

Beyond Water

A discussion of the non-water related environmental issues associated with drilling for natural gas in the Marcellus Shale.

Did you know?

- Pyrite, commonly known as fool's gold, is frequently found in the Marcellus Shale?
- At a distance of 500 feet, hydraulic fracturing is about as loud as a blender - 84 decibels.
- The United States is losing topsoil to erosion about 10 times faster than it can be replaced.

Introduction

Though water has taken a front seat in environmental concerns with Marcellus drilling, developing shale gas in New York will pose a number of other environmental risks, including compromised air quality, natural habitat fragmentation, soil erosion, non-water waste disposal, and increased noise. Many of these issues are not unique to high-volume, horizontal hydraulic fracturing, but common to all drilling and most industrial processes. Air quality degradation, disposal of solid waste from drilling, erosion, harm to stream ecosystems, habitat fragmentation, introduction or expansion of invasive species and noise disturbance are all potential impacts of Marcellus Shale drilling.

Air Quality

Air quality issues have been attributed to natural gas drilling in other parts of the country. Drilling in Wyoming, in particular, has led

to the release of ground level ozone (O_3), causing smog that was worse than the levels recorded in Los Angeles. Air quality issues in the Barnett Shale drilling area in Texas have also been at the forefront of environmental concerns. Guidelines and regulations for drillers aimed at reducing the amount of pollutants released into the air as a result of hydraulic fracturing are being developed by the Environmental Protection Agency (EPA). Separate mitigation measures are included in the revised draft Supplemental Generic



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Environmental Impact Statement (SGEIS) developed by the New York Department of Environmental Conservation (NY DEC).

The goal of hydraulic fracturing is to extract methane (CH_4), a natural gas, from the Marcellus Shale for human use. Some of this methane is released into the atmosphere as a result of the process of drilling and transporting natural gas. Methane is a powerful greenhouse gas; although it stays in the atmosphere for a shorter period of time than carbon dioxide (CO_2), it has 25 times the global warming potential of carbon dioxide over a 100 year period. Gas released during the drilling process is discussed below, but for an in-depth discussion on methane lost in pipelines as fugitive emissions, see *Marcellus Shale Issue 11: Life Cycle Analysis*.

Methane and CO_2 are released during natural gas production several ways, including intentional venting and flaring, and accidental leakage. Venting and flaring are more prevalent in oil wells than natural gas wells, but both still happen during the gas drilling process. Venting is the intentional release of gas from the well bore into the atmosphere. In addition to CH_4 , vented gas from a Marcellus well could contain hydrogen sulfide (H_2S). Flaring involves a controlled burn of gas, the byproducts of which (mostly CO_2 and H_2O) enter the atmosphere. While flared gas is mostly CO_2 and H_2O , it can also contain sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter, carbon monoxide (CO), and about 2% of the original methane (because combustion is not 100% efficient).

Flaring is frequently disruptive to surrounding communities, as it is noisy and involves fire, but venting ultimately contributes more methane to the atmosphere. The NY DEC does not expect venting to be a significant source of common air pollutants, volatile organic compounds (VOCs), or H_2S , as gas in the Marcellus is supposed to be “dry” (few VOCs) and “sweet” (little H_2S).¹

The EPA estimates that about 68 billion standard cubic feet (bscf) of methane are vented or flared annually by completions on unconventional wells. This is equal to about half of the total U.S. residential consumption of natural gas in June, 2011.² Drillers would vent gas intentionally during natural gas drilling for a few reasons.

1) During drilling, gas “kick” happens when the well bore encounters unexpected gas on the way to the target formation (the rock layer from which the natural gas will be extracted). This causes an abrupt spike in pressure in the well, hence, “kick.” The gas can mix with the drilling muds (see below) and must be separated and vented. If a gas kick is too large or cannot be controlled, it can escalate into a blowout, which would also lead to venting, though this would not be intentional.

