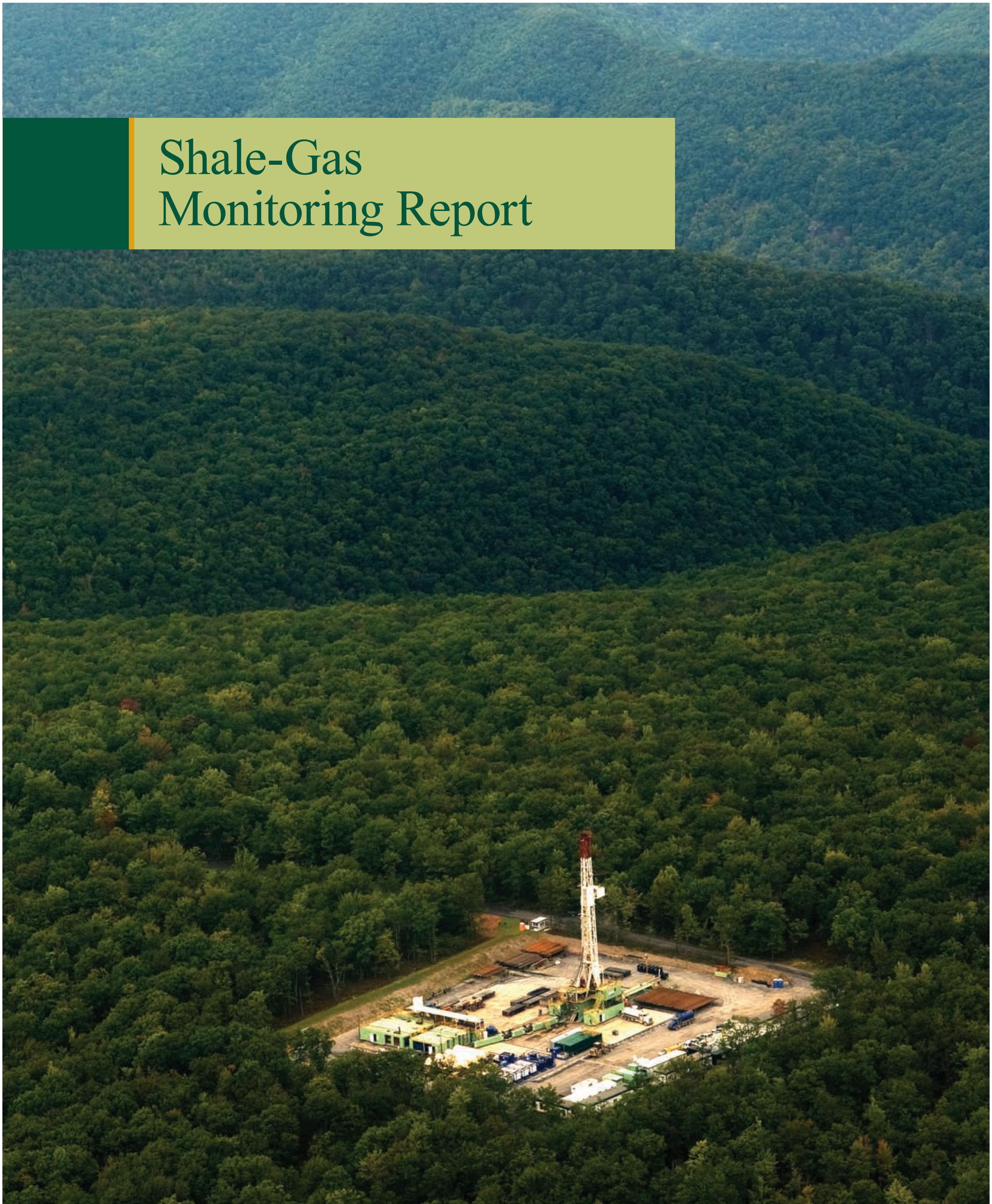
Shale-Gas Monitoring Report



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pennsylvania
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

Preface

As scientists, we define "monitoring" as repeated measurements over time to determine trends or patterns. As managers and stewards of our forests on behalf of all Pennsylvanians, those trends and patterns inform our decisions as we balance the many uses and values of the state forest system.

This Shale-Gas Monitoring Report represents a first iteration of our measurements and is intended to represent a snapshot in time. Future reports are anticipated as more data are collected and analyzed and more trends are observed. Monitoring is a long-term effort and one that the department is committed to continue.

Most people want to be assured that shale-gas activity on state forest land is being "monitored" properly. They may have different perspectives on how monitoring is defined, but they want to know that staff members are on the ground observing and managing the activity that is occurring. I hope that the breadth and depth of this report allays those concerns and demonstrates that shale-gas production on the state forests is being carefully managed.

Monitoring helps us learn whether our management decisions are successful. We already have and continue to make adjustments based on our observations, and our management guidelines will continually be updated as more information is brought forth to inform our decision-making.

It is important to note that a broad set of values is being monitored. This is critical as limiting data collection to one or a few values may lead to misplaced conclusions. Only by viewing this activity in the broadest sense can one get a more complete picture of the various tradeoffs involved. Monitoring does not necessarily give you answers – it gives you data to inform or to be used for decision-making.

This report is not intended to impose a certain viewpoint on the reader. The intent of the report is to present information in as objective a manner as possible. Depending on one's viewpoint, or perspective, the reader can place his or her values on the information presented in the report. For example, the addition of new roads on the state forest can be viewed as increasing access for forest visitors or viewed as diminishment of wild character, depending on one's perspective.

Oftentimes, trends, or effects, are not evident for years or decades. Despite that, there are some findings that can be gleaned from this initial report.

First and foremost is that shale-gas production on state forest lands is neither benign nor catastrophic. There are clearly impacts and tradeoffs associated with this activity. The question is what tradeoffs are acceptable. The Bureau of Forestry considers these tradeoffs and attempts to balance the various uses and values of the forest.

Some examples:

- Water is the resource that most people cite when expressing their concerns about shale-gas production. This report describes our monitoring efforts, as well as other agencies' efforts, in some detail. Although incidents have occurred, the monitoring data show that water quality has not been affected due to this activity.
- Forest conversion and fragmentation also are often cited as concerns. The data do demonstrate that forests are being converted and fragmented, but less than originally expected. This is probably a result of the management decision to place this activity within or adjacent to existing infrastructure or existing disturbances, where it is more noticeable to the public but requires less forest disturbance.
- Invasive species are a concern as areas of disturbance tend to create conditions conducive to invasion by pests or unwanted species. The report clearly shows that invasive species need to be carefully managed and controlled.
- Recreational experiences and expectations vary by user. Some recreationists prefer solitude and a more wilderness-type experience, whereas others, such as motorized vehicle enthusiasts, are happy with a less primitive and more developed experience. The monitoring data show a trend from the more remote experience to a semi-primitive experience. This warrants close scrutiny in the future to ensure that a wide variety of recreational experiences are available on the state forests.

These observations are but a few that could be extracted from the report. Future iterations of the monitoring report will reveal more emerging and interesting trends. As well pads are reclaimed; impoundments are drained and converted back to forest; new well pads and pipelines are added; and new best management practices are implemented, there will be new findings and observations.

Shale-gas production on the state forest likely will continue to grow as the areas currently leased begin or continue to be developed. It is the management philosophy of the bureau to avoid this activity altogether in the most sensitive areas of the state forest. Where the activity is permitted to occur, we will strive to minimize the surface impact to the greatest reasonable extent and to mitigate for the impact whenever possible. And of course, we will continue to monitor this activity, use our observations to adjust management decisions, and report our findings periodically.

This monitoring report is the result of the hard work and effort of many dedicated staff members in the Department of Conservation and Natural Resources and specifically the Bureau of Forestry. I trust that you will find their work and this report informative.

We welcome your observations on this report and on our efforts to manage the state forests in a sustainable manner while balancing the many uses and values of these forests.

Daniel A. Devlin
Deputy Secretary for Parks and Forestry
(Former Director, Bureau of Forestry)
Department of Conservation and Natural Resources

Table of Contents

Executive Summary

Introduction

The Department of Conservation and Natural Resources (DCNR) Bureau of Forestry is broadly responsible for conserving the forests of the commonwealth. One of the bureau's most significant roles is to act, in the public trust, as steward of the commonwealth's 2.2-million-acre state forest system.

Natural gas development is one of the management activities that historically has occurred on state forest land. The activity contributes significantly to Pennsylvania's economy and provides a source of domestic energy. Natural gas development, however, especially at the scale seen in the modern shale-gas era, affects a variety of forest resources and values, such as recreational opportunities, the forest's wild character, scenic beauty, and plant and wildlife habitat.

Overall, approximately 1.5 million acres of state forest are underlain by Marcellus shale. Of that acreage, 44 percent (673,000 acres) is available for gas development either through bureau-issued leases (386,000 acres) or severed lands development (287,000). Modern shale-gas leases restrict surface disturbance in sensitive areas and limit overall surface disturbance to approximately 2 percent of the acreage within the lease tract.

photo courtesy of Martha Rial

Given the host of potential impacts of shale-gas development to the state forest system and its associated uses and values, the bureau has established a Shale-Gas Monitoring Program to track, detect, and report on the impacts of the activity. The program aims to provide objective and credible information to the public and inform and improve shale-gas management efforts. The bureau's Shale-Gas Monitoring Program was initiated in late 2010, when the bureau was authorized to hire a dedicated monitoring team of 15 staff members. The program began full implementation in 2011, when the bureau completed staff hiring, met with advisory committees, and began developing monitoring protocols and building a variety of internal monitoring tools.

The bureau takes a three-tiered approach to its monitoring, recognizing that an effective, long-term monitoring program must be multifaceted. These tiers include: 1) an integrated and dedicated Shale-Gas Monitoring Team; 2) related forest resource monitoring and on-the-ground management activities; and 3) research and external partner collaboration. These tiers form the foundation for the bureau's shale-gas monitoring effort.

An essential function of the Shale-Gas Monitoring Program is to regularly compile and analyze its data and findings. This first report is also an opportunity to communicate basic information about the bureau's monitoring program and its plans for future monitoring efforts.

Monitoring Values

To help guide its monitoring program, the bureau devised a suite of "monitoring values." These values, developed with input from its advisory committees, help focus monitoring efforts on values that relate to the sustainability of the state forest system, the impacts of natural gas drilling on state forest to stakeholders and communities, and the bureau's mission. The values follow with key points and findings:

Infrastructure

Natural gas exploration and development can cause short-term or long-term conversion of existing natural habitats to gas infrastructure. The footprint of shale-gas infrastructure is a necessary part of shale-gas development; however, the bureau attempts to manage this infrastructure to reduce surface disturbance and minimize impacts to other state forest uses and values.

Key points and findings include:

- Approximately 1,486 acres of forest have been converted to facilitate gas development in the core gas districts (state forests subject to shale gas development), including roads, infrastructure and well pads and pipelines. During the same time period (2008 to 2012), the bureau acquired 33,500 acres to add to state forest system, including 8,900 acres in core gas forest districts.
- One hundred and sixty-one total miles of road have been improved or constructed for shale-gas development in the core gas districts. Of these, 131 miles of state forest roads that existed prior to the shale-gas development have been improved or upgraded for gas development activities, and 30 miles of new roads have been constructed for gas development activities.
- One hundred and ninety-one infrastructure pads have been constructed to facilitate shale-gas development in the core gas forest districts.
- One hundred and four miles of pipeline corridor have been constructed or widened in the core gas forest districts.

Flora (Plants)

The bureau oversees the protection of Pennsylvania state-listed native wild plants on state forest lands by reviewing proposed shale-gas development projects and advising bureau managers on the best means to avoid impacts to rare plant species and communities.

There are four main components of the plant monitoring program, including: evaluating vegetation communities immediately adjacent to shale-gas development; monitoring tracts subject to shale-gas development for non-native, invasive plant species; assessing rare plant populations and important wetland habitats; and conducting vegetation inventories in areas of potential future shale-gas extraction.

Key points and findings include:

- A majority of forest conversion for the construction of gas infrastructure on state forest lands occurs in the dry oak-heath community type.
- In undisturbed forest habitat surrounding pads, New York fern (*Thelypteris noveboracensis*) and hay-scented fern (*Dennstaedtia punctilobula*) had the highest average percent cover in the understory, with 31.2 percent and 31.0 percent cover, respectively.
- The most prevalent species in areas around the edges of pads re-vegetated with erosion and sedimentation control seed mixes were *Festuca* species, with 19.2 percent average percent cover, Orchardgrass (*Dactylis glomerata*, 16.0 percent), and red clover (*Trifolium pratense*, 14.2 percent).

Forest Health

The bureau promotes programs to improve and maintain the long-term health and biodiversity of forest ecosystems. The bureau evaluates biotic and abiotic factors affecting the health of trees and woodlands, utilizes integrated pest management techniques to mitigate the effects of destructive agents, and promotes forest health to the public.

Key points and findings include:

- The bureau participates with the USDA Forest Service in the Forest Health Monitoring Program, a national program designed to determine the status, changes, and trends in indicators of forest condition on an annual basis.
- The principal damage-causing agents from 2008 to 2012 in the core gas forest districts were gypsy moth, forest tent caterpillar, and frost.
- Impacts to the forest surrounding disturbance can only be discovered through long-term forest health monitoring.

Invasive Species

The development of shale-gas resources on state forest lands has the potential to increase the spread of nonnative invasive species. The bureau works cooperatively with the Pennsylvania Invasive Species Council, the Pennsylvania Department of Agriculture, the U.S. Department of Agriculture, and other state agencies and organizations to coordinate efforts regarding invasive species.

Key points and findings include:

- Eleven non-native invasive plant species were present at 14 of 18 representative pads across core gas forest districts. The invasive plant with the largest mean population size was Japanese stilt-grass (*Microstegium vimineum*).
- Increased susceptibility to pest attack, especially by nonnative invasive species, may occur wherever there is forest disturbance, especially for trees along newly created edges. However, impacts in the surrounding forests can be discovered only through long-term forest health monitoring.

Water

Numerous methods are employed by the bureau to sample and analyze water resources within the core gas forest districts, with an emphasis on water quality of surface waters. The present focus is surface water quality because this forest system value is of critical concern to stakeholders, could be impacted by shale-gas development, and can be readily and cost-effectively assessed.

Key points and findings include:

- The majority of streams in the core gas forest districts (71 percent) are first-order, headwater streams.
- The majority of streams in the shale-gas region (87 percent) are classified as high quality or exceptional value by the DEP, and many streams are identified as having naturally reproducing trout populations by the Fish and Boat Commission.
- A widespread sampling of field chemistry, including over 300 locations, showed that pH results were primarily in the circum-neutral range, with 72 percent of results between 6.5 and 7.5 and a median pH of 7.01.
- A widespread sampling of field chemistry showed that 91 percent of specific conductance results were below 100 microsiemens(µS)/cm, with a median of 41.3 µS/cm.
- Initial water monitoring results have not identified any significant impacts due to shale-gas development. This is based on one round of field chemistry sampling throughout the shale-gas region and over a year of operation for 10 continuous monitoring devices in key watersheds. At this early stage, the data collected are primarily for establishing baseline conditions.
- Future monitoring efforts include longitudinal surveys of field chemistry, surface water grab sampling, installation of continuous monitoring devices, and an assessment of pipeline-stream crossings.

Soil

Shale-gas development often involves earth disturbance activities that require careful planning and oversight to minimize negative effects on soil quality. Soil resource management and monitoring is achieved in collaboration with DEP. Regulation of earth disturbing activities falls within DEP's jurisdiction. The bureau helps to monitor for problems relating to erosion and sediment control and reports issues to DEP.

Key points and findings include:

- To the extent possible, placement of shale-gas infrastructure has avoided wet soils and soils with high runoff potential.
- Of all pads, impoundments, and compressors constructed, over 85 percent were on well-drained to excessively well-drained soils, and over 80 percent were on soils with medium to very low surface runoff index.
- Of all pipelines constructed, over 70 percent occurred within well-drained to excessively well-drained soils and within soils with medium to very low surface runoff index.
- Of all roads newly constructed or improved due to shale-gas development, over 80 percent occurred within well-drained to excessively well-drained soils and within soils with medium to very low surface runoff index.
- Future research and monitoring will focus on the effects of well pad construction on soil physical and chemical properties, as well as the effects of best management practices on hydrology and sediment loads.

Air

Shale-gas development involves many stages that provide different avenues for the release of air pollutants. Although shale-gas development may emit various pollutants, the natural gas produced through shale-gas development also has the potential to create an overall positive effect on air quality.

The bureau is not conducting air quality monitoring. The bureau relies on DEP to assess potential effects of air emissions from the shale-gas industry and to require applicable air permits of shale-gas operations.

Key points and findings include:

- Since shale-gas development began in Pennsylvania in 2008, there has been a marked decrease in several major air pollutants, such as sulfur, nitrogen oxides, and carbon dioxide. This is due, in part, to the

increased use of natural gas for power generation, the shutdown of several major facilities, and the installation of air pollution control equipment.
- Short-term air sampling at several locations around the state has detected natural gas constituents and associated compounds in the vicinity of shale-gas operations. These compounds were not detected at concentrations that would likely cause health-related impacts, although some were detected at levels which would produce an odor.
- A one-year study is under way in southwest Pennsylvania to study the potential long-term and cumulative effect of air emissions from compressor stations and a major processing facility. A study is also under way to examine the concentrations of ground-level ozone in the vicinity of shale-gas operations.
- A short-term air quality study in Ramsey Village, in Lycoming County along the Pine Creek Rail Trail, did not detect air pollutants above rural background conditions.

Incidents

Incidents occurring on state forest lands related to shale gas development are recorded by both DEP and the bureau. DEP tracks incidents that are investigated involving violations of state environmental laws and regulations. Additionally, the bureau's Incident Reporting System records more general incidents in a variety of categories that occur on state forest land.

Key points and findings include:

- From 2008 through 2012, DEP investigated 324 incidents on state forest land, resulting in 308 notices of violations (NOVs).
- From July 1, 2009, through 2012, 264 incidents in 50 different categories were reported through the bureau Incident Reporting System across all state forest districts directly related to gas development activity.

Fauna (Wildlife)

State forest lands are an important source of food, cover, water, and space for wildlife, which are critical components of ecosystems. The bureau manages forested habitat, ensuring that natural biological communities can thrive. The bureau will base wildlife monitoring efforts on habitat and certain indicator species. The bureau will focus on habitats adjacent to gas development, along with restored gas infrastructure areas. Monitoring efforts will focus on well pads, roadsides, pipeline rights of way, wetlands adjacent to development, forest interior areas near gas infrastructure, and reclaimed or reforested areas.

Key points and findings include:

- Wildlife habitat will change due to shale-gas infrastructure, resulting in more edge and early successional habitat.
- The bureau is monitoring the positive and negative impacts of shale-gas development on wildlife communities to better understand their long-range implications and steps that can be instituted to avoid and mitigate negative impacts.
- The bureau is in the early stages of developing its wildlife monitoring protocols. The bureau will focus on monitoring changes in habitat conditions in relation to shale-gas development.

- Through its monitoring program, the bureau is funding multiple research projects to advance the understanding of the impacts of shale-gas development to wildlife species, such as interior forest birds and timber rattlesnakes.

Recreation

Gas development includes extensive infrastructure that requires careful siting to minimize impacts to recreational features. New infrastructure can affect wild character and viewsheds. Noise-generating activities may affect visitor experience. Roads, well pads, pipelines and other shale-gas infrastructure also can affect snowmobile and hiking trails. At the same time, opportunities to enhance recreational trails and experiences can be realized through new shale-gas infrastructure.

Key points and findings include:

- No national hiking trails in Pennsylvania have been impacted by shale-gas development. Three designated state forest hiking trails have been impacted.
- Statewide, since 2006, there has been a 5 percent increase (145 miles) in total snowmobile trail miles across the state forest system. This is the result of a 203-mile decrease in joint-use trails and a 348-mile increase in designated snowmobile trails.
- Snowmobile trail systems have been impacted in each of the core gas forest districts. New snowmobile trails have been created to replace impacted snowmobile trails.
- The need for road access for shale-gas development has resulted in heavier traffic on state forest roads. Upgraded roads may be safer and easier to drive but may have lost some of their "wild character" value.
- The impact of shale-gas development on recreational experience and wild character as measured by the Recreation Opportunity Spectrum is a 9,341-acre increase in semi-developed and developed acreage; a 913-acre decrease in semi-primitive acreage; an 8,409-acre decrease in semi-primitive non-motorized acreage; and a 19-acre decrease in primitive acreage.

