WATER SOURCE STUDY

UCCB PROJECT

CAT CANYON OIL FIELD

SANTA BARBARA COUNTY, CALIFORNIA

prepared for:

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**APPENDIX**
PURPOSE

Katherman Exploration Co., LLC has been retained by PetroRock LLC to examine the potential water sources (both potable and non-potable) available under and adjacent to their California, United California and Bradley Leases (known as UCCB) in the Cat Canyon Oil Field located in northern Santa Barbara County, California (Figure 1). The anticipated usage of these potential water sources would be for future operations planned for the subject leases. For the purpose of this report, the term potable water is defined by the standards set by the State Water Board and the California Department of Health for drinking water and water supplied to the public by community water systems. These primary and secondary standards or Maximum Contaminant Levels (MCL’s) are utilized by Santa Barbara County Environmental Health and can be accessed in the California Code of Regulations; Title 22, Division 4, Chapter 15: Domestic Water Quality and Monitoring Regulations.

INTRODUCTION

PetroRock LLC is currently pursuing design and operational plans for a cyclic steaming project to develop and produce the oil reserves present in the lower sands of the Sisquoc Formation underlying the UCCB leases located in Sections 14 and 23, Township 9 North, Range 33 West, SBB&M. Originally drilled and produced by CONOCO starting in the mid 1960’s, the CADOGGR records indicate a total of 226 wells drilled on the United California and over 180 wells on the California leases. Much of the production history of both leases involves cyclic steam recovery. The last full year of oil and gas production on these leases was 2007, when Greka Oil and Gas, Inc. was the operator. In that year the average production on the California Lease was approximately 20-30 barrels of oil per day (BOPD), 20 thousand cubic feet of gas per day (MCFPD), and 30-60 barrels of water per day (BWPD). The United California Lease production was 15-20 BOPD, 10-15 MCFPD, and 60-80 BWPD. The average gravity of the oil on both leases was 12 API.

PLANNED OPERATIONS

PetroRock LLC is moving forward with the permitting of a cyclic steaming project in order to extract the oil and gas unproduced and bypassed from the past secondary recovery operations of Conoco, and later Shell Oil (SWEPI) and Vintage Production of Oklahoma. The success of
such an operation requires a reliable source of water (either potable and/or non-potable). In the past a water extraction well on a nearby lease (Goodwin) was the primary source of water (potable) for the steaming activities. While neither this well nor any of the existing area water wells have been examined in detail, it is likely that they produced water from relatively shallow depths (<600 feet).

It is also assumed that this fresh (potable) water was produced (400-600 feet) from aquifers (reservoirs) within the unconsolidated sands of the Paso Robles Formation, the primary source of ground water (potable) in northern and central Santa Barbara County, including the Santa Maria Groundwater Basin, within which the subject leases fall.

**GENERAL STRATIGRAPHY**

Sedimentary units logged in wells and underlying the UCCB area range in age from Pleistocene to Miocene. The units mapped and used in this report are in Figure 2. Worts (1951), in discussing the Santa Maria Ground-Water Basin, divides the subsurface strata into two categories: 1) Unconsolidated Water Bearing Formations, which essentially are devoid of oil production, and 2) Consolidated, Essentially Non-Potable Water Bearing Formations, which include oil-bearing formations below the base of fresh water.

The unconsolidated, water-bearing formations contain potable water and, in the lease area, include the Orcutt Formation, Paso Robles Formation and Careaga Sand.

**ORCUTT SAND:** The Orcutt Sand, which forms the surficial sediments in the lease area, is a Pleistocene terrace deposit of fluvial origin and comprised of gravel, sand, clay and silt. This zone in the Cat Canyon Area is above the regional water table and is devoid of water.

**PASO ROBLES:** The Orcutt is underlain by the non-marine Pleistocene Paso Robles Formation and is comprised of somewhat compacted gravel, sand, clay and silt beds occurring in discontinuous lenticular bodies. This aquifer/reservoir is the primary source of potable water to area ranches and farming operations. The Paso Robles overlies the shallow marine Careaga Sand.

**CAREAGA:** The Careaga includes an upper member of sand and gravel beds, named the Graciosa Coarse-Grained Member. In places, the Graciosa is indistinguishable from the overlying Paso Robles, but this horizon can be a prolific fresh water aquifer. The lower member of the Careaga consists of fine- to medium-grained sand and is referred to as the Cebada Fine-Grained Member. In the subsurface, as indicated in well logs on the UCCB leases (Figure 2), the
contact between the Paso Robles and the upper Careaga Sand appears to be erosional, with clay members of the Paso Robles filling depressions at the top of the Careaga.

