

Reclamation of Marcellus Shale Drilling Sites in West Virginia

by

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Introduction

The rapidly developing boom in natural gas drilling into the Marcellus Shale in the Appalachian Region is the biggest economic and environmental event in the 21st Century. An estimated 100 to 500 trillion cubic feet of natural gas is trapped in the tiny pores of the Marcellus Shale. The U.S. uses about 20 trillion cubic feet of natural gas each year. Hydraulic fracturing (or hydrofracking) is the process of injecting fluids under high pressure into shale layers, thereby creating small fractures and allowing the natural gas to be released and extracted.

Hydraulic fracturing has been used by the oil and gas industry since the 1940s. Combined with more recently developed horizontal drilling techniques, it has made the region's shale deposits economical for gas production. Hydraulic fracturing creates fissures, or fractures, in underground formations to allow trapped natural gas to flow into cracks where the gas can be collected. The Marcellus Shale natural gas deposits are located at depths of 3,000 feet in Ohio dipping to more than 9,000 feet in depth eastward near the Virginia border, and the average depth of Marcellus Shale wells in West Virginia is 5,300 feet. The Marcellus Shale layer varies from between 50 to 100 feet in thickness so it is important to locate and map the formation for accurate drilling.

In the drilling process, bore holes of 6 to 8 inches in diameter are vertically drilled down into the earth's crust to the approximate 5,000-foot depth of the Marcellus Shale layer. About 500 feet above the shale layer, the bore hole is slanted or curved so that the bore hole gradually becomes horizontal when it reaches the shale formation (Figures 1 and 2). Drilling continues for up to 3,000 feet horizontally through the shale. Steel casing is linked together and passed down through the bore hole. After the casing is in place, the section in the Marcellus formation is perforated. Once the bore hole has been drilled and cased, water, sand and a mixture of chemicals are pumped down the well at high pressure to exit at the casing perforations and create fissures in the shale. The sand fills the fissures so that when the pressure is released the fissures remain open to permit the flow of gas to the well. The gas pushes the water back out of the well and they are separated at the surface. The gas is then collected for transport. After the initial pumping of flow back water, the well can supply natural gas with much lower levels of flow back water. Most of the flow back water comes to the surface about three weeks after the initial fracking. Low volumes of water are then "produced" along with gas during the production stage.

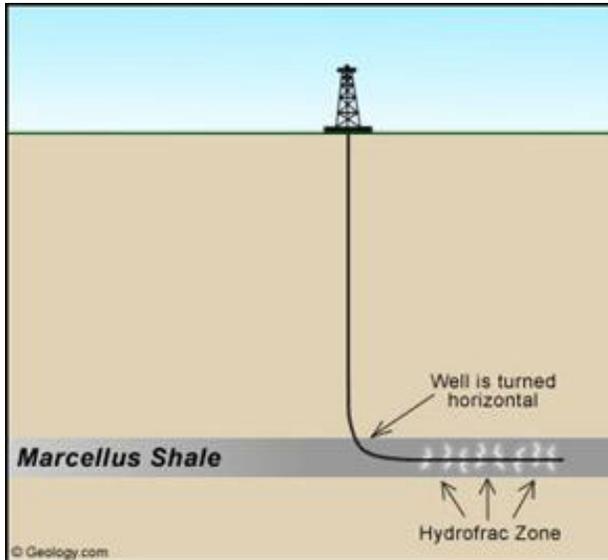


Figure 1. A simplified diagram of the horizontal drilling and hydrofracking procedure to capture natural gas contained in the Marcellus Shale (image courtesy of Brad Cole, Geology.com).

Landowners should become familiar with laws governing permitting requirements, pad site development, disposal of drill cuttings, water usage and wastewater disposal, gas withdrawal, road construction and maintenance, company access and royalties for natural gas withdrawn from wells near or on their property.

Environmental Concerns

Land

To drill a new Marcellus Shale natural gas well, the operator must obtain a well permit from the West Virginia Department of Environmental Protection and post a bond. The bond amount is \$5,000. The company must provide maps showing the location of the well and proximity to other features like coal seams, houses and other structures, surface water locations like streams and



Figure 2. A Marcellus drill rig which is used to bore a vertical and horizontal well.

rivers, and water supplies including ground water wells. Gas well drilling involves constructing roads, clearing and leveling land, and installing drilling pads and pipelines (Figure 3). Drilling pads may range in size from two to ten acres and erosion control strategies must be in place to control erosion and sedimentation on the site. Site plans require gas companies to use preventative measures such as Best Management Practices to restore the site, including re-applying topsoil, and vegetation must be established within nine months of well completion by planting grass, trees or crops (Figures 4 and 5). The practices should minimize discharge of water from the drilling pad to surface waters and preserve

the quality of streams and protect ground water supplies.

Land Reclamation Considerations

Like any major disturbance where topsoil is removed and the excavation cuts into geologic materials, planning is a critical element of the process. The first step should be to install erosion control structures like ditches and ponds that will collect any runoff carrying sediment from the disturbed site. The sediment can settle in ponds before the runoff water is discharged into nearby streams or waterways. If a pond is to be used to hold drill cuttings or other flow back water, these ponds should be lined and not allowed to receive runoff water from the site. The water and contents of these drill cutting or brine holding ponds should be removed by tanker trucks and taken to a water treatment facility, and not released into receiving streams. Also, the soil on out slopes of ponds should be limed, fertilized, seeded with herbaceous species, and mulched to control erosion.



