



Developing natural gas from the Marcellus Shale is a process regulated by both state and federal agencies responsible for the protection of the environment and the sound use of water resources. In fact, between 30-35 individual permits, depending on a well's specific location, are required to drill a natural gas well in Pennsylvania. The industry is committed to planning, drilling and operating its wells in compliance with the regulations that govern natural gas development, and operators typically go beyond what is required by these agencies.

Site Preparation

Protecting the environment begins with constructing roads and grading the drill pad location, through the use of controls to prevent soil erosion and sedimentation. Roads are often improved prior to starting the drilling process to accommodate additional truck traffic, with culverts placed along road berms to reduce sedimentation. Filter socks and erosion control blankets are installed and maintained at the

pad throughout the drilling process to prevent stormwater runoff, and tons of gravel are spread and leveled across the pad to allow precipitation to drain properly. The result of this preliminary work is a drilling pad that is safe and does not cause soil erosion or the sedimentation of streams.

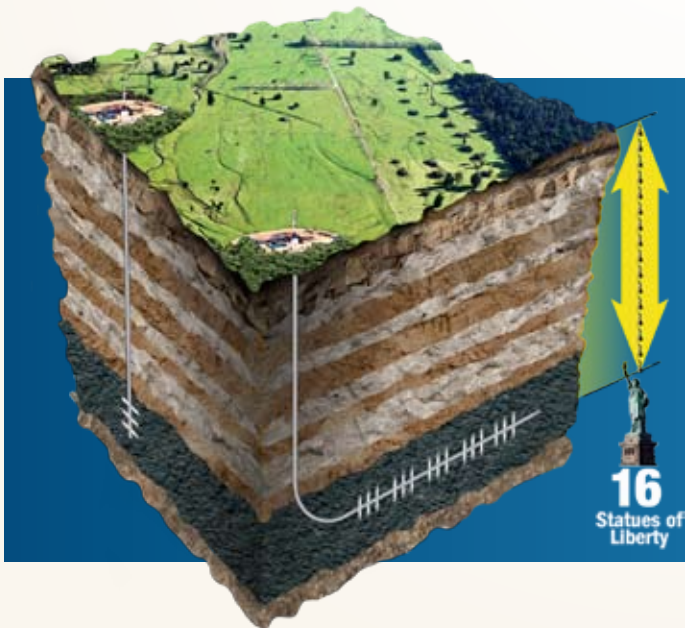
Drilling

The drilling process involves driving several increasingly smaller diameter steel pipes, called casing strings, into the wellbore, with the injection of cement into the pipe and up the sides of the wellbore at the completion of each casing string. This isolates the wellbore with two durable materials – steel and cement – from the earth, including groundwater aquifers. Each successive steel casing string is cemented into place as the well is drilled, extending to the end of the horizontal portion of the wellbore that will produce natural gas. The casing and cementing process is tested as the well is drilled to ensure its integrity. These steel and cement liners remain in place throughout the well's years of production.

FAST FACTS

- Horizontal drilling from a multi-well pad allows for the most efficient extraction of natural gas from an area, reducing estimated total surface impacts by more than 95 percent over vertical drilling techniques.
- Pennsylvania's oil and natural gas regulations consistently achieve the highest ranking among the states by the State Review of Oil and Natural Gas Regulations (STRONGER), an independent monitor of environmental programs.
- Well casing requirements in Pennsylvania are among the strongest in the nation, providing multiple layers of steel and cement between the wellbore and surrounding geology to protect groundwater.

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Marcellus Shale wells can be drilled both vertically and horizontally, as shown on left. The full length of the well is built with thick steel pipe and cement "casing" to isolate the well from the earth and rock. The Marcellus Shale formation is found between 5,000-9,000 feet below ground surface in Pennsylvania. This diagram assumes the formation is 6,000 feet in depth, or 16 Statues of Liberty below the ground. Drinking water aquifers in Pennsylvania, at their deepest, are no more than 500 feet below ground surface, with the well casing and the distance of a mile or more of rock present to protect groundwater supplies.

Material called drilling mud, which is also used to drill drinking water wells, is used to lubricate the drill bit and to aid in bringing rock cuttings to surface. The cuttings are then processed through a shaker and allowed to settle, with the rock fragments held at the drilling location, either for permitted disposal in a lined on-site facility, or for transportation to a permitted landfill. Drilling mud is processed in an on-site treatment facility and recycled for continued use in the drilling process.

Completion and Production

Environmental protection during well stimulation turns to the careful use of water and the additives required to fracture the Marcellus Shale formation, along with the proper management and recycling of flow back water that returns to the surface. Water allocation permits are required to withdraw water from streams for stimulation procedures; the state Department of Environmental Protection and federal interstate river basin commissions monitor withdrawals to ensure the protection of waterways. Permits must also be obtained to purchase water from municipal water suppliers. Water is stored in tanks or lined, secure impoundments at the drilling location.

Approximately 3 to 5 million gallons of water is used to stimulate a horizontal well. Of this, about 20 percent of the water, flowback, is returned to the surface shortly after drilling. More and more of this flowback water is being recycled for use in subsequent operations, significantly reducing consumptive water use. Many drilling companies have been successful in recycling 100 percent of flowback water.



At the completion of the drilling process, the land near the finished well is restored to its original condition, as requested by a landowner. All that remains is a wellhead (called a Christmas Tree), a small amount of production equipment, measuring devices and storage tanks to collect water that returns slowly up the wellbore. Even more energy can be produced by developing multiple wells from a single drilling pad, with a minimum of earth disturbance activity.

The additives used in the well stimulation process are transported and managed at the drilling location according to state and federal regulations. Typically, only five to ten additives are used in the process, and those materials can be found in products in the home. Common additives include a surfactant (or soap) to reduce the friction of the water, a biocide (similar to an anti-bacterial hand cleaner) to keep the wellbore free of bacteria, a scale inhibitor (comparable to a household product used to keep wastewater pipes free of scale) to prevent the buildup of scale, and a lubricant (similar to vegetable oil) to make the water heavier and reduce friction. The well stimulation process has not been identified as the source of

groundwater contamination, as it takes place at depths between 5,000-8,000 feet below ground surface. Most groundwater aquifers are found between 100-200 feet below the surface, typically more than a mile above the shale being fractured.

After the drilling and well stimulation processes are completed, the drilling pad is restored, commonly as requested by the property owner. A completed and secure producing well only requires a surface footprint the size of a large garage, or slightly larger in the case of a multiple gas well pad, and includes the well head, water storage tanks and a small amount of production equipment.

Horizontal drilling allows for multiple wells to be drilled on each pad, resulting in fewer pad sites, access roads and equipment, along with less trucking and greatly reduced surface disruption. Producing wells are monitored and the pad site maintained throughout the life of the well by a well tender. Some water slowly returns to the surface over time, which is stored in tanks and pumped as needed into trucks for treatment at permitted facilities.

Shut in and Abandon/Reclamation

When a well is no longer capable of production, concrete is pumped down the wellbore to seal it from the earth, and production equipment is removed from site. The entire pad is then re-vegetated and fully restored.