

CLASS VI PERMIT APPLICATION NARRATIVE
40 CFR 146.82(a)

Facility Information

Facility Name: Pelican Renewables, LLC
Well Names: Rindge Tract CCS Well #1
Rindge Tract CCS Well #2

Facility Contact: John Zuckerman, Pelican Renewables – Managing Member
2200 W. Forest Lake Rd, Acampo, California, 95220
917-868-4346/john.zuckerman@pelicanrenewables.com

Well Locations: Rindge Tract Island, San Joaquin County, California
38.021507, -121.428926 (Well #1)
38.014567, -121.415405 (Well #2)

Project Background and Contact Information

The effects of climate change are becoming increasingly apparent. These include increased wildfires, record-breaking heat waves, and disruptive changes in weather cycles. The State of California has pledged zero net emissions by 2045 (California Assembly Bill 1279, 2022). Climate mitigation efforts are advancing, but California will also need to capture, remove and permanently sequester tens of millions of tons of carbon dioxide from the atmosphere and large sources in order to achieve this goal. (California Air Resources Board, Scoping Plan of 2022). Pelican Renewables, LLC and its affiliates (Pelican) is a Stockton, California-owned entity with a vested interest in improving the life of all San Joaquin Delta residents and preserving the Delta. The Pelican Carbon Sequestration Project is being developed to reduce the atmospheric content of greenhouse gases, provide new jobs, and create new economic opportunities and revenue for local causes.

The Pelican Carbon Sequestration Project consists of a corn-based ethanol production plant, a carbon dioxide capture and processing facility, transportation infrastructure, and two Class VI carbon dioxide deep injection wells. This Class VI Permit Application is for Rindge Tract CCS Wells #1 and #2. The data gathering, analysis, and presentation have been performed for a two-injection well project.

Figure 1-1 shows an overview of the Pelican Carbon Capture and Sequestration project. The ethanol plant and carbon dioxide capture and processing facility will be located in the Port of Stockton. The Class VI injection wells will be located on Rindge Tract Island in the San Joaquin Delta. The transportation infrastructure will be developed along the San Joaquin River, which will connect the facilities at the Port of Stockton with the injection wells on Rindge Tract Island.

Figure 1-2 shows the facilities at the Port of Stockton. The Pelican Renewables (PR) ethanol plant produces CO₂ as part of its process. Currently, the CO₂ vents to atmosphere (80-90%) or is

captured at the ethanol plant and then converted to a food-grade liquid or dry-ice product (10-20%) by an adjacent facility operated by Airgas. The PR project is designed to capture the full CO₂ stream from the ethanol plant and process the CO₂ for storage and transport to Rindge Tract Island for permanent sequestration.

Figure 1-3 illustrates the overall process for handling the CO₂ from source to injection well. The CO₂ will be transferred to a barge for transport to the Rindge Tract Island offloading facility (about every 3 days at design rates). A pump will move CO₂ from site storage through a transfer line to the dock, at which multiple load points will be utilized to load a barge transport.

The barge transport will have CO₂ stored in multiple tube systems (stacked up to 5 high and in rows). A manifold will be present that connects the tube systems together, equipped with valves to open or isolate as required. After loading, the barge transport will travel down river and upon arrival at Rindge Tract Island, unloading operations will commence to transfer the CO₂ for injection. A pump will offload the barge to an injection line and boost the pressure for sequestration. The location of the pump used for unloading will be located on the barge side of the levee so suction piping to the pump can be short distances and can be kept at a low elevation. The discharge piping from the pump will be routed over the levee.

The pump will boost the pressure of the CO₂ from the Barge Transport to injection pressure (1,400 psig design) at a nominal rate of 100 million standard cubic feet per day (MMscfd). Two Class VI injection wells will be permitted for the PR project. Both are located on the interior of Rindge Tract Island and are connected with transfer piping. The CO₂ flow rate and pressure will be measured on both ends of the transfer line before it reaches the wells and as it is injected into the reservoir. This provides a mass balance check on the transfer line and ensures the integrity of the system.

The two-well system is designed to efficiently use the pore space of the injection zone, provide for operational flexibility, and to allow for maximum deployment of devices to monitor the pressure front and the extent of the plume as injection proceeds. This permit is for both injection wells, Rindge Tract CCS #1 and #2, and the Area of Review (AOR) modeling and delineation, Testing and Monitoring Plan, and Operational Plans were all prepared for a two-well system.

Both wells are designed for a 20-year injection period. CCS #1 is designed to be injection-rate controlled with an approximate flow rate of 1.25 million metric tons per year (Mt/yr). Initial injection pressures would peak at about 4200 pounds per square inch (psi) and drop to about 3700 psi toward the end of the 20-year injection period. CCS #2 is also an injection-rate controlled with an approximate flow rate of 0.75 million metric tons per year (Mt/yr). The injection pressure is a little under 3600 psi. The total amount sequestered over the 20-year period is a little under 40 million metric tons. After about 120 years, about 10 million metric tons end up sequestered in solution (dissolved in aqueous brine), about 25 million metric tons are structurally sequestered, and about 5 million metric tons are sequestered by capillary trapping.

The targeted injection zone is the Mokelumne River Formation (MRF), a Cretaceous, sandy, river deltaic sediment that ranges from 200 to 2300 feet thick and is about 5,500 feet below ground surface at Rindge Tract. The pore water in the MRF is mildly saline with a salinity of about 12,500

parts per million. Neither an injection depth waiver nor an aquifer exemption is being requested in this permit application. The MRF is underlain by the H&T shale, which is the lower confining unit. The upper confining unit is the Capay Shale and low permeability layers of the Meganos Gorge Fill. The details of the subsurface geology are discussed in detail in the following Section of the permit application (Site Characterization Narrative).

The lowermost underground source of drinking water (USDW) is the Markley Formation, which is about 1,000 feet to 2,700 feet above the top of the MRF in the vicinity of Rindge Tract. The salinity of pore water in the Markley formation is highly variable, ranging from 2,000 to 16,000 ppm, and averaging about 3,000 ppm. Because of its depth, the Markley Formation is not currently, and is not expected to be a source of drinking or irrigation water.

Water wells near Rindge Tract and Stockton are much shallower; either in the Modesto formation (unconfined) or Turlock Lake/Laguna formation (unconfined to locally semi-confined or confined). The base of freshwater is around 900 feet below ground surface. Saltwater intrusion from the west is an issue with these aquifers and differentiating between the potential impacts of saltwater intrusion and brine migration from the injection zone will be an important component of the Testing and Monitoring Plan.

The land on Rindge Tract Island is privately owned. No designated federal, state, territorial, or tribal lands are located within the Pelican Class VI project area. Pelican has access agreements with all owners of property within the Area of Review. Consultations with local and tribal organizations will be conducted as needed. State and local agencies with jurisdiction over one or more parts of the project or that may be affected by the project are listed in **Table 1-1**. A list of local tribal organizations is provided in **Table 1-2**.

Pelican Renewables is preparing plans for the injection and transportation of the supercritical CO₂ to the proposed injection site. Permission to construct will require permits from federal, state and local agencies (**Table 1-1**). The permit applications to be prepared for these agencies will address all National Endangered Species Act and National Historic Preservation Act concerns. Pelican does not anticipate the use, transport or storage of any hazardous substances; therefore, permitting under the Resource Conservation and Recovery Act (RCRA) will not be required.

The proposed Pelican Class VI project will require federal permits under Sections 404 and 401 of the Clean Water Act (33 USC §1344), and Sections 10 and 408 of the Rivers and Harbors Act (33 USC §43), including a National Pollutant Discharge Elimination System Permit. As part of the permit application process, Pelican will draft a full Biological Assessment (BA). During the BA development, Pelican will access the US Fish and Wildlife Service (USFWS) “Information for Planning and Consultation” database online. A Section 7 consultation with the USFWS and National Oceanic and Atmospheric Administration (NOAA) Fisheries will be conducted. The Section 7 consultation will enable Pelican to receive technical assistance from USFWS and NOAA Fisheries regarding the project’s potential effects on species of concern and their critical habitats. Federal permitting will also require compliance with Section 106 of the National Historic Preservation Act (16 USC §470).

Pelican Renewables will be required to obtain state and local permits that will include additional analyses of project effects on special status plant, fish and wildlife species. The permit may also be subject to consultation with the State Historic Preservation Officer. The list of California state and local agencies requiring permits for the project includes, but is not limited to, the agencies listed in **Table 1-1**.

Table 1-1. State and Local Agencies

AGENCY	FIRST NAME	LAST NAME	TITLE	PHONE NUMBER	EMAIL	STREET ADDRESS	CITY	STATE	ZIP
CalGem Northern District Sacramento Office	Miguel	Cabrera	District Deputy	916-322-1110	CalGEMNorthern@conservation.ca.gov	715 P Street MS 1804	Sacramento	CA	95814
California Council of Land Trusts	Bridget	Fithian	Chair	916-497-0272	mail@calandtrust.org	1017 L Street #664	Sacramento	CA	95814
California Cultural Resources Division, California Department of Parks and Recreation	Leslie	Hartzell	Ph.D., Division Chief	916-653-6995	not listed	715 P Street Suite 13	Sacramento	CA	94296
California Environmental Protection Agency - Air Resources Board	Rajinder	Sahota	Cap and Trade	916-323-8503	Rsahota@arb.ca.gov	PO Box 2815	Sacramento	CA	95812
California Fish and Wildlife - Ecosystem Conservation Division	Josh	Grover	Deputy Director		Joshua.Grover@wildlife.ca.gov	1234 East Shaw Avenue	Fresno	CA	93726
California Natural Resources Agency	Wade	Crowfoot	Secretary for Natural Resources	916-653-5656	secretary@resources.ca.gov	715P Street, 20th Floor	Sacramento	CA	95814
California Public Utilities Commission	Alice	Reynolds	President	415-703-2431	CDcompliance@cpuc.ca.gov	505 Van Ness Avenue	San Francisco	CA	94102
California State Water Resources Control Board - Regional Board: 5S/Central Valley	Mark	Bradford	Board Chief	916-464-3291	not listed	11020 Sun Center Drive, #200	Rancho Cordova	CA	95670
California Threatened and Endangered Species, California Department of Fish and Wildlife, Habitat Conservation Planning Branch	Jeff	Drongesen	Branch Chief		HCPB@wildlife.ca.gov	1010 Riverside Parkway	West Sacramento	CA	95695
Center on Race, Poverty, and the Environment	Caroline	Farrell	Executive Director	661-720-9140	cfarrell@crpe-ej.org	1012 Jefferson Street	Delano	CA	93215
City of Stockton - Planning, Land Use, Zoning	not listed			209-937-8893	planning@stocktonca.gov	425 North El Dorado St	Stockton	CA	95202
Delta Stewardship Council	Virginia	Madueno	Chair	916-445-5511	hello@deltacouncil.ca.gov	715 P Street 15-300	Sacramento	CA	95814
Office of the State Fire Marshal	Jim	Hosler	Assistant Deputy Director	916-263-6300	not listed	715 P Street	Sacramento	CA	95814
Port of Stockton - Regulatory & Public Affairs	Jeffrey	Wingfield	Deputy Port Director	209-946-0246	jwingfield@stocktonport.com	2201 West Washington Street	Stockton	CA	95203
Port of Stockton - Real Estate and Port Development	Rhonda	Nelson	Director of Real Estate and Port Development	209-946-0246	rnelson@stocktonport.com	2201 West Washington Street	Stockton	CA	95203
Sacramento-San Joaquin Delta Conservancy	Campbell	Ingram	Executive Officer	916-375-2084	cingram@deltaconservancy.ca.gov	1450 Halyard Drive Suite 6	West Sacramento	CA	95691
San Joaquin Valley Air Pollution Control District	Nick	Peirce	Manager, Permitting	209-557-6400	nick.peirce@valleyair.org	4800 Enterprise Way	Modesto	CA	95356
State Historical Resources Commission and Office of Preservation California State Parks	Julianne	Plianco	State Historic Preservation Officer	916-445-7000	info@calshpo@parks.ca.gov	1725 23rd Street Suite 100	Sacramento	CA	95816
State Historical Resources Commission and Office Preservation California State Parks	Adam	Sriro	Commission Char	916-445-7000	info@calshpo@parks.ca.gov	1726 23rd Street Suite 100	Sacramento	CA	95816
US Army Corp of Engineers, Sacramento Civil Works, Regulatory District, and Military District	not listed			916-557-5100	spk-pao@usace.army.mil	1325 J Street	Sacramento	CA	95814
Bureau of Reclamation, Bay-Delta Office, Reclamation Mid-Pacific Region	David	Mooney	Area Manager	916-414-2400		801 I Street, Suite 140	Sacramento	CA	95814
California Natural Resources Agency, Central Valley Flood Protection Board	Andrea	Buckley	Environmental Services and Land Management Branch Chief	916-574-0332	Andrea.Buckley@cvflood.ca.gov	3310 El Camino Avenue, Suite 170	Sacramento	CA	95821
California State Lands Commission, Environmental Science, Planning, and Management Division	Nicole	Dobroski	Chief	916-574-0742	Nicole.Dobroski@slc.ca.gov	100 Howe Avenue, Suite 100 South	Sacramento	CA	95825

Note: not listed information was not located through online sources

Table 1-2. T, Local Tribal Contacts

AGENCY	FIRST NAME	LAST NAME	TITLE	PHONE NUMBER	EMAIL	STREET ADDRESS	CITY	STATE	ZIP
Lytton Rancheria	Marjorie	Mejia	Chairperson	707-575-5917	margiemejia@aol.com	437 Aviation Blvd.	Santa Rosa	CA	95403
Buena Vista Rancheria of Me-Wuk Indians	Rhonda	Morningstar Pope	Chairperson	916-491-0011	rhonda@buenavistatribe.com	1418 20th Street, Suite 200	Sacramento	CA	95811
California Valley Miwok Tribe (federally recognized)	Silvia	Burley	Chairperson	209-931-4567	office@cvmt.net	14807 Avenida Central	La Grange	CA	95329
North Valley Yokuts Tribe	Katherine	Erolinda Perez	Chairperson	209-887-2415	canutes@verizon.net	PO Box 717	Linden	CA	95236
California Tribal TANF Partnership	Lisa	Martin	Regional Manager	209-474-6890	lmartin@cttp.net	2291 W March Lane, Suite D-210	Stockton	CA	95207
Central California Regional Office - Bureau of Indian Affairs	Harley	Long	Superintendent	279-444-0323	harley.long@bia.gov	650 Capitol Mall, Suite 8-500	Sacramento	CA	95814
Environmental Quality - Central California Regional Office - Bureau of Indian Affairs	Eddie	Dominguez	Environmental Quality Services Officer	279-444-0323	eddie.dominguez@bia.gov	650 Capitol Mall, Suite 8-500	Sacramento	CA	95814

State and local permits will require environmental analysis under the California Environmental Quality Act (CEQA). This work will include assessment of all species of concern including special status species under the California Endangered Species Act (CESA). The species of importance to be evaluated will be developed by consulting the California Natural Diversity Database (<https://wildlife.ca.gov/Data/CNDDB>).

Pelican Renewables LLC will obtain all of the necessary permits to support the development of this project in conformance with Federal, State, Local Government, and Tribal requirements.

References

California Assembly Bill 1279, (2022). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB1279, retrieved February 8, 2023.

California Air Resources Board, (2022). Scoping Plan of 2022. <https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents#:~:text=The%202022%20Scoping%20Plan%20for,directed%20by%20Assembly%20Bill%201279>,

GSDT Submission - Project Background and Contact Information

GSDT Module: Project Information Tracking

Tab(s): General Information tab; Facility Information and Owner/Operator Information tab

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

☒ Required project and facility details *[40 CFR 146.82(a)(1)]*

Site Characterization

Pelican Renewables, LLC and their affiliates (Pelican) are developing a carbon dioxide (CO₂) sequestration facility on Rindge Tract Island, located within the Sacramento Delta in San Joaquin County, California. The Class VI Wells will be named Rindge Tract CCS Well #1 and #2. This section discusses the available data that describe the natural environment in the vicinity of Rindge Tract CCS Wells #1 and #2.

An overview of the planned Class VI injection facility (encompassing both Wells #1 and #2) is shown in **Figure 2-1**, and is located at Section 21, Township 02N, Range 05E. The Class VI well injection facility site is located immediately west of the northern limits of Stockton, CA, and is approximately six miles northwest of the planned CO₂ source, Pelican Renewables, Inc. Ethanol Plant, located in the Port of Stockton.

The proposed facility is located on the shallow eastern flank of the Sacramento Basin, a Cretaceous marine basin that is part of the Great Valley province of California. The Sacramento Basin was identified by the California Energy Commission-led and United States Department of Energy-supported West Coast Regional Carbon Sequestration Partnership (WestCARB) as having favorable conditions for CO₂ sequestration, including the presence of multiple sequences of thick sandstone packages with overlying marine shale sequences (Downey and Clinkenbeard, 2010). Extensive gas field development in Cenozoic and Cretaceous sandstone reservoirs has generated abundant data for stratigraphic and structural characterization of the section (USGS, 2020).

The target CO₂ injection zone is the Upper Cretaceous Mokelumne River Formation, with upper confinement by the Capay Shale and low-permeability sediments of the Meganos Gorge fill. The Capay Shale is a regionally extensive Eocene marine shale with low porosity and permeability. The target interval and injection site were chosen based on the quality and thickness of both injection and confining units, and limited faults or other geologic structures in the defined Area of Review (AOR), supported by the availability of characterization information from wireline, core data, and 3D seismic data.

Regional Geology, Hydrogeology, and Local Structural Geology [40 CFR 146.82(a)(3)(vi)]

The proposed sequestration area is located near the southern end of the Sacramento Basin, an asymmetric, northwest-trending basin that is part of the Central Valley of California. The regional setting is shown in **Figure 2-2**. The basin is approximately 60 miles wide and 200 miles long, bounded by the Sierra Nevada Mountains to the East, the Klamath Mountains to the North, the Coast Ranges to the West, and the Stockton Arch to the South. Rindge Tract Island is the proposed location of the Class VI well and is the geographic location that will contain the defined AOR. Rindge Tract Island is within the Sacramento River Delta, bordered on the south by the San Joaquin River, on the west and north by White Slough, and on the east by Fourteen Mile Slough. **Figures 2-3a** and **2-3b** show cross sections through the proposed storage complex at Rindge Tract Island and the delineated AOR.

Tectonic History and Summary of Stratigraphy

The Sacramento Basin is a relict forearc basin initially formed in the Late Jurassic-Early Cretaceous Period. The evolution of the basin is shown in **Figure 2-4**, and a generalized regional stratigraphic column is shown in **Figure 2-5**. In the Late Jurassic, subduction of the Farallon Plate under the North American plate initiated, creating a basin between an active, Andean-style arc to the east, and the Franciscan accretionary prism to the west. Active volcanism on the eastern side continued through the Early Cretaceous, with the axis of volcanism migrating to the east. Starting in the Late Cretaceous during the Laramide Orogeny, the axis of volcanism migrated far to the east as the angle of slab subduction decreased. Starting in the Paleogene, the western limb of the basin was uplifted and eroded. Migration of the Mendocino Triple Junction and development of the San Andreas Fault Zone during the Miocene led to deformation that continues to present day (Ingersoll and Dickinson, 1981).

Regional relative sea level changes that occurred in the Late Cretaceous do not correlate in time with global eustatic sea level, suggesting the deposition and erosion of basin sediments was driven by tectonic events. The sequestration area is located at the southern end of the basin and on the eastern side of the structural and depositional axis of the basin. Cenozoic deformation on the western side of the basin has shortened basin width significantly, possibly by as much as half (Ingersoll and Dickinson, 1981), but there is little evidence of compression in the sequestration area. This forearc basin is preserved with very little deformation because the associated convergent margin was supplanted by a transform system (i.e., the San Andreas Fault Zone) (Orme and Graham, 2018).

The basement of the Sacramento Basin is ophiolitic ocean crust, a remnant trapped between the Sierra Nevada Arc and the Franciscan accretionary prism. Upper Jurassic and Lower Cretaceous sediments are uplifted and exposed within the northwest limb of the basin, but are thin to absent within the sequestration area and at the proposed Class VI wellsite (Moxon, 1990). Mineral provenance studies of exposed Lower Cretaceous sedimentary and metasedimentary sections show sediment sources were the Klamath Mountains and the Sierra foothill terranes (Surpless, 2015). The Jurassic and Cretaceous formations are the lowermost formations in the Great Valley Sequence.

At the start of the Late Cretaceous, the eastern side of the Sacramento Basin was a gently dipping shelf margin, while the west was a deep trough. The sequestration area was located in a deep marine setting. The Dobbins Shale, Forbes Formation, and Kione Formation were deposited as part of a progradational sequence during that time. The Dobbins Shale is composed of pelagic to hemi-pelagic sediments on the basin floor with slope deposits to the east. Mud-rich submarine fans comprise the middle and upper member of the Forbes Formation in the distal basin, with deposition of mud-rich turbidites on the shelf slope (Imperato et al., 1990). The deltaic Kione Formation overlies the Forbes Formation, but does not extend into the sequestration area (Imperato et al., 1990; Nilsen, 1990). This sequence is overlain by the Sacramento Shale, a 50 to 350-foot-thick marine shale deposited during a regional relative sea level high. The Sacramento Shale sits at the base of the Upper Campanian (Upper Cretaceous) sequence.

In Late Campanian to Maastrichtian time, a series of submarine fans developed, depositing the Lathrop, Winters, Tracy, and Blewett formations. Of these, only the Lathrop Formation and the

Winters Formation are present in the sequestration area. The fan deposits prograded from the north and northeast. The Lathrop, Winters, Delta, and Starkey formations were deposited synchronously, representing a linked system consisting of distal, mud-dominated fans (Lathrop Formation), sand-dominated basin floor fans (Winters Formation), muddy slope deposits (Delta Shale) and a deltaic sand and shale system (Starkey Formation). The Starkey Formation contains two basin-wide shale units that are chronostratigraphic markers of relative sea-level highs (Moore et al., 1990). In the vicinity of the sequestration area, the Lathrop, Winters, and Starkey Formations are stacked vertically. Only the uppermost Starkey Sand is present, and there is a lateral facies change to slope and basin plain shale deposits to the west. The Starkey Formation is truncated by angular unconformities to the north, east, and west of the Stockton area (Downey and Clinkenbeard, 2010).

The Starkey Formation is overlain by the H&T Shale, a shallow marine or slope shale that was deposited during a relative sea-level high. The H&T Shale is the base of the Upper Maastrichtian depositional sequence. The H&T Shale is thick and laterally extensive near Stockton, and pinches out to the northeast near Lodi and to the west where it is truncated by a regional unconformity. The H&T Shale also thins north of Stockton and pinches out south of Sacramento (Downey and Clinkenbeard, 2010).

The Upper Maastrichtian Mokelumne River Formation is the proposed injection zone for the Class VI well. It is part of a fluvial-deltaic system that prograded westward across the basin, depositing a minimum of 2,250 feet of sands and shales. The lowest unit in the Mokelumne River Formation is interpreted as a distributary mouth bar and channel sands and consists of very fine to medium grained sandstones. The subsequent units are series of interbedded sands and shales deposited in distributary channels, natural levees, and crevasse splay sands. Lignite seams are present in the interbedded sands and shales and within shale units. Shale units within the Mokelumne River Formation were deposited in distributary bays, and coastal marshes. (Johnson, 1990). On wireline logs within the sequestration area, all lithologies except shale appear to be present. Rapid sedimentation and oblique extension at the end of the Late Cretaceous led to the formation of the Midland and Kirby Fault Zones, which are north-south trending, down to the west growth faults that continued moving until the Oligocene Epoch, shown on **Figure 2-2**. Fault movement funneled sediments to a depositional center on the downthrown block to the west of the sequestration area (Krug et al. 1992). The regional extent of the Mokelumne River Formation is shown on **Figure 2-6**.

During the Paleogene, the western side of the Sacramento Basin underwent up to seven cycles of uplift and erosion followed by renewed subsidence, a rise in relative sea level, and a period of deposition (Sullivan and Sullivan, 2007). During the second cycle of erosion, the Meganos Gorge incised deeply into the Mokelumne River Formation within the sequestration area, in some areas eroding the unit out (Almgren, 1984). The extent of the Meganos Gorge is shown in **Figure 2-6**. Renewed subsidence and sea level rise resulted in filling of the Meganos Gorge with up to 2000 feet of marine sand and shales, known as the Meganos Formation (Almgren, 1984; Boyd, 1984). Sand deposits within the Meganos Gorge are concentrated along the central axis and near the head and outlet of the gorge (Almgren, 1984; Boyd, 1984). Wireline logs in the sequestration area, located on the southeast side of the gorge, indicate gorge fill is shale. Compaction of the original thickness of gorge fill shale is estimated at 40% (Edmondson, 1984). Differential compaction

between gorge fill shale and the surrounding Mokelumne River Formation Sandstone caused thickness variations in subsequently deposited Eocene sediments.

The Meganos Formation and Mokelumne River Formation are overlain unconformably by the Capay Formation, a Lower Eocene basin-wide shallow marine or slope deposited shale. The Capay Formation is identified as the upper confining unit. The Capay thins and pinches out to the north and east towards Lodi (Downey and Clinkenbeard, 2010). To the north and west of the Class VI well location, at Rio Vista and Kings Island Gas Fields, there are sandstones interbedded with shales in the Capay Formation. Based on review of well logs within the sequestration area, the Capay consists of primarily shale with minor thin sand interbeds that are not continuous across the sequestration area (**Figure 2-27**).

The Capay Formation is overlain by the Domengine Formation, deposited during the Middle Eocene in an estuarine and fluvial setting along a north-south trending shoreline. The upper and lower (referred to locally as the River Island Sand) members of the Domengine Formation are unconformity-bounded packages following a succession of thick, medium to coarse-grained, massive to cross-bedded sandstones with interbedded siltstone, shale, and coal. The upper member of the Domengine Formation typically has a shale-rich section at the base, with stacked, thickening-upward interbedded shale, siltstone, and rare sandstone (Sullivan and Sullivan, 2012). Within the sequestration area, shale units within the Domengine are present in all well logs examined.

The Domengine Formation is overlain by the Nortonville Formation, a regionally extensive neritic mudstone deposited during a relative sea level high in the Middle Eocene (Almgren, 1984). The Nortonville Shale is the uppermost member of the identified complex beneath the lowermost USDW within the AOR, and is described as interbedded shales, mudstones, and lithic sandstones (Sullivan and Sullivan, 2012).

Deposition of the Nortonville Formation was followed by another episode of uplift and erosion, with the formation of Markley Canyon 15 miles to the northwest of the sequestration area. Within the sequestration area, the Nortonville Formation remained present in all well logs examined. Markley Canyon was subsequently filled during the Late Eocene by the Markley Formation, a deltaic to shallow marine sandstone unit. The Markley Formation is identified as the lowermost source of underground source of drinking water (USDW) in the sequestration area, based on estimated total dissolved solids concentrations of less than 10,000 ppm (described in Hydrogeology and Hydrology sub-section). The Markley is overlain by the Sydney Flats Shale just east of the Midland Fault, and Miocene-Pliocene alluvial fan and eolian sediments farther east near the sequestration area.

During the Late Oligocene-Early Miocene, the Mendocino Triple Junction migrated to the north of the basin, changing the plate boundary from a convergent to a transform margin, docking the Salinian Block to the west and causing uplift of the Franciscan Complex (Dickinson and Snyder, 1979).

During the Miocene to Pliocene, depositional environments transitioned from marine to intertidal, flood basin, and terrestrial deposits (alluvial fan, eolian). This transition also led to the deposition of freshwater-bearing formations between the Miocene and Holocene. This includes the Mehrten

Formation (Miocene to Pliocene), Laguna Formation (Plio-Pleistocene), Modesto/Riverbank Formations (Pliocene), and other alluvial and stream deposits (Holocene). Additional detail is provided in the Hydrologic and Hydrogeologic Information sub-section.

The Holocene environment of deposition for the sequestration area cycled between a tidal-wetland, with development of peat deposits during interglacial period sea-level highs and a supra-tidal plain, with fluvial and eolian deposition derived from the Sierra Nevada Mountains. Current surface sediments within the AOR are mostly peat, with some exposure of eolian sands and alluvial fans of the Modesto Formation (Atwater, 1982). Reclamation and agricultural development of the sequestration area has contributed to ground level subsidence through oxidation of organic matter comprising peat deposits. Ground elevation within the AOR is near mean sea level. The Island that contains the AOR currently consists of primarily agricultural land and it is leveed to protect it from flooding; therefore, the facilities and CCS operations would be protected from flooding events.

Summary of Sequestration Area Stratigraphy

Figures 2-3a and **2-3b** show cross sections through the proposed sequestration area at Rindge Tract Island and the delineated AOR. **Figure 2-5** summarizes the generalized regional stratigraphy from the land surface to the basement. This column includes the following stratigraphic units of interest within the proposed sequestration area (from top to bottom): the Markley Formation (lowermost Underground Source of Drinking Water (USDW)), Nortonville Shale, Domengine Formation, Capay Shale/Meganos Gorge Fill (upper confining zone), Mokelumne River Formation (proposed sequestration zone), H&T Shale (lower confining zone), other deeper zones that could potentially be used for sequestration, and the remaining formations down to basement at greater than 12,000 feet msl. These stratigraphic units were described in context of the tectonostratigraphic history of the Sacramento Basin in the preceding section. **Figure 2-5** includes ages, locally-used lithostratigraphic nomenclature, lithologies, and depositional information. The lithostratigraphic nomenclature of the Sacramento Basin is complex; for consistency, the names used in this section are based on formations identified from well reports local to the area. **Table 2-1** summarizes the elevations and thicknesses of the injection zone, upper confining zone, and other units below the lowermost USDW beneath the AOR.

Structure

The sequestration area is located on the east flank of the Sacramento Basin. Stratigraphic units dip southwest, and angles increase with stratigraphic age as basin fill causes subsidence. The sequestration area is located away from major structural features of the Southern Sacramento Valley, as shown on **Figure 2-2**.

In the sequestration area, the base of the Mokelumne River Formation strikes northwest to southeast, and dips approximately 160 feet/mile to the southwest. The erosional contact between the Mokelumne River Formation and the overlying Meganos Gorge and Capay Formations is variable in both dip angle and dip direction (see **Figure A3-2** of **Section 3 – Area of Review and Corrective Action Plan**); however, the base of the Mokelumne and underlying units dip southwest overall, since the sequestration area is on the southeast margin of the Meganos Gorge.

The closest major structural feature to the sequestration area is the faulted antiform that forms the oil and gas accumulation trend of the MacDonald Island and Robert Island Gas fields to the southwest. The oil and gas traps are fault-bound on three sides (California Department of Conservation, 1982).

The sequestration area is approximately eight miles north of the Stockton Arch fault zone. The Stockton Arch likely formed as a remnant structure of the Great Valley forearc basin (Imperato, 1992). The Stockton Arch serves as the structural high that separates the Sacramento and San Joaquin Basins. The Stockton Arch faults originated as Cretaceous normal faults subsequently reactivated as reverse faults, and are considered aseismic.

Regional Structure and Stress

Late Cenozoic folds and faults in the Sacramento Valley appear to have formed in an east-west compressive stress regime. The axial traces of many folds are parallel to the trends of adjacent faults, and the folding appears to be related to drag on those faults. The amount of lateral displacement on faults in the valley is difficult to determine. The late Cenozoic kinematic pattern and inferred east-west compressive stress regime in the Sacramento Valley appear to be anomalous with respect to contemporary tectonism in adjacent regions (Harwood and Helley, 1987).

In the California Coast Ranges to the west and in the northern Basin and Range Province to the east, north-trending faults generally show normal and right-lateral displacements; east-trending faults show reverse and left-lateral movement; and northwest- and northeast-trending faults show dominantly right-lateral and left-lateral displacement, respectively (Zoback and Zoback, 1980; Hill, 1982). It is inferred that the maximum horizontal compressive stress was oriented approximately north-south and the least horizontal compressive stress (maximum extension) was oriented approximately east-west (Zoback and Zoback, 1980; Hill, 1982). Hill (1982) related the contemporary stress patterns to movement between the North American and Pacific plates and visualized the western part of the North American plate as a continuous broad zone of deformation following the model first proposed by Atwater (1970).

East-west compressive deformation in the Sacramento Valley suggests that the late Cenozoic stress field was not homogeneous between the continental margin and the northern Basin and Range province. Instead, the Sacramento Valley apparently acted as an independent block where relatively small-scale compressive strain was periodically released in response to large-scale right lateral transform tectonism in the San Andreas fault zone to the west and major east-west crustal extension in the northern Basin and Range Province to the east. Furthermore, the well-dated deformation patterns in the Sacramento Valley indicate that the compressive strain was not released randomly but, rather, that the late Cenozoic structural features formed in a sequential pattern that is progressively younger to the north. Northward progression of the compressive deformation implies a northward-migrating stress regime or a migrating energy source sufficient to initiate deformation in a regional compressive stress field. The interaction of lithospheric plates along the continental margin appears to provide a reasonable mechanism for generating the sequential compressive strain release observed in the valley.

Kinematic patterns of late Cenozoic structural features in the Sacramento Valley differ significantly from those in the Coast Ranges to the west and the northern Basin and Range Province

to the east. For at least the past 2.5 million years, deformation in the valley has occurred in a regional stress field in which the maximum horizontal component of compressive stress was oriented approximately east-west and the minimum component of compressive stress (maximum extension) was oriented approximately north-south (Harwood and Helley, 1987). Within this stress regime, strain has been released primarily by reverse movement on north- and northwest-trending high angle faults and associated folding in the sedimentary rocks of the valley fill. During the late Cenozoic, the Sacramento Valley appears to have acted as an independent block on which relatively small-scale compressive deformation was imposed by eastward-directed subduction that was followed by large-scale transform tectonism along the continental margin and major east-west crustal extension in the Basin and Range.

The well-dated and diverse deformation patterns in the Sacramento Valley indicate that late Cenozoic tectonism evolved through the region in response to major crustal movements outside the valley's physiographic boundaries. East-west compressive tectonism may have been imposed on the valley by eastward subduction of the Juan de Fuca plate, and consequent tectonic wedging of the Franciscan Complex coupled with a major component of westward stress due to east-west extension in the Basin and Range Province.

Tectonic forces aside, until drilling and injection begin, we assume that the sum of stresses (radial, shear, normal) are zero. Once the well is installed, fall-off tests and down-hole strain monitors will allow a more detailed analysis of the stress field within the Mokelumne River Formation (injection zone). In-situ formation stress test data are not available for the upper confining zone (Capay Shale/Meganos Formation). Once the stratigraphic test well is drilled, Pelican will analyze the stress field within the injection and confining zones via in-situ formation stress tests per ASTM Method D 4645-08. Pelican will also demonstrate that the in-situ stress field data are appropriate and consistent with proposed injection pressures and fault stability analyses.

Project Data Sources and Pre-Processing Steps

The principal site characterization data sources include published geological reports; a WestCARB evaluation of the Sacramento Basin; Division of Oil, Gas, and Geothermal Resources (DOGGR) volume reports on petroleum fields in the region (California Department of Conservation, 1982); and geophysical well logs for the proposed sequestration area from the CalGEM Well Statewide Tracking and Reporting System Database. Existing 2D and 3D seismic data in the sequestration area were used to characterize the subsurface geology in the anticipated Area of Review (AOR). Various pre-processing steps were necessary in order to analyze these data in an appropriate and consistent spatial framework. The details of these pre-processing steps are described in **Attachment 1** (Seismic Report) and **Attachment 2** (Petrophysics Report and Products). The purpose of this section is to briefly summarize those pre-processing steps.

The first section of the Seismic Report (**Attachment 1**) discusses the data availability and quality. The second section discusses the conversion from the time domain into the depth domain. A 25 square mile subsection of the Conestrama 3D seismic survey was acquired from PacSeis, Inc. The licensed data is proprietary to PacSeis, Inc. and subject to confidentiality terms of the license to Pelican Renewables.

The first section of the Petrophysics Report and Products (**Attachment 2**) discusses the primary data sources. The second section discusses pre-processing steps to get data into a common spatial framework. The third section discusses data normalization and digital analysis of analog geophysical logs. Legacy wells in the sequestration area and its surroundings were identified from the CalGEM Well Statewide Tracking and Reporting System Database.

In addition to the regional primary data sources and pre-processing steps, additional data from the Citizen Green #1 well were used (**Attachment 3**). The Citizen Green #1 well was drilled in 2011 as part of a California Energy Commission Project to characterize the CO₂ sequestration potential of the Southern Sacramento Basin. The core data from this well are the only core data that are publicly available in the vicinity of the AOR for the units within the proposed storage complex. The Citizen Green #1 well is located approximately three miles north of the AOR. As part of the drilling program, an extensive series of geophysical well logs, core samples, and sidewall core samples were collected. These data are summarized as follows:

- Whole core of the Nortonville and Mokelumne River formations.
- Sidewall cores of the Nortonville, Domengine, Capay, Mokelumne River, H&T Shale, and Starkey formations.
- Petrophysical logs including gamma ray, spontaneous potential, resistivity, density, neutron porosity, combinable magnetic resonance (CMR), spectral gamma ray, elemental captive spectrometry, formation micro imager, and sonic scanner
- Drill cuttings and grab samples

Subsequent analyses included:

- Thin sections taken from sidewall cores
- XRD of cores, cuttings, and grab samples
- Helium porosimetry, air permeability, and saturation determinations for 15 sidewall core samples in the Mokelumne River, H&T Shale, and Starkey formations and brine permeability for a subset of 14 of these cores
- Helium pycnometry (HeP) of four sidewall cores in the Mokelumne River and Starkey formations, and mercury intrusion capillary pressure (MICP) measurements of five samples in the Domengine, Mokelumne River, and Starkey formations

Only a subset of this data is publicly available, including the basic triple-combo well log suite and, through the U.S. Department of Energy, Energy Data eXchange (EDX) database, thin section photographs, XRD data, porosity and permeability analyses, and HeP and MICP data. Additional detail on the availability of data to inform site characterization is discussed in Injection and Confining Zone Details.

The Citizen Green #1 well location is shown on **Figure 2-7** and falls within the extent of licensed 3D seismic data. Citizen Green #1 penetrated into the Winters Formation, with core and sidewall core collected from the Capay Formation, Mokelumne Formation, H and T Formation, Starkey Formation, and Winters Formation. Given the proximity to this project's AOR and lack of site-specific information within the AOR itself, the extensive log suite and rock analyses from Citizen Green #1 are used as an analog for the injection and confining zone units in the project area. Data

for Citizen Green #1 are available from CalGEM and from entries in the National Energy Technology Laboratory EdX system (**Attachment 3**). Apart from the seismic data acquired to characterize the sequestration area, the data specified above are those that Pelican were able to locate within the public domain. No additional publicly available data are available to supplement site characterization. To reduce uncertainty in the geologic characterization and model inputs for the sequestration area, a stratigraphic test well will be drilled within the AOR before the Class VI authorization to construct or convert is issued. As discussed in Section 3 (Area of Review and Corrective Action Plan), the AOR-specific site characterization data collected via the stratigraphic test well and deep monitoring wells will be utilized to inform the model and re-evaluate the AOR prior to commencing injection. Refer to **Section 6 – Pre-Operational Testing Plan** for a description of the site characterization data to be collected via the stratigraphic test well and deep monitoring wells.

Hydrogeology Summary

The proposed project is located within the Eastern San Joaquin Sub-basin (Sub-basin Number 5-22.01) of the larger San Joaquin Valley Groundwater Basin. The San Joaquin Valley Groundwater Basin formed in a broad structural trough that extends approximately 270 miles trending northwest to southeast in the northern portion of the Central Valley of California. The proposed project is located on the eastern edge of the Sub-basin on Rindge Tract Island, which is part of the Sacramento-San Joaquin River Delta.

A complete hydrogeologic review is provided in a sub-section below. The list below provides a high-level summary of the findings presented in that sub-section:

- **Topography:** Generally flat throughout Rindge Tract Island with elevations near mean sea level,
- **Freshwater:** Located at or near the surface from 10 feet to approximately 900 feet below the ground surface at Rindge Tract Island,
- **Freshwater Formations:** Alluvium, Modesto/Riverbank formations, Laguna Formation, and Mehrten Formation,
- **Groundwater Flow:** Generally, from west to east due to significant groundwater pumping near Stockton, California,
- **Groundwater Wells:** 23 groundwater wells were located within one mile of Rindge Tract Island, with the deepest well reaching approximately 300 feet below ground surface,
- **Underground Source of Drinking Water (USDW):** Lowermost USDW is the Markley Formation, which was identified through petrophysical log calculations (**Attachment 2**).

Maps and Cross Sections of the AOR [40 CFR 146.82(a)(2), 146.82(a)(3)(i)]

Figures 2-3a and 2-3b are cross-sections from the static geologic model that highlight the geologic units within the proposed storage complex at Rindge Tract Island and the delineated AOR. **Figure 2-8** presents the conceptual site model of the Area of Review (AOR) and includes the sequestration area stratigraphy and other significant geologic features. **Figure 2-9** includes a map of the delineated AOR and the elements required at 40 CFR 146.82(a)(2). As noted on the map, the elements present within the AOR include the name and location of plugged and abandoned wells

and dry holes as well as surface bodies of water (canals) and roads. Based on a review of information of public record, there are no injection wells; producing wells; deep stratigraphic boreholes; State- or EPA-approved subsurface cleanup sites; springs; mines; quarries; water wells; structures intended for human occupancy; or state, tribal, or territory boundaries present within the AOR. Numerical modeling was conducted to characterize the storage capacity and the extent of the AOR as presented in **Figure 2-9**. The numerical modeling of the AOR is presented in **Section 3: AOR Evaluation and Corrective Action Plan**.

Structural maps were created from interpreted key 3-D seismic horizons confirmed with well ties. Sonic and density logs from the Big Valley Eberhart 1 well were used to convert the seismic data from time to depth. Depths below sea level are referred to as true vertical depth at subsea (TVDSS).

The depth to the top (structure) of the basement is shown on **Figure 2-10**. **Figure 2-11** provides the H&T Shale structure map. The H&T Shale is thick and continuous throughout the section. Overlying the H&T is the Mokelumne River Formation, which is the target sequestration formation. The Mokelumne is continuous up-dip to the east within the proposed injection area. **Figure 2-12** presents the Mokelumne River Formation structure map and **Figure 2-13** presents the Mokelumne isopach map.

As seen by thinning and deepening of the Mokelumne on **Figures 2-3a, 2-3b, 2-12, and 2-13**, the Mokelumne has been eroded by the Meganos Gorge to the west. In the deepest section of the Gorge, it appears that the Meganos Gorge has completely eroded the Mokelumne River Formation; however, well logs indicate that the Mokelumne River Formation is present in the proposed sequestration area and provides abundant storage capacity. **Figure 2-14** highlights the area of the Meganos Gorge. The Capay Shale, the upper confining unit for the sequestration area, is continuous throughout the AOR. The surface of the Meganos Gorge and the overlying Capay are difficult to differentiate within the seismic sections; therefore, the Capay and Meganos Gorge Formation top structure and thicknesses are combined in **Figures 2-15 and 2-16**. The depths to the top of the overlying Domengine Formation and Nortonville Shale are shown on **Figures 2-17 and 2-19**, respectively. The thickness of the Domengine Formation is presented in **Figure 2-18**. The Nortonville Shale is laterally continuous across the AOR, as shown in **Figure 2-20**. As described in a previous section the upper Domengine Formation also contains shale interbeds across the sequestration area. Both the Domengine and the Nortonville are thick and continuous across the sequestration area (**Figures 2-18 and 2-20**). **Figures 2-33 and 2-38a-c** highlight the relative vertical positions of the USDWs to the proposed injection wells and injection zone (Mokelumne River Formation). Detailed explanations of these figures are provided in the section “Hydrologic and Hydrogeologic Information.”

Faults mapped within the AOR include basement faults, listric gravitational faults within the Meganos Gorge, and syn-depositional faults in formations above the objective section. The fault distributions are shown in **Figure 2-21**. Cross sectional maps provided in **Figures 2-22, 2-23, and 2-24** depict the faulting and provide example seismic profiles. The Meganos Gorge Formation consists of sands and shales that have experienced differential compaction and gravitational faults (slump faults) as noted within the sections (**Figures 2-22, 2-23, and 2-24**). Examples of the listric

faults associated with the gorge are shown in **Figures 2-25** and **2-26**. Within the AOR, there are no major structural closures formed by faults or domes.

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

Faults over the Rindge Tract Island (AOR) were interpreted using the Conestrama 3D seismic Volume. Three distinct sets of faults were identified and are illustrated in **Figure 2-22** (cross sectional profile A-A'): 1) shallow syn-depositional faults, 2) slump and gravitational faults of the Meganos Gorge and 3) deep basement faults. The volume provided extensive coverage of the proposed AOR (**Figure 2-21**).

Listric slump faults are interpreted within the Meganos Formation. The Meganos Gorge cut approximately 2,000 feet into the Mokelumne River Formation (MRF). Slumps were generated in the gorge by mass sediments moving downslope. The eastern side of the gorge is mapped by the fault depicted in blue in **Figures 2-22, 2-23, and 2-24** (cross-sectional profiles A-A', B-B', C-C', respectively). The western side of the Meganos Gorge is mapped by the fault depicted in maroon (**Figure 2-24 C-C'**). Slump surfaces that occurred after the infill of the Meganos and the Capay were reactivated by gravitational forces. Within the gorge, syn-depositional faulting is documented by the rollover antiform observed in **Figure 2-24 C-C'**. Should the MRF reservoir be juxtaposed to Meganos infill sand, the stratigraphic nature of the sands and the sealing capacity of the shales would not threaten the vertical migration of CO₂ into reservoirs above the Capay Formation.

The 2-D cross-sections show that these listric slump faults are wholly contained within the Meganos Gorge and do not transect the MRF zone of interest, which lies to the east of the gorge. The interpretation of the 3D seismic volume additionally confirms that the Meganos Gorge slump faults are contained within the Meganos Gorge and are not transecting the MRF. The Meganos Gorge is comprised of approximately 95% silty shale and shaley siltstone (Dickas and Payne, 1967). During the formation and later filling of the gorge, the slopes along the edges failed, forming slump faults that dip toward the center of the channel. Subsequent deposition within the channel and the eventual deposition of the overlying Capay Shale form a thick, continuous seal.

The seismic sequence deposited on top of the basement has variable thickness (**Figure 2-25**). The sequence thickness variation is related to tectonic processes during deposition. The strong reflector that tops the sequence (Nortonville Shale), and the lack of fault continuity into the above sequence, indicates a prolonged period of exposure and erosion. One basement fault was apparently reactivated during the Upper Cretaceous; the fault strikes east-west and is depicted in yellow in **Figures 2-22, 2-25 and 2-26**. This fault does not cut the MRF, as it was eroded in the area by the Meganos Gorge. The fault cut into the lowermost Meganos infill sequence. Over 1500' of the Meganos and Capay sequence is undisturbed and considered an excellent seal.

The presence of hydrocarbons within the region as noted in the 3D seismic volume provides some evidence of sealing along interpreted faults. However, this does not account for pressure or other subsurface changes due to injection operations. During pre-operational testing, Pelican will collect permeability and capillary pressure data from the MRF and Meganos section and static pressure data. Pelican will collect pressure data and cores from the Meganos as specified in the Pre-Operational Testing Plan. Please see the Pre-Operational Testing Plan (Section 6) for additional details.

Pelican assessed the risk of induced seismicity and the potential for fault propagation within the project area, particularly associated with the Meganos Gorge slump and gravitation faults, under planned operational conditions. This assessment is included as **Attachment 4** to this narrative.

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

The injection complex within the AOR consists of a lower confining zone (H&T Shale), an injection zone (Mokelumne River Formation), and an upper confining zone (Capay Shale/Meganos Gorge sedimentary fill). The depositional history and tectonostratigraphic framework of these units at a basin-wide scale is discussed in the sub-section entitled “Regional Geology, Hydrogeology, and Local Structural Geology.” The purpose of this section is to discuss the details of the injection complex in the vicinity of the Class VI injection location. **Table 2-1** summarizes the elevations and thicknesses of the injection zone, upper confining zone, and other zones below the lowermost USDW beneath the AOR.