Figure 3. Marcellus Shale drilling site with water-holding structures and support facilities during drilling operations.

Once water control has been installed, then the forest or pasture where the drilling site is planned can be disturbed. The trees can be harvested by a local timber operator. The absolute most important element to ensure



Figure 4. After the drilling operation and the majority of flow-back water has occurred (six to 12 months after drilling), a well head and barrels are left on site for further gas and water collection. The site can be reclaimed by removing the ponds and ditches, and regrading the pad site to a similar contour before disturbance. A reclamation seed mix which matches the landowner's desires can be used.



Figure 5. Reclaimed Marcellus Shale drill site showing access road, well head and condensate tank.

proper reclamation is *saving and re-applying the soil*. The soil is comprised of all soil layers down to broken or weathered bedrock, including the O, A, E, B, and C horizons. We recommend that at least 2 feet of soil be salvaged, and up to 4 feet if available, and placed in a stockpile. The soil stockpile should be seeded with a vegetation cover if the stockpile will remain there for more than 6 months. If the soil to be salvaged is less than 2 feet deep, we recommend that 2 feet of soil and soil-like rocky material be saved and stockpiled for redistribution during reclamation.

Once horizontal drilling and hydrofracking are completed and much of drilling equipment is removed, then the pond and the area around the fracking operation can be reclaimed. The ponds, both holding ponds and sediment control ponds, can be emptied and pushed in, as well as the pad site. The land contours previously there before disturbance can largely be restored with the soil and geologic materials on site. Pushing topsoil back onto the contoured areas at thicknesses similar to what was removed with largely allow the site to be revegetated with similar plants that were originally present. Soil tests can be done to determine recommended rates of lime and fertilizer to apply during revegetation. Normally, 3 to 5 tons/acre of lime will be applied and 500 pounds/acre of 10-10-10 fertilizer may be spread. An herbaceous seed mixture suitable to the landowner's desires for pasture/hay or other land use should be seeded, followed by the application of 1.5 tons/ac of hay or straw mulch. A seed mix for a grass legume pasture could be

Annual Rye - 30 lbs/ac, Tall Fescue – 15 lbs/ac, Orchardgrass - 10/lbs/ac, White Clover – 10 lbs/ac, and Birdsfoot Trefoil – 5 lbs/ac. If additional information is desired, please contact your local county extension agent or the authors of this fact sheet.

Pipelines to carry natural gas from a well head to larger pipelines are also needed and pipeline disturbances also require reclamation. The same reclamation techniques stated above can be used to reclaim these pipeline corridors. Again, soil salvage and re-spreading is the key to good reclamation.

Water

Drilling and fracking a vertical Marcellus Shale gas well requires about 100,000 gallons of water. On the other hand, a typical horizontal well takes between 2 and 6 million gallons of water. These water requirements, while large, are only one-time events and temporary. The water to conduct these activities can come from a variety of sources including nearby streams, rivers, and lakes. The water is often transported to the drilling sites in tanker trucks and stored on site in tanks or impoundments. The drilling company must identify where they plan to obtain and store the water during drilling operations. During drilling, water and drill cuttings are often deposited into small ponds (Figure 6). Since the drill cuttings typically contain brine and grease, plastic liners are required to keep water from infiltrating through the bottom to protect streams and groundwater. In addition, the landowner should request testing to ensure



Figure 6. A holding pond lined with a plastic material to store drill cuttings and water at a Marcellus well site.

that toxic compounds or radioactivity, if present, are handled properly. The drill cuttings settle out in the ponds and the fluids can be reused in the drilling operation. When the ponds are removed during reclamation, the water and solids in these ponds should be removed by tanker trucks and disposed of at water treatment facilities.

What is injected into the ground? Ninety nine percent of frack fluid is water. The other one percent is composed of sand and small amounts of other additives such as acids, gels, surfactants and corrosion inhibitors. The drilling operator must identify where the returned frack water (flow back water) will be stored, treated and disposed.

Wastewater must be recycled and reused, or collected and treated at a licensed wastewater treatment facility. The frack water initially contains little salt but it usually removes salts in the Marcellus formation and returns to the surface as brine.

About 10 to 30% of the injected water returns to the surface. The remainder stays in the formation.

While it is unlikely that recycling returned frack water will eliminate all of the waste disposal problem, it has many benefits. Recycling reduces the amount of truck traffic needed to haul waste water away from the drill site and it reduces demands on fresh water supplies and the trucking needed to bring that water to the site.

Once the drilling is completed and the injected fluid returns to the surface, gas production begins and low volumes of very saline “produced water” are collected and periodically hauled away. Produced water can be disposed of by underground injection into permitted wells or it might be taken to a licensed treatment facility (Figure 7). The quality of the water may dictate the treatment and disposal options.



Figure 7. An underground injection well into which frack waters can be disposed.

