Produced Water Reuse at the Kern River Oil Field

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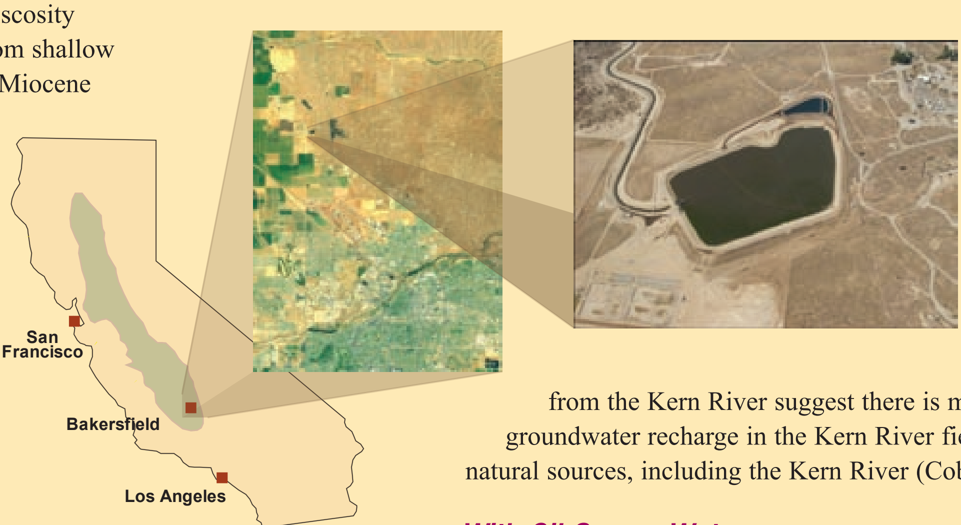
Located along the southeastern edge of the San Joaquin Valley is the giant Kern River oil field. With humble origins – it was discovered in 1899 in a 45-foot shaft dug with shovels – this oil field originally contained approximately 4 billion barrels of oil (1 barrel = 42 gallons). The discovery of the field started an oil boom in Kern County that continues today.

Much of the field's high-viscosity "heavy" oil is produced from shallow fluvial deposits of the late Miocene to Pleistocene Kern River Formation. The productive oil interval ranges from less than 100 feet deep to approximately 1,600 feet deep. Through 2003, approximately 1.8 billion barrels of oil had been produced. Production has remained relatively constant for the past five years, at more than 100,000 barrels per day (DOGGR, 2003). More than 90 percent of the estimated ultimate 2-billion barrel recovery will have been accomplished with steam-assisted, secondary recovery production processes. The Kern River oil field is one of the world's largest steam-flood oil projects and the sixth largest oil field in the United States.



Kern Hydrology

Hydrologically, the field is located near the mouth of Kern River Canyon on the Kern River alluvial fan, a huge fan-shaped wedge of sand and gravel on the east side of the San Joaquin Valley that forms where the bicarbonate-rich waters of the Kern River exit the Sierra Nevada foothills. This is the main gateway through which much of the water that recharges the valley's shallow aquifers flows.

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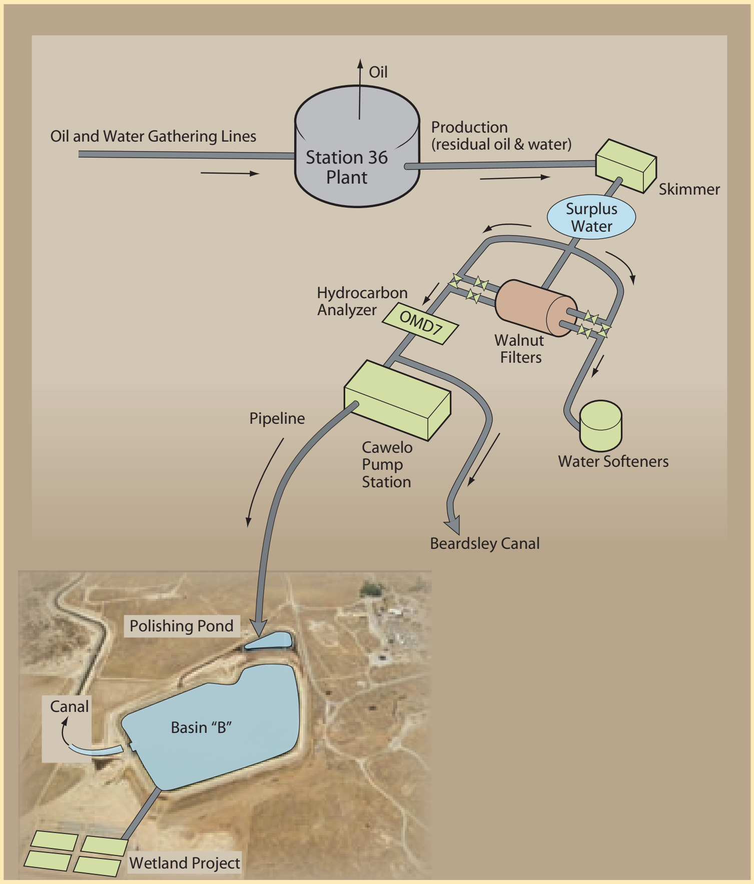
The principal aquifer in the Kern River field is an unconfined aquifer comprised of the lower Kern River and upper Chanac formations. This aquifer is overlain by several perched aquifers within the upper Kern River Formation. Underlying the unconfined aquifer are several confined aquifers in the lower Chanac and Santa Margarita formations that do not appear to be hydraulically connected to the unconfined aquifer (Coburn, 1997). The potentiometric surface in the regional unconfined aquifer and the smaller perched aquifers dip westerly and are parallel to the structural dip of the Kern River Formation. Extensive fluid depletion in zones along the up-dip edge of the field and the lack of a potentiometric gradient showing flow outward from the Kern River suggest there is minimal groundwater recharge in the Kern River field from natural sources, including the Kern River (Coburn, 1997).