Table 2-1. Elevations and Thicknesses of Stratigraphic Units Beneath the Lowermost USDW Within the AOR

Formation	Sequestration Complex Component	Elevation of Top of Unit (range in feet below mean sea level)	Elevation of Top of Unit (range in meters below mean sea level)	Thickness Range (Feet)	Thickness Range (Meters)	Lithology
Nortonville Shale	Pressure Dissipation Zone	3700-4235	1128-1291	58-490	18-149	Shale
Domengine Formation	Pressure Dissipation Zone	3850-4516	1173-1376	497-1229	151-375	Sandstone and shale
Capay Shale/Meganos Gorge Fill	Upper Confining Zone	4593-5577	1400-1700	66-1444	20-440	Shale
Mokelumne River Formation	Injection Zone	4987-6824	1520-2080	197-2034	60-620	Sandstone, shale, minor coal

Note: Top elevations and thickness ranges listed are for the extent shown in Figures 2-12 through 2-20.

The Lower Confining Zone

The lower confining zone is the H&T Shale. In the vicinity of the AOR, the depth to the top of the unit ranges from approximately 6700 to 7200 feet below mean sea level (MSL) (**Figure 2-11**). The only well within the AOR that fully penetrates the H&T Shale is Big Valley Eberhart 1. Big Valley Eberhart #1 is located on the extreme eastern edge of the island. The well log for Big Valley Eberhart #1 shows a gradational contact with the base of the Mokelumne River Formation (**Figure 2-27**). The top of the H&T Shale is at 6690 feet below MSL at this location and the thickness is approximately 100 feet. The variability in the top of the H&T Shale across the AOR is informed, in part, by interpolation from other wells that penetrate the H&T Shale within or near the AOR (**Figure 2-7**). The variability in the top of the H&T Shale is also informed by interpretation of 3-D and 2-D seismic reflection profiles (**Figure 2-7**).

The mineralogy, petrology, and material properties were informed by core and sidewall core taken from the Citizen Green #1 well. Data are provided in **Attachment 3**. The Citizen Green #1 well is the closest location to the AOR for which mineralogic and petrologic data have been collected for the units of interest within the proposed storage complex. X-ray diffraction (XRD) data were not analyzed for shales within the H&T Shale interval; as such, the mineralogic composition of the shale is unknown. However, XRD data were analyzed

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for one sand stringer within the H&T Shale interval at an approximate depth of 6297'. Quartz, andesine (plagioclase feldspar), and potassium feldspars dominate the mineralogical composition of this sample.

Four sidewall core samples were described as shale in the depth interval from 6,899 feet to 6,993 feet that is within the H&T Shale at this location. The intrinsic permeability in brine of one sample (#16) was estimated to be <0.001 mD. The intrinsic permeability in air was estimated to be 0.006 mD (#16) and <5 mD (#14). The porosity was estimated to be 1.8% (#16) and 22.4% (#14). The grain densities were estimated to be 2.73 g/cm³ (#16) and 2.68 g/cm³ (#14). No relative permeabilities were measured.

Key uncertainties in understanding the character of the lower confining zone result from the lack of site-specific data within the AOR. The uncertainties will be reduced by initially treating the Class VI well as a stratigraphic test well with complete core sampling, sidewall core sampling, and geophysical logging. This stratigraphic test well would be drilled before the Class VI authorization to construct or convert is issued. The stratigraphic test well will extend into the H&T Shale in order to sufficiently characterize this unit as a lower confining zone. The key parameters governing the seal quality in the H&T Shale are the density, porosity, intrinsic permeability and anisotropy ratio, relative permeability, and capillary pressure. At least three samples from the H&T Shale at a minimum of 10-foot intervals will be submitted for analytic determination of these key parameters. Mineralogic and petrologic characterization of these samples will also be completed to ensure the compatibility of the lower confining zone with the carbon dioxide stream. See the Pre-Operational Testing Plan for additional details.

The Injection Zone

The selected injection zone for the Class VI well is the Mokelumne River Formation (MRF). Within the AOR, the depth to the top of the unit ranges from approximately 5100 to 6800 feet below MSL (**Figure 2-12; Table 2-1**). Within the AOR, the thickness of the MRF ranges from approximately 200 feet to 1700 feet (**Figure 2-13; Table 2-1**). The variability in thickness depends on the depth of erosion by Paleocene or Eocene unconformities that comprise the upper surface. Six penetrations of the Mokelumne River Formation on Rindge Tract Island and within or near the defined AOR were selected for further analysis. The geophysical logs for these wells are shown on **Figure 2-27**.

Core and sidewall core data from Citizen Green Well #1 indicate textural changes within the injection zone (**Attachment 3**). These changes are likely to influence the permeability distribution within the injection zone. The vertical scale of permeability variation appears to be on the order of 100 feet. We can infer from seismic data (**Attachment 1**) that similar variations exist within the injection zone beneath the delineated AOR (**Figure 2-27**). The geophysical logs for the six penetrations of the Mokelumne River Formation show indicators of textural variability on the same scale. The stratigraphic stacking patterns for Big Valley Eberhart 1 is very similar to type log sections for the Mokelumne River Formation presented by Johnson (1990), with a basal coarsening upward sand unit, interbedded sands and shale, and massive sands at the top of the formation. The shale interbeds will impact CO₂ migration within the injection zone but do not appear laterally continuous enough to serve as a primary confining unit.

The mineralogy, petrology, and material properties were informed by core and sidewall core taken from the Citizen Green #1 well (**Attachment 3**). The Citizen Green #1 well is the closest location for which mineralogic and petrologic data have been collected (approximately three miles north of the delineated AOR at Rindge Tract Island). X-ray diffraction (XRD) data for four samples

within the Mokelumne sands show that the mineralogic composition is dominated by feldspars and quartz (**Table 2-6**). Additional details on the mineralogy of the Mokelumne are discussed in the Geochemistry sub-section. 16 sidewall core samples from the Mokelumne were described as sands or silty sands in the depth interval from 5350 feet to 6800 feet. Within this depth interval, one sample was described as a clay-siltstone layer (approximately 20 feet thick).

Porosity, intrinsic permeability, and grain densities were measured in six samples from the lower Mokelumne River Formation. The intrinsic permeability in brine was estimated to range from 0.57 to 86.3 mD. The intrinsic permeability in air was estimated to range from 4.8 to 367.1 mD. The porosity was estimated to range from 27.7 to 33.0%. The grain densities were estimated to range from 2.65 to 2.70 g/cm³. No relative permeabilities were measured.

Injectivity tests are not available for the Mokelumne River Formation in the project area and are included in the Pre-Operational Logging and Testing Plan in **Section 6** of this application. There are multiple lines of evidence supporting that the Mokelumne River Formation has sufficient injectivity for CO₂ injection: (1) The Mokelumne River Formation is already used for gas storage injection at the MacDonald Island Gas Storage Field; (2) Sidewall core and petrophysical well log analysis indicates that the Mokelumne River Formation has sufficient porosity and permeability to store CO₂ and dissipate pressures; and (3) The mercury capillary entry pressure (MICP) for two sidewall cores Citizen Green #1 are .45 and .49 psia (**Attachment 3**).

Key uncertainties in understanding the character of the injection zone result from the lack of directly measured site-specific data within or near the AOR. The uncertainties will be reduced by initially treating the Class VI well as a stratigraphic test well with complete core sampling, sidewall core sampling, geophysical logging, and injectivity testing. The key parameters governing the injectability and storage capacity in the Mokelumne are the density, porosity, intrinsic permeability and anisotropy ratio, relative permeability, and capillary pressure. Mineralogic and petrologic characterization of these samples will also be completed to ensure the compatibility of the injection zone with the carbon dioxide stream. This stratigraphic test well would be drilled before the Class VI authorization to construct or convert is issued. As noted in the following discussion on the Upper Confining Zone, Pelican will also extend drilling of deep monitoring wells to validate confinement potential for the Upper Confining Zone across the AOR. Pelican will extend each of these wells into the upper Mokelumne such that cores can be collected for analysis. Following test well construction and data collection, characterization data for the Mokelumne will be input into DOE-NETL's CO₂ Storage prospective Resource Estimation Excel aNalysis (CO₂-SCREEN) or a similar tool to quantitatively interpret reservoir quality. See the Pre-Operational Testing Plan for additional details.

The Upper Confining Zone

The top of the injection zone is vertically separated from the lowermost USDW by at least 1000 feet and up to approximately 2600 feet of strata. The upper confining zone is low permeability strata of the Meganos Gorge Fill and Capay Shale that directly overly the injection zone. Within the AOR, the depth to the top of the confining zone ranges from approximately 4900 to 5600 feet below mean sea level (MSL) (**Figure 2-15; Table 2-1**). Within the AOR, the thickness of the upper confining zone ranges from approximately 150 feet to 1400 feet (**Figure 2-16; Table 2-1**). The six penetrations selected for further analysis all contain instances of the upper confining zone,

indicating that this unit is continuous across the AOR (**Figure 2-27**). This is consistent with interpretations from the seismic reflection data (**Attachment 1**). There is minimal textural variability within the Capay Shale across these penetrations (**Figure 2-27**). The Capay-Meganos sequence is a sufficient primary confining zone due to its thickness, extensivity, lack of faults and fractures, and minimal textural variability in the shales within and near the AOR. The secondary confining zones have been identified as an additional protection for USDWs due to the variability in vertical separation between the injection zone and lowermost USDW within and near the AOR.

XRD, porosity, permeability, and MICP data were not analyzed for the upper confining zone at the Citizen Green #1 well. Six core samples were taken within the Capay Shale, but not analyzed. Of the six sidewall core samples collected from the Capay, three were described as shale, one was missing, and two were described as sand or silty sand. At the Citizen Green #1 Well, the depth interval described as Capay ranges from 5108 feet to 5202 feet (**Attachment 3**).

Key uncertainties in understanding the character of the upper confining zone result from the lack of directly measured site-specific data within or near the delineated AOR. The uncertainties will be reduced by initially treating the Class VI well as a stratigraphic test well with complete core sampling, sidewall core sampling, and geophysical logging of the upper confining zone and overlying pressure dissipation zones (i.e., all units beneath the base of the lowermost USDW (Markley Formation)). The core analyses will include XRD, porosity, permeability, and MICP. The key parameters governing the suitability of this zone as a seal are the density, porosity, intrinsic permeability and anisotropy ratio, relative permeability, and capillary pressure. Mineralogic and petrologic characterization of these samples will also be completed to ensure the compatibility of the upper confining zone with the carbon dioxide stream. This stratigraphic test well would be drilled before the Class VI authorization to construct or convert is issued. To confirm that the Capay Shale supports confinement across the AOR, Pelican will additionally drill each of the above confining zone monitoring well holes into the Capay Shale to confirm its confinement potential across the AOR. This will take place at the locations for GMW-1D, GMW-2D, and GMW-3D, which will ultimately monitor the lowermost transmissive sands within the Domengine Formation as defined in the Testing and Monitoring Plan (Section 8). These test holes will be plugged back to the intended monitored zone within the Domengine Formation before the monitoring wells are constructed. See the Pre-Operational Testing Plan for additional details.

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

Geophysical well log data collected from 30 oil and gas wells in the general vicinity of the proposed injection site were evaluated to determine reservoir and confining unit characteristics for the Capay Shale, Meganos Gorge, Mokelumne River Formation (MRF), and the H&T Shale. Geologic units above the Nortonville Shale were not included. The distribution of the 30 wells is shown on **Figure 2-7**. Core data from Citizen Green #1 well were used to calibrate log responses for all other wells. A comparison of core and well log data for Citizen Green #1 is provided in **Attachment 3**. A detailed description of the petrophysical analysis methods and the tabulated results are provided in **Attachment 2**.

Eleven of the 30 wells contained full suites of logs including Resistivity, Spontaneous Potential (SP), Gamma Ray (GR), Density/Neutron and in some cases Sonic Delta-T. There were nine wells that contained resistivity, SP, and DT only. The remaining wells contained only resistivity and SP data. Petrophysical analyses described in the referenced report were used to calculate the estimated formation porosity, permeability, Volume of Clay (VCL), and salinities for wells in the project area. A Petrophysical Zone Averages Report spreadsheet includes tabulation of the unit top and bottom elevations, the gross thickness, net thickness, net to gross (NTG), average porosity, average VCL and average VCL thickness for Nortonville to TD, Domengine Formation and the Mokelumne River Formation (MRF). This information was initially provided to the Pelican modeling team to develop the parameters for the numerical models.

In addition to the petrophysical data analysis, well logs were assembled to create geologic cross sections centered near the sequestration site and extending from 1.5 to 3 miles from northwest to southeast and from west to east. The petrophysical data analysis and geologic cross sections reveal the following formation characteristics:

Nortonville Shale: The well logs indicate a low permeability, laterally continuous formation with average gross thickness of approximately 254 feet. Porosities range from 0.06 to 0.53 with a gross average of 0.35. The NTG for Nortonville is 0 indicating the volume of reservoir rock in this formation is minimal. The average VCL is 0.54. Average air permeability (K_{air}) is 1.3 milliDarcy (mD). There is no deflection from the SP and no separation between the deep and shallow resistivity curves. These observations together suggest very low permeability in the Nortonville.

Domengine Formation: The well logs show the formation has favorable reservoir permeability, and is laterally continuous with average gross thickness of approximately 857 feet. The formation thickness is approximately 800 feet above the injection site, thickening to the northwest to approximately 1,100 feet at the 3-mile radius and thinning to approximately 600 feet to the east. The formation consists of thick blocky sands with intermittent thin interbedded shale, and most notably an approximately 100 to 200 feet thick low permeability section in upper portion of the formation. Wells further to the west of the proposed injection site exhibit thicker sand packages, thinning as you go east. The eastern wells exhibit good, developed sands in the bottom half of the Domengine and poorer quality toward the upper half of the zone. Porosities range from 0.06 to 0.53 with a gross average of 0.35. The average NTG for Domengine is 0.51 and the maximum NTG is 0.923 indicating predominance of reservoir rock in this formation. The average VCL is 0.27. Average K_{air} is 93 mD. The is well developed SP deflection as well as more separation between the deep and shallow resistivities in the western wells compared to the eastern wells. Although this suggests better permeability to the west, the eastern wells still indicate favorable permeability, albeit in thinner packages.

Capay Shale: The well logs indicate a low permeability, laterally continuous formation with relatively uniform thickness ranging from approximately 330 feet thickness west and northwest of the sequestration area/injection site to approximately 100 feet in the east. Overall, the average gross thickness is approximately 200 feet. Porosities range from 0.09 to 0.48 with a gross average porosity of 0.28. The NTG for Capay is 0.016 indicating the volume of reservoir rock in this formation is minimal. The average VCL is 0.49. Average air permeability is 2.5 mD. There is negligible SP deflection and both resistivities stack indicating very low permeability and likely a

barrier to flow. The Capay thickens near the proposed injection site (see Dow Services Allied and RTP #1-21) then thins to the southeast with the top of the unit shallower than the northwest wells, possibly due to the presence of a fault. The low permeability Capay formation should serve effectively as an upper confining unit overlying the MRF sequestration zone.

Meganos Gorge: The well logs indicate a low permeability formation present west of the sequestration area seen in Spaletta #1 well that cuts approximately 700 feet into the MRF and thickens to the west and northwest. The Meganos zone is present in the northwest wells then is not present in the southeast (east of Cities Services Allied well) suggesting a fault. Where Meganos is present, it has the characteristic of a low flow zone like the Capay. The Meganos tends to have larger gross thickness than the Capay, ranging from 600-1000 ft thick. Meganos porosities range from 0.12 to 0.48 with a gross average porosity of 0.28. The NTG for Meganos is 0.13. The average VCL is 0.42. Average air permeability is 4.6 mD. There is negligible SP deflection and both resistivities stack indicating very low permeability and likely a barrier to flow. The low permeability Meganos with the Capay should serve effectively as the upper confining unit overlying and adjacent to the MRF sequestration zone.

MRF: The well logs indicate this formation consists of thick sands with intermittent thin interbedded shale providing favorable reservoir permeability and is laterally continuous with average gross thickness of approximately 645 feet. Well logs in the vicinity of the proposed injection site indicate significant offset in the MRF from the Dow Services Allied well at approximately 6300 feet and RTP #1-21 well top at approximately 5370 feet indicating a fault or slump in this area. Porosities range from 0.11 to 0.39 with a gross average porosity of 0.28. The average NTG for MRF is 0.51 and the maximum NTG is 0.7 indicating predominance of reservoir rock in this formation. The average VCL is 0.25. Average air permeability is 127 mD. The MRF wells have well developed SP deflection as well as more separation between the deep and shallow resistivities in the western wells compared to the eastern wells. Although this suggests better overall permeability to the west, the eastern wells still indicate favorable permeability.

H&T Shale: The well logs indicate a low permeability, laterally continuous formation with average gross thickness is approximately 73 feet. Porosities range from 0.09 to 0.38 with a gross average porosity of 0.23. The NTG for H&T Shale is 0.012 indicating the volume of reservoir rock in this formation is minimal. The average VCL is 0.31. Average air permeability is 0.19 mD. There is negligible SP deflection and both resistivities stack indicating very low permeability indicating a barrier to flow. The low permeability H&T Shale formation should serve effectively as underlying confining unit for the MRF sequestration zone.

Reservoir salinities were calculated for MRF and to identify any units that may have salinities less than the 10,000 parts per million (10 kppm) which is the threshold used to identify an underground source of drinking water (USDW) aquifer. The calculated salinities for Domengine and MRF remain above 10,000 parts per million (ppm). See **Table 2-5** for calculated salinities from legacy wells within and near the AOR, as well as **Attachment 2** for a discussion of the petrophysical calculations to evaluate salinities. There are some wells that have calculated intervals that all are at the top of the MRF that calculated less than 10,000 ppm but these are high resistive zones that are potentially charged and not considered wet and are likely shale stringers. The Domengine have clear wet sands that calculate salinities in similar ranges to the MRF. The units above the

Nortonville Shale show “clean, wet sands” with salinities less than the 10,000 ppm USDW threshold, ranging from 2,000 ppm to 6,000 ppm. SCS understands there have been no water quality samples taken in the MRF with the Area of Review. In addition, SCS conducted an online database review and found no available fluid geochemistry data for the MRF within the AOR and extending out to the edge of the Rindge Tract Island. Two (2) wells located inside the AOR have well logs suitable for salinity calculations; of these 2 wells, Eberhardt 15-34 (API: 407720498), is the only well that penetrates the MRF. Based on the log derived salinity calculations, the salinities for the sand intervals within the MRF range from approximately 11,000 to 22,000 parts per million (ppm) as shown on **Figure 2-38b**. Based on the limited amount of well log data and water quality samples within the AOR, the log calculations are the best tool to estimate the salinity of the MRF at this time. The proposed stratigraphic test well and deep monitoring wells will collect water quality samples of the MRF to confirm that salinity of the formation water is below 10,000 ppm within the sand intervals utilized for injection.

Data Gaps and Recommendations:

Geomechanical data were not available in the information provided for this review. The lack of directly measured site-specific data at Rindge Tract will be reduced by initially treating the Class VI well(s) as a stratigraphic test well(s) with complete core sampling, sidewall core sampling, and geophysical logging of the confining zone and overlying pressure dissipation zones (i.e., all units beneath the base of the Markley Formation (USDW)). In addition, geochemical data will be collected to confirm the lowermost USDW and its salinity, as well as the salinity of the proposed injection zone (MRF) and sand units between the injection zone and lowermost USDW.

Since there was no indication that lab testing has been performed to calculate rock ductility, rock strength, stress, brittleness or other geomechanical parameters, rock cores should be collected from the Class VI test well(s) for geomechanical laboratory analysis. In addition, combination of advanced sonic logs measuring both shear and compressional sonic travel time in the same well(s) can be used for data calibration and application for off-set wells.

Test results regarding Faults and Fractures were not available. Class VI test well(s) should include resistivity imaging tool/s for fracture identification, bedding information (NTG), as well as fault and fracture identification. Imaging tools will also be able to provide rock strength information through the identification of breakouts.

Pore pressure data were not obtained from the available well log data. The acquisition of formation pressures will provide pore pressure and in-situ permeability data. Collecting fluid samples for direct salinity measurements can be used to verify USDW; as mentioned, this information will be collected when the stratigraphic test well is drilled. Gathering segregated downhole water samples would provide the resistivity of formation water (R_w), salinity and Total Dissolved Solids (TDS) values required by CalGEM. Vertical Interference Testing (VIT), from Modular Dynamic Tester (MDT), can also be used to measure vertical communication between sand and shale units.

The permeability estimation model for this project relied on limited rotary sidewall core data taken from the Citizen Green #1 including the Nortonville shale interval and the MRF formation. The uncertainty around permeability warrants collecting additional cores (rotary or whole core). The

core should be collected in all zones to obtain a spectrum of porosities and apparent clay contents. Measurement of air and liquid permeability as well as x-ray diffraction (XRD) measurements for clay content would be beneficial to develop a single permeability transform or to identify units that require a separate transform. Acquisition of magnetic resonance information to compare to core would be helpful to quantify total porosity as well as independently validate the permeability transform. The use of spectroscopy logging tools can be used to validate clay volume calculations and to compare to core XRD measurements. Dielectric logs are another option for calibration of clay volume and has been utilized in the Central Valley for heavy oil and freshwater environments.

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

The initial evaluation of Rindge Tract for carbon sequestration included assessing the potential for earthquakes at or near the injection zone, and the integrity of the target injection formation seal (the Capay Shale and Meganos Gorge Fill) during seismic events. The geologic characterization includes a detailed evaluation of the Capay and Meganos Gorge.

SCS obtained fault and seismicity data from the following sources:

- Northern California Seismic Network (2020)
- USGS and California Geological Society, Quaternary Fault and Fold Database (2022)
- Characterizing the Earthquake Ground Shaking Hazard in the Sacramento-San Joaquin Delta, California (Wong et al, 2009)
- Late Cenozoic Tectonism of the Sacramento Valley, California (Harwood and Helley, 1987)
- USGS Seismic Hazard Map (2018)
- Characterization of Potential Seismic Sources in the Sacramento-San Joaquin Delta, California (Unruh et al, 2009)

According to the USGS National Quaternary Fault and Fold Database, the closest mapped Quaternary fault to the proposed injection site on Rindge Tract is the South Midland Fault, which is located approximately seven miles west of the island. However, upon review of data obtained from previous natural gas exploration, the Rindge Tract AOR is located approximately 1.5 miles northeast of the McDonald Island gas field, which consists of a structural trap formed by a fault-bound anticlinal feature.

The Quaternary South Midland fault was formed during the development of the Rio Vista Basin, part of the ancestral Great Valley forearc basin, and was initially active as a normal fault during the Cretaceous (Harwood and Helley, 1987). The fault was reactivated during the late Cenozoic as a reverse-oblique fault that strikes north-northeast, dips steeply to the west with a right-lateral strike-slip component. Many hundreds of feet of undifferentiated Miocene sediments obscure the South Midland fault trace; therefore, the fault location as depicted on **Figure 2-28**, is inferred.

In 2009, Unruh et al. (2009) published a detailed study of the South Midland fault that included the analysis of gas exploration and production boring data, historical geologic maps, topographic maps, and aerial photographs. Aerial photographs and topographic maps reveal geomorphologic features that indicate movement, such as uplifts and depressions, and stream offsets. Geologic maps and boring logs show the relative locations of geologic units and indicate unit displacement.

According to the study, the South Midland fault experienced displacement as recently as the middle to late Holocene. The National Quaternary Fault Database (USGS, 2022) reports no seismic activity originating at the South Midland fault within recorded history.

SCS reviewed geologic data for the McDonald Island gas field, southwest of Rindge Tract. The McDonald Island gas field consists of a northeast-southwest trending fault bound anticlinal feature that forms a structural trap for natural gas. It is unclear whether the faulting is due to brittle or ductile deformation. SCS found no evidence of seismicity associated with the McDonald Island faults.

SCS examined the USGS Seismic Hazard Map and historical seismicity records to determine the potential for earthquake shaking within the Rindge Tract AOR. The USGS Seismic Hazard Map includes the entirety of California as an area of elevated risk, much of which is due to the Northern California transverse tectonic regime and the blind thrust faults prevalent in Southern California. Using data from the Northern California Seismic Network (1967-2020), SCS plotted earthquake activity proximal to the AOR (**Figure 2-28**). Events shown on **Figure 2-28** lie outside the AOR, and based on the calculated magnitude do not pose a significant risk to the target injection zone or stratigraphic seals. **Table 2-2** below details these events and their location, magnitude, depth, and distance from the AOR.

Table 2-2. Recent Seismic Events in the Vicinity of the AOR

EventID	Date	Latitude	Longitude	Depth (Miles)	Magnitude	Magnitude Type	Number of Stations	Distance from AoR (miles)	Source
21224932	5/8/2002	38.22383	-121.8375	17.43	3.6	Mw	156	25.05	NCSN
21247683	9/29/2002	37.8745	-121.611	4.31	3.42	ML	79	13.17	NCSN
51199149	3/27/2008	37.93083	-121.803	14.11	3.14	ML	103	20.19	NCSN
71280691	9/13/2009	37.85483	-121.772	13.80	3.21	Mw	135	20.92	NCSN
71670931	10/26/2011	37.85383	-121.8915	8.73	3	ML	133	26.68	NCSN
72795746	4/30/2017	37.82516	-121.806	15.20	3.78	Mw	264	23.59	NCSN
73034206	6/22/2018	37.99117	-121.7205	10.40	3.24	Mw	205	14.82	NCSN
73225421	7/16/2019	37.81867	-121.75684	12.38	4.31	Mw	143	21.67	NCSN
73225436	7/16/2019	37.81867	-121.76033	11.71	3.2	ML	110	21.82	NCSN

*Notes: Data obtained from the Northern California Seismic Network (NCSN) earthquake catalog
AoR: Area of review – distance from estimated earthquake epicenter to the boundary of the AoR*

Wong et al (2009) performed a Probabilistic Seismic Hazard Analysis (PSHA) for the Sacramento-San Joaquin Delta area using information on the geology, known faults and seismic history of the region. The PSHA calculates the probability of peak ground acceleration (PGA) and the projected frequency of the PGA. According to the USGS, PGA is “a measure of the maximum force experienced by a small mass located at the surface of the ground during an earthquake.” The results of the PSHA predict PGA of between 0.16 and 0.20% g for a 2% probability within 250 years. The calculations returned a repeat period of approximately 500 years for the area including Rindge Tract. SCS used the USGS Unified Hazard Seismic Tool (Tool) to calculate the PGA at Rindge Tract at 2% within 250 years. The Tool uses a shear wave velocity of 750 m/sec, the uppermost of the Class C fault velocity range/lowermost of the Class B velocity range. The calculated peak Unified Hazard Response Spectrum was 0.3403g, and the annual frequency of an event of greater than 0.2g was $1.7e^{-3}$, or a repeat time of approximately 585 years. Pelican also conducted a risk assessment for induced seismicity as a result of project operations, which is discussed in detail in **Attachment 4** of this narrative.

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

The following sections present the results of a hydrologic and hydrogeologic study for the proposed Pelican CCS Project. The study reviewed online databases, well records, and historical literature relative to groundwater in the Eastern San Joaquin Sub-basin of the San Joaquin River Hydrologic Region. The more refined Study Area extended approximately one mile beyond the boundary of Rindge Tract Island.

Methods

Sources, including geologic maps, well completion reports, well logs, and historical reports, were reviewed to complete this analysis. A list of these sources is displayed in **Table 2-3**.

Table 2-3. Hydrogeologic Data Sources

Online Databases		
Data Type	Source or Author	Website or Record Name
Groundwater Elevation	California Department of Water Resources	http://www.water.ca.gov/waterdatalibrary/
Water Well Completion Reports	California Department of Water Resources	https://dwr.maps.arcgis.com/apps/webappviewer
Groundwater Ambient Monitoring and Assessment Program (GAMA) (water quality, well locations and monitoring data)	California State Water Resources Control Board	https://www.waterboards.ca.gov/water_issues/programs/gama/online_tools.html
Groundwater Elevation/Water Quality	Eastern San Joaquin Sub-basin Data Management System	https://opti.woodardcurran.com/esj/main.php
Groundwater – Produced Water Geochemical Data	USGS: Produced Waters Database v. 2.3	https://tableau.usgs.gov/views/USGSPWDBv3_0/USGSPWDBv3_0Dashboard?%3Aembed=y&%3AisGuestRedirectFromVizportal=y
Literature Review		
Groundwater Basin Information	California Department of Water Resources	California’s Groundwater Bulletin 118 Groundwater Basin Number: 5-22.01
Freshwater Formation descriptions	Eastern San Joaquin Groundwater Authority	Eastern San Joaquin Subbasin - Groundwater Sustainability Plan, June 2022 http://www.esjgroundwater.org/Documents/GSP
Groundwater data, elevations, maps, etc	San Joaquin County Flood Control and Water Conservation District California Natural Resources Agency datasets	San Joaquin County Flood Control and Water Conservation District Annual Groundwater Report for 2021 CNRA_dataset
Hydrogeology Research	David R. O’Leary & John A. Izbicki & Loren F. Metzger	Sources of high-chloride water and managed aquifer recharge in an alluvial aquifer in California, USA
Reservoir Characteristics	California Geologic Energy Management Division	CALIFORNIA OIL & GAS FIELDS, Volume III – Northern California 1982
Well Records		
Oil & Gas Well Records and Reservoir Characteristics	California Geologic Energy Management Division	https://www.conservation.ca.gov/calgem/Pages/WellFinder.aspx
Maps		
Geologic Map	Wagner, Jennings, Bedrossian, and Bortugno, 1981	Geologic Map of Sacramento Quadrangle

Groundwater Basin Overview

The Pelican CCS Study Area is located within the Eastern San Joaquin Groundwater Sub-basin Number 5-22.01 (Sub-basin) of the San Joaquin River Hydrologic Region, as designated by the California Department of Water Resources (DWR) in Bulletin 118. The San Joaquin River Hydrologic Region formed in a broad structural trough that extends approximately 270 miles and trends northwest to southeast in the southern portion of the Central Valley of California. The Mokelumne River bounds the Sub-basin on the north and northwest, the San Joaquin River on the west, the Stanislaus River on the south, and consolidated bedrock on the east. The Study Area, which extends approximately one mile beyond the Rindge Tract Island boundary, is located in the eastern half of the Sub-basin. (**Figure 2-29**).

Topography

The Sub-basin ground surface elevations range from approximately 1,000 feet above mean sea level (MSL) in the Sierra Nevada Mountains on the eastern side to near sea-level on the western side. The topography slopes from east to west as shown in **Figure 2-30**.

Surface water drains west toward the San Joaquin River, which flows north along the western side of the Sub-basin. The Mokelumne and Stanislaus Rivers are major tributaries to the San Joaquin River that flow westerly and define the Sub-basin's northern and southern boundaries. (**Figure 2-30**).

Water Bearing Freshwater Formations

The lithology of the Sub-basin is comprised of unconsolidated to semi-consolidated sedimentary deposits. Water-bearing units include the unconsolidated surficial alluvium and intertidal deposits of the Modesto/Riverbank Formations, and other unnamed Flood Basin deposits near the San Joaquin River delta (Recent to Late Pleistocene), underlain by the Laguna Formation (Plio-Pleistocene) and Mehrten Formation (Miocene to Pliocene). The Mehrten Formation is considered to be the oldest and deepest fresh water-bearing unit, since underlying Formations were deposited in a marine environment and contain more saline pore water relative to younger units (DWR, 2020).

Regional freshwater-bearing formations in the Sub-basin are described in the 2022 Groundwater Sustainability Plan, prepared by the Eastern San Joaquin Groundwater Authority. A summary of these descriptions is provided on **Figure 2-31**.

Surficial units in the Study Area include the Modesto Formation alluvium deposits on its eastern portion, and intertidal deposits at the surface on its western portion (**Figure 2-32**). The alluvium and Modesto/Riverbank formation deposits are undifferentiated units of Recent to Late Pleistocene in age. According to Bulletin 118 (DWR, 2020), these units range in thickness from a “thin veneer”

on the east side of the basin to over 150 feet near the center of the Sub-basin. Groundwater is unconfined within these units.

Freshwater

Base of Freshwater

The vertical extent of fresh, non-saline groundwater in the Sub-basin is illustrated on **Figures 2-33 and 2-34**. Freshwater is defined by the USGS as containing less than 1,000 parts per million (ppm) total dissolved solids (TDS)¹. While water-bearing formations exist in deeper units, high salinity and the drilling depth required to install wells make accessing these aquifers economically infeasible. The base of freshwater in the Sub-basin ranges from approximately 600 to 1,400 feet below ground surface (bgs) (**Figure 2-35**); the base of freshwater in the Study Area is approximately 900 feet bgs. As depicted on **Figure 2-35**, the Valley Springs Formation is the deepest unit within the Sub-basin to contain freshwater and the Mehrten Formation is the deepest unit within the Study Area containing freshwater.

Groundwater Elevations

Current groundwater elevation conditions have been characterized using May 2022 data from the California Natural Resources Agency's network of groundwater monitoring wells within the Sub-basin. The groundwater elevations show a depression in the center of the Sub-basin near the east side of the City of Stockton caused by groundwater pumping in this area (**Figure 2-36**).

Regional Groundwater Flow

As seen in **Figure 2-36**, groundwater pumping has lowered water table elevations and potentiometric pressures have induced groundwater flow east towards the City of Stockton. The lateral gradient along the western side of the Sub-basin near the Study Area ranges from approximately seven feet/mile during the seasonal high to six feet/mile during the seasonal low. Prior to development of groundwater resources in the area, groundwater is likely to have flowed west following the land surface topography and the flow direction of surface water in the Sub-basin.

Local Water Well Review

Review of available online databases including the DWR's water well completion records indicates that there are 23 water wells located inside or within one mile of Rindge Tract Island. Of the 23 well records, 13 included well completion reports. The deepest water well in the Study Area was drilled to 295 feet bgs (well record #334901). **Table 2-4** (below) displays wells with known drilling depth. Ten were drilled to maximum depths of less than 200 feet bgs. Reported static water levels ranged from eight to 20 feet bgs. The water well completion records identify the depth of

¹ https://www.usgs.gov/special-topics/water-science-school/science/saline-water-and-salinity?qt-science_center_objects=0#qt-science_center_objects

completion for these shallow water wells, but the records do not specify the formation. For the purposes of this assessment, wells completed less than 300 feet bgs are described as “shallow”. Based on the Geologic Surface Map and the geologic unit characteristics in the Study Area, these wells are likely completed in the Modesto/Riverbank Formation. **Figure 2-37** displays the location and total depth of the available water well records in the Study Area.

Table 2-4. Well Completion Records with Completion Depths

WCR Number	Legacy Log Number	Township	Range	Section	Baseline Meridian	Total Completed Depth	Top of Perforated Interval	Bottom of Perforated Interval
WCR2004-002067	927054	02N	05E	21	Mount Diablo	85	50	70
WCR2021-009839	-	02N	05E	18	Mount Diablo	63	43	63
WCR1986-004210	187198	02N	05E	5	Mount Diablo	142	-	-
WCR0288639	61314	02N	05E	5	Mount Diablo	120	100	120
WCR1988-004091	250491	02N	05E	27	Mount Diablo	85	-	-
WCR0300272	83715	02N	05E	27	Mount Diablo	54	44	54
WCR2002-008121	808983	02N	05E	27	Mount Diablo	100	60	80
WCR2002-008122	808983a	02N	05E	27	Mount Diablo	85	62	82
WCR0317062	77044	02N	05E	27	Mount Diablo	63	48	63
WCR1981-003194	77044	02N	05E	27	Mount Diablo	82	-	-
WCR1989-011025	334901	02N	04E	12	Mount Diablo	295	-	-
" - " indicates no data available								

Underground Sources of Drinking Water

Figure 2-33 is a cross-section drawn to scale that highlights the vertical separation between the proposed injection wells and zones and USDWs at Rindge Tract. Specifically, this section highlights the freshwater USDWs, deeper non-freshwater USDWs, the lowermost USDW (Markley Formation), and all zones within the proposed sequestration complex (i.e., Nortonville Shale (pressure dissipation zone); Domengine Formation (pressure dissipation zone); Capay Shale/Meganos Formation (upper confining zone); and Mokelumne River Formation (injection zone). More detail on the USDWs is provided in the following sections.

Freshwater

Freshwater in the Study Area is found in the Holocene alluvium and the Late Pliocene and Pliocene Modesto and Riverbank Formations. As indicated by the water well search, there are 23 water wells located within one mile of the Rindge Tract Study Area with the deepest reaching 295 feet bgs. Fourteen of the 23 water wells in the Study Area were listed as Domestic Water Supply wells, and the remaining nine wells did not list the well type. Based on the well completion records and the review of data sources listed in **Table 2-3**, freshwater that currently has a beneficial use is found within the upper several hundred feet in the Study Area. Fresh water is defined as having a Total Dissolved Solids (TDS) of less than 1,000 milligrams per liter (mg/L).

Brackish Water

While high salinity adversely affects water quality in formations deeper than the Modesto and Riverbank Formations, according to the 40 CFR 144.3 definition some may qualify as a potential USDW. According to 40 CFR 144.3 a USDW is defined as:

...an aquifer or its portion: (a)(1) Which supplies any public water system; or (2) Which contains a sufficient quantity of ground water to supply a public water system; and (i) Currently supplies drinking water for human consumption; or (ii) Contains fewer than 10,000 mg/l total dissolved solids; and (b) Which is not an exempted aquifer.

Using these criteria as a template for reviewing the USDW in the Study Area, this analysis focused on defining the lowermost formation with groundwater TDS below 10,000 mg/L, and water-bearing formations containing a sufficient quantity of groundwater to supply a public water system.

Readily available groundwater quality information was reviewed to determine the base of the potential USDW. The data indicate there are no public or private water wells that penetrate deeper than the Modesto/Riverbank Formations. To determine which formations may qualify as a USDW within the Study Area, SCS employed the following methods:

- Evaluated available water quality data for formations deeper than the Modesto/Riverbank Formations,
- Reviewed historic literature in nearby state designated oilfields, and
- Performed salinity calculations using petrophysical logs.

Literature Review

Well files acquired from the CalGEM online well records database were reviewed to identify publicly-available water quality data within the Study Area; however, no water quality records or analytical data were identified. Water quality data obtained from CalGEM's CALIFORNIA OIL & GAS FIELDS, Volume III – Northern California 1982 publication were reviewed and compiled. This resource lists state designated oilfields in California including subsurface producing Formations and, if available, rock property and reservoir fluid data. The literature review yielded little data to support which formation could serve as the lowermost potential USDW as defined by 40 CFR 144.3.

Salinity Calculations

Salinity calculations utilizing petrophysical logs was the next approach to determining the lowermost USDW. Multiple salinities were calculated based on different methods including the Spontaneous Potential (SP) method and the Humble Salinity calculation. The Humble equation is a four-step process: (1) converting measured density to formation porosity, (2) calculation of apparent water resistivity using the Humble equation, (3) correcting apparent water resistivity to a standard temperature, and (4) converting temperature corrected apparent water resistivity to salinity. The SP calculation method utilizes the measured SP baselined to 0 mV and is very sensitive to the recorded drilling mud salinity (Rmf). Please refer to **Attachment 2** for additional details on how the salinity calculations were performed and the complete petrophysical results.

To determine the depth to the lowermost USDW, 10,000 parts per million (ppm) constant line was overlain on the calculated salinity curves (see **Figures 2-38a-c** for examples). Note that TDS is a measure of dissolved solids in a volume of water and recorded in units of mg/l; this unit is interchangeable with parts per million (ppm) (1 ppm is equivalent to 1 mg/liter). The interpretation of the petrophysical calculations shows a clear trend of increasing salinity with depth (Refer to Salinity Log Plots in **Attachment 2**). This transition depth of greater than 10,000 ppm salinity was then compared to the corresponding geologic formation. As shown in **Table 2-5** below, all of the wells analyzed indicate the Domengine has greater than 10,000 ppm salinity, while units above the Domengine calculated salinities are less than 10,000 ppm. According to the 40 CFR 144.3 definition, the Markley is the lowermost USDW in the Study Area.

The base of the Markley/Top of the Nortonville Shale has been mapped for the purposes of displaying the base of the lowermost USDW (**Figure 2-19**). **Figures 2-38a, 2-38b, and 2-38c** additionally highlight the relative positions of the USDWs to the proposed injection wells and zones in the vicinity of Rindge Tract. As discussed in prior sections, one of the Class VI wells will be initially constructed as a stratigraphic test well with complete core sampling, sidewall core sampling, and geophysical logging of the confining zones and overlying pressure dissipation zones (i.e., all units beneath the base of the lowermost USDW (Markley Formation)). In addition, pre-operational water quality testing will be conducted to confirm the lowermost USDW at the stratigraphic test well and each deep well monitoring well drilling location. The stratigraphic test well would be drilled before the Class VI authorization to construct or convert is issued.

Injection Zone Salinity

As discussed in the Area of Review and Corrective Action Plan, Pelican utilized a salinity of 12,500 ppm TDS for the MRF in the geologic model initial conditions. This value was estimated from the Citizen Green 1 well log using the methods discussed in the preceding section on salinity calculations. Although Citizen Green 1 is located outside the AOR (approximately 3 miles north), Pelican utilized an estimated salinity value from this well for consistency with other model inputs estimated from Citizen Green 1. Pelican will collect formation water samples from the MRF for direct salinity measurements within the AOR upon drilling of the stratigraphic test well and deep monitoring wells to confirm its salinity.

Pelican located additional well records from CalGEM that include direct salinity measurements for the MRF and other salinity data relevant to the MRF. The Midland Fee Water Injection Wells in the Rio Vista Gas Field (approximately 13 miles northwest of the AOR) specify a TDS for the MRF of 13,889 ppm based on a direct water sample analysis completed in 1980. The Piacentine_2-27 well located approximately 3 miles north of the AOR in the King Island Gas Field (historical gas producing field for MRF) has available water quality data from 2013 and specifies a direct TDS value of 14,000 ppm for the MRF. In addition to these direct salinity measurements, documentation for the PG&E Test Injection/Withdrawal Well 1 (neighboring the Piacentine_2-27 well) discusses that the EPA calculated and confirmed depth base of USDW at this location is at approximately 3,840', which is approximately 1000' above the MRF at this location.

These three well locations, along with Citizen Green 1, are noted on **Figure 2-39**. Relevant portions of data records specifying these salinity values are included in **Attachment 3**.

Table 2-5. Calculated Salinities to Identify Lowermost USDW

Well Name	API	Domenging Salinity (ppm)	Depth to 10,000 ppm or > Salinity (feet md)	Top Markley (feet md)	Top Nortonville Shale (feet md)	Top Domengine (feet md)	Domengine Sand Base (feet md)	Formation with Salinity > 10,000 ppm	Average Markley Salinity (ppm)
Allied Properties No 1	4077004690000	11,002	4,461	4,057	4,152	4,455	5,186	Domengine	3,221
Allied Properties No 1 sec 22	4077004760000	12,012	5,038	4,244	4,412	4,678	5,433	Domengine	2,044
Big Valley Everhardt No 1	4077203510000	10,876	4,581	4,034	4,121	4,325	4,907	Domengine	5,197
Cortopassi	4077004750000	10,428	4,812	4,057	4,242	4,456	5,043	Domengine	1,305
Eberhardt 15-34	4077204980000	10,445	4,782	3,993	4,096	4,382	5,117	Domengine	3,516
McCulloch Stefani No 1	4077005160000	10,414	4,440	3,781	3,879	4,107	4,927	Domengine	2,873
Pacific States No 1	407700470000	10,927	4,409	4,012	4,166	4,411	5,106	Domengine	2,949
Rindge Tract No 1	4077004710000	10,191	4,473	4,090	4,203	4,465	5,341	Domengine	6,007
Rocha et al unit No 1	4077203350000	11,382	5,067	3,814	3,915	4,151	5,243	Domengine	3,765
RTP 1-21	4077207250000	10,042	4,763	4,110	4,159	4,408	5,198	Domengine	4,036
SFEC - Luckey 7-1	4077205220000	10,412	4,654	3,875	3,981	4,277	5,375	Domengine	1,615
Shell AI Prop 1-8	4077004680000	11,960	4,295	3,902	4,011	4,290	5,421	Domengine	6,789

Stockton Port District No 1	4077203210000	11,476	4,500	4,134	4,217	4,496	5,221	Domengine	3,834
Victor Leo et Al #1	40770467000	10,427	4,535	3,789	3,886	4,135	5,040	Domengine	3,298
Zuckerman 1-19	4077204760000	10,049	4,635	3,939	3,990	4,364	5,343	Domengine	3,044
Zuckerman No A-1	4077203160000	20,836	4,934	4,041	4,130	4,484	5,483	Domengine	15,675
Citizen Green 1	4077206880000	14,629	4,356	4,190	4,280	4,340	?	Domengine	9,882

Note: Bold wells are those inside the AOR. Rindge Tract No. 1 does not penetrate the MRF.

Geochemistry [40 CFR 146.82(a)(6)]

In the context of Class VI injection, CO₂ sequestration involves the compression of gaseous CO₂ into a supercritical fluid and injection into deep subsurface geologic units. Supercritical CO₂ is not miscible with formation fluids, but can dissolve into them up to a solubility limit dependent on temperature, pressure, and composition of the fluid. When this dissolution happens, carbonic acid (H₂CO₃) is formed, which creates a weak acidic solution. The weak acidic solution will interact with the formation solid phase assemblage. The interaction between formation fluids, carbonic acid, and formation assemblage can precipitate dissolved constituents and alter the injection zone. There is less potential for acidified formation fluids to interact with the confining zone because it is physically separated from the formation fluid in most areas by supercritical CO₂. Understanding both the solid-phase and aqueous phase geochemistry of the injection complex is important for identifying potential reactions that could occur as a result of CO₂ injection.

To evaluate the potential interactions between the formation fluids and the injection zone solid phase assemblage, data are required for the formation fluid composition, pH, temperature, pressure; and the minerals in the solid-phase assemblage. No primary data have been collected for this evaluation (i.e., no test well within the AOR). All data are pre-existing data from wells in the vicinity of the project area.

SCS reviewed publicly available XRD data from the Citizen Green #1 well (**Attachment 3**). As discussed in the sub-section “Injection and Confining Zone Details”, XRD data were not collected for the shales within the lower or upper confining zones. XRD data are available for four samples from the Mokelumne River Formation sands (injection zone) and one sample from a shale baffle in the Mokelumne River Formation. A summary of these data is included in **Table 2-6** below. All sand samples were dominated by feldspars and quartz. The shale baffle sample was dominated by potassium feldspar, quartz, and kaolinite. The solid-phase assemblages for the injection zone are dominated by silicate minerals; the samples contained no carbonates or sulfates. Samples will be collected from the lower and upper confining zone units and the injection zone for XRD analysis when the test well is drilled.

SCS reviewed brine composition data from the USGS Produced Water Database for wells drilled in the southern Sacramento Basin in the vicinity of the project area. This database provides well location information, depths, geologic formations, and analytical data for brines encountered during the drilling process. Data were evaluated for 27 wells (**Figure 2-39**). There are no available nearby data in the produced waters database for brine in the Mokelumne River Formation (injection zone). 13 of the 27 samples have formations listed as unknown, and all other samples are from units located stratigraphically above or below the injection zone. The available data are summarized in **Table 2-7**. pH values indicate these produced waters are near neutral.

Table 2-6. XRD Data for the Mokelumne River Formation: Citizen Green #1
Pelican Renewables

Depth	Wireline Depth (ft)	6598	NA	6466	6400	5249	5247
	True Vertical Depth (ft)	5970.1	NA	5843.1	5780.1	4725.2	4723.5
Flow Properties	Porosity (Helium %)	31.3	NA	31.3	33	NA	NA
	Permeability (gas, mD)	135.5	NA	71.9	367.1	NA	NA
Mineral Composition (%)	Quartz	33.924835	34.2	36.325405	40.30969	17	27.8
	K-Feldspar	21.998177	24.1	12.587689	17.08427	32.7	16.2
	Albite	0	0	0.22734216	0	6.5	34
	Labradorite	0	0	36.58359	29.232862	0	0
	Andesine	34.47543	31	0	3.6258943	0	0
	Kaolinite	3.6258416	2.9	2.6778169	5.230892	34.9	3.6
	Chlorite	5.4110084	2	5.3593655	3.9868908	0	17
	Pyrite	0.213066	0.5	0.69619757	0	0	0
	Hornblende	0.230967	1.1	0.5695263	0.17200066	0	0
	Sepiolite	0	NA	0	0	0	0
	Detrital Mica	0.12067264	4.2	4.9730654	0.35749906	8.4	0
	Montmorillonite	0	NA	0	0	trace	1.1

Notes:

NA = Data not available or not recorded.