The older consolidated formations, which generally contain non-potable water and oil in the lease area, include the Foxen Mudstone, Sisquoc Formation and Monterey Shale.

**FOXEN:** The Foxen unconformably underlies the Careaga, and consists primarily of mudstone, clayey siltstone and in places fine-grained silty sandstone beds. In addition, the Foxen sands (lower) have produced oil in other areas of Cat Canyon, mostly to the north. In the UCCB area the Foxen Formation does contain silty sands directly below the Base of the Careaga interval, which do not appear to be oil-bearing, but rather water-bearing. In the lease area, the Foxen attains a thickness of up to 1,300 feet and overlies unconformably the Sisquoc Formation.

**SISQUOC:** The Sisquoc interval consists of an upper zone of siltstone and claystone underlain by thick fine- to coarse-grained sandstone beds and clay interbeds. Many of these Lower Sisquoc sands are oil-bearing not only on the subject leases, but within the larger area of the Cat Canyon Oilfield. The Sisquoc in the lease area is unconformably underlain by shales and cherts of the Miocene Monterey Formation, which is also a primary source of oil production within the Cat Canyon field area, as well as across the bulk of the Santa Maria Basin. Water produced from these older formations is considered non-potable and generally contains salinities of 12,000 parts per million (ppm) or greater.

**MONTEREY SHALE:** The Monterey Formation is comprised of a series of deep water marine, calcareous and siliceous shales that are naturally fractured through diagenetic change. The shales are not only the major oil producing horizon in the Santa Maria Basin, but are also the primary source rock for the oil found throughout the basin regardless of which reservoir the oil is produced from. Water associated with the Monterey is generally considered non-potable, however these older rocks can produce water that is highly variable in its salinity. Varying from 600 to 30,000 ppm the Monterey salinities are often dependent on depth, as well as proximity to Monterey outcrops. In the Cat Canyon Area Monterey TDS levels are generally between 7,000 and 20,000 ppm.

**STRUCTURE**

The general structure of the UCCB area consists of a homoclinal which deepens from east to west. The slope of the homoclinal varies based on the unit mapped, with greater slopes on the deeper formations, ranging from about 9° at the Top Careaga to more than 15° at the Top S1B
Sand within the Sisquoc Formation. Below the Careaga Sand, the underlying units are shown to thicken from east to west (Figure 3). The Careaga Sand thickness is greater near the center of the lease area, from northwest to southeast, and thins slightly on the northeast and southwest corners.

WATER SOURCES

Currently there are no available water sources on the subject leases, therefore new sources of water must be developed for PetroRock’s cyclic steaming project outlined above. PetroRock anticipates needing a minimum of 30+ acre feet per year (AFY) up to 300 acre-feet of water per year. The following are various options for obtaining both potable and non-potable water supplies in quantities necessary for the anticipated cyclic steam operations. The estimated rate of water production for these various options is shown in a rate of gallons per minute (gpm), as well as barrels per day and acre feet per day, assuming an operational period of 12 hours per day for water sources derived from a well, and 24 hours per day for a pipeline source and/or associated water production from the producing wells on these leases or other leases in the vicinity.

OPTION 1—POTABLE WATER FROM EXISTING WATER WELLS

This option includes the development of fresh water from the reworking of any existing water well on the Goodwin property and/or from any existing water well in the lease area. The Goodwin A water well was, according to very limited records, supplying fresh water to the subject lease during a period of steaming operations from the mid-1960’s through the early 1980’s. However, the location of this well is currently unknown. This option also includes the potential purchase of water from existing domestic or irrigation water wells from nearby properties. Unfortunately due to the fact that local water well data is held confidential by the State and County, we were unable to obtain any meaningful data on nearby water wells. This issue will require a further investigation should Option 1 be a viable candidate for obtaining fresh water. Obviously, the downside of this option is that the project may be restricted in how much water can be purchased and whether a nearby existing well would even be capable of supplying the volume of water necessary in the early years of the project. In addition this supposed Goodwin water well is likely located on a lease currently operated by another operator, Greka Oil & Gas. Below is a listing of the estimated costs involved in implementing Option 1.
Cost of pipeline - Est. $50,000-$75,000 per mile from an area water well; distance to the Goodwin Lease from the proposed central tank battery is approximately 0.6 mile. The distance to the PetroRock Travis Lease is 1.2 miles. Purchase price and/or availability for water from an adjacent property – unknown

OPTION 2 — POTABLE WATER FROM FUTURE UCCB PASO ROBLES WELLS

Drill a new water well(s) on the leases into the Paso Robles Formation, which is the primary water source for all area wells. The Paso Robles is present underlying the entire lease. The upper portion of the Paso Robles appears to be above the regional water table; however, based on well logs from the lease area, the thickness of the saturated zone ranges from 200 to 750 feet (Figure 4). Because the regional water table is relatively flat, the thickest saturated zone will be near the northwest corner of the lease, near the well pad sites S, T, U and V. However, water can be accessed with a well drilled on or near the central tank battery. The estimate of water in storage within the Paso Robles interval under the UCCB properties only is approximately 39,800 acre-feet (AF). Below is a list of pertinent estimated costs.