- Initial measurements at six out of the seven operating compressor stations measured on state forest lands were louder than the 55db(A) suggested by the updated *Guidelines for Administering Oil and Gas Activity on State Forest Lands*.
- Forty-six out of 116 comment card respondents in core gas forest districts indicated that Marcellus activity had changed their visitation experience. Forty-one out of 116 respondents indicated that Marcellus activity had changed their recreational use of the state forest.

Community Engagement

Natural gas development on state forest lands has potential economic and social effects on local communities. The bureau interacts with local communities through the implementation of its public participation policy, which includes public education and participation as an integral part of the management of state forest lands.

The components included in the community engagement section of this report are advisory committees, gas tours on state forest land, and focus groups.

Key points and findings include:

- Natural gas development on state forest lands has potential economic and social effects on local communities.
- The bureau uses advisory committees to promote stakeholder feedback and produce recommendations.

- Outreach offers valuable opportunities to demonstrate how natural gas activity is conducted and managed on public lands and has become a source of understanding public perceptions.
- Focus groups have been designed to identify and understand the social effects on communities resulting from natural gas development on state forest lands. One pilot focus group targeting community leaders in Pine Creek Valley was conducted in November of 2013. Two additional groups targeting government leaders in Tioga and Clinton counties were conducted in 2014.

Timber

One of the purposes for the creation of a state forest system was to provide a continuous supply of timber, lumber, wood and other forest products. According to the bureau's strategic plan, state forest lands should provide a sustained yield of high-quality timber consistent with the principles of ecosystem management. In relationship to shale-gas management, the bureau will monitor the impacts to silvicultural practices, timber sales, distribution and placement, logging access, and revenues.

Key points and findings include:

- Initial analysis shows that some timber management activities in core gas forest districts may be shifting away from areas leased for shale-gas development. Some of this change, however, may be due to gypsy moth salvage harvesting.
- The effect of shale-gas development on timber harvest placement and harvest allocation goals is inconsistent across core gas forest districts. More information and data are needed to discern reliable trends.
- Shale-gas development is indirectly decreasing timber harvest revenue due to Route 44 bonding costs resulting from heavy hauling associated with shale-gas development.

Energy

The modern energy mix within the United States today consists chiefly of five energy sources: oil or petroleum, natural gas, coal, various renewable energy sources, and nuclear energy. The second-largest portion of U.S. energy usage is derived from natural gas or methane at approximately 25 percent of all consumption. Natural gas is a fuel of choice for heating and industrial processes and electrical production where available in large quantities at a competitive price. Natural gas can be expected to gain market share over time and may gain the majority of new national energy consumption that arises from normal annual energy need increases.

Key points and findings include:

- Approximately 15 percent of all shale gas produced in Pennsylvania comes from state forest lands. This gas is sold and distributed across the eastern and midwestern United States to service energy markets on a daily basis.
- Natural gas in the United States is an open-market traded commodity that has seen the price per product unit fall from a high of approximately $10 per Mcf (1,000 cubic feet) in 2010 to the current (end of 2013) $4.75 per Mcf as a direct result of Pennsylvania shale gas coming onto the market grid and forcing gas prices to moderate with respect to the gas supply.
- On state forest land, the number of wells per pad ranges from one to ten, with approximately four to eight wells being the average. A typical well drains approximately 100 acres, but that figure can be less or greater depending on a number of factors.
- The bureau anticipates that approximately 3,000 gas wells may be drilled on state forest lands to fully develop the current leased acreage on commonwealth gas leases, on which approximately 568 had been drilled by the end of 2013. A portion of these new wells will be drilled on existing well pads.
- State forest lease tracts targeting shale gas are estimated to be approximately one-fifth developed. This, however, is only a projection, as future energy development patterns are difficult to accurately predict and depend on market conditions and the performance of individual tracts.

Revenue

Since the first leases in 1947, the development of natural gas resources on state forest land has generated a steady and increasing revenue source for the commonwealth in the form of rents and royalties. The data presented have been tracked and tabulated by the bureau since 1947.

Key findings and points include:

- The pre-shale-gas period of oil and gas activity provided a total income to the commonwealth of approximately $153,659,522. The shale-gas period (through 2012, for the purposes of this report) has provided $582,250,644 in revenue. The combined total of all revenue from the oil and gas lease program from 1947 to the end of 2012 has been approximately $735,910,166.
- The influx of shale-gas production revenue began in 2009 when most of the wells that had been first proposed in 2007, 2008, and early 2009 were drilled and connected to the pipeline system and gas was delivered to the market.
- Royalty income is just beginning to come to DCNR from the hundreds of new shale-gas wells on state forest land.
- Steady revenue growth from gas extraction is expected to continue for the next decade as the full development of the leases comes to a conclusion.

Forest Landscapes

Approaches to forest management must take into account not only the direct impacts of various activities, but also the cumulative, landscape-level impacts of these activities over time. Landscapes are contextual in nature, and thus there is no firm definition of what constitutes a "landscape" in a forested setting. This chapter, however, attempts to address certain forest values and impacts of shale-gas activities across the greater forested land base. This initial report focuses on the landscape-level impacts of shale-gas development to forest conversion, the value of "wild character," forest fragmentation, and restoration.

Key points and findings include:

- Approximately 1,486 acres of the 2.2-million-acre state forest system have been converted to facilitate shale-gas development. During the same time period (2008 to 2012), the bureau acquired 33,500 acres to add to state forest system, including 8,900 acres in the core gas forest districts.
- One assessment of the current impact of gas infrastructure on wild character, using the Recreation Opportunity Spectrum as a measurement tool, is a 9,340-acre increase in semi-developed and developed acreage. Correspondingly, there was a 912-acre decrease in semi-primitive area, an 8,409-acre decrease in semi-primitive non-motorized area, and a 19-acre decrease in primitive area.
- In core gas forest districts, the bureau's forest fragmentation analysis showed the largest increases in edge forest in Tiadaghton State Forest (1,813 acres) and Tioga State Forest (1,257 acres). Overall, core gas forest districts added 4,355 acres of edge forest.
- In the core gas forest districts, there was a loss of 9,242 acres of core forest greater than 200 hectares. Core forests are large parcels of interior forest not affected by roads, pipelines, well pads, and other infrastructure.
- Elk, Moshannon, and Tiadaghton state forests have had a combined total of 10 well pads that have been partially reclaimed by reducing the pad size and replanting the adjacent areas with vegetation. No gas infrastructure sites have received full ecological restoration.

Partner Monitoring

Susquehanna River Basin Commission

(Remote Water Quality Monitoring Network)

The Susquehanna River Basin Commission (SRBC) is a federal, interstate commission that guides the conservation, development, and administration of water resources of the Susquehanna River basin.

In response to increased levels of shale-gas development in the Susquehanna River basin, SRBC established its Remote Water Quality Monitoring Network (RWQMN) for real-time, continuous monitoring of field chemistry parameters. The RWQMN is intended to help SRBC and its stakeholders develop a baseline characterization of water quality in the shale-gas region and monitor for potential changes in water quality due to shale-gas development.

In November 2009, SRBC announced it was seeking partners with whom it could expand its RWQMN to rivers and streams remotely located in the northern tier of Pennsylvania. In 2010, the bureau provided $280,000 from the Oil and Gas Lease Fund to SRBC to purchase monitoring equipment and for subsequent operation and maintenance costs. This funding source allowed for the establishment of 10 monitoring stations.

The bureau selected sites on state forest that were expected to experience shale-gas development and aid in the collection of baseline water quality data. It also selected areas where private shale gas development borders state forest and which DEP designated high quality or exceptional value streams.

Forest Certification

Pennsylvania state forests are certified (FSC® C017154) under Forest Stewardship Council™ standards. Timber harvested from Pennsylvania's state forests are FSC certified to ensure that the chain of custody from the forestland to the mill can be continued and that products are coming from forests managed in an environmentally responsible manner.

Third-party audits are conducted annually to ensure that state forests are managed in compliance with FSC® standards. Every five years, a comprehensive re-certification audit is conducted, followed by four annual surveillance audits. Results of these audits are included in reports to reflect the focus of the audit and to outline any areas for needed improvement.

In 2010, an audit with an intensified focus on shale-gas activities was conducted. In 2013, the bureau underwent a comprehensive five-year re-certification and was issued a new certificate with no major corrective action requests issued.

Since 2008, there have been four corrective action requests and six observations made related to the recent shale-gas activity and management. A summary of those findings by the auditors is listed in the report.

Research Partnerships

The bureau regularly seeks partnerships and cooperates with projects that advance the goals of its shale-gas monitoring program. These research projects are part of the bureau's overall monitoring approach, and help address specific questions and issues with a greater degree of scientific vigor and certainty. Research partnerships also help the bureau address management issues and questions with additional expertise and resources. The projects listed in this section will be completed in 2014 and 2015, and represent the bureau's initial round of research projects related to shale-gas development on state forest lands.

The following are research projects currently funded by the bureau's Shale-Gas Monitoring Program:

- Evaluating Storm Water and Erosion and Sedimentation Control Measures Associated with Shale-Gas Infrastructure in Forested Landscapes
- Quantifying Soil and Landform Change Across Shale-Gas Infrastructure in Northern Pennsylvania
- Quantifying the Cumulative Effects of Multiple Disturbance Regimes on Forested Ecosystems in Northern Pennsylvania
- Effects of Natural Gas Pipelines and Infrastructure on Forest Wildlife
- Assessing Potential Impacts of Marcellus and Utica Shale Energy Development on the Timber Rattlesnake (*Crotalus horridus*) in North Central Pennsylvania

Part 1: Introduction

» A Steward of the State Forest System

The Department of Conservation and Natural Resources (DCNR) Bureau of Forestry is broadly responsible for conserving the forests of the commonwealth. Specifically, its mission is to "ensure the long-term health, viability, and productivity of the commonwealth's forests and to conserve native, wild plants." While this forest conservation responsibility extends across all ownerships in Pennsylvania, one of the bureau's most significant roles is to act, in the public trust, as steward of the commonwealth's 2.2-million-acre state forest system (Figure 1.1).

The state forest system is truly a priceless asset for the citizens of Pennsylvania, stretching across 48 of the commonwealth's 67 counties and comprising 13 percent of Pennsylvania's forested land base. State forests were originally created "to provide a continuous supply of timber, lumber, wood and other forest products, to protect the watersheds, conserve the waters and regulate the flow of rivers and streams of this Commonwealth and to furnish opportunities for healthful recreation to the public" (Conservation and Natural Resources Act, 1995). The Bureau of Forestry manages state forests – the largest block of public land in the commonwealth – for many uses and values. The overarching goal of state forest management is to "manage state forests sustainably under sound ecosystem management, to retain their wild character and maintain biological diversity while providing pure water, emphasizing opportunities for dispersed recreation, habitats for forest plants and animals, sustained yields of quality timber, and environmentally sound utilization of mineral resources" (Penn's Woods 1995).

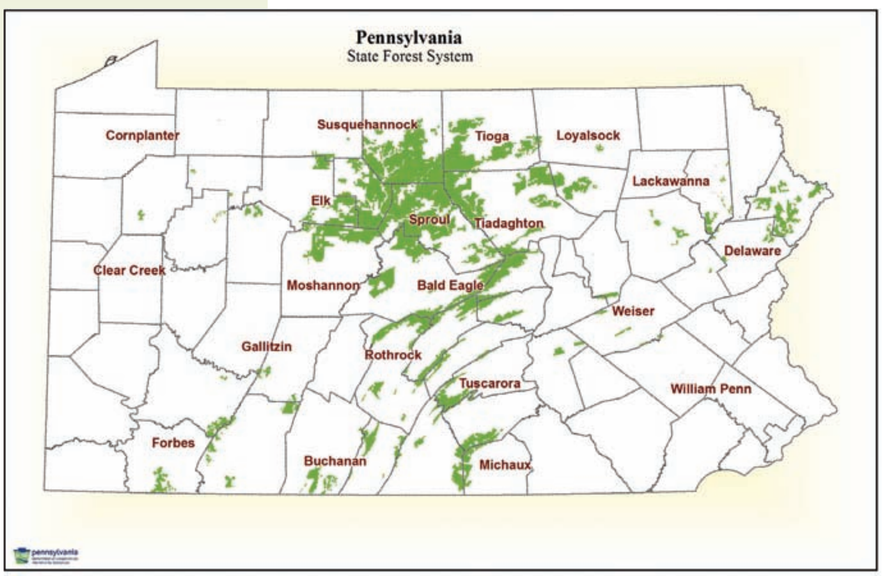


Figure 1.1

Natural gas development is one of the management activities that have historically occurred on state forest land. The activity contributes significantly to Pennsylvania's economy and provides a source of domestic energy. State forests, in providing multiple uses and values to society, are considered "working forests." The economic use and sound utilization of mineral resources is part of the bureau's mission in managing these lands. Natural gas development, however, especially at the scale seen in the modern shale-gas era, can have impacts on a variety of forest resources and values, such as recreational opportunities, the forest's wild character, scenic beauty, and plant and wildlife habitat.

As part of its overarching goal of ensuring the sustainability of the commonwealth's forests, the bureau, in 2010 and 2011, put into place a Shale-gas Monitoring Program to monitor, evaluate, and report on the impacts of shale-gas development to the state forest system and its stakeholders. Additionally, in 2011, the Governor's Marcellus Shale Advisory Commission recommended that "DCNR should monitor and document effects, both positive and negative, of natural gas development on plants and forests, wildlife, habitat, water, soil, and recreational resources." This document represents the bureau's effort to report on the initial findings of this monitoring program and to communicate to stakeholders information about the activity on state forest lands.

The Bureau's Challenge: Balancing Uses and Values

Given the broad set of uses and values for which the state forest is managed and the diverse expectations of its stakeholders, the bureau aims to balance these uses and values across the state forest system. Managing for multiple resources as well as human needs and values in a single landbase is a considerable challenge. Different forest uses and values can sometimes conflict. Furthermore, all citizens of Pennsylvania share ownership of the state forest system, and as a result, there are many contrasting views and perspectives regarding management strategies and permitted activities.

The resource management conflicts and trade-offs involved in natural gas development are reflected in the variety of views expressed by bureau stakeholders, which often depend on the perspectives, experiences, and values of the individual or group. State forest users who enjoy back-country recreational experiences or have a cabin near heavy gas activity may look upon shale-gas development unfavorably. Other users who utilize natural gas for home heating or who experience improved road access because of the development may have more positive views of the activity. Some stakeholders may approve of the activity but only at a limited scale, while others may believe any natural gas development is incompatible with state forest management. The bureau must consider the many viewpoints about the activity and its impacts as the bureau manages the state forest system for the citizens of the commonwealth.

An Ecosystem Approach

In managing for the varied uses and values of the state forest system, the bureau takes an "ecosystem management approach." A key principle of this approach is to keep the complex interdependencies among organisms, communities, and natural processes within an ecosystem functioning over long periods of time. Forest ecosystem management is the implementation of practices that promote the long-term health of the forested systems. Another aim of this approach is the maintenance of ecosystem integrity to accommodate short-term stresses and adapt to long-term changes. The application of ecosystem management should guarantee that resource management activities are compatible with the long-term ecological health of the state forest system.

Forest Resource Monitoring

Forest resource monitoring plays an essential role in ecosystem management by aiding in measuring ecological health, as well as other social and economic considerations. Systematically monitoring key indicators and the results and impacts of management activities creates an important feedback loop for forest managers. Monitoring allows managers to objectively analyze both short-term and long-term changes in the forest and the impacts of management decisions. Forest managers can then learn from this information and adapt management practices accordingly.

The bureau monitors a variety of activities and resources on state forest land. Monitoring shale-gas development is especially important because the activity has the potential to impact other important forest uses and values. The systematic monitoring of shale-gas activity helps forest managers better understand the impacts and inform management decisions and practices. These impacts can be positive, negative, or neutral, depending on the forest resource value being considered and the perspective of the individual stakeholder or state forest user. The objective reporting of shale-gas monitoring information promotes transparency while providing stakeholders with credible, objective information about the activity on state forest lands.

II. Natural Gas Development and State Forest Lands

Pennsylvania allows land to be subdivided not only by surface acreage but also by subsurface minerals (coal, limestone, sandstone, etc.) and various fluids (oil and gas). This ability to "sever" certain subsurface rights in part or whole has been a key feature in Pennsylvania land ownership patterns since minerals extraction first began in Pennsylvania in the late 1700s.

In the case of state forest lands in Pennsylvania, approximately 312,000 acres have some severed gas and oil subsurface rights attached to the title, which is approximately 14 percent of the system (Figure 1.2). On these "severed lands," The bureau respects the ownership of the subsurface rights and, consistent with state law, allows "reasonable" surface access for mineral extraction.

The commonwealth owns the majority of state forest land, approximately 1.8 million acres (86 percent), in "fee simple," meaning the bureau owns and controls all the surface and subsurface rights (Table 1.1). Across the 2.2-million-acre state forest system, approximately 388,000 acres have been leased by the commonwealth (Figure 1.2).

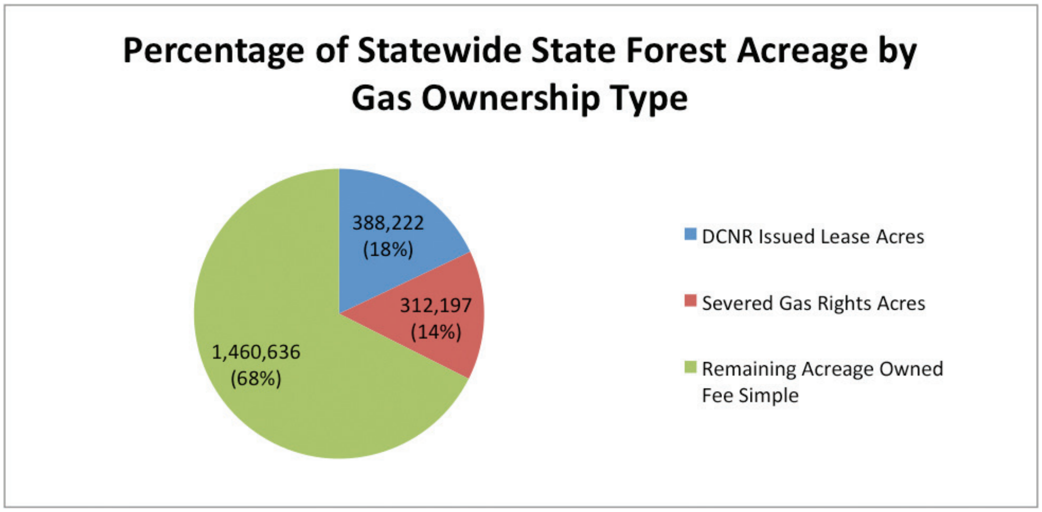


Figure 1.2

State Forest	DCNR Issued Lease Acres	Severed Gas Rights Acres	Remaining Acreage Owned Fee Simple	Total State Forest Acreage
Michaux	0	8,296	77,206	85,502
Buchanan	2,007	8,119	59,551	69,677
Tuscarora	0	5,037	90,988	96,025
Forbes	17,350	4,149	37,021	58,519
Rothrock	0	1,204	94,771	95,975
Gallitzin	2,597	3,013	18,760	24,370
Bald Eagle	0	1,601	191,789	193,390
Clear Creek	463	12,833	2,670	15,966
Moshannon	45,016	40,157	104,858	190,032
Sproul	140,414	32,996	132,030	305,439
Lackawanna	0	0	29,603	29,603
Tiadaghton	50,076	1,566	94,948	146,590
Elk	7,493	44,427	148,032	199,952
Cornplanter	0	1,362	129	1,491
Susquehannock	61,456	86,372	112,286	260,113
Tioga	40,704	17,710	103,477	161,890
William Penn	0	734	73	807
Weiser	0	310	27,749	28,059
Delaware	0	512	82,591	83,103
Loyalsock	20,646	41,798	52,106	114,550
Total	**388,222**	**312,197**	**1,460,636**	**2,161,054**

Table 1.1 Statewide state forest acreage by gas ownership type (All state forest districts).
Note: Data is based on GIS analysis. In some severed rights acres the Commonwealth has partial ownership.

