SOUTHWEST PENNSYLVANIA ENVIRONMENTAL HEALTH PROJECT

Illustrated Stages of Shale Gas Development:
Examining the potential for ground/surface water and air contamination

Shale gas development (commonly known as "fracking") is the process of extracting gas from shale deposits and delivering it to consumers. While companies have been extracting gas for many years, today's process uses methods like horizontal drilling and hydraulic fracturing to reach resources trapped in deep shale rock formations. The complex process used to reach this trapped gas has many different stages that take place over a period of years.

This document explains some of the industrial activities you may see during each stage. The timeline for each stage varies greatly from site to site depending upon the amount of work required to extract the gas.

TERMS TO REMEMBER:

Particulate Matter (PM): potentially dangerous mixture of small particles and liquid droplets found in the air.

Volatile Organic Compounds (VOCs): organic compounds that easily become vapors or gases. Many VOCs are also **hazardous air pollutants (HAPs)** such as benzene, formaldehyde, toluene and xylene.

INITIAL EXPLORATION

Energy companies search for underground reservoirs of gas using mapping, geological clues, seismic testing, and other methods. Generally, this is done in an office setting, so you may not see this occurring in your community.

Bob Donnan. Seismic Testing. 2014.

Seismic testing

Seismic testing is used to help determine the geological characteristics below the surface of the ground before drilling starts. Marcellus Shale seismic testing usually uses 2D or 3D imaging. With this testing, energy companies often bore holes where they can place dynamite charges for later detonation. Seismic equipment in the area monitors the shock waves after detonation. Trucks will stop at a set location, lower a large plate onto the highway that puts most of the weight of the truck on the surface, and then set off a series of vibrations into the ground. After a few minutes, they move forward and repeat the process. If trucks stop in front of your house, you are exposed to idling diesel emissions and ground vibrations.

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LEASING AND PERMITTING

After an energy company determines that a place has enough resources to pursue, leases are purchased from mineral rights owners, if necessary, and permits are requested and issued by the state.

WELL PAD DEVELOPMENT

Once the energy company concludes that an adequate amount of gas can probably be extracted, access roads are constructed and the well site is developed. The next step in development is building a well pad, a large 3-10 acre structural platform surrounding the drilling operations. The well pad holds the drilling rig, storage tanks, and other machinery and equipment.

Third, the energy company uses the drilling rig to drill the well(s). A typical well is drilled 5,000 to 9,000 feet vertically and up to 15,000 feet horizontally. Several wells may be drilled on one well pad. Note that companies are looking to supersize with larger pads and longer laterals.

Judy Patrick Photography. 2016. Provided by Ahtna, Inc.

Casing – permanent infrastructure

Shallow test wells are drilled to varying depths, and casing (cement and/or steel) for the permanent well will be put in place. Pipes are installed to create a barrier between the flow of natural gas/fracking fluids and groundwater. Potential contamination of the groundwater may occur as the initial wellbore is drilled and cement is injected into the ground. If well casings fail, there may also be ground water contamination.

Pete Stern. Drilling in Loyalsock State Forest, PA. 2013. Provided by FracTracker Alliance, fractracker.org/photos.

Drilling on well-pads

This is the drill you will see during the drilling stages. Issues at this point could include spills of drilling muds, fracking fluids, or other activities associated with clearing and use of the well pad itself. In addition, there may also be impacts from air contamination by PM, VOCs, and diesel emissions.

PREPARATION FOR HYDRAULIC FRACTURING

After the well has been drilled, the drilling rig is removed and the well is ready for hydraulic fracturing.

Bob Donnan. Truck transport. 2014.

Truck transport of water, fluids, and sand

Each well fracked on a site requires significant amounts of water, along with sand, to help prop open the cracks created by fracking. The exact amount of water and sand needed varies from well to well, but one well may use 2 to 10 million gallons of water. This amount may change as lateral lengths increase. In this photo, three water-hauling trucks surround one truck hauling the fine silica sand used during hydraulic fracturing. Potential problems for water contamination include water withdrawals from local water sources using contaminated lines, spills of flowback water or chemicals taken on and off-site by the trucks, and leaks/spills (either intentional or accidental) occurring during transport. To get water and sand to the wells, diesel trucks are needed, releasing toxic air emissions. These include increased PM and diesel emissions. In addition, since silica sand is easily picked up by wind and can travel long distances, increased air contamination from silica dust can occur.

Bob Donnan. Freshwater impoundment. 2014.

Freshwater impoundments

Impoundments are used during hydraulic fracturing and for nearby or off-site well pads. While as residents we do not get this bird's eye view, the steep sides of the pit are noticeable from the ground. Contamination associated with freshwater impoundments would most likely be associated with run-off of the soil used in construction. However, these impoundments may be re-purposed into flowback impoundments in which chemical contaminants are deposited. There may also be significant truck traffic associated with impoundments, increasing PM and diesel emissions.

John B. McFarland. Fracking a well. 2015.

