Water and the Oil and Natural Gas Industry:
Responsible Stewardship of a Precious Resource
March 2014

Water is a precious resource across the West. As westerners, we all have an interest in ensuring water is wisely used and conserved. Because the oil and natural gas industry both uses and produces water, companies carefully plan for and develop new ways to more efficiently and economically handle water in their operations.

Industry Uses Water

Industry uses water during well drilling and completion and to inject into old fields to increase production. Water is produced from wells along with oil and natural gas, and is also a product of oil and natural gas combustion. Oil and natural gas companies continue to push for more efficient and economic ways to handle water.

Besides wanting to do what's right to conserve water, companies are highly motivated to conserve water resources because, unlike farmers and ranchers who have first-in-time water rights, they must purchase most of the water used in drilling and completions operations. By improving processes to treat and reuse water multiple times, companies continue to reduce the amount required.

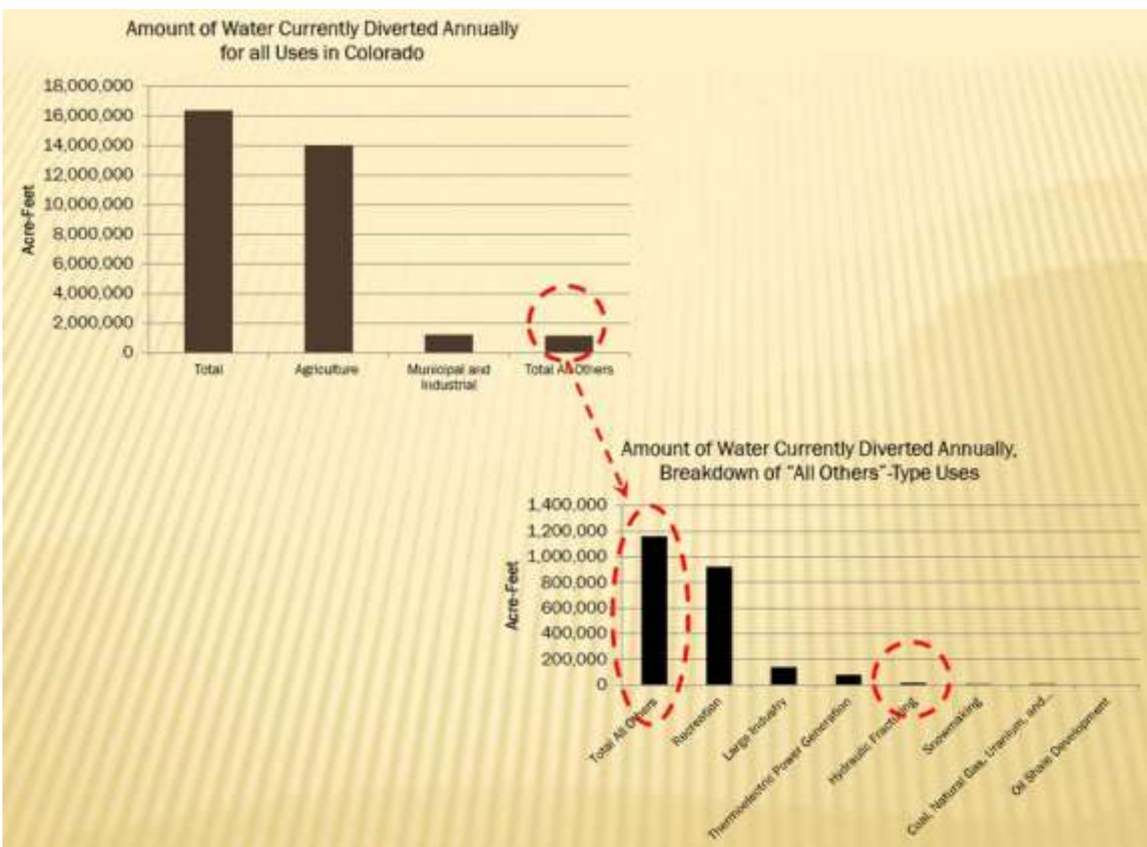

Figure 1. *Water Use in 2012 in Colorado. Source: Colorado Division of Water resources.*