2) Well completion involves the removal of fluids and excess solids from the well bore so that the gas can flow freely out of the well. These fluids are accompanied by gas from the formation that must be separated, vented, and then flared when there is enough gas flowing to sustain the fire. The NY DEC estimates

that completion can take up to 3 days per well, though 12 to 24 hours is common, and has proposed that gas flaring not exceed 120 million standard cubic feet (mmscf) in a year.¹ A 2009 report estimates that a Marcellus well will produce, on average, 2.5 bscf,³ so the NY DEC’s suggested cap would limit flares to 4.8% of the total gas production of a well. If the average is closer to the Chesapeake projection of 4.2 bscf,⁴ flaring would be limited to 2.9% of the total gas production of a well.

Steps can be taken to reduce the amount of venting and flaring that occur during oil and natural gas extraction. Both venting and flaring are ultimately wastes of economically valuable resources in the form of natural gas and together they contribute, by one estimate, 1% of anthropogenic carbon dioxide emissions and 4% of anthropogenic methane emissions worldwide, exacerbating global climate change. Any process that reduces flaring during well completion is called a reduced emissions completion (REC). RECs often involve the use of a portable device that is installed at the well head that is specifically designed to separate liquid from gas at the high liquid-to-gas ratios found during the initial flowback period. The gas captured by this device can be delivered to transmission lines as usual, reducing the need for venting or flaring.⁵

Aside from the gas from the formation itself, most of the equipment that facilitates getting the gas out of the ground and to market also produces emissions in various ways.

1) Building a well pad and drilling and fracturing wells is a

truck-intensive process. All of the equipment, personnel, proppant (sand and other silica or ceramic pieces of various sizes injected into the well to hold open the fractures after the pressure from the fluid has diminished), and chemicals must be transported to the site by truck, and in the early stages of development in the region, all of the water needed to fracture the well usually must be transported by truck as well. As development progresses, some of the water may be transported to well pads via pipeline, reducing the number of truck trips required. All of the equipment and the waste fluids must also be transported away from the well pad. The NY DEC reports, based on Independent Oil and Gas Association of New York (IOGA) estimates, that 1,979 round trips would be required at an average well in the early stages of development in the region. As development ramps up and pipelines are put in place for water, this number decreases by about 29%, to 1,420 round trips.⁶ Additionally, the second and subsequent wells on any pad will require somewhat fewer truck trips, as some of the equipment will already be there.

Other equipment associated with drilling and fracturing includes the drilling equipment to create the well bore and the pumps required to force the water and proppant under pressure into the target formation, hydraulically fracturing the well. Power for the hydraulic fracturing pumps usually comes from diesel engines, which release nitrogen oxides (NO and NO₂, known together as NO_x) and CO during use. The final draft SGEIS estimate that the

Text Box 1: Estimating NO_x Emissions

They were created using the assumption that the engine would run 24 hours, 365 days per year, though the fracturing process is only expected to take 40-100 hours, and drilling a well could take several weeks, but not an entire year.¹ If a well takes 100 hours to fracture, the emissions for a single well would be 1.64 tons of NO_x, not the 144.1 tons estimated in the SGEIS. In a peak development year, the NY DEC estimates that 2,462 wells might be drilled. That would make the total emissions of NO_x from pump engines for the region about 4,052 tons. This is about equal to the total annual NO_x emissions (4015 tons) from the 306 megawatt coal-fired power plant on the east shore of Cayuga Lake, just north of Ithaca.⁷

amount of NO_x released per typical drilling rig diesel engine, if the engine operates continuously for a year, is 333.7 tons of NO_x per year. Their estimate for a typical diesel engine-powered hydraulic fracturing pump, operating continuously for a year, is 144.1 tons of NO_x per year. These are likely overestimates for the amount of emissions that will actually be produced from a Marcellus drilling rig. See Text Box 1.

Compressor stations, used to transport natural gas in pipelines, require engines to power them, although natural gas can be used rather than diesel to fire them. Natural gas emits NO_x and CO from combustion as well, but not as much as diesel fuel. The NY DEC's estimate for NO_x emissions from one compressor station engine is 48.3 tons per year. The engine in a compressor station is expected to run continuously, so this estimate is probably close to the actual amount that would be released annually by a compressor station.

