Testimony on the Economic and Environmental Impacts of Hydraulic Drilling of Marcellus Shale on Philadelphia and the Surrounding Region

Before The Joint Committees on the Environment and Transportation & Public Utilities of the Council of the City of Philadelphia

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Good morning. I appreciate the opportunity to speak on this crucial issue. I am Dr. David Velinsky and I am the Vice President for Environmental Research at the Academy of Natural Sciences. The Academy is Philadelphia's natural history museum, and our environmental research program has been studying human impacts on the environment for over sixty years. I direct an interdisciplinary team of scientists and technical staff that focuses on the ecological processes and environmental health of natural systems, particularly waterways, watersheds, and estuaries.

My colleague, Dr. Boufadel, and I were invited to provide scientific background on the issue of gas drilling in the Marcellus Shale and to discuss its potential impacts on the environment. I'd like to thank the Council for asking Temple University and the Academy of Natural Sciences to speak at this hearing. Our institutions are two of Philadelphia's important scientific resources, and we are pleased to apply our scientific capabilities to a topic of critical interest to our City and the Commonwealth of Pennsylvania. As our institutions propose to collaborate further on studying the Marcellus Shale, it is very appropriate that we are co-presenters today.

Today I'm going to start with some of the basic science of the Marcellus Shale and the natural gas deposited within it; touch on the drilling method known as hydraulic fracturing; and then look at some of the potential impacts of the drilling practice on the aquatic and terrestrial ecosystems. Finally I will discuss some preliminary research that has been conducted on these impacts, and briefly touch upon the further research that we feel is necessary to resolve a variety of uncertainties that surround the potential impacts of gas drilling in the Marcellus Shale. Dr. Boufadel's testimony will then focus on the hydrogeology of drilling and the potential below ground impacts.

I would also note that the Academy of Natural Sciences does not take a position on the overall advantages or disadvantages of obtaining gas from the Marcellus Shale. We recognize the enormous potential of this resource, for both the possible economic benefit of the Commonwealth and as an energy source with reduced greenhouse gas emissions. As environmental scientists, our role is to outline the potential changes to our ecosystem that may result from this process and to point out relative levels of uncertainty.

The Marcellus Shale, as this slide indicates, runs roughly from New York to West Virginia and lies on average about a mile underground (a little less than the distance from City Hall to the Art Museum), although that varies widely and in some places, such as Marcellus, New York, where it protrudes above the surface. As you can see from this map, a significant proportion of the Marcellus Shale is located under Pennsylvania, particularly along the Susquehanna Basin and, to a lesser extent, the Delaware.

What actually is the Marcellus Shale we've heard so much about? Technically, shale is a fine-grained sedimentary rock formed from mud deposited in ancient river bottoms, lagoons or even the continental shelf. There are types of shale formations around the world that occupy regions below the earth's surface. The Marcellus Shale was formed about 300 million years ago in an enclosed sea that once covered part of Pennsylvania. Microscopic algae produced in the surface waters were deposited in the bottom of the ancient sea that had low oxygen, and then were eventually covered over with other types of sediments. The methane gas was formed as the organic rich sediment degraded over time. This process needed the right temperature, pressure and time for methane to form and remain. This gas is now embedded in the tiny pores of the shale.

I would point out that the Marcellus is only one of many classes of shale that were formed by ancient geological processes. As you can see from the diagram, in this region there are shales that lie both above and below the Marcellus, and some of these may also contain gas. In fact, the presence of shale gas has been known for some time and extracting shale gas has been done in other parts of the country.

However until recently, it was believed that most of this shale gas could not be effectively utilized. Many shale gas deposits have low permeability, that is to say, the deposits are trapped in the grain of the rock, and there isn’t enough pressure for the gas to be withdrawn by simply boring a well into it. Many of these shales are also located at depths that were not easily reached by conventional drilling technologies.

This was the case until recently with the Marcellus gas. Several recent developments, however, have made it a more promising fuel source. First, new studies, notably by USGS and then Penn State, revealed that the extent and potential volume of the gas was much larger than previously estimated. Secondly, technical advances in drilling, specifically horizontal drilling combined with the older technique of hydraulic fracturing, have now provided a means for economically accessing the gas.

This method is quite simple in principle, although in the past was a daunting engineering task. Wells are drilled down to the level of the Marcellus Shale—as mentioned, roughly a mile—and the drilling tool is turned horizontally into the shale. Explosives are introduced into the horizontal bore, loosening the rocks, and then high-pressure water—a few million gallons per well—is pumped into open factures in the shale. The gas then flows through these fractures and is withdrawn through the vertical shaft.