Blue = Sample was collected from a shale baffle within the Mokelumne River Formation

Table 2-7. Produced Waters Data in the Vicinity of the Project
Pelican Renewables
(Results in mg/L, unless otherwise noted)

Well Name	Well API	Date	Depth Upper	Depth Lower	Formation	Geochemical Parameters																										
						pH (Std. Units)	TDS	Charge Balance	Boron	Barium	Bromide	Calcium	Chloride	Caesium	Fluoride	Iron (Total)	Iodide	Potassium	Lithium	Magnesium	Manganese	Sodium	Rubidium	Sulfate	Silicon	Strontium	Bicarbonate Alkalinity	DIC	DOC	Acetate	H2S	NH3
Walnut Grove Unit A-2	04067000290000	1982-06-08	2890	3036	Unknown	7.05	9750	0.1	45	5.6	17.68	200	5380	--	0.47	0.18	17	54.10	0.39	123.5	0.33	3000	0.12	1.167	22	5.7	434	85.61	7.5	--	0.1	8
Patterson Unit #2	04077002150000	1982-06-03	3060	3513	Unknown	7.58	7800	-0.7	3	8.5	23.57	230	6490	0.03	0.26	0.1	21	36.5	0.2	114	0.15	3650	0.06	0.38	23	8.2	259	42.49	8.16	4	0.9	11
Capital D-2	04067002280000	1982-06-08	3526	3549	Markley-nortonville	7.05	9100	4.1	35	5.7	16.63	163	4300	0.02	0.27	4.1	18	64.8	0.37	80	0.11	2650	0.07	0.2101	36	4.8	567	102.5	27.86	20	0.3	14
Jensen #2	04067201750000	1982-06-07	--	3600	Markley-nortonville	7.91	7150	-1	36	7.8	19.32	165	4460	0.02	0.23	--	18	86.7	0.38	77.7	--	2450	0.09	0.8028	36	5.7	555	81.1	26.84	44	--	9.6
Tyler Island #6	04067201360000	1982-06-07	3608	3713	Nortonville	7.04	5850	2.4	32	6.2	17.92	168.5	3720	--	0.14	17.2	16.5	95.4	0.17	65	0.51	2160	0.1	0.306	16	4.4	530	79.62	155.8	190	0.1	6.8
Tyler Island #8	04067201570000	1982-06-07	3610	3722	Nortonville	8.12	6500	4.1	30	8.2	21.38	215	4060	0.02	0.25	--	20	134.7	0.52	49.7	0.12	2450	0.11	16.4	20	4.2	440	53.87	8.77	86	--	12
Tyler Island #10	04067201770000	1982-06-07	3668	3743	Nortonville	7.19	7150	-35.6	45	8.9	20.6	156	4540	0.07	0.28	4.60	18	64.5	0.4	84.3	0.12	1020	0.09	0.529	32	5.9	609	112.20	15.32	10	--	11
Wineman Zone Unit (WZU) #13	04095205360000	1982-06-02	4756	4778	Unknown	7.7	442	9.8	3	0.4	11.66	29.2	2610	--	1.4	--	7	20.1	0.14	9.1	--	2000	0.045	0.5100	29	0.75	808	149.3	16.72	11	0.10	11
Winters Community #1	04113000940000	1982-06-01	5000	5010	Unknown	7.22	13600	-2.6	39	3.9	28.1	120.1	7460	--	1.2	14.2	28	25.6	0.32	48.4	0.48	4350	0.03	1.2920	20	5.1	322	62.45	11.76	11	0.8	24
Langhart Spreckels #8	04067201500000	1982-06-07	4000	5218	Unknown	7.46	18800	1.2	102	4.5	29.34	120	9530	--	0.69	0.10	28	35.9	0.085	92.8	0.16	6000	0.09	0.37	36	8.4	730	127.5	11.48	13	--	18
Perry Anderson #19 (RVGU 223) Upper Zone	04095200660000	1982-06-03	5547	5582	Unknown	7.28	7480	1.3	110	5.7	27.8	158	8650	0.05	4.6	0.13	33	52	0.51	32.4	0.19	5500	0.13	29.87	57	8.8	705	67.82	212.5	396	--	21
Sacramento River Unit 2-2	04067200630000	1982-06-08	5503	5770	Unknown	8.09	14300	0.5	14	2.9	25.74	66	7130	--	0.64	0.13	22	28.7	0.015	71.2	0.07	4450	0.08	0.2739	31	4.8	1146	173.5	44.92	17	0.2	13
Rio Vista State 12 (RVGU 220)	04095200420000	1982-06-03	5824	5925	Martinez	7.57	9230	-0.7	24	4	26.68	113	7590	0.03	0.49	0.65	25	32.6	0.26	33.5	--	4650	0.06	5.95	32	6.6	482	85.25	84.21	482	0.7	22

Suisun Community #17	04095003080000	1982-06-04	3460	6068	Unknown	7.66	18800	1.2	29	13.7	58.64	130	9200	0.06	0.38	0.1	41	36.5	1.31	75.6	0.05	5800	0.09	0.6566	39	8.7	627	95.87	46.88	38.00	0.2	28.0
Perry Anderson #19 (RVGU 223) Middle Zone	04095200660000	1982-06-03	6070	6172	Unknown	6.85	4220	11.2	19	1.5	9.84	41.6	2420	0.04	0.28	29.2	12	14.1	0.14	8.1	0.34	1900	0.035	8.43	14	3.1	934	46.71	388.6	755	0.2	21
Union Unit 2 #1	04113200800000	1982-06-01	6333	6394	Starkey	7.53	24700	1.3	92	2.600	25.27	100	7020	--	1.8	--	25.0	29.1	0.42	49.2	0.09	4450.0	0.08	0.902	30	6.9	481	79.12	31	42	0.5	16
McCormick #6	04095203070000	1982-06-03	5971	6560	Martinez	7.57	9880	3.5	58	4.600	31.12	126	7770	0.07	2.4	0.2	27.0	55	0.48	27.1	0.05	5200.0	0.28	40.6	39	13.8	1531	73.45	507	1030	0.3	22
Perry Anderson #19 Lower Zone	04095004090000	1982-06-04	5910	6800	Anderson, Martinez	7.02	16900	-0.3	72	4.600	35.03	121	8430	0.06	1.1	2.9	29.0	43.6	0.44	25.8	0.14	5250.0	0.15	52.48	50	11.7	1507	61.22	533	1190	0.1	21
Bunker Gas zone unit #801	04095204080000	1982-06-02	6834	6838	Unknown	7.5	20200	-2.9	41	6.900	49.37	246	11300	0.03	1.3	0.13	25.0	74.5	0.3	54.8	0.32	6500.0	0.15	9.02	36	12	386	68.56	41	24	--	19
Rio Vista State 11	04067200070000	1982-06-03	6500	7550	Martinez	7.08	13000	-1.2	180	8.800	36.9	252	11400	0.05	0.66	1	29.0	56.7	0.49	51.7	0.10	6800.0	0.11	20.59	39	21	482	74.66	113	229	0.5	27
Feykert #2	04095200690000	1982-06-04	7572	7730	Unknown	7.3	11000	-0.7	153	3.200	19.84	87	5320	--	4.4	--	21.5	70.4	1.35	16.4	0.10	3250.0	0.21	55.16	66	13.2	730	67.68	213	420	--	35
Brown - Amerada Sorenson #1	04113200790000	1982-06-01	7866	7890	Unknown	7.33	12700	3.2	188	2.400	19.3	76	6360	--	2.6	22.2	23.0	37.3	0.59	17.8	0.54	4300.0	0.12	84.62	33	5.9	1070	119.6	216	333	0.3	22
Sonol Securites #3	04077201710000	1982-06-09	9700	9730	Winters	6.81	19500	6.3	340	4.300	13.57	165	9290	0.06	1.7	10.9	25.5	94.8	1.69	40.5	0.51	6600.0	0.31	169.9	66	28.7	1152	99.63	294	580	0.8	67
Yamada L-W #1	04077202890000	1982-06-09	9830	10070	Winters	6.92	18800	5.1	188	2.800	31.27	86	8580	0.12	2.1	0.13	26.0	90.9	2.16	17.7	--	6000.0	0.3	40.36	76	17.8	2321	110.9	696	1360	0.4	64
Serpa #4	04095204390000	1982-04-27	10356	10412	Unknown	8.7	7416	18.3	94	1.600	17.88	13	3750	0.03	2	--	25.0	73.1	1.46	5.16	--	3500.0	0.13	53.01	16	2.4	2500	124.6	711	1400	0.3	30
Peterson #4	04095000070000	1982-06-02	9130	10419	Unknown	7.22	15900	-22.5	130	9.500	36.28	279	12400	0.11	1.2	0.22	39.0	76.5	0.62	60	0.33	4600.0	0.2	9.66	40	19.6	579	61.72	120	233	--	34
Peterson Estate #3-27	04095203360000	1982-06-08	8752	11140	Unknown	6.82	13000	1.9	59	12.500	55.32	322	11700	0.12	7.1	6.8	31.0	83.2	0.94	34.8	0.55	7400.0	0.3	14.21	66	17.9	1266	--	--	--	--	34
CAS No.						--	--	--	7440-42-8	7440-39-3	7726-95-6	7440-70-2	16887-00-6	7440-46-2	7782-41-4	7439-89-6	7553-56-2	7440-09-7	7439-93-2	7439-95-4	7439-96-5	7440-23-5	7440-17-7	14808-79-8	7440-21-3	7440-24-6	--	--	--	71-50-1	7783-06-4	7664-41-7

Abbreviations:
mg/L = milligrams per liter

CAS No. = Chemical Abstracts Service Number
-- = No Data

Notes:
Blondes, M. S., Gans, K. D., Engle, M. A., Kharaka, Y. K., Reidy, M. E., Saraswathula, V., Thordsen, J. J., Rowan, E. L., & Morrissey, E. A. (2019). U.S. Geological Survey National Produced Waters Geochemical Database v2.3 [Data set]. U.S. Geological Survey. <https://doi.org/10.5066/F7J964W8>
Data derived from the Yousif Kharaka dataset

A smaller subset of the produced water data for 12 nearby wells was evaluated via geochemical modeling. The geochemical modeling was completed using PHREEQC version 3 (Parkhurst and Appelo, 2013), using an ion-association model created by Lawrence Livermore National Laboratory (LLNL). These models determined saturation indices of various minerals based on chemical compositions of the produced waters, as well as the simulated effect of increasing $p\text{CO}_2$ on the saturation indices of the various minerals from $10^{-3.5}$ to 1 atmosphere (atm). **Tables 2-8 through 2-19** summarize the saturation indices as a function of $p\text{CO}_2$ for the 12 produced water samples in the vicinity of the AOR. The saturation indices for all of the solid phases were at least two orders of magnitude less than one. The injection of supercritical CO_2 is not expected to induce formation plugging for the produced waters modeled by the precipitation of silicate, sulfate, or carbonate solid phases. The saturation indices decrease (i.e., become more negative) as the $p\text{CO}_2$ increases and the pH lowers.

As none of these produced water samples are within the AOR and were not collected from the Mokelumne River Formation (injection zone), formation fluids will be sampled from the Mokelumne for chemical analysis when the test well is drilled. These waters will be examined via geochemical modeling for any changes related to increasing $p\text{CO}_2$.

Table 2-8. Saturation Indices for Solid Phases in Brines near the AOR

Jensen #2					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.283	5.441	4.788	4.237	3.977
Mineral	Saturation Index				
Quartz	-2.13	-2.13	-2.13	-2.13	-2.13
Tridymite	-2.31	-2.31	-2.31	-2.31	-2.31
Chalcedony	-2.39	-2.39	-2.39	-2.39	-2.39
Cristobalite(alpha)	-2.65	-2.65	-2.65	-2.65	-2.65
Coesite	-2.91	-2.91	-2.91	-2.91	-2.91
Cristobalite(beta)	-3.06	-3.06	-3.06	-3.06	-3.06
SiO2(am)	-3.31	-3.31	-3.31	-3.31	-3.31
C	-4.35	-4.29	-4.04	-3.67	-3.46
Witherite	-3.24	-3.92	-4.23	-4.33	-4.36
Boric_acid	-5.49	-5.49	-5.49	-5.49	-5.49
Barite	-5.62	-5.59	-5.58	-5.59	-5.59
S	-6.92	-6.62	-6.42	-6.26	-6.19
N2(g)	-5.53	-5.8	-5.99	-6.15	-6.22
Calcite	-5.87	-6.56	-6.86	-6.97	-6.99
Aragonite	-6.02	-6.7	-7.01	-7.11	-7.14
Magnesite	-6.27	-6.96	-7.26	-7.37	-7.39
Monohydrocalcite	-6.78	-7.46	-7.77	-7.88	-7.9
Nahcolite	-9.12	-8.96	-8.61	-8.16	-7.92
H2(g)	-6.69	-7.16	-7.53	-7.85	-7.99

Table 2-9. Saturation Indices for Solid Phases in Brines near the AOR

Patterson Unit #2					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.054	5.338	4.76	4.235	3.98
Mineral	Saturation Index				
Quartz	-2.38	-2.38	-2.38	-2.38	-2.38
Tridymite	-2.55	-2.55	-2.55	-2.55	-2.55
Chalcedony	-2.63	-2.63	-2.63	-2.63	-2.63
Cristobalite(alpha)	-2.89	-2.89	-2.89	-2.89	-2.89
Coesite	-3.14	-3.14	-3.14	-3.14	-3.14
Cristobalite(beta)	-3.29	-3.29	-3.29	-3.29	-3.29
C	-4.51	-4.32	-3.98	-3.58	-3.37
SiO2(am)	-3.54	-3.54	-3.54	-3.54	-3.54
Witherite	-3.71	-4.14	-4.3	-4.35	-4.36
Barite	-6	-5.95	-5.94	-5.93	-5.93
N2(g)	-5.64	-5.85	-6.01	-6.16	-6.24
S	-7.01	-6.75	-6.57	-6.41	-6.34
Boric_acid	-6.6	-6.6	-6.6	-6.6	-6.6
Calcite	-6.17	-6.6	-6.76	-6.81	-6.82
Aragonite	-6.31	-6.74	-6.9	-6.95	-6.97
Magnesite	-6.52	-6.95	-7.11	-7.16	-7.17
Monohydrocalcite	-7.09	-7.52	-7.68	-7.73	-7.74
Nahcolite	-9.22	-8.94	-8.51	-8.04	-7.8
H2(g)	-6.63	-7.03	-7.36	-7.66	-7.81

Table 2-10. Saturation Indices for Solid Phases in Brines near the AOR

Rio Vista State 11					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.391	5.568	4.907	-4.351	4.09
Mineral	Saturation Index				
Quartz	-2.54	-2.54	-2.54	-2.54	-2.54
Tridymite	-2.7	-2.7	-2.7	-2.7	-2.7
Chalcedony	-2.77	-2.77	-2.77	-2.77	-2.77
Cristobalite(alpha)	-3	-3	-3	-3	-3
Coesite	-3.24	-3.24	-3.24	-3.24	-3.24
Cristobalite(beta)	-3.34	-3.34	-3.34	-3.34	-3.34
SiO2(am)	-3.54	-3.54	-3.54	-3.54	-3.54
C	-4.86	-4.75	-4.5	-4.13	-3.93
N2(g)	-3.75	-4	-4.18	-4.33	-4.41
Barite	-4.54	-4.47	-4.45	-4.44	-4.45
Witherite	-3.4	-4.05	-4.37	-4.49	-4.51
S	-5.91	-5.53	-5.3	-5.13	-5.06
Boric_acid	-5.1	-5.1	-5.1	-5.1	-5.1
Calcite	-5.25	-5.9	-6.22	-6.34	-6.36
Aragonite	-5.4	-6.04	-6.37	-6.48	-6.51
H2S(g)	-6.08	-6.15	-6.3	-6.44	-6.52
H2(g)	-5.54	-5.98	-6.36	-6.67	-6.82
Magnesite	-5.73	-6.38	-6.7	-6.82	-6.84
Anhydrite	-7.14	-7.08	-7.05	-7.05	-7.05
Gypsum	-7.4	-7.33	-7.31	-7.3	-7.31
Monohydrocalcite	-6.31	-6.95	-7.28	-7.39	-7.41
Bassanite	-7.79	-7.72	-7.7	-7.69	-7.7
CaSO4:0.5H2O(beta)	-7.91	-7.84	-7.82	-7.81	-7.82
Nahcolite	-9.06	-8.88	-8.54	-8.1	-7.86
Rhodochrosite	-6.87	-7.51	-7.84	-7.95	-7.98

Table 2-11. Saturation Indices for Solid Phases in Brines near the AOR

Tyler Island #10					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.182	5.396	4.781	4.244	3.986
Mineral	Saturation Index				
Quartz	-2.25	-2.25	-2.25	-2.25	-2.25
Tridymite	-2.42	-2.42	-2.42	-2.42	-2.42
Chalcedony	-2.5	-2.5	-2.5	-2.5	-2.5
Cristobalite(alpha)	-2.76	-2.76	-2.76	-2.76	-2.76
Coesite	-3.01	-3.01	-3.01	-3.01	-3.01
Cristobalite(beta)	-3.16	-3.16	-3.16	-3.16	-3.16
SiO2(am)	-3.4	-3.4	-3.4	-3.4	-3.4
C	-4.42	-4.31	-4.01	-3.63	-3.42
Witherite	-3.44	-4.01	-4.24	-4.32	-4.34
Boric_acid	-5.43	-5.43	-5.43	-5.43	-5.43
Barite	-5.83	-5.78	-5.76	-5.76	-5.77
N2(g)	-5.5	-5.74	-5.92	-6.07	-6.15
S	-6.97	-6.68	-6.49	-6.33	-6.26
Calcite	-6.06	-6.64	-6.87	-6.95	-6.96
Aragonite	-6.21	-6.78	-7.01	-7.09	-7.11
Magnesite	-6.37	-6.94	-7.17	-7.25	-7.27
H2(g)	-6.54	-6.98	-7.33	-7.64	-7.79
Monohydrocalcite	-6.99	-7.56	-7.79	-7.87	-7.89

Table 2-12. Saturation Indices for Solid Phases in Brines near the AOR

Tyler Island #6					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.135	5.38	4.783	4.251	3.995
Mineral	Saturation Index				
Quartz	-2.59	-2.59	-2.59	-2.59	-2.59
Tridymite	-2.77	-2.77	-2.77	-2.77	-2.77
Chalcedony	-2.85	-2.85	-2.85	-2.85	-2.85
Cristobalite(alpha)	-3.1	-3.1	-3.1	-3.1	-3.1
Coesite	-3.35	-3.35	-3.35	-3.35	-3.35
Cristobalite(beta)	-3.49	-3.49	-3.49	-3.49	-3.49
C	-4.58	-4.43	-4.11	-3.72	-3.51
SiO2(am)	-3.73	-3.73	-3.73	-3.73	-3.73
Witherite	-3.73	-4.24	-4.44	-4.5	-4.52
Boric_acid	-5.61	-5.61	-5.61	-5.61	-5.61
Barite	-6.24	-6.2	-6.19	-6.19	-6.19
N2(g)	-5.78	-6.01	-6.19	-6.34	-6.42
S	-7.27	-7	-6.81	-6.65	-6.58
Calcite	-6.1	-6.61	-6.81	-6.88	-6.89
Aragonite	-6.25	-6.76	-6.95	-7.02	-7.04
Magnesite	-6.53	-7.04	-7.23	-7.3	-7.31
Rhodochrosite	-6.77	-7.28	-7.48	-7.54	-7.56
H2(g)	-6.48	-6.9	-7.25	-7.55	-7.69
Monohydrocalcite	-7.04	-7.55	-7.74	-7.81	-7.83

Table 2-13. Saturation Indices for Solid Phases in Brines near the AOR

Tyler Island #8					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.377	5.501	4.816	4.253	3.99
Mineral	Saturation Index				
Quartz	-2.44	-2.44	-2.44	-2.44	-2.44
Tridymite	-2.61	-2.61	-2.61	-2.61	-2.61
Chalcedony	-2.69	-2.69	-2.69	-2.69	-2.69
Cristobalite(alpha)	-2.95	-2.95	-2.95	-2.95	-2.95
Coesite	-3.2	-3.2	-3.2	-3.2	-3.2
Cristobalite(beta)	-3.35	-3.35	-3.35	-3.35	-3.35
SiO2(am)	-3.6	-3.6	-3.6	-3.6	-3.6
C	-4.63	-4.6	-4.37	-4.01	-3.81
Barite	-4.28	-4.27	-4.27	-4.27	-4.28
Witherite	-3.07	-3.82	-4.19	-4.32	-4.35
S	-6.11	-5.8	-5.59	-5.43	-5.36
N2(g)	-4.75	-5.04	-5.24	-5.4	-5.48
Boric_acid	-5.6	-5.6	-5.6	-5.6	-5.6
Calcite	-5.54	-6.3	-6.67	-6.8	-6.83
Aragonite	-5.69	-6.44	-6.81	-6.94	-6.97
Magnesite	-6.23	-6.98	-7.35	-7.48	-7.51
Gypsum	-7.53	-7.53	-7.52	-7.53	-7.54
Anhydrite	-7.54	-7.54	-7.54	-7.54	-7.55
H2S(g)	-7.13	-7.3	-7.48	-7.64	-7.72
Monohydrocalcite	-6.46	-7.22	-7.59	-7.72	-7.75
Nahcolite	-9.07	-8.94	-8.63	-8.19	-7.96

Table 2-14. Saturation Indices for Solid Phases in Brines near the AOR

Capital D-2					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.126	5.368	4.77	4.238	3.981
Mineral	Saturation Index				
Quartz	-2.18	-2.18	-2.18	-2.18	-2.18
Tridymite	-2.36	-2.36	-2.36	-2.36	-2.36
Chalcedony	-2.44	-2.44	-2.44	-2.44	-2.44
Cristobalite(alpha)	-2.69	-2.69	-2.69	-2.69	-2.69
Coesite	-2.95	-2.95	-2.95	-2.95	-2.95
Cristobalite(beta)	-3.09	-3.09	-3.09	-3.09	-3.09
C	-4.27	-4.14	-3.83	-3.44	-3.23
SiO2(am)	-3.34	-3.34	-3.34	-3.34	-3.34
Witherite	-3.73	-4.25	-4.44	-4.51	-4.53
Boric_acid	-5.53	-5.53	-5.53	-5.53	-5.53
N2(g)	-5.64	-5.85	-6.01	-6.16	-6.23
Barite	-6.53	-6.44	-6.4	-6.38	-6.38
S	-7.16	-6.85	-6.65	-6.48	-6.41
Calcite	-6.17	-6.68	-6.88	-6.95	-6.96
Aragonite	-6.31	-6.83	-7.03	-7.09	-7.11
Magnesite	-6.52	-7.04	-7.24	-7.3	-7.32
H2(g)	-6.51	-6.94	-7.29	-7.59	-7.74
Monohydrocalcite	-7.09	-7.6	-7.8	-7.87	-7.88
Nahcolite	-9.29	-9.04	-8.64	-8.17	-7.93
NH3(g)	-9.29	-9.04	-8.64	-8.17	-7.93

Table 2-15. Saturation Indices for Solid Phases in Brines near the AOR

Sacramento River Unit 2-2					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.786	5.827	4.988	4.339	4.057
Mineral	Saturation Index				
Quartz	-2.43	-2.43	-2.43	-2.43	-2.43
Tridymite	-2.6	-2.6	-2.6	-2.6	-2.6
Chalcedony	-2.68	-2.68	-2.68	-2.68	-2.68
Cristobalite(alpha)	-2.92	-2.92	-2.92	-2.92	-2.92
Coesite	-3.17	-3.17	-3.17	-3.17	-3.17
Cristobalite(beta)	-3.3	-3.29	-3.29	-3.29	-3.29
C	-3.75	-3.83	-3.8	-3.55	-3.37
SiO2(am)	-3.52	-3.52	-3.52	-3.52	-3.52
Witherite	-2.88	-3.8	-4.48	-4.78	-4.85
N2(g)	-5.18	-5.45	-5.68	-5.85	-5.93
S	-7.66	-7.05	-6.72	-6.51	-6.42
Barite	-7.17	-6.86	-6.76	-6.72	-6.71
Magnesite	-5.05	-5.96	-6.64	-6.94	-7.01
Calcite	-5.15	-6.07	-6.75	-7.05	-7.11
H2(g)	-5.67	-6.21	-6.7	-7.07	-7.23
Aragonite	-5.29	-6.21	-6.89	-7.19	-7.26
Nahcolite	-8.6	-8.56	-8.4	-8.04	-7.83

Table 2-16. Saturation Indices for Solid Phases in Brines near the AOR

Langhart Spreckels #8					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.43	5.554	4.864	4.297	4.034
Mineral	Saturation Index				
Quartz	-2.37	-2.37	-2.37	-2.37	-2.37
Tridymite	-2.54	-2.54	-2.54	-2.54	-2.54
Chalcedony	-2.61	-2.61	-2.61	-2.61	-2.61
Cristobalite(alpha)	-2.86	-2.86	-2.86	-2.86	-2.86
Coesite	-3.11	-3.11	-3.11	-3.11	-3.11
Cristobalite(beta)	-3.23	-3.23	-3.23	-3.23	-3.23
C	-4.07	-4.09	-3.89	-3.55	-3.35
SiO2(am)	-3.46	-3.46	-3.46	-3.46	-3.46
Witherite	-3.41	-4.16	-4.54	-4.68	-4.71
Boric_acid	-5.2	-5.2	-5.2	-5.2	-5.2
N2(g)	-5.12	-5.34	-5.51	-5.66	-5.73
S	-7.23	-6.76	-6.5	-6.31	-6.23
Barite	-6.79	-6.55	-6.46	-6.42	-6.42
Calcite	-5.61	-6.36	-6.74	-6.88	-6.91
Magnesite	-5.65	-6.4	-6.78	-6.92	-6.95
Aragonite	-5.75	-6.5	-6.89	-7.02	-7.05
H2(g)	-5.83	-6.34	-6.74	-7.07	-7.22
Nahcolite	-8.83	-8.7	-8.39	-7.96	-7.72
Monohydrocalcite	-6.58	-7.33	-7.71	-7.85	-7.88
H2S(g)	-7.53	-7.57	-7.71	-7.85	-7.92
Rhodochrosite	-6.66	-7.41	-7.79	-7.92	-7.95

Table 2-17. Saturation Indices for Solid Phases in Brines near the AOR

Walnut Grove Unit A-2					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.038	5.327	4.752	4.228	3.973
Mineral	Saturation Index				
Quartz	-2.36	-2.36	-2.36	-2.36	-2.36
Tridymite	-2.54	-2.54	-2.54	-2.54	-2.54
Chalcedony	-2.62	-2.62	-2.62	-2.62	-2.62
Cristobalite(alpha)	-2.88	-2.88	-2.88	-2.88	-2.88
Coesite	-3.13	-3.13	-3.13	-3.13	-3.13
Cristobalite(beta)	-3.28	-3.28	-3.28	-3.28	-3.28
SiO2(am)	-3.54	-3.54	-3.54	-3.54	-3.54
C	-4.73	-4.53	-4.19	-3.78	-3.57
Witherite	-3.89	-4.31	-4.46	-4.51	-4.53
Boric_acid	-5.4	-5.4	-5.4	-5.4	-5.4
Barite	-5.59	-5.58	-5.57	-5.58	-5.59
S	-6.8	-6.56	-6.38	-6.23	-6.16
N2(g)	-5.61	-5.83	-6	-6.15	-6.22
Calcite	-6.27	-6.69	-6.85	-6.9	-6.91
Aragonite	-6.42	-6.84	-6.99	-7.04	-7.06
Magnesite	-6.55	-6.97	-7.12	-7.17	-7.19
Monohydrocalcite	-7.18	-7.6	-7.76	-7.81	-7.82
Rhodochrosite	-7.19	-7.61	-7.76	-7.81	-7.83
Nahcolite	-9.29	-9	-8.58	-8.1	-7.86

Table 2-18. Saturation Indices for Solid Phases in Brines near the AOR

Sonol Securities #3					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.58	5.732	4.993	4.401	4.132
Mineral	Saturation Index				
Quartz	-2.41	-2.41	-2.41	-2.41	-2.41
Tridymite	-2.57	-2.57	-2.57	-2.57	-2.57
Chalcedony	-2.63	-2.63	-2.63	-2.63	-2.63
Cristobalite(alpha)	-2.85	-2.85	-2.85	-2.85	-2.85
Coesite	-3.09	-3.09	-3.09	-3.09	-3.09
Cristobalite(beta)	-3.18	-3.18	-3.18	-3.18	-3.18
SiO2(am)	-3.37	-3.37	-3.37	-3.37	-3.37
N2(g)	-2.82	-3.03	-3.2	-3.34	-3.41
Barite	-3.97	-3.91	-3.89	-3.88	-3.88
C	-4.92	-4.77	-4.58	-4.24	-4.04
S	-5.26	-4.78	-4.49	-4.3	-4.21
Witherite	-3.44	-4.13	-4.61	-4.8	-4.84
Boric_acid	-4.89	-4.89	-4.89	-4.89	-4.89
H2S(g)	-5.22	-5.16	-5.28	-5.41	-5.48
Anhydrite	-6.29	-6.23	-6.2	-6.19	-6.2
Calcite	-5	-5.7	-6.18	-6.36	-6.41
Gypsum	-6.62	-6.56	-6.53	-6.52	-6.53
Aragonite	-5.15	-5.84	-6.32	-6.51	-6.55
H2(g)	-5.23	-5.66	-6.06	-6.4	-6.55
Magnesite	-5.34	-6.03	-6.51	-6.7	-6.74
Bassanite	-6.93	-6.87	-6.84	-6.84	-6.84
CaSO4:0.5H2O(beta)	-7.05	-6.98	-6.96	-6.95	-6.96
Rhodochrosite	-5.75	-6.44	-6.92	-7.11	-7.15
Monohydrocalcite	-9.01	-8.85	-8.59	-8.18	-7.95
Nahcolite	-9.01	-8.85	-8.59	-8.18	-7.95

Table 2-19. Saturation Indices for Solid Phases in Brines near the AOR

Yamada L-W #1					
PCO2	-3.5	-2.5	-1.5	-0.5	0
pH	6.922	6.045	6.29	4.486	4.194
Mineral	Saturation Index				
Cristobalite(alpha)	-2	-2	-2.86	-2.86	-2
Quartz	-2.43	-2.43	-2.43	-2.43	-2.43
Tridymite	-2.6	-2.59	-2.59	-2.59	-2.59
Chalcedony	-2.65	-2.65	-2.65	-2.65	-2.65
Cristobalite(beta)	-3.1	-3.1	-3.18	-3.18	-3.1
Coesite	-3.11	-3.1	-3.1	-3.1	-3.1
SiO2(am)	-3.36	-3.36	-3.36	-3.36	-3.36
N2(g)	-2.98	-3.13	-3.31	-3.46	-3.53
C	-4.36	-4.28	-4.26	-4.05	-3.88
S	-6.15	-5.4	-4.97	-4.71	-4.61
Barite	-5.42	-5.05	-4.88	-4.81	-4.8
Witherite	-3.03	-3.78	-4.53	-4.9	-4.99
Boric_acid	-5.22	-5.22	-5.22	-5.22	-5.22
H2S(g)	-5.59	-5.3	-5.36	-5.49	-5.56
H2(g)	-4.64	-5.1	-5.59	-5.98	-6.15
Calcite	-4.55	-5.3	-6.05	-6.42	-6.51
Aragonite	-4.69	-5.45	-6.19	-6.57	-6.65
Magnesite	-4.9	-5.65	-6.39	-6.77	-6.86
Anhydrite	-7.68	-7.3	-7.13	-7.07	-7.06
Gypsum	-8.08	-7.71	-7.54	-7.47	-7.46
Monohydrocalcite	-5.7	-6.45	-7.19	7.57	-7.66
Bassanite	-8.32	-7.95	-7.78	-7.72	-7.7
CaSO4:0.5H2O(beta)	-8.4	-8	-7.89	-7.82	-7.8

Other Information (Including Surface Air and/or Soil Gas Data, if Applicable)

The PR Project has focused has focused its Operational Plan, Testing and Monitoring Plan and Post-Injection Site Care Plan on deep geologic and hydrogeologic resources. The objectives of these plans are to continue to refine site characterization data that will update the multiphase transport model that delineates the Area of Review, detect any excursions between predicted plume and pressure front extents, and control the injection such that CO₂ is confined to the injection zone. These objectives all support the protection of underground sources of drinking water that are used for irrigation and drinking water near the PR project. These multiple layers of protection will provide early warning of any issues before surface air and/or soil gas could ever be affected. Pelican Renewables, LLC does not propose any shallow (i.e., at or near surface) environmental monitoring and views the monitoring programs described above to be protective of human health and the environment.

Site Suitability [40 CFR 146.83]

40 CFR 146.83 requires Owners and Operators of Class VI injection wells demonstrate to the Director that the wells are sited within a geologic area appropriate for the intended use. The first specific requirement is to demonstrate that there is sufficient extent, thickness, porosity, and permeability to sequester the carbon dioxide (CO₂) permanently and that the site has an adequate storage capacity for the design volumes. The second criterion within the regulation is to demonstrate the integrity of the confining zone, faults within the project area, and the potential for pressure build-up that could compromise the confining zone.

The information informing the suitability of the site include:

- Core descriptions and tests on materials from the Citizen Green #1 Well,
- Well deviation surveys,
- Geophysical logging data from wells in the area,
- Two- and three-dimensional seismic data, and
- Numerical modeling of multiphase flow.

The sequestration area in the vicinity of the proposed Class VI injection well has a simple geologic structure. Detailed geologic mapping and geophysical (seismic) surveys have established that over a regional scale, the thickness and porosity of the Mokelumne River Formation (MRF) are sufficient to store large amounts of CO₂. In particular, there is sufficient pore-space beneath Rindge Tract Island to accommodate approximately 40 million metric tons of supercritical CO₂ at typical storage efficiencies, and retain the plume extent and the critical pressure front beneath the footprint of the island.

The injection zone has the temperature and pore pressure to maintain the CO₂ in a supercritical state:

- Using the proposed injection depth of 6,400 feet and a formation water gradient of 0.44 pounds per square inch (psi) per foot the formation pressure was calculated at 2,816 psi. The reported reservoir shut-in pressure in the Mokelumne River Formation at 6,301 feet average depth at the Roberts Island Gas Field wells measured 2,750 psi (formation water gradient of 0.437 psi/ft), and 2,350 psi at 5,220 feet at the MacDonald Island Gas Field (formation water gradient of 0.450 psi/ft.), both of which are normally pressured. Consequently, the Mokelumne River Formation is normally pressured at the proposed injection location and depth.
- Subsurface temperatures have been measured in petroleum wells in the vicinity of the sequestration area. The temperature gradient is 11 to 14 °F per 1,000 feet in the depth range of 0-7,000 feet, this depth range includes the injection and upper and lower confining units. The heat flow ranges from 30 to 34 milliwatts per square meter (mW/m²) according to the Geothermal Map of North America (Blackwell and Richards, 2004). The subsurface temperatures in the proposed sequestration zones are suitable for injection and storage of CO₂

Trapping mechanisms include structural trapping, capillary trapping, and solution trapping. The porosity and intrinsic permeability are suitable for storage. For a 20-year injection rate of about 1.25 million metric tons per year, the pressure front for both Well #1 and Well #2 is attenuated after about 25 years, and the extent of the plume becomes stable after about 100 years.

Candidate injection zones are bounded by multiple continuous, laterally-extensive low-permeability confining zone shale units overlying and underlying the storage zone. The potential injection sands are well below the lowermost Underground Source of Drinking Water (USDW) and are separated from the lowermost USDW by multiple alternating sand-shale intervals. The potential injections sands are also vertically separated from existing freshwater supply and irrigation wells by sufficient distance and geologic structure to prevent endangerment.

40 CFR 146.83 sets the minimum requirements for siting a Class VI injection well. This Site Characterization Narrative and **Section 3**, the Area of Review and Corrective Action Plan demonstrate that:

- The injection zone is of sufficient extent and has properties sufficient to sequester more than 40 million metric tons of supercritical CO₂,
- The confining zone will contain the supercritical CO₂ at proposed injection pressures with an appropriate safety factor that will not propagate fractures in the confining zone (see **Section 7**, Well Operating Plan), and
- The separation and presence of confining layers will prevent USDWs from becoming endangered.

AOR and Corrective Action

AoR and Corrective Action GSDT Submissions

GSDT Module: AoR and Corrective Action

Tab(s): All applicable tabs

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

- ☒ Tabulation of all wells within AoR that penetrate confining zone ***[40 CFR 146.82(a)(4)]***
- ☒ AoR and Corrective Action Plan ***[40 CFR 146.82(a)(13) and 146.84(b)]***
- ☒ Computational modeling details ***[40 CFR 146.84(c)]***

Financial Responsibility

Financial Responsibility GSDT Submissions

GSDT Module: Financial Responsibility Demonstration

Tab(s): Cost Estimate tab and all applicable financial instrument tabs

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

☒ Demonstration of financial responsibility [40 CFR 146.82(a)(14) and 146.85]

Injection Well Construction

This application is for two new Class VI wells. Schematics showing the surface and subsurface well construction details are provided pursuant to 40 CFR 146.82(a)(11) and are supplemented with annotations on the graphic.]

Pre-Operational Logging and Testing

Pre-Operational Logging and Testing GSDT Submissions

GSDT Module: Pre-Operational Testing

Tab(s): Welcome tab

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

☒ Proposed pre-operational testing program [40 CFR 146.82(a)(8) and 146.87]

Well Operation

Text, tables, and figures are provided to fulfill the operating data requirements for the permit application, listed at 40 CFR 146.82(a)(7) and (10) and with 40 CFR 146.88.

Testing and Monitoring

Testing and Monitoring GSDT Submissions

GSDT Module: Project Plan Submissions

Tab(s): Testing and Monitoring tab

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

☒ Testing and Monitoring Plan [40 CFR 146.82(a)(15) and 146.90]

Injection Well Plugging

Injection Well Plugging GSDT Submissions

GSDT Module: Project Plan Submissions

Tab(s): Injection Well Plugging tab

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

☒ Injection Well Plugging Plan ***[40 CFR 146.82(a)(16) and 146.92(b)]***

Post-Injection Site Care (PISC) and Site Closure

PISC and Site Closure GSDT Submissions

GSDT Module: Project Plan Submissions

Tab(s): PISC and Site Closure tab

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

☒ PISC and Site Closure Plan ***[40 CFR 146.82(a)(17) and 146.93(a)]***

GSDT Module: Alternative PISC Timeframe Demonstration

Tab(s): All tabs (only if an alternative PISC timeframe is requested)

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

☒ Alternative PISC timeframe demonstration ***[40 CFR 146.82(a)(18) and 146.93(c)]***

Emergency and Remedial Response

Emergency and Remedial Response GSDT Submissions

GSDT Module: Project Plan Submissions

Tab(s): Emergency and Remedial Response tab

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

☒ Emergency and Remedial Response Plan ***[40 CFR 146.82(a)(19) and 146.94(a)]***

Injection Depth Waiver and Aquifer Exemption Expansion

No Injection Depth Waiver or Aquifer Exemption Expansions are requested by this Permit Application.

Other Information

An Environmental Justice Report was included and uploaded to the GSDT as Other Information.

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Figures

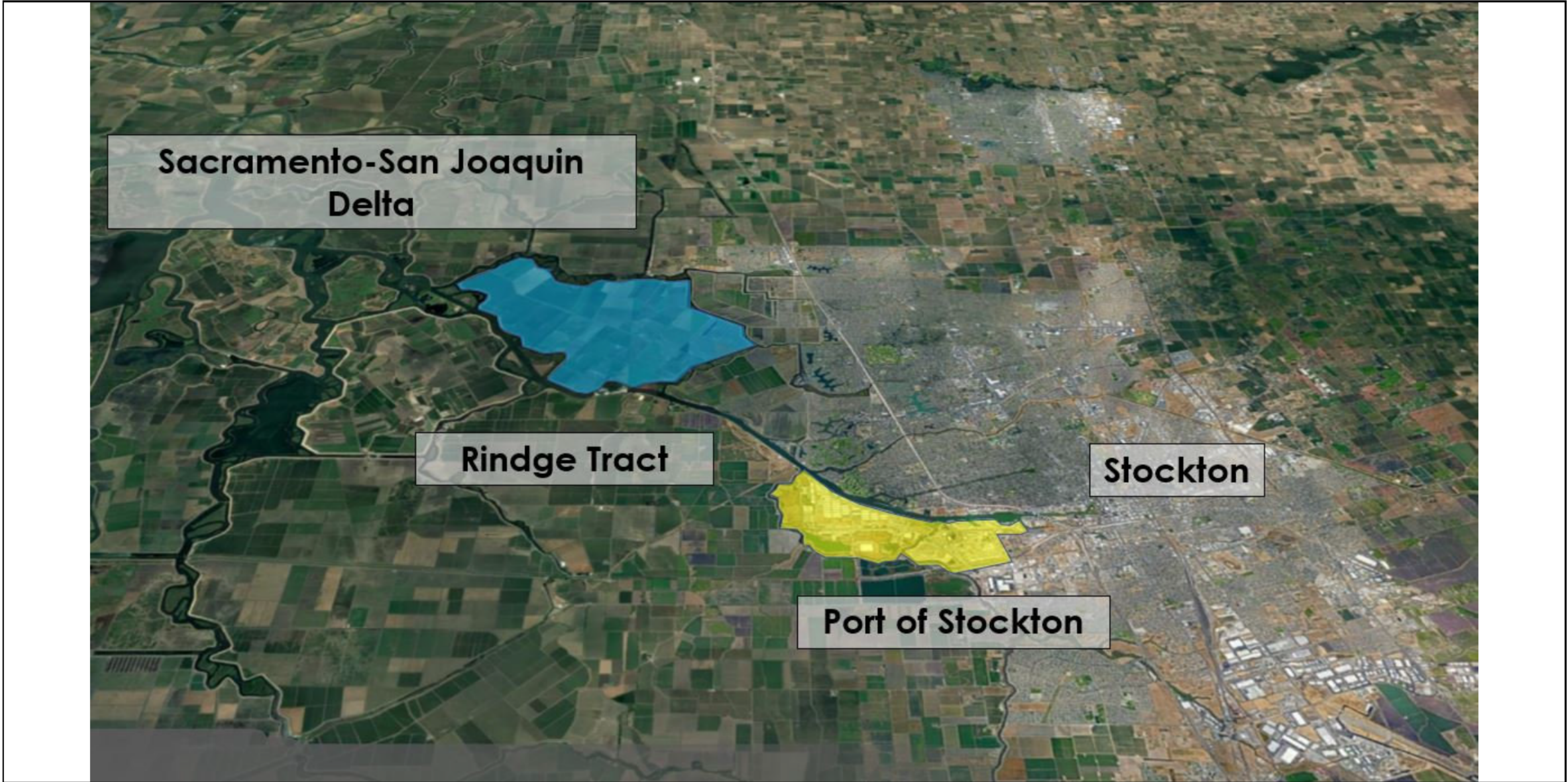


FIGURE 1-1
OVERVIEW OF PELICAN RENEWABLES, LLC
CARBON SEQUESTRATION PROJECT
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