Compressor stations are also a source of methane emissions. They

represent the largest methane emissions source from the "processing" stage of natural gas development, when liquids and other impurities are removed from natural gas so it can be transported.⁸

One important concern with the release of VOCs and NO_x in particular is that these gasses are precursors to ground level ozone. In sunlight, VOCs and NO_x gasses react with each other to produce ozone. If this reaction happens high in the stratosphere, the ozone serves to block harmful UV radiation from the Earth's surface. If it happens close to the ground, however, it causes smog, which can harm human respiratory systems. It can also seriously damage plants, reducing crop yield and making ecosystems more vulnerable to pests and disease. Ozone creation is seasonal. Because the reaction that creates ozone is dependent upon sunlight, ground-level ozone layers rise in the summer, when there is more sunlight.

The DEC estimates that the NO_x emissions from drilling and fracturing activities will be 10.4%

over current upstate emissions in peak development years, assuming that no mitigation of flaring or venting, and no mitigation of equipment engine emissions with engines running 24 hours per day, 365 days per year, though that does not represent a realistic scenario. See Text Box 2.

Even if emissions are not as high as estimated by the NY DEC, they will still represent an increase over the emissions that would occur if there was no development of the Marcellus Shale in New York.

Drilling Muds and Cuttings

Waste fluid from hydraulic fracturing and formation water are not the only waste products that require careful disposal. There are other sources of waste associated with drilling and hydraulic fracturing, specifically, drilling muds and drilling cuttings.

Drillers use different fluids to lubricate the drill bit and carry cuttings back to the surface during drilling. They usually use compressed air or fresh water mixed with mud for this until the wellbore has extended beyond the aquifers and has been sealed off from the surrounding rock. This reduces the chance that the chemicals used in drilling muds will come into contact with potable water.⁹ To continue drilling beyond that point and to drill the horizontal legs of the well, drillers sometimes use drilling muds to lubricate the well and make the drilling easier and faster. Drilling muds have as their base any of a number of fluids. Water can be used as the base fluid. Potential chemical bases include potassium chloride mixed with mineral oil and/or syn-

thetic oil.⁸ Drilling muds are often recovered, treated, and reused in other wells, especially if getting the mud to and from different well sites is convenient, as on a multi-well pad. Compressed air, rather than drilling muds, can be advantageous when there are few “water zones” (rock formations that are saturated with water) between the groundwater and the target formation, or when drilling muds can damage shale.¹⁰ Shale can be damaged if it absorbs the water from drilling muds, sloughs off, and clogs the bottom of the well bore; shale can also lose permeability if drilling muds are forced into spaces around the wellbore.¹¹ Compressed air drilling is a common practice in New York State.¹

Drilling a well displaces rock from the well bore. This rock is reduced to a mixture of coarse chips and fine particles and shavings called drill cuttings, or just cuttings. If fluid, rather than air, has been used to drill a well, these cuttings are wet. If the well has been drilled using air, they will be drier, though they may contain some formation water. Cuttings from the Marcellus formation

itself will represent as much as half or more of the total cuttings, as the lateral well legs within the Marcellus are in some cases longer than the vertical well length to the Marcellus. This means that the drill cuttings will contain the same minerals and trace elements that are found in the Marcellus Shale. The NY DEC estimates that a well drilled to a depth of 7,000 feet with a single horizontal lateral of 4,000 feet will produce cuttings that total 217 cubic yards, or 5,859 ft³ – enough to fill two school busses and a standard dorm room.¹ This estimate is for each well. A six-well pad would generate about 1,302 yds³. (This is probably a maximum estimate, since another estimate gives a lower volume of cuttings for similarly proportioned wells.¹²

Marcellus well cuttings contain all of the trace elements present in other Marcellus waste, including naturally occurring radioactive material (NORM) and pyrite (FeS₂). The NY DEC has determined that Marcellus drill cuttings show radiation levels similar to other natural sources in the environment (e.g., dark shales that outcrop at the

