Environmental Impacts

DURING MARCELLUS SHALE GAS DRILLING: CAUSES, IMPACTS, AND REMEDIES

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ERRATA: CHANGES FROM PREVIOUS VERSION

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This version of the report corrects and/or clarifies portions of the report dated May 15, 2012. The information contained in this errata document supersedes the affected portions that report. We have corrected the following typographical errors, which do not affect the conclusions of the report:

Page 3, paragraph 1:	The units shown should have been trillion cubic feet (TCF) rather than billion cubic feet (BCF).
Original version:	The Barnett shale in Texas was the first to be developed and produced 1.936 *billion cubic feet (BCF)* of natural gas during 2011.[2] The Haynesville shale now appears to be the largest shale gas-producing field, according to the Energy Information Administration.[3] The third-largest producing field is the Marcellus in Pennsylvania and West Virginia, with estimated production of 1.2 *BCF* during 2011 (Considine, et al. 2011b).
Revision in this report:	The Barnett shale in Texas was the first to be developed and produced 1.936 *trillion cubic feet (TCF)* of natural gas during 2011.2 The Haynesville shale now appears to be the largest shale gas-producing field, according to the Energy Information Administration.3 The third-largest producing field is the Marcellus in Pennsylvania and West Virginia, with estimated production of 1.2 *TCF* during 2011 (Considine, et al. 2011b).
Page 30, fourth bullet:	The third word “number” should read “rate.”
Original version:	Both the *number* of environmental violations and subsequent environmental events that caused some physical impact on the environment steadily declined over the past four years, in conjunction with action by state regulators.
Revision in this report:	Both the *rate* of environmental violations and subsequent environmental events that caused some physical impact on the environment steadily declined over the past four years, in conjunction with action by state regulators.

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REPORT 2012 – 1

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Executive Summary

The development of shale gas through hydraulic fracturing has awakened what some have described as an American energy renaissance. Shale gas formations thought to be economically unrecoverable as recently as a decade ago now provide nearly 25 percent of our nation's total natural gas supply. According to the Energy Information Administration's reference case forecast of April 2011, natural gas production from shale formations will comprise 46.5 percent of total U.S. dry gas production in 2035.

The investments under way for developing these shale resources are generating tens of thousands of jobs, billions in state and local tax revenues, and hundreds of billions in direct economic activity. Indirect benefits to oil and gas suppliers, to U.S. manufacturers that utilize natural gas as a feedstock, and to consumers enjoying lower electricity and heating bills multiply the already substantial direct economic gains. In short, the incentives for states to encourage and facilitate development are substantial.

But surprisingly little comprehensive analysis exists to quantify the success or failure of states in effectively and safely managing natural gas development. Without such information, it is very difficult for regulators, elected officials, and citizens to engage in productive dialogue around natural gas development and the process of hydraulic fracturing. Whether considering regulatory changes in a state where development is already under way, or debating the permitting of natural gas development where it has not yet occurred, quantifying measurements of success are necessary for building consensus and making sound decisions.

[The incidence of polluting environmental events [in Pennsylvania] declined 60 percent between 2008 and August 2011 …]

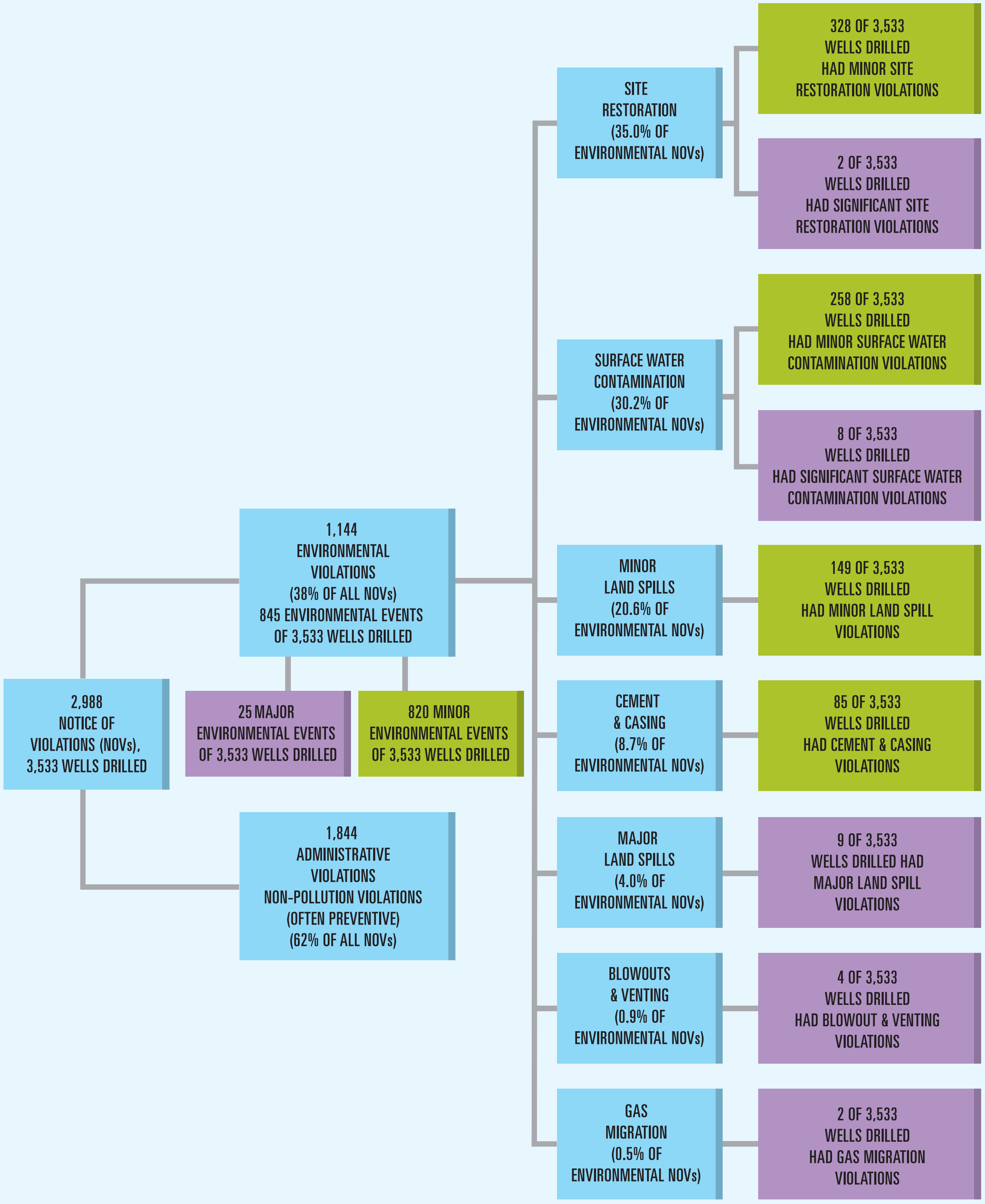
To address this question, this study provides a detailed analysis of notices of violations (NOVs) from the Pennsylvania Department of Environmental Protection (PA DEP) from January 2008 through August 2011, categorizing each violation. Of the 2,988 violations, 1,844, or 62 percent, were for administrative or preventative reasons. The remaining 38 percent, or 1,144 NOVs, were for environmental violations. The number of these environmental violations, however, is a misleading metric because an individual event may be associated with multiple environmental violations. As such, the 845 unique environmental events considered in this study were associated with 1,144 NOVs.

To produce an accurate accounting of the environmental impacts of these 845 unique events, this study defines major and non-major environmental events through a detailed examination of NOV records.

Major environmental events are defined in this study to include major site restoration failures, serious contamination of local water supplies, major land spills, blowouts and venting, and gas migration. Our evaluation of NOV records identified 25 such events. In all but six cases, the resulting environmental impacts from major events have been mitigated.

Non-major environmental events concern site restoration, water contamination, land spills, and cement and casing events that do not involve what is classified as having major environmental impact. Many of the NOVs in this category, while resulting in measurable pollution, were rather

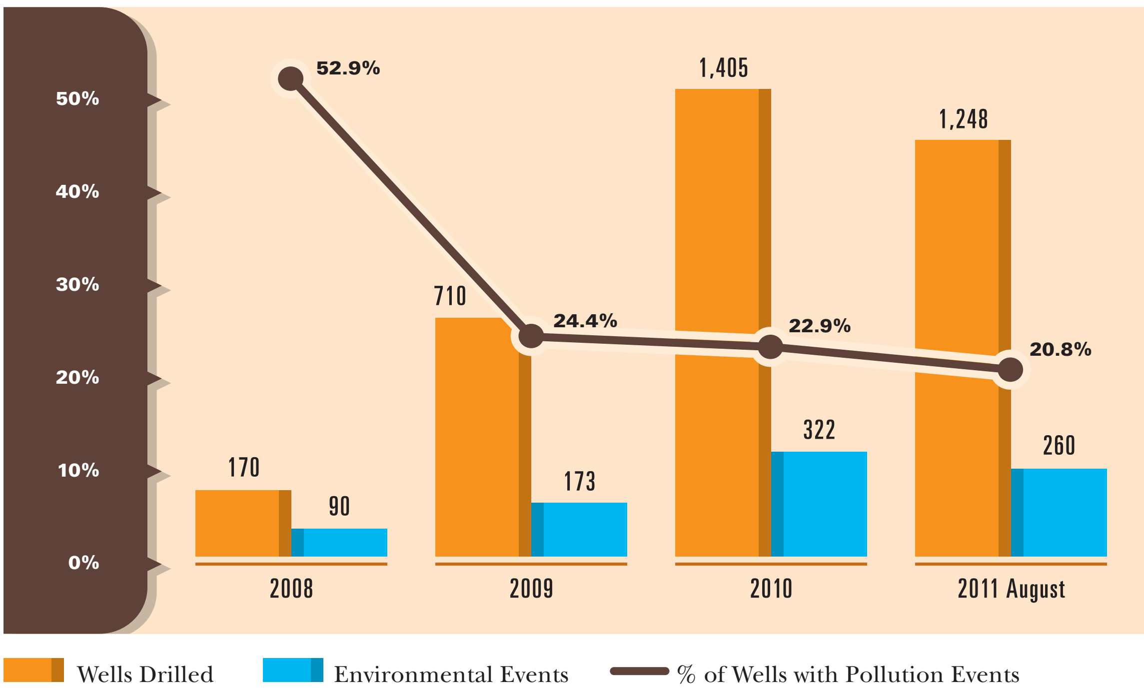
FIGURE ES1: ENVIRONMENTAL VIOLATIONS AND EVENTS IN PENNSYLVANIA MARCELLUS



minor, involving, for example, a gallon of diesel fuel or antifreeze spilled on the ground. The 820 non-major events identified, comprise the overwhelming majority of environmental NOV's issued by the PA DEP, as shown in figure ES 1.

Significantly, the incidence of polluting environmental events declined 60 percent between 2008 and August 2011, from 52.9 percent of all wells drilled in 2008 to 20.8 percent through August 2011 (Figure ES2). On this basis, the Marcellus industry has cut its incidence of environmental violations by more than half in three years, a rather notable indicator of improvement by the industry and oversight by the regulators.

FIGURE ES2:
WELLS DRILLED AND ENVIRONMENTAL EVENTS IN PENNSYLVANIA MARCELLUS



In conclusion, this study demonstrates that the odds of non-major environmental events and the much smaller odds of major environmental events are being reduced even further by enhanced regulation and improved industry practice. Moreover, the environmental impacts of most of these events have been almost completely mitigated by remedial actions taken by the companies.

The observed impacts of development in Pennsylvania captured within the paper provide a metric to gauge the regulatory proposal, known as the *Supplemental Generic Environmental Impact Statement* or SGEIS, currently under review in New York State. The last part of this study compares each of the 25 major incidents that occurred in Pennsylvania against New York's proposed SGEIS guidelines. Findings indicate that each of the underlying causes associated with these specific events could have been either entirely avoided or mitigated under New York State's proposed regulatory framework. This suggests that regulators are not only responding effectively within their states, but are learning and acting on the experiences of other states as well – a positive sign for the continued successful state regulation of natural gas development through hydraulic fracturing.

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1. Introduction

There are a growing number of states that are reviewing their regulations regarding shale energy development. This study examines New York as a representative example, since it has just completed a three-month public comment period addressing proposed environmental regulations governing shale gas development. A majority of citizens of New York may be supportive of oil and natural gas resource development if the environmental impacts appear manageable in light of the anticipated economic benefits. There is, however, a void of factual information concerning the environmental impacts, inadequate data on assessing the risks from development, and an incomplete articulation of strategies on how regulation may mitigate these impacts and risks.

Existing research previously conducted by Considine, et al. (2011a) provides a categorization of incidents in the Pennsylvania Marcellus Shale, parsing administrative failures from physical environmental events. There is, however, a noticeable lack of digestible research classifying physical incidents, and specific explanations of the causes and impacts associated with each category of physical incident. Offering this information is an important precursor to understanding the safeguards New York has adopted, and in communicating how regulation can prevent future incidents and protect local residents.

This study provides an extension of the research by Considine, et al. (2011a) with a more detailed analysis of notice of environmental violations (NOV) from the Pennsylvania Marcellus Shale industry. Not all environmental violations result in environmental pollution because many violations are citations for administrative failures or are issued to prevent pollution from occurring. Accordingly, this study makes the critical distinction between environmental violations and events, providing a complete enumeration and classification of environmental violations and the corresponding subset of events that resulted in actual, measurable pollution during drilling and completion operations in the Pennsylvania Marcellus. The categories for violations and events include drilling or well construction failures, surface handling and treatment of fluids, and failures in the drilling and completion process itself. Based upon this analysis, this study then examines how New York's proposed regulatory regime addresses these different categories of concern.

Coupling known risk with existing responses will both: 1) help the public differentiate between largely unrealized threats, such as migration of fracturing fluids out of a formation, and existing issues of concerns, such as improper surface disposal or wellhead and well casing failures, and 2) enable regulators to demonstrate strengths and potentially identify areas where state rules should be strengthened.