Cost to drill and complete the well - $100/foot

Depth of well – 750 to 900 feet

Specifications for well - 8 inch PVC casing; well screen (perf's) range from 400 to 900 feet

Estimated water production rate - 300 gpm or 5,100 bbls/day or 0.7 AF/day*
* Assumes operation of the well for 12 hrs/day

Estimated water quality - 800-1,000 TDS
OPTION 3 — POTABLE WATER FROM FUTURE UCCB CAREAGA WELLS

Drill a new water well into the Careaga Sands. The Careaga is the lowermost water-bearing formation of the Santa Maria Groundwater Basin and produces potable water from deeper strata. However, there is no indication that the Careaga is being accessed as a water source anywhere in the vicinity of the subject leases or within the Cat Canyon area, making this groundwater a new source of untapped fresh water. The top of the Careaga ranges from about 1,100 feet below grade (-500 feet VSS) in the northwest corner of the lease area to about 550 feet below grade (180 feet VSS) in the northeast lease area (Figure 5). The thickness ranges from about 350 feet near the northeast corner of the lease to greater than 425 feet in the northwest portion of the lease (Figure 6). Because the regional structure slopes from east to west, the shallowest drill location to tap into the Careaga water is on the east side of the lease, near Site Z. The estimate of water in storage within the Careaga interval under the UCCB properties only is approximately 42,700 acre-feet (AF). Below is a list of pertinent estimated costs.

Cost to drill and complete the well - $100/foot

Depth of well - 900 to 1,100 feet

Specifications for well – 8 inch PVC casing; well screen (perf’s) from 600 to 1,100 feet

Estimated water production rate - 400 gpm or 6,850 bbls/day or 0.9 AF/day *

* Assumes operation of the well for 12 hrs/day

Estimated water quality - 600-700 TDS
OPTION 4— NON- POTABLE WATER FROM FUTURE UCCB FOXEN WELLS

Drill a new water well to be completed in the base of the Careaga and the upper Foxen or just from the upper Foxen only. The estimated TDS of the Foxen is between 1,500 and 4,000 ppm; the resulting water will be non-potable and will require treatment prior to use in the cyclic steam operation. A well completed in the Careaga and Foxen, where the water from both zones would be comingled may be as deep as 1,500 feet below grade, assuming drilling to the mid-point of the Foxen (Figure 7). Sand in the upper part of the Foxen appears to be better developed in wells in the northeastern updip portion of the lease, in the area of Sites AA and AB, and possibly Site Z. Due to the expected brackish nature of the comingled produced water and the non-potable water solely from the Foxen, there likely would be a reasonable volume of non-potable water that can be produced per year although the produced volume from the Foxen is unknown. Below is a list of pertinent estimated costs.

Cost to drill and complete the well - $150/foot

Depth of well – 1,500 feet

Specifications for well - 8 inch Steel casing; well screen (perf’s) from 1,000 to 1,500 feet

Estimated water production rate - 200 gpm or 3,400 bbls/day or 0.44 AF/day *

* Assumes operation of the well for 12 hrs/day

Estimated water quality – 1,500-4,000 TDS

Additional cost for treatment - unknown
OPTION 5— NON- POTABLE WATER FROM FUTURE UCCB SISQUOC WELLS

Drill a new water well to be completed in the Sisquoc S1B Sand. The estimated TDS of the Sisquoc water generally is greater than 10,000 ppm and may be as high as 20,000 ppm. Water from the S1B Sand will require treatment prior to use in the cyclic steam operation. The top of the S1B Sand in the lease area ranges from about 3,000 feet below grade (-2,400 feet VSS) to about 2,200 feet below grade (-1,300 feet VSS) from west to east (Figure 8). The thickness ranges from about 200 feet at the northeast corner of the lease to more than 300 feet near the southwest corner (Figure 9). Although at deeper drill depths, a well drilled at Sites I and/or J has the likelihood of penetrating the thickest accumulation of S1B sands. Note that the S1B Sand shows a higher resistivity in a few wells in the southeast portion of the lease where it has been completed and produced oil. Water production from this sand in oil producing well(s) has been up to 170 to 190 bbls per day. However, a completion in a non-oil bearing section of the S1b may result in a significant increase in water productivity. Below is a list of pertinent estimated costs.