Text Box 2: Estimating Total Emissions

These are very conservative assumptions that produce an overestimate of the amount of NO_x that will be emitted in a year. The emissions reduction measures outlined in the SGEIS would reduce the actual total emissions and the percent increase over the baseline. The NY DEC estimates that VOC emissions would be 1.3% over upstate New York emissions with the same assumptions in place as with the NO_x calculations. As with NO_x, mitigation measures are likely to decrease the actual amount. The increased VOC and NO_x emissions due to increased truck traffic were estimated to be an additional 0.17% and 0.66% over baseline, respectively.

surface) and therefore likely do not pose a danger of radiation exposure to either workers or the general public. (For more information on NORM, please see *Marcellus Shale Issue 4: Understanding Naturally Occurring Radioactive Material in the Marcellus Shale*.)

Pyrite is a mineral that is commonly found in dark shales such as the Marcellus Shale. When oxidized, pyrite can damage certain storage pit liners and contaminate water with acid discharge. At Marcellus well sites in New York, cuttings would be stored either in lined pits or steel tanks if the cuttings are dry. If the well has been drilled with oil-based muds, the cuttings must be contained within tanks and disposed of in an off-site solid waste facility.

Dry cuttings could be buried onsite if they are buried with chemicals that neutralize potential acidic discharge from oxidizing pyrite. If this is not done correctly, the discharge could cause a change in soil or groundwater pH, making them more acidic and potentially damaging local vegetation.¹

Erosion and sedimentation

Some of the steps in gas drilling can contribute to erosion and sedimentation of topsoil. These include clearing land for well pads, access roads, and pipelines, and heavy truck traffic on inadequate roads.

Some 8.8 acres, on average, are cleared to construct a single well pad for a horizontal Marcellus well in Pennsylvania.¹³ This includes 3.1 acres for the wellpad itself and 5.7 for the support structures, including access roads.¹³ Clearing space for these structures removes the

vegetation, which can cause soil erosion. Though other kinds of human activities, such as agriculture and logging, cause the majority of soil erosion in the U.S. and worldwide, regional development of natural gas resources has the potential to add to this problem. Erosion and sedimentation controls are constructed around access roads at well pads, possibly including berms, ditches, sediment traps, sumps, or fencing.⁶ Berms are raised mounds of soil, often constructed in conjunction with a ditch, that help prevent erosion. Sediment traps help catch eroded soil before they enter nearby surface waters, and silt fences are actual fences designed to trap sediment before it washes offsite. These are the flexible black plastic fences commonly seen at construction sites. By one estimate, 8.5 tons of sediment would be eroded from a 2.57 acre well pad disturbance in New York.¹⁴ The estimates for actual disturbance from well pad construction are more than 3 times that, so if the erosion estimate is correct, more sediment could erode from the average well pad in New York. All of these measures will reduce, but not eliminate, soil erosion. Stormwater Pollution Prevention Plans, required for each well site, would include plans for erosion control.

Truck traffic on roads that are not designed for heavy trucks causes damage to the roads and can also cause erosion of the soil around them.³ Recall that there will be an estimated 1,979 round trips per well during early development of a typical well, and 1,420 during peak development (although these numbers are likely to be somewhat smaller if

the well is the second or subsequent well drilled on a pad). Undeveloped roads that would be damaged by drilling truck traffic are not uncommon in either Pennsylvania or in the areas likely to see drilling in New York.

Erosion is an environmental problem for several reasons. First, it reduces available topsoil, diminishing plant growth. Topsoil erosion is an environmental problem worldwide that reduces the amount of land available to produce crops. The U.S. is losing topsoil ten times faster than it can be replenished.¹⁵ Second, all of the topsoil lost has to go somewhere. Usually it is washed downstream by runoff into local surface water. Under normal circumstances, vegetation acts as a kind of natural filter during strong precipitation, slowing the rate at which soil and water enter surface water. Well pads, access roads, and staging areas will be cleared of vegetation, as is the case with most construction sites, so the filtering effects are reduced or eliminated and runoff increases, carrying water and soil quickly into nearby surface waters. As discussed further in the next section, runoff and excess sedimentation are harmful to stream ecosystems, especially the headwater streams commonly found in the areas of New York State likely to be drilled. Mitigation measures at well pads and access roads are likely to significantly reduce, though not eliminate, runoff.