I will leave it to the representatives of the drilling companies to explain any further details or clarify anything I've missed on the process. The questions we are considering are the potential environmental impacts of the gas drilling.

I would point out that while hydraulic fracturing and it's relationship to water quality has received the most attention, the impacts resulting from the entire process of gas drilling in the shale must be considered. We need to think about whether there are specific impacts on water quality and quantity, but we also have to look at larger impacts on natural resources and the natural services, such as water filtration, that are provided by the existing ecological systems.   I will discuss this latter concept, known as ecosystem services, in few moments.

In terms of overall impacts, as these photos show, gas drilling is an industrial process. There is the footprint of the well pad itself, the extraction and transportation of water to be used for fracturing, the disposal of fracturing water once it has been used (about a third of the amount is withdrawn from the well), potential impact of these activities on ground water, and the attendant issues that come from roads, construction, truck traffic, and air and noise issues, to name a few.

I'm not saying that these processes can't be managed or that they are unjustified from a cost-benefit perspective, but it is doubtful that they could be done with zero impact. However careful and conscientious drillers may be—and many are trying to be—it would be simplistic to say you could introduce these sorts of activities into natural or agricultural settings without altering elements of the system.

Let's take a moment and look specifically at the fracturing water, since that has received the most attention. On average about three million gallons of water are used for each well. The effect of this practice on water *quantity* quite simply depends on the source of the water. Three million gallons withdrawn from the Delaware down at Penn's Landing would not have a measurable effect on the flow of the river—it's simply too small a fraction. Three million gallons withdrawn from a small upland waterway—what we call a first- or second-order stream—could have a significant impact on available water locally and its biological diversity.

A number of substances are added to the fracturing water to increase its effectiveness in obtaining the gas.   These substances include lubricants to reduce friction, biocides and scale inhibitors to prevent bacterial growth, and coarse substances to assist the fracturing. None of these, for the most part, are found naturally in waterways. While best practices are that none of the fracturing water will ever be released into the environment, the level of risk involved in using these substances must be assessed.

In addition to the chemicals added to the water prior to use, the fracturing process adds a number of substances from the underground environment to the water that is withdrawn. As result, withdrawn fracturing water has very high levels of total dissolved solids.

The measure of *total dissolved solids or* TDS, is simply the amount of material in dissolved form—including minerals, salts or metals—that are in a given volume of water. High total dissolved solids can be a serious impairment to water quality in freshwater systems. As this slide shows, the amount of various dissolved materials in fracturing water exceeds by many orders of magnitude that found in typical river water. Substances such as barium and strontium, normally in trace amounts, are in very high relative concentrations in withdrawn fracturing water.

Is this a potential impact on the environment? Again, it depends on how the water is handled and how and where it is disposed of. The introduction of three million gallons of fracturing water with the TDS noted to the Delaware at Penn's Landing would probably have no measurable effect on the river as a whole. Three million gallons of such water spilled into a first- or second-order stream would have a profound impact on the local aquatic system. It should be noted that there is no economical treatment process for TDS other than dilution. In other words, at some point this water will have to be introduced into larger waterway or injected in deep wells.

So, to summarize there are several potential sources of environmental impact from gas drilling in the Marcellus Shale. First, water withdrawal could have impacts locally on the quantity of water available for natural processes. Second, there could be impacts on water quality. This could happen from accidental spills; treatment of withdrawn water; or other, as yet poorly understood processes. Dr. Boufadel will address some of the potential impacts on groundwater movement and quality.

The third area of potential impact is habitat and land fragmentation. This issue is not directly related to hydraulic fracturing but may be the most significant and least considered of the potential problems. Fragmentation is simply the reduction in the amount of forest cover and natural open space, breaking it up into smaller fragments, and a loss of connectivity between these fragments, in other words reducing the amount of space available for organisms, and interrupting or blocking important ecological processes in an area.

The effects of habitat fragmentation due to human alterations of the landscape have been studied for many years and are well understood. We know that there are critical sizes of contiguous natural systems that must be present for diverse populations of organisms to function, and we know that those sizes and diversities of organisms are necessary for ecological processes to occur.

This latter function—ecological processes—is sometimes called ecological services, because they represent a variety of potentially costly services that human societies get for free from natural ecosystems. I mention this because it is important to understand that we don't preserve natural systems just out of some altruism or fuzzy moral sense. We preserve natural systems because human society depends on them directly, whether it is for water filtration, air quality, or fertile soil.

The combined effects of habitat fragmentation and potential release of fracturing water into natural systems could have significant impacts on aquatic ecosystem services. Changes in TDS can be toxic, both on a chronic and acute scale, to aquatic organisms, reducing the size of biological communities and ultimately impacting human needs such as fisheries and water quality. Studies by Academy scientists, as well as from other local institutions, has shown that headwater forested streams provide the greatest filtration capacity for nutrient removal.