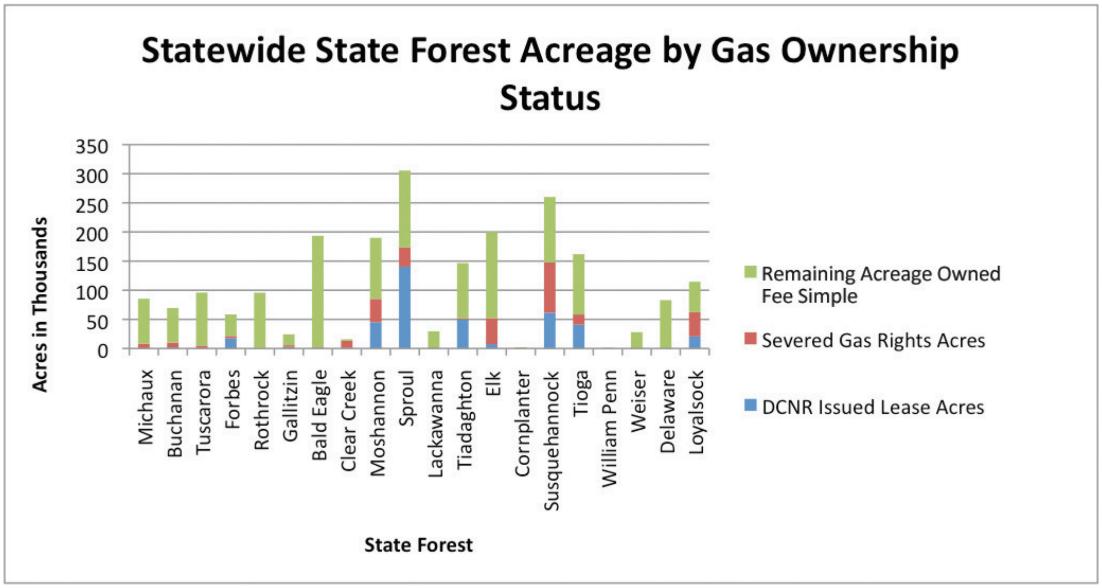


Figure 1.3

Pre-Shale-Gas Development

Oil and gas development has been part of state forest management since 1947. During this time, DCNR (or its predecessor agencies) has conducted 74 oil and gas lease sales, resulting in more than 2,000 wells drilled on state forest lands.

For purposes of this report, state forest gas development is divided into two time periods – the historical period from 1947 to 2008, and the shale-gas time period from 2008 to present day.

In the pre-Marcellus period, approximately 1,400 historic natural gas wells were drilled on state forest lands for the Oriskany sandstone and the Upper Devonian gas sandstone targets (Figure 1.4). The Oriskany sandstone is a conventional gas target present in the geologic section below the Marcellus and considered to be a "deep" target in Pennsylvania. The Upper Devonian sandstones are a "shallow" gas target and are considered to be unconventional targets as their reservoir properties tend toward low permeability and porosity. Of the approximate 1,400 gas wells drilled on state forest lands from 1947 to 2008, approximately 750 remain in service as producing gas wells or as gas storage wells. The gas storage wells are entirely developed within the Oriskany sandstone horizon and for the most part utilize the original existing wells for production access to the reservoirs.

The 74 lease sales mentioned above resulted in hundreds of thousands of acres of state forest lands being under lease at various times. The least amount of acreage under lease in any one year was fewer than 50,000 acres in the startup years of 1947 to 1951, and the greatest amount of acres under lease peaked in 1984 at near 1 million acres. The largest single lease sale offering of 450,000 acres occurred in 1982. Prior to Marcellus Shale development, a lease sale of 217,000 acres was offered targeting the Trenton-Black River formation, which occurred in 2002.

A large decrease in the acreage under lease occurred between 1984 and 1997 (Figure 1.5). This was due to the fact that natural gas operators had been unsuccessful in discovering commercially feasible quantities of gas during this time period. In order to avoid paying annual lease agreement rental fees, the operators relinquished undeveloped leased acreage back to the commonwealth.

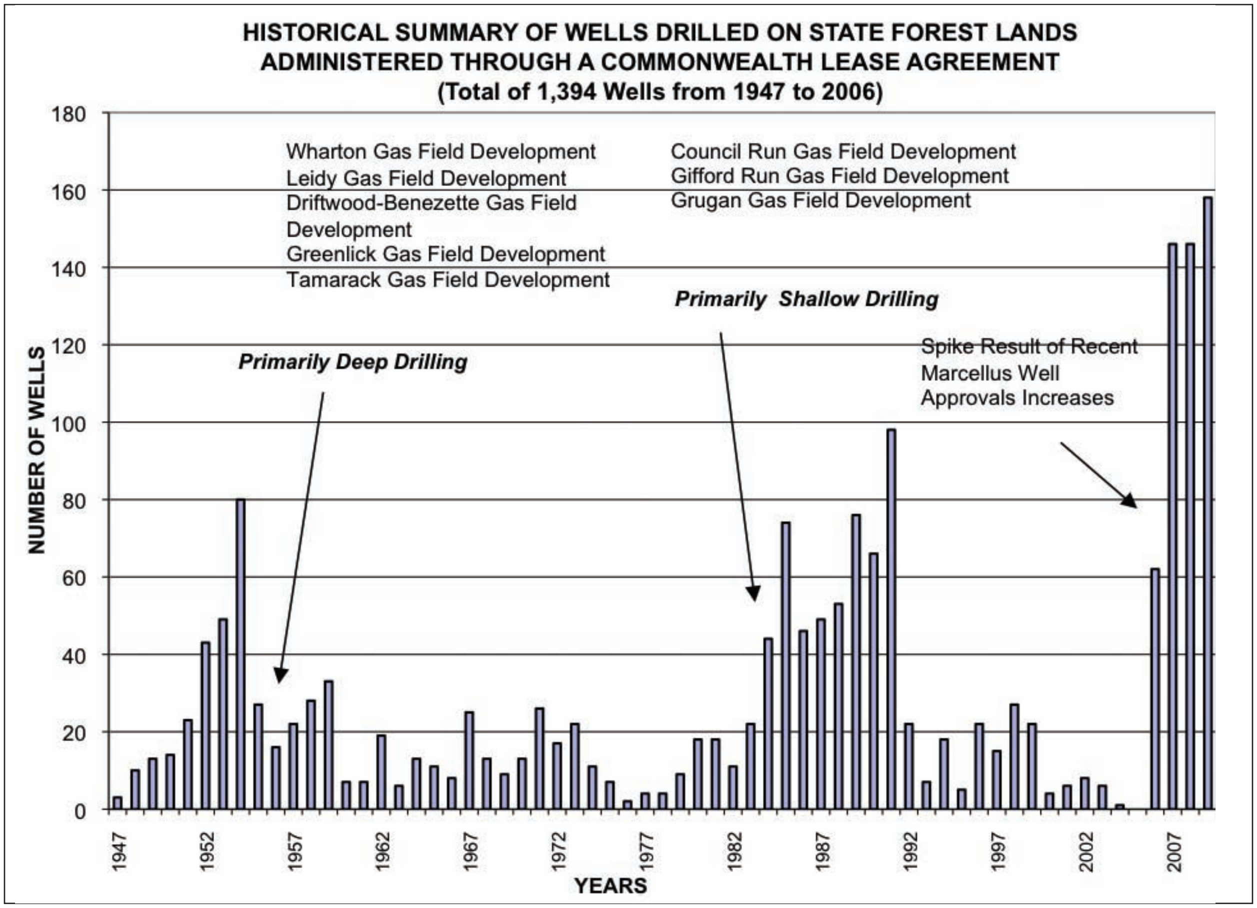


Figure 1.4

The bureau's leases currently do not limit the depths or geologic formations which may be drilled for oil or natural gas. Consequently, many historically leased acres now include a combination of both older deep and shallow natural gas wells, as well as more recent shale-gas wells.

Natural Gas Storage on State Forest Lands: The bureau issued its first natural gas storage agreement in 1956. Since then, the number of acres under lease for this purpose has remained under 100,000 acres. Most of the acreage under lease by the bureau for gas storage is represented by the Wharton, Leidy, and Greenlick storage fields located in northern Clinton and southeastern Potter counties. The Oriskany sandstone was originally drilled for natural gas production in this area in the early 1950s, and the sandstone formation was converted over to natural gas storage within a short period of time.

Marcellus and Other Shale-Gas Geology and Development

The geologic diagram shown in Figure 1.6 represents a simplified "layer cake" depiction of the rock formations, which historically have been and currently are being targeted for natural gas development in Pennsylvania.

On the top right of the diagram are the shallow sandstones that were the mainstay of Pennsylvania's gas drilling for many decades – these include the Venango, Bradford, and Elk groups of rocks. Closer to the bottom of the diagram is the much deeper Oriskany sandstone, which was targeted for drilling in about the 1950s. In between these two depths of rock targets are other black shales, including the Marcellus.

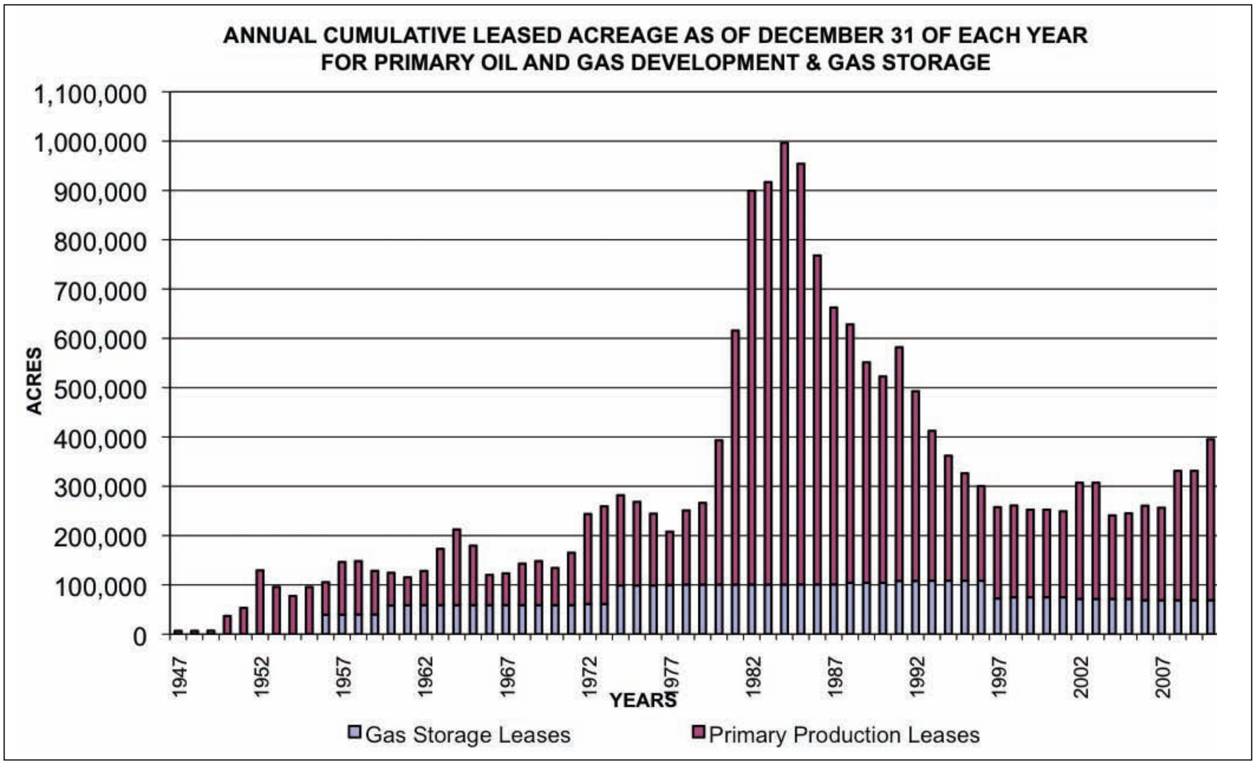


Figure 1.5

Marcellus Shale: The Marcellus Shale is an organic-rich rock unit of Middle Devonian Age (approximately 375 million years in age), which is found throughout most of Pennsylvania (except for the southeastern portion of the state). At some locations, it is present at the ground surface and can be seen in road cuts, etc.

However, in most locations within the state, it is located only below the ground surface. Where the Marcellus is located at certain depths and certain thicknesses, it does lend itself to natural gas drilling and production. These areas are generally located north and west of the Allegheny Front, which is a physical geographic line of demarcation between the uplifted plateau section of the state (the northern, northwestern, and southwestern areas) and the ridge and valley areas of the state.

In general, Marcellus Shale is thickest (>250 feet) in northeastern Pennsylvania and thinnest (<50 feet) in western and northwestern Pennsylvania. Figure 1.7 is a contour map of Marcellus Shale thickness in Pennsylvania. The limit-of-study area edge is approximately coincident with the Allegheny Front.

Marcellus Shale is composed of very fine grain silica particles resembling sand, some clay content, and up to 10 percent organic material called kerogen. It is the kerogen material that has been acted upon by heat and pressure over millions of years to produce oil, condensate, natural gas liquids, and natural gas.

Prior to the success of Range Resources' Marcellus well development in the early 2000s in southwestern Pennsylvania, natural gas drillers often observed "hits" of gas coming from the Marcellus and other black shales while drilling through them to reach deeper rock targets. The flow of gas from these shales was not sustained for any length of time and thus not considered economically feasible to develop. However, using a combination of lateral drilling (technology which has existed in at least basic form since the early 1870s) and hydraulic fracturing (used in Pennsylvania since at least the 1950s), shale-gas wells did become economically viable. By 2007, it was becoming apparent that the Marcellus was becoming a legitimate new gas "play" (an area of gas development) in the state.

Other black shales: Two other black shales lying above the Marcellus are also being targeted for drilling. These are the Burket and Geneseo black shales. As Marcellus wells are being drilled, the natural gas operators are drilling through these shallower black shales. If these shales have potential, they too are being developed for gas production.

The Utica Shale is located several thousand feet deeper than the Marcellus and is not shown on Figure 1.7. Currently, there are no wells on state forest lands producing gas from the Utica Shale.

The overwhelming majority of shale-gas production on state forest lands is coming from the Marcellus Shale, and for purposes of this report, discussion will focus on Marcellus Shale wells.

Marcellus Shale production areas in PA: So far, the natural gas industry has focused on two main areas in Pennsylvania where they have had the most success in establishing commercial production – in northeastern/north-central and southwestern Pennsylvania. In southwestern PA (where there are fewer acres of state forest lands), the Marcellus is considered a "wet gas" because it produces natural gas liquids in addition to natural gas. These liquids add to the value of the gas produced from the wells. Figure 1.8 shows these two areas of the greatest current Marcellus production and highlights the economic fairway for the Marcellus in Pennsylvania.

Since the first wells were drilled into the Marcellus in Pennsylvania in the mid-2000s, nearly 8,000 such wells have been drilled across the state. Very few Marcellus wells have been plugged and abandoned, indicating that the rock unit has commercial potential across vast areas. The map in Figure 1.9 shows the locations of Marcellus wells permitted and completed through the end of 2012.

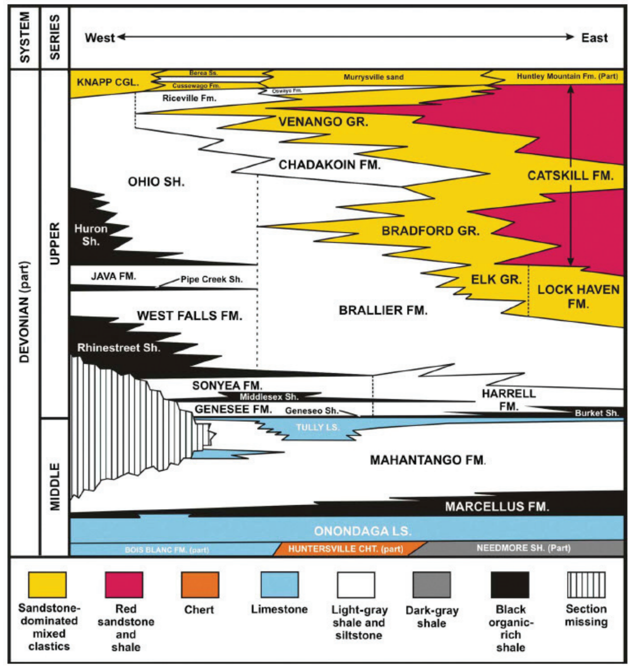


Figure 1.6 Stratigraphic column of shale targets in central Pennsylvania.

Carter, Harper, Schmidt, and Kostelnik, AAPG Journal, January 2014

Marcellus Shale and State Forest Land

Because the Marcellus Shale play underlies such a large area in northern and western Pennsylvania, it is coincident with large areas of state forest lands. Figure 1.10 indicates the position of state forest lands in relation to the Marcellus play fairway and the lease/subsurface ownership status of the acreage on state forest lands.

Overall, approximately 1.5 million acres of state forest are underlain by Marcellus Shale. Of that acreage, 44 percent (673,000 acres) is currently subjected to gas development either through bureau-issued leases (386,000 acres) or severed lands development (287,000). See Figure 1.11, Figure 1.12, and Table 1.2.

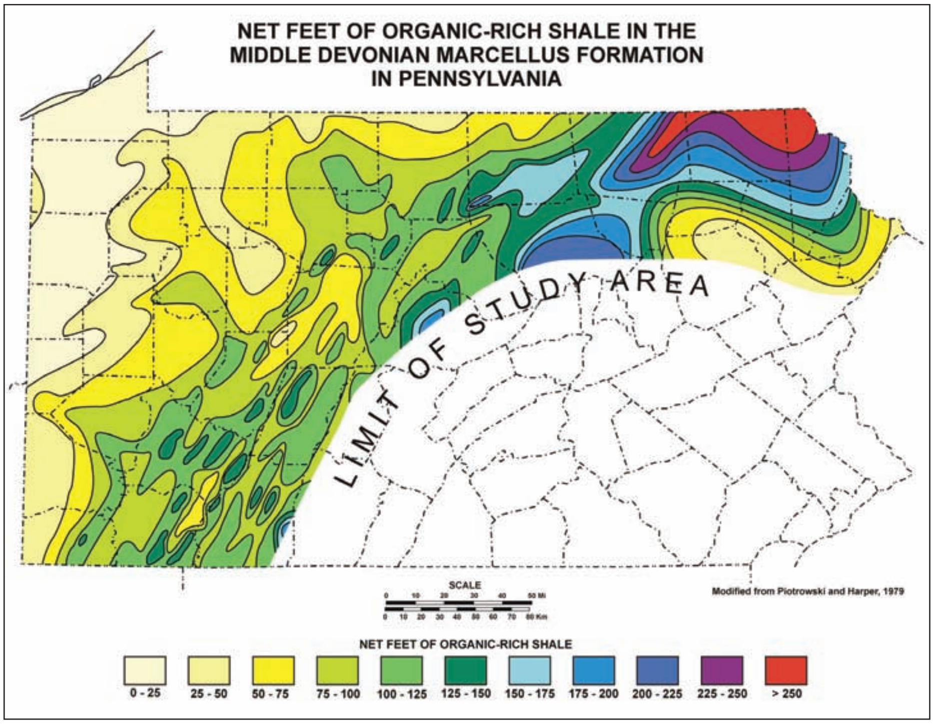


Figure 1.7 Possible limits of the Marcellus Shale present in Pennsylvania.
Harper, Topographic and Geologic Survey of PA, 2012