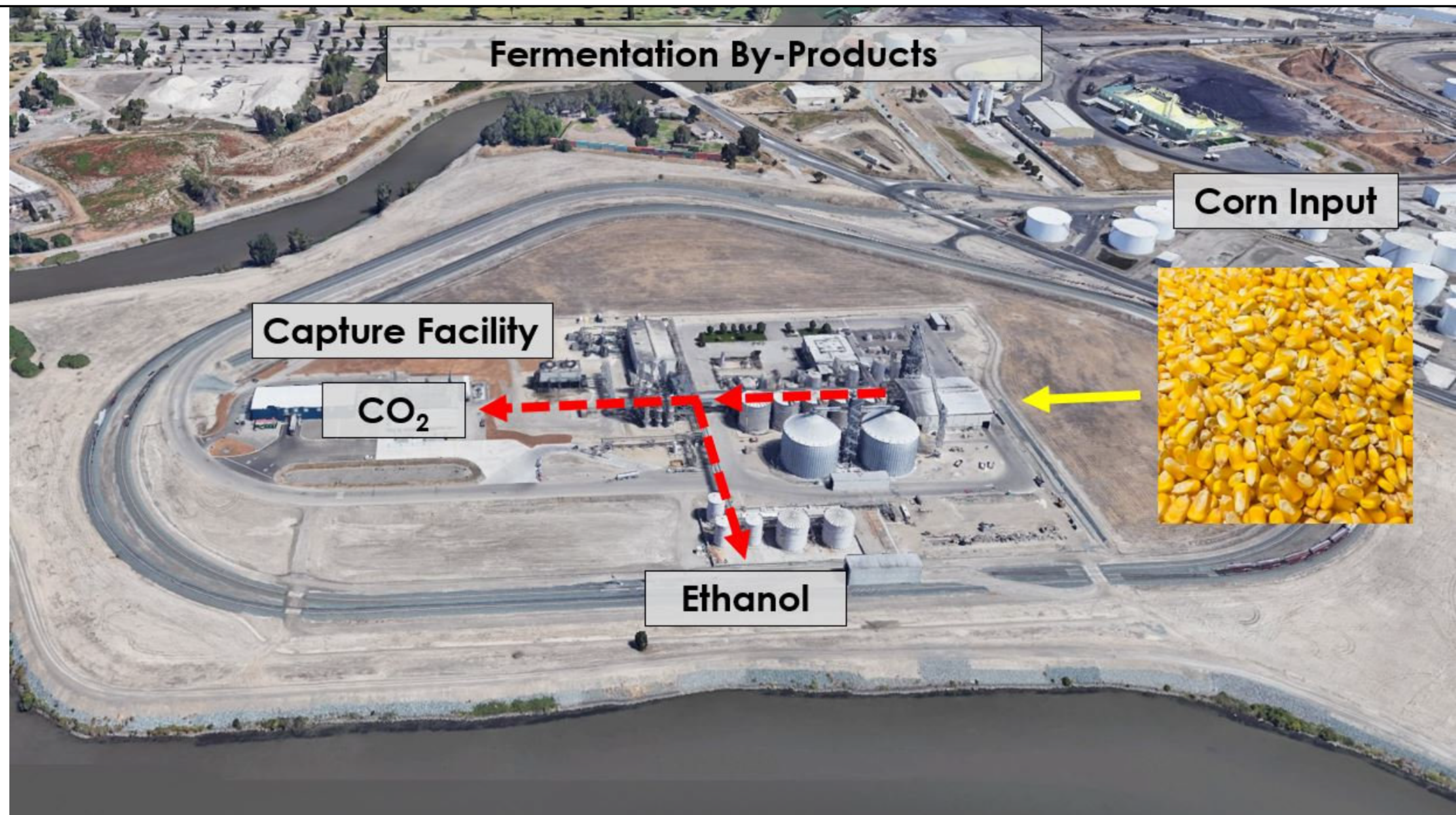


FIGURE 1-2
ETHANOL PLANT AND CARBON DIOXIDE CAPTURE FACILITY
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

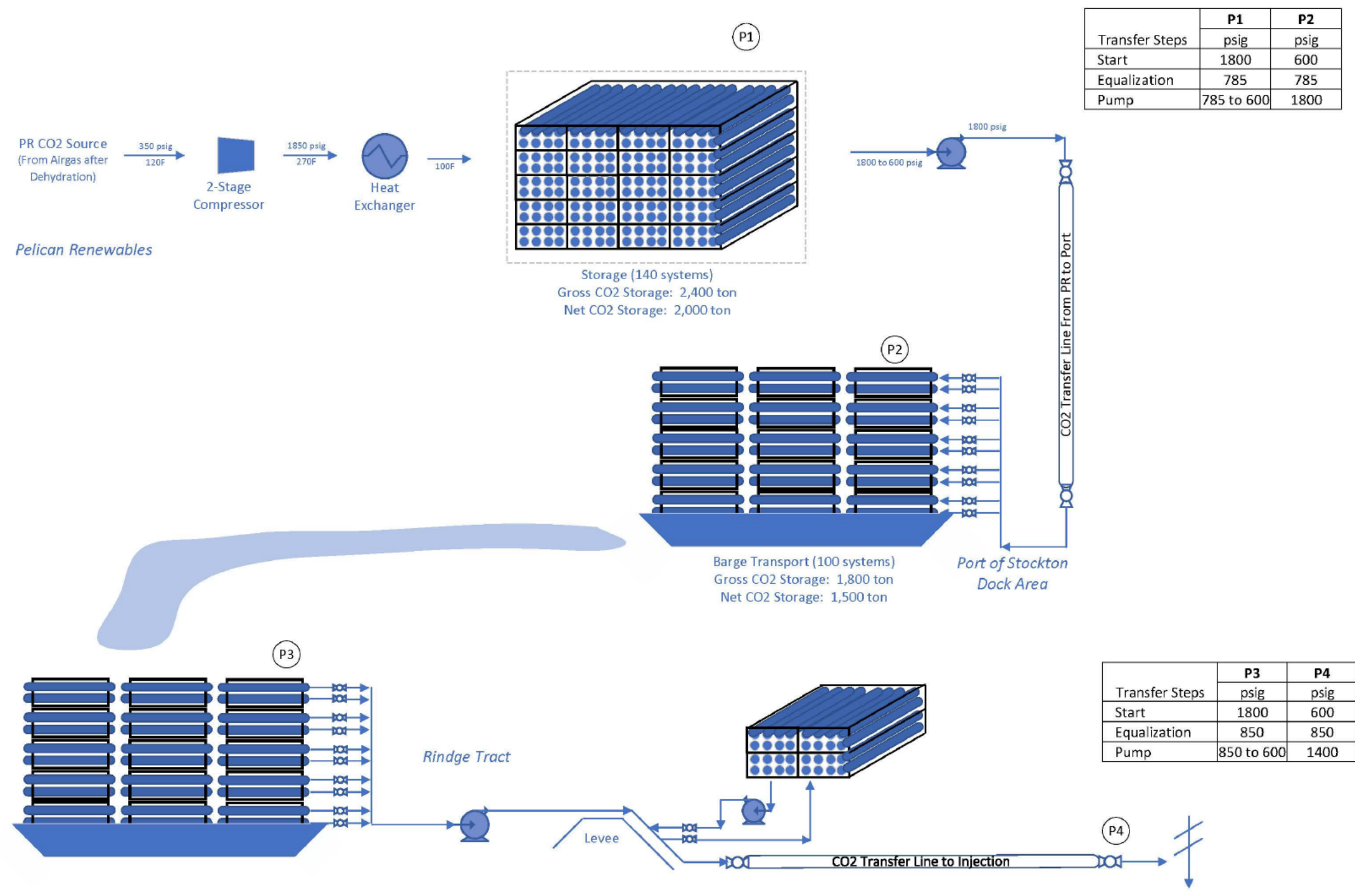
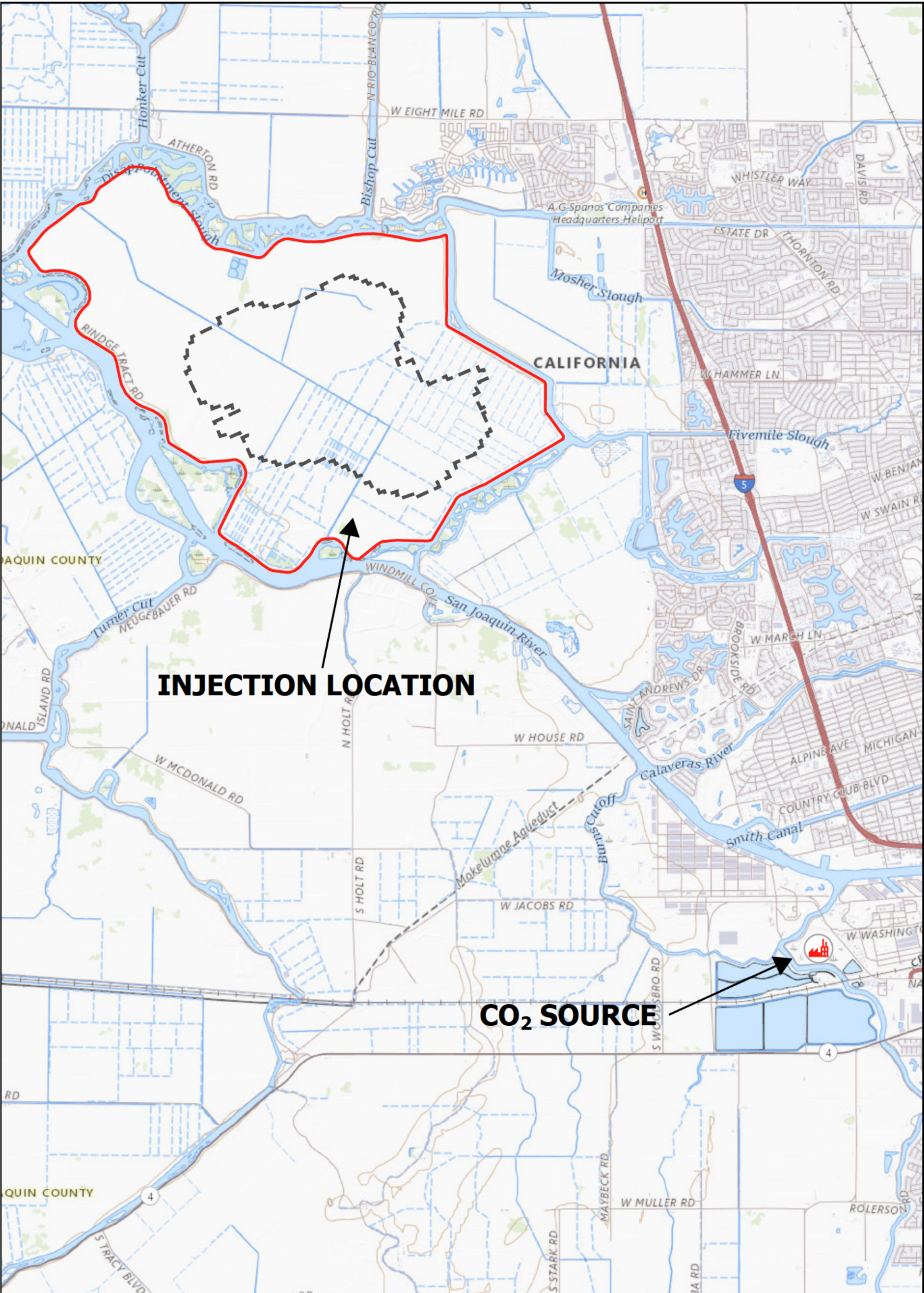


FIGURE 1-3
GENERAL PROCESS DIAGRAM - HP CO₂ TRANSPORT
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

January 2023



Legend




-  Pelican Renewables Ethanol Plant
-  Delineated Area of Review
-  Rindge Tract Island

FIGURE 2-1
LOCATION MAP
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

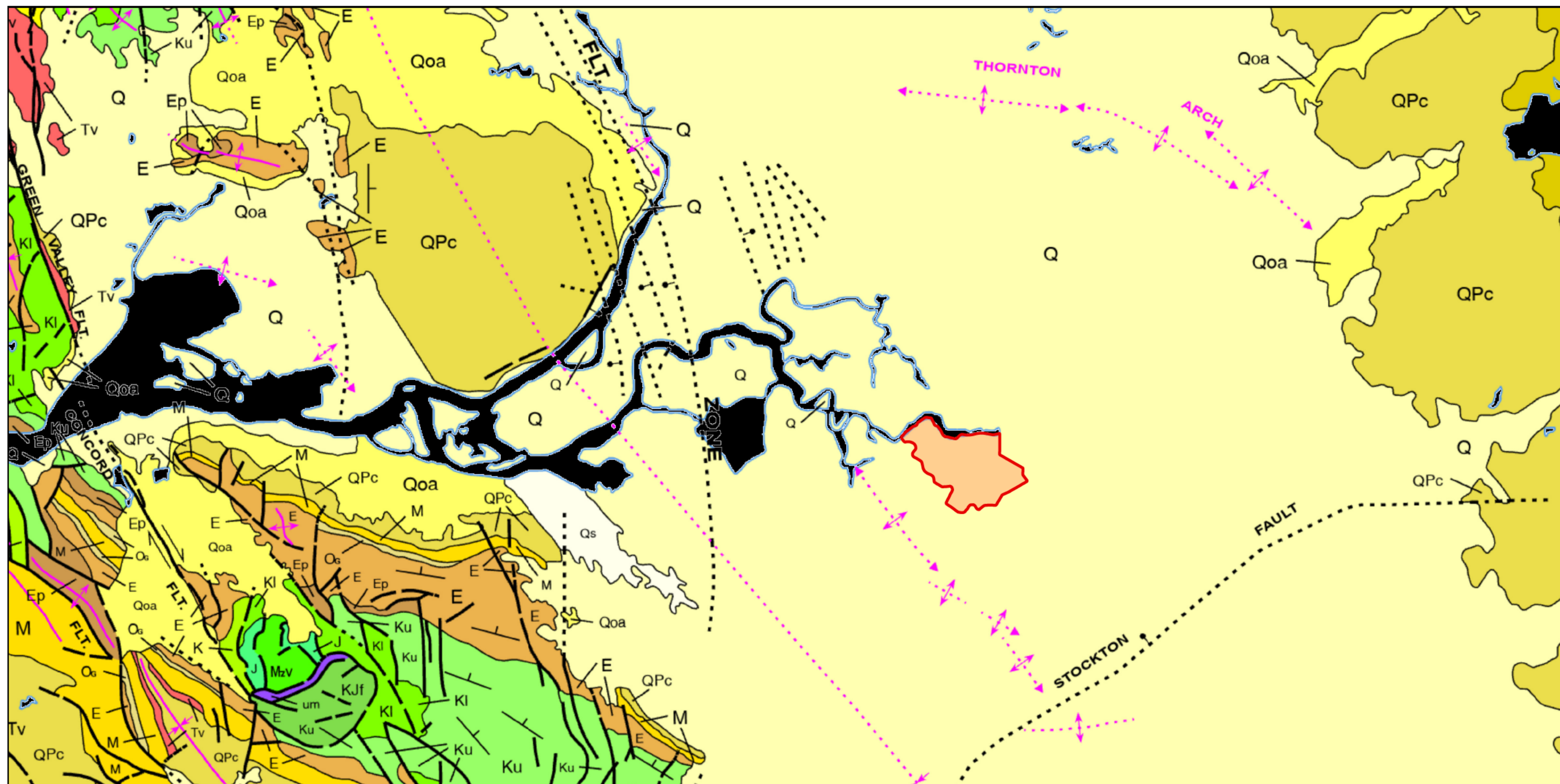
SCS ENGINEERS

Wichita, KS

April 2024

0 6,000
Feet





Legend

Rindge Tract Island

Fold Types

- anticline, concealed
- anticline, concealed, double plunge
- anticline, concealed, south plunge

Fault Type

- fault, concealed
- normal fault, concealed

Geologic Formations

- | | |
|-----------------------------|---------------------|
| Eocene | Paleozoic |
| Paleocene, undifferentiated | Holocene |
| Franciscan Complex Melange | Quaternary Alluvium |
| Franciscan Complex | Plio-Pleistocene |
| Upper Cretaceous | Mesozoic Plutonic |
| Tertiary Volcanic | Water |

FIGURE 2-2

REGIONAL GEOLOGIC MAP
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

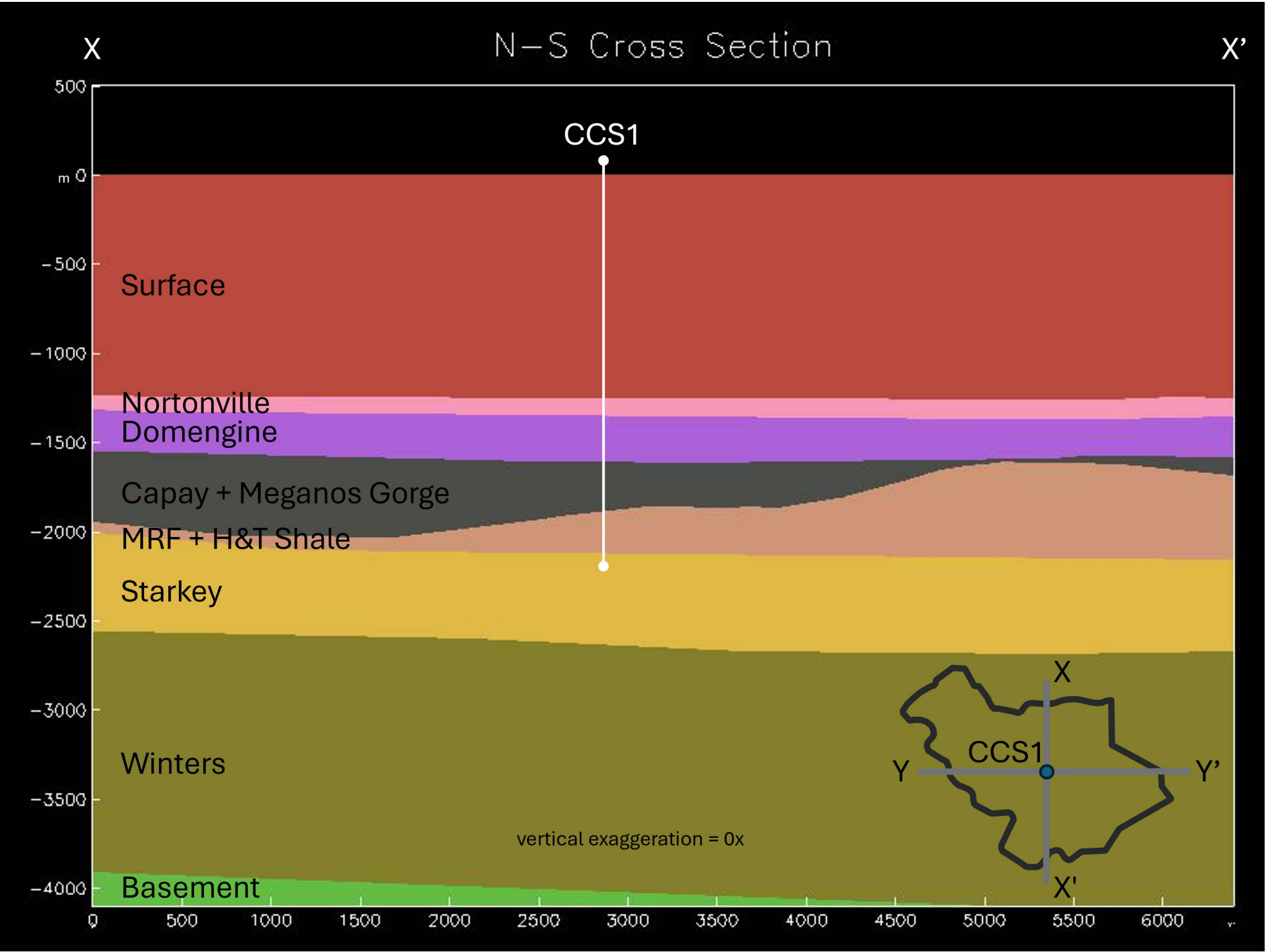
SCS ENGINEERS

Wichita, KS

November 2022

0 27,000 54,000
Feet





Notes:

- Data presented is scaled in meters.
- The H&T Shale is grouped with the Mokelumne River Formation (MRF). For details on reasoning, please refer to the Static Geologic Model description in Section 3 – Area of Review and Corrective Action Plan.

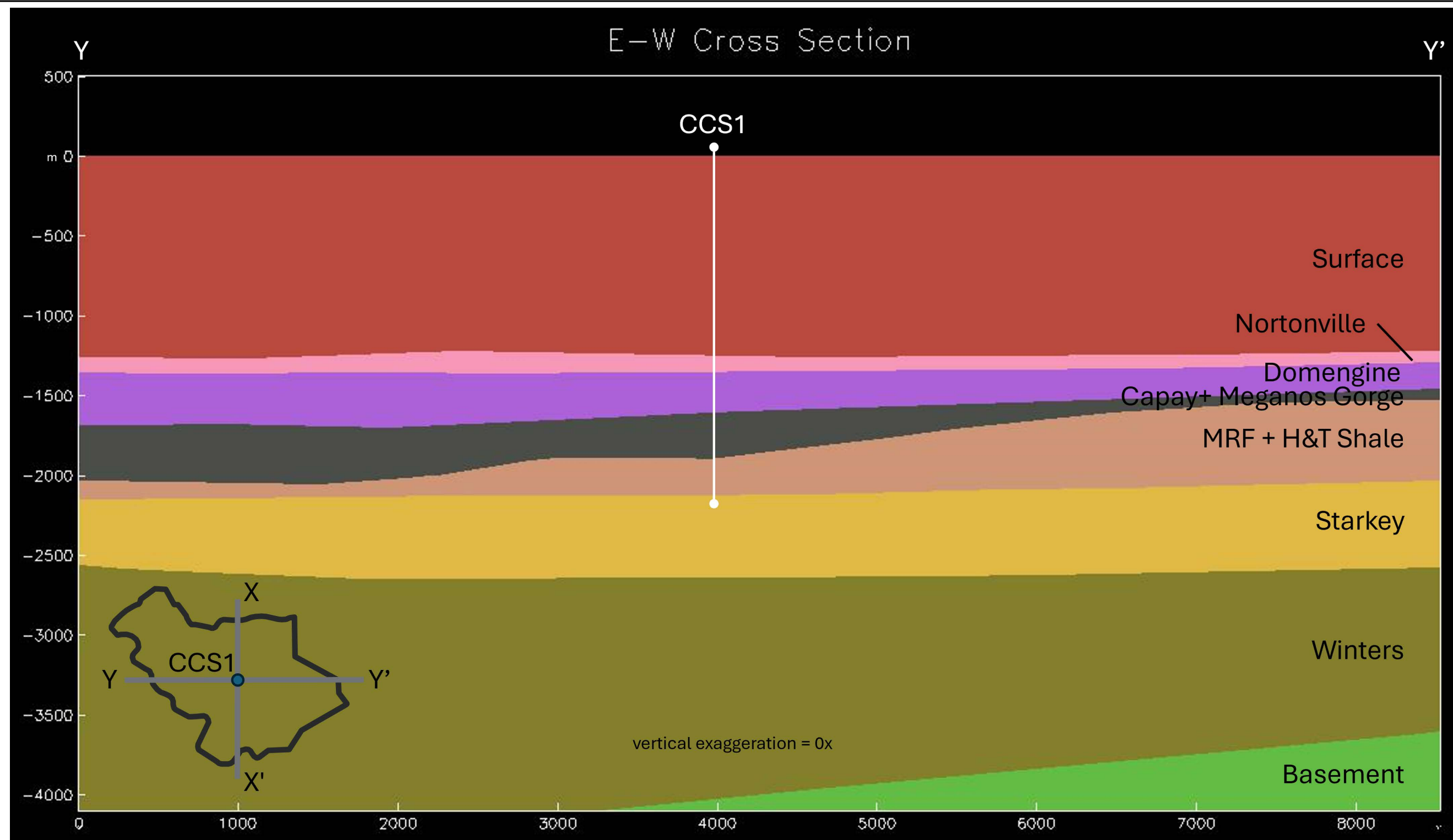
Source:
Lawrence Livermore National Laboratory, 2024. Personal communication from Briana Schmidt to Kacey Garber.

FIGURE 2-3A
NORTH-SOUTH CROSS SECTION
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

April 2024



Notes:

- Data presented is scaled in meters.
- The H&T Shale is grouped with the Mokelumne River Formation (MRF). For details on reasoning, please refer to the Static Geologic Model description in Section 3 – Area of Review and Corrective Action Plan.

Source:

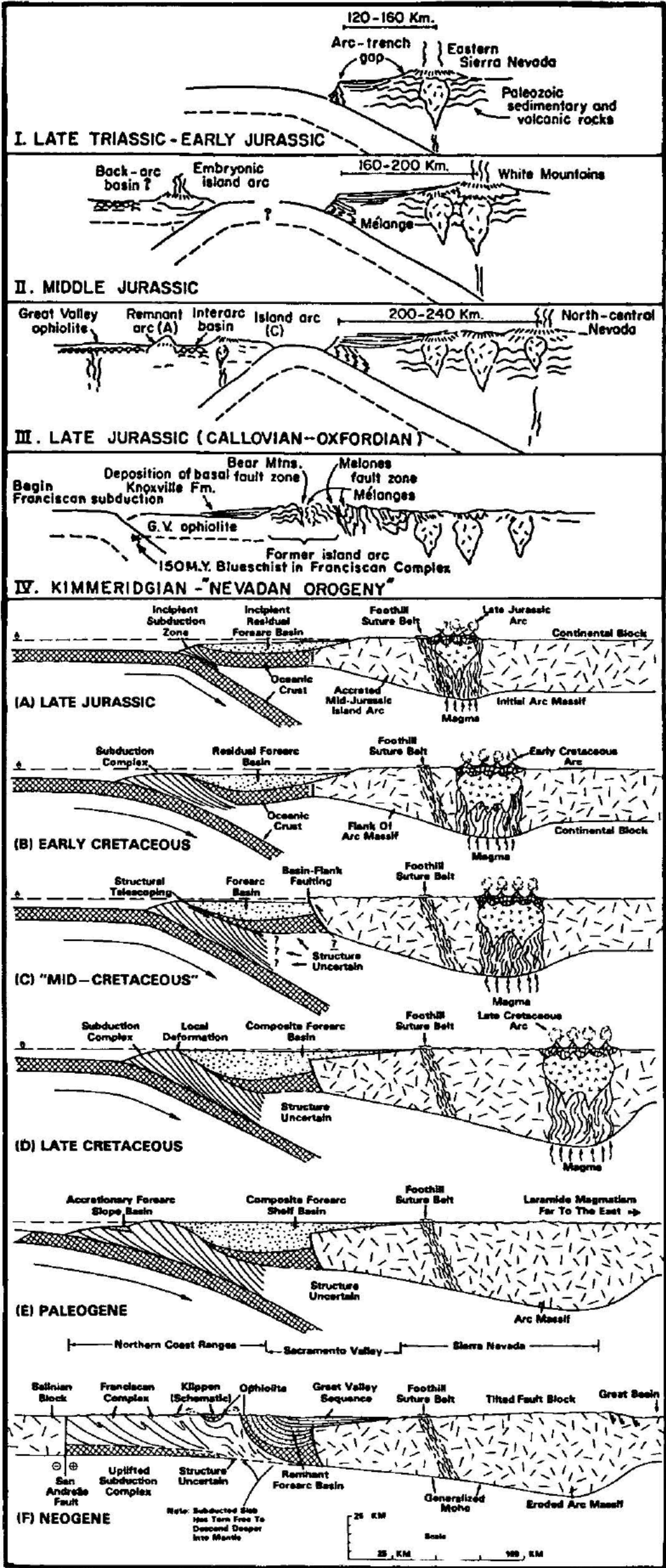
Lawrence Livermore National Laboratory, 2024. Personal communication from Briana Schmidt to Kacey Garber.

FIGURE 2-3B
EAST-WEST CROSS SECTION
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

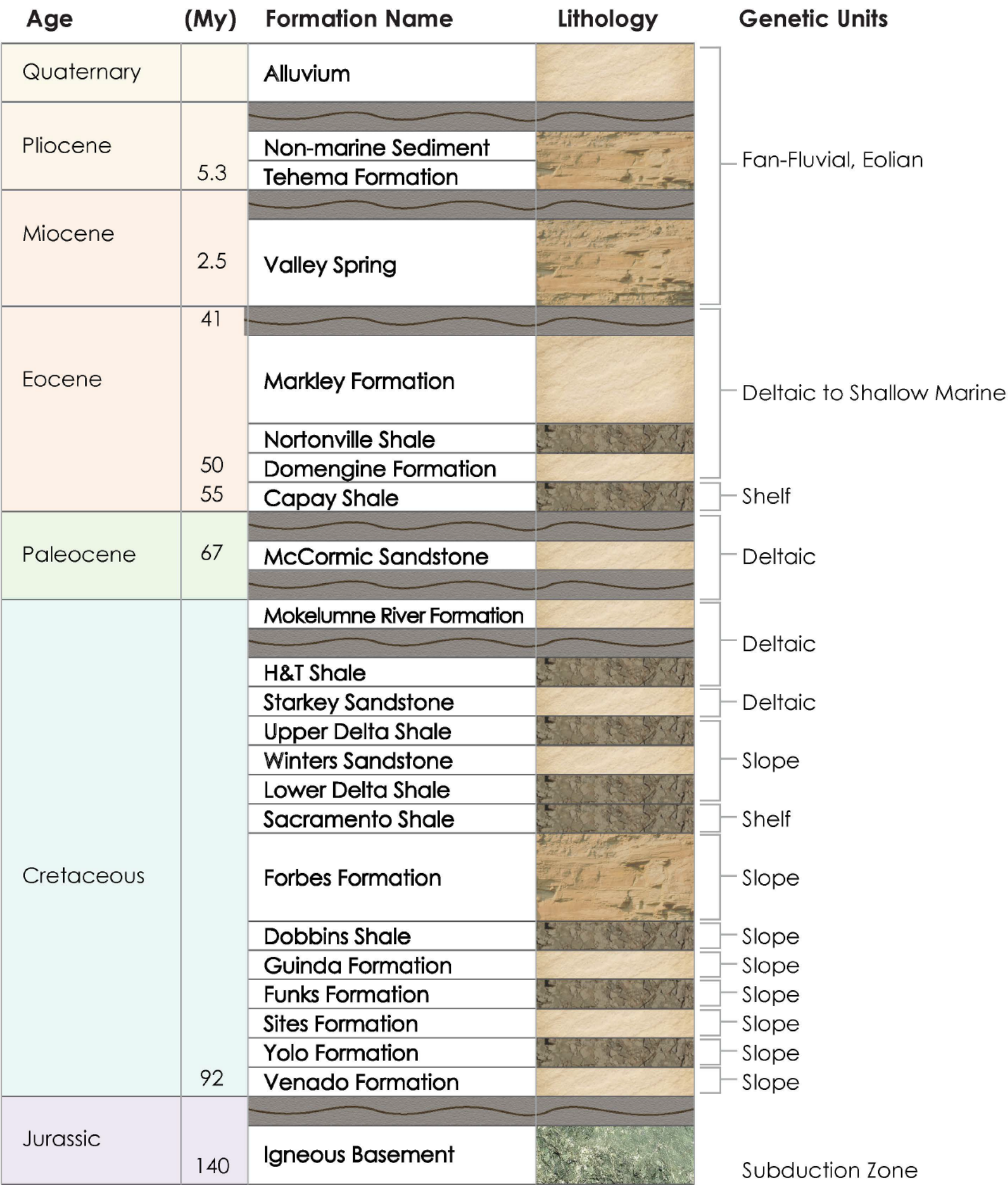
April 2024



Note:

- Schematic cross sections of northern California during Mesozoic and Cenozoic from formation of Coast Range ophiolite behind east-facing intraoceanic arc (III) to termination of Great Valley fore arc by conversion to transform margin (F). A-F are true-scale drawings, whereas I-IV are more schematic.
- Figure adapted from Ingersoll and Dickinson (1981).

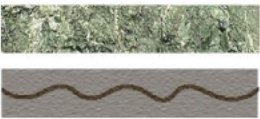
FIGURE 2-4
TECTONIC HISTORY OF SACRAMENTO BASIN
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA



Key

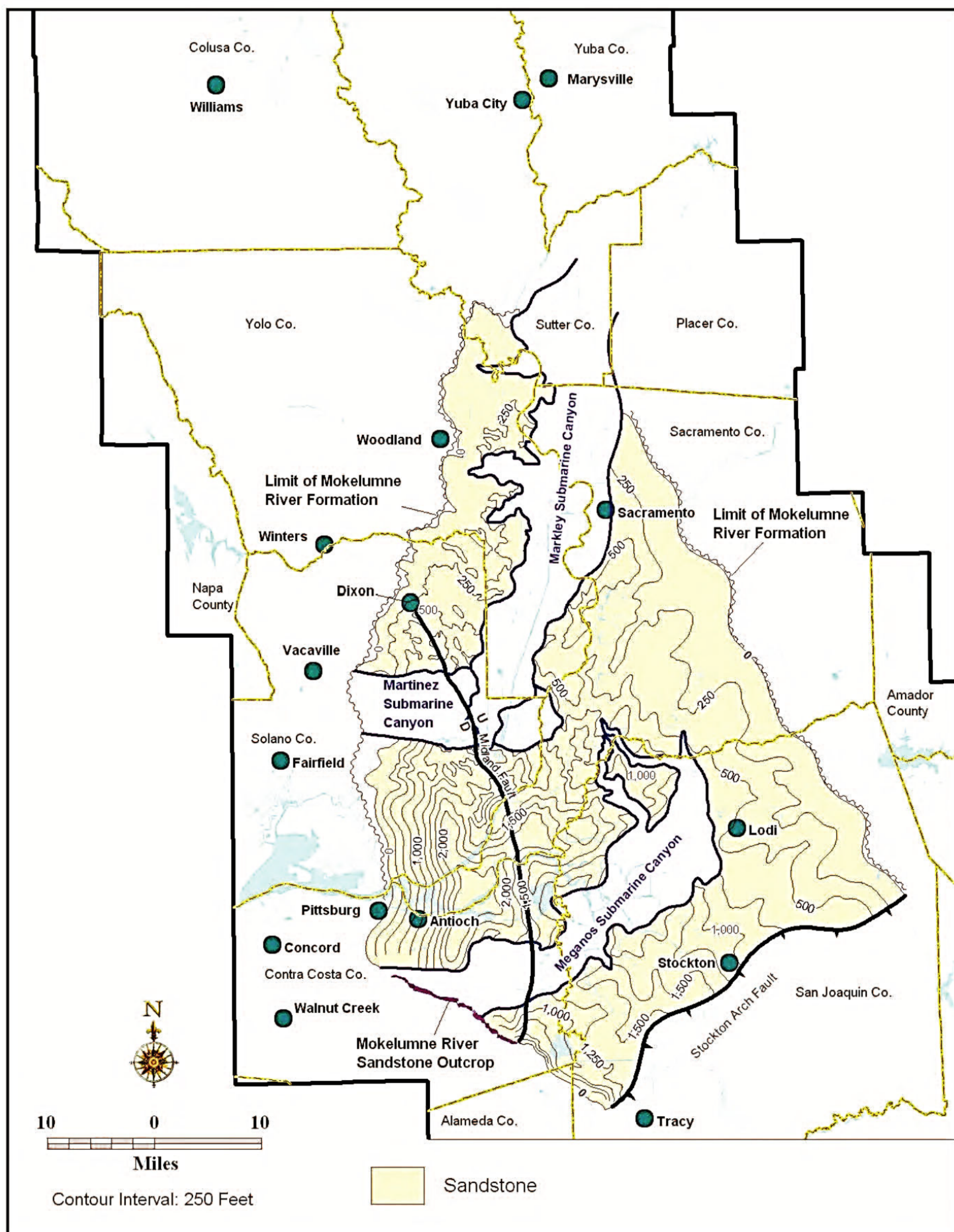


Sandstone
Shale
Mixed Sandstone and Shale



Igneous
Unconformity

FIGURE 2-5
GENERALIZED REGIONAL
STRATIGRAPHIC COLUMN
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA



Source:
California Geological Survey

SCS ENGINEERS

Wichita, KS

November 2022



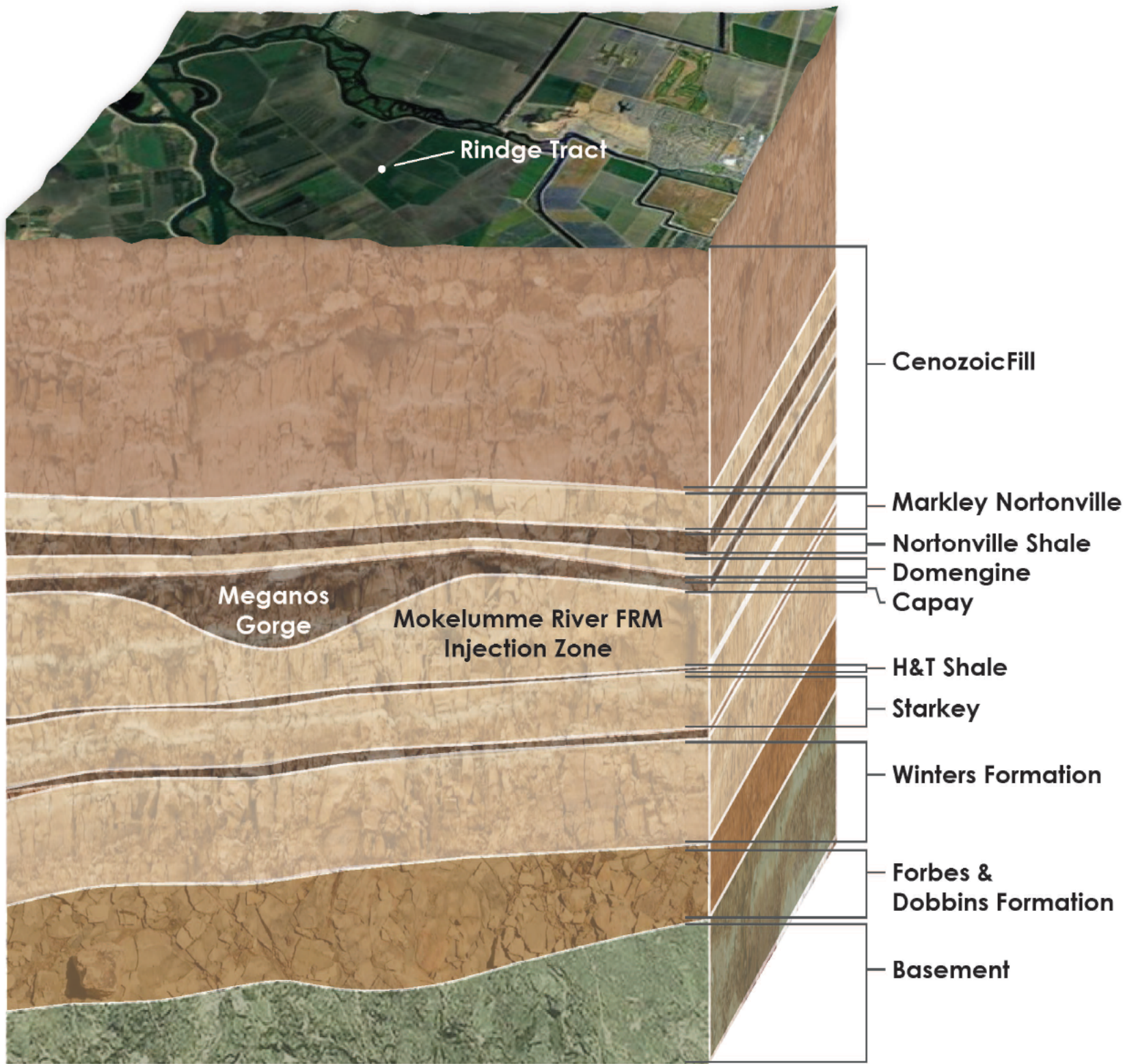
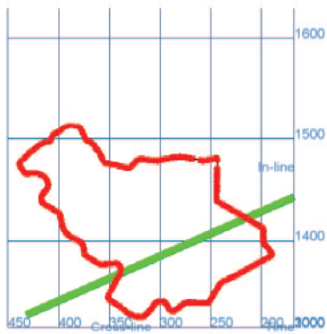
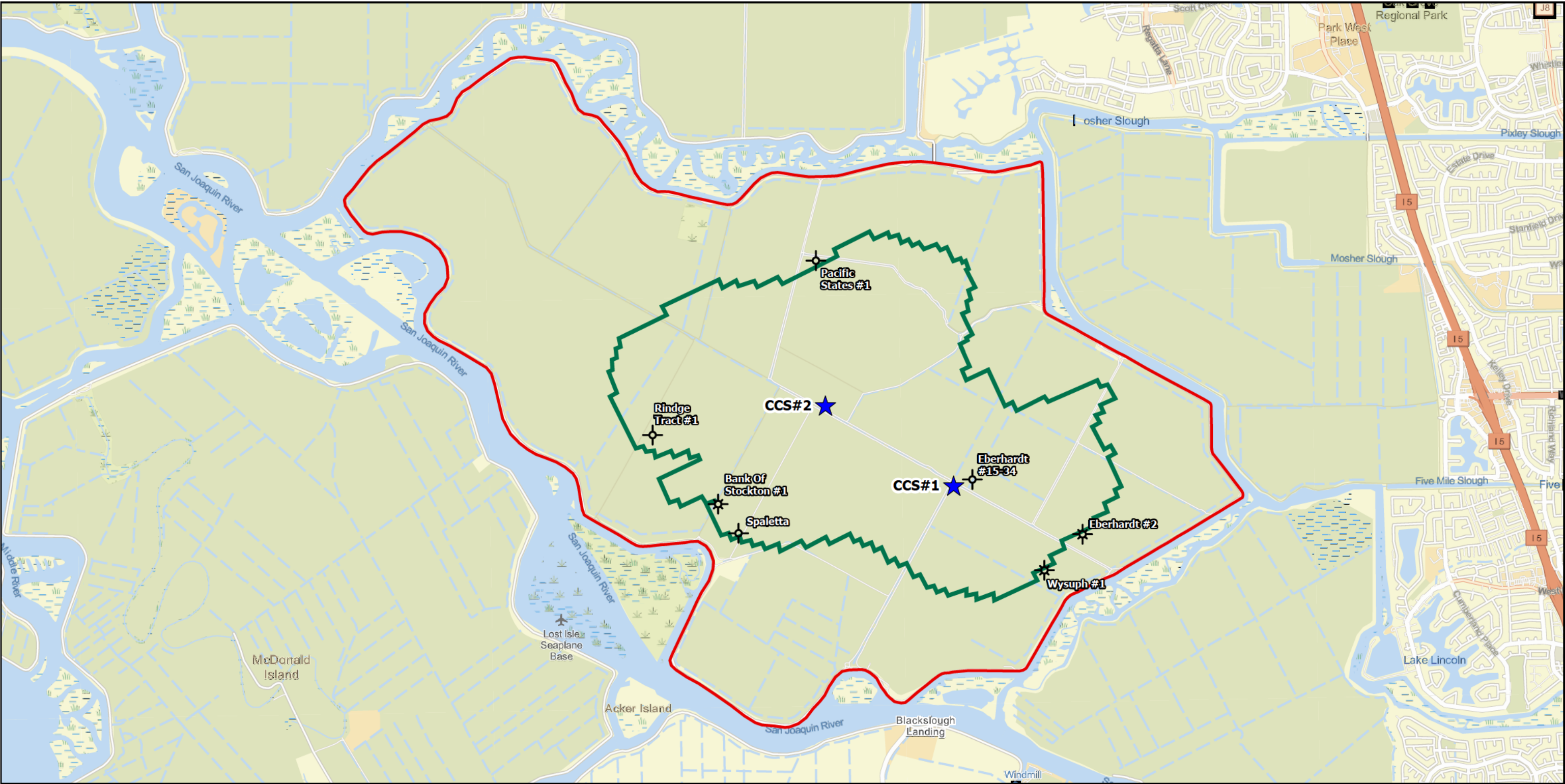


FIGURE 2-8
AOR CONCEPTUAL SITE MODEL
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA



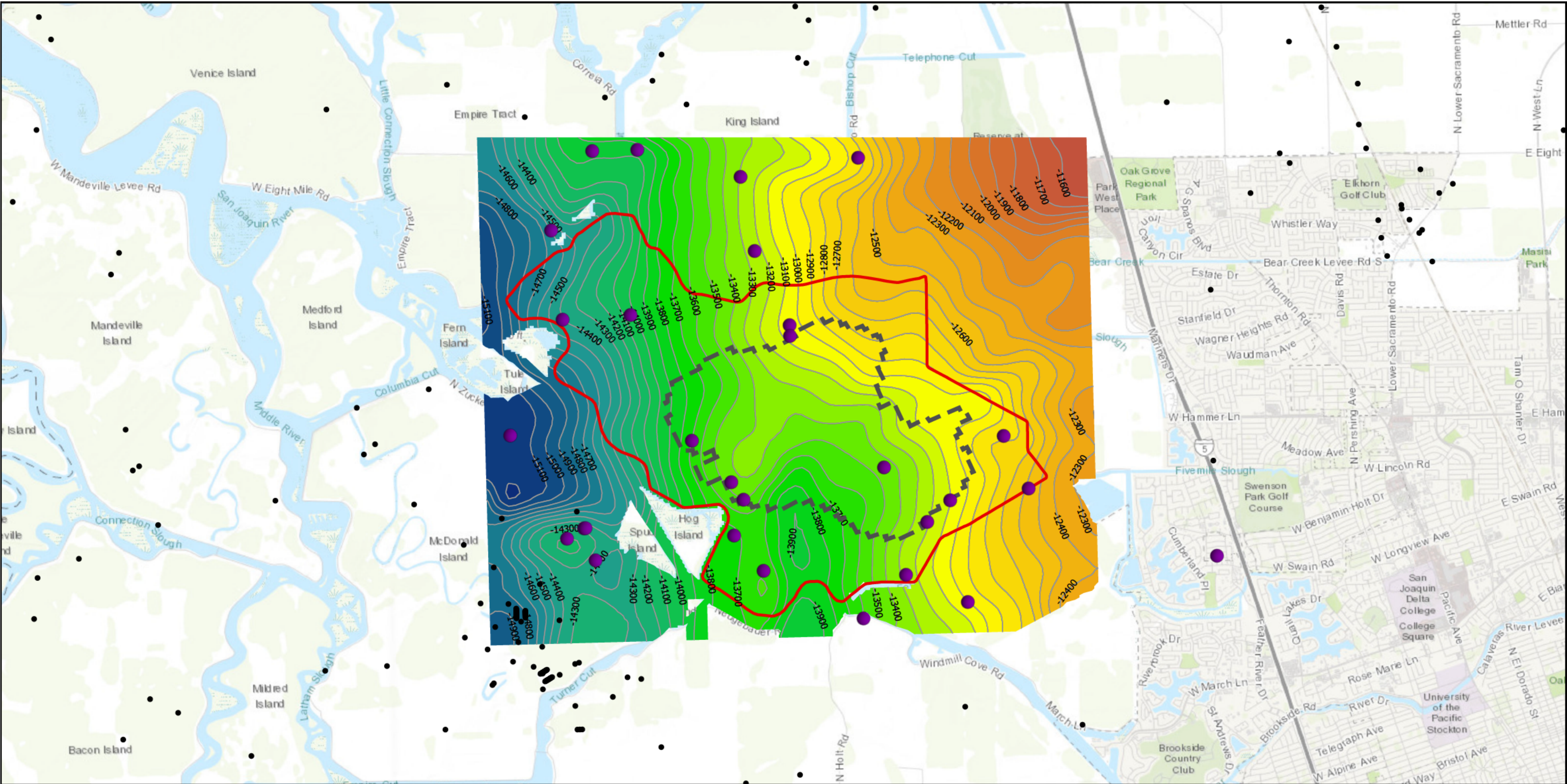
Legend

- | | |
|--------------------------------|---------------------|
| Delineated Area of Review | Unpaved Road |
| Injection Well | Unpaved Road |
| Well Type and Status | Canal |
| Dry Gas - Plugged & Abandoned | Rindge Tract Island |
| Dry Hole - Plugged & Abandoned | |

Note:
The following elements are not present within the AOR:
producing wells; deep stratigraphic boreholes; State or EPA-approved subsurface cleanup sites; springs; mines; quarries; water wells; structures intended for human occupancy; state, tribal, or territory boundaries; or faults.

FIGURE 2-9
DELINEATED AREA OF REVIEW
WITH ELEMENTS SPECIFIED UNDER 40 CFR 146.82
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS			
Wichita, KS	October 2024		

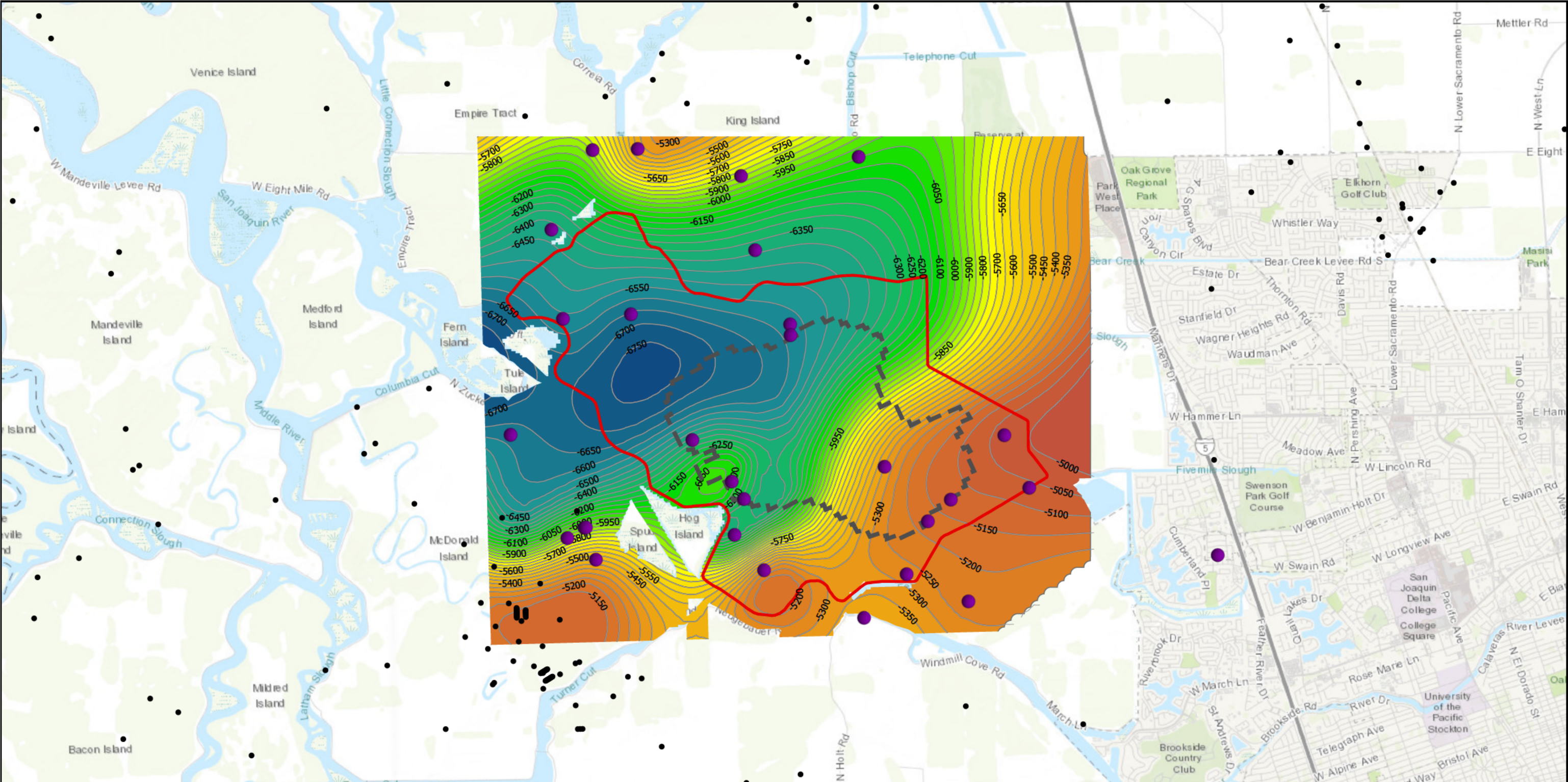


Legend

- Well Control Used in Interpretation
- Oil & Gas Wells
- ▬ Delineated Area of Review
- ▬ Rindge Tract Island

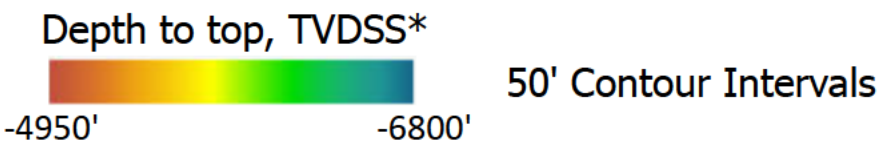


FIGURE 2-10
BASEMENT STRUCTURE MAP
PELICAN RENEWABLES, INC.
SAN JOAQUIN COUNTY, CALIFORNIA



Legend

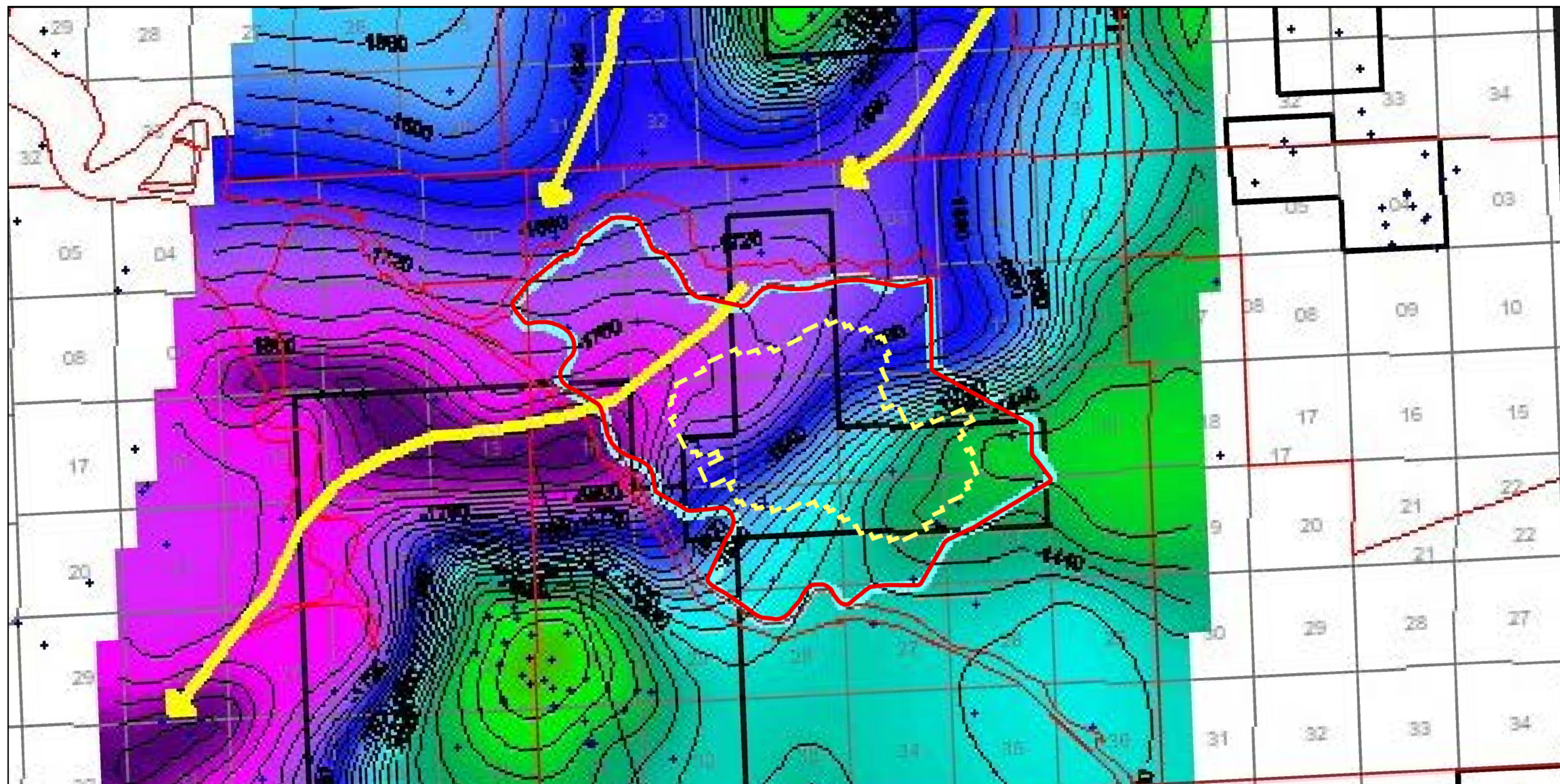
- Well Control Used in Interpretation
- Oil & Gas Wells
- ▤ Delineated Area of Review
- 🔴 Rindge Tract Island



Note:
- TVDSS* = True Vertical Depth Sub Sea.