Cost to drill and complete the well - $200/foot

Depth of well – 2,500 to 3,200 feet

Specifications for well - 8 inch Steel casing; well screen (perf’s) from 2,200 to 3,200 feet

Estimated water production rate - 75 gpm or 1,250 bbls/day or 0.2 AF/day *

* Assumes operation of the well for 12 hrs/day

Estimated water quality – 10,000-15,000 TDS

Additional cost for treatment - unknown
OPTION 6— NON-POTABLE WATER FROM THIRD PARTY OPERATORS AND FUTURE UCCB PRODUCING WELLS

Procure water associated with oil production in the Sisquoc and Monterey producing wells from adjacent producers. This produced water is non-potable and would require treatment prior to use in the cyclic steam operation. Potential sources include adjacent leases operated by B. E. Conway, Greka, and ERG Operating Co. The estimated TDS of the produced water from the Sisquoc Formation may range from 10,000 ppm to 20,000 ppm. The TDS of the produced water from the area Monterey wells is estimated to be 7,000 ppm to 20,000 ppm. Conway Energy and ERG water production trends were obtained from available public information (CADOGGR website) and verbal communication with B. E. Conway. The Conway water production currently averages 150-180 barrels per day or 6,300-7,500 gallons per day. The ERG water production at their Cantin Lease currently averages 200 barrels per day, but in 2012-13 the lease averaged as much as 600-700 barrels of water per day. Likewise, there is produced water associated with the oil production on Greka’s leases. Produced non-potable water from PetroRocks’s UCCB future wells also will be a primary source of non-potable water to be recycled. Below is a listing of the estimated costs involved in implementing Option 6.

Cost - Est. $50,000-$75,000 per mile from an adjacent lease to the proposed central tank battery.

Additional cost for treatment - unknown
CONCLUSIONS

The primary goal of this PetroRock requested study was to identify the various water resource options for the project and to determine measures to make the overall water use by PetroRock a less than significant impact on the environment. Ultimately the sources of water for the UCCB project will be dependent upon the type of water, salinity and volume that is approved for usage for this project by the Santa Barbara County Planning & Development Department, and eventually by a vote of the Planning Commission. Based upon the report findings and the associated options for water sources, the following is recommended.

**Potable Water Sources:**

Option 1 is not likely a viable option, as PetroRock does not have legal access to a neighboring well(s) nor is the current status of the well(s) known at this time. Options 2 and 3 advocate for a potable water supply from future water wells drilled and completed on the subject property (leases) to meet an expected demand for water of as much as 300 acre-feet (AF) per year. However, due to the current drought conditions negatively affecting the regions groundwater basins, the following mitigation measures are suggested to reduce potable water use for the project to a less than significant level.

1. Restrict the use of potable water for the proposed project to 35 acre-feet (AF) per year for the life of the project from sources on and under the subject leases. The annual extraction of 35 AF of water represents 0.04% of the total water in storage (82,500 AF) under the subject leases (see Appendix). In addition the average annual recharge to the Paso Robles and Careaga aquifers under these leases from rainfall infiltration and runoff is estimated at 165 AF. Consequently, the projected yearly usage equals only 21% of the annual recharge.

   OR

2. Restrict the use of potable water for the proposed project to 50 acre-feet (AF) per year for the first three (3) years of the project, then reduce the potable water usage to 20 AF for the following five (5) years. Additional water requirements for the project during this five year period would be met from a non-potable water source as outlined in Option 4, 5 and 6. Eventually the project would phase out the potable water use for steam generation with the use of non-potable water sourced from the producing wells that will be
drilled and steamed as the main component of the project (option 6). The extraction of 50 AF of water represents 0.06% of the total water in storage 82,500 AF) under the subject leases and 30% of the annual recharge (see Appendix).

3. Implement a minimum distance to any adjacent or nearby domestic or ag water wells to 500 feet.

4. Maintain a well monitoring program whereby the static water levels, the pumping water levels, the observed drawdowns, the well production volumes, water quality, etc. are recorded on a quarterly basis.

Some water use components of the project, such as an office, a control building/facility, safety procedures, dust control, facility maintenance, etc. will still require a minimal amount of potable water over the life of the project.