In summary, both loss of forest area and introduction of increased TDS can reduce or impair ecosystem service in small watersheds such as those in the upper Delaware. In particular removal of nutrient pollution, a major environmental stressor in agricultural landscapes, can be impaired by fragmentation and by changes in water chemistry such as increased TDS.

At this time there is very little information available as to the impacts of long-term exposure of a watershed to Marcellus Shale drilling activities, nor do we know if there is a cumulative impact of drilling activity—and in particular of possible exposure to water with elevated TDS—on the ecosystem services of a small watershed.

Let me be clear on this point. The question we believe needs to be addressed is whether there is a threshold point past which a certain density of drilling activity has a impact on the ecological health and services of the watershed regardless of how carefully drilling is conducted.   Past studies that have looked at particular well sites or particular incidents fail to give a picture of the chronic impacts that might be expected from drilling and especially hydraulic fracturing.

We are saying that regardless of the practices being followed by drillers, there may be a point at which drilling will have a definite signal in the ecological function of a watershed. Conversely, there may be some level of activity, some maximum number of well pads, below which, drilling doesn't have measurable ecological impact. Right now we have no idea if either of those are valid hypotheses.   We are proposing multi-variable cumulative ecological studies that would answer those questions.

One of the ways we measure ecological functioning is to look at certain key chemical indicators and at the abundance of certain types of organisms. Testing the electrical conductivity of a waterway is a good way of assessing the TDS and also a good proxy for human caused disturbance. This is because increases in pollution, erosion, water withdrawal and many other disturbances are often reflected by increased contamination of the water.

There are also certain organisms, notably amphibians and particular orders of insects that are highly sensitive to degraded and contaminated environments. By sampling watersheds for these measures, we are able to get an approximation the relative heath of the watershed and the ecosystem services of which it is capable.

To at least get preliminary assessment of cumulative impact of drilling in the shale, Academy scientists have been working with a University of Pennsylvania graduate student to collect data on water chemistry and indicator organisms. I would now like to briefly review the preliminary results of that research. Let me emphasize, this data is very tentative and will require further review and replication, but it does suggest that the impact of the drilling may be directly connected to density of drilling.

Our researcher looked at measures of ecological function downstream in nine small watersheds - three in which there had been no drilling, three in which there had been a defined low density of drilling activity and three in which there had been a defined high density of drilling activity.

Three indicators were measured: the conductivity of the water, the abundance of certain sensitive insects (also called an EPT index) and the abundance of salamanders. This last measure is particularly important as amphibians are especially vulnerable to changes in the environment and absence of amphibians is often an ecological "early warning" system.

The results of the research can be seen in these graphs. For each of the measures, there was a significant difference between high-density drilling locations and locations with no or low density drilling. Water conductivity was almost twice as high in the high density sites as it was in the low density and reference sites, while number of both salamanders and sensitive insects were approximately 25% reduced. Statistical analysis indicates that there is a less than 5% probability that these differences were the result of random chance.

This suggests that there is indeed a threshold at which drilling—regardless of how it is practiced—will have a significant impact on an ecosystem. Conversely it also suggests that there may be lower densities of drilling at which ecological impact cannot be detected.

With this initial data, which I emphasize remains tentative; we are proposing a comprehensive research plan to the State DEP (i.e., Growing Greener Program), which would develop guidelines and an assessment tool for regulators and managers to minimize the ecological impact of drilling. Our goals are to determine if this apparent threshold in the preliminary data remains valid over a larger sample, and to better understand the interactions between well density, size of the impacted stream and watershed, and the resulting ecological indicators.

We propose to look at four streams in each of three size classes for each of the three levels of well density (none, low and high). We will also use computer modeling to analyze the impact of drilling on deforestation. When this study has been completed, we will be able to indicate with a much higher level of certainty what the ecological risks are of drilling in the shale and how they might be managed. It is this and other types of scientific studies that are needed to provide regulators and drillers the necessary information for environmentally sound gas extraction from Pennsylvania.

In conclusion, I would like to thank the Council for this opportunity to discuss these issues. We believe the gas in the Marcellus Shale could have positive effects on the Pennsylvania economy, and there may be possible ways it could be extracted safely. Again, I'd like to emphasize that the Academy does not take a position on the overall advantages or disadvantages of obtaining gas from the Marcellus Shale. At this time, however, there remain significant uncertainties and we urge a cumulative impact assessment on the scale described above before any large-scale drilling occurs.