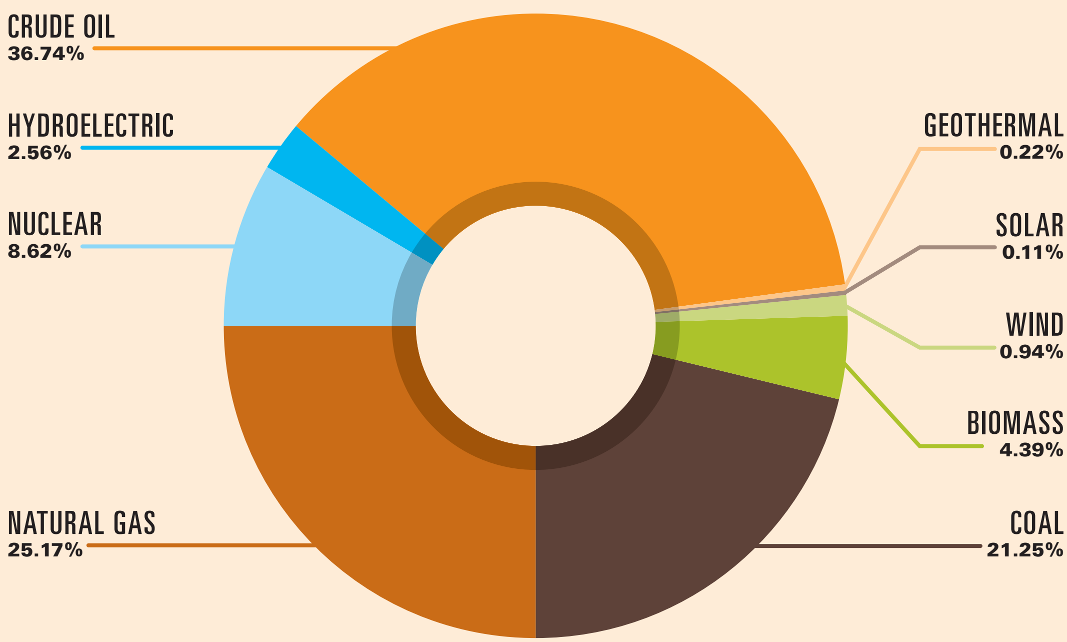
To quantify these risks and assess their impacts, this study provides a detailed analysis of environmental violations incurred during the drilling of natural gas wells in the Pennsylvania Marcellus from 2008 through 2011. The analysis of environmental violations estimates their probability of occurrence and severity, and identifies their causes, describing the response of natural gas production companies, available technologies to remedy these problems, and the implications for regulation.

The structure of this study is as follows. The next section provides an overview of the emergence of the shale energy industry. The study then provides a primer on the economic impacts from developing and producing energy from shale formations. What follows next is an overview of shale energy development, which is then followed by a discussion of complications associated with shale energy drilling and completion operations. The next three sections of the report provide the core analysis of the environmental violations and environmental events. A detailed discussion of 25 major environmental events appears in Appendix B. The implications for New York State regulatory policy are presented in section eight. The study concludes with a summary of the main findings and recommendations.

2. Emergence of Shale Energy

The U.S. economy is powered by fossil fuels, with slightly more than 83 percent of domestic energy consumption supplied by oil, natural gas, and coal. Oil leads with a share of 36.7 percent, natural gas is second with 25.2 percent, and coal provides 21.3 percent of total energy consumption (see Figure 1). Nuclear energy supplies 8.62 percent of total consumption, with biomass and hydroelectricity providing 4.39 percent and 2.56 percent, respectively. Wind energy provided 0.94 percent of total energy consumption during 2010, up from 0.76 percent in 2009. Geothermal energy furnished 0.22 percent of total consumption during 2010. Finally, solar photovoltaic provided 0.11 percent during 2010 (see Figure 1).

FIGURE 1: SHARES OF TOTAL ENERGY CONSUMPTION BY SOURCE, 2010



Source: U.S. Energy Information Administration

The contribution from natural gas in total energy consumption has been rising in recent years, expanding from 22.3 percent in 2006 to 25.2 percent in 2010. Much of this increase has been due to greater use of natural gas in electric power generation. Since 2005, natural gas use in electricity production has increased 25 percent. In 2010, more than a third of U.S. end-use natural gas consumption occurred in electric power generation. The electricity industry is now the single largest user of natural gas, and will likely expand consumption significantly in future years to meet higher demand for electricity and to replace aging coal-fired power plants. Since natural gas electric power generation has only 41 percent of the carbon dioxide emissions of coal-fired power generation, such a transition could significantly reduce greenhouse gas emissions.[1]

1 According to data from the U.S. Energy Information Administration, net electricity generation from coal and natural gas in 2009 was 1,755,904 and 920,929 thousand megawatt hours, respectively, while emissions of carbon dioxide were 1,742.2 and 372.6 million metric tons from coal and natural gas, respectively.

These additional demands for natural gas have been increasingly supplied by shale gas production. There are three major shale gas plays in the United States. The Barnett shale in Texas was the first to be developed and produced 1.936 trillion cubic feet (TCF) of natural gas during 2011.[2] The Haynesville shale now appears to be the largest shale gas-producing field, according to the Energy Information Administration.[3] The third-largest producing field is the Marcellus in Pennsylvania and West Virginia, with estimated production of 1.2 TCF during 2011 (Considine, et al. 2011b). As conventional natural gas deposits deplete, the role of shale gas in the U.S. natural gas supply is likely to continue to increase. Indeed, the Energy Information Administration projects that the share of shale gas in total U.S. dry gas production will rise from 24.8 percent in 2011 to 46.5 percent in 2035.[4]

This large reserve base suggests that it will take decades to fully develop the shale energy potential.

Shale resources also contain crude oil and petroleum liquids. The Marcellus Shale in Appalachia is emerging as a major producer of natural gas liquids such as propane and butane. These fuels are a critical input in petrochemical industries. Production of crude oil from the Bakken shale play in North Dakota is also increasing rapidly. For example, crude oil production from North Dakota rose from an average of 123,620 barrels per day during 2007 to 418,923 barrels per day during 2011 (North Dakota, 2011). From negligible amounts in 2007, the Eagle Ford shale play in south Texas produced 83,434 barrels per day during 2011 (Texas Railroad Commission, 2011). The Niobrara plays in eastern Colorado and Wyoming are also promising. Production from these new oil-producing areas and the deep waters of the Gulf of Mexico are reversing the long-term decline in U.S. oil production that began in the early 1970s.

According to the Energy Information Administration (2011), there are nearly 24 billion barrels of technically recoverable oil and 862 trillion cubic feet of natural gas from shale resources. The Potential Gas Committee (2011) estimated that the total natural gas resource base for the United States is even larger at 1,898 trillion cubic feet. This large reserve base suggests that it will take decades to fully develop the shale energy potential.

2 http://www.rrc.state.tx.us/barnettshale/index.php
3 http://205.254.135.7/todayinenergy/detail.cfm?id=570
4 http://205.254.135.7/analysis/projection-data.cfm#annualproj

3. Economic Impacts of Shale Energy Development

Shale gas production is different from conventional natural gas production from shallow fields because the production decline curve is much steeper, with output declining roughly 50 percent during the first few years of production before leveling out. This high rate of output early during the production period often implies very high rates of return, even at low prices. These high rates of return provide the incentive to continue drilling, which allows shale energy-producing companies to maintain or increase production as they bring new wells on stream to offset the steep production decline of older wells. Accordingly, shale energy development resembles continuous energy manufacturing, unlike conventional natural gas development with an intensive three- to seven-year period of well and pipeline infrastructure development, and relatively little labor and resource use afterward.

The continuity of drilling effort and the economic activity that it generates set shale resource development apart from other energy development activities. Developing coal mines, wind turbines, hydroelectric resources, and solar energy involves significant job creation during construction. Once the facilities are in place, however, their operation requires relatively few workers. In contrast, the labor-intensive aspects of shale gas development accelerate over time and can persist for decades, if the reserves in place are large enough, and market prices for natural gas justify continued investment.

[Shale energy resources during 2010 alone supported more than 600,000 jobs, increased gross domestic product or value added by $76 billion …]

Transportation costs are high for key materials used in the exploration, drilling, and construction of gas-processing plants and pipelines. Therefore, support industries, including well support, steel, sand and gravel, concrete, trucking, and scientific and engineering services, often arise locally. Most of these support activities are not easily outsourced to foreign suppliers. And in regions with private mineral rights, shale gas development requires lease and bonus payments to landowners, who in turn pay taxes and spend this income on local goods and services. While the footprint of a shale well site is small, the shale deposits occupy an extensive geographical area, necessitating the leasing of large tracts of land.

Economic-impact studies have been conducted for the Barnett, Fayetteville, Haynesville, and Marcellus Shale gas plays. These studies employ input-output models to estimate the direct, indirect, and induced impacts on regional value added (the regional equivalent of contribution to the nation's gross domestic product), employment, and tax revenues. "Direct impacts" constitute the purchases by natural gas companies from other sectors of the economy. "Indirect impacts" refer to the supply chain. For example, a natural gas company contracts with a drilling supply company, which then hires workers and other companies to supply it with materials, equipment, and services. "Induced impacts" constitute the rounds of transactions throughout the economy set off by the spending of workers, hired directly or indirectly, on goods and services. "Induced impacts" also result from landowners' spending of lease, bonus, and royalty payments.

The development of these shale energy resources during 2010 alone supported more than 600,000 jobs, increased gross domestic product or value added by $76 billion, and generated more than $18.6 billion in tax revenues at the local, state, and federal levels (IHS, 2011). Similarly, the study by Considine, et al. (2011) finds that development of the Marcellus Shale in Pennsylvania supported nearly 140,000 jobs and generated $11.6 billion and $1.1 billion in value added and state and local taxes, respectively.

If shale gas development was allowed in New York State, Considine (2010, 2011a) estimates that the accumulated value added from 2012 to 2021 would come to more than $11.4 billion, with more than 18,000 additional jobs in 2021 and approximately $214 million in state and local taxes by 2016 (see Appendix A).

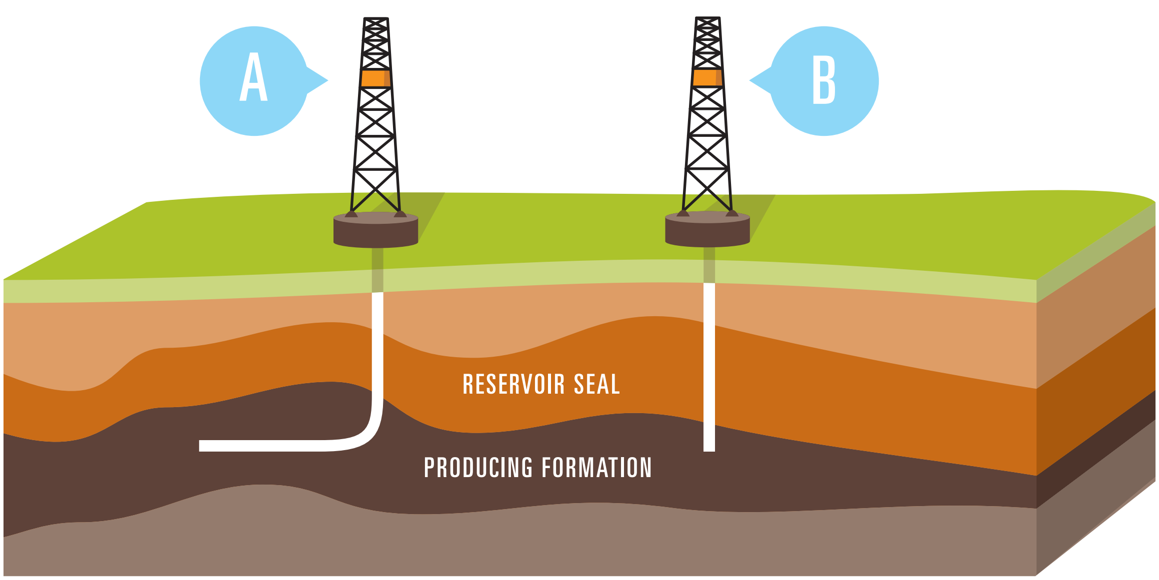
4. Producing Energy from Shale Formations

Two distinct technologies – horizontal drilling and hydraulic fracture stimulation – enable shale energy development. Horizontal drilling involves vertically drilling down to the shale-bearing strata and then drilling horizontally to establish lateral well sections that may be up to a mile in length. This approach allows greater surface contact with the energy-bearing shale layer. Producers then inject a water-based solution that contains between 2 and 4 percent sand and chemicals under high pressure into the well, which cracks the rock and increases the permeability of the reservoir. Most of the gas reserves in the Marcellus Shale are only economically recoverable using horizontal wells and hydraulic fracturing. Companies are constantly increasing the speed and efficiency of these operations.
The first step in drilling a well is to install a well pad to support a drilling rig. Land is cleared, an area for the well is leveled off, and gravel roads are laid. After a well is completed, all surrounding land is restored and replanted, typically required under regulatory and bond release programs.

Two types of wells can be constructed: a vertical well in which a large drilling rig rotates a steel pipe with a drill bit on the end; and a horizontal well in which a drilling motor pushes fluid through a stationary drill pipe, causing the bit to rotate. In either case, as the well is drilled, a new length of pipe is connected to the one already in use so that the latter can be pushed deeper into the hole. Currently, both vertical and horizontal wells are being drilled in most shale plays. Both types of wells are drilled to a predetermined vertical depth, but the latter then makes a turn, permitting it to be drilled sideways for several thousand feet. While the cost of a horizontal well is three to four times that of a vertical well, they are much more productive because they have far more contact with the gas-bearing rock (Figure 2).