Hydraulic fracturing ("fracking")

Water use and disposal are important issues during the hydraulic fracturing stage. To "frack" a shale gas well, millions of gallons of fresh water are hauled in or withdrawn from local sources. Chemicals are added to the fluid to efficiently fracture the rock formation that traps the oil and gas. Sand is added to prop open fractures in the shale so the gas can escape. This mixture of water, chemicals, and sand is called "fracking fluid." There are potential impacts from air contamination by VOCs, HAPs, PM, diesel emissions, and silica dust from sand. Due to the volume of water being forced underground and mixing with hazardous materials, there is a potential for groundwater contamination.

PRODUCTION

The wastewater that returns to the surface during gas operations is a mixture of flowback and produced water. Flowback water contains the fracking fluid mentioned above. Produced water is water previously trapped in underground formations that is released with the gas and/or oil. Produced water can contain naturally occurring, but still dangerous, materials that are present in the shale layer, including radioactive compounds, toxic organic and inorganic chemicals, and heavy metals such as arsenic. It also contains a significant amount of salt that was trapped in the shale, which is why it is often referred to as brine. The wastewater is held in pits or tanks at the well site until it is treated, recycled, or disposed of in an underground injection well.

Bob Donnan. Flowback impoundment. 2014.

Flowback impoundments
These large ponds are used for storage of flowback fluids, drilling muds, and other chemicals and water used in the hydraulic fracturing process. Concerns include torn impoundment pond liners, improper runoff management, leaks, and deposits from impoundment pond aeration. Accidents, leaks and spills can occur when the flowback water is trucked to and from the site. There may also be a cause for concern from VOCs, methane, and ethane emissions in the air coming off this impoundment. This practice was disallowed in 2016 in PA, but some still remain.

Bob Donnan. Flaring. 2014.

Flaring
Flaring is used for burning off flammable gas when there is too much pressure in the pipelines. Flaring generates heat, noise, and light. There may be cause for concern from VOCs, methane, and ethane emitted into the air.

Bob Donnan. Condensate tanks. 2014.

Condensate tanks – permanent infrastructure
In areas with "wet" gas, such as in western PA, gas contains a mixture of natural gas and other commercially viable components such as ethane and propane, used as feedstocks for plastics and other industries. Methane is separated from these liquid components using a condensation process. Liquid contamination may leak from these condensate tanks into surface waters. Since tanks are also designed to vent, there may also be VOCs, methane, and ethane emissions in the air.

Ramsey Martin. Glycol dehydrator.

Glycol dehydrators
Associated with the condensation process, glycol dehydration is used to separate wet oil or water out of the natural gas stream. Ethylene glycol, used in the dehydration process, binds readily to water, creating the potential for spills which may significantly contaminate nearby water sources. There may be leaks associated with these glycol dehydrators. In addition to leaks, there may be cause for concern from VOCs, methane, and ethane in the air.

Bob Donnan. Christmas tree. 2014.

Christmas trees/wellheads – permanent infrastructure

This represents completion of drilling. A “Christmas tree” provides chemical injection points, pressure relief, and well monitoring points for pressure, temperature, corrosion, erosion, sand detection, and flow rate. These may be a source for leaks, which could contaminate water supplies.

TRANSPORTATION AND PROCESSING

After the gas is accessed, it is processed and transported to consumers. Work activity near well sites generally slows at this point, though some wells are re-fracked periodically in an attempt to boost gas production from a site.

Movement of gas from producing regions to consumers requires an extensive and elaborate transportation system. In many instances, gas has to travel a great distance to reach the point of use.

Bob Donnan. Gas pipelines. 2014.

Gas pipelines – permanent infrastructure

Once the gas wells are drilled and the natural gas begins to flow, the gas and gas liquids must get to market. Natural gas pipelines move gas to compressor stations and to end users.

A natural gas liquids (NGLs) pipeline is used to transport raw-unseparated NGLs or NGLs that have been processed in cryogenic and fractionation plants. NGLs are volatile liquids that are brought to the surface with shale gas development along with methane, such as ethane, butane and propane.

During pipeline construction, heavy diesel equipment is brought in to clear the land for incoming pipelines. Pipeline leaks can contaminate the air and local water sources. Toxins also accumulate on the interior lining of pipelines and must be regularly cleaned, via pig launchers.

Stevenson Gas Metering Station. Provided by Bridgeport Utilities.

Metering stations – permanent infrastructure

These stations are designed for simultaneous, continuous analysis of the quality and quantity of natural gas transferred via pipeline. Occasionally, gas, including VOCs, may be vented at these metering stations. Metering stations appear frequently along pipelines and can emit many of the same pollutants as compressor stations.

Robert Donnan. 2014

Compressor stations – permanent infrastructure

Compressor stations help move natural gas from one location to another. While being transported through a gas pipeline, natural gas needs to be constantly pressurized. Gas, including VOCs, may be vented at these stations on a sporadic basis, when pressure needs to be released and/or when pipes need to be cleaned. The frequency of these blowdown events is dependent on the volume of gas being transported via pipelines. Venting can cause an increase in VOCs, nitrogen oxides, and PM in the air.

Bob Donnan. Pig launcher. 2014.