FIGURE 2-12
MOKELUMNE RIVER FORMATION STRUCTURE MAP
PELICAN RENEWABLES, INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS			
Wichita, KS	April 2024		



Legend

- Delineated Area of Review
- Rindge Tract Island

Source:
Oil & Gas Field Redevelopment Group, LLC. (n.d.) Final Report.
Figure 7. Digitized Selected Time Intervals Imported into GeoGraphix p.12.

FIGURE 2-14

MEGANOS GORGE BOUNDARY
PELICAN RENEWABLES, INC.
SAN JOAQUIN COUNTY, CALIFORNIA

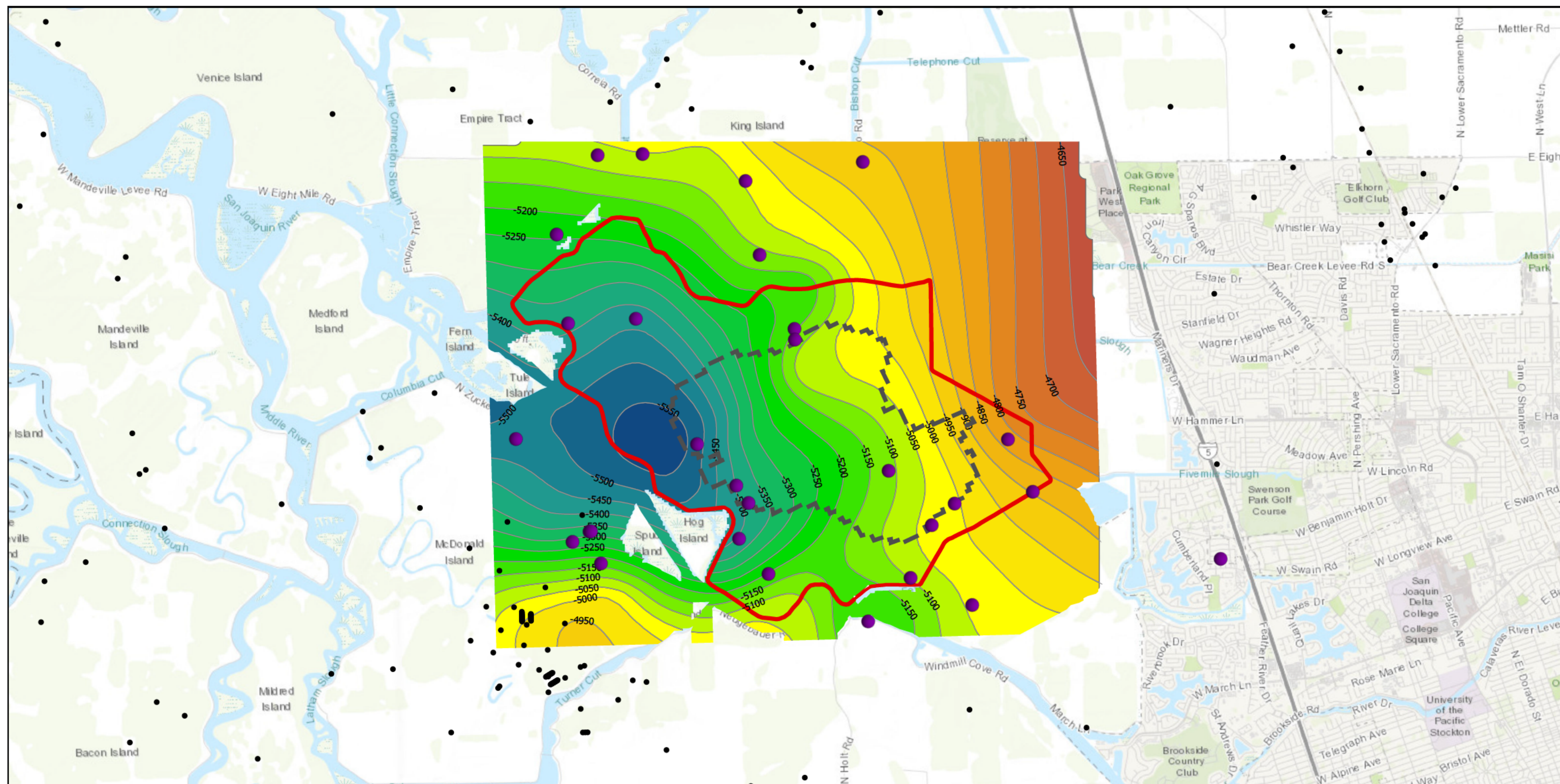
SCS ENGINEERS

Wichita, KS

January 2023

0 5,000 10,000
Feet





Legend

- Well Control Used in Interpretation
- Oil & Gas Wells
- ▤ Delineated Area of Review
- 🔴 Rindge Tract Island

Depth to top, TVDSS*
 -4650' -5550'

50' Contour Intervals

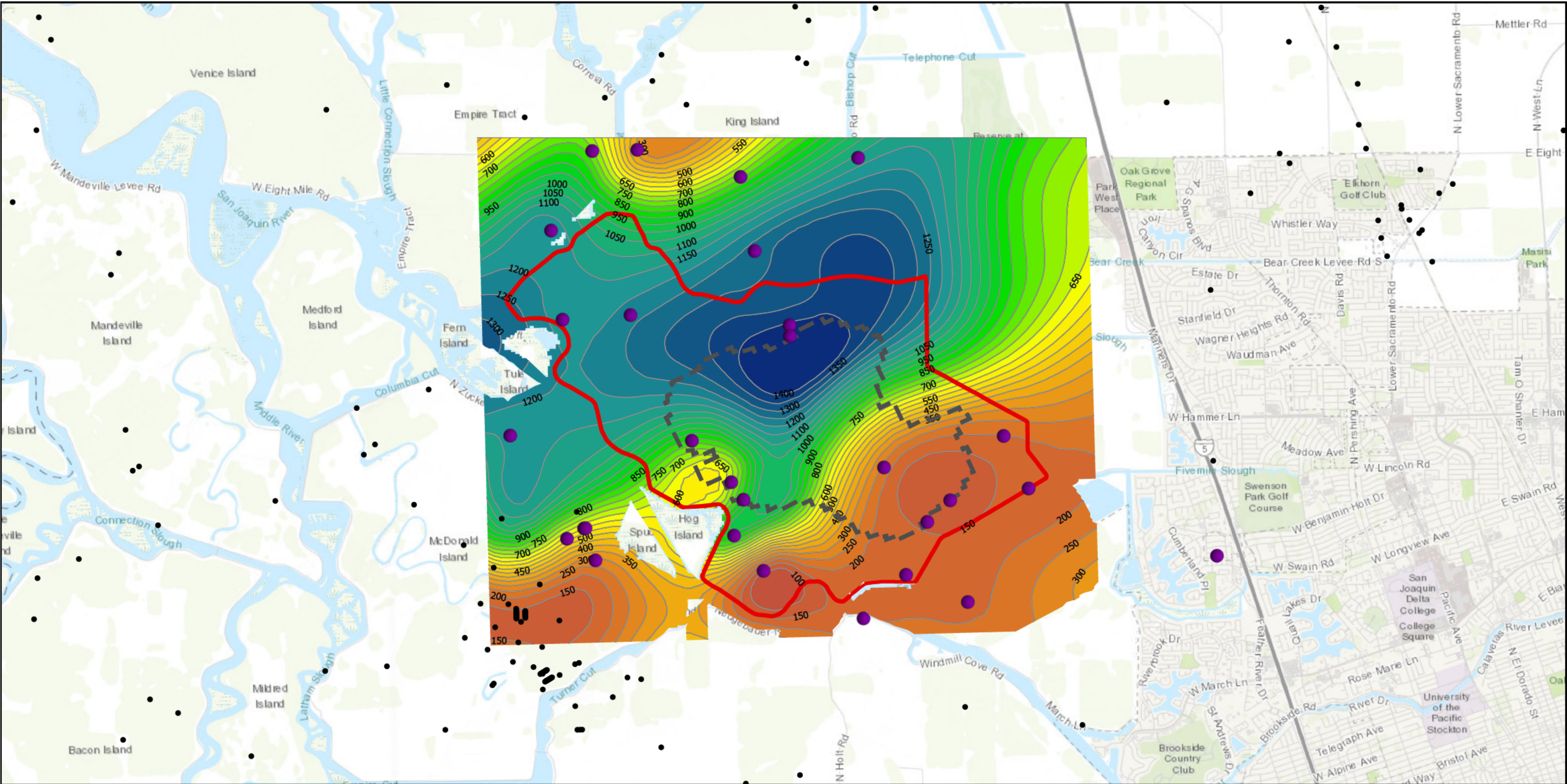
Note:
 - TVDSS* = True Vertical Depth Sub Sea.

FIGURE 2-15
 CAPAY & MEGANOS GORGE STRUCTURE MAP
 PELICAN RENEWABLES, INC.
 SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS
 Wichita, KS April 2024

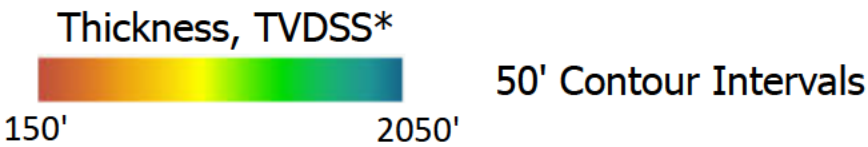
0 5,000 10,000 Feet





Legend

- Well Control Used in Interpretation
- Oil & Gas Wells
- ▤ Delineated Area of Review
- 🔴 Rindge Tract Island

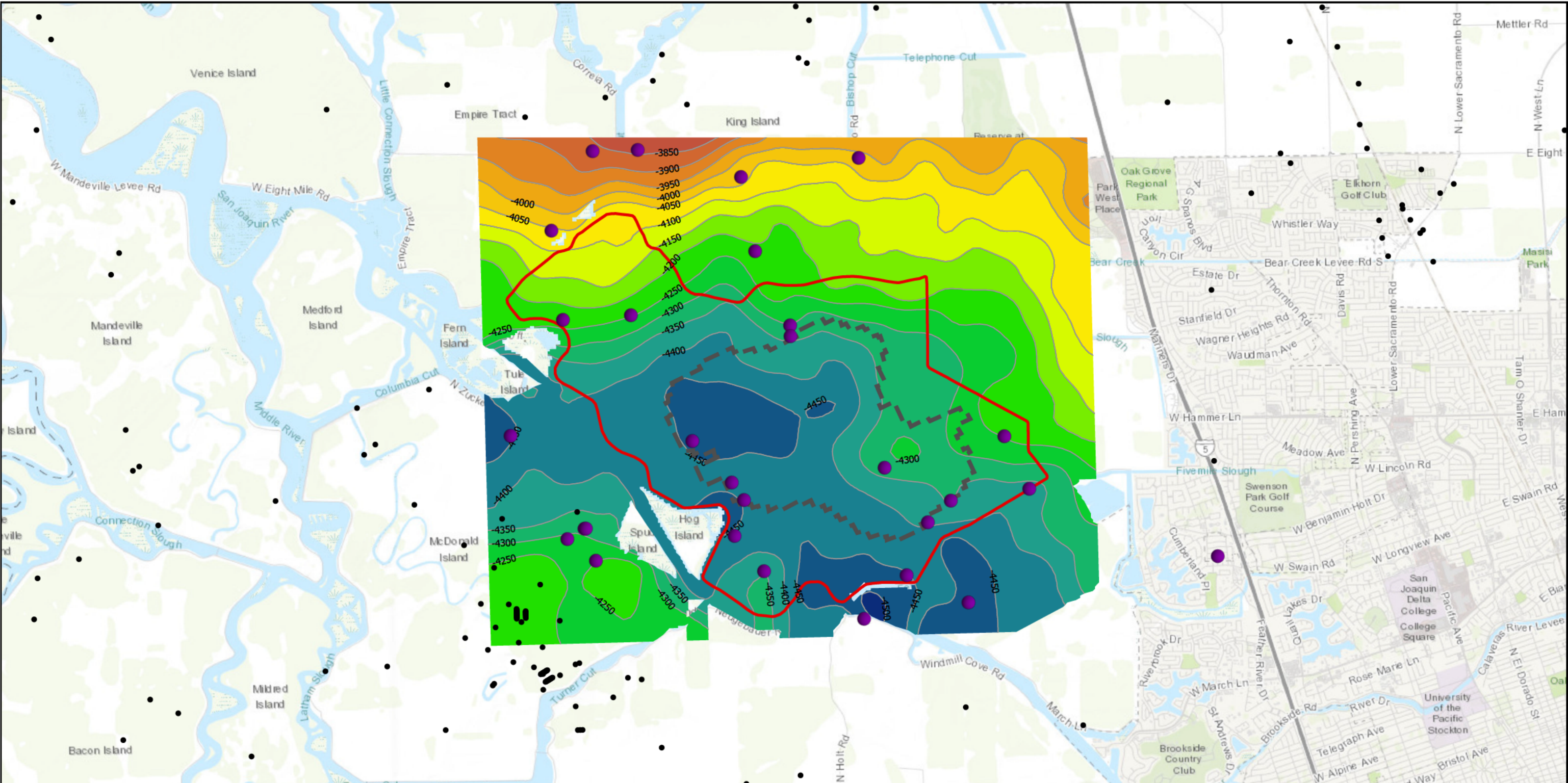


Note:

- Depth grid converted using time-depth relationship from Big Valley Eberhart 1.
- TVDSS* = True Vertical Depth Sub Sea.

FIGURE 2-16
CAPAY SHALE & MEGANOS GORGE ISOPACH
MAP PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS		0 5,000 10,000 Feet		
Wichita, KS	April 2024			

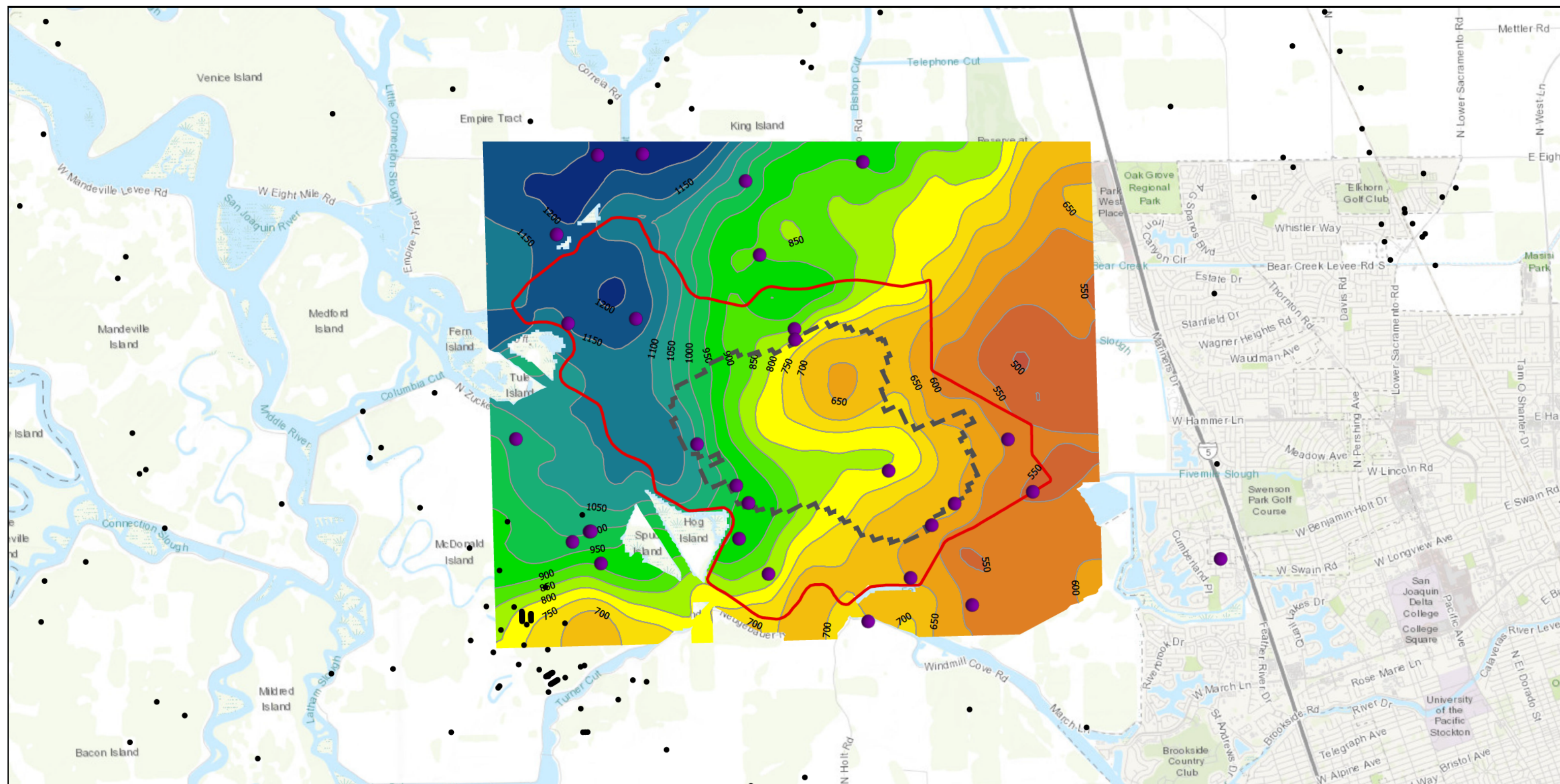


Legend

- Well Control Used in Interpretation
- Oil & Gas Wells
- ▤ Delineated Area of Review
- ▭ Rindge Tract Island

Depth to top, TVDSS*
 -3850' -4500'
 50' Contour Intervals

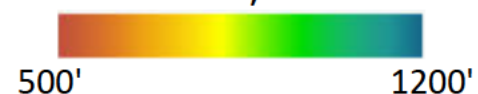
FIGURE 2-17
 DOMENGINE FORMATION STRUCTURE MAP
 PELICAN RENEWABLES, INC.
 SAN JOAQUIN COUNTY, CALIFORNIA



Legend

- Well Control Used in Interpretation
- Oil & Gas Wells
- ▬ Delineated Area of Review
- ▬ Rindge Tract Island

Thickness, TVDSS*



50' Contour Intervals

Note:

- Depth grid converted using time-depth relationship from Big Valley Eberhart 1.
- TVDSS* = True Vertical Depth Sub Sea.

FIGURE 2-18

DOMINGINE FORMATION ISOPACH MAP
PELICAN RENEWABLES, INC.
SAN JOAQUIN COUNTY, CALIFORNIA

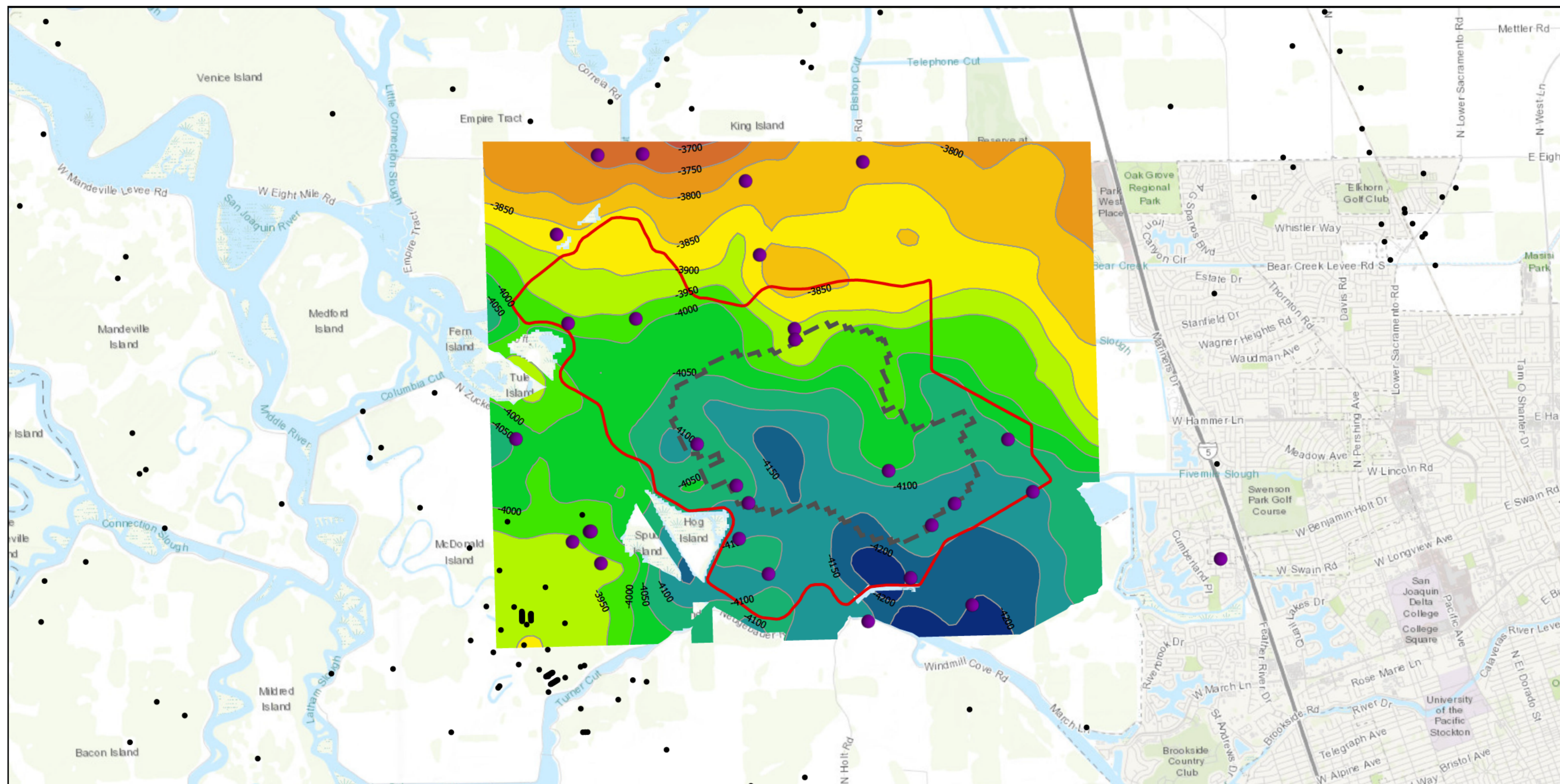
SCS ENGINEERS

Wichita, KS

April 2024

0 5,000 10,000 Feet





Legend

- Well Control Used in Interpretation
- Oil & Gas Wells
- Delineated Area of Review
- Rindge Tract Island

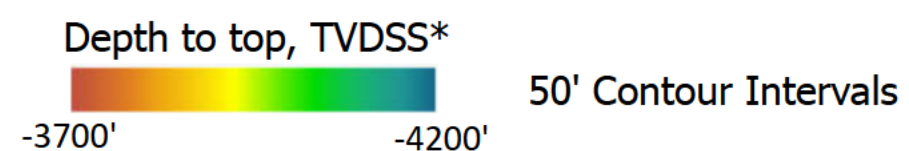
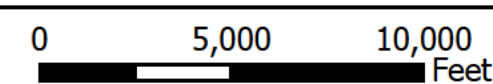


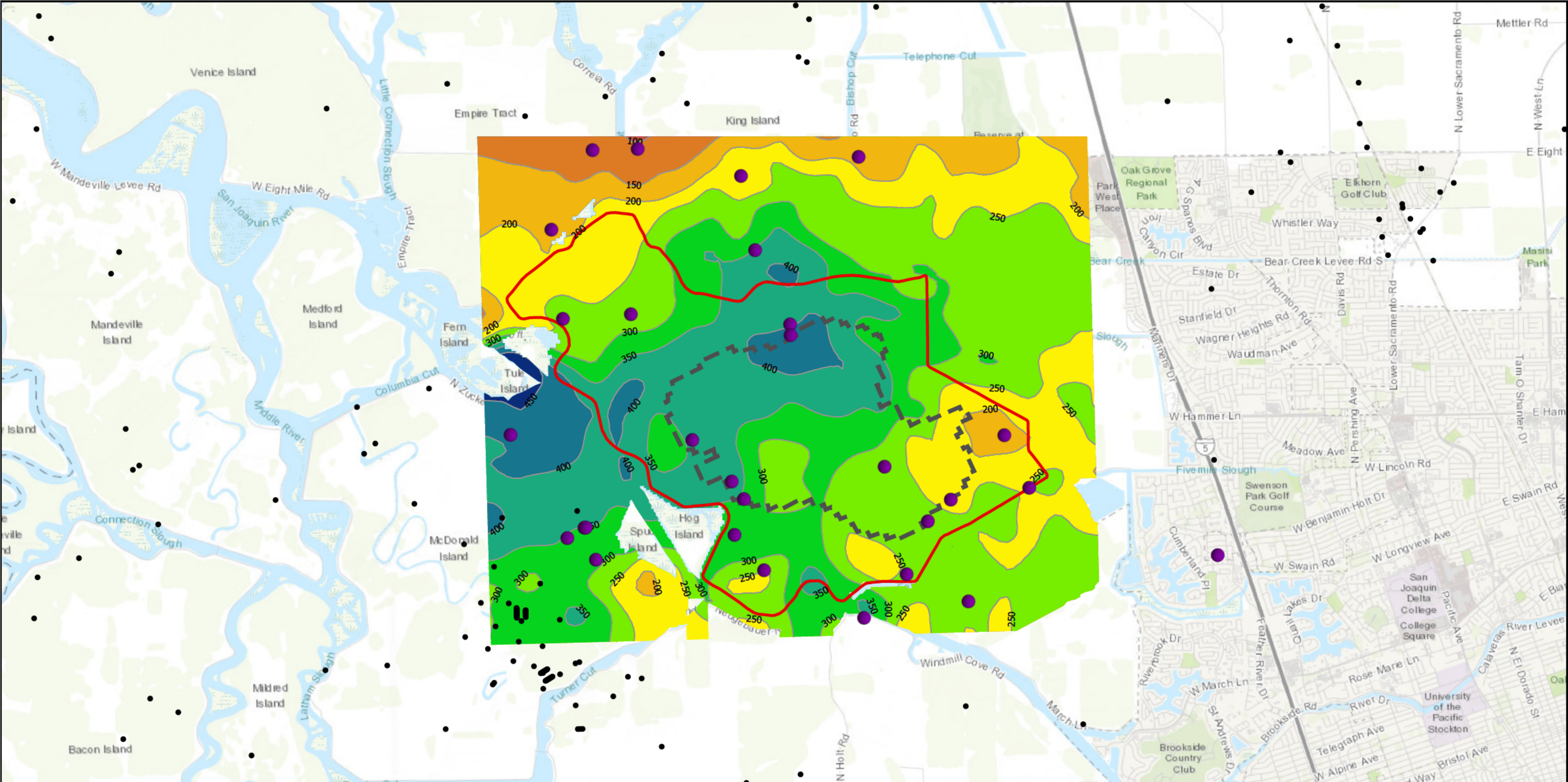
FIGURE 2-19
NORTONVILLE SHALE STRUCTURE MAP
PELICAN RENEWABLES, INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

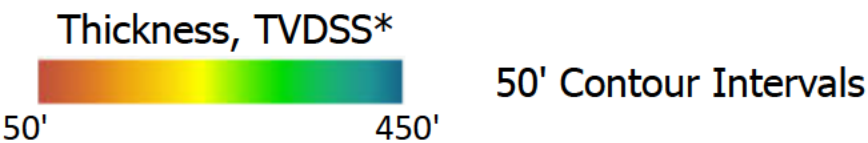
April 2024





Legend

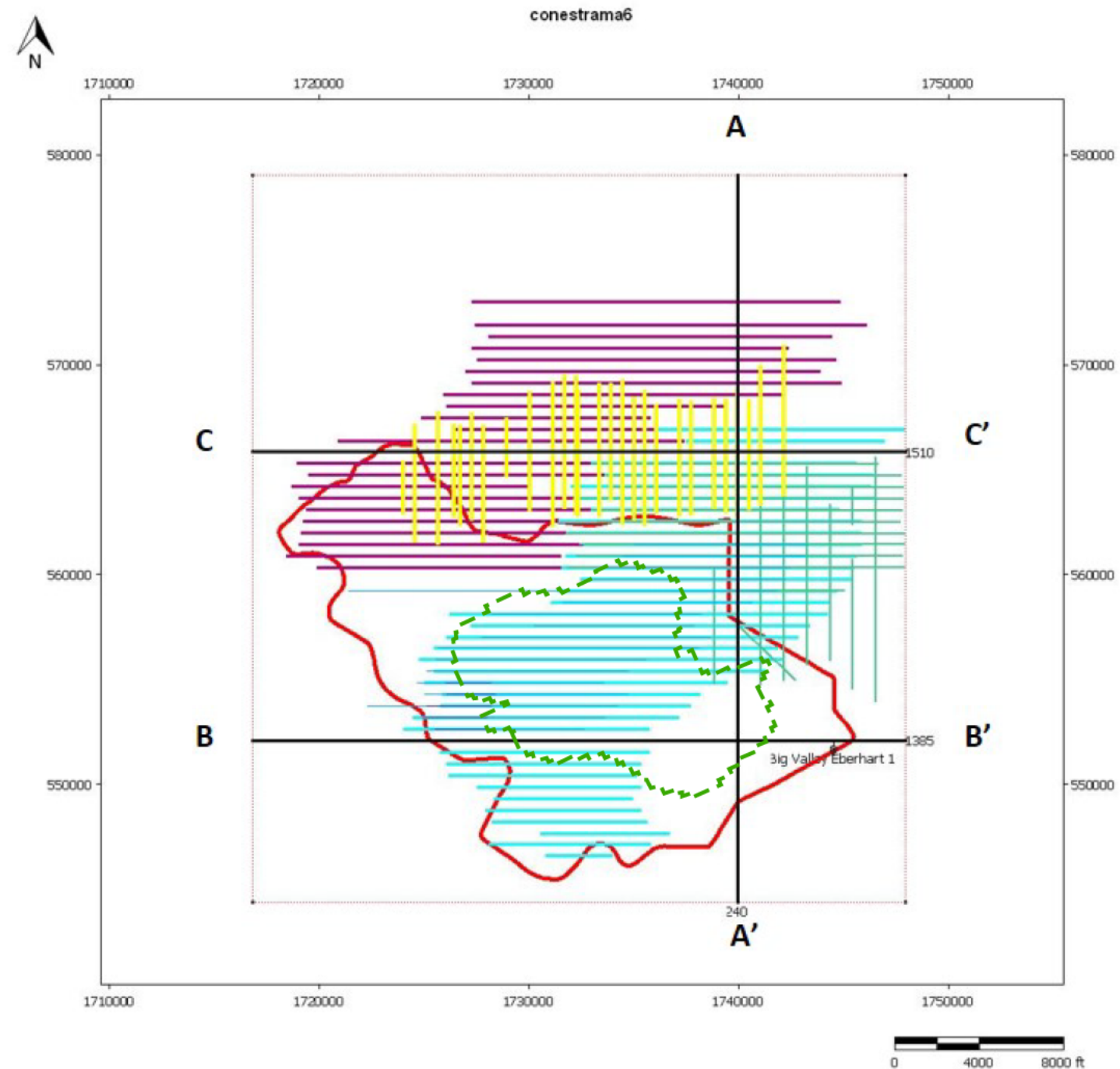
- Well Control Used in Interpretation
- Oil & Gas Wells
- ▤ Delineated Area of Review
- 🔴 Rindge Tract Island



Note:
- Depth grid converted using time-depth relationship from Big Valley Eberhart 1.
- TVDSS* = True Vertical Depth Sub Sea.

FIGURE 2-20
NORTONVILLE ISOPACH MAP
PELICAN RENEWABLES, INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS			
Wichita, KS	April 2024		



Legend

- Listric faults dipping West
- Listric faults dipping East
- Listric faults dipping North
- Basement fault dipping North



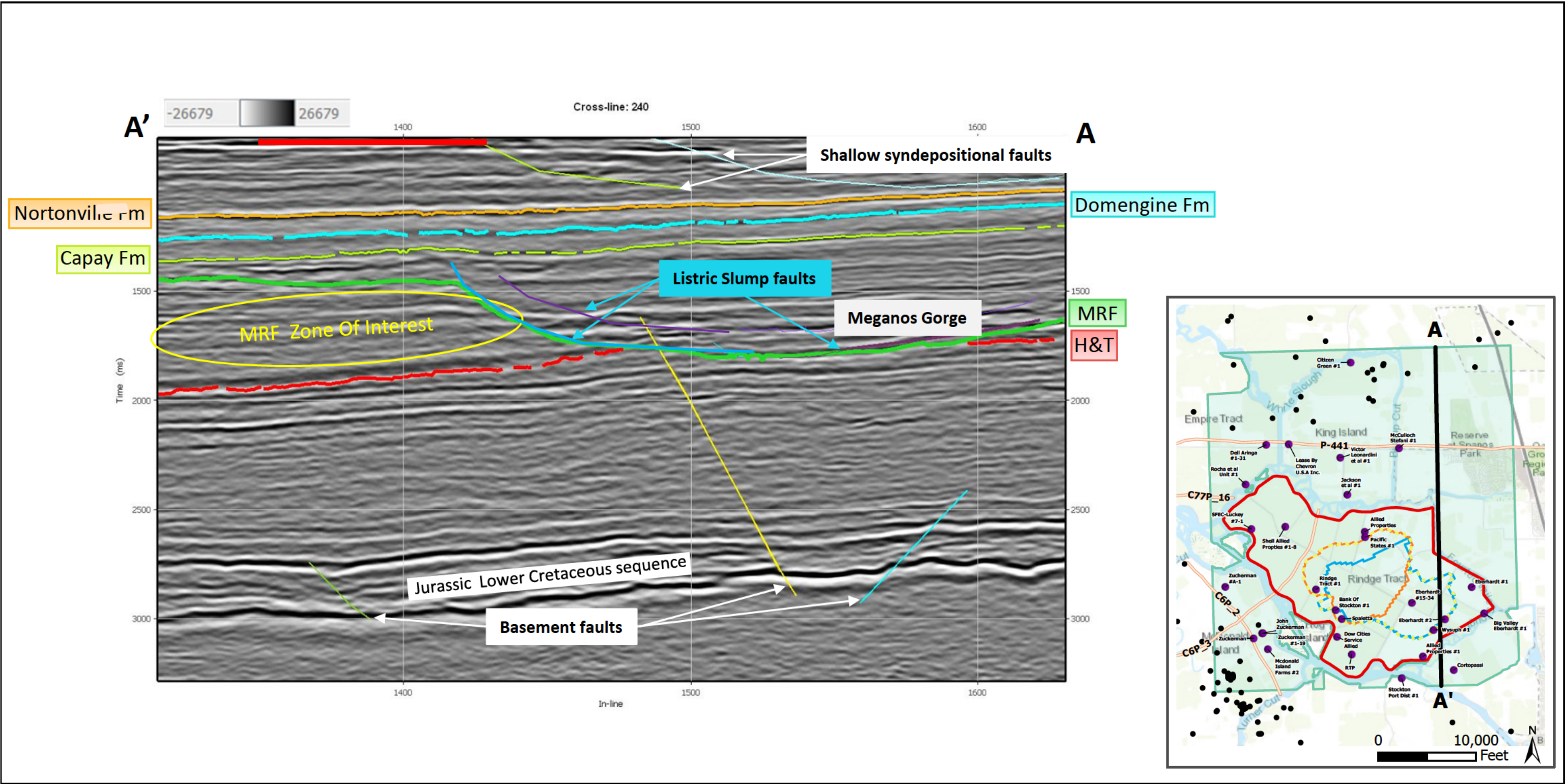
Delineated Area of Review

FIGURE 2-21
FAULT DISTRIBUTION MAP
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

April 2024



Legend

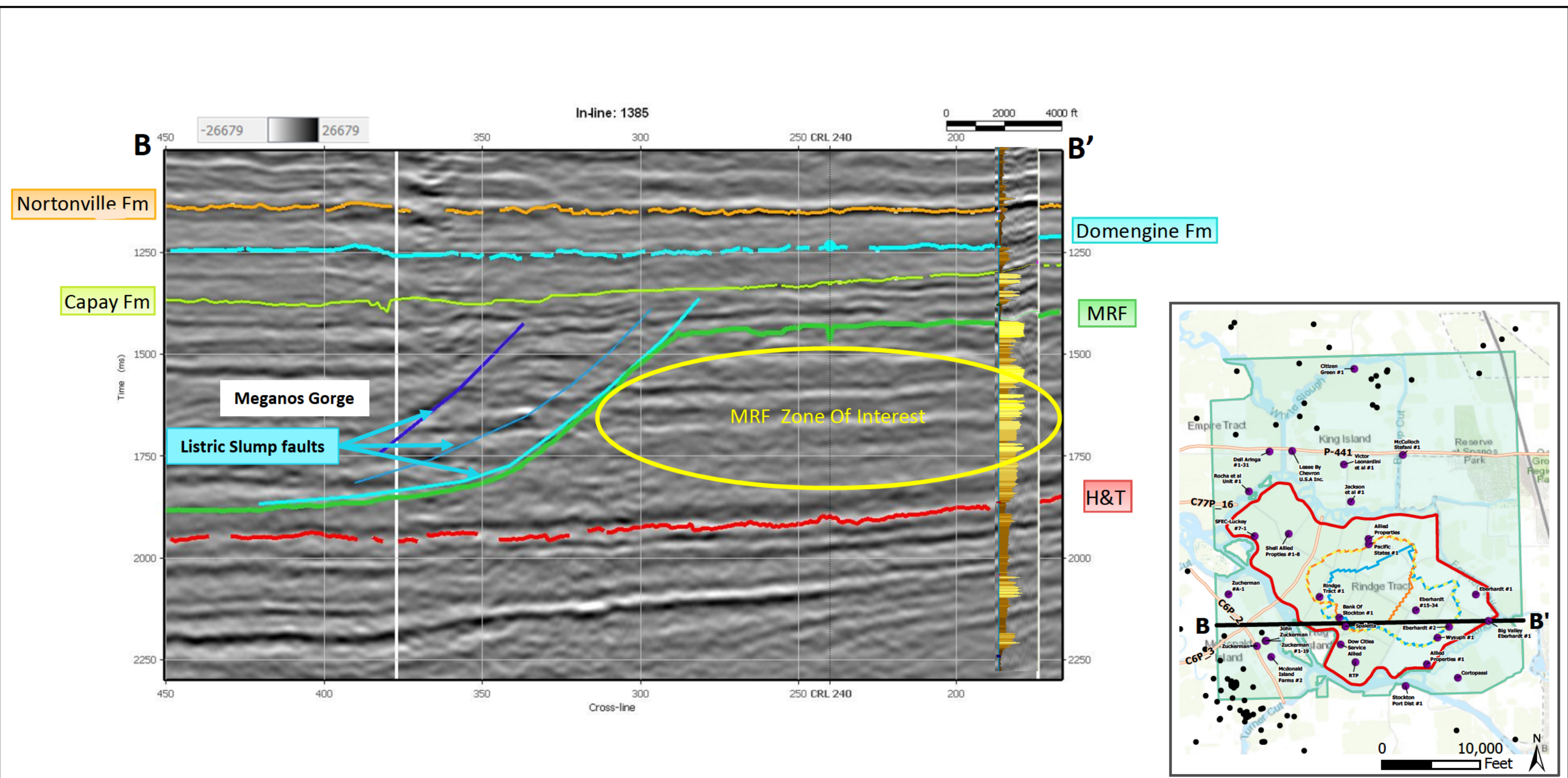
- Well Control Used in Interpretation
- Oil & Gas Wells
- ▨ Delineated Area of Review
- ▨ Maximum Predicted Extent of Super Critical CO₂
- ▨ Pressure Front
- Cross Section A-A'
- Select PacSeis 2D Data
- ▨ Conestrama 3D Data
- ▨ Rindge Tract Island

FIGURE 2-22
CROSS-SECTION A-A'
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

April 2024



Legend

- Well Control Used in Interpretation
- Oil & Gas Wells
- Delineated Area of Review
- Maximum Predicted Extent of Super Critical CO₂
- Pressure Front

- Cross Section B-B'
- Select PacSeis 2D Data
- Conestrama 3D Data
- Rindge Tract Island

FIGURE 2-23

CROSS-SECTION B-B'

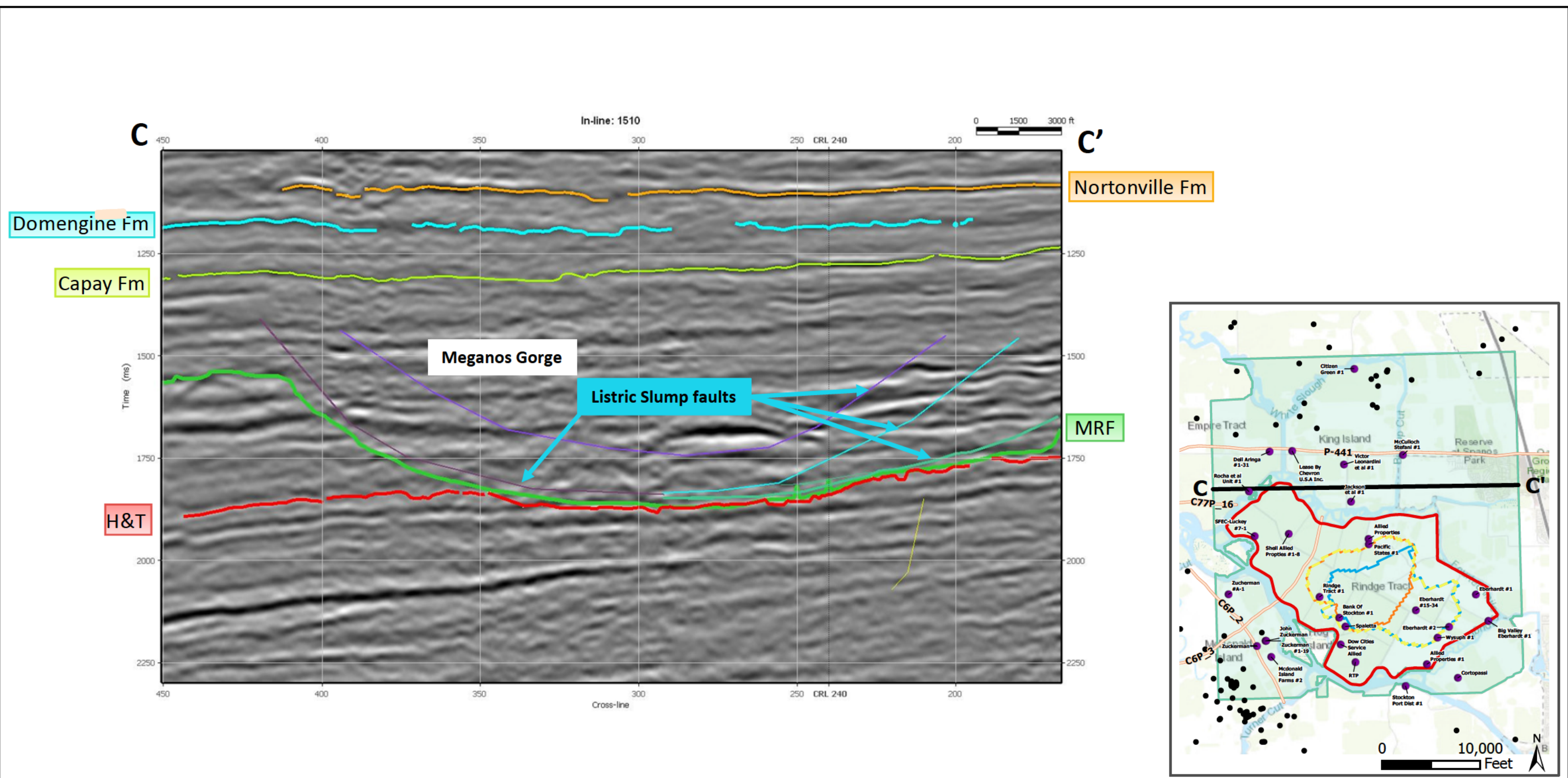
PELICAN RENEWABLES INC.

SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

April 2024



Legend

- Well Control Used in Interpretation
- Oil & Gas Wells
- Delineated Area of Review
- Maximum Predicted Extent of Super Critical CO₂
- Pressure Front

- Cross Section C-C'
- Select PacSeis 2D Data
- Conestrama 3D Data
- Rindge Tract Island

FIGURE 2-24

CROSS-SECTION C-C'

PELICAN RENEWABLES INC.

SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

April 2024

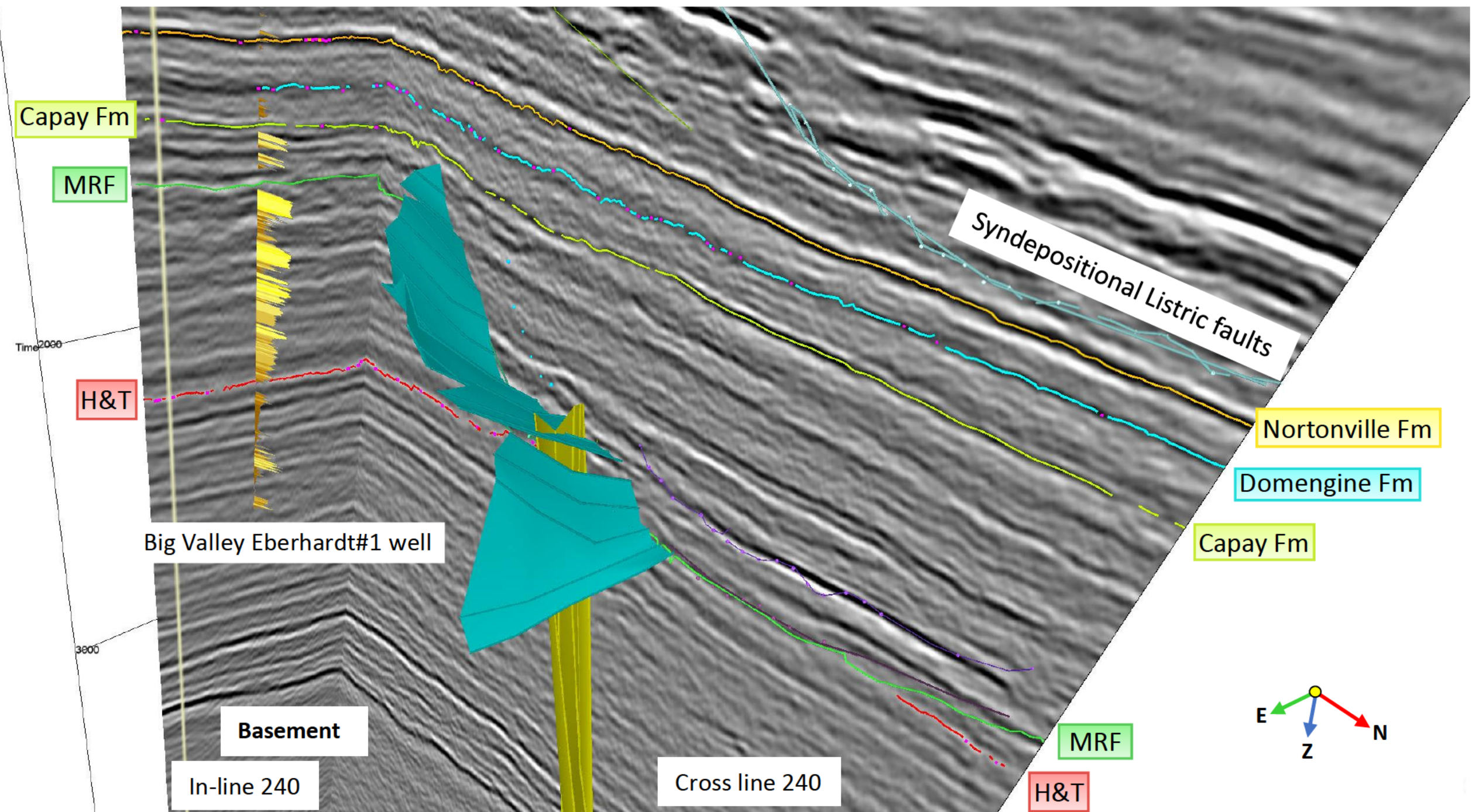


FIGURE 2-25
 3-D FAULT VISUALIZATION
 PELICAN RENEWABLES INC.
 SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

January 2023

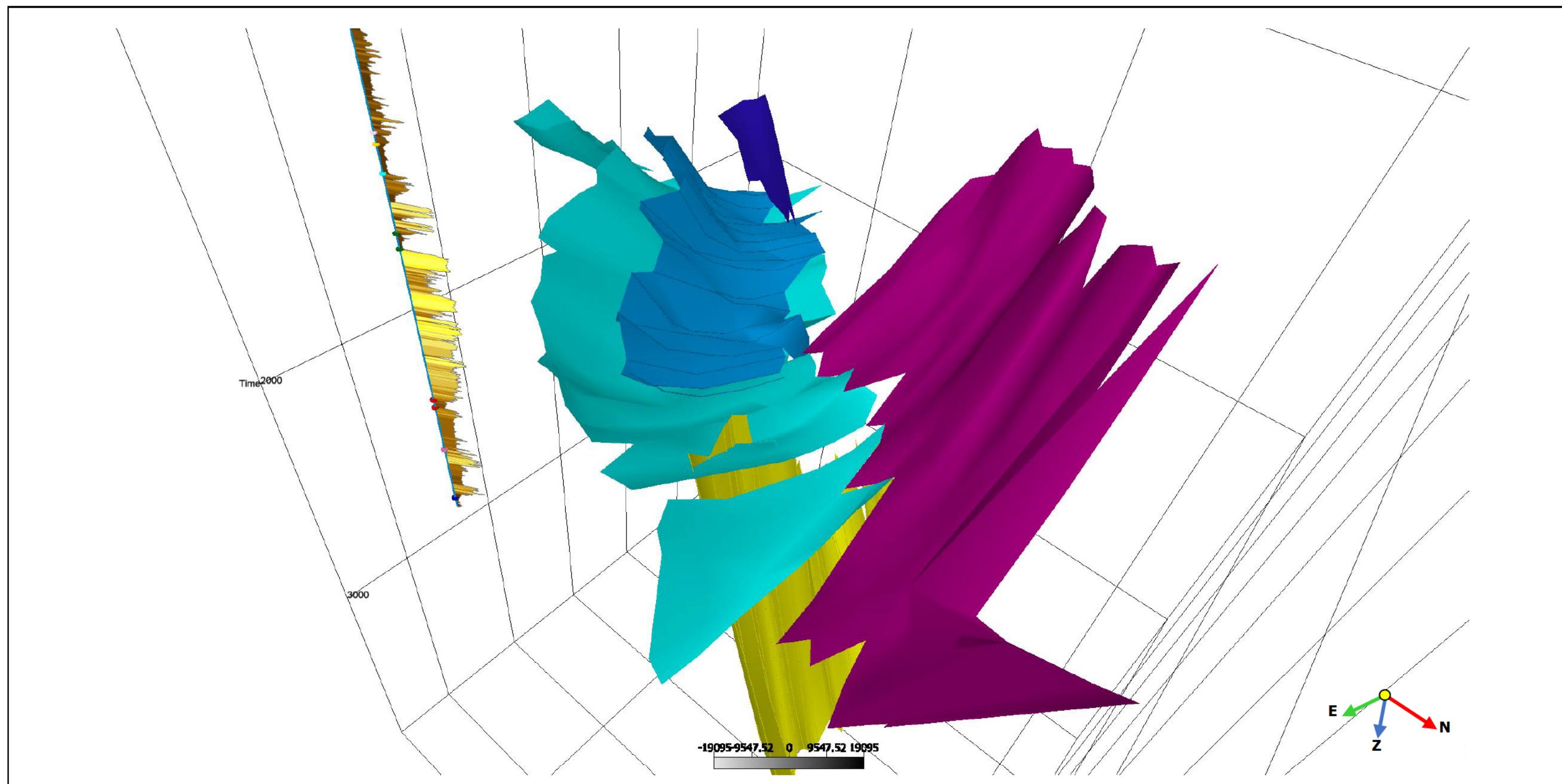


FIGURE 2-26
LISTRIC FAULTS ASSOCIATED WITH
THE GENERATION OF THE MEGANOS GORGE
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

January 2023

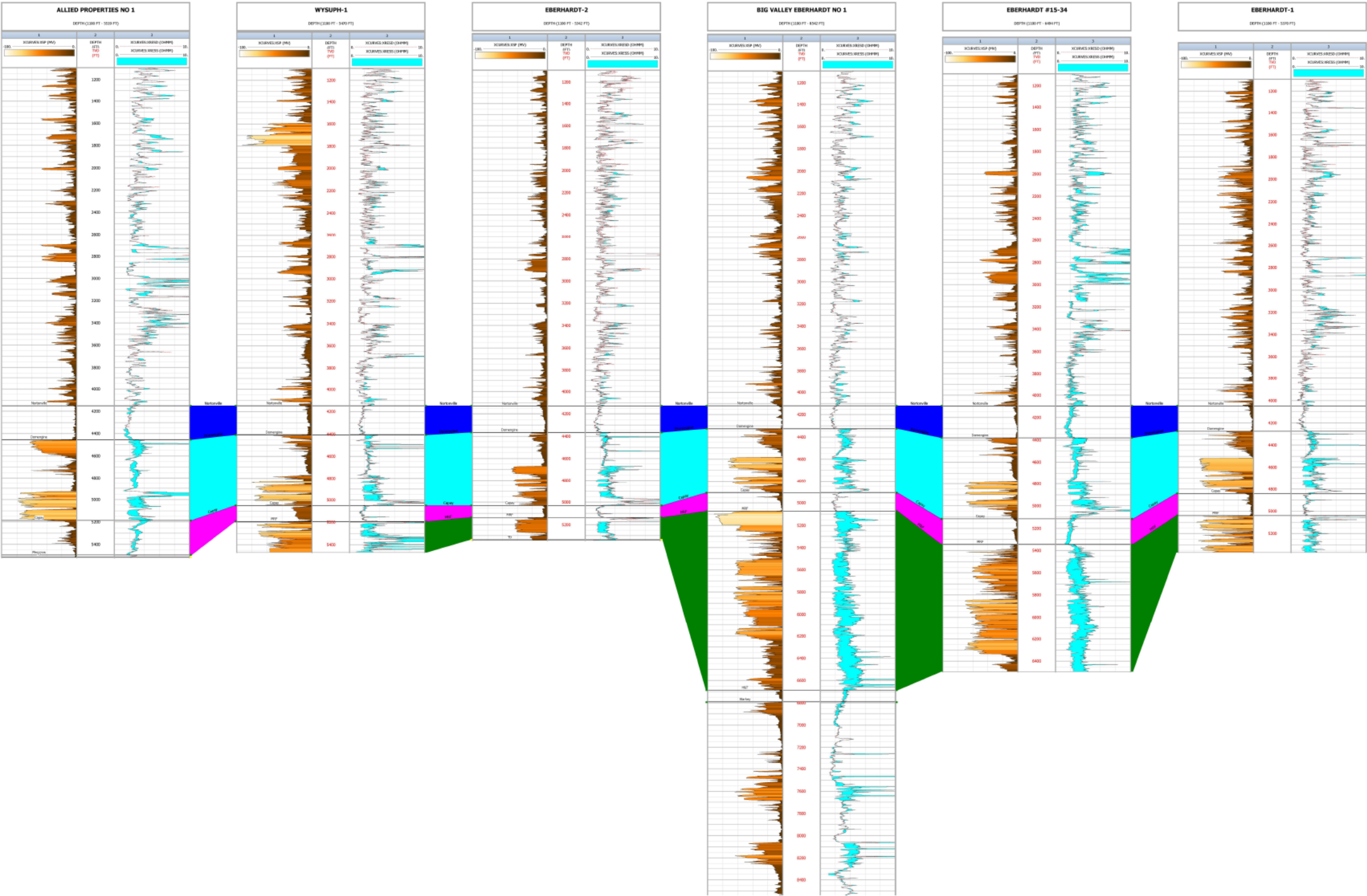
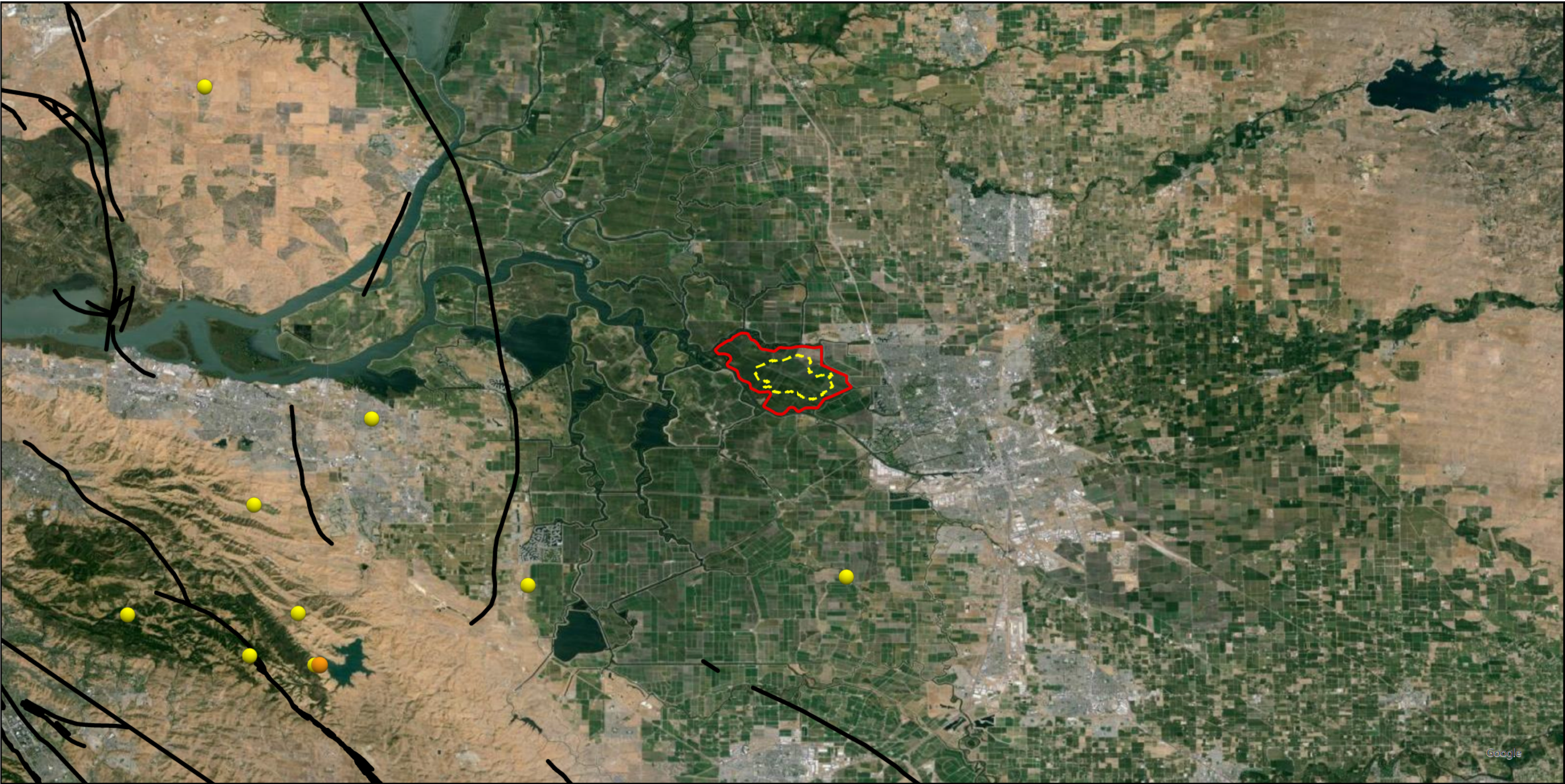


FIGURE 2-27
WELL LOGS FOR RINDGE TRACT ISLAND WELLS
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA



Legend

- <4.0 Magnitude

≥4.0 Magnitude

Quaternary Faults

Delineated Area of Review

Rindge Tract Island
- Sources:
1. Northern California Seismic System, Northern California Earthquake Catalog.
2. United States Geological Survey, Interactive Fault Map.
- FIGURE 2-28**
QUATERNARY FAULTS AND SEISMICITY NEAR
RINDGE TRACT (1967-2020)
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA
- | | | | |
|----------------------|------------|-----------------------|--|
| SCS ENGINEERS | | 025,00050,000
Feet | |
| Wichita, KS | April 2024 | | |

LEGEND

-  Rindge Tract Island
-  Eastern San Joaquin Valley Subbasin
-  San Joaquin Valley Groundwater Basin



FIGURE 2-29
GROUNDWATER BASIN VICINITY MAP
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

SCS ENGINEERS

Wichita, KS

November 2022



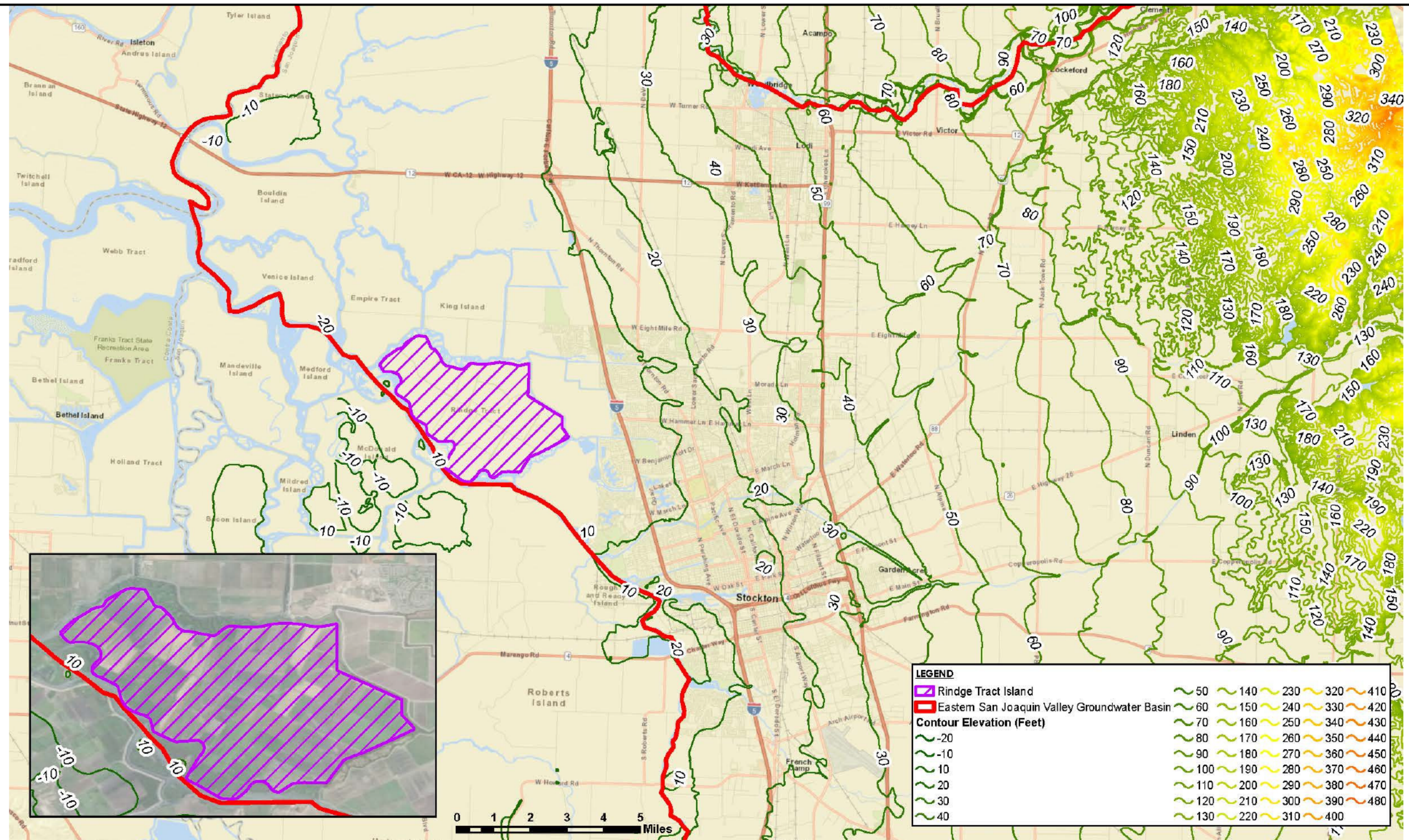


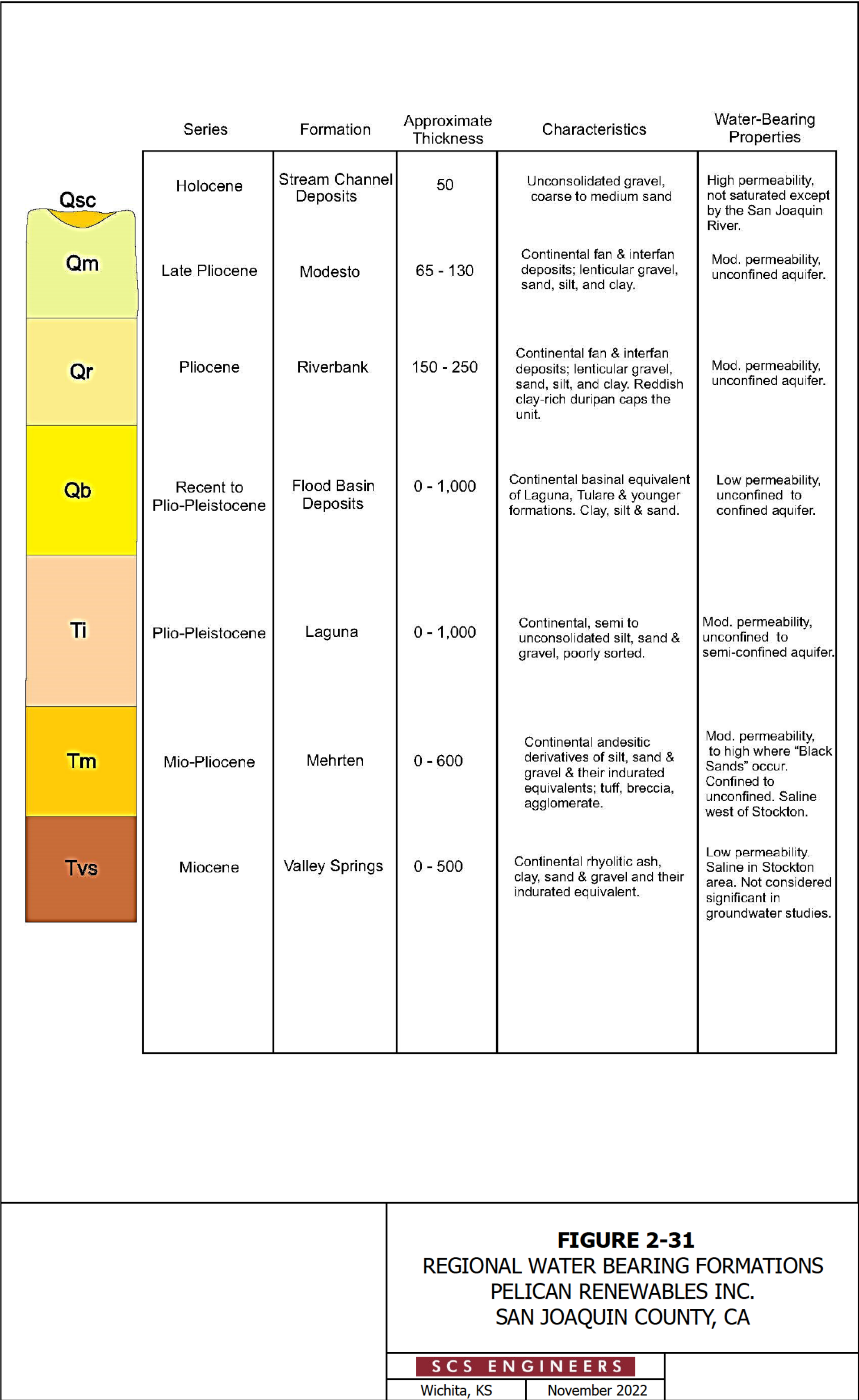
FIGURE 2-30
TOPOGRAPHIC MAP
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

SCS ENGINEERS

Wichita, KS

November 2022





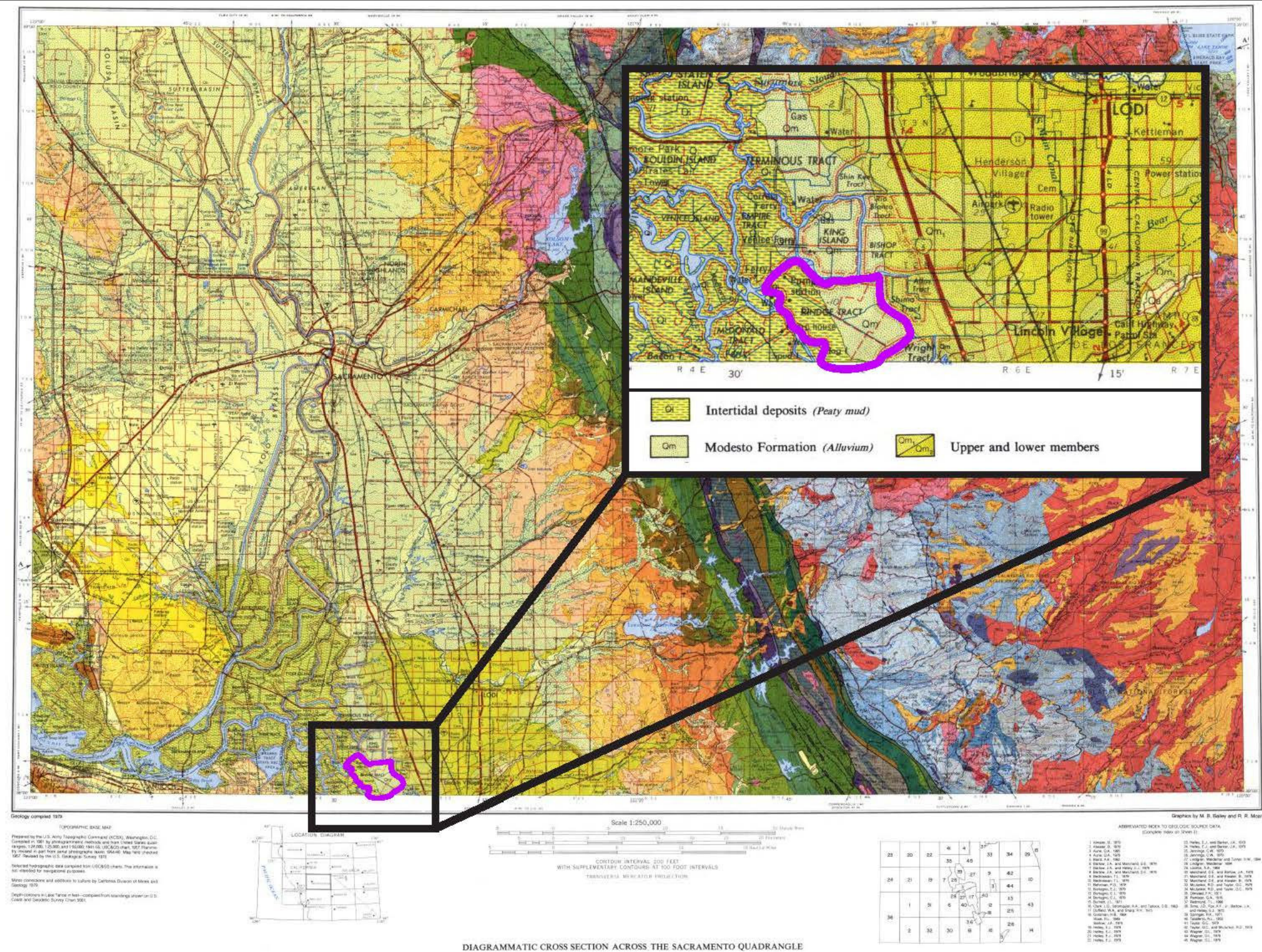


Figure Adapted From:
 California Division of Mines and Geology.
Geologic Map of the Sacramento Quadrangle, California.
 1981. 1:250,000; Compilation by Wager, D.L., Jennings, C. W., et al.

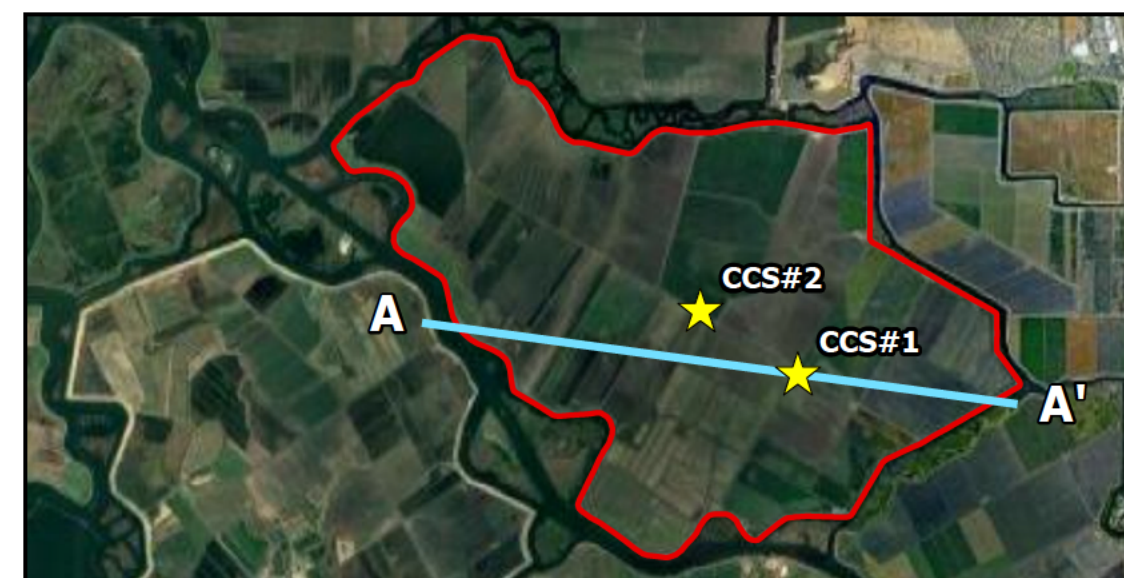
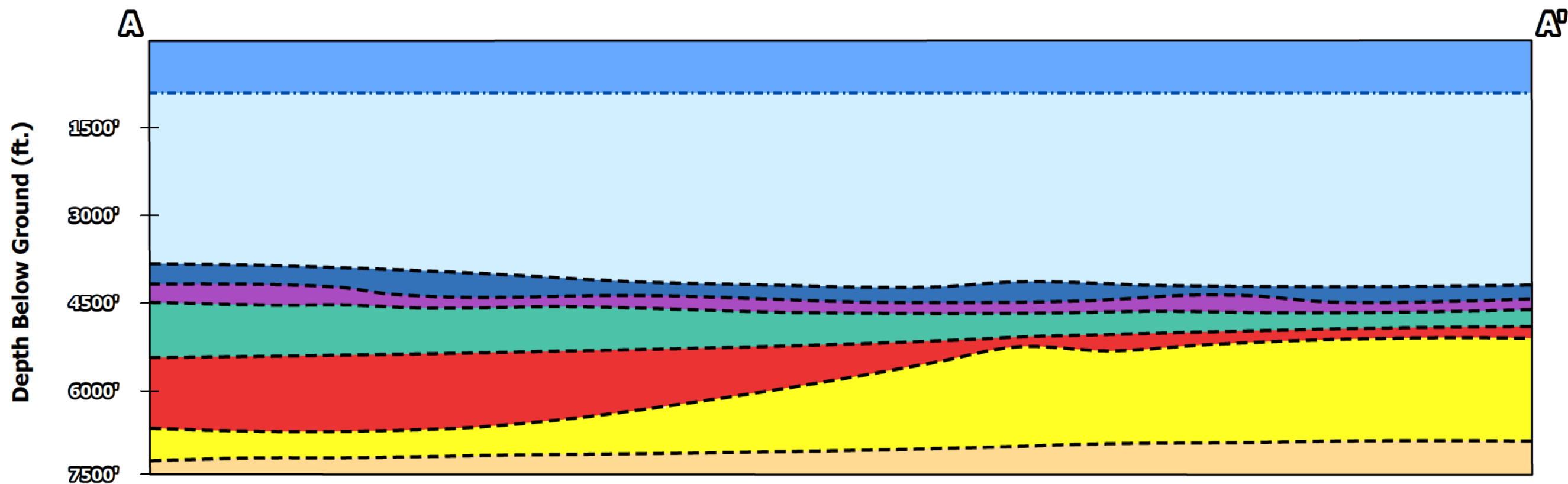
FIGURE 2-32
HOLOCENE GEOLOGIC MAP
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

SCS ENGINEERS

Wichita, KS

November 2022





Legend

- Freshwater USDWs
- Eocene - Holocene USDWs
- Markley Fm. (Lowermost USDW)
- Nortonville Shale
- Domingine Fm.
- Capay/Meganos Fms.
- Mokelumne River Fm. (Injection Zone)
- H&T Shale & Deeper Units
- - - Approximate Base of Freshwater (900 feet)
- - - Approximate Contacts between Geologic Units

FIGURE 2-33

CROSS SECTION OF USDWS AND CO₂ STORAGE COMPLEX
BENEATH RINDGE TRACT
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

March 2023



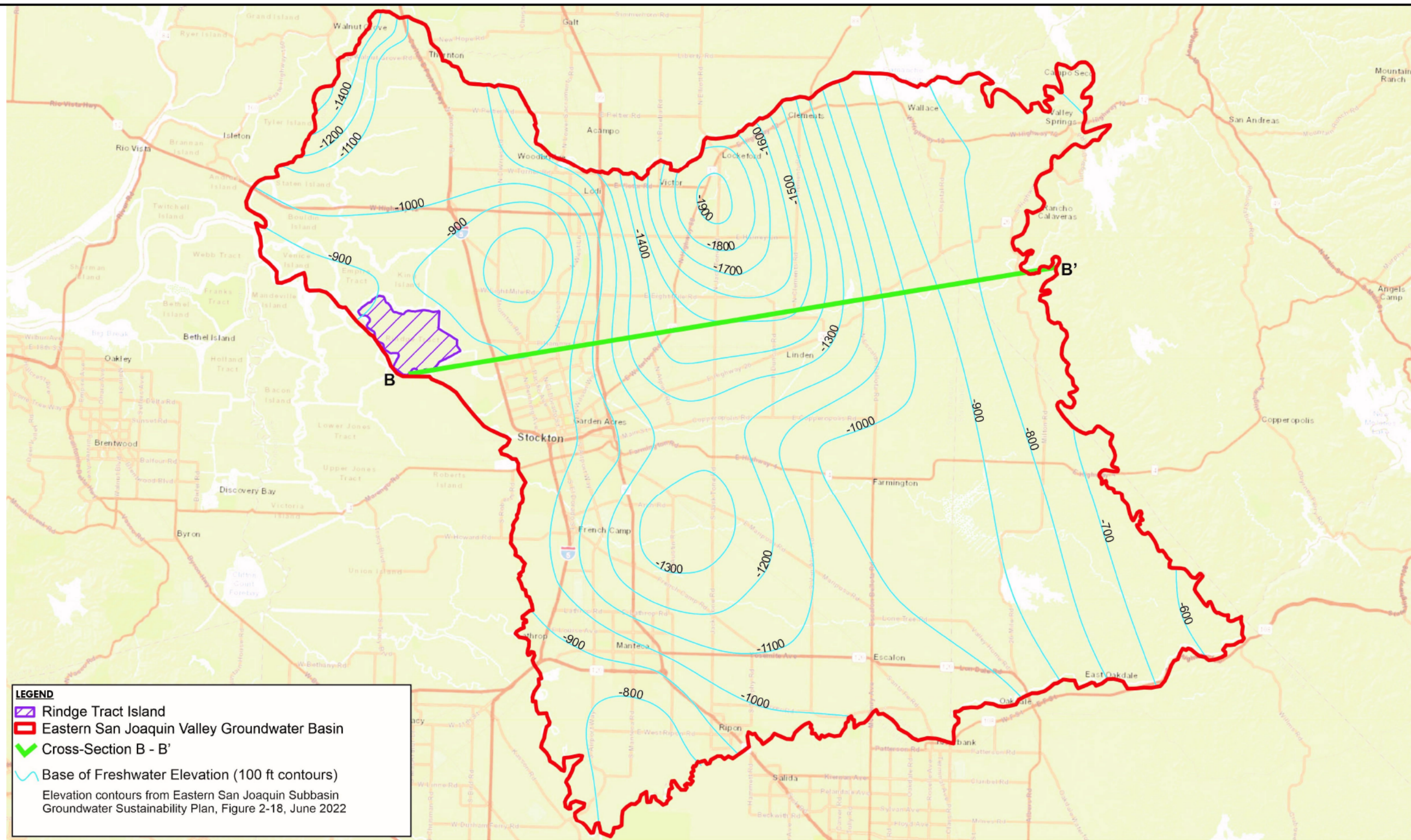


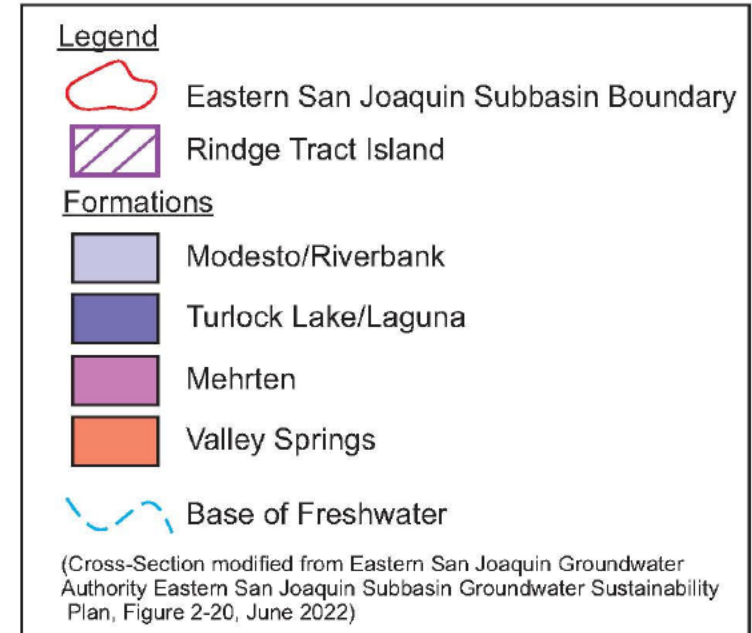
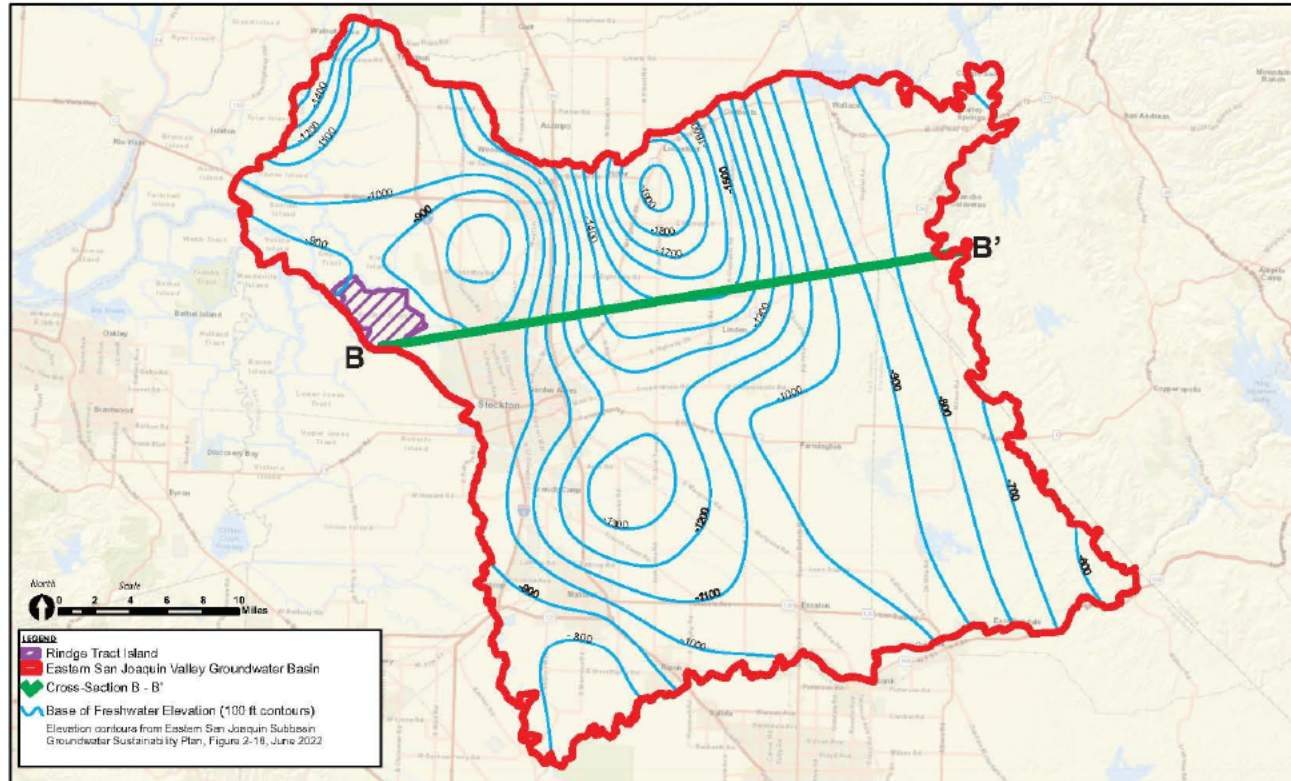
FIGURE 2-34
BASE OF FRESH WATER ELEVATION CONTOURS
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

SCS ENGINEERS

Wichita, KS

November 2022





Cross-Section B-B'

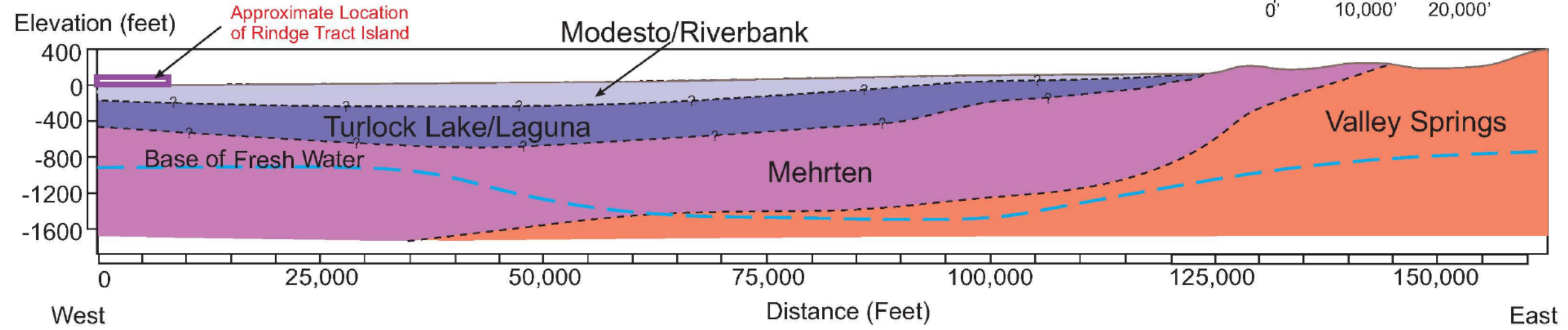
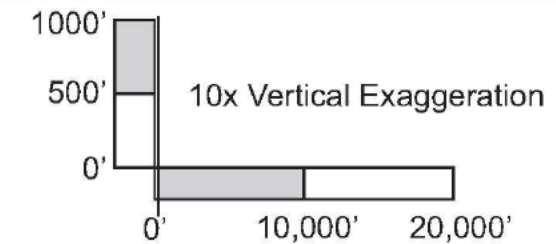


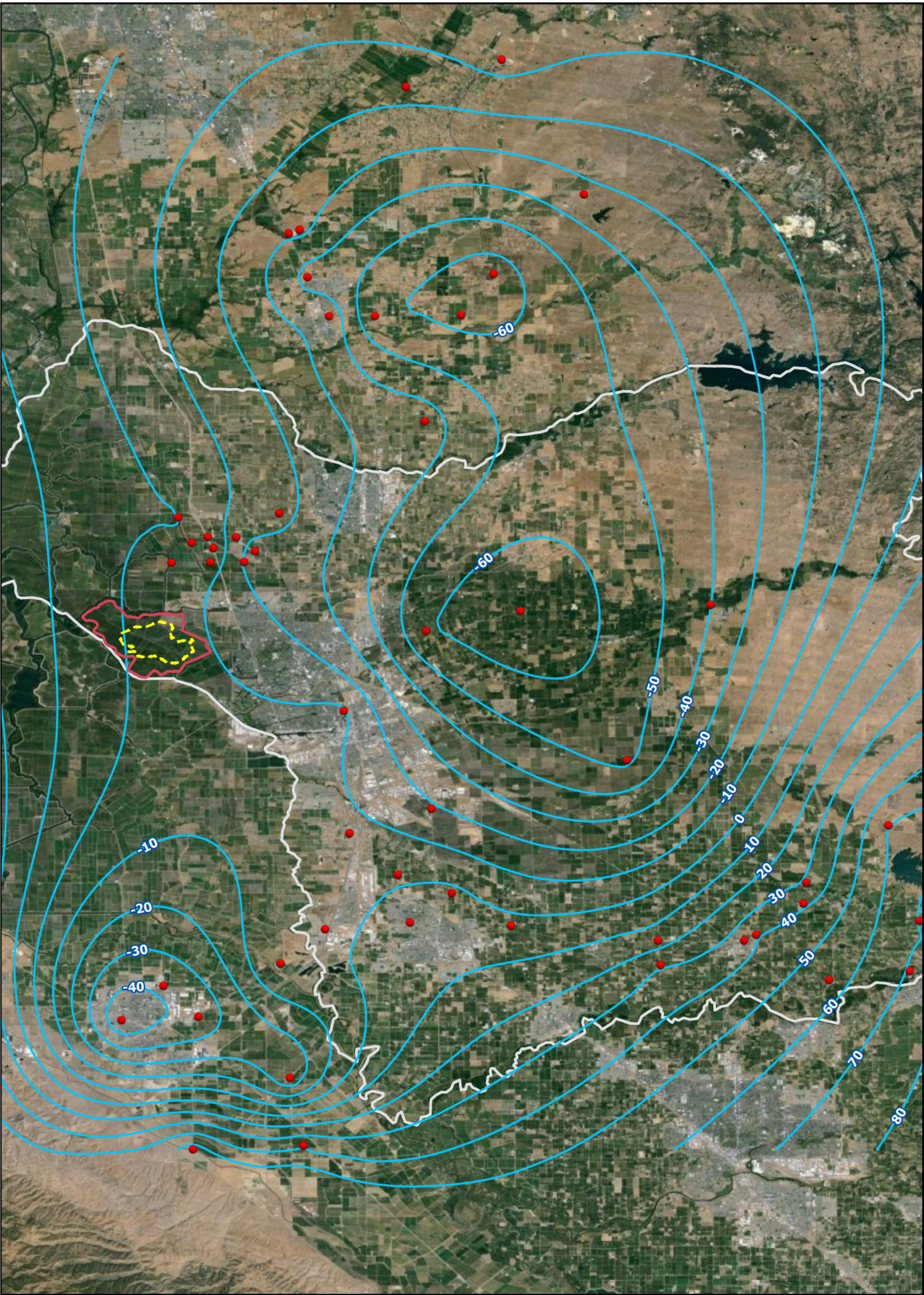
FIGURE 2-35
BASE OF FRESH WATER CROSS SECTION B-B'
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

SCS ENGINEERS

Wichita, KS

November 2022





Legend

- Groundwater Well
- ~ May 2022 Groundwater Contours (10')
- Eastern San Joaquin Groundwater Subbasin
- - - Delineated Area of Review
- S Rindge Tract Island

FIGURE 2-36
GROUNDWATER ELEVATION MAP
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