With Oil Comes Water

In mature oil fields with high water-to-oil recovery ratios that use steam as the primary recovery technique, water is the result—lots of it! Steam is injected as vapor into the Kern River Formation, where it heats the oil to lower the viscosity. The steam condenses and occupies part of the pore space that is effectively produced on a daily basis. Because the steam and the produced water are geochemically equivalent, it is difficult to know how much recycling actually takes place. But about nine barrels of water are produced along with every barrel of oil. Therefore, over 900,000 barrels, or 116 acre-feet of water are produced each day. Chevron reclaims about half of this water to generate new steam to enhance oil production and for other in-field uses. However, the remaining water, approximately 58 acre-feet, represents what would normally be a costly disposal problem and potentially wasteful use of water.

Various degrees of treatment of produced water are often required prior to any discharge for agricultural use. But produced water from the Kern River oil field is uniquely of very high quality and contains a minimal amount of dissolved solids and metals. To treat any hydrocarbons that may be left in the water after flotation and mechanical separation, the produced water is filtered through large walnut shell-filled filters. The shells have exceptional surface characteristics for coalescing and filtration, plus excellent resilience to wear and tear. Chevron conducts a rigorous water-monitoring program to ensure the quality of its produced water prior to discharge. Discharge is governed by National Pollutant Discharge Elimination System permits overseen by the California State Water Resources Control Board. Any deviation from the standards can result in a substantial fine by the state.



Kern River field produced water system schematic and reservoir for produced water for Cowelo Water District.

Two discharge points currently exist for the excess produced water: the Beardsley Canal, operated by the North Kern Water Storage District, and a pipeline to the Cawelo Water District. Both discharge points convey excess produced water strictly for agricultural use. Historically, the Beardsley Canal was the sole discharge point for all water leaving the oil field; however, in the early 1990s it became apparent that another discharge point would be required to handle the ever-increasing volume of produced water.

A User is Found

Just a few miles from the oil field, Chevron (then Texaco) learned that valley farmers needed additional water for irrigation. After lengthy discussions, the Cawelo Water District recognized that Chevron's excess produced water was a safe and reliable source of agricultural water and in 1994 signed a long-term conservation agreement with Chevron. Cawelo then had an 8.5-mile pipeline permitted and built to connect its local reservoir with the Kern River oil field. Chevron spent about $1.8 million to build a pump station to deliver the water into the pipeline. Through a long-term contract that was signed in 1996 and runs through 2011, the water district is able to buy millions of barrels of water at a very reasonable price. Chevron and Cawelo are also jointly exploring the innovative use of constructed wetlands to further treat produced water for agricultural reuse. This pilot project is in its third year and shows great promise in reducing residual organic compounds to very low or nondetectable levels.

Local farming interests in this semi-arid region of California use blended excess produced water to irrigate over 46,000 acres of crops, including grapes, citrus, almonds, and pistachios. Blending with fresh water sources is required to lower the concentration of boron from naturally occurring levels of about 1.0 milligram per liter (mg/l) to below 0.5 mg/l, to avoid any leaf or plant damage. This unique and novel venture creates a long-term, economical use of excess produced water and achieves the mutual goals of Chevron and Cawelo. The project also stresses the importance of maximizing fresh-water resources through cooperative efforts among public agencies and private industries. John Jones, former manager of the Cawelo Water District, stated, "This is a major conservation project for us. It's a resource that we knew was there." It is a "win-win" situation for both entities.

References

Coburn, M.G., and J.M. Gillespie, 1997. Aquifer architecture of the Kern River, Chanac and Santa Margarita formations in the Kern River Field, California, Am. Assoc. of Pet. Geol., 81: 682.

DOGGR (California Division of Oil, Gas and Geothermal Resources) Annual Report, 2003.