Standard drilling practice includes several measures intended to protect the environment. Oil and gas wells penetrate the water table, generally extending several thousand feet below potable water supplies. As the well is drilled, steel pipe called casing is inserted into the well bore and then

FIGURE 2: HORIZONTAL AND VERTICAL WELLS

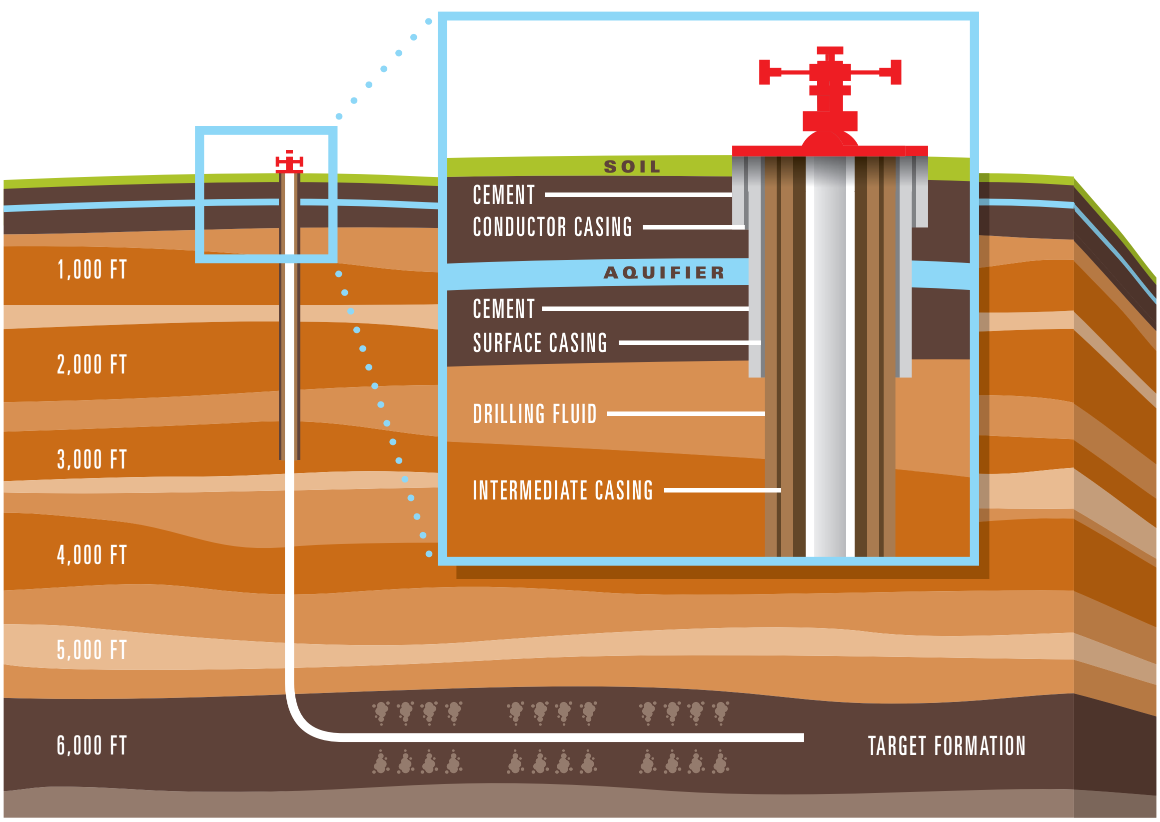


cemented into place to form a barrier that protects subsurface groundwater from contamination. Well drillers are also responsible for ensuring that any fluids or chemicals used or produced during drilling and completion of the well do not contaminate surface waters such as streams, rivers, or lakes. In Pennsylvania, all fluids on a well site are now contained within plastic tarpaulins, plastic-lined pits, or steel tanks, facilitating the recycling or transportation of these fluids to well-disposal sites permitted by the U.S. Environmental Protection Agency.

After the well is drilled to its final depth, another steel pipe is installed inside of larger ones above it and cemented into place. The drilling rig then leaves the site, and a wellhead is installed on the surface. The wellhead is a collection of valves, often referred to as a Christmas tree, which controls the flow of gas and allows it to be turned off completely if necessary and allows the use of equipment for performing well stimulation and maintenance.

Once drilling is complete, hydraulic fracturing, which stimulates the well to produce more gas by creating new fractures that intersect and connect to as many of the natural fractures to the well as possible, can occur. The first step in this process is to use shaped explosive charges to perforate the bottom section of the steel pipe. Doing so allows hydraulic fracturing fluid to be pumped into the rock to fracture the shale, and then allows hydraulic fracturing fluid and gas into the pipe casing and to the wellhead at the surface. The resulting well is a set of pipes within pipes known as casing strings. The point where one casing string ends and another extends is known as the "shoe." Most companies use multiple strings of casings of varying lengths, diameters, and grades (Figure 3).

FIGURE 3: GROUNDWATER PROTECTION THROUGH PROPER WELL CONSTRUCTION



5. Complications Associated With Natural Gas Development

The extraction, processing, and transportation of natural gas all affect the environment. Koomey and Krause (1997) outline the basic steps for estimating environmental externalities[5] and the costs they impose on society, involving these general steps:

- Identifying insults to the physical and human environment;
- Charting pathways that convert the insults to stresses;
- Estimating the physical or social consequences of the stresses; and
- Valuing the environmental and social costs of the stresses.

The first three steps collectively can be referred to as environmental-impact assessment and can be accomplished with varying degrees of accuracy or confidence. As a result, most studies estimating environmental externalities specify a degree of uncertainty.

Some upstream negative externalities of natural gas production are unavoidable. They involve the clearing of land for well pads and pipelines; local congestion due to truck traffic; and noise and dust. Lease and bonus payments to landowners or direct outlays by companies to repair infrastructure damage caused by gas drilling activity compensate for most of these impacts. Nonetheless, the sheer presence of gas wells has effects on the ecosystem.

Environmental hazards associated with natural gas production are infrequent, but can lead to contamination of local water supplies and impairment of air quality. Perhaps the most publicized environmental risk arises from the use and disposal of fluids used in hydraulic fracturing. The New York City Department of Environmental Protection (2009) study of the potential impacts of natural gas drilling on the New York City watershed raised the possibility that water from hydraulic fracturing could migrate from the gas-bearing layers, which are 5,000 feet below the surface, up to water tables less than 500 feet from the surface.

The presence of 4,500 feet of rock above the hydraulic fractured zone makes such an eventuality unlikely. Indeed, there exists no documented evidence of such an event since hydraulic fracturing was first introduced approximately 60 years ago. Vaughan (2010) argues that water-supply contamination from so-called stray gas occurs more often from failures in well design and construction, breaches in spent hydraulic-fracturing water-containment ponds, and spills of leftover natural gas liquids used in drilling.

Where groundwater has been impacted, the PA DEP has concluded that the issue stems not from hydraulic fracturing per se, but poorly formulated cement and improperly designed wells – traits that should be of concern in all wells, not just high-volume hydraulic fracture (HVHF) wells. Methane contamination of water is manageable with the use of water treatment systems that remove methane and metals related to methane contamination. Migration of natural gas into structures, however, poses a serious risk of explosions, which have happened on a number of occasions.

Stray gas events can be significantly mitigated by proper well construction. These methods, however, cannot entirely eliminate stray gas emissions because there are many sources of stray gas,

5 Environmental externalities refer to effects external to production and consumption activities by firms or households. For example, water pollution from natural gas production is a production externality, while air pollution during combustion of natural gas for home heating is a consumption externality.

entirely unrelated to shale gas drilling, such as shallow gas reserves, unplugged orphan wells, decaying plant and animal materials, and septic fields. To address this issue, mandatory standards for water-well construction should be adopted in Pennsylvania, which surprisingly do not yet exist due to strong opposition from rural communities and the agricultural industry. To determine the frequency of environmental incidents, a detailed examination of the environmental violations reported in the Pennsylvania Marcellus appears in the next section.

6. Notice of Violations in the Pennsylvania Marcellus

The Pennsylvania Department of Environmental Protection (PA DEP) regulates natural gas development in the Commonwealth of Pennsylvania. The responsibility of the PA DEP is to enforce a body of regulations that date back to the 1930s that recently have been updated to reflect the environmental impact of the development of the Marcellus Shale and other unconventional sources of natural gas. If an operating company fails to comply with these regulations, the PA DEP issues a Notice of Violation (NOV).

These violations are indicative of many different situations. To fully understand the effectiveness of current regulations in mitigating the environmental impacts of Marcellus Shale development and the various incidents that garnished an NOV, a closer examination of these violations is required. A notice of environmental violation often does not indicate an actual environmental event because many of these citations are for administrative violations or are issued to prevent pollution from occurring. Consequently, to estimate the actual environmental impact of shale gas drilling, a careful analysis is required of the environmental violations to determine what actually happened, which appears in section seven below and in greater detail in Appendix B. Meanwhile, this section provides an overview of environmental violations to provide a context for the identification and discussion of the environmental events that resulted in measurable pollution or harm to the environment that are discussed below.

The database for this inquiry includes NOVs issued to operators from January 2008 through August of 2011.[6] Each NOV is analyzed by first determining the legal statute that prompted its issuance, and then by comparing the statute with the descriptions of the violation provided by the PA DEP and its well site inspectors. This study classifies the violations into seven categories: cement & casing, blowouts & venting, major and non-major spills on land, gas migration, site restoration, and water contamination. More detailed definitions of these categories appear in Table 1 below.

TABLE 1: CLASSIFICATION OF ENVIRONMENTAL VIOLATIONS

Violation Type	Description
Cement & casing	Cement and casing job cited as defective and the cause of the pollution
Blowouts & venting	Citation for a blowout or hazardous venting
Major spills on land	Citation for major (> 400 gallons) spills of materials on land
Minor spills on land	Citation for minor (< 400 gallons) spills of materials on land
Gas migration	Citation for migration of gas in underground aquifers or substrates
Site restoration	Citation for violations of site restoration regulations
Water contamination	Citation for tainted water as the primary focus of the citation

The next step reconciles the legal citation with the description of the violation to determine if pollution took place. For example, if a statute discussed discharges of material into waters of the Commonwealth, then the NOV would be classified as a violation involving water contamination as long as this matched the PADEP description and inspector's comments. This close scrutiny of each

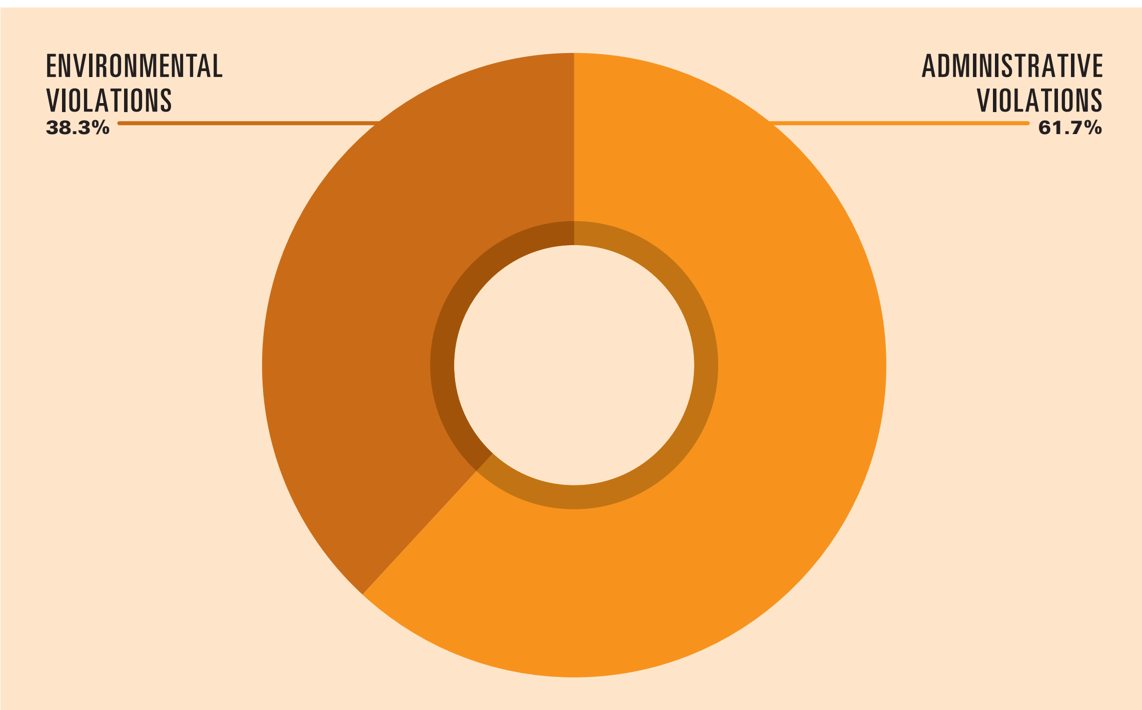
6 http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/OG_Compliance

violation allows a more precise determination of the frequency of NOVs that result in measurable pollution or damage to the environment.

This approach also allows the identification of those violations that affected the environment. To identify these violations, our analysis used a series of indicators developed from the well inspector's comments for each NOV. These violations stood out based upon the amount of fluids spilled, the amount of water or land disturbed, and the potential threat to human health or safety. Once these violations had been identified, our analysis employed the Environmental Facility Applications Tracking System (eFACTS) from the PADEP to classify the violations into those that did and did not involve actual environmental harm.

The raw number of NOVs does not tell the whole story. Our analysis of the NOVs reveals that only a fraction of them were issued for a violation that involved an environmental impact. Among the 2,988 violations issued, only 1,144 were for a violation that involved an environmental event. The other 1,844 violations issued were administrative violations or citations to prevent pollution. Hence, 38.3 percent of the 2,988 NOVs issued were for environmental violations of some type, which is illustrated below in Figure 4. Determining what proportion of these environmental violations were preventative in nature is problematic because it is nearly impossible to assess whether pollution would have occurred had these violations not been issued. Regardless, the number of these violations that did not involve pollution should be considered as a good metric for regulatory oversight. While some in the industry may find these NOVs a nuisance, state oversight through robust regulation does provide incentives for companies to more closely comply with environmental regulations and, most importantly, adopt technological innovations to avoid these citations altogether.

FIGURE 4: SHARES OF ADMINISTRATIVE AND ENVIRONMENTAL VIOLATIONS



A further disaggregation of the environmental violations using the six categories of violations identified above in Table 1 is displayed below in Figure 5. Understanding the distinctions of these categories is important to understanding the key risks of concern to regulators. The environmental violations constitute 38.3 percent of all NOVs and are split seven ways in Figure 5. For example, the largest portion is the 13.4 percent of all NOVs arising from breaking site restoration rules (Figure 5). The next largest category is water contamination with 11.6 percent of all NOVs. Minor spills on land constitute 7.9 percent of all violations. Cement and casing violations comprise 3.3 percent of all NOVs. Violations for major land spills, blowouts and venting, and gas migration constitute 1.5, 0.3, and 0.2 percent of all violations, respectively (Figure 5).

