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IN FOCUS

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Hydraulic Fracturing and Water Use in California

Hydraulic fracturing (sometimes referred to as fracking) is a technique that uses water, sand, and chemicals under pressure to enable or enhance the production of natural gas and crude oil from formations with low permeability. In California, recent drought and estimates of recoverable energy resources have drawn attention to the current and future impacts of fracturing on the state's water quantity and quality. While available data and data gaps on water use in hydraulic fracturing are presented herein, analysis of water quality topics is beyond the scope of this discussion.

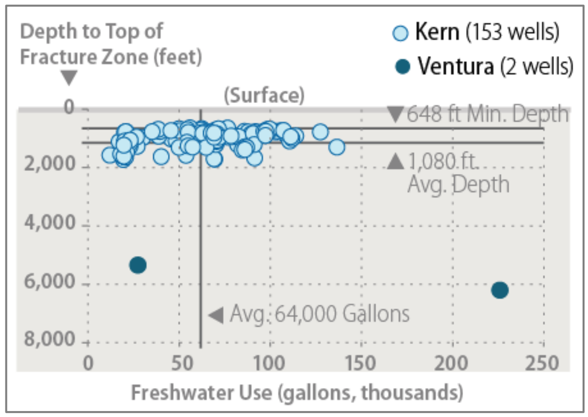
Fracturing has gained attention nationally in association with energy development from shale and related tight oil formations, such as the Bakken (ND), Eagle Ford (TX), and Marcellus (PA, WV, MD). These "unconventional" formations are both sources and reservoirs for hydrocarbons. In these formations, fracturing is combined with horizontal drilling to enhance permeability to access natural gas and crude oil trapped in the shale.

How Much Water Is Used in Fracturing in California?
In California, fracturing historically has been associated with aging conventional petroleum fields in central and southern California. Data from the California Department of Conservation's Division of Oil, Gas, and Geothermal Resources (DOGGR) for early 2014 indicate that fracturing in California is used primarily in shorter vertical wells (often with some directional drilling), rather than in extended horizontal wells or wells accessing deeper formations. These vertical wells intercept low-permeability formations. More than 95% of recent fractured wells are accessing California's diatomite formations, which are sedimentary rock formed mainly of the hard skeletons of fossilized unicellular algae (diatoms). The wells in these formations are at depths of 1,000 feet on average (see **Figure 1**). And the fractured intervals are short—50 to 100 feet—compared to the long fractured intervals used to tap shales being developed in other states.

To stimulate production from these diatomite formations, relatively fewer fracture stages are often used, in contrast to the multistage fracturing along the comparatively long laterals used to stimulate natural gas or oil production from shale formations such as the Marcellus, Bakken, and Eagle Ford. Also, fracturing in California rarely involves the use of friction reducers. (When reducers are used, more water is typically required.) Due to these differences, the water quantity used in fracturing a well in California (**Figures 1 and 2**) is on average an order of magnitude lower than the high-volume, multistage fractures of horizontal wells drilled in shales (e.g., a typical Marcellus Shale gas well uses 3 to 8 million gallons of water). State data on water use associated with well drilling and other completion activities do not appear to be available in California.

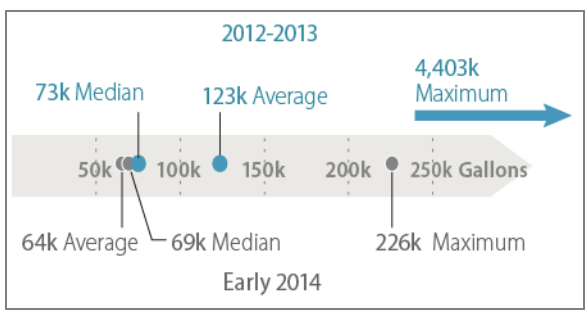
None of the available fracturing disclosures for California in 2012, 2013, or early 2014 revealed fracturing for gas well stimulation. Data from the limited set of disclosures (19) from gas wells fractured in 2011 in California (Sutter, Colusa, and Glenn counties) indicate an average water use of 25,000 gallons.

Figure 1. Depth of Fractured Well and Water Use for Fracturing in California in Early 2014



Source: Data from DOGGR well stimulation disclosures (accessed June 26, 2014, included data from January 2014 to May 6, 2014).

Figure 2. Estimates of Water Use for Well Fracturing in California During 2012 and 2013 and in Early 2014



Source: Data from FracFocus and DOGGR.