April 2024

0 25,000
Feet



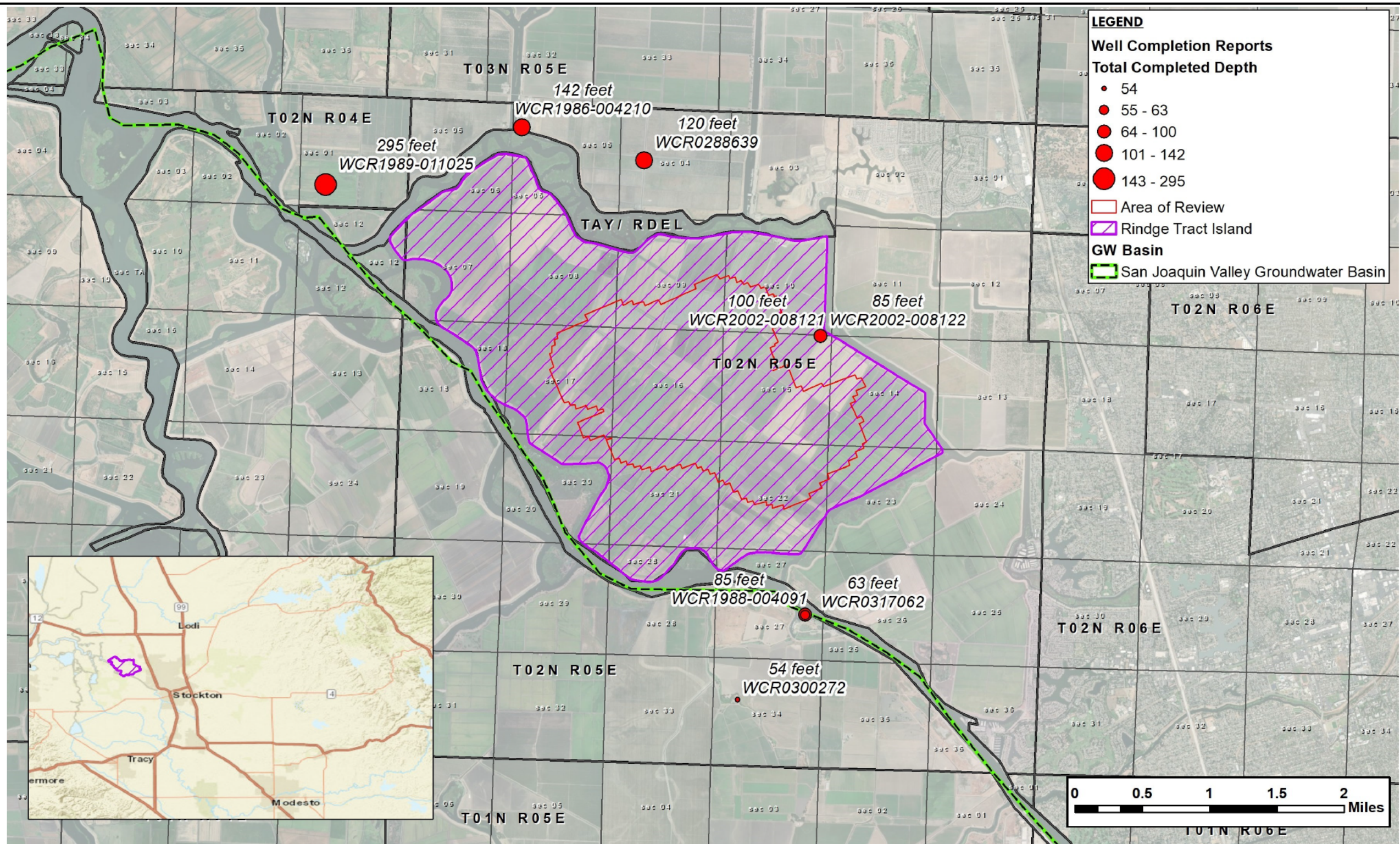


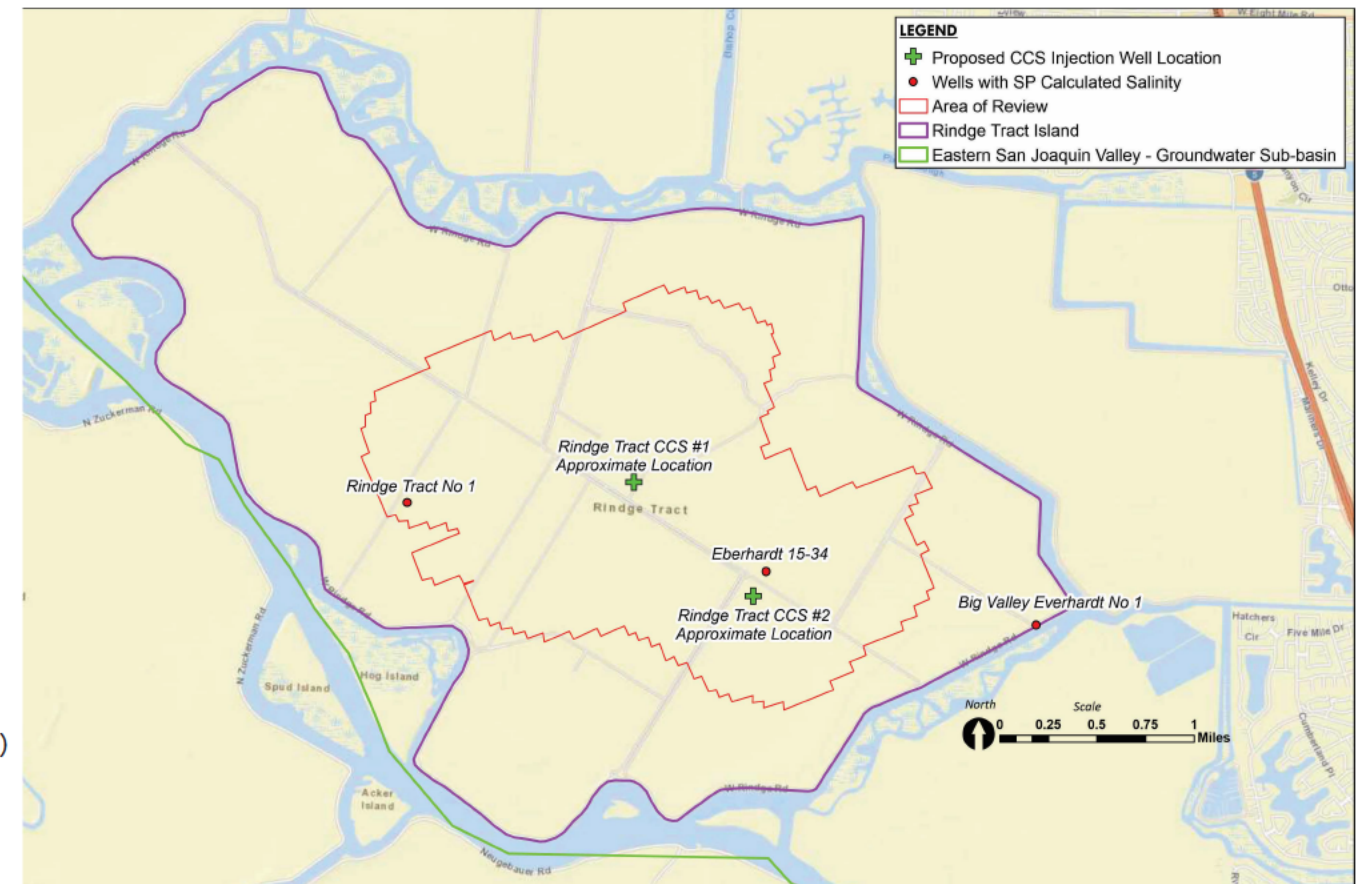
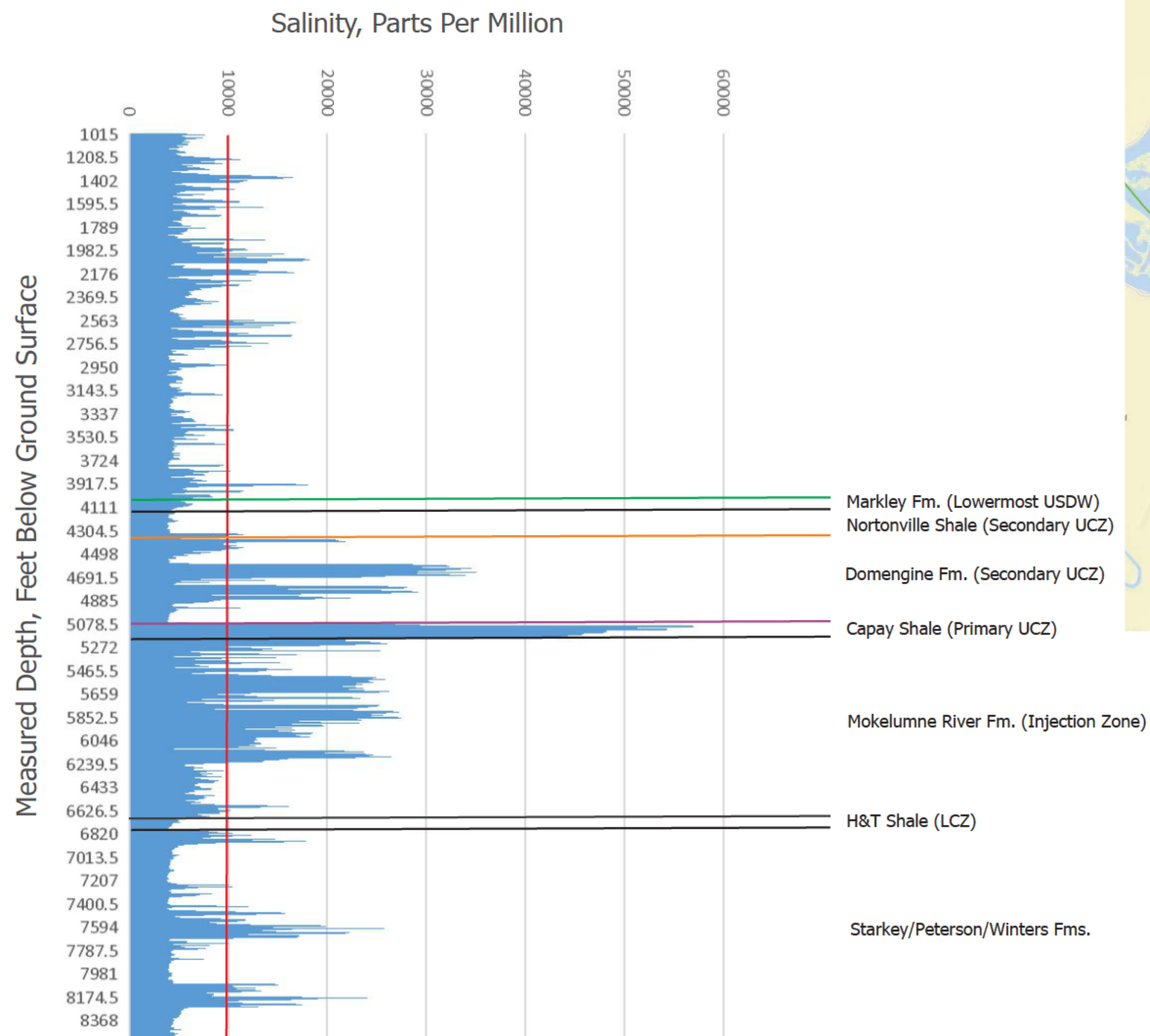
FIGURE 2-37
WATER WELL DEPTH AND LOCATION
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CA

SCS ENGINEERS

Wichita, KS

April 2024





Notes:

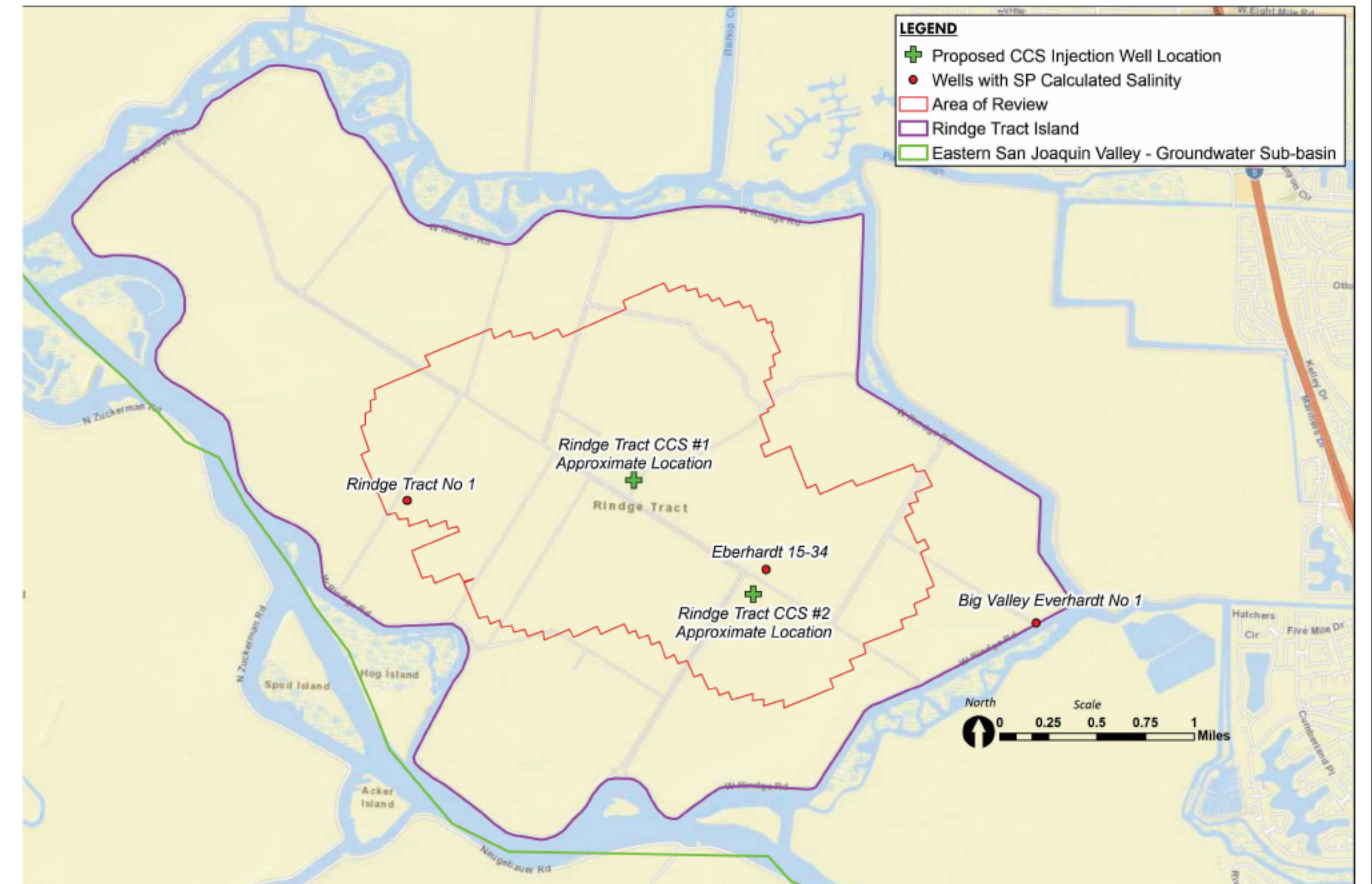
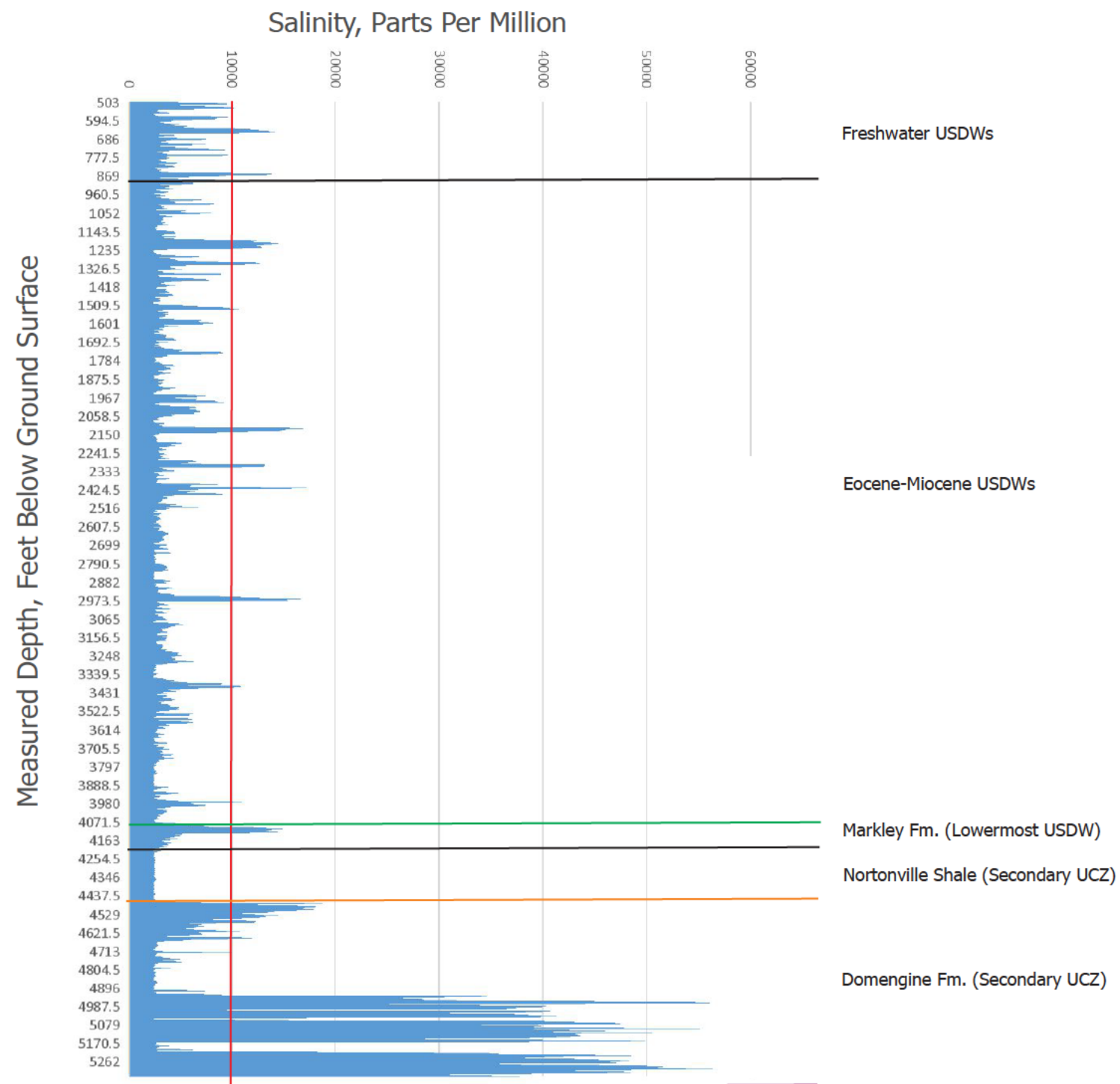
- Salinity Calculations Performed by The Rock Data Solutions.
- Logging was not completed above 1015 feet.
- Freshwater is located approximately 900 feet below ground surface.
- USDW = underground source of drinking water
- UCZ = upper confining zone
- LCZ = lower confining zone

FIGURE 2-38A
CALCULATED SALINITY AND A FUNCTION OF DEPTH –
BIG VALLEY EBERHART No 1
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

March 2023



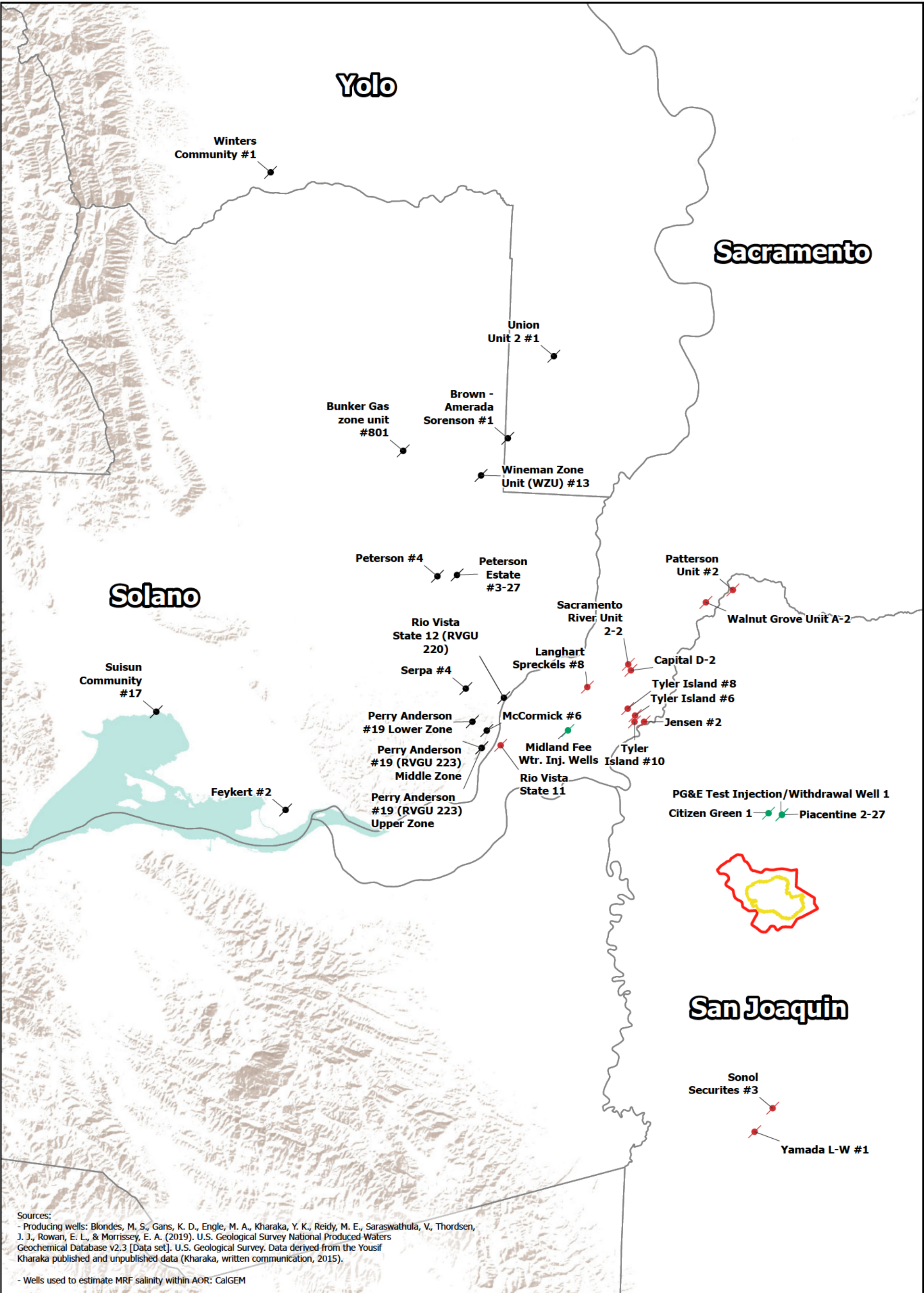
- Notes:
- Salinity Calculations Performed by The Rock Data Solutions.
 - USDW = underground source of drinking water
 - UCZ = upper confining zone
 - LCZ = lower confining zone

FIGURE 2-38C
CALCULATED SALINITY AND A FUNCTION OF DEPTH –
RINDGE TRACT No 1
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

March 2023



Sources:
- Producing wells: Blondes, M. S., Gans, K. D., Engle, M. A., Kharaka, Y. K., Reidy, M. E., Saraswathula, V., Thordsen, J. J., Rowan, E. L., & Morrissey, E. A. (2019). U.S. Geological Survey National Produced Waters Geochemical Database v2.3 [Data set]. U.S. Geological Survey. Data derived from the Yousif Kharaka published and unpublished data (Kharaka, written communication, 2015).
- Wells used to estimate MRF salinity within AOR: CalGEM

Legend







-  Wells with Produced Water Data Utilized for Geochemical Modeling
-  Wells with Produced Water Data Not Utilized for Geochemical Modeling
-  Wells Used To Estimate MRF Salinity Within AOR
-  Rindge Tract Island
-  Delineated Maximum Area of Review
-  County Boundaries

FIGURE 2-39
DISTRIBUTION OF AVAILABLE GEOCHEMICAL DATA FOR
PRODUCED WATERS IN THE VICINITY OF THE PROJECT
PELICAN RENEWABLES INC.
SAN JOAQUIN COUNTY, CALIFORNIA

SCS ENGINEERS

Wichita, KS

August 2024

0 25,000
Feet



Attachment 1

REDACTED

Attachment 2
REDACTED

Attachment 3

Citizen Green 1 Data - EDX

Side wall core #	Depth from logging tool	Formation	From PEX (SP) - Burton			Notes - Burton	Sample Comments - Burton	From PEX (SP) - Beyer						Notes - Beyer
			Formation top (Measured)	Formation bottom (Measured)	thickness (Measured)			Formation or Unit Top (Measured)	Formation or Unit Bottom (Measured)	Formation or Unit Thickness (Measured)	Formation or Unit Top (Vertical)	Formation or Unit Bottom (Vertical)	Formation or Unit Thickness (Vertical)	
50	4090.0	Nortonville Formation	4000	4350	350	moved up 60 ft to shaler zone	missing	3995	4343	348	3620	3920	300	sample not recovered
49	4140.1	Nortonville					missing							sample not recovered
48	4225.0	Nortonville				moved down 15 to avoid sand stringer	missing							sample not recovered
		Nortonville shale						3995	4200	205	3620	3798	178	Unit depths and thicknesses
47	4295.1	Nortonville shale & sand					unconsolidated sand (stuck in tool)	4200	4343	143	3798	3920	122	Unit depths and thicknesses
46	4475.0	Domengine sand	4350	5100	750	Actual top at 4350, but want to start lower because of whole core and unconsolidation	unconsolidated sand (stuck in tool)	4343	5098	755	3920	4596	676	
45	4600.0	Domengine ss					unconsolidated sand (stuck in tool)							
44	4725.0	Domengine ss					removed by Shala							
43	4850.0	Domengine ss					missing							
42	4975.0	Domengine ss					unconsolidated sand							
41	5070.1	Domengine ss					unconsolidated sand							
40	5108.0	Capay shale	5100	5210	110	moved up 10 ft to avoid sand stringer	unconsolidated shale	5098	5215	117	4596	4693	97	
39	5117.0	Capay shale				moved up 10 ft to avoid sand stringer	1 very small piece-shale (counted as missing by							
38	5140.0	Sand in Capay					unconsolidated sand							
37	5165.0	Capay shale	5150	5210	60		unconsolidated shale							
36	5183.0	Capay shale					missing							sample not recovered
35	5202.0	Capay shale					unconsolidated silty sand							
34	5350.0	Mokelumne ss	5210	6850	1640	total thickness; sidewalls in selected sand layers and below 6100 because of whole core and unconsolidation above 6100	unconsolidated silty sand	5215	6840	1625	4693	6200	1507	
33	5770.0	Mokelumne ss	5700	5910	210	sand layer within Moke	unconsolidated sand							
32	5840.0	Mokelumne ss					unconsolidated silty sand							
31	6023.0	Mokelumne ss	5995	6080	85	sand layer within Moke	unconsolidated sand							
30	6052.0	Mokelumne ss					unconsolidated sand							
29	6090.0	Mokelumne (shaley)	6080	6100	20	clay-siltstone layer	removed by Shala							
28	6166.0	Mokelumne ss	6100	6760	660		unconsolidated sand							
27	6232.0	Mokelumne ss					unconsolidated sand							
26	6268.0	Mokelumne ss				moved up 30 ft to avoid silt zone	hard core, but not well							
25	6334.0	Mokelumne ss					unconsolidated sand							
24	6400.0	Mokelumne ss					hard core-silty sand							
23	6466.0	Mokelumne ss					hard core-silty sand							
22	6532.0	Mokelumne ss					hard core-silty sand							
21	6598.0	Mokelumne ss					hard core-silty sand							
20	6664.0	Mokelumne ss					hard core-silty sand							
19	6800.0	Mokelumne ss	6760	6880	120	not convincingly shale (gradational contact from 6750 to 6830)	hard core-silty sand							gradual transition from Moke to H&T
18	6840.0	H&T shale					hard core-sandy shale	6840	7032	192	6200	6383	183	gradual transition from Moke to H&T
17	6899.0	H&T shale	6880	7030	150	definitely shale	removed by Shala							
16	6918.0	H&T shale					hard core-shaly, marly?							

Citizen Green 1 Data - EDX

[illegible]



Petroleum Services

Sidewall Core Analysis

Lawrence Berkeley Natl. Laboratory

Citizen Green #1 Well

**King Island Field
San Joaquin County, California**

FINAL REPORT

November 12, 2012

CL File: 57111-212369LA

Performed by:

Core Laboratories, Inc.

3437 Landco Drive

Bakersfield, California 93308

(661) 325-5657

The analyses, opinions or interpretations contained in this report are based upon observations and material supplied by the client for whose exclusive and confidential use this report has been made. The interpretations or opinions expressed represent the best judgment of Core Laboratories. Core Laboratories assumes no responsibility and makes no warranty or representations, express or implied, as to the productivity, proper operations or profitability, however, of any oil, gas, coal or other mineral, property, well or sand in connection with which such report is used or relied upon for any reason whatsoever.



Petroleum Services Division
3437 Landco Dr.
Bakersfield, California 93308
Tel: 661-325-5657
Fax: 661-325-5808
www.corelab.com

November 12, 2012

Jonathan Ajo-Franklin
Lawrence Berkeley Natl. Laboratory
#1 Cyclotron Road, MS 90-1116
Berkeley, CA 94720

Subject: Sidewall Core Analysis
File No.: 57111-212369LA

Dear Mr. Ajo-Franklin:

Enclosed are final data for 15 rotary sidewall samples submitted to our laboratory from well Citizen Green #1, King Island Field, San Joaquin County, CA.

Air porosity, permeability, and saturation (PKS) determinations, along with white and ultraviolet light photographs, were performed on each of 15 samples. Brine permeability at 3400 psi was performed on the 14 suitable samples. Thin Section slides from endtrims of each sample were prepared. Per request, sample remainders were returned to Lawrence Berkeley National Laboratory. Core analysis procedures are documented on the following pages for reference.

Thank you for this opportunity to be of service to Lawrence Berkeley Natl. Laboratory. Please do not hesitate to contact us at (661-325-5657) if you have any questions regarding these results or if we can be of any additional service.

Sincerely,
Core Laboratories

Larry Kunkel
Area Manager

Distribution: 1 original report, 1 CD copy: Addressee





Petroleum Services Division
 3437 Landco Dr.
 Bakersfield, California 93308
 Tel: 661-325-5657
 Fax: 661-325-5808
 www.corelab.com

Basic Test Procedures ⁽¹⁾

Core Analysis

- Remove visible drilling mud contamination from sidewall sample.
- Expose a fresh sample surface and photograph (if requested) under white and ultraviolet (UV) lighting.
- Retain endtrim for future analysis.
- Record lithological description.
- Package samples, if required, using nickel foil and end screens.
- Seat sleeve at depth - 100psi (750psi maximum).
- Remove water by Dean Stark extraction using toluene. Summation of fluids method used for samples <0.5" long or irregular shaped.
- Record stablized produced water volume.
- Leach remaining oil and salts by Soxhlet extraction using an 80/20 mixture of methylene chloride/methanol.
- Dry at 235 °F to stable weight (minimum of 24 hours).
- Cool to ambient temperature in dessicator to prevent moisture accumulation.
- Record stable dry weight.
- Determine grain volume and grain density by helium expansion (Boyle's Law).
- Determine helium (Boyle's Law) pore volume at 250psi confining pressure.
- Determine steady-state permeability to air at 250psi confining pressure. Emperical method used for samples <0.5" long or irregular shaped.

(1) See Core Analysis Procedures page for specific methods used.











Company: Lawrence Berkely Natl. Lab.
Well: Citizen Green #1
Field: King Island

Location: Sec. 28-3N-5E
Elevation:
Drlg Fluid:

File No.: 57111-212369LA
API No.: 04-077-20688
Date : 8/10/2012

Rotary Sidewall Core Analysis Results

Core Images		Sample Number	Depth ft	Rec in	Perm. Kair md	Porosity %	Fluid Saturation				Grain Den g/cc	Sample Wt. g	Method
White Light	UV Light						Oil %	Water %	O/W Ratio	Total %			
		24	6400.0	1.5	367.1	33.0	0.0	90.1	0.00	90.1	2.68	23.0	4
		Sst gy vf-fgr slty no stn no flor											
		23	6466.0	1.6	71.9	31.3	0.0	92.0	0.00	92.0	2.68	24.2	4
		Sst gy vf-fgr vslty carb scly smica no stn no flor											
		22	6532.0	1.5	54.8	30.3	0.0	91.2	0.00	91.2	2.70	24.6	4
		Sst gy vf-fgr vslty carb smica no stn no flor											
		21	6598.0	1.7	135.5	31.3	0.0	95.0	0.00	95.0	2.67	23.9	4
		Sst gy vf-fgr slty carb smica no stn no flor											

F/ Indicates Visible Fracture(s) Present





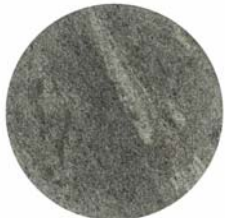





Company: Lawrence Berkely Natl. Lab.
Well: Citizen Green #1
Field: King Island

Location: Sec. 28-3N-5E
Elevation:
Drlg Fluid:

File No.: 57111-212369LA
API No.: 04-077-20688
Date : 8/10/2012

Rotary Sidewall Core Analysis Results

Core Images		Sample Number	Depth ft	Rec in	Perm. Kair md	Porosity %	Fluid Saturation				Grain Den g/cc	Sample Wt. g	Method
White Light	UV Light						Oil %	Water %	O/W Ratio	Total %			
		20	6664.0	1.4	46.4	30.8	0.0	90.1	0.00	90.1	2.66	22.4	4
Sst gy vfgr vslty carb scly mica no stn no flor													
		19	6800.0	1.3	4.8	27.7	0.0	96.0	0.00	96.0	2.65	20.0	4
Sst gy vfgr vslty carb scly smica no stn no flor													
		18	6840.0	1.7	4.0	27.4	0.0	95.2	0.00	95.2	2.65	22.7	4
Sst gy vfgr vslty cly carb smica no stn no flor													
		16	6918.0	1.7	0.006	1.8	0.0	92.5	0.00	92.5	2.73	30.9	4
Sst gy vfgr slty vcalc no stn no flor													

F/ Indicates Visible Fracture(s) Present











Company: Lawrence Berkely Natl. Lab.
Well: Citizen Green #1
Field: King Island

Location: Sec. 28-3N-5E
Elevation:
Drlg Fluid:

File No.: 57111-212369LA
API No.: 04-077-20688
Date : 8/10/2012

Rotary Sidewall Core Analysis Results

Core Images		Sample Number	Depth ft	Rec in	Perm. Kair md	Porosity %	Fluid Saturation				Grain Den g/cc	Sample Wt. g	Method
White Light	UV Light						Oil %	Water %	O/W Ratio	Total %			
		15	6936.0	1.4	299.850	34.2	0.0	94.2	0.00	94.2	2.66	23.0	4
Sst gy vfgr slty mica no stn no flor													
		14	6955.0	0.4	<5.0	22.4	0.0	98.3	0.00	98.3	2.68	5.9	4
Mdst gy vsly no stn no flor													
		9	7104.0	1.6 F/	114.3	27.6	0.0	86.6	0.00	86.6	2.67	25.8	1
Sst gy vfgr vsly carb cly mica no stn no flor													
		8	7136.0	1.6	432.6	31.3	0.0	91.9	0.00	91.9	2.69	23.9	4
Sst gy vf-fgr slty-ssly smica no stn no flor													

F/ Indicates Visible Fracture(s) Present









Company: Lawrence Berkely Natl. Lab.
Well: Citizen Green #1
Field: King Island

Location: Sec. 28-3N-5E
Elevation:
Drlg Fluid:

Citizen Green 1 Data -
EDX

File No.: 57111-212369LA
API No.: 04-077-20688
Date : 8/10/2012

Rotary Sidewall Core Analysis Results

Core Images		Sample Number	Depth ft	Rec in	Perm. Kair md	Porosity %	Fluid Saturation				Grain Den g/cc	Sample Wt. g	Method
White Light	UV Light						Oil %	Water %	O/W Ratio	Total %			
		7	7174.0	1.7	4.9	25.2	0.0	95.8	0.00	95.8	2.80	26.2	4
		Sst gy vfgr vslty-slty carb scly mica no stn no flor											
		5	7258.0	1.7	2.3	23.1	0.0	99.0	0.00	99.0	2.70	25.7	4
		Sst gy vf-fgr vslty scly no stn no flor											
		4	7309.0	1.5 F/	11.1	23.0	0.0	99.5	0.00	99.5	2.66	21.7	1
		Sst gy vfgr vslty cly no stn no flor											

* - Air Perm. For sample 6936ft corrected due to data entry error

F/ Indicates Visible Fracture(s) Present



Company: Lawrence Berkely Natl. Lab.
Well: Citizen Green #1
Field: King Island

Location : Sec. 28-3N-5E
Elevation :
DrIng Fluid :

CL File No. : 57111-212369LA
API No. : 04-077-20688
Date : 8/10/2012

Humidity Controlled Core Analysis Results

Sample Number	Depth ft	Perm. Kair md	Routine POR %	Humid POR %	Routine So %	Humid So %	Routine Sw %	Humid Sw %	Routine GD g/cc	Humid GD g/cc	Wt Ratio Hum/Dry Ratio	Clay Factor %
24	6400.0	367.1	33.0	32.1	0.0	0.0	0.0	89.8	2.68	2.66	1.005	5.1
23	6466.0	71.9	31.3	29.7	0.0	0.0	0.0	91.6	2.68	2.64	1.009	8.6
22	6532.0	54.8	30.3	29.3	0.0	0.0	0.0	90.8	2.70	2.68	1.006	5.6
21	6598.0	135.5	31.3	30.8	0.0	0.0	0.0	94.9	2.67	2.66	1.003	2.9
20	6664.0	46.4	30.8	30.0	0.0	0.0	0.0	89.9	2.66	2.64	1.005	4.6
19	6800.0	4.8	27.7	26.2	0.0	0.0	0.0	95.8	2.65	2.61	1.008	8.0
18	6840.0	4.0	27.4	25.7	0.0	0.0	0.0	94.9	2.65	2.61	1.009	9.0
16	6918.0	0.006	1.8	1.2	0.0	0.0	0.0	88.6	2.73	2.72	1.002	2.3
15	6936.0	299.9	34.2	33.5	0.0	0.0	0.0	94.1	2.66	2.64	1.004	4.1
14	6955.0	<5.0	22.4	18.5	0.0	0.0	0.0	98.0	2.68	2.60	1.019	18.9
9	7104.0 F/	114.3	27.6	23.8	0.0	0.0	0.0	84.5	2.67	2.59	1.019	19.2
8	7136.0	432.6	31.3	30.6	0.0	0.0	0.0	91.7	2.69	2.67	1.004	3.9
7	7174.0	4.9	25.2	23.2	0.0	0.0	0.0	95.4	2.80	2.76	1.009	9.4
5	7258.0	2.3	23.1	21.6	0.0	0.0	0.0	98.9	2.70	2.67	1.007	7.3
4	7309.0 F/	11.1	23.0	19.4	0.0	0.0	0.0	99.5	2.66	2.59	1.017	17.4

* - Air Perm. For sample 6936ft corrected due to data entry error



Company: Lawrence Berkely Natl. Lab.
Well: Citizen Green #1
Field: King Island

File No.: 57111-212369LA
API No.: 04-077-20688
Date : 8/10/2012
Core Type: Rotary SW Core

Core Analysis Procedures and Conditions

	Procedure (1)	Procedure (2)	Procedure (3)	Procedure (4)
Sampling Method	Percussion	Percussion	Percussion	Rotary
Drill Coolant	N/A	N/A	N/A	N/A
Jacket Material	Nickel	None	N/A	None
Saturation Method	Dean Stark (Toluene)	Dean Stark (Toluene)	Retort	Dean Stark (Toluene)
Porosity Method				
Grain Volume	Boyle's Law (Helium)	Boyle's Law (Helium)	Bulk Vol-Pore Vol	Boyle's Law (Helium)
Pore Volume	Boyle's Law (Helium)	Bulk Vol-Grain Vol	Summation Of Fluids	Bulk Vol-Grain Vol
Bulk Volume	Pore Vol + Grain Vol	Mercury Displacement	Mercury Displacement	Mercury Displacement
Permeability Method	Air	Empirical	Empirical	Air

Common Conditions

Sleeved Sample Seating Pressure: N/A

Confining Pressure Pore Vol & Permeability: 400 psig

Samples Dried At 235 Degrees Fahrenheit

Additional Extraction by Soxhlet with Methylene Chloride/Methanol

Oil Density used in Calculation: 0.97g/cc



SUMMARY OF LIQUID PERMEABILITY MEASUREMENTS

Net Confining Stress: 3400 psi Temperature: 75°F

Fluid: Simulated Formation Brine

PETROLEUM SERVICES

Lawrence Berkeley Natl. Laboratory

Core Lab File No: 212369LA

Well: Citizen Green #1
Field: King Island
Location: San Joaquin County

Sample ID	Depth Interval, feet	Sample Orientation	Sample Length, cm	Sample Area, cm ²	Specific Permeability to Brine, mD
24	6400.0	H	2.590	4.247	2.72
23	6466.0	H	2.670	4.255	2.87
22	6532.0	H	2.650	4.287	23.1
21	6598.0	H	2.640	4.250	86.3
20	6664.0	H	2.510	4.203	23.6
19	6800.0	H	2.170	4.226	0.570
18	6840.0	H	2.480	4.181	0.670
16	6918.0	H	2.720	4.213	<0.001
15	6936.0	H	2.580	4.302	139
9	7104.0	H	2.750	4.314	0.00297
8	7136.0	H	2.660	4.218	123
7	7174.0	H	2.670	4.195	0.0973
5	7258.0	H	2.690	4.145	0.0353
4	7309.0	H	2.270	4.201	<0.001

Simulated Formation Brine requested by client: 18,700 ppm with 80% NaCl and 20% KCl

Brine Saturation Procedure

- Place dried samples in saturator cell.
- Vacuum samples overnight.
- Saturate samples with brine at 2000 psi for several hours
- Unload saturator, weigh samples and store under brine
- Load in hydrostatic coreholder at net confining stress.
- Flow through saturate sample with several pore volumes of brine at 400 psi back pressure.
- Begin brine permeability test.

Brine Permeability Procedure

- K_w was measured at three flow rates with the exception of the very low permeability samples.
- For low K_w samples, a constant pressure was applied and time and volume were used to calculate flow rate.
- Flow rate, differential pressure and test temperature were measured at each rate.
- Brine permeability was calculated using sample length & area, brine viscosity, flow rate and differential pressure.

Solid phase chemistry		Resource		Sand Samples	WC	Whole Core																						
Quant XRD - Standard		Completed by J. Rye, Franklin & N.E. Sullivan		42212013																								
Citizen Green #1		Flow Properties		Quant XRD Weight %																								
Wellbore Depth (ft)	TUD (ft)	Formation	Porosity (p.u. wt %)	Permeability (gas mD)	Quartz (%)	(mm)	K-Fieldspar (%)	K-Fieldspar (mm)	Albite (%)	Albite (mm)	Labradorite (%)	Labradorite (mm)	Analcime (%)	Analcime (mm)	Kaolinite (%)	Kaolinite (mm)	Clinochlo (%)	Clinochlo (mm)	Pyrite (%)	Pyrite (mm)	Homotrichite %	Amphibole (mm)	Serpentine (%)	Serpentine (mm)	Detrital Mica (%)	Detrital Mica (mm)	Mordenite/Zeolite	
8	7105	6962.3 Top Shallow Sand	21.4	432.6	42.62204	1.003	6.66232	0.696236		0	0	0	0	35.57602	1.4783	1.362616	0.322677	4.6722794	0.459105	0.45269	0.126002 (trace %)	0	0	0	0	2.416244	0.58234654	0
9	7105	6962.3 Top Shallow Sand	27.6	114.3	36.86208	0.462223	6.515051	0.71813		0	0	0	0	27.234473	0.602629	0.623464	0.441126	0.326732	0.331125	1.677777	0.147636	0	0	1.232791	0.15643029	6.467123	0.236664	0
15	6926	6206.6 vinyay	34.2	269.9	44.121003	0.403019	16.630375	0.337020		0	0	0	0	35.431965	0.436227	4.219407	0.343268	4.487265	0.402615	0	0	0	0	0	0	0.14624651	0.4060205	0
21	6926	5971.1 Middlemore River Fm	31.3	135.5	53.636276	1.16662	21.589777	1.40104		0	0	0	0	34.47943	1.52166	3.5264416	0.446264	0.4176265	0.62217	0.213666	0.16267	0.239667	0.306776	0	0	0.13621264	0.21717613	0
22	6465	5843.1 Middlemore River Fm	34.2				24.1			0				31		2.9		2		0.5						4.2		
23		5843.1 Middlemore River Fm	31.3	71.9	35.334658	1.79463	12.507689	2.6742		0.20736216	0	0.46343	36.56929	0.70637	0	0.677469	0.3393695	0.446744	0.66619167	0.16844	0.6666263	0.21466765	0	0	4.5736364	0.6619443	0	
24	6465	5901.1 Middlemore River Fm	33	367.1	40.30469	0.9161	17.68427	0.61662		0	0	26.23262	0.64662	3.626643	0.623466	0.235662	0.461134	0.986666	0.57266		0	0.1726666	0.52136165	0	0	0.33746666	0.65267623	0
WC (shale tails)	5365	4725.2 Middlemore River Fm	NA	NA		17 -	32.7 -			6.5 -	0 -	0 -	0 -			34.9 -	0	0	0 -	0 -		0 -		0 -		8.4 -	None	1.1
WC (no reservoir sand)	5247	4725.5 Middlemore River Fm	NA	NA		27.9 -	16.2 -			34 -	0 -	0 -	0 -			3.6 -	17	0	0 -	0 -		0 -		0 -		0 -		

README.kingIslandPCsat

J. Ajo-Franklin, June 22nd, 2022 : Contact info, ja62@rice.edu, (510)-735-4350

This submission includes information on helium pycnometry & MICP measurements conducted on sidewall sub-samples from the Citizen Green #1 well drilled on King Island, CA (API 07720688) as part of the WESTCARB partnership basin characterization effort. Cores were acquired with a rotary sidewall tool at a range of depths. See the sidewallCore submission for additional formation data.

<https://edx.netl.doe.gov/dataset/citizen-green-1-well-sidewall-core-permeability-studies>

Samples are from the Starkey and Mokelumne River formation as well as one Domengine sample from Black Diamond Mine Regional Park. The location of the cores are shown in [citGreen_compositeSidewal_Illus_v1.jpg](#). Samples WestCarb8 and WestCarb9 are located in the 1st Starkey Sand while samples WestCarb23 and WestCarb24 are in the middle of the Mokelumne River formation. The Domengine sample is from BDMRP as mentioned previously.

All measurements were conducted at Lawrence Berkeley National Laboratory (LBNL) & Stanford University (courtesy of Ronny Pini).