Stream Ecology

Marcellus drilling activity has the potential to adversely affect the biota and ecosystems of streams and rivers in the area underlain by the

formation. Some of these adverse effects could also extend downstream to areas that do not see gas drilling. The Delaware River Basin Commission (DRBC) has determined that the potential threat to the streams of the Delaware River Basin from natural gas development is sufficient for them to regulate drilling in their watershed, which includes sections of 7 New York counties in the southeast portion of the state.

One obvious potential consequence of hydraulic fracturing is the removal of high volumes of water from streams and rivers. The NY DEC estimates that the total water required for Marcellus Shale drilling in New York could reach 9 billion gallons of water in a peak development year. This is enough water to fill the Empire State Building over 32 ½ times. Though this amount is dwarfed by the total amount of freshwater withdrawn in New York, which is 10 billion gallons *per day*, most of the area underlain by the Marcellus Shale in New York are part of headwater areas of river basins. (See Fig. 2 in *Marcellus Shale Issue 7: Water – Into the Wells*.) Headwaters are often the part of the river that is most sensitive to water withdrawal. With its overall lower volume, if the same amount of water is withdrawn from a small headwater stream as from a larger part of the river system downstream, the physical effect will be greater in the headwater. Altered flow in a river can affect specific aspects of ecosystems like water temperature, movement of sediment through the stream, and the shape of the channel itself, all of which may alter abundance and diversity of stream biota

and how the ecosystem functions.¹⁶ Because of the inherent sensitivity of headwaters, special attention is being paid by governing bodies of the rivers that will see withdrawals for Marcellus drilling. For more on who determines withdrawal policies throughout the region, see *Marcellus Shale Issue 7: Water – Into the Wells*.

Impacts from land-use alteration can also be felt more strongly in headwaters.¹⁶ Loss of forest cover, increases in the amount of impermeable land surface, and increased erosion and sedimentation near streams can also radically affect stream organisms and ecosystems. Forest cover influences temperature, levels of dissolved oxygen, erosion rates, and input of nutrients into streams from leaves.¹⁷ The revised SGEIS suggested that the edge of the well pads not be closer than 150 feet to streams without requiring site-specific review. Such required setbacks from streams may alleviate serious nutrient input and temperature impacts, but combined with the creation of new impermeable surfaces from drilling,¹⁶ removal of vegetation from land will inevitably alter sediment runoff into streams. Excess sediment in streams can dramatically alter habitat and harm aquatic organisms.¹⁷ Many river species depend upon hard substrate at the bottom of streams to successfully complete their life cycles; this substrate can be filled in or covered by enough sediment. Fish and invertebrate eggs can be smothered, and freshwater mussels, many species of which must attach to hard surfaces, can have their available habitat reduced or eliminated.¹⁷ Filter feeders, including freshwater mussels,

can see effects ranging from reduced feeding ability in waters turbid from excess sediment, to mortality when sediment clogs gills.

There are also risks to the environment associated with moving water from one area to another. Water from one area can carry with it invasive microorganisms, plants, and animals into new habitats. Invasive species are already among the most serious threats to aquatic animals, and this could worsen that situation.¹⁸

Habitat Loss and Fragmentation

Some degree of habitat loss and fragmentation will be an unavoidable result of Marcellus Shale gas development in New York State. Habitat loss is the conversion of one kind of habitat to another, dissimilar habitat. In the case of Marcellus Shale drilling in New York, this would mostly involve clearing of forest land for access roads, well pads, and pipelines. Habitat fragmentation occurs when one continuous area of habitat is broken up into smaller pieces, separated by areas of a different type of habitat.¹⁹ Its main components are habitat loss, reduction in the size of patches of the original habitat, and an increase in the distance between individual patches of the original habitat.¹⁹