FIGURE 5:
SHARES OF ADMINISTRATIVE VIOLATIONS AND ENVIRONMENTAL VIOLATIONS BY CATEGORY

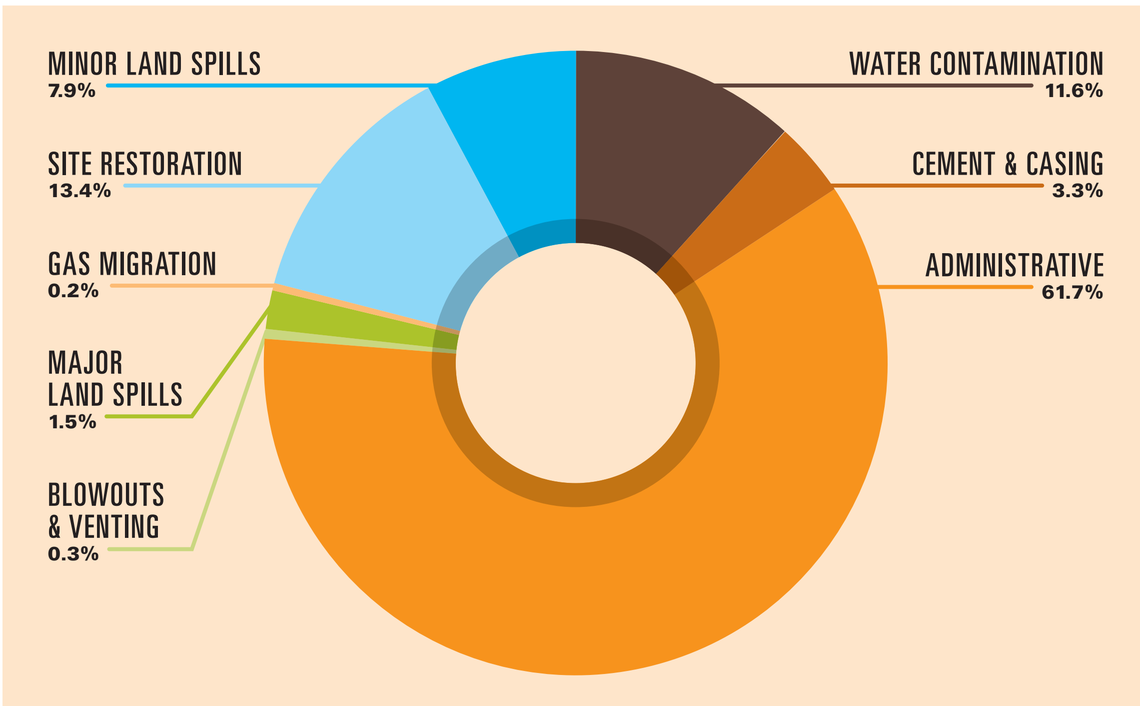
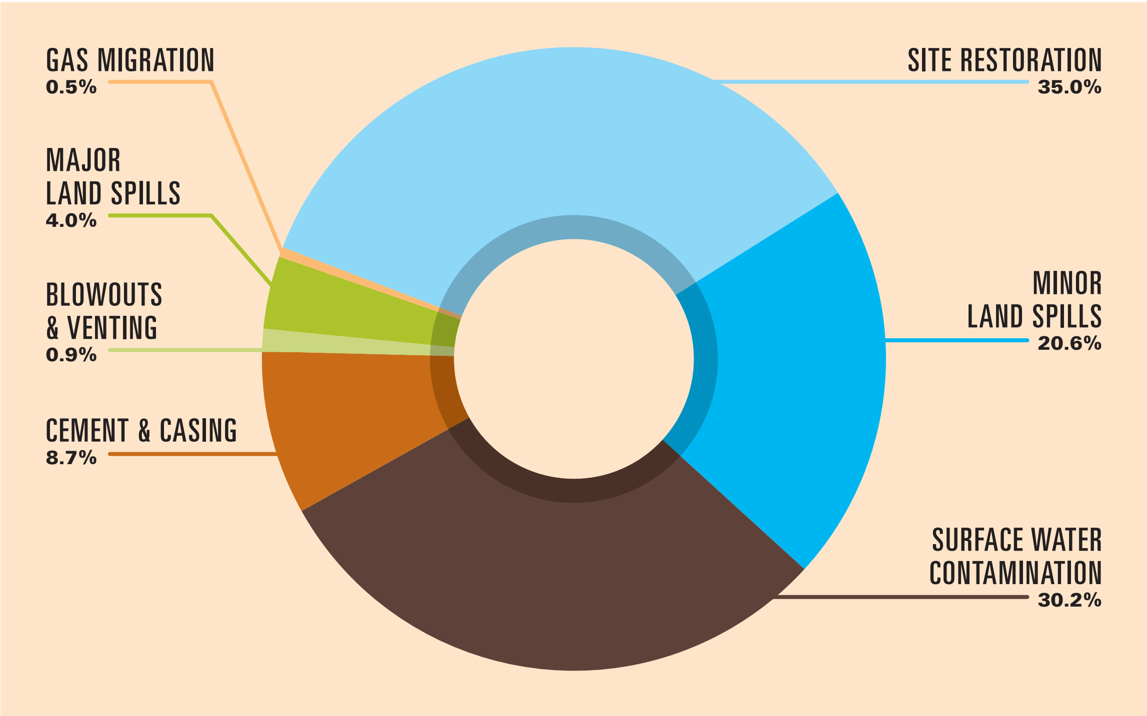


Figure 6 below displays a disaggregation of the environmental violations. Of these 1,144 violations, 35 percent involved site restoration issues, slightly more than 30 percent entailed surface water contamination, and almost 21 percent were for minor spills on land. Cement and casing violations constituted 8.7 percent of violations that resulted in pollution. Major land spills comprised 4 percent of these violations, while blowouts and venting and gas migration comprised 0.9 and 0.5 percent, respectively (Figure 6).

FIGURE 6: COMPOSITION OF ENVIRONMENTAL VIOLATIONS

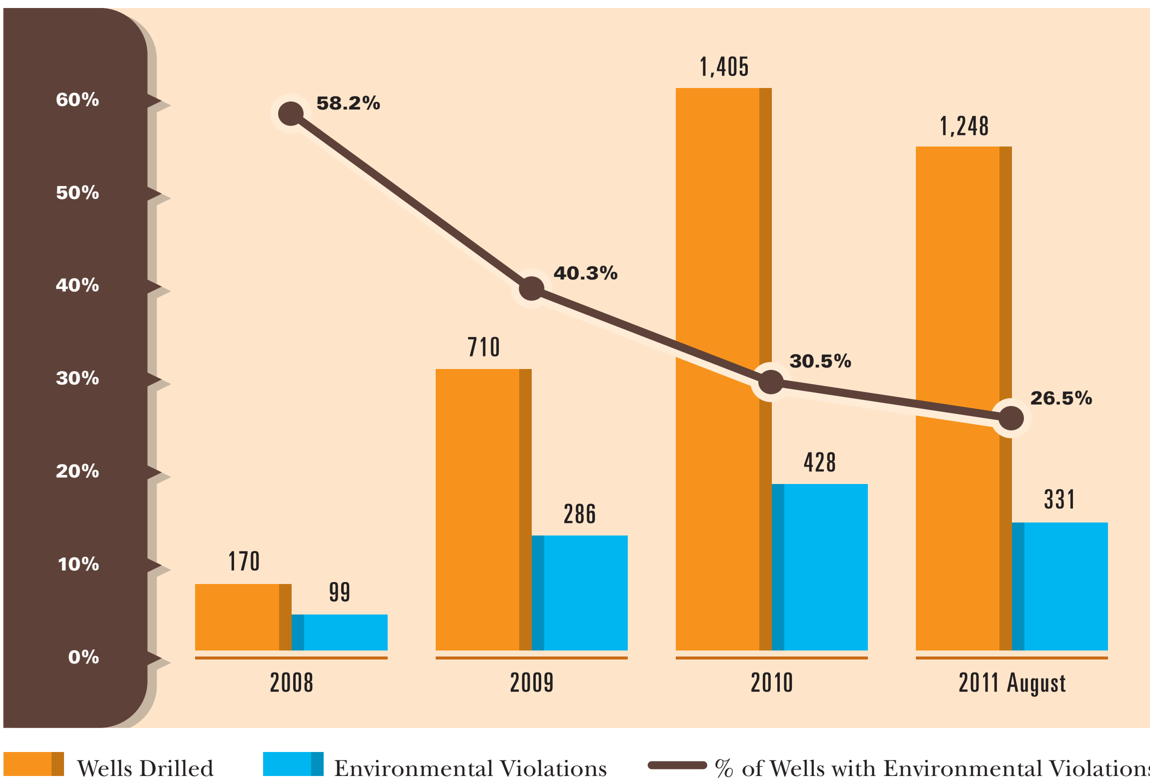


Many of the NOVs that resulted in measurable pollution, however, were rather minor, involving, for example, a gallon of diesel fuel or antifreeze spilled on the ground. The next section identifies the incidents that presented or had the potential to present significant environmental impact.

Significantly, the record of environmental violations in Pennsylvania shows that the rate of environmental violations expressed as a percentage of wells drilled declined over time. For example, in 2008 there were 170 wells drilled and 99 environmental violations, or more than 58 percent of all wells drilled in that year incurred some violation. In the first eight months of 2011, there were 331 recorded violations, or 26.5 percent of the 1,248 wells drilled during the first eight months of 2011. So, on this basis, the Marcellus industry has cut its incidence of environmental violations by more than half in three years, a rather notable indicator of improvement by the industry and oversight by the regulators. While a 26.5 percent rate of environmental violations appears high, it is important to note that most of these violations are not major.

[The Marcellus industry has cut its incidence of environmental violations by more than half in three years, a rather notable indicator of improvement by the industry …]

FIGURE 7: WELLS DRILLED AND ENVIRONMENTAL VIOLATIONS



While difficult to conclusively illustrate causation between regulatory actions and decreases in environmental violations, the history of regulations in Pennsylvania suggests such a relationship may exist. The PA DEP has made significant regulatory changes over the four-year time frame. The agency opened up a new field office, hired additional staff, and made a number of rule changes that were heavily advertised. These regulatory milestones are summarized in Table 2. This trend is expected to continue as stronger regulatory requirements are promulgated, enforcement efforts become well established, and industry gains a better understanding of the new regulatory requirements.

TABLE 2: REGULATORY DECISIONS AND INCIDENCE OF ENVIRONMENTAL VIOLATIONS

Date	Decisions by Pennsylvania Department of Environmental Protection	Wells with Environmental Violations
2008		58.2%
August	Required companies to identify treatment and storage of wastewater	
December	Imposed permitting fees to facilitate the hiring of additional regulators	
2009		40.3%
January	Partnered with industry for new wastewater treatment plants and technologies	
February	Opened Scranton office for regulatory oversight of northeastern Marcellus	
April	Announced new standards for wastewater discharges with dissolved solids	
2010		26.5%
May	Announced new discharge rules and well construction standards	
June	Enforcement campaign to ensure compliance by trucks hauling wastewater	
October	"Operation FracNet," for compliance by vehicles hauling wastewater	

While the distinction between administrative and other violations is important, an additional delineation is required because some environmental events generate multiple environmental violations. Using a count of environmental violations, therefore, would over-estimate the number of actual environmental events that took place. Accordingly, to fully understand the effectiveness of current regulations on mitigating environmental impacts of Marcellus Shale development and the various incidents that garnished an NOV, an even closer examination of these events is required.

7. Environmental Events

In this section, the notices of environmental violation are analyzed to determine how many actual events took place that resulted in environmental pollution. These events were found by examining each individual inspection report and determining what took place based upon the various NOVs issued. The classification system for environmental events is the same as it is for environmental violations. Below is a closer look at each category of environmental event and their nature.

7.1 Blowouts & Venting

Blowout and venting events are among the most serious, and are classified as major for two primary reasons. First, they are uncontrolled in nature and, thus, innately dangerous. Blowouts are usually the result of excess pressure in the well and, as a result, often occur in a violent manner. The other reason blowout and venting events are considered major is their environmental impacts. When a blowout or uncontrolled venting occurs, the potential exists for large amounts of fluids and gases to be released from the wells, despite initial mitigation efforts by operators. In such cases, negative environmental impacts are almost impossible to avoid.

7.2 Spills on Land

As the title suggests, these events are spills in which a drilling substance is spilled onto a surface other than water. These spills often took place on the drilling pad itself and did not have environmental impacts as they are contained within the boundaries of the pad site. The majority of spills were small, and the average amount of fluid spilled was approximately 176 gallons for non-major events. This was determined by taking the average amount of fluid spilled from the events that reported the spilled fluid volumes. The types of fluids spilled vary greatly among the environmental events. The most common type of fluid spilled was diesel fuel. Other fluids spilled included drilling mud, production fluid, hydrochloric acid, drilling soap, produced water, freshwater, and gel friction reducer.

7.3 Gas Migration

Gas migration into freshwater is very rare but serious, usually occurring due to a flaw in the cement and casing of a well. These flaws can be repaired, and the volume of gas escaping from vents is very small. The environmental impacts of gas migration can be mitigated and, therefore, gas migration incidents do not necessarily represent a long-term or permanent environmental impairment. Gas migration, however, is a real danger to public safety because sequestered methane is very volatile and can be explosive. The highly publicized case of gas migration in Dimock, Pennsylvania, illustrates these environmental, health and safety, and public relations impacts. As the discussion below illustrates, however, the environmental impacts can be repaired and, therefore, diligent monitoring and inspection are typically required to minimize these occurrences to the extent possible, and the associated environmental, health, and safety impacts that could potentially result from gas migration.

7.4 Cement & Casing

In almost all cases of cement and casing violations, there was some measurable amount of gas escaping from the well itself. This is not to be confused with a blowout or gas migration, as gas venting from these wells is vented in a less extreme manner. The venting that took place is the primary environmental impact of these events, but the amount of gas that was released is difficult to quantify. The amount of time and quantity of gas was not listed in any of the well inspectors' comments in the NOVs, but in 73 of the 86 instances of casing and cementing events, it was explicitly noted that gas was vented from the well. In the other 13 cases, the pollution observed constituted small leaks coming from the casing. Cement and casing violations are in nature less dangerous than blowouts or gas migration, but in some cases can lead to those events.