Files included:

<i>README.kingIslandPCsat</i> :	This file
Cal1.txt :	Calibration file for pycnometer
Cal2.txt :	Calibration file for pycnometer
Cal3.txt :	Calibration file for pycnometer
Cal4.txt :	Calibration file for pycnometer
Cal5.txt :	Calibration file for pycnometer
citGreen_compositeSidewal_Illus_v1.jpg :	Plot of sidewall locations from CG #1 well
DOMERP.XLS	MICP data for Domengine Sample
Log File.docx	Notes on pycnometer and MICP data
WECA8RP.XLS	MICP data for Starkey Sample, Sidewall #8
WECA9RP.XLS	MICP data for Starkey Sample, Sidewall #9
WECA23RP.XLS	MICP data for Mokelumne River Sample, Sidewall #23
WECA24RP.XLS	MICP data for Mokelumne River Sample, Sidewall #24
WestCarb8_300R.txt	Helium pycnometer data for Sidewall #8
WestCarb8_500R.txt	Helium pycnometer data for Sidewall #8
WestCarb9_500R.txt	Helium pycnometer data for Sidewall #9
WestCarb23_500R.txt	Helium pycnometer data for Sidewall #23
WestCarb24_500R.txt	Helium pycnometer data for Sidewall #24

MICROMERITICS INSTRUMENT CORPORATION
AutoPore IV 9500 V1.09

Serial: 827

Port: 1/1

Page 1

Sample ID:

weca23rp

Operator:

Submitter:

Ronny

C:\DOCUME~1\EVERYO~1\MYDOCU~1\RON
NY\WECA23RP.SMP

File:

LP Analysis Time:

3/26/2013 3:09:17PM

Sample Weight: 0.3120 g

HP Analysis Time:

3/26/2013 4:18:03PM

Correction Type: Blank

Report Time:

3/26/2013 4:18:03PM

Show Neg. Int: No

Summary Report

Penetrometer parameters

Penetrometer:

#13-0376 (13) 3 Bulb, 0.412 Stem, Solid

Pen. Constant:

11.007

μL/pF

Pen. Weight: 61.5470 g

Stem Volume:

0.4120

mL

Max. Head Pressure: 4.6800 psia

Pen. Volume:

3.6621

mL

Assembly Weight: 108.7390 g

Hg Parameters

Adv. Contact Angle:

140.000

degrees

Rec. Contact Angle: 140.000 degrees

Hg Surface Tension:

485.000

dynes/cm

Hg Density: 13.5386 g/mL

User Parameters

Param 1:

N/A

Param 2:

N/A

Param 3: N/A

Low Pressure:

Evacuation Pressure:	50	µmHg
Evacuation Time:	5	mins
Mercury Filling Pressure:	0.21	psia
Equilibration Time:	20	secs

High Pressure:

Equilibration Time:	20	secs
---------------------	----	------

Blank Correction Sample:

C:\DOCUME~1\EVERYO~1\MYDOCU~1\RONNY\CALP1RP3.SMP

(From Pressure 0.10 to 60000.00 psia)

Intrusion Data Summary

Total Intrusion Volume =	0.2397	mL/g
Total Pore Area =	5.901	m ² /g
Median Pore Radius (Volume) =	57312	Å
Median Pore Radius (Area) =	55	Å
Average Pore Radius (2V/A) =	813	Å
Bulk Density at 0.21 psia =	1.5646	g/mL
Apparent (skeletal) Density =	2.5039	g/mL
Porosity =	37.5113	%
Stem Volume Used =	18	% ****

Pore Structure Summary

Threshold Pressure:	0.45	psia (Calculated)
Characteristic length =	2384835	Å
Conductivity formation factor =	0.033	
Permeability constant =	0.00442	
Permeability =	32944.5414	mdarcy
BET Surface Area =	230.0000	m ² /g
Pore shape exponent =	1.00	
Tortuosity factor =	2.052	
Tortuosity =	8.8139	
Percolation Fractal dimension =	2.957	

Backbone Fractal dimension =	2.732	
Mayer Stowe Summary		
Interstitial porosity =	47.6300	%
Breakthrough pressure ratio =	3.8014	
Material Compressibility		
Linear Coefficient =	-2.7098e-03	1/psia
Quadratic Coefficient =	5.4330e-05	1/psia ²

MICROMERITICS INSTRUMENT CORPORATION
AutoPore IV 9500 V1.09

Serial: 827

Port: 1/1

Page 1

Sample ID:
Operator:
Submitter:

weca24rp

Ronny

File:

C:\DOCUME~1\EVERYO~1\MYDOCU~1\R
ONNY\WECA24RP.SMP

LP Analysis Time:
HP Analysis Time:
Report Time:

3/27/2013 4:56:08PM
3/27/2013 6:38:53PM
3/27/2013 6:38:53PM

Sample Weight: 0.3120 g
Correction Type: Blank
Show Neg. Int: No

Summary Report Penetrometer parameters

Penetrometer:

#13-0376 (13) 3 Bulb, 0.412 Stem, Solid

Pen. Constant:
Stem Volume:
Pen. Volume:

11.007
0.4120
3.6621

$\mu\text{L/pF}$
mL
mL

Pen. Weight: 61.6860 g
Max. Head Pressure: 4.6800 psia
Assembly Weight: 109.0800 g

Hg Parameters

Adv. Contact Angle:
Hg Surface Tension:

140.000
485.000

degrees
dynes/cm

Rec. Contact Angle: 140.000 degrees
Hg Density: 13.5379 g/mL

User Parameters

Param 1: N/A Param 2: N/A Param 3: N/A

Low Pressure:

Evacuation Pressure:	50	µmHg
Evacuation Time:	5	mins
Mercury Filling Pressure:	0.21	psia
Equilibration Time:	20	secs

High Pressure:

Equilibration Time:	20	secs
---------------------	----	------

Blank Correction Sample:

C:\DOCUME~1\EVERYO~1\MYDOCU~1\RONNY\CALP1RP3.SMP

(From Pressure 0.10 to 60000.00 psia)

Intrusion Data Summary

Total Intrusion Volume =	0.2037	mL/g
Total Pore Area =	7.690	m ² /g
Median Pore Radius (Volume) =	47693	A
Median Pore Radius (Area) =	57	A
Average Pore Radius (2V/A) =	530	A
Bulk Density at 0.21 psia =	1.6928	g/mL
Apparent (skeletal) Density =	2.5837	g/mL
Porosity =	34.4818	%
Stem Volume Used =	15	% ****

Pore Structure Summary

Threshold Pressure:	0.49	psia (Calculated)
Characteristic length =	2186853	A
Conductivity formation factor =	0.025	
Permeability constant =	0.00442	
Permeability =	20916.0376	mdarcy

Citizen Green 1 Data
- EDX

BET Surface Area =	230.0000	m ² /g
Pore shape exponent =	1.00	
Tortuosity factor =	2.079	
Tortuosity =	7.3470	
Percolation Fractal dimension =	2.893	
Backbone Fractal dimension =	2.698	

Mayer Stowe Summary

Interstitial porosity =	47.6300	%
Breakthrough pressure ratio =	3.8014	

Material Compressibility

Linear Coefficient =	7.2463e-05	1/psia
Quadratic Coefficient =	-3.0043e-04	1/psia ²

Field: Rio Vista Gas Field

Wells: "Midland Fee Wtr. Inj." 1 (067-20154) and "Midland WI" 2 (067-20271)

Zone: Mokelumne River

Project no.: 60600003

Initial project approval year: 1980

Data requested for the 2016 Annual UIC Project Review:

1724.7(a) ENGINEERING STUDY

1724.7(a)1 – Statement of Purpose

1724.7(a)2 – Method of determining fracture gradient, and description of any step rate tests

1724.7(a)3 - Reservoir fluid data for each injection zone

1724.7(a)4 - Area of Review/Casing Diagrams

1724.7(b) GEOLOGIC STUDY

1724.7(b)2 - Isopach map of injection zone

1724.7(b)3 - Geologic cross section through the injection well(s)

1724.7(c) INJECTION PLAN

1724.7(c)1 – A map showing injection facilities

1724.7(c)2 – Maximum anticipated surface injection pressure (pump pressure) and daily rate of injection by well

1724.7(c)3 – Monitoring system or method to be utilized to ensure that no damage is occurring and that the injection fluid is confined to the intended zone

1724.7(c)4 – Method of injection

1724.7(c)5 – List of cathodic protection measures of plant, lines, and wells, if such measures are warranted

1724.7(c)6 – Treatment of the water to be injected

1724.7(c)7 – Source and analysis of the injection liquid

1724.7(c)8 – Location and depth of each water-source well that will be used in conjunction with the project

APPENDICES

Appendix A – Post-Job Fracture Report Summaries

Appendix B – Step Rate Test Guidelines

Appendix C – Formation Water Analysis

Appendix D – Casing Diagrams for Wells within Area of Review

Appendix E – Isopach map of Injection Zone

Appendix F – Geologic Cross-Sections

Appendix G – Map of Injection Facilities

Appendix H – Source of Injected Fluid (Including Test Schedule of Injected Water)

Attachment 1: List of Wells Contributing to Injected Water

Attachment 2: Maps of Wells Contributing to Injected Water

1724.7(a) ENGINEERING STUDY

1724.7(a)1 – Statement of Purpose

The purpose of this project is to dispose of water which is produced in conjunction with natural gas from the Rio Vista Gas Field and other natural gas fields located within the Sacramento Basin. Disposed water is to be injected into the Mokelumne River formation utilizing wells “Midland Fee Wtr. Inj.” 1 (067-20154) and “Midland WI” 2 (067-20271) in the Rio Vista Gas field. The sources of produced water are detailed below (Appendix H), as well as details regarding the geology surrounding the injection wells, the operational methods to be employed, and the testing and monitoring of the injected water.

1724.7(a)2 – Method of determining fracture gradient, and description of any step rate tests

The fracture gradients of the “Midland Fee Wtr. Inj.” 1 and “Midland Fee WI” 2 wells have been determined by means of pre-frac tests conducted in 2007. The tests were conducted by injecting fluid at a pressure above frac gradient for a short amount of time before ceasing injection and measuring the instantaneous shut in pressure (ISIP) coinciding with the closure of induced fractures. The downhole ISIP was then divided by the depth of the perforated interval to yield a fracture gradient for each well. The pre-frac tests resulted in calculated fracture gradients of 0.69 psi/ft and 0.74 psi/ft for the “Midland Fee Wtr. Inj.” 1 and “Midland Fee WI” 2 wells respectively. Summaries of the tests and their analysis by Halliburton are included below in Appendix A (the calculated fracture gradients have been highlighted in red).

In the event of a step rate test being required for this project it would be conducted in accordance with the procedures included in Appendix B, outlining the necessary methods to safely and effectively determine fracture gradient by means of such a test. If a variance in step rate time durations (as outlined in step 8 of the document included in Appendix B) is needed, CRC will request the variance in step rate injection time to be approved by a DOGGR representative before commencement of injection operations.

1724.7(a)3 - Reservoir fluid data for each injection zone

A water sample analysis from “Midland Fee Wtr. Inj.” 1 dated June 4, 1980 (corresponding to the well’s initial completion) indicates initial formation water with a TDS concentration of 13,889 ppm. The analysis report is included below in Appendix C.

1724.7(a)4 - Area of Review/Casing Diagrams

All applicable wellbore diagrams are included below in Appendix D.

1724.7(b) GEOLOGIC STUDY

1724.7(b)2 - Isopach map of injection zone

An isopach map of the injection zone (Mokelumne River) is included in Appendix E below.

Appendix C

GEOCHEMICAL ANALYSIS OF WATER Pro-391

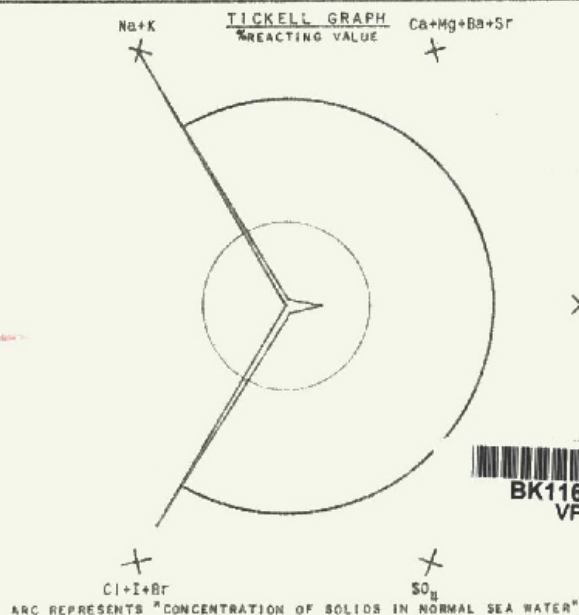
DATE OF REPORT	June 4, 1980	WELL NO.	Midland Fee WI-1, Sec. 3
DATE OF SAMPLING	No date	COMPANY	Chevron USA
SAMPLED BY	Operator	FIELD	Rio Vista, 3N/3E
LABORATORY NO.	32-8M-48	ZONE	
ANALYST	Yamada	SAMPLE SOURCE	

RADICALS		PARTS PER MILLION MILLIGRAMS PER LITER	REACTING VALUE EQUIVALENTS PER MILLION	REACTING VALUE PERCENT
SODIUM	Na	5053.6	219.82	48.73
CALCIUM	Ca	61.5	3.07	0.68
MAGNESIUM	Mg	8.9	0.73	0.16
BARIUM	Ba			
STRONTIUM	Sr			
POTASSIUM	K	75	1.92	0.43
SULPHATE	SO ₄	294.9	6.14	1.36
CHLORIDE	Cl	6867.2	193.70	42.94
CARBONATE	CO ₃	58.8	1.96	0.44
BICARBONATE	HCO ₃	1448.5	23.74	5.26
HYDROXIDE	OH			
IODIDE	I			
SILICA	SiO ₂	12.8		
IRON, ALUMINA	R ₂ O ₃	8.2		
TOTAL		13889.4	451.08	100.00

GROUP	CHEMICAL CHARACTER	MISCELLANEOUS		
ALKALIS	PRIMARY SALINITY	BORON	77.2	PPM
EARTHS	SECONDARY SALINITY	HYDROGEN SULFIDE	Absent	
STRONG ACIDS	PRIMARY ALKALINITY	EQUIVALENT SALT	12000	PPM
WEAK ACIDS	SECONDARY ALKALINITY	RESISTIVITY @ 77°F	0.470	O.M.
Ca/EARTHS		CHLORINITY	11320	PPM
CHLORIDE SALINITY		SPECIFIC GRAVITY	1.0100	
SULPHATE SALINITY	CARBONATE/CHLORIDE	pH	8.32	

REMARKS

D. F. Moran
G. C. Cates
L-C Laboratory



BK11629433
VPC

Pro-391 (Rev. 7-71)
PRINTED IN U.S.A.

SIGNED: R. M. Yamada



ZALCO LABORATORIES, INC.
Analytical & Consulting Services

4309 Armour Avenue
Bakersfield, California 93308

(661) 395-0539
FAX (661) 395-3069

Core Laboratories
3437 Landco Dr
Bakersfield CA 93308

Laboratory No: 1304060-01
Date Received: 4/5/2013
Date Reported: 4/9/2013

Attention: Larry Kunkel

Sample Identification: Chamber 1507

Sampled by: Date: 3/26/2013 Time:

Report Notes:

COMPLETE GEOCHEM ANALYSIS

pH.....	7.68	Specific Gravity @ 60 F...	1.009
Electrical Conductivity (EC).....	21.3	Resistivity.....	0.4695
(millimhos/cm @ 25 C)		(ohm meters @ 25 C)	

Constituents	mg/L	mg/L	Reacting %
Calcium, Ca	430	21	4.72
Magnesium, Mg	130	11	2.35
Sodium, Na	4300	190	41.14
Potassium, K	33	0.84	0.19
Iron, Fe (total)	< 1.0	0	0
Alkalinity as:			
Hydroxide, OH	0	0	0
Carbonate, CO ₃	0	0	0
Bicarbonate, HCO ₃	150	2.5	0.54
Chloride, Cl	8200	230	50.86
Sulfate, SO ₄	42	0.87	0.19
Sulfide, S	< 1.0		
Boron, B	9.6		
Barium, Ba	3.2		
Silica, SiO ₂	< 40		
Strontium, Sr	15		
Totals (Sum)	13200	456	100

Total Dissolved Solids, (Gravimetric)	14000
Calculated Hardness, CaCO ₃	1600
Total Alkalinity, CaCO ₃	150
Sodium Chloride, (total)	13000

Primary Salinity	82.66
Secondary Salinity	14.14
Total Salinity	96.8

Cation/Anion Balance, %	3.0%
Sodium, Na (Calculated), mg/L	4635.12
Langelier Scale Index	1.13
Stiff/Davis Stability Index	1.11

Primary Alkalinity	0
Secondary Alkalinity	0
Total Alkalinity	0

Mark G. [Signature]
Laboratory Authorization

This report is furnished for the exclusive use of our Customer and applies only to the samples tested. Zalco is not responsible for report alteration or detachment.

Geochemical analyses for the Piacentine_2-27 well (approx. 3 miles north of the AOR)

Well Name					Well Number		API	
"PG&E Test Injection/Withdrawal Well" 1							077-20739	
Engineer		Mary Bottoms			12/8/2016			
Well Class								
Oil & Gas	Dry Gas	Exploratory			Gas Storage	Water Disposal	Obser.	
		Outpost	New Field	New Pool				
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Casing	Depth of Casing				Size	Weight	Grade	Hole Size
Conductor	60	630	4716	4814	20			28
Surface					13 3/8	54.5#	J55	17 1/2
Intermediate					9 5/8	40#	N80	J55
Production Liner					5 1/2	17#	L80	17
Notes								
<div style="display: flex; align-items: center;"> <div style="flex: 1;"> </div> <div style="flex: 1;"> <p>310'</p> <p>445'</p> <p>3570'</p> <p>mud 4054'-3942'</p> <p>4054'</p> <p>4588'</p> <p>4717'-4728'</p> <p>Gravel pack 5 1/2" liner 4686'-4809'</p> <p>4814'</p> </div> </div>								
TD								
Perf	CIBP	Cement	Retainer	WSO	Fish	DV Collar		

**PG&E Test Injection/Withdrawal Well 1 Abandonment
Return Observation Wells to Field Operator
King Island Gas Field, San Joaquin County, California**

1. Introduction

This document is a plan to abandon PG&E Test Injection/Withdrawal Well 1 (I/W well) and return ownership of compression test observation wells Piacentine 1-27 and Piacentine 2-27 to the King Island Gas Field (the Field) operator. These wells were used during the Compression Testing Program (CTP) performed by PG&E to evaluate the feasibility of compressed air energy storage (CAES) at the King Island Gas Field in San Joaquin County, California. The I/W well was used as the injection/withdrawal well, the Piacentine 1-27 was used as a pressure and temperature monitoring well and the Piacentine 2-27 was geophysically logged to monitor the air bubble development. The Plan details are in accordance with the requirements of Environmental Protection Agency (EPA) Underground Injection Control (UIC) Permit No. R9UIC-CA5-FY13-1 (The Permit).

The CTP was conducted from February 14 to June 4, 2015. The Permit requires a post-test monitoring period of six to nine months. PG&E has elected to carry out the Plan at the end of the minimum post-test monitoring period (six-months), shortly after December 4, 2015.

2. EPA Requirements

The following EPA requirements applicable to this Plan, either stated in the Permit or in subsequent emails or letters to PG&E during the CTP or post-test monitoring period, are summarized in the table below:

PG&E CAES Project
 Permit No. R9UIC-CA5-FY13-1
 I/W Well Abandonment and Return Observation Wells to Field Operator

Well	EPA Requirement	Reference
I/W Well	Internal mechanical integrity test (MIT) at the conclusion of the post-test monitoring period.	Permit: Part II.D.2.b.iii
	Plugging and abandonment of I/W well if bottomhole pressure (BHP) exceeds normal hydrostatic gradient at end of post-test monitoring period.	Permit: Appendix H UIC Permit Application: Attachment P, Section P-4
	Perforation and plugging with cement of key intervals with poor cement bonding.	EPA email to PG&E dated April 10, 2015
Piacentine 1-27	Internal MIT prior to conversion to production service.	Permit: Part II.D.2.b.iii
	Well ownership reverts to Field operator after conclusion of the post-test monitoring period. PG&E will work with Field operator to meet any EPA requirements after transfer of ownership.	Permit: Appendix H UIC Permit Application: Attachment P, Section P-4
Piacentine 2-27	Well ownership reverts to Field operator after conclusion of the post-test monitoring period. PG&E will work with Field operator to meet any EPA requirements after transfer of ownership.	Permit: Appendix H UIC Permit Application: Attachment P, Section P-4

3. Internal Mechanical Integrity Tests (MITs)

Internal MITs will be performed shortly after the conclusion of the post-test monitoring period on the I/W well and the Piacentine 1-27 on December 4, 2015. The internal MITs will be conducted in accordance with Permit Part II.D.2.a.i and follow the procedures provided in **Attachment A.1** (I/W well) and **Attachment A.2** (Piacentine 1-27).

4. I/W Well Abandonment

The I/W well will be plugged and abandoned shortly after completion of the internal MIT. A preliminary procedure for plugging and abandonment of the I/W well was provided in Attachment Q-1 of the UIC Permit Application titled: *Underground Injection Control Permit Application and Technical Attachments, PG&E Compressed Air Energy Storage*

PG&E CAES Project
Permit No. R9UIC-CA5-FY13-1
I/W Well Abandonment and Return Observation Wells to Field Operator

Project, Compression Testing Program, King Island Gas Field, San Joaquin County, California, revised April 18, 2014 (PG&E, 2014). A proposed I/W well abandonment schematic was provided in Attachment Q-3 of the UIC Permit Application and Appendix G of the Permit.

A revised I/W well abandonment procedure and schematic have been prepared and are provided as **Attachments B and C**. Notable changes in the revised abandonment plan are listed below:

- Removal of mandrel containing Spartek downhole pressure-temperature sensor and delivery to PG&E.
- Run mill to bottom and clean out fill, if any.
- Revised depth interval for injection zone plug based on actual well completion.
- Revised depth interval for USDW plug based on EPA estimate of depth to base of USDW.
- Remedial squeeze plugging of interval 950'–984'. Remedial squeeze zone and surface casing shoe plugs are combined.
- Revised depth interval for fresh water plug based on California Division of Oil and Geothermal Resources (DOGGR) estimate of depth to base of fresh water.

In their letter to PG&E dated February 9, 2015, EPA stated that the quality of cement bonding in the I/W well is sufficient to provide adequate isolation of USDWs above 3,840 feet (EPA calculated depth base of USDW) from the injection zone and injected fluids. EPA further stated that the cement bond above 3,785 feet varies from good to poor and must be addressed. EPA's concern regarding the interval between 3,785 feet and the surface casing shoe at 630 feet is that formation fluid might migrate from higher to lower salinity USDW zones through poorly bonded intervals.

In response to EPA's request for a remedial cementing operation procedure, PG&E performed a salinity analysis using open hole geophysical logs and a re-evaluation of the cement bond log over specific intervals between the surface casing shoe at 630 feet and the base of USDW at 3,840 feet. The results of these analyses were presented in a salinity evaluation report prepared by Digital Formation and a cement bond log (CBL) analysis report prepared by Crescent. These reports were submitted to EPA along with a cover letter dated March 31, 2015 providing a summary of the results and concluding that the current cement bond is adequate to prevent fluid migration between zones of different salinities and remedial cementing should not be performed.

In an email to PG&E dated April 10, 2015, EPA approved the PG&E Cementing Plan dated March 31, 2015 for the period of air injection operations. However, EPA indicated that during I/W well plugging and abandonment, key intervals with poor bonding should be perforated and plugged with cement.

PG&E CAES Project
Permit No. R9UIC-CA5-FY13-1
I/W Well Abandonment and Return Observation Wells to Field Operator

PG&E still believes that the current cement is adequate to provide long-term isolation of USDW zones. In addition, temperature and noise logging performed on June 18, 2015 and temperature logging performed on July 10, 2015 (**Attachment D**) showed no evidence of fluid migration in the interval of EPA concern. Notwithstanding this evidence, PG&E is prepared to perforate and plug with cement the depth interval of 950-984 feet, which shows what appears to be the poorest bond signature, though not indicative of “free pipe”.

In accordance with Permit Part II.F.4, PG&E will submit a plugging and abandonment report on Form 7520-14 within 60 days after plugging the I/W well. The report shall be certified as accurate by the person who performed the plugging operation.

5. Observation Wells Ownership Transfer to Field Operator

After the well re-work is completed, ownership of the Piacentine 1-27 will be transferred back to the Field operator. If a full-field development project does not proceed, ownership of the Piacentine 2-27 will be transferred back to the Field operator. Both wells will remain under DOGGR jurisdiction after the transfer back to the Field operator.

6. Well Monitoring and Quarterly Reporting to EPA

PG&E will collect continuous digital wellhead pressure and temperature data on the I/W well and Piacentine 1-27, and monthly digital bottomhole pressure data on the I/W well, until the end of the post-test monitoring period on December 4, 2015. Monthly bottomhole pressure surveys will be performed on the I/W well through November 2015. The data will be presented in the third and fourth quarter 2015 reports, to be submitted to EPA by October 28, 2015 and January 28, 2015, respectively. The Piacentine 2-27 is fully cased and cemented and not perforated and will not be monitored during or after the post-test monitoring period.

PG&E CAES Project
Permit No. R9UIC-CA5-FY13-1
I/W Well Abandonment and Return Observation Wells to Field Operator

7. References

PG&E, 2014. Underground Injection Control Permit Application and Technical Attachments, PG&E Compressed Air Energy Storage Project, Compression Testing Program, King Island Gas Field, San Joaquin County, California, revised April 18, 2014.

ATTACHMENT A.1

Internal Mechanical Integrity Test Procedure – I/W Well

PG&E

PG&E Test Injection/Withdrawal Well No. 1

Location: X=1734880.641 Y= 577346.753 (NAD 27, Zone III)
Section 27, T 3N, R 5E, San Joaquin County, California.
Elevation: -3.75' ground. +8.25' KB (NGVD 29)

Take all measurements from KB which is 12' above ground.

Present Condition

TD:4815' MD PD: 4813' MD

Casing: 13-3/8", 54.5#, J-55 surface casing cemented at 630
9-5/8", 40#, J-55 & N-80 intermediate casing cemented at 4716'.
5-1/2" premium wire wrap liner gravel packed from 4687' to 4814'
Baker Model SC packer at 4614'.
Tubing: 5-1/2", 17#, J-55, LT&C with seal bore assembly stabbed into
Baker SC packer at 4614'. SPSRO down hole pressure gauge at 4610'.

Note: The annulus is full of 4% KCl water with corrosion inhibitor plus biocide.

Annulus Mechanical Integrity Test

1. Notify EPA 48 hours in advance.
2. Move in United Well Control Test unit. Connect test unit to 9-5/8" X 5-1/2" annulus valve. Move in a vacuum truck with clean fresh water.
3. Install a memory electronic gauge for monitoring tubing pressure. Pressure up 9-5/8" X 5-1/2" annulus to 2500 psig and hold for 1/2 hour. Monitor annulus and tubing pressures electronically. Measure and record the volume of water necessary to achieve the test pressure and water temperature used for the test. In addition have the company man manually record pressure readings of both annulus and tubing every 5 minutes during the entire test. Company man signs and dates both printed electronic charts and manual pressure tabulation. Send electronic copies, and signed paper copies of the test to EPA.
4. Redo the test if the pressure drops by more than 5% during the test interval.
5. Have the testing contractor provide the last calibration report for the test gauge.
6. At the conclusion of the test, blowdown the annulus pressure to atmospheric conditions and shut-in the well.

October 23, 2015

ATTACHMENT A.2

Internal Mechanical Integrity Test Procedure – Piacentine 1-27

IRANI ENGINEERING, INC.
PETROLEUM ENGINEER
2625 FAIR OAKS BOULEVARD, SUITE 10
SACRAMENTO, CALIFORNIA 95864
916-482-2847
FAX 916-482-7514

Princeton Natural Gas, LLC

Piacentine No. 1-27

Location: 3490' North and 990' East from southwest corner of
Section 27, T 3N, R 5E, MDB&M, San Joaquin Co., California.

Elevation: -6' ground, USGS. +7' KB.

Take all measurements from KB which is 13' above ground.

Keep hole full at all times.

Check operation of BOE daily

Present Condition (Producing)

TD 4900' MD PD: 4715' (bridge plug)

Casing: 8-5/8", 24#, J-55, cemented to surface @ 627'.

5-1/2", 15.5#, K-55, cemented at 4900'. Top of cement in the annulus
is at 4175'.

Tubing: 2-3/8", 4.7#, J-55, EUE tubing With Baker Model R-3 packer at 4611',
Wireline re-entry sub below packer at 4612', Baker Model R nipple
(1.781" ID) at 4606', and Baker Model L sleeve (1.875" ID, F profile)
at 4573'.

Perforations: 4670'-4682'. Open

4684'-4690', 4700'-4705'. Cement squeezed.

4720'-4724', 4750'-4764'. Cement squeezed, Below
bridge plug at 4715'.

Note: Annulus is full of 4% KCl water treated with biocide and corrosion
inhibiter.

Annulus Mechanical Integrity Test

1. Notify EPA 48 hours in advance.
2. Move in United Well Control Test unit. Connect test unit to 5-1/2" X
2-3/8" annulus valve (2-1/16" valve). Move in a vacuum truck with clean
fresh water.
3. Install a memory electronic gauge for monitoring tubing pressure.
Pressure up 5-1/2" X 2-3/8" annulus to 2500 psig and hold for 1/2 hour.
Monitor annulus and tubing pressures electronically. Measure and record
the volume of water necessary to achieve the test pressure and water
temperature used for the test. In addition have the company man manually
record pressure readings of both annulus and tubing every 5 minutes during
the entire test. Company man signs and dates both printed electronic
charts and manual pressure tabulation. Send electronic copies, and
signed paper copies of the test to EPA.
4. Redo the test if the pressure drops by more than 5% during the test
interval.
5. Have the testing contractor provide the last calibration report for the
test gauge.
6. At the conclusion of the test, blowdown the pressure to atmospheric
conditions and shut-in the well.

October 22, 2015

ATTACHMENT B

Revised I/W Well Abandonment Procedure

IRANI ENGINEERING
 PETROLEUM ENGINEER
 2625 FAIR OAKS BLVD., SUITE 10
 SACRAMENTO, CALIFORNIA 95864
 916-482-2877
 FAX 916-482-7514

PG&EPG&E Test Injection-Withdrawal Well No. 1

Location: Section 27, T 3N, R 5E, MDB&M San Joaquin County, California.
 X=1734880.641 Y= 577346.753 (NAD 27, Zone III)
 Elevation: -3.75' ground. +8.25' KB (NGVD 29)

Take all measurements from KB which is 12' above ground.
 Check operation of BOE day.
 Keep hole full at all times.

Present Condition

TD: 4815' MD (4756' VD) PD: 4814' MD (4755' VD)

Casing: 13-3/8", 54.5#, J-55 surface casing cemented at 630'

9-5/8", 40#, J-55 & N-80 intermediate casing cemented at 4716' (4665' VD).

5-1/2" premium wire wrap liner gravel packed from 4716' (4665' VD) to
 4814' (4755').

Tubing: 5-1/2", 15.5#, J-55, LT&C, LT&C thread with seal assembly stabbed into
 SC packer at 4614' (4569').

Note: A downhole permanent pressure gauge is at 4610' (4565' VD). There is
 1/4" cable that runs outside of tubing and it is affixed to the tubing with
 5-1/2" Cross Coupling Cable Protectors at every connection. The cable goes
 through the outlets in the tubing hanger and tubing head top flange and is
 connected to an instrument junction box at surface.

Note: There is 4% KCl water with corrosion inhibitor and biocide in the annulus.
 This is a directional well with maximum angle of 20 degrees.

Note: Base of Fresh Water is 210' (per DOG)

Note: Base of USDW is estimated at 3842' MD (3840' VD)

Note: We will squeeze section 950'-984' with cement as required by EPA. The cement
 volume will be 5 times more than the volume of this section (34' of 12-1/4" X
 9-5/8" annulus has a volume of 10.65 CF. We will use 58 CF of cement, 50
 sacks, for the squeeze job).

Abandonment Program

1. Move in Workover rig. Kill tubing with 10 ppg mud. Disconnect 1/4" cable from
 the instrument junction box. Remove the cable fittings. Cut 1/4" cable.
 Remove X-mas tree. Install BOE and test to 3000 psig. Notify EPA and if EPA
 requires notify DOG to witness the BOE test. Remove the cable fittings above
 the tubing hanger.
2. Pull up tubing. Cut the cable below the tubing hanger. Pull seal assembly out
 of SC packer at 4637' MD. Circulate and change hole to 10 ppg mud. Pull out 5-
 1/2" tubing while cutting the 1/4" cable from the outside of the tubing. Lay
 down tubing. Do not remove the gauge from its mandrel. Deliver the gauge and
 mandrel to Hal with PG&E.

IRANI ENGINEERING
PETROLEUM ENGINEER
2625 FAIR OAKS BLVD., SUITE 10
SACRAMENTO, CALIFORNIA 95864
916-482-2877
FAX 916-482-7514

3. Pick up 2-3/8", 4.7#, J-55, EUE work string tubing and 4.5" mill. Run mill to bottom and clean out fill if any. Change hole to 10 ppg fresh mud. Pull out and lay down mill. Run open-ended tubing to 4814'. Reverse hole clean.
4. Zone Plug: Equalize 240 sacks Class G cement (over 300 lineal feet) at 4814' MD. Wait on cement for 6 hours. Locate top of cement plug which must be above 4514' MD (100' above the top of SC-1 packer). Notify EPA to witness the cementing operation.
5. USDW Plug: Equalize 150 sacks Class G cement premixed 2% CaCl₂ (over 400 lineal feet) at 3942' MD (100' below USDW which is at 3842' MD). Wait on cement for 4 hours. Locate top of cement plug which must be above 3742' MD. Notify EPA to witness the cementing operation.
6. Cement squeeze zone 984' and Shoe plug combined: United perforate 4 JH at 984'. With open-ended tubing at 984', equalize 250 sacks Class G cement (over 690 lineal feet of cement). Pull tubing out. Pump 58 cf of mud into 9-5/8" casing. This will cause 58 cf of slurry to be squeezed in the formation at 984'. Wait on cement for 4 hours. Locate top of cement plug which must be above 530' (100' above the shoe of 13-3/8" casing). Notify EPA to witness the cementing operation.
7. Base of Fresh Water Plug: Equalize 135 sacks of Class G cement premixed 3% CaCl₂ (over 370 lineal feet) at 310' (DOGGR determined that the base of fresh water is at 210'). Wait on cement for 4 hours. Top of cement plug should be at surface. Notify EPA to witness the cementing operation.
8. Cut 9-5/8" and 13-3/8" casing 5' below ground. Weld steel plate on stub. Abandon well.

October 22, 2015



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
 REGION IX
 75 Hawthorne Street
 San Francisco, CA 94105-3901

February 9, 2015

Mike Medieros
 Manager, Renewable Energy Development
 Pacific Gas and Electric Company
 245 Market Street, Room 1309
 San Francisco, CA 94105

2015 JAN 3 PM 3:06
 RECEIVED-SACRAMENTO
 Fed 12

Re: **Underground Injection Control (UIC) Permit**
Class V Experimental Well, R9UIC-CAS5-FY13-1
Pacific Gas and Electric Company (PG&E) (P0300)
Authorization to Inject/Requirement for Remedial Cementing

Dear Mr. Medieros:

This letter is to notify you that the EPA has reviewed the revised Well Completion Report dated January 29, 2015. The report addresses EPA's comments transmitted to PG&E on January 16, 2015 sufficiently to provide this authorization to inject.

Accordingly, with this letter, EPA authorizes injection into PG&E Test Injection/Withdrawal (I/W) Well 1, subject to the conditions of the subject permit effective on August 20, 2014. Please also note the following specific permit conditions, and additional requirement for remedial cementing: 077-20739

Part II. Section D. Subpart 3. Injection Pressure Limitation

- a. Maximum Allowable Surface Injection Pressure is limited to **2,500 pounds per square inch gage (psig)**.

Part II. Section D. Subpart 4. Injection Volume (Rate) Limitation

- a. Injection rate shall not exceed **13.5 million standard cubic feet per day (MMscfd)**.

Part II. Section D. Subpart 5. Injection and Withdrawal Fluid Limitations

As stated in the subject permit.

Part II. Section E. Subpart 1. Injection Fluid Monitoring Program

- a. Analysis of injection fluids – as stated in the subject permit.

Part II. Section G. Financial Responsibility

1. Demonstration of Financial Responsibility – Financial assurance was evaluated and found adequate.

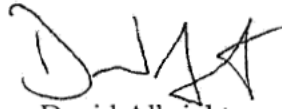
Additional Requirement for Remedial Cementing:

We have reviewed and concur with the updated cement bond log interpretation provided by PG&E and its consultants in the revised Well Completion Report. Cement bonding appears to be generally good from the casing shoe at 4,716 feet upward to 4,220 feet. The bonding also appears to be fair to good upward to 3,785 feet, notwithstanding the possible micro-annulus effect seen throughout the length of the log. The quality of the cement bonding is sufficient to provide adequate isolation of USDWs above 3,840 feet from the injection zone and injected fluids. However, the cement bond above 3,785 feet varies from good to poor, and must be addressed.

Fluid movement through the apparent micro-annulus is considered unlikely, but migration of the more mobile oxygen-depleted air and ambient air through the micro-annulus could be possible. In consideration of the short term 90-day duration, the compression test may proceed. However, following completion of the test we require that you carry out the remedial cementing. Please submit a proposed procedure for the remedial cementing operation within 30 days of receipt of this letter.

Please call Michele Dermer of my staff at (415) 972-3417 if you have any questions.

Sincerely,



David Albright
Manager, Drinking Water Protection Section

cc.: Mike Woods, CA DOGGR, District
Anne Olson, Regional Water Quality Control Board, Central Valley Region

Plan revision number: v6.0
Plan revision date: 10/15/2024

Attachment 4

Fault Stability and Risk of Induced Seismicity

Fault stability and induced seismicity risk were evaluated using the Stanford Center for Induced and Triggered Seismicity (SCITS) Fault Slip Potential (FSP 2.0) software, a probabilistic screening tool that uses Coulomb-Mohr failure criterion to calculate the conditions under which failure (slip) will occur on fault planes due to pressure perturbations from injection.

In 1979, Jaeger and Cook described Mohr–Coulomb failure criterion ($|\tau|$) using principal stresses to evaluate the conditions under which a material will fail, such that:

$$|\tau| = \tau_0 + \sigma \tan \varphi$$

Where:

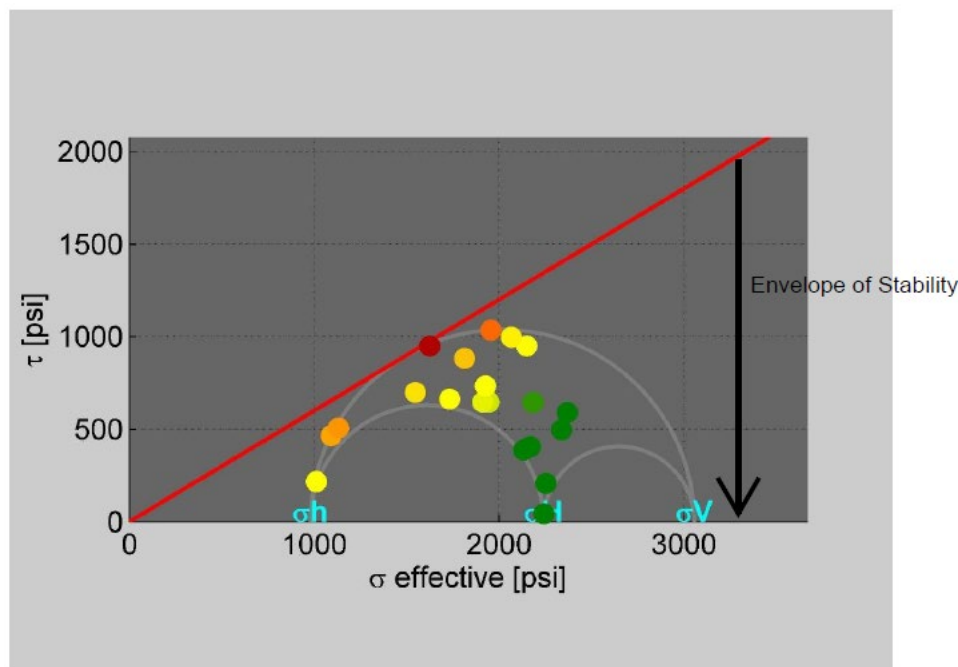
$|\tau|$ is the Mohr-Coulomb failure criterion

τ_0 is the apparent internal cohesion

σ is the principal stress

φ is the angle of internal friction

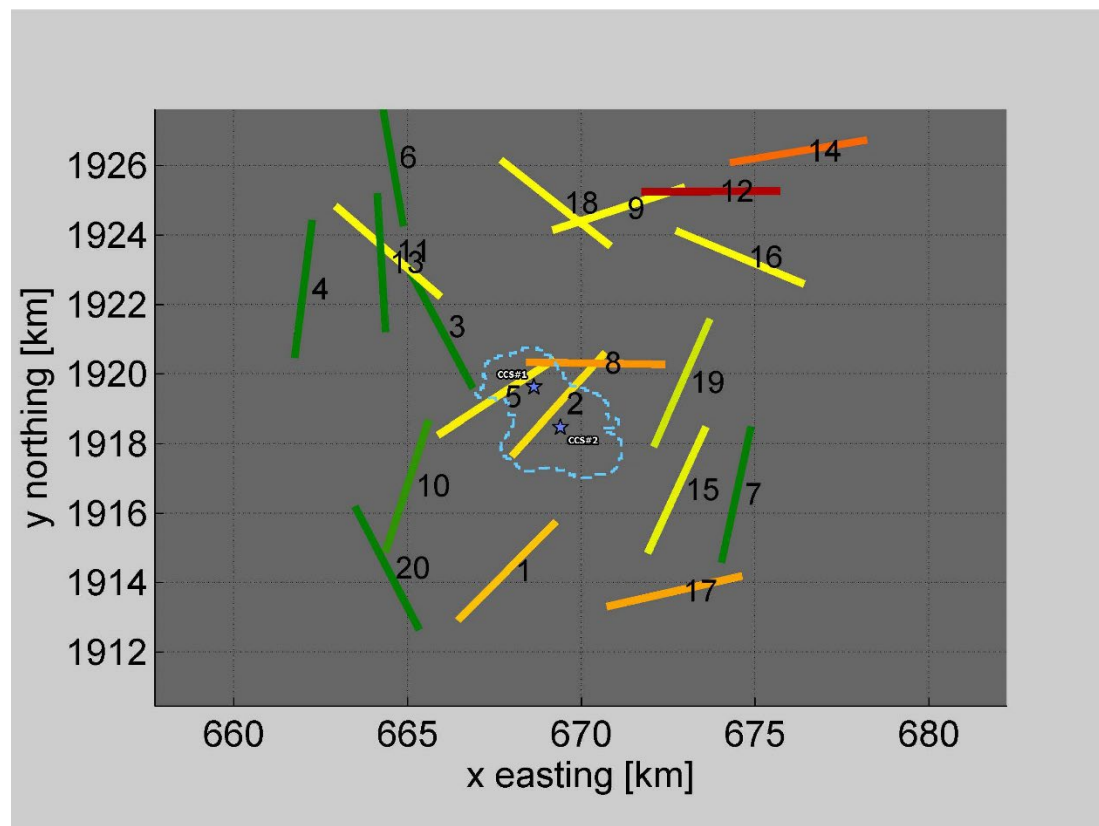
FSP 2.0 (Walsh et al., 2017) uses MatLab computational software to incorporate site-specific parameters, including in-situ vertical and horizontal stress, hydrologic conditions, injection volume and pressure to evaluate the threshold pressure at which a fault will slip, depending on the location and orientation of the fault. The results are plotted on a Mohr diagram, which identifies the envelope of stability as shown here:



Mohr diagram of calculated Coulomb-Mohr stress criterion for generated faults.

Note: Each of the colored dots represents a fault and the probability of failure at the plotted critical stress. The dots are coded from green (very low-to-no risk of slip) to dark red (highest risk of slip).

FSP 2.0 was used to evaluate the potential for induced seismicity due to pressure perturbations from carbon dioxide injection at proposed injection wells CCS#1 and CCS#2. The pressure changes used in FSP 2.0 were based upon the injection volumes, pressure, and period of injection. Maximum horizontal stress orientation was approximated from the conterminous US maximum horizontal stress orientation map (Zoback et al., 1991; Lundstern and Zoback, 2020). Additional FSP input included geomechanical and hydrological parameter values from the static and dynamic models demonstrated in this application. To evaluate slip potential on faults of varying orientations at varying distances from the injection wells, FSP 2.0 enables users to generate random faults. Twenty faults were generated at varying strike and dips and the estimated pore pressure change due to injection calculated. The results, as shown in the Mohr diagram, provide the distance and orientation of faults at which slip is likely to occur during injection.



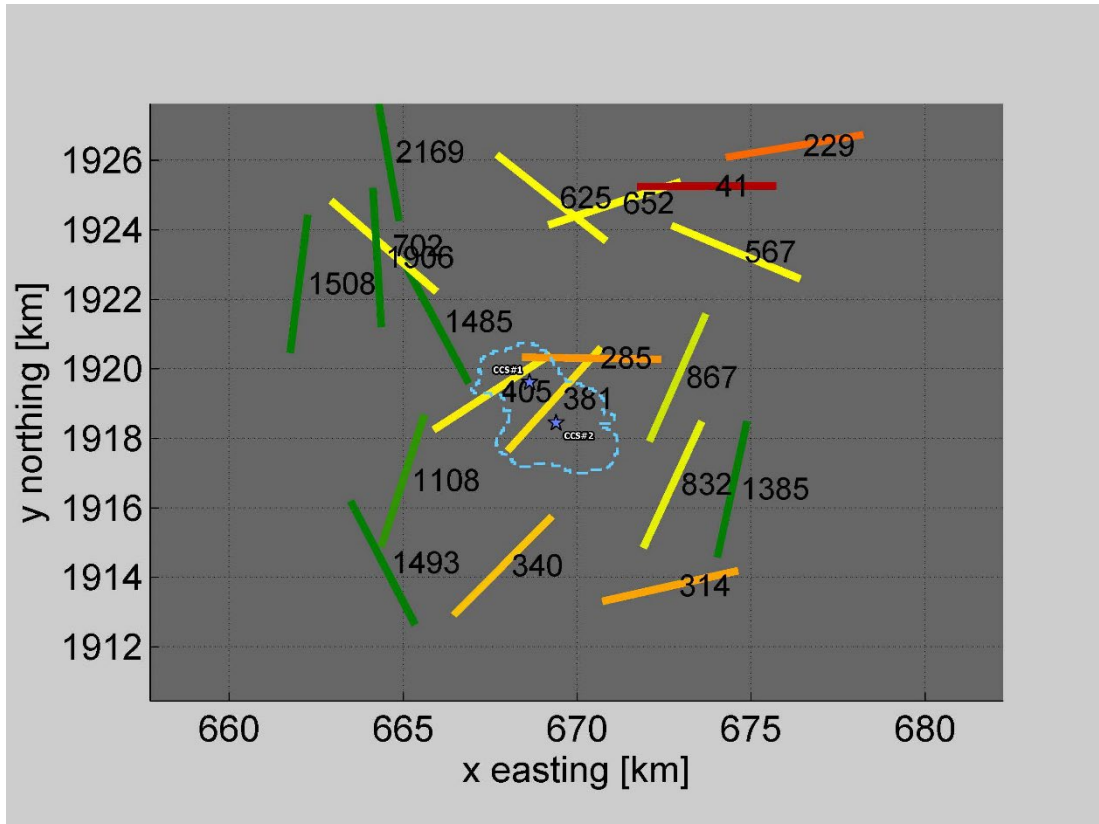
Legend

- ★ Injection Well Location
- ▭ Delineated Area of Review

Injection well locations (CCS #1 and CCC #2) and randomly generated faults.

Note: Faults are colored coded from most likely to slip (dark red) to least likely (green)

Pressure changes through time based were based on the proposed 20-year injection period. The calculated maximum pressure change (41psi) occurred on Fault #12 in 2045, the last year of injection.



Legend

- ★ Injection Well Location
- Delineated Area of Review

Coulomb-Mohr pressure change to slip in psi within the AoR.

The FSP 2.0 screening was based on the most conservative estimate of potential slip and provides a “worst case” scenario for induced seismicity on the randomly generated faults. The number and distribution of faults are hypothetical. No faults were identified within the 3D seismic volume at the critical distance, orientation, or potential pressure changes that would exceed the Coulomb-Mohr criterion. During microseismicity monitoring (described in the Testing and Monitoring Plan), small events of Magnitude 1.0 may suggest faulting not previously identified. The results of this screening will enable Pelican to observe and evaluate pressure changes of any faults similar in orientation and distance to those generated by FSP 2.0 with higher slip potential.

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FSP 2.0 Input

Stress Data		
Vertical gradient	0.75	psi/ft
A-Phi Parameter	0.60709	
Maximum Horizontal Stress Direction	80	Degrees (azimuth)
Initial Reservoir Pressure Gradient	0.28	psi/ft
Reference Depth	6500	ft
Hydrology Data		
Unit Thickness	500	ft
Porosity	30	%
Permeability	250	mD
Injection Wells		
CCS#1	3424.7	metric tons/day
CCS#2	2054.8	metric tons/day
Injection Period	20	years
Additional Parameters		
Density of Super Critical CO ² *	772.3382	kg/m ³
Dynamic Viscosity of Super Critical CO ² *	6.82E-05	Pascal-seconds
Compressibility	3.60E-08	Pascal ⁻¹
Rock Compressibility	1.08E-09	Pascal ⁻¹

Notes:

Psi/ft: pounds per square inch per foot

A-phi parameter is FSP 2.0 default

Hydrology data approximated

mD: millidarcies

kg/m³: kilogram per cubic meter

**calculated at 310 bars and 76 degrees C*

References:

Baker, E. T., Jr., 1979, Stratigraphic and hydrogeologic framework of part of the coastal plain of Texas: Texas Department of Water Resources Report 236, 43 p.

Jaeger, John and Cook, N.G., 1979. Fundamentals of Rock Mechanics, Chapman and Hall Publishers, London.

Lundstern, J.E. and Zoback, M.D., 2020. Multiscale variations of the crustal stress field throughout North America, Nature Communications, 2020 Apr 23:11(1) doi:10.1038/s41467-020-15841-5.

Walsh, F.R and Zoback, M.D., 2016. Probabilistic assessment of potential fault slip related to injection-induced earthquakes: Application to north-central Oklahoma, USA. Geology v. 44 no. 12, pp. 991-994 doi:10.1130/G38275.1

Zoback, M. L., M. D. Zoback, J. Adams, S. Bell, M. Suter, G. Suarez, K. Jacob, C. Estabrook, M. Magee, 1991, Stress Map of North America, Geological Society of America.