Biodiversity, the variety of organisms in an ecosystem, is considered a key indicator of ecosystem health, and much research has been done on the effects of habitat loss and fragmentation on biodiversity. Scientific literature shows a clear negative effect of habitat loss on the number of species in an ecosystem.¹⁹

A commonly cited example of this is the negative effects of rainforest habitat destruction on the native species. Effects of habitat fragmentation on biodiversity are less clear, but are known to at least occasionally be dramatically negative. Negative effects of habitat fragmentation on biodiversity come from problems with organisms migrating between patches of the original habitat.²⁰ If the patches are too far away, the organisms may not be able to migrate at all.²⁰ Also, the farther away patches become, the more time organisms have to spend in the space between patches of the original habitat, leaving them more vulnerable to predators, less likely to find suitable feeding, and less able to reproduce.²⁰ Habitat fragmentation can, however, also have positive effects on populations. If populations exist in isolated patches, a disturbance to one patch, even if it wipes out all of the individuals in that patch, does not affect the populations of the rest of the patches.²⁰ Many species need more than one type of habitat to successfully complete a life cycle. A more fragmented habitat increases the chances that the different habitats needed are close or adjacent to one another.²⁰ This is true for the reptiles and amphibians that inhabit New York State forests. Edge habitats are also ideal environments for a number of species. The number of these kinds of species increases when habitats become more fragmented. The ecosystem at the edge of a forest is different than the ecosystem in the center of a large forest. When the patch of forest is large enough, shade and humidity increase and temperature decreases with distance

from the edge of the patch. Many species, including groups of songbirds and amphibians, can only thrive with the conditions present in deep forest. Different species, such as deer, raccoons, and jays can thrive in edge environments. The Nature Conservancy and Audubon Pennsylvania estimate that an average of 21.2 acres of new edge habitat is created per multi-pad well site.¹³ Thus, although habitat fragmentation may have positive effects on certain species, allowing total diversity to remain high, significant habitat fragmentation almost always changes the composition of the species in an ecosystem.

The effects of habitat loss and fragmentation due to gas drilling in the northeastern U.S. have not been widely studied, though a study done on reptile and amphibian diversity at gas well sites in the Monongahela National Forest in West Virginia suggests that the picture may be complicated. They found that while they found fewer woodland salamanders near gas wells than they did in forests, they found more amphibians, including American toad tadpoles, in areas with higher road densities. They believe the drainage ditches serve as breeding grounds. They also found no difference in the number of reptiles near gas wells and in forests farther away from them, and found the small mammal population to be higher near gas wells than farther away from them. The small mammals they found are characteristic of

early successional habitats, habitats that are recovering from a recent disturbance, like the kind of habitat provided by a gas well.²¹ More research is needed to determine the likely impacts of gas well driven habitat fragmentation in New York.

Some studies have been done in other areas that have seen gas drilling that might provide some insight into potential effects of gas drilling in New York State. One report indicates that boreal forests cover 53% of Alberta, Canada, which has seen intense oil and gas development – the energy sector made up 23.4% of their GDP in 2003.²² Ninety percent of those forests have been fragmented since the early 1900s.²² While most of their forest fragmentation has come from logging, the oil and gas industry is now interacting with the timber industry to alter forests. They have seen changes in the kinds of species that inhabit areas that have been fragmented. The species that inhabit older forests, continuous forests, and species that avoid humans have decreased while the species that inhabit younger forests, fragmented forests, non-native species, and human-tolerant species have increased.²² This situation in Alberta also indicates that a high number gas companies operating and competing for leases in the same area might increase the amount of habitat fragmentation, as access roads are built without coordination among companies.²²

The American Southwest, which

The effects of habitat loss and fragmentation due to gas drilling in the northeastern U.S. have not been widely studied.

has also seen gas drilling, is home to a variety of reptiles with fairly specific habitat needs that could be disrupted by gas drilling. In this case, the concern was that roads would alter the geomorphology of blowing sand dunes, thus altering and eliminating the habitat of these reptiles.²³ One study of six lizard species found no indication that the access roads altered the size or area of the sand dune features.²³ Though higher abundance of all six species was positively correlated with the amount of area, abundance was not correlated with the presence or absence of access roads or drilling activity.²³