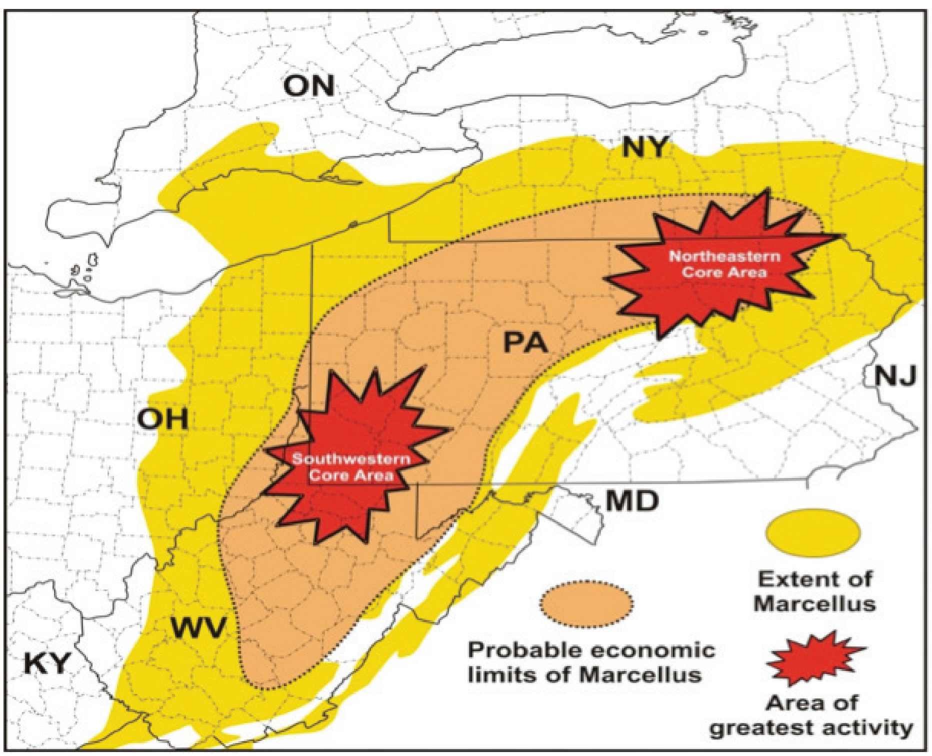


Figure 1.8 Location of current concentrations of driiling activity for the Marcellus in the Appalachian Basin.
Harper, Topographic and Geologic Survey of PA, 2012

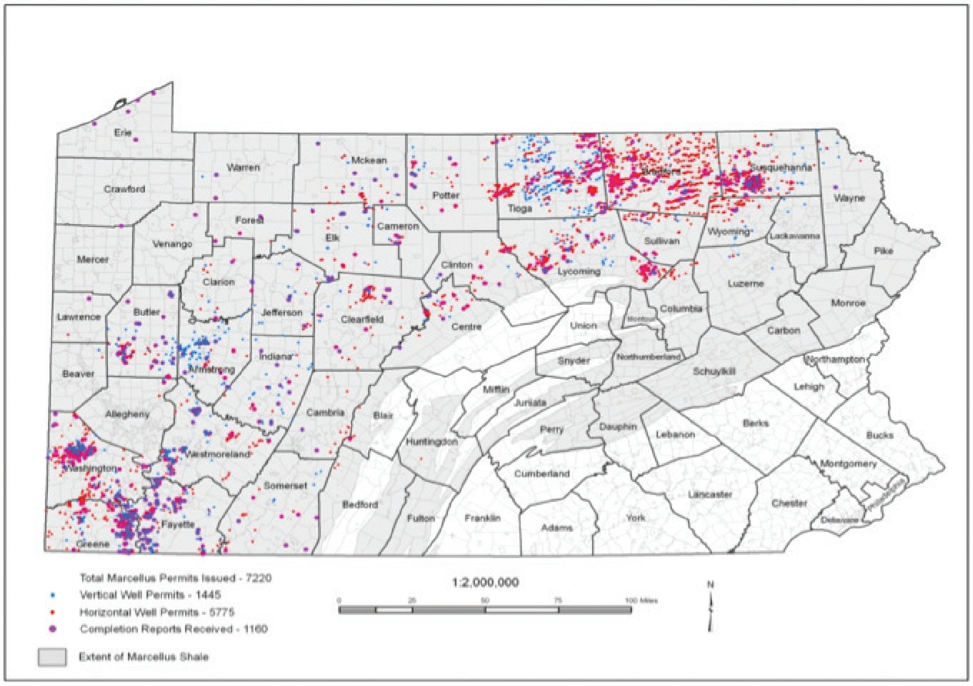


Figure 1.9 Extent of the Marcellus In PA and locations of well permits issued by the state for the Marcellus from 2008 to the end of 2012.
Harper, Topographic and Geologic Survey of PA, 2012

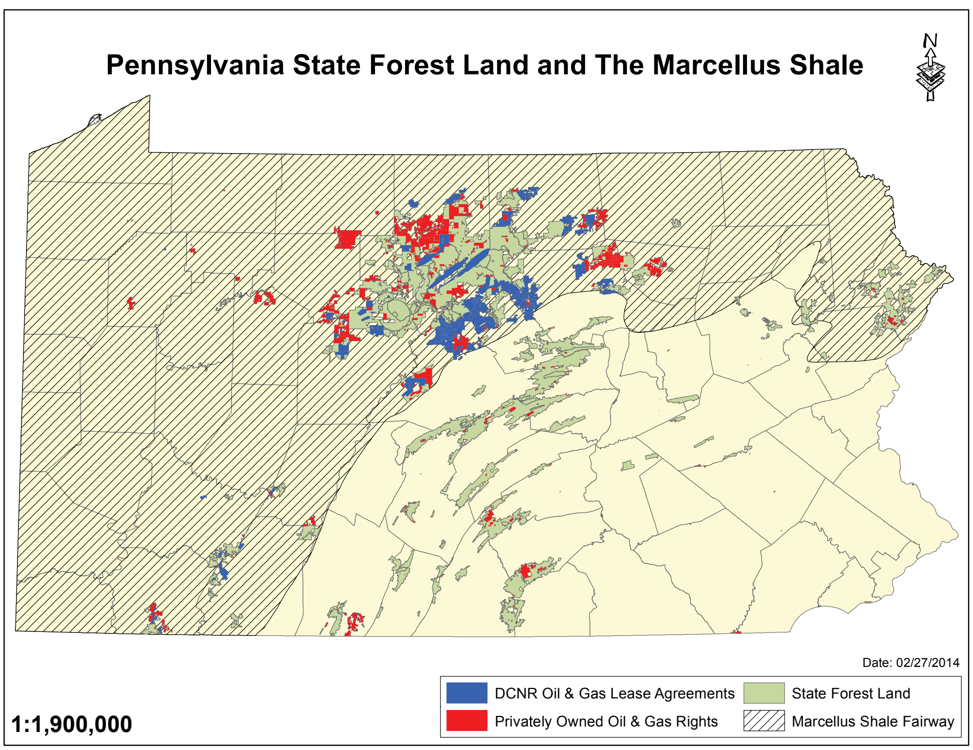


Figure 1.10

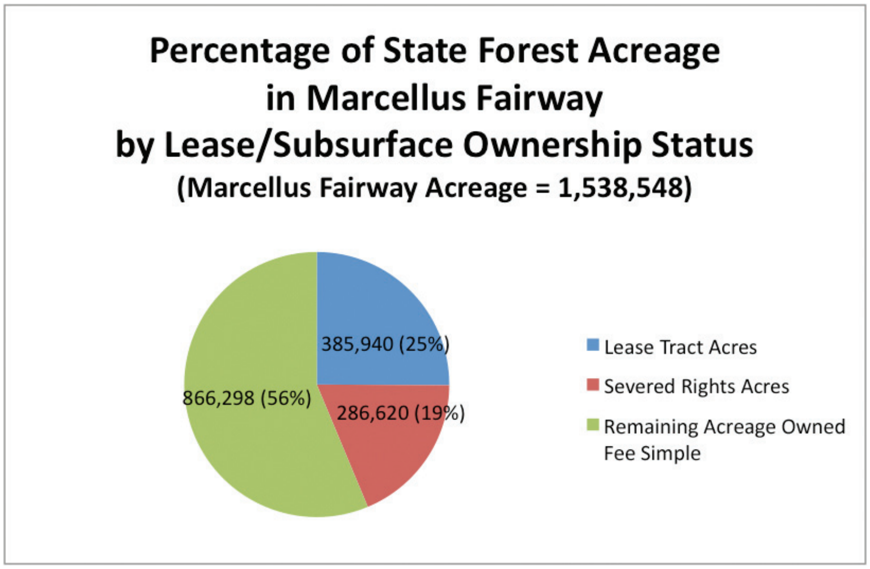


Figure 1.11

surface protections, such as: increased setbacks from critical recreation infrastructure, streams, state parks, and designated wild and natural areas; surface disturbance limit of approximately 2 percent of total tract acreage; increased bonding for well plugging; requirement for pollution liability and deep drilling insurance; and prohibited entry in areas of special concern without written approval.

An executive order, issued in 2010, prohibits additional leasing of state forest and parks for oil and natural gas development.

DCNR Shale-Gas Leases

In 2008, DCNR held its first competitive gas lease sale targeting the Marcellus Shale in its north-central Pennsylvania holdings. The summary of the results of the 2008 leasing event and the subsequent events in 2010 is detailed in Table 1.3. The shale-gas leases the bureau issued in 2008 and 2010 provide enhanced

As a result of the 2008 and 2010 lease sales and the large acreage inventory of the existing historical leases, the period from 2008 until 2013 saw approximately 568 new wells drilled on state forest lands. Table 1.4 details a

State Forest	District Acreage in Marcellus Shale Fairway	Lease Tract Acres	Severed Rights Acres	Total Acreage Subject to Gas Development
Forbes	58,519	17,350	4,149	21,499
Gallitzin	24,370	2,597	3,013	5,610
Clear Creek	15,966	463	12,833	13,296
Moshannon	190,032	45,016	40,157	85,173
Sproul	305,348	139,829	32,996	172,825
Lackawanna	18,159	0	0	0
Tiadaghton	105,572	50,076	1,290	51,367
Elk	199,952	7,493	44,427	51,920
Cornplanter	1,491	0	1,362	1,362
Susquehannock	260,113	61,456	86,372	147,828
Tioga	161,890	40,704	17,710	58,414
Delaware	83,103	0	512	512
Loyalsock	114,033	20,646	41,798	62,444
Total	**1,538,548**	**385,630**	**286,620**	**672,250**

Table 1.2 State forest acreage in Marcellus fairway subject to natural gas exploration and development.

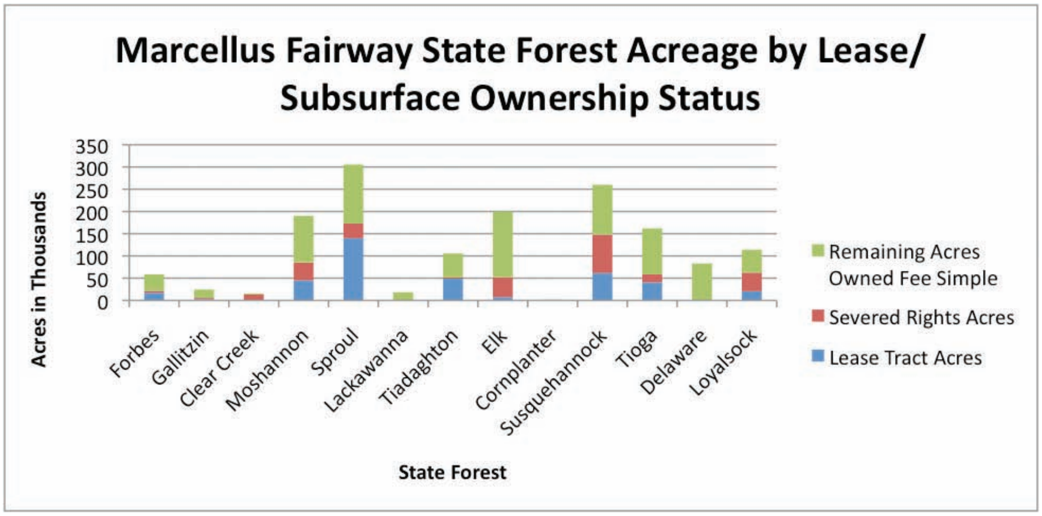


Figure 1.12

listing of well activity on state forest lands from 2008 to the end of 2013.

Leased Tract Summary

This document *http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20028689.pdf* represents an index to existing commonwealth oil and gas leases on Pennsylvania state forest lands. The document details the current lessee(s) of record for each lease contract in existence, the corresponding effective lease date, contract number, contract acreage, and defined royalty rate due the commonwealth for oil or gas production from the leased tract. Additional information regarding state forest district, county, and township pertinent to each lease can also be found on this index.

Lease Event	# of Tracts	# of Acres	High Bid Total
September 2008	18	74,023	$168,408,695
January 2010	6	31,947	$128,397,888
May 2010	11	32,896	$120,162,000
Total	35	138,866	$416,968,583

Table 1.3 State forest shale-gas leases 2008-2010.

Year	Wells Approved on State Forest Leases	Wells Approved on Severed Lands (Private Subsurface Rights)	Total Wells Approved
2008	10	11	21
2009	136	43	179
2010	244	59	303
2011	264	51	315
2012	64	12	76
2013	59	20	79
Totals	**777**	**196**	**973**
Total Number of Shale-Gas Wells Drilled on SF Lands: *568* (Wells spud by the DEP definition)			
Total Number of Shale-Gas Wells Reporting Royalty Production in December 2013: *394*			

Table 1.4 Shale-gas well locations approved by BOF (end of 2013).

Year	Well Pads Approved on State Forest Leases	Well Pads Approved on Severed Rights Lands	Total Well Pads
2008 to 2013	199	27	226

Table 1.5 Number of approved well pads on state forest, Dec. 2013.

The index also contains information related to environmental provisions included in the 2008 and 2010 leases pertaining to allowable disturbance thresholds permitted per lease and current status of each tract in relation to those defined lease thresholds.

Shale-Gas Management on State Forest Lands

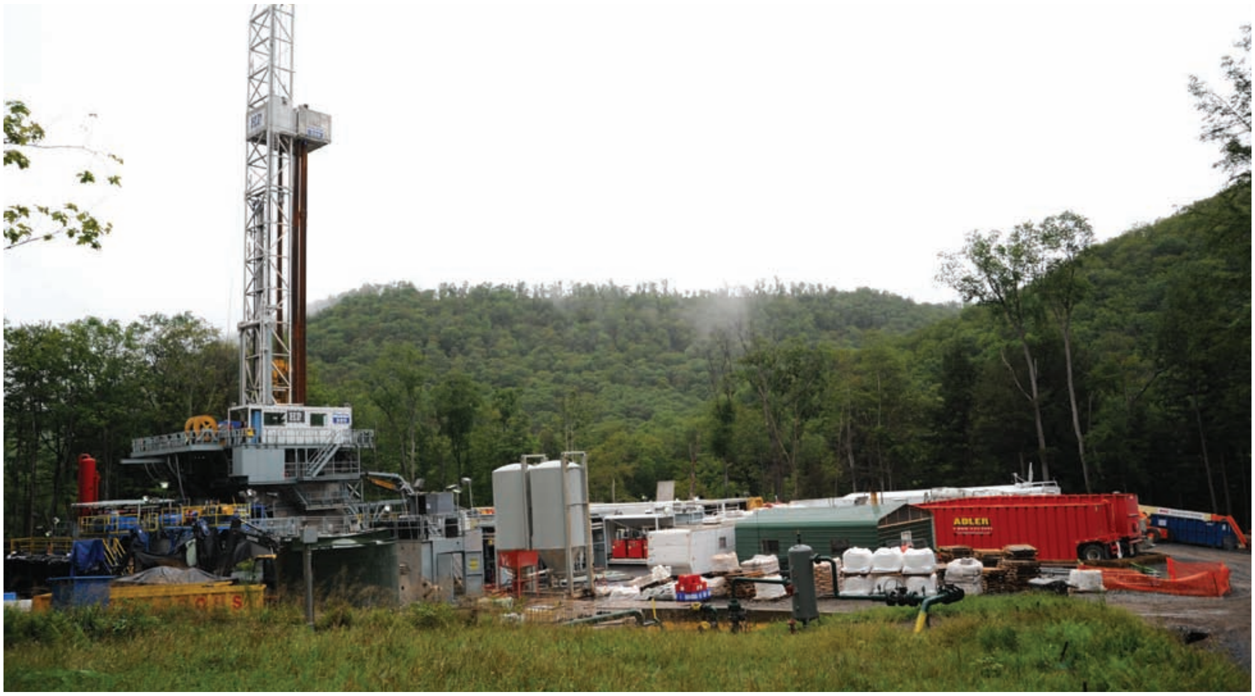
The Bureau of Forestry's mission statement recognizes natural gas as a component of state forest management. When considering shale-gas resources, the bureau approaches its management in the context of ensuring the long-term sustainability of the state forest system. Decisions are guided by many sources of information, including laws and regulations, public input, the *State Forest Resource Management Plan*, gas leases and contracts, and guidelines and procedures. Examples of legislation or regulations that influence decisions include:

- *Act 18 (Conservation and Natural Resources Act):* This act created the Department of Conservation and Natural Resources and states, "The department is hereby empowered to make and execute contracts or leases in the name of the commonwealth for the mining or removal of any valuable minerals that may be found in state forests."
- *State Forest Rules and Regulations:* Lawful rules and regulations provided under Act 18 for "land which is owned or leased by the commonwealth and which is administered by the Bureau of Forestry."
- *Act 13 (Oil and Gas Act):* Since DCNR shale-gas lease agreements occurred in 2008 and 2010, there have been substantial changes to state oil and gas law. Some of these changes include: increased notification; increased setback distances from rivers, streams, wetlands, wells, and public water supplies; increased well bonding; increased penalties; enhanced ability for the state to suspend, revoke, or deny a permit; mandatory disclosure of hydraulic fracturing chemicals; mandatory on-site inspection of erosion and sedimentation controls; mandatory notification to DEP prior to commencing critical stages of development, such as hydraulic fracturing and cementing; updating well construction and casing standards; consideration of public resources; new air quality standards; and the adoption of permit updates. These enhanced environmental standards, many signed into law by Gov. Corbett under Act 13, strengthened the protections in place for all shale-gas development, included that conducted on state forest lands.
- *Applicable Department of Environmental Protection regulations*, including but not limited to: Chapter 78 (Oil and Gas Wells), Chapter 102 (Erosion and Sedimentation Control), and Chapter 105 (Dam Safety and Waterway Management).

According to the bureau's *State Forest Resource Management Plan*, "…The extraction of mineral resources on state forest lands will be managed and utilized by exploration and development using wise and sound conservation practices for the long-term good of the citizens of the commonwealth."

When administering the activity, whether through the lease or other agreement with a private owner, several key principles guide management decisions:

- The bureau is responsible for managing and protecting natural resource values and uses on state forest lands where multiple activities occurring in close proximity may present conflicts. The bureau strives to balance those potential conflicts to ensure the long-term viability of those resources for the commonwealth.
- The safety of workers and the general public will be foremost when making management decisions.
- The lease is a binding contract, and the bureau is obligated to ensure that all lessees are following the lease provisions. Bureau staff should have a detailed understanding of the applicable leases in order to successfully manage oil and gas activities on state forest lands in accordance with the bureau's mission. Historic leases are referred to as "legacy leases."
- Bureau staff and operators should work cooperatively to establish constructive relationships to enable consistent, reasonable, and environmentally sound development of oil and gas resources.



- Planning is an important component of state forest management. The bureau and operators should work together to review and discuss work plans relating to oil and gas development, production, and transmission prior to the initiation of the activity (for leased and private ownership). Planning is a mutually beneficial tool that promotes efficiency and cost effectiveness, while minimizing adverse impacts to state forest resources, uses, and values.
- Bureau staff will use adaptive resource management to monitor oil and gas activities on state forest lands. This approach includes the documentation of impacts – both beneficial and adverse. The knowledge and experience gained from these efforts will promote continued understanding to and improvement to the guidelines, best management practices, and the bureau's ability to manage oil and gas activity.
- Whenever feasible, the placement of roads, pipelines, impoundments, compressor stations, well pads, and associated oil and gas infrastructure should utilize existing disturbances, such as road networks, right-of-way corridors, or abandoned mine lands in order to minimize forest conversion and impacts to state forest lands.

The Oil and Gas Lease

The oil and gas lease the bureau uses to manage oil and gas exploration and development on state forest lands is a product of multiple generations of experience since the first leases were issued in 1947. The lease agreement used for shale-gas operations on state forest lands is one of the most robust and comprehensive oil and gas agreements in the country. The lease itself is multifaceted and designed to protect the environment, recreation opportunities, and rare plant and wildlife habitat while considering other forest management values and activities, such as timber harvesting. At the same time, the lease allows for an economic return to the commonwealth through rental and royalty payments as the gas resource is extracted.

The modern shale-gas lease agreement is designed to minimize the surface impacts of exploration and development, especially during development, when large amounts of surface infrastructure are needed to support operations.

One method the bureau uses is to limit the number of well pads that any given lease tract may contain, thus limiting overall surface development impacts.