Pig launchers – permanent infrastructure

This structure is used in the process of maintaining pipelines. Devices known as “pigs” are used to perform various maintenance operations on a pipeline, such as cleaning and inspecting the pipes. This practice is accomplished by inserting the “pig” into an oversized section in the pipeline, and then reducing this section to the normal diameter. The launcher is then closed and the pressure-driven flow of the product in the pipeline is used to push the pig down the pipe, “cleaning” the interior of the pipe, until it reaches the receiving trap. Radioactive materials such as radon, as well as Polychlorinated Biphenyl (PCB) are among the contaminants that accumulate in pipelines. There may be VOCs, methane, and ethane released in the air.

Bob Donnan. Processing plant. 2014.

Processing plants – permanent infrastructure

Processing plants purify natural gas by removing common contaminants. Emissions, spills and leaks include VOCs and PM from equipment vents, generators, and trucks.

Garth Lenz, iLCP. Houston, PA Cryogenic and Fractionation Plant.

Cryogenic and fractionation plants – permanent infrastructure

The first step at a cryogenic and fractionation plant is to remove natural gas liquids (NGLs) from natural gas. This is done by cooling the NGLs to sub-zero temperatures to condense the NGLs, such as butane, ethane, and propane. Once NGLs have been removed from the natural gas stream, they must be separated into their individual products to be useful. Separation is accomplished through fractionation, which consists of boiling and condensing the NGLs. NGLs are then shipped to market and often used in refineries and petrochemical plants for fuel or feedstock. The methane gas that remains after removing liquids is transported via pipeline to its end use. Emissions, spills and leaks may include: VOCs, polycyclic aromatic hydrocarbons, and PM from generators and trucks.


Ted Auch. Shell Ethane Cracker in Beaver County, PA. 2016. Image provided by FracTracker Alliance, fractracker.org/photos

Petrochemical facilities/cracker plants – permanent infrastructure

Petrochemical facilities, also known as cracker plants, take ethane and break it down into smaller molecules to create ethylene. The ethylene is then used in the manufacturing of plastics. Emissions, spills, and leaks may include VOCs, polycyclic aromatic hydrocarbons, and PM from generators and trucks.

STORAGE

Storage facilities are used to store gas to maintain a supply year round.


Earthworks. Underground natural gas storage facility.

Underground natural gas storage (UNGS) facilities - permanent infrastructure

Underground natural gas storage facilities are usually created by converting previously used underground sites such as depleted oil and gas fields, water aquifers, and old salt caverns. They are typically filled to capacity, which can lead to extremely high pressures within the UNGS facilities, causing an increased chance of leaks and explosions. This, along with improper construction or plugging can cause natural gas to leak into drinking water. Some UNGS facilities are up to 100 years old, and the risk for leaks and explosions increases as the storage facility ages. Occasionally gas, including VOCs, may be vented at these facilities.

WASTE

Throughout the hydraulic fracturing process, several forms of solid, semi-solid, and liquid waste are produced.


Torch CAN DO. K&H injection well facility.

Class II injection wells – permanent infrastructure

Class II injection wells are used to dispose of liquid waste brought to the surface from gas production. This liquid waste – or produced water – is mostly brine, containing various naturally occurring salts that were present in the shale rock formation. It also contains other naturally occurring compounds that can be carried by water, such as naturally occurring radioactive materials (NORMs), hydrocarbons, heavy metals, and other toxic substances. In addition, produced water also contains materials used in developing and maintaining the well, such as lubricants, fracking fluid, and pigging fluid. If an injection well fails, the contents may contaminate ground water and surrounding soil.

Bill Hughes. Dumping of radioactive waste. 2014

Solid waste disposal - permanent infrastructure

Solid waste, including rocks, dirt, and drill cuttings (ground up rock pulled up from the formation after drilling), along with semi-solid waste known as sludge, is disposed of in municipal landfills, usually owned by private companies. Sludge contains NORMs and other toxic compounds that were present in the rock and used during well development. Due to exemptions in The Resource Conservation and Recovery Act (RCRA), oil and gas waste is not considered toxic or subject to federal cradle to grave tracking. Landfills are equipped with radioactivity sensors. However, shale gas waste is allowed to be diluted with non-radioactive waste reduce the radioactivity of the load. Loads that are too radioactive are required to be taken to landfills engineered and approved to handle radioactive materials. Waste from each site is often taken to multiple landfills. Contamination of water and ground may occur due to spills/accidents during transport, or from water draining from landfills if not properly handled. Additional concern is that landfill liners may not last as long as the radioactive materials need to be contained.

Bob Donnan. Road application. 2014.

Road application of brine

Sometimes brine is sprayed to reduce dust on the roads or for de-icing in the winter. This fluid may contain high levels of barium, salts, and other dangerous but naturally occurring substances including radioactive materials. The concentration of these compounds in the brine is usually unknown. Watch for any use of contaminated water on roadways, as run-off may contaminate nearby wells or surface/groundwater. In addition, there is an increase in PM and VOCs, as well as diesel emissions causing air pollution. Road application most often uses wastewater from conventional gas development, but some residents report that wastewater from unconventional activity has been used. As of early 2019, use of brine for road application has been disallowed and under review by PA government.

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