One study done on birds in the grasslands of Alberta Canada showed different results for each of the three species studied. One bird species, known to be human-tolerant, showed increased abundance with increased well density. A second showed no correlation with gas well density, and a third species decreased in abundance with an increase in well density.²⁴

Animals aren't the only parts of ecosystems that can be affected by habitat fragmentation and well development. A study done on oil wells in the Great Plains of Saskatchewan found that lease sites were found to have fewer herbaceous plants and desirable, less club moss and leaf litter, more bare ground, altered soil chemistry, and a higher abundance of undesirable grass species than non-lease sites. It was also shown that these impacts could last for fifty years or more, and for up to 25 meters away from the well pad footprint.²⁵

Though these studies were done

in ecosystems that are not the same as those that would be affected by gas drilling in New York, each of them documented changes that can be correlated with gas drilling. More research should be done in ecosystems similar to New York, including Pennsylvania to determine the nature of ecosystem changes as a result of habitat fragmentation.

The NY DEC proposes to minimize the impact of gas drilling on wildlife by, where possible, requiring multiple wells per pad, designing pads to minimize tree removal and fit the terrain, planting bushes around the site to create "soft" edges, limiting mowing and prohibiting both mowing and construction during grassland bird nesting season if the pad is located in grassland, limiting the amount of ground that is disturbed both for well pads and access roads, and requiring reclamation as soon as possible using native species.¹

Different kinds of development, e.g. urban development, agriculture, and road construction, create different patterns of habitat fragmentation.²³ Natural gas development will also break up ecosystems in a distinctive way. The footprint of Marcellus drilling consists of well pads and staging areas, where drilling takes place and equipment and materials are stored, access roads to reach the pads, and pipelines to transmit gas once it has been recovered. Additional pipelines may be built to carry the water needed for hydraulic fracturing to the wellpads, in lieu of truck transportation.

The individual well pads used for Marcellus drilling will be larger than the well pads that have been

built in New York State for vertical gas drilling. More wells being drilled from a single pad and the increased storage requirements for materials and equipment needed for horizontal drilling and hydraulic fracturing contribute to this.

The collective footprint of these pads over the region, however, will be smaller. Vertical wells can be drilled with 40-acre spacing. Proposed Marcellus drilling regulations have the horizontal wells limited to 640-acre spacing. The NY DEC predicts that the footprint of multi-well pad for horizontal drilling in the Marcellus will be 3.5 acres on average.¹ They also predict that the average multi-well pad will take up 7.4 acres including access roads.¹ An aerial survey of existing Marcellus well pads in Pennsylvania shows an average footprint of 3.1 acres per well pad, plus 5.7 acres cleared for access roads and other associated infrastructure for each pad. This is a total of 8.8 acres per well.¹³ The average footprint of a vertical well pad is smaller, less than one acre according to the aerial survey of Pennsylvania.¹³ The NY DEC estimates that one vertical well covers 4.8 acres, including access roads. With vertical wells spaced at 40 acres, there could be 400 wells in 25 square miles, with footprints covering 1,920 total acres, using NY DEC estimates. With multi-well horizontal pads, there would be 25 in 25 square miles, with footprints covering 185 total acres using NY DEC estimates or 220 using Pennsylvania data. These estimates include access roads.

The apparent industry trend toward multi-well pads could reduce the total footprint of drilling further,

Table 1: How loud is drilling activity?

| Activity Type | Composite dBA at 500 ft | Duration (in days) | This is like... |
|--------------------------|-------------------------|--------------------|-----------------------------|
| Access Road Construction | 69 | 3-7 | A vacuum or hairdryer |
| Well Pad Preparation | 64 | 7-14 | Normal conversation |
| Air Well Drilling | 58 | 28-35 | A quiet office |
| Horizontal Drilling | 56 | | |
| Hydraulic Fracturing | 84 | 2-5 | A lawnmower or food blender |

but actual trends in Pennsylvania show mixed results. Since 2006, the number of Marcellus wells drilled on their own pads has decreased from 100% to 17%.²⁶ The current average number of wells per pad is 2.11.²⁶ There is, however, little indication that many new wells are subsequently drilled on well pads that already have wells on them; only 13% of pads had been revisited for additional wells as of August 2010.²⁶ This may change later, as development is still in the early stages in Pennsylvania.