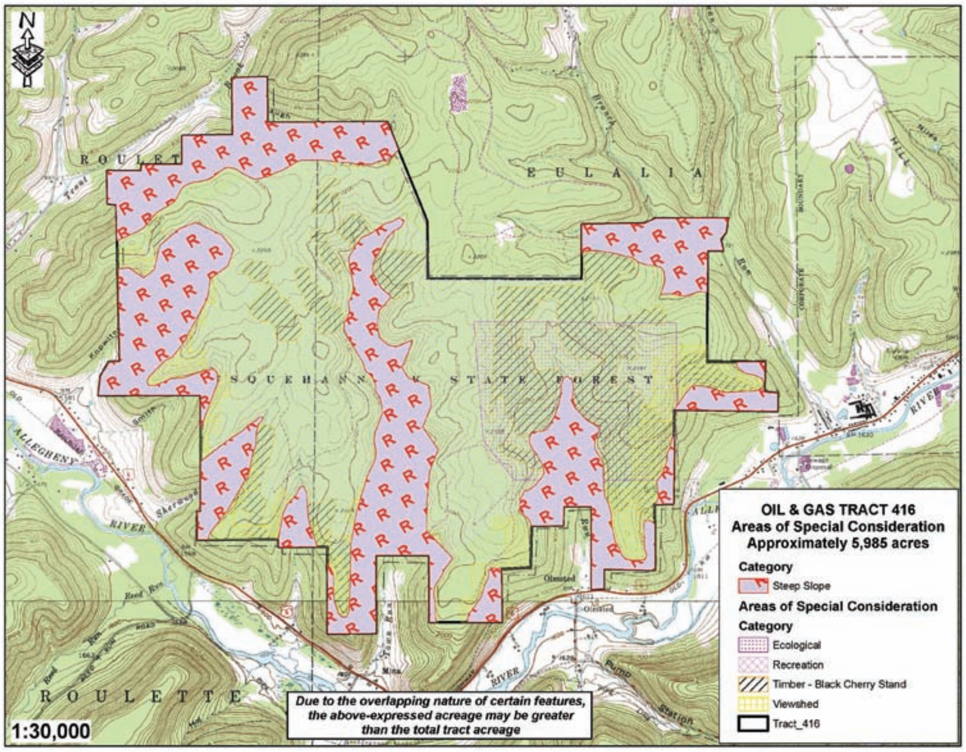


Figure 1.13 Sample lease tract map with ecological, recreational, timber management, and scenic areas of special consideration.

Technology advancements in shale-gas development are conducive to this goal as operators continue to improve how much shale gas they can drain from a single well and well pad. Expected future technological improvements are all considered to be positive in respect to reducing the amount of surface disturbance.

Another way the bureau limits impacts to state forest resources is through extensive pre-lease and development planning. Before tracts are offered for lease, the bureau identifies areas off limits to surface development, such as designated Wild and Natural Areas as well as sensitive areas that require special consideration when planning development activities. Figure 1.13 shows an example of a map provided to potential lessees.

Surface Use Agreements

On lands where the oil and gas rights have been previously severed from the surface, the deed reservation clause is used as the primary guidance for management of the lands by the bureau. In most cases, the reservations are such that the commonwealth has little to no ability to directly control gas management activities due to the rights of the subsurface owner, reserved in the deed. In these cases, the bureau strives to enter into a voluntary surface use agreement (SUA) with the severed-rights owner or lessee, which has advantages to both parties.

With an agreement in place, both parties know with certainty that operations can be scheduled and carried out with a minimal difficulty as both parties are required to agree on operations prior to their commencement. This near elimination of uncertainty is beneficial to the operator, and the ability to manage surface impacts has much value to the bureau. The SUA typically includes environmental guidance, best management practices, and surface impact mitigation provisions.

Guidelines for Administering Oil and Gas Activity on State Forest Lands

Another critical document that guides gas activity on state forest lands is *Guidelines for Administering Oil & Gas Activity on State Forest Lands*. The administration of oil and gas development is complicated by a myriad of existing ownership rights, the quantity and various vintages of existing lease agreements, the number of private operators involved, and rapid advancements in oil and gas technologies. The objective of the guidelines document is to establish and communicate a set of "guidelines" and best management practices (BMPs) that provide consistent, reasonable, and appropriate direction for managing oil and gas activity on state forest lands in accordance with the bureau's mission. Specifically, these guidelines provide information for:

- Bureau staff: to manage oil and gas activities consistently across state forest districts
- Operators: to clearly communicate the Bureau of Forestry's mission, expectations, and protocols for managing natural gas development activities in an environmentally sound manner
- Public: to provide transparency in the management of their state forest lands

Guidelines for Administering Oil & Gas Activity on State Forest Lands can be found at http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20028601.pdf.

Staffing

With the advent of shale-gas development on state forest lands, the bureau adjusted its internal structure to more effectively administer leases and address the myriad management issues associated with the activity. The bureau formed a Gas Leadership Team in its central office headquarters to coordinate the activity, provide guidance to field staff, and address issues related to shale-gas development.

The bureau also formed a Gas Management Team (GMT), which includes field and central office staff engaged in shale-gas management. The GMT is a multidisciplinary team that implements management of all aspects of the gas leasing and development program. The team consists of approximately 65 professionals who meet regularly to discuss the larger issues within the gas and land management program.

The bureau's Minerals Division administers subsurface management programs, including oil and gas management. The division has 10 staff members, including geologists, an accountant, administrative personnel, and one water monitoring specialist. The division administers subsurface minerals leases, manages gas development on state forest lands, serves as geologic consultants for other commonwealth agencies, and coordinates and/or conducts geologic research on state forest lands. Other central office program staff involved with shale-gas management include right-of-way specialists, wildlife biologists, botanists, recreation specialists, communications specialists, silviculture specialists, and program managers and directors.

Field staff in the bureau's state forest districts are responsible for on-the-ground implementation of shale-gas development programs and directly coordinate with natural gas operators during all phases of development. Personnel involved include dedicated gas foresters and district managers to oversee the program.

The bureau tracks staff time dedicated to different programs. In 2012, approximately 56,500 hours were dedicated to gas-related activities.

III. Monitoring Efforts/Results

Shale-gas development raises concerns about a wide range of environmental and social values of the state forest system, including water quality and quantity, plant and animal habitats, core forest areas, recreation and aesthetics, forest soils, and air quality.

Shale-gas development requires the clearing of forests to construct well pads, roads, pipelines, and other infrastructure. This conversion directly affects forestland by increasing habitat fragmentation and reducing the overall amount of forest cover. Construction activities could impact plants and animals and their habitat, such as wetlands, forest-interior bird species, and species of concern, including timber rattlesnakes, bats, Allegheny woodrats, and an array of native plant species.

In addition to environmental concerns, shale-gas development could alter the character of north-central Pennsylvania, an area known as the "Pennsylvania Wilds," that abounds with scenic beauty and outdoor recreational opportunities. Understanding impacts to state forest visitors is critical to sustaining tourism and the ability to provide healthful outdoor recreation opportunities to Pennsylvanians.

Monitoring also helps the Bureau of Forestry understand the positive effects of shale-gas development on state forest lands. Road improvements and construction associated with the development has promoted increased access to state forest land for recreation activities and administrative purposes. The increase in forest edge around well pads and pipeline corridors may provide additional habitat for edge-frequenting wildlife species. Seeded pipeline corridors have the potential to increase sightings of popular wildlife species such as turkeys and white-tailed deer. Restoring cleared and disturbed forestlands may also bring additional opportunities to enhance habitat diversity in large blocks of mature forest.

Shale-gas development on state forest lands has also played a significant role by increasing domestic energy supplies and revitalizing the economies of many local communities. Revenue generated from state forest leasing has provided a significant funding source for DCNR and other conservation efforts and state forest and park improvements. Additionally, each well on state forest land is assessed an "impact fee," which is allocated by state law and helps fund, among other initiatives, Growing Greener and the environmental and conservation programs funded under the Marcellus Legacy Fund.

The Bureau's Shale-Gas Monitoring Program

Given the host of potential impacts of shale-gas development to the state forest system and its associated uses and values, the bureau has established a Shale-Gas Monitoring Program to track, detect, and report on the impacts of the activity. The program aims to provide objective and credible information to the public and inform and improve shale-gas management efforts.

The bureau's Shale-Gas Monitoring Program was initiated in late 2010, when the Bureau of Forestry was authorized to hire a dedicated monitoring team of 15 staff members. The program began full implementation in 2011, when the bureau completed staff hiring, met with advisory committees, and began developing monitoring protocols and building a variety of internal monitoring tools, such as tracking and mapping databases. At this time, the bureau also initiated a variety of shale-gas-specific research projects to better understand the specific potential impacts to state forest land. Data collection and field implementation began in earnest in 2012, with a fully staffed program and established protocols and procedures. In early 2013, the bureau began compiling its monitoring data and initiated the writing of this report.

Monitoring Defined

Monitoring is defined as "…the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective" (Elzinga et al. 1998). A well-designed monitoring program can demonstrate that current management objectives and strategies are working and provide supporting evidence for their continuation. A monitoring program can also identify when current management objectives and strategies are not working by detecting changes. These changes, either desirable or undesirable, are critical for providing the evidence supporting updates, changes, or continuation of on-the-ground management practices.

It is important to note that monitoring data are sometimes of limited value in conclusively identifying the exact cause of detected changes. Identifying the exact cause of change falls into the realm of "research," where great effort is made in isolating and testing the responses from potential change agents in a controlled environment through a rigorous experimental design. However, monitoring data and information plays an important role in identifying trends, guiding research, and evaluating management guidelines and practices. (The Bureau of Forestry does fund research projects as part of its overall monitoring program. See Part 4 for additional information.)

Depending on the monitoring value and indicator, the amount of time and data necessary to register change or trends varies significantly. Measuring acres of cleared forest, fragmentation, visitor attitudes, and certain water quality parameters can be accomplished in a short time frame. However, other data related to changes in plant communities, wildlife habitat, aquatic communities, tree mortality, soil impacts, and forest health – to name a few – may take longer for change to be noted or for any clear trends to emerge, which is why monitoring must be approached from a long-term perspective.

The Bureau's Monitoring Approach

To help guide its monitoring program, the bureau devised a suite of "monitoring values." These values, developed with input from its advisory committees, help focus monitoring efforts on values that relate to the sustainability of the state forest system, the impacts of natural gas drilling on state forest to stakeholders and communities, and the Bureau of Forestry's mission. The bureau organizes and reports on its monitoring efforts by these values, which include:

- Water
- Wildlife
- Plants
- Invasive species
- Incidents
- Air
- Land-use (forest landscapes)
- Soils
- Revenue
- Energy
- Recreation
- Local communities (community engagement)
- Forest health
- Timber products
- Infrastructure

These monitoring values may change over time as more is learned about the activity and its impacts on state forest lands.

To systematically monitor these values, the bureau takes a three-tiered approach, recognizing that an effective, long-term monitoring program must be multifaceted. These tiers include: 1) an integrated and dedicated Shale-Gas Monitoring Team; 2) related forest resource monitoring and on-the-ground management activities; and 3) research and external partner collaboration. These tiers form the foundation for the bureau's shale-gas monitoring effort.

An Integrated and Dedicated Monitoring Team

The core of the bureau's monitoring effort includes a dedicated and integrated Shale-Gas Monitoring Team. This team consists of 15 staff positions embedded in various program areas of the the bureau. Staff are located in the bureau's headquarters in Harrisburg, Penn Nursery in Spring Mills, and the Tiadaghton Forest Resource Management Center in Waterville. The dedicated monitoring team positions and their program areas are outlined below.

- Forest assistant manager – Resource Inventory and Monitoring Section
- Forester (three positions) – Resource Inventory and Monitoring Section
- Forest technician (three positions) – Resource Inventory and Monitoring Section
- Biometrician – Resource Inventory and Monitoring Section
- Plant specialist – Resource Inventory and Monitoring Section

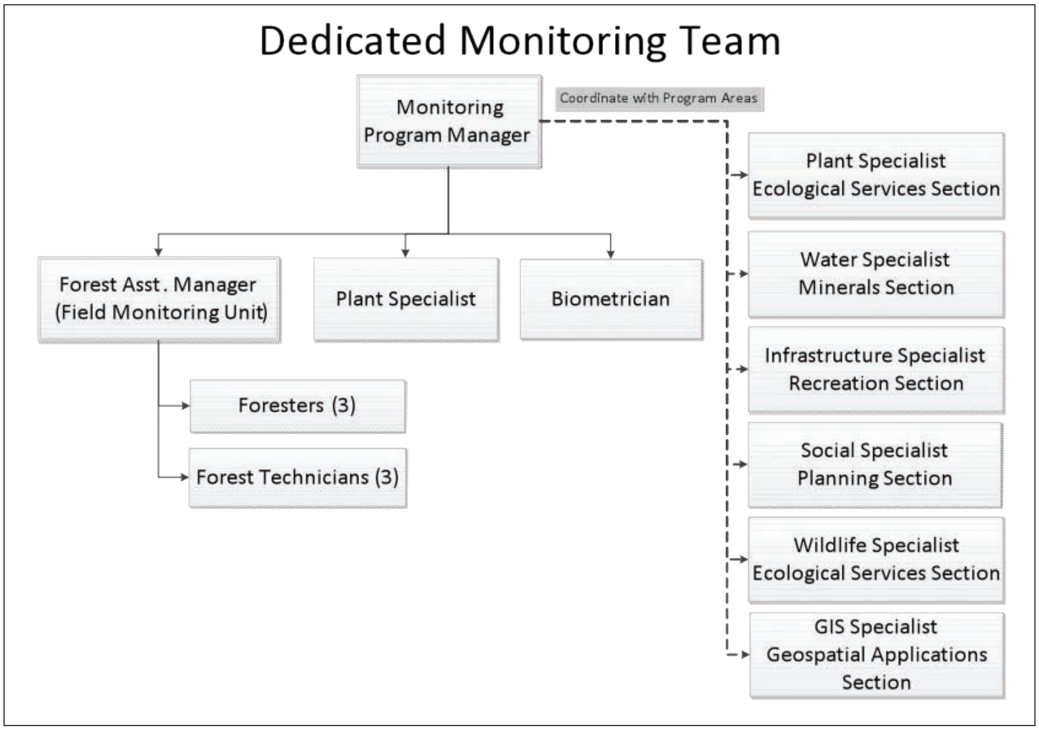


Figure 1.14 Dedicated and integrated Shale-Gas Monitoring Team.

- Plant specialist – Ecological Services Section
- Wildlife specialist – Ecological Services Section
- Water specialist – Minerals Division
- Infrastructure specialist – Recreation Section
- Social specialist – Resource Planning Section
- GIS specialist – Geospatial Applications Section

Supervision and coordination of the dedicated monitoring team falls under the responsibility of the forest program manager for the Forest Resource Inventory and Monitoring Section. The organizational structure is shown in Figure 1.14.

The Shale-Gas Monitoring Team has compiled and/or developed numerous monitoring protocols to address specific monitoring values. These protocols are in various stages (proposed, pilot, implementation, and discontinued) and subject to continuous review and refinement. In total, there exist three protocols for soils, five for water, six for local communities, five for infrastructure, one for invasive species, seven for plants, and one for animals. A summary of these protocols is found in Table 1.6.

Related Forest Resource Monitoring and On-the-Ground Management Activities

Monitoring data used in this report is not limited to targeted protocols developed specifically for shale-gas monitoring. The bureau and its partners regularly collect data and information on forest resources – such as forest health data and forest community inventories – that are valuable in discerning trends and analyzing potential impacts. Where appropriate, these data sources are used to support monitoring the values outlined in this report.

When it comes to on-the-ground management activities, the bureau incorporates regular monitoring as part of its oil and gas management program administration. These mechanisms include planning, on-the-ground management, and tracking and reporting of activities and accomplishments.

Monitoring Value	Protocol Name	Status
Water	Widespread Field Water Chemistry Sampling (hand-held meters)	Implemented
	Pebble Counts	Implemented
	Pipeline ROW Stream Crossing	Pilot
	Water Quality Monitoring Stations (sondes & grab samples)	Implemented
	Water Quality Monitoring Stations (HOBOs & grab samples)	Implemented
Soils	Well Pad Soils	Proposed
	Wetland Buffer Soils	Proposed
	Roadside Soils	Proposed
Local Communities	Focus Groups	Pilot
	Gas Tour Surveys	Implemented
	DCNR Comment Cards	Implemented
	Noise	Implemented
	Viewshed Analysis	Implemented
	ROS Analysis	Implemented
Infrastructure	Road Assessment	Implemented
	Chemical Dust Control	Implemented
	Bridges	Implemented
	Trails	Implemented
	Post Construction Stormwater Management	Implemented
Invasive Species	Early Detection – Rapid Response (EDRR)	Implemented
Plants	Well Pad Vegetation	Implemented
	Roadside Vegetation	Implemented
	Species of Special Concern	Pilot
	Wetland Buffer Vegetation	Pilot
	Seismic	Proposed
	Reclamation	Proposed
	Vegetation & Overstory Inventory	Implemented
Animals	Drift Fence Arrays	Discontinued

Table 1.6 Shale-gas monitoring protocols.
Details regarding each protocol can be found in the respective sections of this report and the Bureau of Forestry's website.

DCNR has dedicated nine forester positions to administering shale-gas programs in the core-gas state forest districts (Figure 1.15). Core-gas state forest districts are state forest districts that fall in the shale-gas fairway and are involved with the majority of the leasing and development for shale-gas that is occurring on state forest land.

These districts currently include the Moshannon, Sproul, Tiadaghton, Elk, Susquehannock, Tioga, and Loyalsock state forests. These "gas foresters" are responsible for:

- Maintaining district mineral records and reviewing mineral exploration permits

- Monitoring compliance with various specific terms of the lease
- Reviewing lease development plans and providing recommendations
- Administering and monitoring infrastructure construction
- Administering right-of-way agreements and monitoring the implementation of and compliance with specific terms of the agreement
- Administering road use agreements and monitoring the implementation of and compliance with specific terms of the agreement
- Monitoring and mitigating impacts to other forest uses by negotiating restricted gas traffic during peak recreational use periods, e.g. hunting seasons, joint-use snowmobile trails, etc.

The major components of the bureau's approach to on-the-ground management include:

Proactive planning to avoid sensitive resource areas. This planning occurs at various points in time and ranges from the State Forest Environmental Reviews (SFER) that occur prior to lease sales to the review and approval process for locating specific infrastructure. Proposed locations for well pads, rights-of-way, access roads, compressor stations, and water impoundments are thoroughly reviewed by district personnel in the field as well as by central office program area specialists prior to approval and construction. In certain situations, additional field surveys are conducted by bureau experts or environmental consultants. Overall, this effort represents a significant and critical process as potential negative impacts are avoided or minimized as a result. Significant measures are taken to protect, minimize, avoid, or mitigate impacts to water quality, wetlands, vernal ponds, spring seeps, sensitive habitats, federally or state-listed plant and wildlife species, trails, recreation features, and other special resources. Appropriate monitoring of the resources follows to ensure long-term protection.

Field management and inspections. Once approval is granted and construction begins, on-the-ground management and inspections are critical for protecting special natural resources and state forest uses and values. Weekly inspections occur for most construction activities. Field inspections include items for safety and recreation, permitting, and environmental resources.

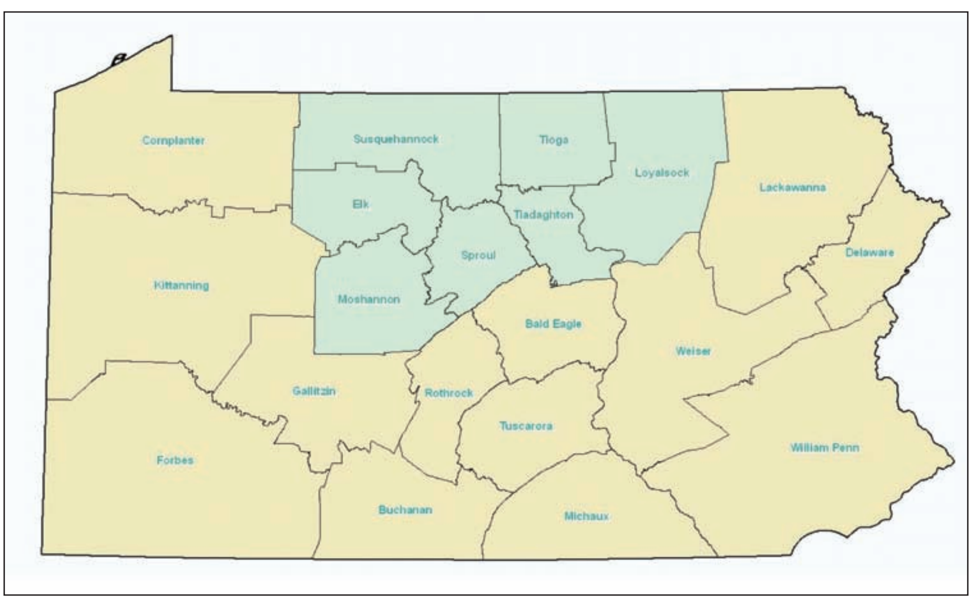


Figure 1.15 Core gas state forest districts.