Voluntary disclosures of fracturing in California in 2013 (791 wells fractured using, on average, 123,000 gallons of water per well) indicate an annual freshwater use of around 300 acre-feet (97 million gallons), with the majority of the use in Kern County. For regional context, this quantity represents less than 0.01% of the average annual freshwater withdrawals in Kern County. For context within oil and gas operations, DOGGR injection well data for 2013 indicate that 12,110 acre-feet (4 billion gallons) of freshwater sourced from water wells or domestic water supplies were used by the oil and gas industry for enhanced oil recovery through steam and water flooding. Based on these data, fracturing freshwater use in 2013 may have represented less than 3% of the freshwater use in the state for oil and gas production enhancement techniques.

> In contrast to fractured wells in the Marcellus, Bakken, or Eagle Ford shales, the water quantity associated with the typical fractured well in California is on average an order of magnitude lower than shale fractured wells elsewhere.

Under California's 2013 well stimulation law, SB 4, operators began reporting to the state the water used in fracturing and other stimulation techniques in January 2014. Fracturing in 2014 may be dampened as efforts are made to comply with new state rules, including public notification and groundwater monitoring and testing requirements. In the long term, the future water supply impact of fracturing will be shaped by the numbers and types of wells fractured and the level of reliance of fracturing technologies and practices on freshwater. Geology, regulations, and market conditions are among the factors influencing a producer's decisions on when and where to invest. The discussion below provides current information on how well development in some basins may influence the future water use for fracturing in the state.

Is the Water Quantity Used for Fracturing Anticipated to Increase Substantially? The development of California's shale resources, most notably the Monterey shale, as a reservoir appears to be constrained by multiple factors, such as increasing indications that a significant quantity of oil that was formed in the Monterey shale migrated out and into shallower formations (e.g., diatomites) and that much of the Monterey shale formation may not have experienced conditions favorable to oil generation. Therefore, although there have been attempts and experimentation with directly developing the Monterey shale and other California shales, there are few indications that they will produce much natural gas or crude oil in the near future.

In some of southern California's existing oil fields (e.g., the Los Angeles basin), fracturing is not needed to stimulate oil production; instead, water is injected to maintain reservoir pressure. The gas fields in northern California generally have been in small, discrete conventional formations. While there is some debate about the utility and economics of fracturing to enhance production in these fields, data do not indicate extensive use to date.

As a result, stimulation of the diatomites in Kern County likely may continue to dominate well fracturing activities in the state. In these formations, new wells are most likely to be vertical wells, in close proximity to each other and within existing oil fields. How many of these wells are developed is key to forecasting future impact.

While more fracturing operations may occur in the diatomites than in other California formations, more information on the likelihood of higher-volume fractures is needed. That is, not all fractured wells in California fall close to the average water use; for example, 8% of fractured wells (i.e., the state's 24 fractures that each used above 1 million gallons) represented 27% of the water use for fracturing. More detailed analyses of these higher-volume fractures are key to forecasting fracturing's water supply impact.

How Much Water Is Lost Due to Fracturing? DOGGR data for early 2014 indicate that almost 3,000 gallons of the average 64,000 gallons injected per well were brought back to the surface; that is, an average recovery rate of 5%. Other water also flows to the surface during the operating life of a well. This recovered and formation water is broadly known as *produced water*. In general in California, the ratio of the volume of oil brought to the surface and the produced water is 1:9. DOGGR data for 2013 indicate that produced water from oil and gas operations in California totaled 410,000 acre-feet (133.5 billion gallons). Produced water can vary widely in its quality and in its constituents. Therefore, determining how much water is lost to a formation or lost due to degradation of water quality as a result of fracturing is difficult to calculate. This is especially the case for California, where significant quantities of produced water are reused in oil and gas operations (e.g., reinjected to maintain pressure or to steam flood an oil field) or in some cases treated and used in agriculture. Available California data do not appear to differentiate between reinjection for oil and gas operational benefits and reinjection for disposal, as both types of injection use Class II wells permitted through the U.S. Environmental Protect Agency (EPA) underground injection control (UIC) program. In February 2014, a California Department of Conservation witness testified that in California approximately 70%-75% of all produced water (flowback fluid and formation water) from oil and gas wells is injected into hydrocarbon formations for enhanced oil recovery (water flooding). Around 20%%-25% is injected into Class II wells for disposal, and roughly 5% is treated for reuse. Industry reports some reuse for agricultural purposes where water quality requirements are met. There has been interest in reusing produced water in subsequent fracturing activities. DOGGR data indicate that primarily freshwater continued to be used for fracturing in early 2014; there also are some recent indications from DOGGR stimulation notices that produced water use in fracturing may be on the rise.

More information on water use for hydraulic fracturing in California will be forthcoming as SB 4 is implemented. By January 1, 2015, the state must have final well stimulation rules in place and must complete a broad scientific study on well stimulation impacts. Water use and disposal reporting, groundwater monitoring, environmental assessment, and other requirements associated with the new law should generate data supporting more quantitative analyses of the impact of oil and gas development using hydraulic fracturing on California's water resources.

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