7.5 Site Restoration

Our analysis above defines site restoration events when a company did not restore a drilling site properly under guidelines issued by the PA DEP. To properly restore a site, a company needs to restore 70 percent of the perennial vegetation cover, and remove all drilling equipment and waste from the site within nine months after drilling is completed. In most cases, the NOVs indicated how much land was disturbed or what types of problems existed. In most cases, erosion was a problem, and in some cases vegetation was not restored or equipment was left on-site. While these land disturbances had an impact on the environment, they were not as serious in nature as spills or water contamination events and can be completely rectified through minor reclamation efforts.

7.6 Surface Water Contamination

Water contamination events result from spills that impact bodies of water directly. In most cases, these events are minor. Our analysis tracks all types of spills from a gallon of diesel fuel to hundreds of barrels spilled into the many small creeks and ponds in rural Pennsylvania. The spilled substances included many of the same materials spilled on land: fuels, drilling mud, production fluids, hydrochloric acid, sediments, and produced fluids.

The impacts of these events varied by the amount of fluids spilled. Our analysis indicates that on average 105 gallons of fluid were spilled for minor water contamination events. Water contamination events could have direct negative environmental effects or none at all. In areas with sensitive ecosystems, like wetlands, certain forms of aquatic life could be adversely affected by the spill. In other instances, the impacts of the spills can be mitigated with no observable damage to plants or wildlife.

7.7 Analysis of Environmental Events

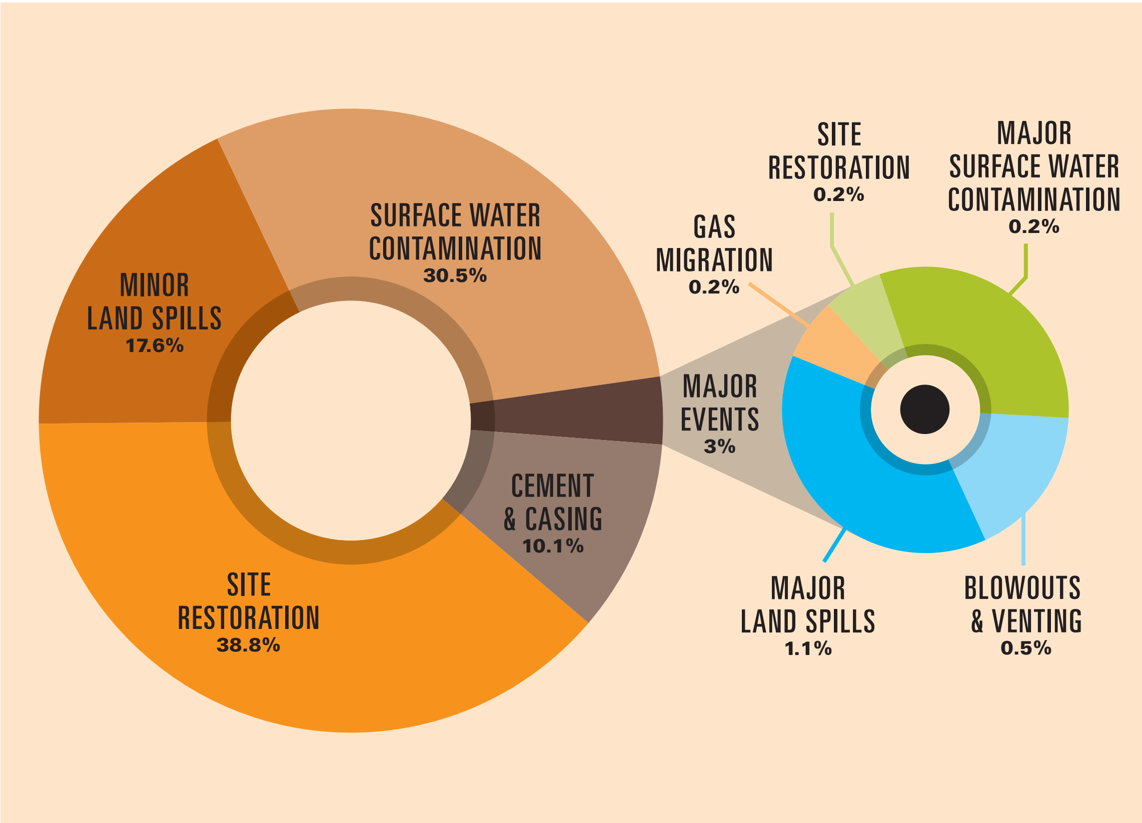
Our analysis of the environmental records from the PA DEP indicates the total number of unique incidents that resulted in environmental pollution is 845 over our sample period from January 2008 through August 2011, tabulated below in Table 3. Note from above that the total number of environmental violations is 1,144. Based upon our evaluation of the environmental impacts associated with each environmental event, there were 25 incidents that resulted in major environmental impact. Of these 25 incidents, nine involve major spills of materials on land, another eight entail spills that contaminated local water supplies, four incidents concern well blowouts and venting, two events incur major site restoration impacts, and two events concern gas migration. There were no reported cases of hydraulic fracturing fluid migrating into potable water supplies.

TABLE 3:
POLLUTING ENVIRONMENTAL EVENTS
IN THE PENNSYLVANIA MARCELLUS SHALE

	2008	2009	2010	Jan – Aug 2011	2008 to 2011
Major Impacts					
Blowouts & Venting	0	0	2	2	4
Major Land Spills	0	2	2	5	9
Gas Migration	0	1	1	0	2
Site Restoration	1	0	0	1	2
Water Contamination	0	5	1	2	8
Subtotal	**1**	**8**	**6**	**10**	**25**
Minor Impacts					
Cement & Casing	0	2	27	56	85
Site Restoration	72	68	90	98	328
Minor Land Spills	4	56	66	23	149
Water Contamination	13	39	133	73	258
Subtotal	**89**	**165**	**316**	**250**	**820**
Grand Total	**90**	**173**	**322**	**260**	**845**

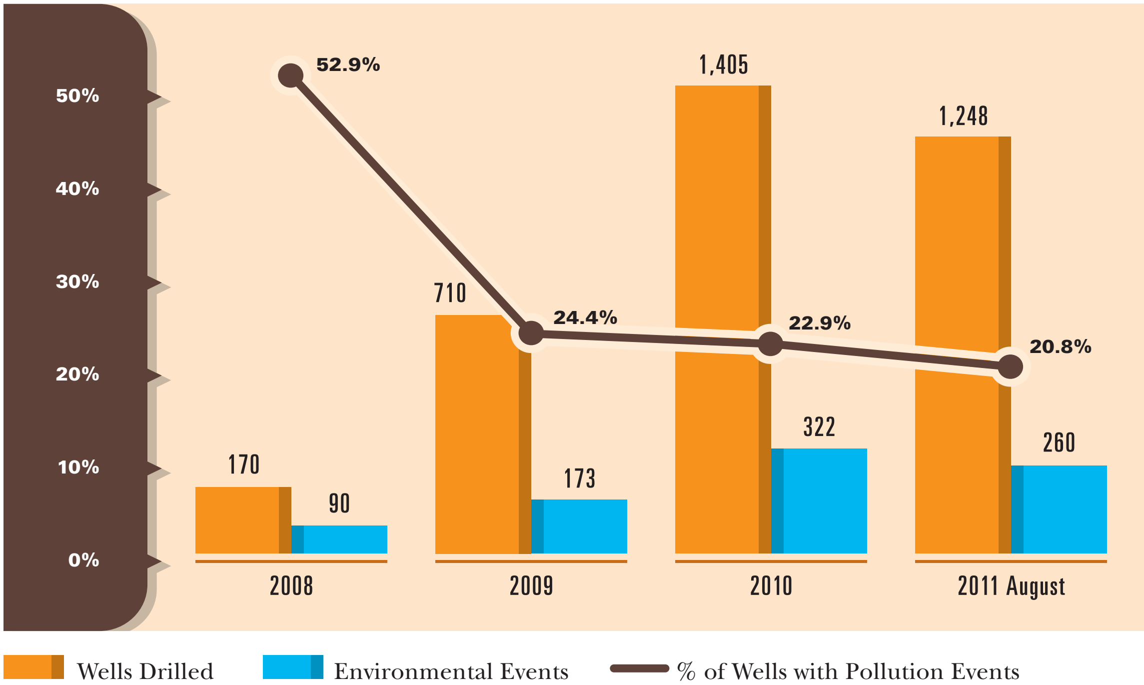
Of all the polluting environmental events, 38.8 percent involved site restoration, 30.5 percent involved spills contaminating surface water, 17.6 percent were nonmajor land spills, and 10.1 percent involved cement and casing problems. Three percent of all environmental events created major problems for the environment, 1.1 percent from major land spills, 0.9 percent involving major water contamination, 0.5 percent from blowouts and venting, 0.2 percent involving major site restoration problems, and 0.2 percent from gas migration (see Figure 8 below).

FIGURE 8: POLLUTING ENVIRONMENTAL EVENTS BY CATEGORY



Like the environmental violations, the number of environmental events varied with the number of wells drilled, as illustrated in Figure 9 below. The incidence of these events, however, steadily declined over the past four years. For example, more than half of all wells involved some level of environmental pollution in 2008, albeit most instances were minor, but that proportion declined to slightly over a fifth of all wells in 2011.

FIGURE 9: WELLS DRILLED AND POLLUTING ENVIRONMENTAL EVENTS



These findings are based solely on the Pennsylvania Marcellus record and are not necessarily indicative of the incidence of polluting environmental events one would expect to find in the future in other regulatory jurisdictions or involving other drilling companies. As indicated previously, however, enforcement activity and awareness of new regulatory requirements by the regulated community is likely to result in a decline in the incidence of polluting environmental events as illustrated above. Moreover, as the analysis presented in Appendix B illustrates, the long-term environmental impacts of these events are almost completely mitigated by remedial actions taken by the companies.

In most cases, due to the severity of these 25 major environmental events, information is available to determine what went wrong, who was responsible, and how the impact was remediated. Appendix B discusses each of the major environmental events that occurred during Marcellus Shale development in Pennsylvania.

The first major conclusion that can be reached from this analysis is that there are only two documented cases in which subsurface potable water supplies were tainted from Marcellus gas drilling activity. These subsurface water contamination events resulted from stray gas or gas migration into potable water supplies due to improper casing of multiple wells in the areas. According to our analysis, local water supplies have been completely restored to one of the affected areas, and in the second area the impacts are still being mitigated. Further, additional safety protocols and engineering measurements through proper state-based regulation can and should eliminate future incidents.

The second finding is that there were four serious well blowouts, implying a 0.11 percent probability of a well blowout. In other words, there is roughly a one-tenth of one percent chance of a serious well blowout in the Pennsylvania Marcellus gas drilling industry. To put this in some context and relative perspective, there are 40,000 highway deaths in America each year. If an individual drives an average amount each year for 50 years, there is a one percent chance of dying in an accident, roughly 12 times higher than the odds of a well blowout in the Pennsylvania Marcellus. Also, it is important to keep in mind that these four well blowouts did not result in loss of life.

The third major conclusion is the environmental damages resulting from these events were mitigated with the exception of six cases, two of which are too early to determine if remediation has been completed and for the other four cases, remediation efforts have been undertaken but not verified as completely effective. Hence, even when there are serious environmental impacts, regulators and drilling companies act to completely remediate the environmental damages. This implies that the PA DEP is acting effectively to minimize and in many cases prevent environmental harm from occurring. Hence, the Pennsylvania data shows that of the polluting environmental events that resulted in environmental damage, the regulatory agencies and drilling companies acted to completely remediate those damages.

The fourth and final conclusion is that the majority of the events were due to operator error, negligence, or a failure to follow proper procedures when drilling. This suggests that the industry has room for improvement, and the frequency of environmental events can be reduced. The following subsections discuss the implications of these findings for Pennsylvania and New York.

7.8 Pennsylvania Regulatory Response to Environmental Events

Since 2008, more than 3,500 Marcellus wells have been drilled in Pennsylvania from more than 100 drilling rigs. The sudden creation of a multibillion-dollar industry of well development, including drilling and completion activities and major infrastructure construction – of pipelines, dehydration systems, gas-processing facilities, and compressor stations – had a range of environmental impacts that caught state regulators by surprise. This section discusses the environmental issues created, the response by regulators and industry, and the implications for regulatory policy for Pennsylvania and New York.

There is little debate that Marcellus Shale development caught the PA DEP unprepared with up-to-date environmental regulations for unconventional production from the Marcellus Shale despite ongoing conventional oil and gas industry activity that drilled thousands of wells annually.

The response of the PA DEP to Marcellus Shale development and its associated impacts on Pennsylvania land and potable water was predictable and justified. As noted above, NOVs of all types were issued, and significant monetary fines were assessed to the industry for the more serious violations. Coincidental to these actions, the PA DEP, through collaboration with its Technical Advisory Board and by working in concert with its various stakeholders, has moved to update its oil and gas regulations. These stakeholders include representatives from industry, academia, and various environmental groups. As such, its regulations have evolved with respect to well construction and protection of the environment. These regulations, like all good regulatory regimes, will likely undergo almost continuous refinement. The Commonwealth of Pennsylvania's efforts to update its regulations have involved audits of its regulations by members of the American Petroleum Institute (API).

In addition, the Commonwealth, with support from industry, has moved to add to the number of field inspectors. This addition was financed through a significant increase in permit fees. Also, the Corbett administration recently announced that the PA DEP itself has been reorganized, and that Oil and Gas Management has been elevated in stature and is now managed by a Deputy Secretary. Ostensibly, these changes reflect the Commonwealth's efforts for more consistent enforcement of the regulations from region to region and at the same time recognize regional differences.

In summary, the regulations associated with oil and gas development in Pennsylvania remain a work in progress. Much has been accomplished in terms of updating the regulatory framework that had effectively functioned for more than 70 years. New regulations reflect the development of unconventional oil and gas resources. It should be noted that the industry has responded in positive fashion to complex geography and water-related challenges in Pennsylvania that are not common elsewhere. Revisions in the regulatory framework through significant improvements in well site construction and completion methodologies are a positive development, and must continue to address lessons learned.