Drilling activity can introduce non-native, invasive species to New York State and spread already established invasives to areas previously unaffected. Trucks, equipment, and other materials that travel from other parts of the country can bring seeds, microorganisms, and even animals with them when they arrive. Though the same is true of every vehicle or piece of equipment moved into any area, Marcellus gas development will increase occurrences in New York. Invasive species can alter and damage local ecosystems, especially if those ecosystems are already disturbed or weakened by environmental changes from gas

drilling. Often invasive species will have left the diseases and predators that limit their population behind, and can out-compete native species and disrupt the normal ecosystem interactions of their new environment. They can also be very difficult to eradicate once established. New York State already has a number of invasive species, both aquatic and terrestrial, whose spread can be worsened both by high levels of truck traffic and movement of water from one area to another.¹

In Canadian forests that have already seen drilling, practices like reclaiming well sites with industrial, non-native grass blends, especially in forests, introduces non-native species to an area.²²

Noise and Animals

As with most industrial activities, gas drilling can be noisy. Though drilling and fracturing noise levels are expected to be similar for both vertically fractured wells and horizontally fractured wells, the longer duration of activity caused both by the increased length of the wells themselves and the development of multiple wells on a pad is expected to make noise more of an issue with

horizontal drilling than vertical. As with habitat fragmentation, the overall sources of noise will be fewer than they would be with vertical drilling, but the noise disturbance from each individual well pad would be greater. See table 1 for the NY DEC estimates of noises associated with gas wells.

Eighty-five decibels is the minimum level at which hearing damage can occur, if exposure to the noise lasts longer than 8 hours. According to the National Institutes of Health, these sounds will range from comfortable hearing to annoying. Rural night time background level is around 35 dBA.²⁷ That is a little louder than a whisper, and a little less loud than a refrigerator's hum.²⁸

Humans can be annoyed or harmed by loud or constant noise, and wildlife can also be affected. Noise can interrupt communication among animals, hunting, foraging, or predatory-evasion abilities. It can cause panic reactions that risk injury to the animal itself or its neighbors. It can cause animals to temporarily or permanently abandon certain areas, in favor of marginal habitats with less noise. On the other hand, some species seem to be able to

acclimate to noise after repeated exposure, and not all of the disruptions are permanent. The response of an individual species to certain types of noise cannot be generalized.²⁹ In a study done in the boreal forest of Alberta that compared bird occurrence and density between well pads, which were considered quiet, and compressor stations, which have a constant noise level of 75-90 dBA, birds were found to occur less often overall the noisier the site was. Some of the individual bird species were more affected than others by compressor station noise, in fact some species showed no significant difference in abundance among the different site types, but none of them occurred more often at the compressor stations than at the well pads.³⁰

Summary

Besides the risks posed to water by developing the Marcellus Shale, several negative ecological impacts could be felt over the regions seeing drilling. Increases in certain air pollutants, such as volatile organic compounds and nitrogen oxides, both of which contribute to lower air quality, will happen as a result of engines running drilling and hydraulic fracturing equipment, truck traffic, and venting of natural gas in well completion activities. Solid waste from drilling, if not properly disposed of, can leach chemicals into the ground. Erosion and habitat fragmentation caused by the build-up of drilling sites pose threats to both terrestrial and aquatic ecosystems and wildlife. Even the noise produced by drilling and fracturing wells has the

potential to affect populations in the areas near well pads and compressor stations. At least some environmental degradation is going to occur in New York if gas drilling proceeds. To what extent this happens depends upon the regulations put in place to ameliorate these effects and how closely the regulations are followed in practice.

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