Incidents. The bureau tracks environmental and public incidents that occur on its lands, including areas with shale-gas development. When appropriate, bureau staff report incidents to DEP.

Waivers. Operators may submit waiver requests for certain conditions specified in the lease, including buffers, non-development areas, viewshed areas, spacing, offsets, and drilling requirements. Any deviation from conditions specified in any of the leases or agreements requires a waiver. Proper justification and review ensures that potential impacts to environmental and social values (non-development areas, aesthetics, wetland buffers, etc.) are avoided or minimized. Requests must be justified and submitted in writing to the state forester for review and approval. The bureau's intent is to review the waiver requests on a case-by-case basis and to consider granting waivers where the waiver provides greater protection for environmental or social values and is in the best interest of the commonwealth. The waiver process aids in the further refinement of future lease terms and management practices.

Research and External Partner Collaboration

When appropriate and as resources become available, the bureau seeks to fund and cooperate with research entities in a coordinated fashion to address specific bureau needs related to shale-gas development. The intent is to leverage opportunities and resources for work that the bureau would not be able to accomplish otherwise, or work that is best suited for a research effort. In addition to working directly with researchers on state forest land, the bureau stays abreast of projects occurring on other ownerships in the shale-gas region. The bureau is currently working with several partners or pursuing projects relating to water quality, habitat fragmentation, rattlesnake impacts, and visitor use and recreation impacts. See the chapter specifically devoted to this topic for more information.

Core Monitoring Areas

While the shale-gas region in Pennsylvania covers almost two-thirds of the state and many state forest districts, the bureau currently focuses its monitoring efforts in what it refers to as "core gas districts." While conventional gas activity has occurred outside these defined districts, and shale-gas activity may occur outside the region in the future, this region – consisting of Susquehannock, Elk, Moshannon, Sproul, Tioga, Tiadaghton, and Loyalsock state forest districts – currently is home to the most concentrated shale-gas activity. Monitoring efforts, data collection, and reporting are all focused on this seven-district region. The composition of this core area may change over time if there are changes in the patterns of gas exploration and development.

Shale-Gas Monitoring Reports

An essential function of the Shale-Gas Monitoring Program is to regularly compile and analyze its data and findings. As mentioned previously, this reporting serves two functions: It assists the bureau in evaluating impacts and adjusting, if necessary, its management planning and practices. And it communicates to the public the impact of the activity on commonwealth-owned state forest lands. This first report is also an opportunity to communicate basic information about the bureau's monitoring program and its plans for future monitoring efforts. Periodically, the bureau will issue additional reports as more data and information are collected.

The data included in this report are derived from a variety of sources. Most of the data and information presented go through Dec. 31, 2012. When possible, the most up-to-date information was incorporated into each section's monitoring analysis.

Part 2: Monitoring Values
»Infrastructure

I. Key Points:

- Approximately 1,486 acres of forest have been converted to facilitate gas development in the core gas districts, including roads, infrastructure, well pads, and pipelines.
- 161 total miles of road have been improved or constructed for shale-gas development in the core gas districts. Of these, 131 miles of state forest roads that existed prior to the shale-gas development have been improved or upgraded for gas development activities, and 30 miles of new roads have been constructed for gas development activities. This road work involved the conversion of approximately 242 acres of forest.
- 191 infrastructure pads have been constructed to facilitate shale-gas development in the core gas districts. This involved the conversion of approximately 786 acres of forest.
- 104 miles of pipeline corridor have been constructed or widened in the core gas districts. This involved the conversion of approximately 459 acres of forest.
- Six new bridges and six large culvert stream crossings have been either replaced or installed by gas companies in the core gas districts.
- 83 percent of all dust control activities on state forest lands related to shale-gas development have used non-potable water rather than chemical dust suppressants.
- Extensive amounts of heavy truck traffic have been reduced on state forest roads through the use of water transport systems.
- Waivers are typically granted to reduce overall impact to the forest. The most common lease-term waivers are related to buffers on wetlands and roads.

II. Introduction

State forest lands located within the shale-gas region are experiencing significant activity associated with the development of the shale-gas resource. Natural gas exploration and development can cause short-term or long-term conversion of existing natural habitats to gas infrastructure. The footprint of shale-gas infrastructure is a necessary part of shale-gas development; however, the bureau attempts to manage this infrastructure to reduce surface disturbance and minimize impacts to other state forest uses and values.

In addition, the existing transportation infrastructure on state forest lands, such as roads and bridges, is experiencing a considerable increase in use due to shale-gas development. The bureau strives to design and maintain its infrastructure to efficiently serve its intended purpose and ensure the safety of its staff and state forest users, while providing opportunities for quality outdoor experiences.

This chapter focuses on the infrastructure required for shale-gas development as well as the effect of shale-gas development on existing state forest roads. State forest infrastructure that is generally associated with recreation, such as hiking and ATV trails, is covered in greater detail in the Recreation section of this report.

Roads

The right of ingress and egress to private subsurface estates is provided for by law. This may include the right to construct new roads as necessary. Similarly, lessees are permitted to construct new roads to develop their leased lands. The bureau works with private subsurface owners and lessees to use existing roads whenever feasible, reducing the need for additional clearing and new road construction. The use of state forest roads by private subsurface operators is mandated by a road use agreement. A road use agreement is required for lessees using state forest roads outside of their lease boundaries. Road use agreements set limitations on road use and establish conditions for road improvements and maintenance. Some state forest districts have also successfully used road use agreements to coordinate the construction of recreational infrastructure, such as alternative snowmobile trails, where the operators have affected traditional recreational use of state forest roads and trails.

Most state forest roads are improved dirt roads surfaced with shale, gravel, or limestone and designed to accommodate travel by licensed motor vehicles at maximum speeds of 25 miles per hour. Historically, the majority of traffic on state forest roads has been attributed to the following:

- Recreational users of state forests in passenger vehicles
- Bureau personnel in light duty and occasional heavy duty vehicles for administration of state forest lands
- Bureau maintenance staff and equipment to maintain and rehabilitate roads
- Commercial timber operators utilizing tri-axle log trucks or tractor-trailers to haul timber purchased from the bureau to lumber mills (averaging two to four trips per day)

These types of traffic are considered the traditional uses of state forest roads, and the roads were constructed and are maintained to accommodate such uses.

On average over the past few years, the bureau has annually administered the construction of approximately 12 miles of new road and 100 miles of road improvements as part of its statewide timber management program. These timber haul roads are built to the specifications in the Silviculture Manual. This new construction is typically considered temporary in that the majority of these roads are retired at the conclusion of the timber sale operation. Roads that are improved as part of a timber sale include both public use roads and previously retired haul roads that are reopened. Improvements to these types of roads as part of a timber sale are implemented to bring the road condition up to the minimum standard necessary to accommodate the sale.

The minimum road standards required to facilitate shale-gas development on state forest land exceed the minimum requirements necessary to accommodate the traditional uses of state forest roads. Shale-gas development requires extensive truck traffic (hundreds of trips per day during periods of peak activity) by vehicles larger than those typically using state forest roads. As a result, existing roads that are utilized by the shale-gas industry must be upgraded to meet different standards. Commonly, the road's base material must be increased to accommodate frequent trips of heavier equipment, and road widths must be increased to accommodate wider trucks and two-lane travel. Similar road characteristics are necessary when new roads are constructed for this activity.

Although temporary in nature, the volume and frequency of shale-gas truck traffic is in stark contrast to the public's expectations and typical experiences on state forest lands. Heavy truck traffic increases social and environmental concerns related to noise, dust, access limitations, public safety, and user experience, as well as operational concerns associated with road conditions, maintenance, and rehabilitation. One primary attribute of the state forest roads being affected by shale-gas development is the "wild character" of the road. State forest roads, in general, have a traditionally rustic and aesthetically pleasing value and wild character. Scenic or pleasure driving is the largest motorized recreational use of state forest lands. Even when other recreational activities are the primary reason for forest visits, most of the visiting public appreciates and values what they see on their way to their ultimate destination. It is important that the wild character of state forest roads be preserved to the greatest extent possible during and following use by gas companies.

The bureau has adapted to this non-traditional forest road use by shale-gas operators by developing updated standards applying to road construction and road improvements for shale-gas development. Implementation of these new standards is required before use of state forest roads commences. This ensures that any road suitability issues are addressed prior to handling the increased truck traffic.

In addition, heavy-hauling restriction guidance has been given to gas operators to avoid conflict with traditional forest users. On days with heavy-hauling restrictions, operators are asked not to operate heavy-hauling trucks (e.g., water trucks, drill rigs) on state forest roads. The heavy-hauling restriction dates are adapted from year to year, but the general timeframes are found in Figure 2.1.

State Forest Heavy Hauling Restrictions

Holidays
- Memorial Day weekend
- Fourth of July holiday and weekend (if applicable)
- Labor Day weekend

Hunting and Fishing Seasons
- Opening weekend of trout season
- Opening weekend of youth spring gobbler season
- Opening weekend of regular spring gobbler season
- Regular bear season
- Portion of regular firearms deer season, including opening day

Heavy hauling and seismic activity may be restricted during the following dates at the discretion of the district forester:

- Seismic activity may be restricted during the morning hours of spring turkey season.
- Special activities or events on state forest or adjacent state park lands as identified by district. Restricted roads and hours of operation will be determined by the district.
- Opening day of deer archery season
- Opening day of youth/special use hunting
- Opening day of early muzzleloader season

Operators should be advised that the list of restricted dates has been minimized to the greatest extent possible and that potential visitor use conflict may be encountered beyond the specified dates.

The bureau will permit minor truck traffic between the hours of 10 p.m. and 4 a.m. for daily or essential needs only (e.g., cutting removal, drinking water delivery, sanitation, cement).

Figure 2.1

There are distinct benefits associated with the use of state forest infrastructure by shale-gas operators for their development operations. With regard to cost, it is of benefit to the bureau that the roads needed for gas operations are improved or constructed at the cost of the gas companies. Forest managers ensure that that these roads meet or will meet the standards needed by the bureau and forest users while also being suitable for the gas industry. In most cases, roads used by gas companies will not need large scale maintenance investments by the bureau for many years. This allows the bureau's limited road maintenance budget to be utilized on other roads.

Not only are roads improved, but also bridges and large culverts. These stream crossing improvements have also been completed by gas companies at no cost to the bureau. In some cases, crossings have been installed in areas where it may have been cost prohibitive for the bureau to otherwise provide access for traditional forest activities such as timber management and recreation. In such cases, construction by the gas companies has opened new areas for access by other forest users.

Another distinct benefit of working with the gas companies on infrastructure construction has been an increased knowledge of new technologies for infrastructure construction and maintenance. This new knowledge has and will continue to benefit the bureau through cost savings and durability improvements related to construction and maintenance techniques.

Well Pads

A well pad is the area where shale-gas well drilling and hydraulic fracturing occurs. A typical shale-gas well pad is approximately 3.5 to 7 acres. On state forest land, the number of wells per pad ranges from one to 10, with approximately four to eight wells being the average. A typical well drains approximately 100 acres, but that figure can vary depending on a number of factors. Well pads are typically constructed of crushed limestone or other rock, compacted to form a stable operating surface. Modern drilling rigs weigh several thousand tons and require construction of a solid pad that can adequately support their weight and maneuverability needs.

Compressor Pads and Compression Systems

Compressor stations are commonly used in association with gas production and pipelines. Gas well pressures and volumes steadily decline over the life of production. Similarly, gas moving through steel pipelines creates friction, causing pressure loss. Compressor stations use turbines, motors, or engines powered by electricity, diesel fuel, or natural gas to increase the pressure of the gas within the pipelines to overcome friction and move the gas from one location to another. During production, compressors draw gas from the well bore as production volumes decrease and discharge it at higher pressure through the gathering pipeline. Secondary compression may be necessary, depending on the length of the gathering line, to increase pressure as the gas enters larger marketing or transmission lines.

The footprint of a compressor station is variable. Compressors are specifically engineered for a given compression need. Compressors are generally housed within a structure and under roof. These sites may also include gas-related infrastructure such as separators, which capture undesirable particles or liquids, that may condense out of the gas stream as it flows through the pipeline. Chemicals necessary to aid production during cold temperatures can also be stored at a compression site.

There are currently two strategies for providing the compression necessary for successful gas production:

- Distributed – The compressors are co-located on the established well pad and service all the producing wells within that pad. Distributed compressors are smaller, produce less horsepower, and are more numerous than those associated with centralized compression. The configuration is dynamic, and compression is moved and adjusted as necessary.
- Centralized – The compression is strategically located within the development field to service gas produced from multiple well pads and dozens of individual wells. Centralized compression often requires several large units that produce considerable horsepower. These facilities typically require the development of an additional pad site to accommodate the necessary infrastructure.

A negative aspect of gas compression is the noise created by the engines. Noise from compressors can dramatically affect a state forest user's recreational experience and generate conflict. The undeveloped wild character of state forests offers peace, solitude, and a feeling of remoteness for many users. Unlike compressors, most sources of potential noise on state forest land are temporary in nature. Thus, the continuous noise from compressor stations makes them predominantly incompatible with other state forest resources, uses, and values. As such, alternatives that avoid siting compressors on state forest lands are pursued where possible; however, a certain amount of compression will be necessary on state forest lands for efficient gas transportation and production. The bureau's objective is to maintain and perpetuate a visitor's anticipated recreational experience on state forest lands. Additional information regarding compressor noise and monitoring of compressor noise is presented in the Recreation section of this report.

Fresh Water Storage and Water Conveyance Systems

The water-intensive nature of shale-gas development requires extensive advance planning. DEP and corresponding interstate river basin commissions have jurisdictional responsibility for surface water resources and associated withdrawal requests. However, when the surface or groundwater withdrawal point is located within state forest lands and the commonwealth owns the surface and subsurface rights, the terms for

When reviewing requests for water acquisition, the bureau takes into consideration potential impacts to watersheds, headwater streams, wetlands, and adjacent ecological resources.

Whenever feasible, freshwater is moved from centralized storage facilities to the active location(s) via pipeline, significantly reducing heavy hauling, minimizing vehicular conflicts, and decreasing air and dust pollution. These pipelines may be above-ground or buried water pipeline networks, or a combination of both. When feasible, buried pipelines are installed to minimize additional earth disturbances by being co-located with existing gas pipelines, buried in the ditchline or vegetated berm, or trenched and buried beneath the running surface of the road.

There are several options for water storage, depending on the specific needs of the project:

- Earthen impoundments – non-portable, open pits that may involve significant construction operations; typically five to 14 acres in size and can serve many well pads, thereby reducing the overall disturbance. Constructed dam breasts over 15 feet high must be permitted. These water impoundments are tracked as a type of pad by the bureau.
- PortaDams – semi-portable, above-ground impoundments consisting of heavy-duty liners on a steel framework; perimeter can be lined with hydraulic fracturing tanks for additional storage capacity; typically three to five acres in size and can serve multiple well pads.
- Above-ground storage tanks – semi-portable, bolted together, cylindrical tanks that are often set on concrete.

accessing the water withdrawal site are set forth in the lease agreement. On the other hand, when the surface or groundwater withdrawal point is located within state forest lands and the commonwealth owns the surface rights and a private party owns the subsurface rights, the terms for accessing the water withdrawal site are customarily contained in a surface use agreement.

The development of a single shale-gas well requires an average of 5 million gallons of water for the completion process (i.e., hydraulic fracturing). This quantity of water must be readily available and in close proximity to the well site throughout this process. Centralized fresh water storage facilities and temporary pipelines for transporting water are preferred over the traditional method of housing multiple storage tanks on the well pad and filling them via truck. Centralized freshwater facilities reduce truck traffic and in some cases can decrease total acreage disturbed because an impoundment is not needed at each pad.

Typically, water needed for shale-gas development can be acquired through:

- Surface water withdrawals
- A third-party supplier who trucks the water on site
- Groundwater well withdrawals.

Other Types of Infrastructure and Pads

Other types of infrastructure are occasionally required to facilitate shale-gas development. These include storage pads, meter stations, valve stations, tap stations, and stone pits.

- Storage pads – facilities that provide for the temporary storage of equipment and stockpiling of materials used in the development of shale-gas infrastructure. Not to be confused with gas storage fields.
- Meter stations – facilities that measure the amount of natural gas being supplied by a given source to a gas transmission pipeline (receipt meter station) or the amount of natural gas being withdrawn from a gas transmission pipeline by a customer (sales meter station).
- Valve stations – facilities used to isolate a segment of the main pipeline on a gas transmission pipeline. These stations are typically located at distances of 15 to 50 miles along each line to limit the amount of pipeline that may need to be depressurized for tie-ins and maintenance. These facilities also aid in reducing the amount of gas that would be lost in the event of a pipeline break.
- Tap stations – facilities that direct gas from a gathering system to a transmission pipeline to other locations. These facilities typically have only pressure regulating equipment.
- Stone pits – facilities where stone is extracted to support shale-gas development activities.

For reporting, these types of infrastructure have been grouped together and referred to as "other" infrastructure pads.

Pipelines

The development of oil and gas resources requires pipelines for delivering the product to market. Moving produced gas from the well to the marketplace requires significant planning, engineering, and infrastructure development. Gathering pipelines move natural gas from multiple well pads to centralized marketing pipelines. Marketing pipelines flow to transmission pipelines, which transport large volumes of gas over long distances to distribution centers or storage facilities.

Existing pipeline infrastructure and capacity may be inadequate for current and anticipated gas production needs. When compared to other aspects of gas development, pipeline construction has the greatest potential to cause forest conversion and fragmentation due to the length and quantity of pipelines required. Therefore, careful pipeline planning occurs early in the development process to address production needs while minimizing impacts and implementing ecosystem management. Midstream pipelines accommodate multiple operators, thereby reducing additional right-of-way needs, costs, and unnecessary impacts and improving efficiency.

Lessees or subsurface owners have the right to construct pipelines to transport oil and gas produced on state forest land. To construct a pipeline on state forest lands, lessees must obtain a license for right-of-way. The bureau has developed a formal process to administer such requests. The bureau works with all operators to coordinate the location and establish the conditions for pipeline construction.

Infrastructure Approvals and Waivers

The bureau conducts an extensive review of all gas activities and infrastructure proposed by operators. To facilitate these reviews, the bureau is typically provided with the operator's unconstrained conceptual site plan as early in the development process as possible. The bureau then evaluates the plan for known areas of concern or potential conflicts and coordinates with the operator to develop an infrastructure layout that minimizes impacts to state forest land while facilitating efficient extraction of gas.

Bureau staff confirm that all approvals, permits, and review requirements have been satisfied for the proposed activity and provide final approval. Final approval letters are issued to lessees for all proposed infrastructure. Commencement of construction and installation of proposed infrastructure is authorized upon receipt of final approval from the bureau.

The recent *DCNR Oil and Gas Leases* and also the *Guidelines for Administering Oil and Gas Activity on State Forest Land* contain a number of provisions intended to prevent gas development operations from interfering with other state forest uses and values. For example, the recent vintage of leases prohibits well drilling and site clearing within the following distances from certain features:

- 200 feet from any building
- 200 feet from any stream or body of water
- 300 feet from any stream or body of water designated as exceptional value by DEP
- 300 feet from any trail or road
- 300 feet from the boundary line of leased premises
- 600 feet from the boundary line of a state park or a state forest Wild or Natural Area.

These restrictions are in place to minimize the impact of development when it occurs near valued resources. For instance, the buffer for streams helps prevent erosion and sedimentation impacts, and the buffer for trails and roads helps preserve the wild character of these travel corridors.

Any deviation from conditions specified in leases or agreements with the bureau requires an approved waiver.

The bureau grants waivers when the proposed deviation from lease terms is the most effective way to resolve conflicts between competing resource uses and values, minimizes overall impact to the forest, and is in the best interest of the commonwealth. The waiver process is a mechanism to resolve complex, on-the-ground resource management challenges and to monitor the effectiveness of management practices and guidelines. Each waiver request is reviewed on a case-by-case basis.