8. Implications for Regulatory Policy in New York State

The oil and gas industry in New York dates back to the early 1800s, and the state has formally regulated the industry since 1963. New York State regulates the oil and gas industry using a combination of statute, regulation, and a generic environmental impact statement with authority under the State Environmental Quality Review Act (SEQRA) passed in 1976.

The Environmental Conservation Law, Article 23 – Mineral Resources, and Article 71 – Enforcement, govern the industry. Regulations affecting oil and gas are found in Title 6 of the New York State Register and Official Compilation of Codes, Rules and Regulations of the State of New York (NYCRR) Chapter V – Resource Management Services, Subchapter B: Mineral Resources.[7] At first glance, these seem somewhat limited in breadth. However, SEQRA gave state regulators significant authority to develop a robust regulatory program to identify potential environmental risks and provided the flexible framework to mitigate them.

Adopted in 1976, SEQRA was designed to "encourage productive and enjoyable harmony between man and his environment." SEQRA requires that government agencies "review the environmental impact of its actions, not limited to a specific environmental medium, such as air or water, but includes all environmental and many socioeconomic issues that arise in considering the result of any governmental action." The agency must disclose and address impacts that can be reasonably anticipated and, to the best of their ability, attempt to avoid or minimize adverse environmental impacts. The goal of the SEQRA process is not to eliminate all activities that may have risk, but to identify potential adverse impacts and ways to mitigate them. Ultimately, this is a subjective decision making legal challenges complex and difficult.

Until three decades ago, New York's oil and gas industry was regulated through inconsistent state and municipal requirements for drilling. This approach resulted in a few well site issues and generally inconsistent state and local rules governing the industry. In 1980, state legislators chose to revise the regulatory program using its SEQRA authority rather than promulgate new regulations. The process started in 1980 and ended in 1992 with the adoption of the final Generic Environmental Impact Statement (GEIS). The GEIS abrogated the right of municipalities to regulate any aspect of oil and gas development, and provided a flexible permitting program that could react quickly to changes on the ground and allow the issuance of permits in a timely fashion.

The 1992 GEIS looked at all common impacts deemed significant, including surface waters, groundwater, agriculture, historical sites, archaeological sites, significant habitats, floodplains, freshwater wetlands, state lands, coastal zones, streams, and general habitat loss. A unique environmental assessment form for drilling was developed from the GEIS.

8.1 Supplemental Generic Environmental Impact Statement (SGEIS)

In 2008, the New York State Department of Environmental Conservation (NYS DEC) began reviewing the 1992 Generic Environmental Impact Statement for oil, gas, and solution mining (GEIS) to determine the extent to which it should be supplemented to address the potential environmental

7 http://www.dos.ny.gov/info/nycrr.html

impacts of the high-volume hydraulic fracture stimulations (HVHF) used to develop the natural gas resources in the Marcellus Shale formation.

In accordance with SEQRA, the purpose of the 2009 draft SGEIS (DSGIES) was to inventory the potential environmental risks, determine which impacts are significant, and provide mitigation measures. This process is routinely used to address the environmental impacts of many industrial processes. The host of complex environmental impacts analyzed in the draft SGEIS range from the initial water withdrawals to the ultimate disposal of the waste products. In preparing the DSGEIS, NYS DEC sought to recognize, characterize, and provide appropriate mitigation measures based upon sound science, engineering, and experience.

The 2009 DSGEIS was put forth for public comment, a process that ended December 31, 2009, with the receipt of more than 13,000 comments. Comment evaluation lasted through 2010 and well into a new state executive administration.

In 2011, the DEC released a revised DSGEIS (RDSGEIS), which outlines a much more procedural approach to regulating wells using high-volume hydraulic fracture stimulations (HVHF), defined in the RDSGEIS as a completion using 300,000 gallons of water or more. Concurrently, NYSDEC issued revised draft regulations based on the RDSGEIS. This can be seen as a major change in approach. Since 1992, the GEIS has been used as a flexible regulatory tool allowing real-time modernization of regulations to match industry innovation. Now, a much more detailed and formal regulatory structure is proposed for wells using HVHF.

The most productive way to evaluate whether this framework will be ultimately successful is to study prior environmental incidents using the new RDSGEIS. The Department has indicated that they have done this. In 2011, DEC staff studied high-volume hydraulic fracturing incidents throughout Pennsylvania to assess their causes and identify solutions. Given the above analysis that aggregates all environmental incidents occurring in Pennsylvania, we will be able to assess the degree to which New York regulators have been successful in incorporating lessons learned into the RDSGEIS.

8.2 New York Regulations and Environmental Events

Through statutes, regulations, and permit conditions derived from the 1992 GEIS, New York State's program for regulating the oil and gas industry is quite comprehensive. The RDSGEIS and proposed regulations dramatically increase regulatory scrutiny of wells using HVHF. Using the categories defined in *Table 1: Classification of Environmental Violations*, this section will summarize how the regulatory structure of New York State is designed to avoid or mitigate these types of events.

8.21 Blowouts & Venting

Both New York State's existing and proposed regulations acknowledge the potential environmental damage caused by emissions of methane into the atmosphere, and the potential health, safety, and environmental hazards of blowouts. Consideration is given both to avoidance and mitigation.

New York State's regulatory emphasis is placed on avoiding uncontrolled emissions of hydrocarbons. Since the 1992 GEIS, the state has required blowout preventers, equipment inspections, equipment testing, and permits to flare. The RDSGEIS and proposed regulations build on this by requiring advanced equipment, redundant systems, certified staff, and systematic equipment testing to avoid blowout preventer failure and reduce blowout severity:

> "The current DSGEIS requires pressure testing of blowout prevention equipment, the use of at least two mechanical barriers that can be tested, the use of specialized equipment designed for entering the wellbore when pressure is anticipated, and the on-site presence of a certified well control specialist." (NYS DEC 2011A, p. ES-25)

> "A remote blowout preventer actuator, which is powered by a source other than rig hydraulics, shall be located at least 50 feet from the wellhead. All lines, valves and fittings between the blowout preventer and the remote actuator and any other actuator must be flame resistant and have an appropriate rated working pressure." (NYS DEC 2011B)

Rigorous testing may prevent problems with blowout preventers. Also, requiring properly certified staff and remote actuation also may limit the severity of a blowout. Berms and other secondary containment may help mitigate the impact. These types of systems may help prevent blowouts similar to those described in Appendix B.

8.22 Spills on Land

Site design guidelines included in both the 1992 GEIS and subsequent supplemental drafts include detailed descriptions of site design, operations design, and containment technology to avoid and mitigate the impact of spills. Predrilling inspections by NYS DEC staff are and will continue to be required. In the RDSGEIS, it is clear that well design reviews will be a critical part of the permitting process:

> "Before a permit is issued, Department staff would review the proposed layout of the well site based on analysis of application materials and a site visit. Risky site plans would either not be approved or would be subject to enhanced site-specific construction requirements." (NYS DEC 2011A, p. ES-24)

Also, the RDSGEIS requires testing of equipment used for hydraulic fracture stimulation:

> "Fracturing equipment components would be pressure tested with fresh water, mud or brine prior to the introduction of chemical additives." (NYS DEC 2011A, p. ES-25)

With this approach, any faulty equipment should be identified prior to the commencement of completion operations. The foregoing requirements are likely to have a positive impact in avoiding or reducing the occurrence of the impacts of the types of spills identified in Appendix B.

8.23 Gas Migration, and Casing & Cementing

Gas migration issues were a concern before the GEIS was finalized in 1992. In the 1980s, in order to avoid hydrocarbon migration into shallower zones, NYS DEC felt it important to require submission of a casing and cementing plan to help assess the appropriateness of the design, given the local geology. Ultimately, the regulation developed requires a minimum of two casing strings, except in aquifers where three are required. NYS DEC conducts inspections of the casing during operations. In the case of an aquifer area, NYS DEC must be on-site to witness the cement returning to the surface.

The revised DSGEIS continues this practice, but adds a wellbore integrity review for wells proposing to use HVHF:

> "The Department's staff reviews the proposed casing and cementing plan for each well prior to permit issuance. Permits are not issued for improperly designed wells, and in the case of high-volume hydraulic fracturing the as-built wellbore construction would be verified before the operation is allowed to proceed." (NYS DEC 2011A, p. ES-23- 24)

In the proposed regulations, NYS DEC will also require extensive testing of the casing to make sure it can adequately ensure a sufficient margin of safety in HVHF operations, avoiding a casing breach, and potential migration of methane and fluids. These proposed regulations also set boundaries on how hard a well can be pushed during operations:

> "If hydraulic fracturing operations are performed down casing, prior to introducing hydraulic fracturing fluid into the well, the casing extending from the surface of the well to the top of the treatment interval must be tested with fresh water, mud or brine to at least the maximum anticipated treatment pressure for at least 30 minutes with less than a 5 percent pressure loss. This pressure test may not commence for at least 7 days after the primary cementing operations are completed on this casing string. A record of the pressure test must be maintained by the operator and made available to the department upon request. The actual hydraulic fracturing treatment pressure must not exceed the test pressure at any time during hydraulic fracturing operations." (NYS DEC 2011B)

Under the proposed regulations, the operator must sample water wells within a 1,000- to 2,000-foot radius before any site disturbance, and for a period after drilling and completion of a well using HVHF. If gas migration is detected, NYS DEC, like the PA DEP, can begin an enforcement action to force the operator to mitigate the problem. The proposed regulations also give NYS DEC the authority to revoke previously issued permits and approvals for noncompliance (as described in proposed regulations 750-3.5).

8.24 Site Restoration

Existing and proposed regulations outline detailed site restoration requirements, including how to mitigate erosion, sedimentation, and general agricultural issues such as topsoil stockpiling. The RDSGEIS and proposed regulations are much more specific as to the impacts on site locations by identifying specific areas such as Grassland and Forest Focus Areas that require extensive predevelopment studies. The proposed regulations are explicit in terms of site restoration after drilling. Partial site reclamation is defined as having occurred after:

1) all planned wells at the well pad have been completed, and a DEC inspector verifies that the drilling/fracturing equipment has been removed,
2) pits used for those operations have been reclaimed, and surface disturbances not associated with production activities have been scarified or ripped to alleviate compaction prior to replacement of topsoil, and
3) reclaimed areas are seeded and mulched after topsoil replacement, and vegetative cover reestablished that will ultimately return the site to pre-construction conditions (as described in proposed regulations 750-3.11 (e) (1) (vi)).

As with the PA DEP's approach, an improperly restored site would subject the operator to fines and other enforcement actions. This enforcement power rests in statute and regulation.

8.25 Water Contamination

Section 553.2 of the Environmental Conservation Law defines offsets from streams and other water bodies at a minimum of 50 feet and offsets from water wells at a minimum of 150 feet. In practice, proposed sites near water bodies usually trigger an enhanced review due to the presence of floodplains, aquifers, and other sensitive areas. This approach allows the conditions on the ground to define locations. For non-stimulated and low-volume hydraulic fracture stimulations, this remains the case.

Under the RDSGEIS and proposed regulations, wells proposing to use HVHF will be required to follow very strict "bright line" setbacks from water bodies and aquifers. Surface locations, including drilling and ancillary equipment, are prohibited in the following areas:

- within 2,000 feet of public drinking water supplies;
- on the state's 18 primary aquifers and within 500 feet of their boundaries;
- within 500 feet of private wells, unless waived by landowner;
- in floodplains;
- on principal aquifers without site-specific reviews; and
- within the Syracuse and New York City watersheds.

Looking at the incidences described in Appendix B, it is not clear that these offsets alone would necessarily eliminate contamination of streams or aquifers. Topography and the severity of the incident played a role. It seems that improved site design and better containment, if used in conjunction with "bright line" setbacks, is likely to avoid or reduce the occurrence of these impacts.

8.26 Commentary

New York State has the luxury of learning from the experience of Pennsylvania. As shown above, some of the strict procedures included in the RDSGEIS and proposed regulations may indeed help avoid or mitigate the impact of well site events. Many others, however, might provide little extra protection, while creating restrictions that ultimately stifle industry and investment. The 1992 GEIS recognized the need for flexibility when complex engineered systems are involved. Only time will tell if this strict approach fares as well or better than the landmark 1992 GEIS. Below in Table 4 is a summary of some of the major environmental events discussed in Appendix B if SGEIS requirements had been applied to the five polluting environmental categories.

