEST RANCH A 2127	422393384200	OIL-CO2
WEST RANCH A 2031	422393384300	OIL-CO2
WEST RANCH A 2032	422393384400	OIL-CO2
WEST RANCH A 2033	422393384500	OIL-CO2
WEST RANCH A 2049	422393384600	OIL-CO2
WEST RANCH A 1087	422393385300	SI-CO2
WEST RANCH A 2025	422393385400	OIL-CO2
WEST RANCH A 2041	422393385500	OIL-CO2
WEST RANCH A 2043	422393385600	SI-CO2
WEST RANCH A 1088	422393386000	INJ
WEST RANCH A 2125	422393386100	OIL-CO2
WEST RANCH A 2018	422393386200	OIL-CO2
WEST RANCH A 2196	422393386300	OIL-CO2

WEST RANCH A 2195	422393386400	OIL-CO2
WEST RANCH A 1121	422393386800	INJ
WEST RANCH A 1130	422393386900	INJ
WEST RANCH A 2092	422393387000	OIL-CO2
WEST RANCH A 2090	422393387100	OIL-CO2
WEST RANCH A 2197	422393387600	OIL-CO2
WEST RANCH A 2198	422393387900	OIL-CO2
WEST RANCH A 2019	422393388100	SI-CO2
WEST RANCH A 2073	422393388300	SI-CO2
WEST RANCH A 1109	422393388700	SI-CO2
WEST RANCH A 1154	422393389100	SI-CO2
WEST RANCH A 2089	422393390100	OIL-CO2
WEST RANCH A 1122	422393390200	INJ
WEST RANCH A 1123	422393390300	INJ
WEST RANCH A 1124	422393390700	INJ
WEST RANCH A 1125	422393390800	INJ
WEST RANCH A 2081	422393390900	OIL-CO2
WEST RANCH A 900 ST	422393392300	OIL-Conventional
WEST RANCH A 902	422393392400	OIL-Conventional
WEST RANCH A 904	422393393400	OIL-Conventional
WEST RANCH A 908	422393393600	OIL-Conventional
WEST RANCH A 500	422398062200	P&A
DRUMMOND JH 10	422398062400	P&A
VANDERBILT STATE 18	422398062700	P&A
VANDERBILT STATE 16	422398066500	P&A
TONEY 18	422398082200	P&A
TONEY 48	422398112500	P&A
VANDERBILT STATE 12	422398127200	P&A
WEST RANCH A 475	422398146700	P&A
WEST RANCH A 913	422393393800	OIL-Conventional
WEST RANCH A 912	422393393900	TA
WRSOGU 1-12	TBD	P&A
WRSOGU 1-13	TBD	P&A
WRSOGU 1-16	TBD	P&A
WRSOGU 1-20	TBD	P&A