To request a waiver, the operator submits the following to the bureau:

- Identification of the specific lease term for which a waiver is sought
- Description of the proposed deviation
- Justification of the need to deviate from the identified lease term
- Identification of alternatives considered and investigated
- Any necessary mapping, including GIS data where applicable

The waiver request is reviewed by bureau staff to determine if it is sufficiently documented, justified, and consistent with local management objectives. Modifications to the project or additional alternatives may be suggested to the operator during this review process. Often a compromise can be reached that balances the objectives of the operator and the protection of high-value resources.

The state forester reviews the waiver request and provides an approval or denial. If it is determined that the requested waiver does not minimize overall impact to state forest resources, uses, or values and is not in the best interest of the commonwealth, the waiver request will be denied. Waiver approvals may be subject to additional conditions that require the operator to provide reasonable protection or mitigation measures.

Through 2012, the bureau approved 35 waivers of lease terms for well drilling and site clearing. The breakdown of waivers by type is shown in Table 2.1. The most commonly waived lease term was the buffer on wetlands. At times, the development plans for gas extraction necessitate impacts in the vicinity of wetlands. In such cases, the goal is to minimize impacts to the wetlands themselves and allow impacts in the wetland buffers only when absolutely necessary.

The justification for waiving wetland buffers was typically that doing so minimized impacts on the wetlands themselves. In several instances, wetlands occurred in previously disturbed areas (e.g., clear cut, strip mine), and these disturbed/low-quality wetlands were preferentially developed instead of impacting undisturbed forest. See the Flora chapter for more information about wetland buffer waivers.

Type of Waiver	Number of Waivers
Wetland Buffer	15
Road Buffer	9
Lease Boundary Buffer	5
Trail Buffer	2
Natural Area Buffer	1
Stream Buffer	0
Other	3

Table 2.1

The second most common waiver of lease terms was for buffers of existing roads. The justification for road waivers was typically that the waiver eliminated the need to construct a new access road, thereby reducing forest fragmentation.

Justification for other types of waivers of lease terms followed these same themes. Waivers were often granted to take advantage of existing disturbance. The decision to grant a waiver typically balanced one type of impact against another, such as allowing a lease boundary buffer to be encroached upon to maximize the distance from a water supply watershed. For pad placement, waivers were sometimes granted to minimize the number of pads necessary to drain the gas from a leased tract. Pad location was preferentially given to flat areas in order to limit the amount of cut and fill necessary and to reduce erosion risks.

Overall, the waiver of lease terms approval process is viewed as successful adaptation that gives operators access to gas resources while minimizing impacts to state forest resources, uses, and values. The waiver approval process is a collaborative effort in which the concerns of the operator and the bureau are all balanced to achieve an outcome that is in the best interest of the commonwealth.

III. Monitoring Efforts/Results

Several practices have been designed to monitor the development of new shale-gas infrastructure and the impacts on existing state forest infrastructure:

- Spatial data assessment – GIS analysis of data collected on the construction of shale-gas infrastructure and the effects on the state forest road system
- Infrastructure and recreation field visits – a periodic review of issues, new methods, products, and benefits of shale-gas development with district personnel and the bureau's infrastructure monitoring specialist
- Forest road survey - designed to monitor the structural and material aspects of forest roads that are newly constructed or improved for utilization by shale-gas development
- Road shutdown, reroute, and general traffic control monitoring – within each of the core shale-gas districts
- Bridge and crossing inspection – the evaluation and entry into the bureau bridge inspection database of new and replacement bridges and culverts greater than 36 inches
- Dust control notification - implementation of the dust control notification form and database for all chemical dust control applications for state forest roads

Each of these monitoring efforts is discussed in greater detail in the sections that follow.

Spatial Data Assessment

The bureau monitors the state forest and shale-gas infrastructure spatially, through the use of GPS and GIS systems, and in tabular form through numerous database applications. This spatial data comes from both submittals by the gas companies and data gathered by bureau field staff. The analysis that follows provides a spatial assessment of the state forest road system, as affected by shale-gas development, and the infrastructure constructed specifically for shale-gas development.

Roads

An inventory of state forest roads has been used since the late 1960s in the form of straight-line diagrams. These documents describe the road condition, length, width, materials, and drainage infrastructure. Over time, as technology has advanced, so has the bureau's methodology for inventorying and monitoring road infrastructure. Presently, the bureau incorporates the use of GIS technology as the primary data capturing and analysis tool.

The linear distance of new road construction and existing road miles that were widened to facilitate gas development can be expressed in acres by estimating the final right-of-way width that will be maintained in a non-forested condition. It is estimated that approximately 242 acres of forest were cleared to construct new roads and widen existing roads (Table 2.3). Final right-of-way (ROW) widths that will be maintained in a non-forested condition for some roads have not yet been determined, and some of this acreage could be returned to a forested condition over time.

In the core gas state forest districts, a total of 161 miles of roads have been constructed or modified to facilitate shale-gas development (see Table 2.2). The Tiadaghton State Forest has seen the greatest mileage of new road construction and existing road modifications to accommodate this activity (see Figure 2.2).

Overall, the increase in road miles on developed tracts resulting from new construction to support shale-gas activities ranged from 0.1 percent in the Susquehannock State Forest to 9.7 percent in the Tiadaghton State Forest (see Figure 2.3).

State Forest District	Miles of New Road Construction	Miles of Existing Road Modified	Total
Moshannon	4.7	11.5	16.2
Sproul	4.0	39.1	43.1
Tiadaghton	13.5	44.4	57.9
Elk	0.3	0.0	0.3
Susquehannock	0.1	8.3	8.4
Tioga	6.0	15.8	21.8
Loyalsock	1.6	11.8	13.4
Total	**30.2**	**130.9**	**161.1**

Table 2.2 Miles of road construction and modification for 2008-2012 by state forest in the core gas region.

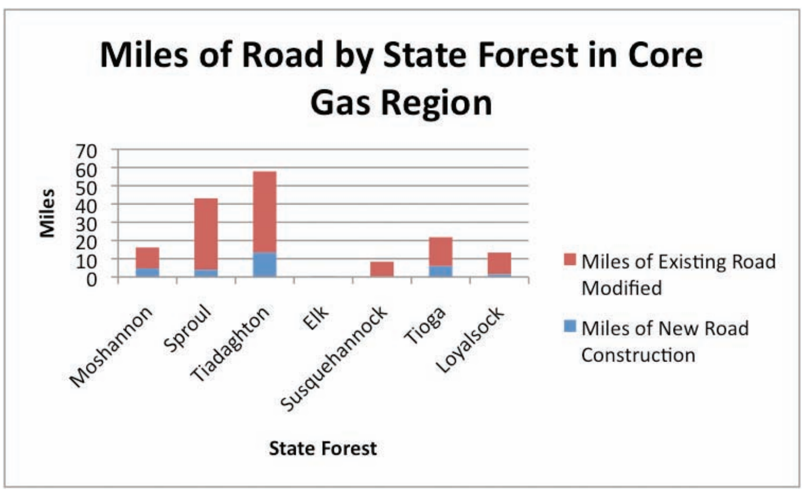


Figure 2.2 Miles of road construction and modification for 2008-2012 by state forest in the core gas forest districts.

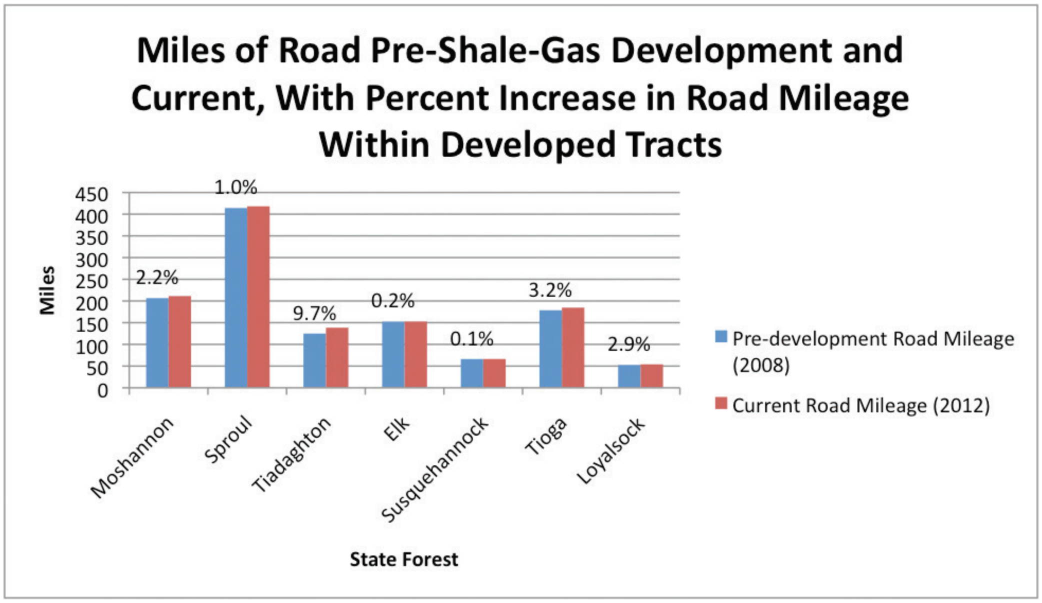


Figure 2.3 Percent increase in total district road mileage on developed tracts attributed to gas development from 2008 to 2012.

State Forest District	Acres Converted to Road ROW
Moshannon	31.7
Sproul	20.8
Tiadaghton	68.1
Elk	1.2
Susquehannock	4.1
Tioga	47.5
Loyalsock	68.2
Total	**241.6**

Table 2.3 Acres converted from forest to road ROW from 2008 to 2012.

The density of roads can be expressed as an average of the miles of roads in relation to the area of each state forest tract. As would be expected, given the mileage data presented above, an increase in road density has also resulted between pre-development (2008) and 2012 (Table 2.4).

Each state forest in the core gas region has experienced an increase in road density (Figure 2.4). The greatest percentage change in road density has occurred on the Tiadaghton State Forest, followed by the Tioga State Forest.

State Forest District	Pre-Development Average Tract Road Density (miles/square mile)	Current (2012) Average Tract Road Density (miles/square mile)	Change in Road Density (miles/square mile)	Percent Change in Road Density
Moshannon	1.8	2.0	0.2	9.5
Sproul	1.0	1.1	0.1	12.7
Tiadaghton	1.0	1.5	0.4	38.9
Elk	0.9	0.9	0.0	2.7
Susquehannock	1.2	1.2	0.1	7.5
Tioga	1.1	1.3	0.2	21.0
Loyalsock	0.7	0.8	0.1	19.1

Table 2.4 Road density on tracts with shale-gas development from 2008 to 2012.

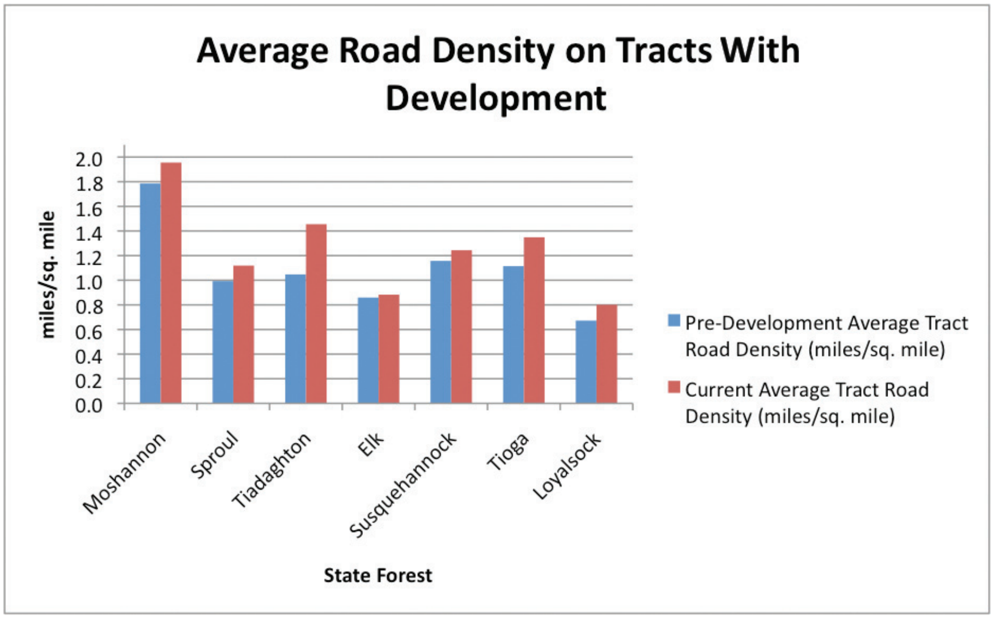


Figure 2.4 Average road density on tracts with development from 2008 to 2012.

Pads

The term "pad" is used to reference infrastructure sites that include well pads, compressor stations, freshwater impoundments, storage pads, stone pits, and meter, valve, or tap stations. Associated with each pad is a limit of clearance (LOC). The LOC is a bureau designation that is negotiated between the district and gas company where actual removal of predominant vegetation cover – including overstory, midcanopy, or understory vegetation, and/or original soil substrate – will occur. The LOC includes the as-built operational area of the infrastructure plus the area that was cleared around it to facilitate the construction of that infrastructure.

In the core gas state forest districts, there are a total of 191 infrastructure pads (all types) covering approximately 786 acres and requiring a limit of clearance of approximately 1,087 acres (see Table 2.5).

State Forest District	Number of Infrastructure Pads	Actual Pad Acres	LOC Acres
Moshannon	12	63.3	96.7
Sproul	42	156.5	196.0
Tiadaghton	69	318.3	389.2
Elk	4	6.5	19.3
Susquehannock	11	32.2	37.3
Tioga	39	135.7	252.6
Loyalsock	14	73.1	95.6
Total	**191**	**785.6**	**1,086.7**

Table 2.5 Number and acreage of all infrastructure pads by state forest district from 2008 to 2012.

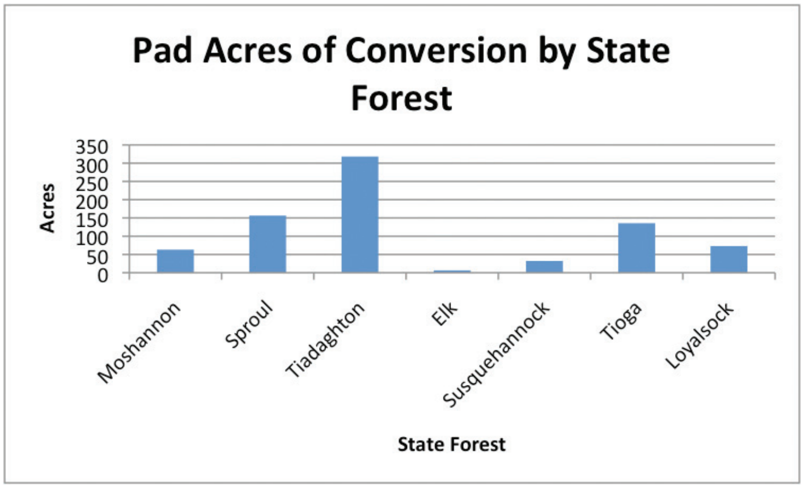


Figure 2.5 Acres converted to infrastructure pads by state forest district from 2008 to 2012.

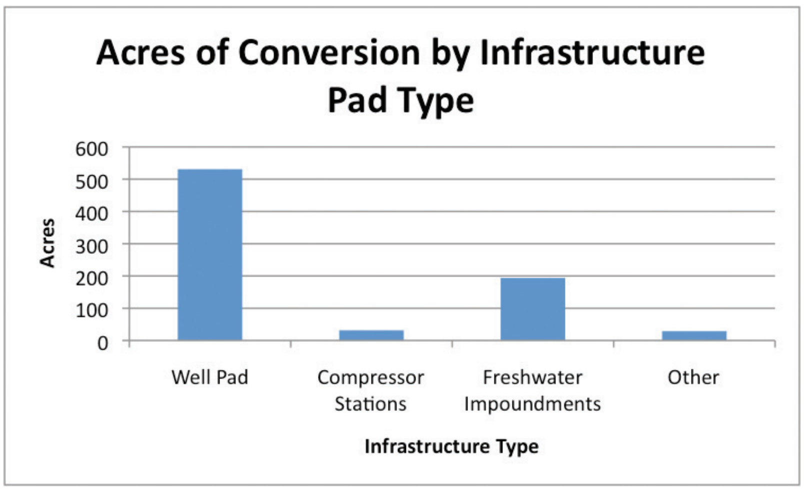


Figure 2.6 Acres converted by infrastructure type from 2008 to 2012.

State Forest District	Number of Well Pads	Well Pad Acres	LOC Acres
Moshannon	11	47.6	85.9
Sproul	35	115.9	150.8
Tiadaghton	51	189.2	235.3
Elk	4	6.5	19.3
Susquehannock	5	20.8	22.0
Tioga	27	103.1	193.3
Loyalsock	10	47.9	66.4
Total	**143**	**531.1**	**773**

Table 2.6 Number and acreage of well pads by state forest district from 2008 to 2012.

The Tiadaghton State Forest has the greatest number of pads and the greatest number of acres converted to infrastructure pads (Figure 2.5).

Figure 2.6 shows that the majority of acres converted were for well pad infrastructure (531), followed by freshwater impoundments (194). A synopsis of impacts related to each pad type is provided in the paragraphs and tables below.

In the core gas state forest districts, there are 143 individual gas well pads covering approximately 531 acres and requiring a limit of clearance of approximately 773 acres (see Table 2.6). The well pad acreage presented is the as-built footprint of the operational areas of the well pads. The Tiadaghton State Forest has the greatest number of well pads and acres converted to this infrastructure.

In the core gas state forest districts, there are nine individual compressor pads covering approximately 32 acres and requiring a limit of clearance of approximately 40 acres (see Table 2.7). The compressor pad acreage presented is the as-built footprint of the operational areas of the compressor stations. The Tiadaghton and Tioga state forests have the greatest number of compressor pads, but the Loyalsock State Forest has the greatest number of acres converted to this infrastructure.

State Forest District	Number of Compressor Pads	Compressor Pad Acres	LOC Acres
Sproul	1	1.7	2.6
Tiadaghton	3	5.7	6.1
Susquehannock	1	0.03	1.0
Tioga	3	9.4	15.0
Loyalsock	1	15.0	15.0
Total	**9**	**31.7**	**39.5**

Table 2.7 Number and acreage of compressor pads by state forest district from 2008 to 2012.

In the core gas state forest districts, there are 26 freshwater impoundment pads covering approximately 194 acres and requiring a limit of clearance of approximately 229 acres (see Table 2.8). The freshwater impoundment acreage is the as-built footprint of the operational areas of the impoundments. The Tiadaghton State Forest has the greatest number of freshwater impoundments and the greatest number of acres converted to this infrastructure.

Approximately 70 percent of the impoundments on state forest lands employ a freshwater conveyance system to pump water from a surface water source to the impoundment. This has led to a significant reduction in the amount of trucks using the state forest road system. As a result, this has alleviated some of the forest visitor concerns related to the frequency of encountering trucks on state forest roads, the amount of dust and noise, and the overall condition of state forest roads. Table 2.9 provides data from Pennsylvania General Energy and Anadarko Petroleum Corporation regarding the benefits of using water conveyance systems over the use of conventional trucking in Tiadaghton State Forest.

State Forest District	Number of Freshwater Impoundments	Freshwater Impoundment Acres	LOC Acres
Moshannon	1	15.6	15.6
Sproul	3	36.7	40.4
Tiadaghton	12	108.4	133.6
Susquehannock	3	9.0	10.7
Tioga	5	17.5	29.7
Loyalsock	2	6.5	6.5
Total	**26**	**193.8**	**229.1**

Table 2.8 Number and acreage of freshwater impoundments by state forest from 2008 to 2012.

Operator	Million Gallons Pumped in 2012	Truck Round Trips Eliminated Due to Pumping in 2012
Pennsylvania General Energy	190.9	41,300
Anadarko Petroleum Corporation*	100.8	22,000

Table 2.9 Statistics on water use and truck trips saved due to the use of water conveyance systems. Data provided by operators.

*Anadarko utilized its water conveyance system for both commonwealth and private land development. The data presented cover both.