TABLE 4: MAJOR ENVIRONMENTAL EVENTS AND NY SGEIS REQUIREMENTS

Category	PA Event	Example 2011 NY SGEIS Requirements
Blowouts & Venting	**Incident B.12:** Chief Oil and Gas – Bradford County uncontrolled flowback **Incident B.13:** EOG Resources – Clearfield County well blowout **Incident B.17:** Talisman Energy – Tioga County blowout **Incident B.23:** Chesapeake Energy – Leroy Township blowout	• Pressure testing of blowout prevention equipment • Using at least two mechanical barriers that can be tested • Using specialized equipment designed for entering the wellbore when pressure is anticipated • A certified well control specialist to be present during post-fracturing cleanout activities • Requiring a remote blowout preventer actuator, which is powered by a source other than rig hydraulics • Requiring that all lines, valves, and fittings between the blowout preventer and the remote actuator and any other actuator must be flame resistant, and have an appropriate rated working pressure
Spills on Land	**Incident B.7:** Atlas Resources – Diesel spill **Incident B.12:** Chief Oil and Gas – Susquehanna County fluid spill **Incident B.11:** Anadarko – Clinton County mud spill **Incident B.14:** JW Operating Company – Mud spill **Incident B.15:** Cabot Oil & Gas – Susquehanna County hose failure **Incident B.18:** Talisman – Jackson production fluid release **Incident B.19:** Carrizo – Monroe mud spill **Incident B.20:** Carrizo – Wyoming County drilling mud spill **Incident B.22:** Ultra Resources – Flowback spill	• Requiring a Spill Prevention Control and Countermeasure Plan (SPCC) • Completing a regulatory review of the proposed layout of the well site • Requiring a site visit by DEC staff to make sure the site can be designed for adequate containment • Prior to the initiation of HVHF operations, pressure test all fracturing equipment components • Approval of risky site plans would be subject to enhanced site-specific construction requirements • Bans surface access on most state lands • The authority by regulators to revoke previously issued permits and approvals for noncompliance (e.g., chemical spills)
Spills into Surface Water	**Incident B.2:** PA General Energy – Creek discharge **Incident B.4:** Cabot Oil & Gas – Stevens Creek fish kill **Incident B.5:** Range Resources – Stream discharge into Brush Run **Incident B.6:** EOG Resources – Clearfield County stream discharge **Incident B.8:** Talisman Energy – Armenia pit overflow **Incident B.9:** Atlas Resources – Hopewell pit overflow into Dunkle Creek **Incident B.16:** Chief Oil and Gas – Susquehanna County fluid spill **Incident B.24:** CNX Gas Company – Mud spill	• Require a State Pollutant Discharge Elimination System (SPDES) permit covering HVHF operations • Including restrictions on siting of surface locations will take substantial acreage out of possible production, including (1) within 4,000 feet of, and including, the unfiltered surface water supply watersheds; (2) within 500 feet of, and including, a primary aquifer; (3) within 100-year floodplains; (4) within 2,000 feet of any public (municipal or otherwise) water supply, including wells, reservoirs, natural lakes, or man-made impoundments, and river or stream intakes; and (5) in the New York City and Skaneateles Lake watersheds • Demonstrate a source to treat or otherwise legally dispose of wastewater associated with flowback and production water

continued on next page

TABLE 4: MAJOR ENVIRONMENTAL EVENTS AND NY SGEIS REQUIREMENTS

Category	PA Event	Example 2011 NY SGEIS Requirements
Gas Migration, Casing & Cementing	**Incident B.3:** Cabot Oil & Gas – Dimock gas migration **Incident B.10:** Chesapeake Energy – Bradford County gas migration incident	• Regulatory preapproval of casing and cementing plan • Additional layers of cement and steel casing around each underground well • Cement and steel casings to extend at least 75 feet below the deepest freshwater zone – going beyond regulations required in other natural gas producing states • Require extensive testing of the casing to make sure it can adequately handle HVHF operations • Set hydraulic fracture stimulation operating boundaries to never exceed test pressure to protect casing from excessive pressure • Water samples within a 1,000- to 2,000-foot radius before any site disturbance for a period after drilling and completion of a well using HVHF • Identify any abandoned wells within the proposed spacing unit and within one mile of the proposed surface location • The authority by regulators to revoke previously issued permits and approvals for noncompliance
Site Restoration	**Incident B.1:** Atlas Resources – Major site restoration failure **Incident B.21:** Chesapeake Energy – Washington County pit fire **Incident B.25:** Ultra Resources – Major site restoration failure	• Sites must be designed to mitigate erosion, sedimentation • During operations, topsoil must be stockpiled • Require partial site reclamation after all planned wells at the well pad have been completed • Department inspectors must verify that the drilling/fracturing equipment has been removed; pits used for those operations have been reclaimed, and surface disturbances not associated with production activities have been scarified or ripped to alleviate compaction prior to replacement of topsoil • Reclaimed areas must be seeded and mulched after topsoil replacement, and vegetative cover reestablished that will ultimately return the site to pre-construction conditions

9. Conclusions

Since 2008, more than 3,533 Marcellus wells have been drilled in Pennsylvania from more than 100 drilling rigs. This study assesses the effectiveness of the state's regulations in mitigating environmental impacts associated with the development of Marcellus Shale in Pennsylvania by surveying records of notices of violations from the Pennsylvania Department of Environmental Protection (PA DEP) from January 2008 through August 2011. The major findings are as follows:

- Of the 2,988 notices of environmental violations (NOVs), the majority (62 percent) are administrative violations or violations issued to prevent pollution from occurring. The remaining citations (38 percent) were in response to an event that impacted the surrounding environment.
- Of the 845 incidents that caused measurable amounts of pollution, 820 were classified as non-major, and only 25 involved major impacts to air, water, and land resources. This implies that over the 44 months surveyed, there was a [0.7 percent] probability of a major environmental event.
- Of the 25 problematic incidents that involved major environmental impacts, six cases did not have their environmental impacts completely mitigated.
- Both the rate of environmental violations and subsequent environmental events that caused some physical impact on the environment steadily declined over the past four years, in conjunction with action by state regulators. Notably, the percentage of wells resulting in a major environmental event declined significantly; an indicator that the attention of regulators was focused on the areas of greatest concern. The foregoing suggests that surface activity, rather than the drilling or development process itself, remains the greatest ongoing risk.

The findings are significant as they illustrate how the PA DEP has been able to effectively manage the brisk pace of unconventional gas development, while preserving the economic opportunity that development has afforded the community.

Pennsylvania provides a strong metric to gauge the regulatory proposal being proposed for New York State. Our research classifying the 25 major events that occurred in Pennsylvania with the 2011 New York SGEIS guidelines demonstrates that each of these specific events would be avoided or mitigated under New York State's regulatory framework currently in place.

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APPENDIX

A. Economic Impact Analysis

The development path for New York shale energy will likely follow one similar to that experienced in northern Pennsylvania. During 2008, 52 Marcellus wells were drilled in five counties in northern Pennsylvania: McKean, Potter, Tioga, Bradford, and Susquehanna. The number of Marcellus wells drilled in the same five counties during 2009 was 296 (see Considine et al. 2011b). The New York counties due north of this zone include, from west to east: Allegany, Steuben, Chemung, Tioga, and Broome. As the Marcellus Shale formation extends northward into New York State, it comes closer to the surface, making it less attractive to drilling companies to exploit. Therefore, drilling would probably be concentrated in the southern half of the New York border counties mentioned above.

The Utica shale is another promising natural gas resource extending into New York, but there is no evidence to date that the New York Utica shale is productive. Range Resources completed and tested a horizontal Utica well in western New York, but the results are confidential. Range's only comment is that it plans to drill additional Utica wells. Hence, prospects for the Utica shale in New York are promising, but there is simply not enough evidence of commercial prospects that would justify its inclusion in the scenarios developed below. Leasing activity in the Utica shale in northeastern Ohio, however, is rather intense, given the prospects of rich deposits of oil and natural gas liquids, especially in Stark County. In light of these considerations, a safe assumption is that the Marcellus Shale will be the first formation to be developed in New York State if horizontal drilling with hydraulic fracturing is allowed. Hypothetical trajectory of future drilling appears in Table A1 (Considine, et al. 2011a).

TABLE A1: PROJECTED MARCELLUS ACTIVITY IN NEW YORK (2012, 2016, 2021)

	Millions of Current Dollars		
	2012	**2016**	**2021**
Total spending	**172.6**	**1,899.9**	**2,209.9**
Lease and bonus	66.6	502.2	502.2
Exploration	5.9	68.9	73.8
Drilling and completion	78.2	918.5	984
Pipeline and processing	19.1	224.5	240.5
Royalties	0	152.3	373.5
Other	2.9	33.5	35.9
	Assumed Number of Wells*		
Horizontal	14	304	330
Vertical	28	9	10
Total	**42**	**314**	**340**
	Gas Equivalents of Million Cubic Feet per Day		
Production	0.1	487.6	952.1

Under this scenario, 42 wells would be drilled in the first year, 314 wells four years later, and 340 wells in 2021. Horizontal drilling's share is based on the observed ratio in northern Pennsylvania (Considine, et al. 2011a). Total spending under this scenario would start out at $172.6 million; increase eleven fold, to $1.9 billion by 2016; and reach $2.2 billion in 2021 (Table A1). The value added that such activity from direct, indirect, and induced effects would create is $1.7 billion in 2016 (see Table A2). Note that the impacts are spread across a broad array of industries, which reflects the stimulus that natural gas investments have on the supply chain, boosting output in key shale energy supply chain industries, such as construction, wholesale trade, truck transportation, and engineering and scientific services (see Table A2). Similar gains in employment are achieved with Marcellus development supporting more than 15,000 jobs in 2016 alone. Assuming a 3 percent discount rate, the accumulated value added from 2012 to 2021 would come to more than $11.4 billion. There would be more than 18,000 additional jobs in 2021 (see Table A2). And local and state tax revenues would have grown by more than $214 million in 2010 dollars by 2016 (Considine, et al. 2011a).

TABLE A2: PROJECTED VALUE ADDED IN NEW YORK BY SECTOR (2012, 2016, 2021)

Sector	Millions of 2010 Dollars		
	2012	2016	2021
Ag., forestry, fishing, and hunting	0.3	3.3	3.8
Mining	19.8	232.3	249.2
Utilities	3.5	38.1	44.8
Construction	14	163.4	175.7
Manufacturing	4	44.8	51.1
Wholesale trade	16.4	189.1	207
Retail trade	9.9	107.4	125.9
Transportation and warehousing	3.9	43.6	48.9
Information	4.9	53.9	62.9
Finance and insurance	12.5	136.9	158.6
Real estate and rental	21	224	268.3
Professional/scientific and tech services	13.2	150.1	166.5
Business management	2.3	25.9	28.8
Administrative and waste services	4.1	45.5	51.6
Educational services	3.1	32.1	40.6
Health and social services	10.6	112.1	135.3
Arts/entertainment and recreation	1.2	13.1	15.7
Hotel and food services	3.3	35	42.1
Other services	3.4	35.8	42.9
Government and misc.	1.7	18.4	21.6
Total	**153**	**1,704.8**	**1,941.2**

APPENDIX

B. Detailed Discussion of Major Environmental Events

The sections below explain the nature of the 25 major environmental events and their impacts. For each event, this discussion explains what went wrong, why, who was responsible, and what remedies were followed.

B.1 Atlas Resources – Major site restoration failure

On December 4, 2008, Atlas Resources was issued an NOV for failing to properly restore a site after drilling had been completed earlier that year (PA DEP 2008). This instance was considered major because Atlas allowed 15 acres of land to remain disturbed after drilling was completed (PA DEP 2008). This amount of land disturbance was the second-largest site restoration failure in the sample and for this reason is considered a major environmental event. After receiving the NOV, Atlas did eventually clean up the site and mitigate the impacts that the drilling had in the area. Atlas was fined $9,641 for the violation, and was at fault because there were no circumstances that prevented it from restoring the site (PA DEP 2008).

B.2 PA General Energy – Creek discharge

On March 15, 2009, PA General Energy was cited for discharging Airfoam into a stream in Lycoming County, Pennsylvania (Swift 2011). Airfoam is a substance used to help lift water and drill cuttings to the surface during drilling. The Airfoam escaped when snowmelt and rain washed over the well pad, causing the substance to migrate to a nearby stream (Swift 2011). The site was restored, and the impacts of the Airfoam runoff were mitigated. PA General Energy was fined $28,960 for the event because of impacts on the waters of the Commonwealth.

The pollution caused by the event was difficult to avoid because the operator did not anticipate the level of snowmelt and rain that occurred. Preventing such events, however, is possible. Once the event happened, the operator was able to mitigate the impacts by placing a protective barrier around the stream that had been contaminated by Airfoam. While barriers like this are not always feasible, they can be effective when used in such situations.

B.3 Cabot Oil & Gas – Dimock gas migration

On May 13, 2009, the Pennsylvania Department of Environmental Protection issued multiple environmental violations to Cabot Oil & Gas because 19 families in Dimock had their water wells contaminated with methane. This contamination arose from gas migration that occurred after Cabot improperly cemented multiple gas wells in the area (PA DEP 2010a). Cabot was initially fined $120,000, but later was fined more than $500,000 by the PA DEP. In addition to the $500,000 fine, Cabot later settled for $4.1 million with the residents who had their water affected (PA DEP 2010a).

This incident carried the largest fine of any environmental event in the Pennsylvania Marcellus and could be considered the most severe. The gas migration contaminated a large amount of drinking water. The three wells that were found to be the source of the migrating gas were plugged, and since then there has been a noticeable improvement in the water quality of the affected water wells.

B.4 Cabot Oil & Gas – Stevens Creek fish kill

In Dimock, Pennsylvania, on September 16, 2009, the Pennsylvania Department of Environmental Protection reported that approximately 8,000 gallons of produced fracturing fluids spilled into Stevens Creek (Lustgarten 2009). The cause of the spill was reportedly linked to the failure of a supply pipe near the creek and resulted in reports of fish swimming erratically in the affected area. Some fish were also found dead in the creek, and the PA DEP reported that the surrounding wetland area was affected as well. Cabot Oil & Gas eventually cleaned up the impacted area, but received a $56,650 fine for the spill.

The Stevens Creek fish kill was considered to be a major event because of the large volume of fracturing fluid that was spilled, and the incident was classified as water contamination. The environmental impacts of this event were very severe. Equipment failure is a part of any industry, and natural gas drilling is no different. However, this event still had such a significant environmental impact that Cabot was still held responsible. The impacts of this event were not easily mitigated, and significant effort was required to restore the site, but eventually the area was restored. This event was severe and the regulatory actions of the PA DEP reflected this reality.

B.5 Range Resources – Stream discharge into Brush Run

On October 10, 2009, Range Resources reported that a temporary aboveground water transfer line had a connection failure that resulted in the accidental release of 250 barrels, or 10,500 gallons, of partially recycled flowback water into Brush Run creek (PA DEP 2010b). Approximately 300 minnows were killed by the spill, but other aquatic life in the stream survived. Range was fined $141,175 for the spill (PA DEP 2010b), which resulted from equipment failure. The site was restored under supervision of the PA DEP, and the environmental impacts have been mitigated.

This event was major due to its direct impact on waters of the Commonwealth and was classified as water contamination. Equipment failure is something that cannot be avoided in most cases, and Range Resources was able to quickly mitigate the impacts from this spill. The reason Range was fined so heavily for the event is twofold. The first reason is that the spill occurred in a high-quality watershed that fed multiple fisheries in the area, and the second is the fact that Range did not report the spill immediately (PA DEP 2010b). This event is interesting because while Range was not entirely responsible for the event, they failed to follow proper procedures for dealing with the spill.

B.6 EOG Resources – Clearfield County stream discharge

On October 12, 2009, an independent consultant found that a cap on a holding tank had gone bad and allowed approximately 190 barrels, or 7,980 gallons, of produced fluid to enter Little Laurel Creek (PA DEP 2009a). EOG Resources was unaware of the leak until it was reported to the company, and a quantity of a foamy substance was observed in the creek that the produced fluid had entered. EOG Resources was fined $99,125 for the incident but was able to mitigate some of the impacts by flushing the stream (PAFBC 2009). EOG Resources was at fault for this event and could have prevented it by better inspecting its storage tanks.