During drilling, water mixed with clay, called drilling mud, is cycled through the well bore and returns to the surface. Drilling mud lubricates and cools the drill, keeps pressure on the walls of the bore hole and brings rock fragments, called cuttings, to the surface. Water used for drilling is a very small fraction of overall water use for well development, whether the well is vertical or horizontal.

Once the well is drilled, it must be completed, which involves stimulating the flow of oil or natural gas, usually done by hydraulic fracturing or "fracking." Fracking horizontal wells may require between one and five million gallons of water. While this may seem like a lot of water, it must be put in the proper context of other water uses. Oil and natural gas operations consume well under one percent of total water usage. For example, in Colorado about 14,000 acre-feet of water are used each year for hydraulic fracturing, but the entire state uses 16.4 million acre-feet per year (see Figure 1).[1] Only 0.08 percent of water use in Colorado is for hydraulic fracturing. Nationwide, the entire oil and natural gas industry represents about 0.025 percent of total water use.[2]

Compared to the water use of other economic sectors, oil and natural gas is low. In 2005, thermoelectric power plants accounted for 49% of total U.S. water use and irrigation used 31%. Conversely, the entire mining sector, which includes coal, mineral, gravel oil and natural gas extraction, accounted for 0.01 percent of total US water use (see Figure 2).[3]

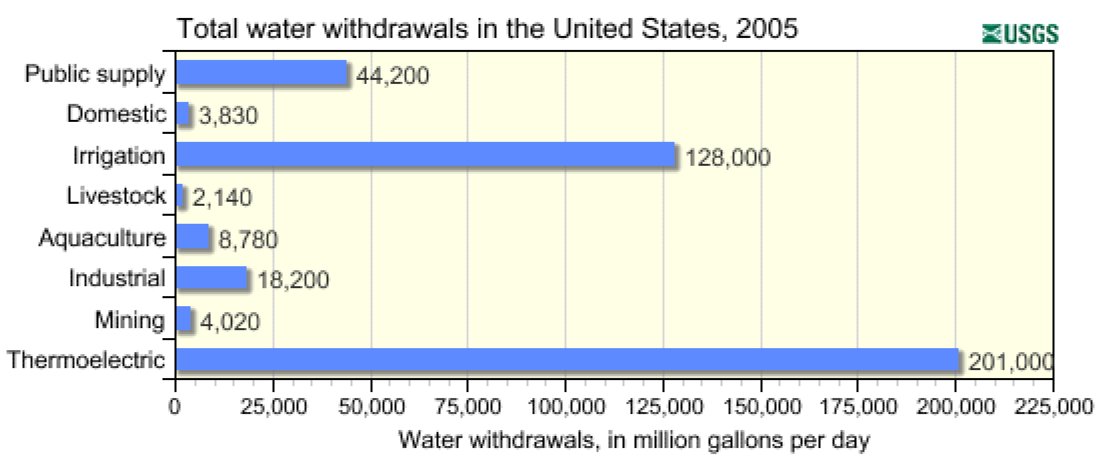

Figure 2. *Total U.S. Water Use by Sector in 2005. Source: USGS*

When the water used to produce natural gas is compared to that for other energy sources, it is also low. On anenergy content per gallon of water basis, natural gas's water intensity is about 0 to 2 gal/million btu (MMbtu). Oil's water intensity is anywhere from 1 to 62 gal/million btu (MMbtu), with oil sands mining, not conventional drilling, representing the high end of the

[1] *Water Sources and Demand for the Hydraulic Fracturing of Oil and Gas Wells in Colorado from 2010 through 2015*, Colorado Division of Water Resources, Colorado Water Conservation Board, and Colorado Oil and Gas Conservation Commission, 2012.
[2] *Total Water Use in the United States*, U.S. Geological Survey, 2005.
[3] Ibid.

