A Discussion on Hydraulic Fracturing Stimulation.

A TEAM APPROACH TO WELLBORE INTEGRITY

Noble Energy's DJ Basin Wellbore Integrity (WBI) team was created in 2012 to improve how we protect aquifers and the environment. The WBI team developed best-practice standards to help ensure preexisting wells near planned drilling areas are structurally sound and avoid impacting aquifers and the environment as a result of our onshore development activities. Prior to any drilling activity, the WBI team evaluates the infrastructure of nearby wells (*e.g.*, casing integrity, cement coverage, equipment quality). Based on the results of the evaluation, wells are then remediated or plugged and abandoned where necessary. Noble Energy is working with regulators and other operators to share these voluntary best management practices to help avoid environmental impacts associated with onshore oil and natural gas development.

What is hydraulic fracturing stimulation?

Hydraulic fracturing stimulation (commonly referred to as "hydraulic fracturing" or "fracking") is a process used in 90 percent of the oil and natural gas wells drilled in the United States.

After a well is drilled and several layers of steel pipe are cemented in place to isolate subsurface operations from the environment, a mixture composed primarily of water, sand and a small amount of additives is injected at high pressure into the rock formation. This creates small fractures in the rock that provide a flow path for trapped oil and natural gas. The sand keeps the fractures open, allowing oil and natural gas to flow into the wellbore, and the water mixture to return to the surface, where it is reused or recycled.

Why are additives used in hydraulic fracturing?

Additives are used to improve the performance of hydraulic fracturing stimulation. They are predominantly used for lubrication, to keep bacteria from forming and to help carry the sand. Most of the additives used in hydraulic fracturing are chemicals found in common household products like soaps, disinfectants and skin lotions.

What are porosity and permeability, and why do they matter?

Depending on porosity and permeability, underground rock formations may contain trapped oil and natural gas. Porosity is the percentage of the rock's volume that is open space, or pores, that can hold oil and natural gas. Permeability is the rate of flow at which fluids (water, oil or natural gas) can pass through these pore spaces. Smaller pore spaces are more difficult for liquids to pass through, resulting in lower permeability. The process of hydraulic fracturing stimulation is used to create a connection between the small pore spaces, enabling trapped oil and natural gas to flow more freely into well bores. Hydraulic fracturing enables recovery of oil and natural gas that would not otherwise be accessible.

Is there a difference between hydraulic fracturing stimulation when applied to conventional versus unconventional formations?

Conventional formations, such as sandstone, have higher permeability than unconventional formations, such as shale. Therefore, fluids can flow more easily through the formation. The hydraulic fracturing stimulation process is basically the same when applied to unconventional formations as it is when applied to conventional formations, though slight modifications may be made to adapt to the geologic characteristics of the area.

What is FracFocus?

FracFocus is a national hydraulic fracturing chemical registry website that provides fact-based information about hydraulic fracturing to the public. FracFocus also provides a centralized database for operators to upload timely, consistent chemical data that enables the public to search well records using multiple criteria. Several states have either mandated the use of FracFocus through regulation, or are discussing a mandatory use requirement for operators. Noble Energy is an active participant in FracFocus. In mid-2011, the company began voluntarily disclosing chemicals used for all onshore wells.

How do you avoid groundwater contamination and remain confident that hydraulic fracture fluids will not go beyond the target rock zone?

Before drilling a well, area geologic characteristics – such as the presence, thickness and features of rock layers between the ground surface and target geologic formation – are assessed. Based on this evaluation, the porosity and permeability of the rock layers are estimated. This helps predict how the target geologic formation will respond to hydraulic fracturing stimulation. Other oil and natural gas wells in the area are also identified, to ensure they will not impact or be impacted by hydraulic fracturing stimulation activity.

To prevent hydraulic fracturing stimulation fluid from impacting groundwater, construction of the wellbore includes layers of protective steel and cement to protect shallow groundwater aquifers. Noble Energy uses best-management practices when installing multiple casing and cement layers to ensure they prevent natural gas migration and drinking water contamination.

Hydraulic fracturing stimulation fluids are pumped into completed wells at varying pressures to create small fractures in the target geological formation. This process is closely monitored, with pressure tests conducted on the wellbore before and during the hydraulic fracturing stimulation process. If the pressure is lost, fracturing stops.

Furthermore, there are many layers of rock between drinking water aquifers and the target geological formation that prevent hydraulic fractures from moving out of the target geological formation. As an example, hydraulic fracturing stimulation can be conducted at depths of 7,000 to 8,000 feet below the surface; drinking water aquifers are typically less than 1,000 feet below the surface. The planning process includes modeling the extent of the hydraulic fracturing stimulation, and the actual process is closely monitored.

What is commonly misunderstood about hydraulic fracturing stimulation?

Common misunderstandings exist regarding the point at which hydraulic fracturing stimulation takes place and how long it lasts. Some think hydraulic fracturing stimulation occurs over a long period of time (months or years), but it is actually a short-term activity that lasts anywhere from a few hours to several days. Hydraulic fracturing stimulation takes place after the well is drilled and multiple layers of steel pipe, called casing, are inserted into the full length of the well. It is the step following drilling and before the well begins producing oil and/or natural gas.

GROUNDWATER PROTECTIVE LAYERS

1. Cement Layer 1
2. Conductor Casing
3. Cement Layer 2
4. Surface Casing
5. Cement Layer 3
6. Intermediate Casing
7. Cement Layer 4*
8. Production Casing

At various stages of the drilling and completion process, the mechanical integrity of the casing and cement are tested to ensure proper installation. We use best management practices installing and cementing the multiple strings of casing necessary to prevent gas migration or drinking water contamination.

**In some locations this layer is not required by regulation.*

This graphic represents a generic depiction of our onshore well depth and casing.