This event was considered a water contamination event and is another example of a company being negligent. The area that was affected by this spill was also heavily used for fishing, so the Fish and Boat Commission was also present during the evaluation of this incident. The impacts from the incident were mitigated, but the area is still undergoing testing to ensure that water quality is normal. With better training of crews and the paying of more attention to details like storage containers, events like this one can easily be prevented in the future.

B.7 Atlas Resources – Diesel spill

On October 30, 2009, Atlas Resources experienced a 790-gallon diesel fuel spill due to the improper connection of a fuel line at its drilling site in Westmoreland County (PA DEP 2009b). Atlas was able to recover 250 gallons of fuel from the spill, but the rest was unaccounted for (PA DEP 2009b). Atlas also placed other collection devices around the spill in hopes of mitigating the impacts further, but was unable to successfully clean up the entire spill. The PA DEP found Atlas at fault and fined the company $17,500 for the spill (PA DEP 2009b). This event could have been prevented by following procedures for equipment inspection.

B.8 Talisman Energy – Armenia pit overflow

On November 23. 2009, Talisman Energy experienced a pit overflow into a small un-named waterway in Bradford County (PA DEP 2010c). Between 4,200 to 6,300 gallons of fracturing fluid were spilled into the waterway, which is upstream from a fishery. The flowback was caused when a pump failed and sand collected around the valve, causing fluid to flow uncontrolled toward the waterway (PA DEP 2010c). Talisman Energy was fined $15,506 for the event and was able to clean up the spill (PA DEP 2010c).

This event is considered a major water contamination event because it affected a high-quality watershed. Talisman was not at fault for this event because the equipment failure was not due to negligence and was unavoidable. Talisman also responded quickly to the spill and was able to mitigate most of the impacts of the spill.

B.9 Atlas Resources – Hopewell pit overflow into Dunkle Creek

On December 5. 2009, the Pennsylvania Department of Environmental Protection discovered multiple environmental violations that led to the contamination of a high-quality watershed in Hopewell County, Pennsylvania (PA DEP 2010d). This event was severe due to the type of watershed that was affected. While the overflow of the pit had significant environmental effects, the pollution impacts were mitigated. Atlas Resources was fined $97,350 for allowing diluted fracturing fluids to overflow from a wastewater pit (PA DEP 2010d). This incident violated the Pennsylvania Oil and Gas Act, as well as the Solid Waste Management Act, and although the impacts were mitigated, Atlas failed to notify the PA DEP (PA DEP 2010d).

This event is considered a major water contamination because a significant amount of high-quality water was tainted by the spill. A large fine is usually indicative of a significant amount of pollution. A large amount of pit fluid flowed directly into Dunkle Creek and despite the ability of Atlas to clean up the spill, a large fine was assessed. This large fine was likely due to the fact that Atlas could have prevented this incident by better maintaining the storage pit that held the diluted fracturing fluid. Also, the situation was exacerbated by the fact that Atlas failed to report this event to the PA DEP. The cause of this event was considered negligence on the part of Atlas Resources and should have been prevented. This event is an example of what can go wrong when an operator fails to follow regulations and guidelines for pit construction. In conclusion, this event could have been avoided.

B.10 Chesapeake Energy – Bradford County gas migration incident

On May 17, 2011, the PA DEP fined Chesapeake Energy $900,000 for violations related to natural gas drilling activities in Bradford County (PA DEP 2011g). This was the largest fine issued by the PA DEP to date and was issued due to the severity of the gas migration. At various times throughout 2010, the PA DEP investigated private water well complaints from residents of Bradford County's Tuscarora, Terry, Monroe, Towanda, and Wilmot townships near Chesapeake's drilling operations (PA DEP 2011g). Gas was also observed to have been bubbling up from the Susquehanna River during the initial investigation (Efstathiou 2010g). The PA DEP determined that due to improper well casing and cementing in shallow zones, natural gas from non-shale shallow gas formations had experienced localized migration into groundwater and contaminated 16 families' drinking water supplies (PA DEP 2011g). Chesapeake has agreed to take corrective action to mitigate the impacts of this migration and restore water supplies (PA DEP 2011g). Currently, the impacts have yet to be fully mitigated, and the 16 families are currently receiving alternative water supplies from Chesapeake (PA DEP 2011g).

B.11 Anadarko – Clinton County mud spill

On April 23, 2010, Anadarko Resources spilled 9,300 gallons of drilling mud at its drilling site in Clinton County (PA DEP 2010e). The spill was restricted mostly to the well pad, and the effects were completely mitigated (PA DEP 2010e). The PA DEP confirmed that there was no impact on the land or water on or around the site. The cause of the spill was operator error, but even though there were no impacts on the surrounding water or land, Anadarko was fined $58,000 for the event (PA DEP 2010e). Events like this one can be avoided, but Anadarko did make the best of a bad situation and cleaned up the spill very quickly.

B.12 Chief Oil and Gas – Bradford County uncontrolled flowback

On May 27, 2010, Chief Oil and Gas experienced an uncontrolled flow-back in Bradford County. Pennsylvania (PA DEP 2010f). This flow-back caused more than 1,000 feet of dead vegetation adjacent to the well pad and was found to be major due to this impact on land (PA DEP 2010f). Uncontrolled flow-back falls under the category of blowouts and venting using our classification system, and thus is considered to be a serious event. This event, in particular, was interesting because of the amount of vegetation that was killed. Blowouts are typically caused when there is an excess amount of pressure in the well; however, no official report was filed on the cause of this event. Given the absence of a report of what caused the uncontrolled flow-back, it is difficult to determine if the operator was at fault or not. This event also caused the soil surrounding the well to be considered residual waste, which means that the same containment procedures had to be used for this soil as diluted fracturing fluids (PA DEP 2010f). There is no report of this event being resolved, and it is likely that it will be difficult for Chief to fully restore the site.

B.13 EOG Resources – Clearfield County well blowout

On June 3. 2010, EOG Resources experienced a well blowout at its Punxsutawney Hunting Club well in Clearfield County, Pennsylvania (WJACTV 2010). The blowout lasted for 16 hours, and spewed both gas and produced chemicals onto the surrounding countryside (WJACTV 2010). The blowout was caused when blowout equipment failed due to lack of maintenance, and the spill went unchecked due to excess pressure in the well. An estimated 1 million gallons of fracturing fluid were spilled, and fortunately the impacts have been mitigated (WJACTV 2010). Proper maintenance of well blowout equipment could have prevented this event, and EOG Resources was fined $353,419 for the event, making it the second-largest fine issued by the PA DEP to Marcellus operators.

What makes the Clearfield well blowout such a significant event was the poor response by EOG Resources. The company was not able to get control of the situation for a significant period after the initial event occurred, and an evacuation of the area was required. Moreover, the impacts of this event were also very severe, with a large amount of forest contaminated by the fluids that were released. This event was entirely preventable and could have had a far less damaging effect on the area had it been properly handled by EOG.

B.14 JW Operating Company – Mud spill

On July 30, 2010, The JW Operating Company spilled 1,500 gallons of drilling mud at its site in Cameron County (PA DEP 2010g). The impacts of the spill were mitigated, and JW was fined $8,000 for the event (PA DEP 2010g). The PA DEP records do not indicate the cause of the event. Due to the large volume of drilling mud spilled, this event is major. The JW Operating Company also failed to notify the PA DEP, who was notified by a contractor working on the site.

B.15 Cabot Oil & Gas – Susquehanna County hose failure

On November 3, 2010, Cabot Oil and Gas reported a spill of 135 barrels, or 5,670 gallons, of drilling mud onto plastic (PA DEP 2010h). Cabot was quick to act and was able to vacuum up all of the drilling mud before any major environmental impacts occurred. This event was indeed Cabot's fault, so an NOV was issued, but since all environmental impacts were mitigated, no fine was issued. We consider this a major event given the large volume of drilling mud that was spilled. There was no environmental impact because remedial action was taken.

B.16 Chief Oil and Gas – Susquehanna County fluid spill

On January 10, 2011, Chief Oil and Gas reported a release of production fluid at its drill site in Susquehanna County (PA DEP 2011a). The PA DEP reported that 150 barrels of production fluid were spilled, but there is no information on whether the environmental impacts had been mitigated (PA DEP 2011a). The PA DEP conducted an Act 2 assessment of the site to determine if the polluted land should be considered solid waste and whether it should be removed from the site (PA DEP 2011a). This event was caused by a partially open valve and was the fault of Chief Oil and Gas. The PA DEP has yet to assess a fine for this incident. Chief did follow the proper protocol for reporting the spill.

B.17 Talisman Energy – Tioga County blowout

On January 17, 2011, Talisman Energy experienced a minor well blowout in Tioga County, Pennsylvania. The blowout lasted for several hours and spilled a large amount of fracturing fluids on the well pad located in a state forest (Levy 2011). The blowout was caused when blowout preventers failed due to excess pressure. This pressure buildup could have been avoided had Talisman properly monitored the well. The impacts of this spill were mitigated, and Talisman was able to clean up the well site. Talisman was fined $51,478 for the event, and was cited for an uncontrolled discharge and hazardous venting (Levy 2011).

The root cause of this event was failure of blowout prevention equipment to contain the pressures that were encountered. This was preventable, and the reason that Talisman was at fault was the fact that the pressure buildup was allowed to continue as long as it did, leading to the blowout.

B.18 Talisman Energy – Jackson production fluid release

On January 26, 2011, Talisman Energy released production fluid at its drilling site in Tioga County. Approximately 500 barrels, or 21,000 gallons, of production fluid were spilled into state forestland (PA DEP 2011b). PA DEP found that Talisman was responsible for this spill. Talisman complied with the PA DEP's investigation of the site and conducted sampling of the site to determine if the land that was affected needs to be removed (PA DEP 2011b). Due to the swift action of the PA DEP and Talisman, much of the possible impacts of this spill was avoided. This event is still considered serious due to the large amount of fluid that was spilled and its proximity to state forestland.

B.19 Carrizo – Monroe mud spill

On January 25, 2011, Carrizo, LLC experienced a mud spill at its drilling location in Washington County near the town of Monroe (PA DEP 2011c). Approximately 1,500 gallons of drilling mud and cuttings were spilled when mixing the substance. The spill was completely confined to plastic beneath the rig, so any potential impacts were mitigated (PA DEP 2011c). The spill was unavoidable and not the fault of Carrizo because it was following proper procedures. Carrizo also reported this spill to the PA DEP in a timely manner, and as of now, there has not been a fine issued to Carrizo.

B.20 Carrizo – Wyoming County drilling mud spill

On February 14, 2011, Carrizo, LLC received an NOV for spilling 1,500 gallons of drilling mud outside of a containment area (PA DEP 2011d). Drilling mud can consist of many different things, but it is typically made of bentonite clay, water, and other drilling additives. This mud spill was considered major given the volume of mud released. Carrizo cleaned up the spill, but did not follow proper procedures for reporting it. The PA DEP found Carrizo responsible for the spill, but no information is yet available on the penalty or if the impacts of the spill have been mitigated.

B.21 Chesapeake Energy – Washington County pit fire

On February 23, 2011, while testing and collecting fluid from wells on a drill site in Washington County, three condensate separators caught fire, injuring three subcontractors working on the site (PA DEP 2011g). The PA DEP conducted an investigation of the incident and determined that the cause was improper handling of condensate, which is a wet gas found only in certain geological areas. Chesapeake was fined $188,000 for the event, which was the maximum penalty that could be assessed for a fire of this type (PA DEP 2011g). There was minimal environmental damage, according to the PA DEP, and the fire was contained (WTAE 2011). To ensure the fire was contained, approximately 20 acres of land was cleared and will need to be restored (WTAE 2011). The men who were injured in the fire were wearing flame-resistant clothing at the time the fire erupted, and it was stated that none of their injuries were life threatening (CBS 2011).

B.22 Ultra Resources – Flowback spill

On March 15, 2011, Ultra Resources left a valve to a storage tank open and allowed 5,300 gallons of produced fluid to spill (Myers 2011). This spill was cleaned up, but did present a high threat to a nearby high-quality water source in Tioga County. Ultra also waited two hours to contact the PA DEP, and although the impacts from this spill have been mitigated, Ultra was still issued an NOV for the event, due to negligence on its part. This event was major given its impact on the environment and the large amount of fluid spilled. Ultra also could have handled the situation much better, and events like this one should be easy to avoid.

B.23 Chesapeake Energy – Leroy Township blowout

On March 19, 2011, Chesapeake Energy experienced a well blowout in Bradford County, Pennsylvania. The cause of this incident was equipment failure and resulted in a large amount of produced water flowing into nearby Towanda Creek (Hamill 2011). The impacts of this event are still being monitored, but no aquatic life was harmed, and the water quality of the surrounding wetlands is still normal. Blowouts are significant events because they are indicative of both environmental damage, and a threat to human health and safety. In some instances, blowouts can be prevented, but in this case, it was beyond the operator’s control. Equipment failure was the cause of the blowout, and despite careful measures taken by Chesapeake, the equipment still failed.

B.24 CNX Gas Company – Mud spill

On July 5, 2011, CNX Gas Company spilled 2,400 gallons of drilling mud into an unnamed tributary that feeds into Ten Mile Creek (PA DEP 2011e). This spill was significant given the size of the spill and the area affected. Any time a substance is leaked into water, serious environmental impacts are likely. In this case, the extent of the damage has yet to be fully reported, but water contamination has been cited. The cause of this spill is also still unknown, but the event was cited as a violation of the Pennsylvania Clean Streams Act, and NOVs were issued. The impacts of this event have yet to be fully mitigated, and the PA DEP will be investigating this incident further to determine the extent of any damage.

B.25 Ultra Resources – Major site restoration failure

On August 16, 2011, Ultra Resources was issued an NOV for failing to restore 21 acres of land affected by drilling activity in Tioga County (PA DEP 2011f). This was the largest amount of land not restored after drilling activities. Site restoration is important because it allows the local ecosystem to return to its natural condition, and if it is not completed, major erosion can take place and damage more land than was originally affected by drilling. Ultra did eventually clean the site. Given the large amount of land that was disturbed, Ultra was fined $58,000 for the incident (PA DEP 2011f). This event was both the fault of Ultra and preventable, and shows how seriously the PA DEP takes site restoration.

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