range. Coal mining water intensity is on the order of 10 gal/MMbtu, and Uranium mining and enrichment is about 5 gal/MMbtu. On the very high end of water use for fuel production is ethanol, which requires hundreds to thousands of gal/MMbtu depending on the crop used to create the ethanol.[4]

Water is also added back to Earth's hydrological cycle when natural gas is burned. The total production of natural gas from an average well, about 1 billion cubic feet (Bcf), produces 12 million gallons of water when the natural gas is burned. Over twice the water used to frack a typical natural gas well returns to the air as water vapor when the natural gas is burned.

Industry Protects Water

There are legitimate concerns about ensuring drilling and hydraulic fracturing do not contaminate ground and surface water, and that is why the oil and natural gas industry is heavily regulated under the Clean Water Act, Safe Drinking Water Act, and Spill Prevention, Control and Countermeasures Rules. These along with state regulations require such best practices as:

- Baseline Testing: Before drilling takes place, companies must locate all nearby water wells and test the water quality before and after drilling in some states. The requirement to test before and after drilling protects both the water well owner and the oil and natural gas companies.
- Spill Prevention: As well pads are constructed, berms are built around equipment filled with liquids in order to contain any spills, and the company must have a plan in place to respond in case a spill does occur.
- Pit Rules: Companies are moving awy from the use of pits. They typically store liquids in above-ground storage tanks, which have systems in place to contain leaks. Where pits are used, they are double-lined, and regulations often require leak detection systems. Spills must be reported, and companies must clean them immediately.

Some fears about groundwater contamination arise from a misunderstanding of the properties of groundwater and the many layers of rock underneath the surface of the ground. Underground water aquifers are not big voids in the earth that contain water, but rather rock formations with sufficient quantities of water and large enough pore space to enable water to flow. Only relatively shallow aquifers, usually 1,000 feet or less, have the requisite physical properties to enable their use for drinking water, crop irrigation or livestock watering. On the other hand, oil and natural gas is contained far deeper underground, usually a mile or two below the surface. The water encountered when drilling to these depths cannot be used for drinking or agriculture as it does not meet quality standards.

Wells are carefully constructed to ensure that any fluids pumped into them, as well as the oil or natural gas coming out, do not leave the wellbore and contaminate underground sources of drinking water. Two to three alternating layers of steel pipes and cement are constructed in the well bore to keep fluids from migrating out into the rock formations and to keep water from drinking water aquifers from flowing into the well.

---

[4] Water Consumption of Energy Resource Extraction, Processing and Conversion, Mielke and others, Harvard Kennedy School, 2010.

Well construction is heavily regulated to protect drinking water during the drilling, fracking and production phases of the well. Drinking water aquifers are also protected from contamination by the thousands of feet of rock between them and the formations that contain oil and natural gas.

Despite the heavy regulation and engineering that prevents fluids in the wellbore from reaching underground aquifers and the extremely low risk of fracture migration, some have attempted to argue that aquifers are at risk. In a widely discredited study, Myers (2012) used modeling to argue that fracking fluids could migrate from the depth of fracturing to drinking water aquifers in less than ten years, but he made several unrealistic assumptions in his model.[5] In a direct rebuttal, Flawelling and Sharma credibly show the several physical and hydraulic constraints on water movement in the subsurface and concluded migration would take millions of years, not ten, to travel across just 100 meters of rock.[6]

There has also been concern that methane from natural gas wells will contaminate residential water wells. One study found a large fraction of water wells in the Marcellus region of Pennsylvania contained methane and claimed it must have come from improperly constructed wells.[7] The authors did not show the actual pathways between natural gas wells and water wells and did not consider natural methane in the groundwater system. They failed to take baseline water samples and could not measure any changes due to drilling. Another study found methane in 78% of 1,701 water wells prior to natural gas drilling in Susquehanna County, PA.[8] The isotopic signature of the methane did not match that of the Marcellus formation in both studies, indicating that the methane is naturally occurring and not from natural gas wells.