What is in returned frack water?
Returned frack water (RFW) contains both

inorganic compounds like salts and metals as well as organic compounds like natural gas liquids and oils. Table 1 shows a typical range of inorganic concentrations in RFW. The wide range in salt content often reflects the stage in well development when the sample was taken. At the early stages after fracking, most of the RFW is the injected water and as that volume decreases, more salty water dominates, resulting in a decrease in flow but an increase in saltiness (Figure 8).

Table 1. Chemical analysis of five returned frack waters (RFW). All values other than pH are in mg/L. TDS is total dissolved solids, a measure of the salt content. TSS is suspended solids and O&G is oil and grease.

	RFW 4	RFW 5	RFW 3	RFW 2	RFW 1
Total Dissolved Solids (TDS)	189,000	104,000	38.7	12.61	8.8
Total Suspended Solids (TSS)	519	570	99	220	44
Chlorine	107,000	65,000	17,100	7,172	6,575
Sodium (Na)	48,100	33.7	8,560	2,863	3,550
Calcium (Ca)	22,200	12,800	1,640	1,749	319
Magnesium (Mg)	2,000	1,470	193	122	31
Strontium (Sr)	2,970	1,440	301	nd	nd
Potassium (K)	668	444	243	57	nd
Sulfate (SO ₄)	49	414	28	71	99
Barium (Ba)	1,300	176	175	nd	27
Iron (Fe)	48	30	37	27	37
pH	6	6	7	6	8
Oil & Grease	3	nd	5	49	5

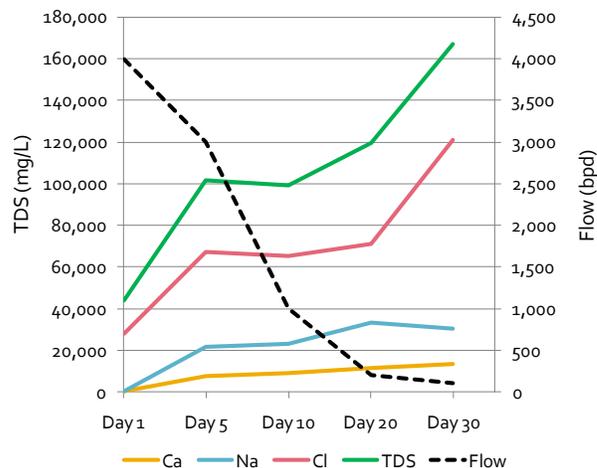


Figure 8. After completion of fracking, flow back of water to the surface is initially high but decreases rapidly. At the same time, salt concentrations increase.

NEWS RELEASE

Monday, August 22, 2011 @ 4:35 PM

The West Virginia Department of Environmental Protection filed an emergency rule today with the Secretary of State's Office to increase the DEP's regulatory oversight of horizontal well development in the state.

The rule, which adds new permit application requirements for operators drilling horizontal gas wells, as well as new operational rules to protect the state's water quality and quantity, will become effective after approval by the Secretary of State and remain in effect for 15 months.

The emergency rule is intended to help the DEP better regulate the state's growing natural gas industry, which is benefitting from improved horizontal drilling techniques that allow operators to more easily access deep shale gas, such as that found in the Marcellus Shale. Those same drilling techniques involve significant surface area disturbances and large-volume

hydraulic fracturing that uses millions of gallons of water per well.

The rule adds specific language to the state Office of Oil and Gas regulatory program that requires operators to include an erosion and sediment control plan and site construction plan, certified by a registered professional engineer, and a well site safety plan for well work permit applications involving well sites that disturb three acres or more of surface.

The rule also requires permit applicants to submit a water management plan if they intend to use more than 210,000 gallons of water during any one-month period. The water management plan shall include information such as type of water source -- surface or ground water; the counties from which water withdrawals will be taken; latitude and longitude of each anticipated withdrawal location; anticipated volume of each withdrawal and anticipated months withdrawals will be made; planned management and disposition of wastewater from fracturing and production activities; a listing of anticipated additives to be used in the water for fracturing; and, upon well completion, the listing of actual additives that were used.

Permit applicants, drilling within the boundaries of any municipality, are also required to place a legal newspaper advertisement in the area where the well is proposed. No well work permit will be issued until 30 days notice has been provided to the public.

In addition to permit application requirements, the rule adds operational language that instructs companies to protect the quality and quantity of surface and ground water systems both during and after drilling operations and during reclamation; requires operators to comply with record-keeping requirements for the quantity of flowback water from hydraulic fracturing and the method of management or disposal of the flowback; stipulates that all drill cuttings and drilling mud be disposed of in an approved solid waste facility; and adds casing and cementing standards to prevent the migration of gas and other fluids into fresh ground water and coal seams.

DEP Cabinet Secretary Randy Huffman said: “As Gov. Tomblin has pointed out, this is not the end of the debate, but only the first step in addressing the myriad of concerns our citizens have regarding this practice. There is much discussion and debate yet to take place. And we look forward to working with the legislature to ensure a comprehensive approach to regulating horizontal drilling is addressed.”

To view the rule go to www.dep.wv.gov and click on Oil and Gas.