Non-Potable Water Sources:

As was discussed in the above mitigation measures for potable water sources, we feel it is important in the long term (after the first three years) to begin recycling the water produced back during the early steaming phases of the project in addition to the non-potable reservoir water that will be extracted along with the oil and gas to provide a non-potable water source for this operation. This non-potable water is expected to fully replace the need for potable water in the generation of steam for the project by year nine. Therefore, it is suggested that PetroRock implement the following measures allowing the processing and use of non-potable water:

1. Utilize Option 6 and begin the process of recycling of produced water from PetroRock's steaming operation after year three.

2. Consider Options 4 and 5 if additional non-potable water is required above that supplied by the PetroRock operations as stated above.

3. Provide annual water sampling data to demonstrate that the recycled and non-potable water to be treated and use for steaming is indeed classified as non-potable according to the standards set by the State Health Dept. and the County of Santa Barbara.
Therefore, after careful consideration of all of the water resource option relative to the needs of the project, it is recommended that a combination of fresh (potable) water and recycled (non-potable, higher salinity, brackish water) water during the life of the project would appear to be preferable, where fresh water is utilized in the early phases of the project in order to prove the viability of steaming for enhanced oil recovery, and is then phased out over time and replaced by recycled produced water and/or a brackish water source that will be processed in a treatment plant for use in the steam generation. It is estimated that the project's cyclic steam wells will not produce a sufficient amount of non-potable, associated water suitable for recycling and treatment with eventual use in the steam process until at least year four of the project. This will also allow time to analyze what type of water treatment will be required in order to process the non-potable water for use as a steam water source.

This report was written and compiled by C. E. Katherman and C. A. Walch

Date: June 24, 2015

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FIGURES
Figure 1: Site Location
Figure 2: Type Log – California 76
Figure 3: West to East Cross Section Showing Homoclinal Structure

Note downgradient thickening of stratigraphic units, especially below the Careaga/Foxen Contact

Line of Section Shown on Figure 5
Figure 5: Contour Map on Top Careaga Sands

Cross Section A-A' Shown on Figure 3
Figure 6: Contour Map on Careaga Sand Thickness
Figure 7: Contours on Base Careaga Sand/Top Foxen Formation
Figure 8: Contours on Top S1B Sand, Sisquoc Formation
Figure 9: Contours on S1B Sand Thickness – Sisquoc Formation
APPENDIX
I. Estimates of Water in Storage

A. Paso Robles - Water In Storage

\[ 610 \text{ ac's} \times 43560 \text{ sf} \times 250 \text{ ft} \times 7.48 \text{ g/sf} \times 0.26/325850 \text{ gals} = 39847 \text{ Acre feet} \]

Assumptions

Lateral Extent or Area = 610 acres

Square Feet/Acre = 43560 SF

Average Gross Thickness = 450 Feet

Net Saturated Thickness = 250 Feet

Water per Square Foot = 7.48 Gallons/SF

Gallons per Acre Foot = 325,850 gallons

Specific Yield = 26\% (medium sand)
B. Careaga - Water In Storage

\[ 610 \text{ ac's} \times 43560 \text{ SF} \times 350 \text{ ft.} \times 7.48 \text{ G/SF} \times 0.20/325850 \text{ gals} = 42697 \text{ Acre Feet} \]

**Assumptions**

- Lateral Extent or Area = 610 acres
  - Square Feet/Acre = 43560 SF

- Average Gross Thickness = 400 Feet

- Net Water-Saturated Thickness = 350 Feet

- Water per Square Foot = 7.48 Gallons/SF

- Gallons per Acre Foot = 325,850 gallons

- Specific Yield = 20% (fine sand)
II. **Estimates of Annual Water Recharge**

**Paso Robles/Careaga Recharge within UCCB Leases**

610 acres x 0.27 AF/ac = **165 AF/yr**

**Assumptions**

- Cat Canyon average annual rainfall = 18-20 inches
- Average annual period of recharge = 5 days/year
- Average annual recharge amount = 0.27 AF/ac
  (calculated from 5 days of 1 inch of rain or more, soil permeabilities of 0.40 gal/day/sq. ft.)
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III. *Estimates of Annual Water Recharge (under drought conditions)*

**Paso Robles/Careaga Recharge within UCCB Leases**

610 acres x 0.16 AF/ac = **98 AF/yr**

**Assumptions**

- Cat Canyon average annual rainfall = 9-10 inches
- Average annual period of recharge = 3 days/year
- Average annual recharge amount = 0.16 AF/ac
  
  (calculated from 3 days of 1 inch of rain or more, soil permeabilities of 0.40 gal/day/sq. ft.)