Several new state regulations require baseline water samples to be taken prior to and after drilling in order to understand any impacts on water quality. It is difficult to definitively understand local groundwater systems, but by testing the water quality of nearby water wells, the uncertainty of drilling impacts on drinking water can be removed. The large amount of new testing on groundwater in oil and natural gas fields will result in much more data that can be used to increase our knowledge of groundwater systems in drilling areas.

Industry Produces Water

Produced water is water from the oil or natural gas bearing formation that comes to the surface along with the oil or natural gas. In fact, sometimes wells produce significantly more water than oil or natural gas. Approximately 21 billion barrels of produced water per year are generated from oil and natural gas exploration and production. As fields age, more and more water is produced. In the United States, the ratio of water to oil is about 5:1 to 8:1.[9]

---

[5] Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers. T. Myers, *Groundwater,* 2012.

[6] Constraints on Upward Migration of Hydraulic Fracturing Fluid and Brine, S.A. Flewelling and M. Sharma *Groundwater,* 2013.

[7] Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction, R.B. Jackson and others, *PNAS,*2013.

[8] Evaluation of Methane Sources in Groundwater in Northeast Pennsylvania, L.J.Molofsky and others, *Groundwater,* **51,** p. 333-349, 2013.

[9] Produced Water Management Information System, National Energy Technology Lab, DOE, 2009

Produced water varies in quality and is often salty and can contain organic materials along with oil or natural gas. It can also contain naturally occurring radioactive material (NORM). Radioactive water and heavy brines are often disposed of back underground in deep disposal wells regulated by EPA under the Underground Injection Control (UIC) program.

Companies are developing new ways of reusing produced water. In some cases, it can be of high enough quality to use for agriculture or other industries, particularly water from coal bed methane (CBM) formations. In some areas of the West, CBM water is clean enough to be discharged to the land to provide ranchers with water for livestock or wildlife.

Oil and natural gas companies continually develop ways to recycle and reuse water. Many operators reuse water that returns to the surface after fracking, called flowback water, for multiple fracturing jobs, and some use produced water to fracture new wells. Recycling and reusing water cuts out many water hauling truck trips and reduces air quality impacts as well as conserves freshwater. Some of the techniques used to conserve water include recycling produced water for other processes, treating produced and flowback water to augment local river systems, and using effluent from a local water treatment plant for hydraulic fracturing.

The ability to reuse water depends on several factors, such as the geology of the oil or natural gas formation, water infrastructure near the wells, and the water quality required for the end use. Usually the water has to be treated before it can be reused, and water treatment can be cost prohibitive. Water that has been recycled eventually becomes too laden with salts, metals and other materials to be used in operations and must be disposed of. Handling of both flowback and produced water varies greatly by region based on these factors.

Companies have also been developing ways to hydraulically fracture with less or even no fresh water. The ability to use non-fresh water or produced water for hydraulic fracturing reduces the impact on water resources and on infrastructure such as roads and water treatment plants. Some wells can also be fractured using no water at all with materials such as air, nitrogen or propane. As with water reuse, the ability to use such materials depends on the formation being fractured and the infrastructure around the well, but companies continue to seek ways to reduce their water footprint.

Finally, produced water can be reused in aging fields to increase production, a process known as water flooding. By injecting water in to the oil formation, the pressure is increased and more hydrocarbons flow toward the oil or natural gas well. This practice allows for some economic benefit to the otherwise costly disposal of produced water.

Effective water management will remain a major concern of oil and natural gas development and production for the foreseeable future, especially in the semi-arid West. Industry continues to invent new ways to reuse water and reduce the quantity of fresh water used while striving to protect and conserve this most precious resource.