State Forest District	Number of Other Infrastructure	Other Infrastructure Acres	LOC Acres
Moshannon	0	0.0	2.7
Sproul	3	2.2	2.2
Tiadaghton	3	14.9	14.9
Susquehannock	2	2.4	3.6
Tioga	4	5.7	14.6
Loyalsock	1	3.8	8.5
Total	**13**	**29.0**	**45.7**

Table 2.10 Number and acreage of other infrastructure pads by state forest district from 2008 to 2012.

In the core shale-gas state forest districts, there are 13 other types of infrastructure pads covering approximately 29 acres and requiring a limit of clearance of approximately 46 acres (see Table 2.10). The other infrastructure acreage is the as-built footprint of the operational areas of the other types of infrastructure. The Tioga State Forest has the greatest number of these types of pads, but the Tiadaghton State Forest has the greatest number of acres converted to these types of infrastructure.

Throughout the state forest system, primary land use and land capability are dictated by the bureau's management zoning designations. Management practices are applied to these zones to protect and enhance the values for which the land was zoned. The different land management zones are described below.

- Multiple Resource Management Zone is the least restrictive management zone and applies to areas managed for many resources, such as timber, water, recreation, fauna, flora, and minerals.
- Aesthetic/Buffer Management Zone applies to areas where connectivity, aesthetics, and water quality conservation are the primary values. These areas are associated with linear features such as roads, trails, and streams, or encompass a significant feature of state forest land.
- Limited Resource Management Zone is applied to areas where management alternatives are limited due to site quality or topographic constraints. Recreation, aesthetics, water, and soil protection are the primary values.
- Natural Area Management Zone applies to areas that have been designated as or are pending designation as State Forest Natural Areas. Natural areas are defined as areas of unique scenic, historic, geologic, or ecological value, that will be maintained in a natural condition, usually without direct human intervention.
- Wild Area Management Zone applies to areas that have been designated or are pending designation as State Forest Wild Areas. Wild areas are defined as extensive areas that the general public will be permitted to see, use, and enjoy through such activities as hiking, hunting, fishing, and the pursuit of peace and solitude. No development of a permanent nature will be permitted so as to retain the undeveloped character of the area and conserve ecological resources.
- Special Resource Management Zone applies to areas that will be managed for specific values, such as public wild plant sanctuaries, special wildlife management areas, certain recreation sites, vistas, and reservoirs.
- Anthropogenic Site Management Zone applies to human-made structures or facilities such as roads, ROWs, mineral sites, tower sites, buildings, and so forth. The primary value for this zone is human amenities.

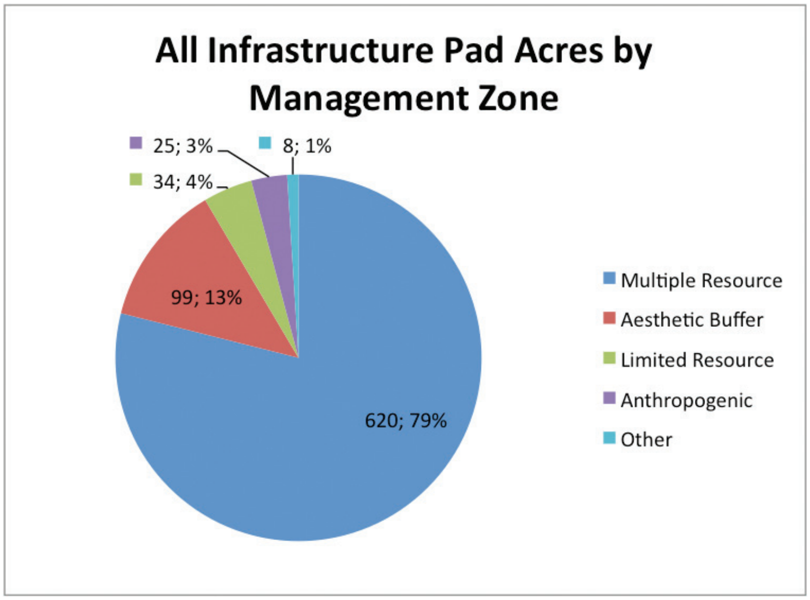


Figure 2.7 Acres converted to infrastructure pads by management zone from 2008 to 2012.

The pie chart above (Figure 2.7) shows the impact of infrastructure pads by management zone. The majority of acres (620) converted to support shale-gas infrastructure are in the Multiple Resource Management Zone designation. It should be noted that no pad infrastructure has been allowed in the Natural Area and Wild Area management zones, as surface development is incompatible with these zones. To the extent possible, impacts to the Aesthetic/Buffer Management Zone have been minimized, but occasionally infrastructure is sited in such zones to take advantage of proximity to existing road corridors and thus limit new forest clearing.

Pipelines

In the core gas forest districts, approximately 104 miles of pipeline corridor have been constructed as a result of shale-gas development. Twenty-one miles of these corridors are coincident with previously existing pipeline corridors. Co-locating pipelines was done to utilize existing corridors rather than create new corridors. This has resulted in a total of 843 miles of pipeline corridor within the gas state forest districts. Approximately 760 miles of pipeline corridor existed prior to the commencement of shale-gas development. These pre-existing corridors are covered by right-of-way agreements. Sproul State Forest has the greatest number of miles of pipeline corridor, with approximately 215 miles, and the Moshannon and Susquehannock state forests following closely behind, with approximately 191 miles and 177 miles respectively (see Table 2.11 and Figure 2.8).

State Forest District	Pipeline Corridor Type		Miles of Shale-Gas Lease ROWs Coincident with Existing ROWs	Total
	Existing	Shale-Gas Lease		
Moshannon	188.5	5.9	3.6	190.8
Sproul	207.3	14.5	7.0	214.7
Tiadaghton	25.4	52.4	7.1	70.7
Elk	110.8	2.0	0.0	112.9
Susquehannock	173.7	3.9	0.2	177.4
Tioga	44.7	18.5	2.7	60.5
Loyalsock	9.2	6.5	0.0	15.6
Total	**759.5**	**103.7**	**20.6**	**842.7**

Table 2.11 Miles of pipeline corridor by type, 2012.

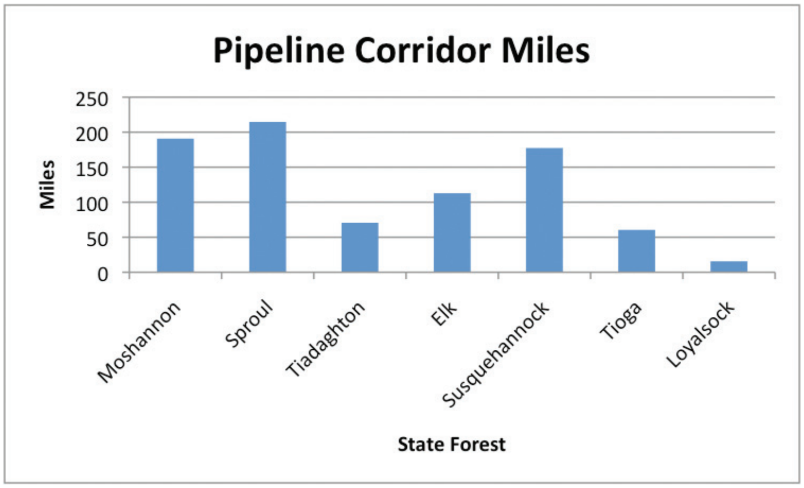


Figure 2.8 Miles of pipeline corridor by state forest district 2012.

The linear distance of new pipeline construction and existing pipeline miles that were widened to facilitate gas development can be expressed in acres by estimating the final ROW width that will be maintained in a non-forested condition. It is estimated that approximately 459 acres of forest have been cleared to construct new pipelines and widen existing pipelines (Table 2.12). Final ROW widths that will be maintained in a non-forested condition for some pipelines have not yet been determined, and some of this acreage could be returned to a forested condition over time.

State Forest District	Acres Converted to Pipeline ROW
Moshannon	39.2
Sproul	78.2
Tiadaghton	144.2
Elk	9.1
Susquehannock	29.4
Tioga	94.4
Loyalsock	64.3
Total	**458.8**

Table 2.12 Acres converted from forest to pipeline ROW from 2008 to 2012.

The density of pipeline corridor can be expressed as an average of the miles of pipeline corridor in relation to the area of each state forest district. Table 2.13 shows the density of existing and shale-gas lease pipeline corridor types for each state forest district. The Moshannon State Forest has the highest density of existing pipeline corridors, with approximately 0.6 miles of pipeline corridor per square mile, and the Tiadaghton State Forest has the highest density of shale-gas lease pipeline corridors, with 0.23 miles per square mile.

Pipeline corridors at times must cross streams. Pipeline crossings represent a potentially significant impact on streams and rivers in state forests. Pipeline crossings are typically constructed by an open-cut trench across the stream or by horizontal directional drilling (HDD) beneath the stream. The open-cut trench represents a direct impact on the riparian vegetation, stream bed, and water. The HDD can affect riparian vegetation, depending on the details of the operation, and can affect nearby water bodies through an inadvertent return – a release of high-pressure drilling mud outside the drilling hole. Following construction, riparian areas must be revegetated (at least with herbaceous vegetation), which may have varying degrees of success, leading to potential erosion and sedimentation control issues. The number of stream crossings and the DEP Chapter 93 stream designations for lease agreement crossings are found in Table 2.14 and Figure 2.9. A total of 35 lease agreement pipeline corridor stream crossings occur in the core gas districts, with the highest number occurring in the Tioga State Forest. A protocol has been developed to examine the condition of pipeline stream crossings, and it is presented in the Water chapter of this report.

State Forest District	Pipeline Corridor Type		Total Density
	Existing	Shale-Gas Lease	
Moshannon	0.6	0.02	0.6
Sproul	0.4	0.03	0.4
Tiadaghton	0.3	0.23	0.3
Elk	0.4	0.01	0.4
Susquehannock	0.4	0.01	0.4
Tioga	0.2	0.07	0.2
Loyalsock	0.1	0.04	0.1
Total Avg. Density (mi./sq. mi.)	**0.3**	**0.1**	**0.4**

Table 2.13 Density of pipeline corridors per square mile by state forest district 2012.

State Forest District	Stream Classification				Total
	EV	HQ	CWF	Not Classified	
Moshannon		2			**2**
Sproul		1	2		**3**
Tiadaghton	1	7			**8**
Susquehannock		2			**2**
Tioga			16	1	**17**
Loyalsock	1	2			**3**
Total	**2**	**14**	**18**	**1**	**35**

Table 2.14 Number of stream crossing by DEP Chapter 93 stream classification from 2008 to 2012. EV = Exceptional Value, HQ = High Quality, and CWF = Cold Water Fishes

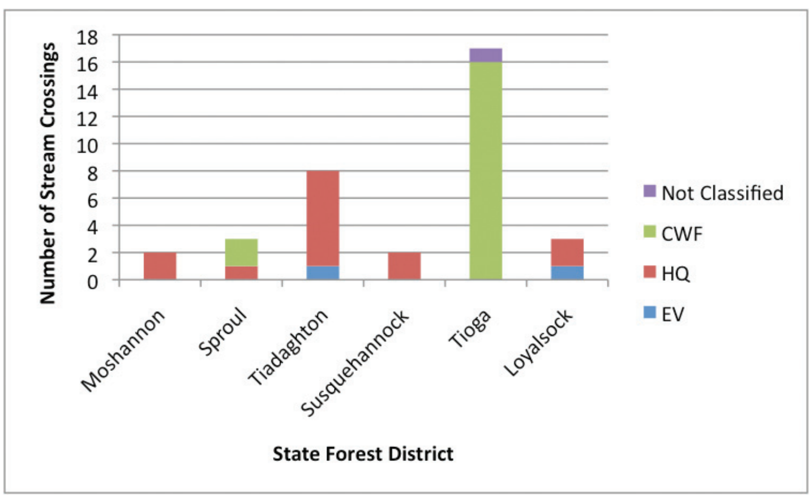


Figure 2.9 Number of stream crossings by DEP Chapter 93 stream classification from 2008 to 2012. EV = Exceptional Value, HQ = High Quality, and CWF = Cold Water Fishes

Extracted gas must be transported from well pads through gathering pipelines to connect with marketing pipelines that lead to storage or distribution centers. Gathering pipelines are constructed to reach marketing pipelines in the most efficient and ecologically sensitive way possible. Many pipelines follow existing road or ROW corridors to minimize forest conversion. In most cases, this results in pipelines that follow gentle slopes. However, there are times when the most efficient method is to cross a mountain ridge perpendicular to the slope. This results in pipeline segments that fall on relatively steep slopes. Slopes of the lease agreement pipeline corridors for the core gas districts are found in Table 2.15 and Figure 2.10. The majority of pipeline corridors on lease agreements are on slopes less than 20 percent. However, there are approximately three miles of pipeline that were constructed on slopes in excess of 20 percent. Gas companies are required to install erosion and sedimentation control measures for all pipeline construction, but particular attention is paid to these measures when building on steep slopes. The effectiveness of erosion and sediment control practices is monitored by both DEP and bureau gas foresters on a regular basis.

	Slope Category						
State Forest District	**0 to 10%**	**11 to 20%**	**21 to 30%**	**31 to 40%**	**41 to 50%**	**> 50%**	**Total**
Moshannon	5.70	0.23					**5.9**
Sproul	13.59	0.84	0.02	0.07			**14.5**
Tiadaghton	47.32	3.21	0.86	0.37	0.40	0.23	**52.4**
Elk	2.00	0.01					**2.0**
Susquehannock	2.52	0.95	0.30		0.10		**3.9**
Tioga	17.56	0.80	0.09	0.10			**18.5**
Loyalsock	4.24	1.43	0.46	0.25	0.04	0.05	**6.5**
Total	**92.9**	**7.5**	**1.7**	**0.8**	**0.5**	**0.3**	**104**

Table 2.15 Miles of lease agreement pipeline corridor by slope class and state forest from 2008 to 2012.

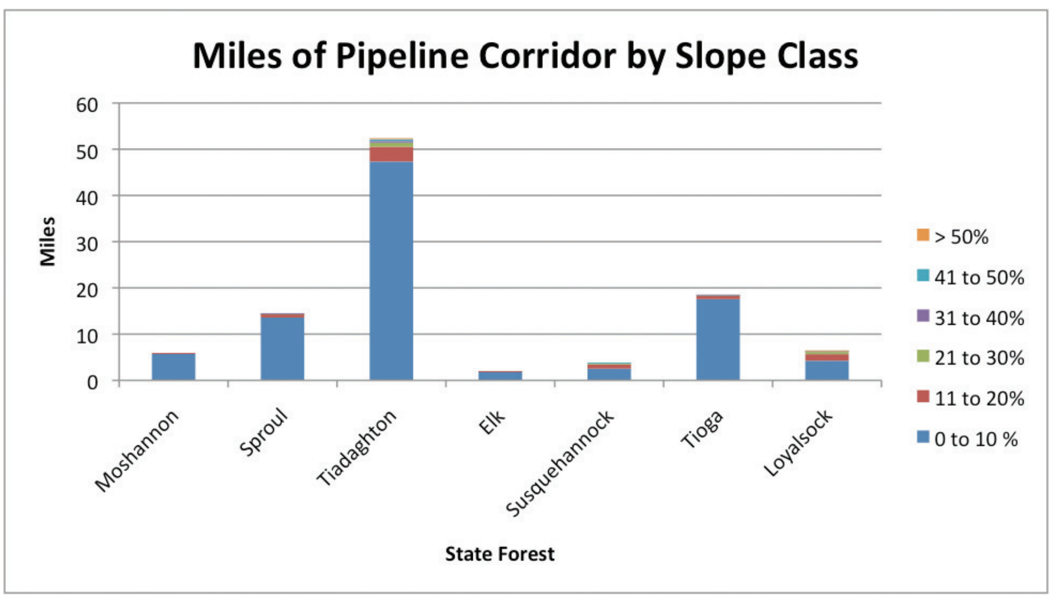


Figure 2.10 Miles of lease agreement pipeline corridor by slope class and state forest from 2008 to 2012.

Total Conversion

From 2008 to 2012, approximately 1,486 acres of state forest land were converted from a forested condition to facilitate gas development activities (Table 2.16 and Figure 2.11). This figure could change with time because some edges of pads, roads, and pipelines may not be maintained and could revert to a forested condition in the future.

State Forest District	Pad Acreage	Road Acreage	Pipeline Acreage	Total Acreage
Moshannon	63.3	31.7	39.2	**134.2**
Sproul	156.5	20.8	78.2	**255.5**
Tiadaghton	318.3	68.1	144.2	**530.6**
Elk	6.5	1.2	9.1	**16.8**
Susquehannock	32.2	4.1	29.4	**65.7**
Tioga	135.7	47.5	94.4	**277.6**
Loyalsock	73.1	68.2	64.3	**205.6**
Total Acreage	**785.6**	**241.6**	**458.8**	**1,486.0**

Table 2.16 Total acreage converted to non-forest by infrastructure type from 2008 to 2012.

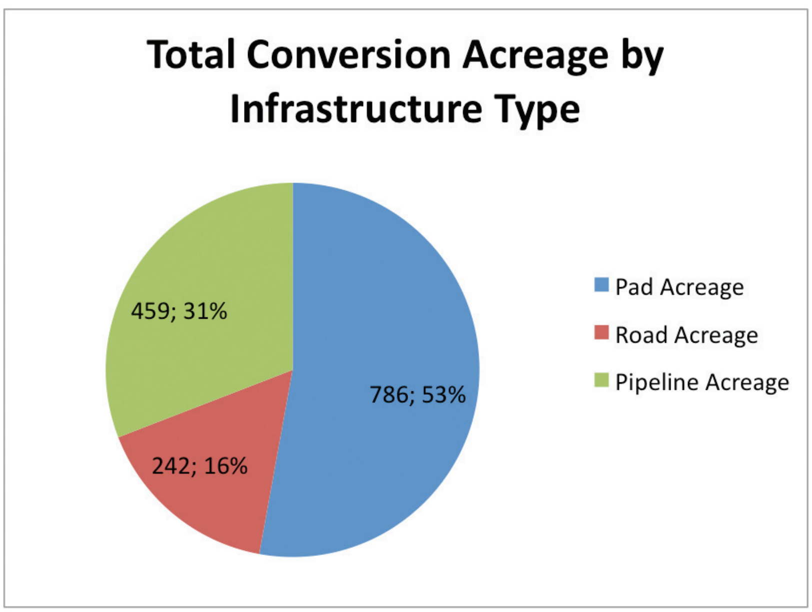


Figure 2.11 Total acreage converted to non-forest by infrastructure type from 2008 to 2012.

Seismic Surveys

Seismic data facilitates the successful exploration and development of conventional and unconventional oil and natural gas reservoirs in Pennsylvania. Seismic data is acquired when an energy wave travels through the subsurface and is reflected off of the various layers of rock at depth to a data recording device at the earth's surface called a geophone. Each layer of rock acts as its own reflective surface, where the reflectivity of any given surface is dependent on its density and the velocity at which the energy wave can travel through the medium.

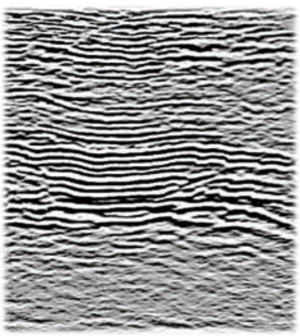


Figure 2.12

These energy waves are most commonly generated on land from an explosive charge buried within a previously drilled borehole, or from a heavy truck-mounted vibrating plate (commonly referred to as vibroseis). The energy reflection from the layers of rock (the signal) is gathered and recorded on the surface by geophones and is processed to produce an image, which may be interpreted and used to guide the exploration and development process. The images produced are representative of a cross-section through the earth and show the various layers of rock encountered at the subsurface (Figure 2.12). The acquisition of seismic data is considered integral to interpreting subsurface structure and effectively developing oil and natural gas reservoirs.

Seismic data is acquired in two-dimensional (2-D) or three-dimensional (3-D) form as indicated by the image produced of the subsurface.

2-D surveys: require an energy source that is in line with the receiver to produce a vertical profile of the subsurface. 2-D surveys consist of one or more seismic lines acquired individually. Each line will produce an image in a single vertical plane.

3-D surveys: require a multitude of geophones placed in an array, which collect the reflection signals from points outside the plane of the energy source to produce a "cube-like" profile of the subsurface. Multiple seismic lines collecting data simultaneously are required to produce a three-dimensional image. 3-D surveys are more complex and labor intensive and require more land-base.

Two methods of seismic surveys commonly occur on state forest lands:

Explosive surveys: utilized for cross-country surveys where road access is limited; drill buggies, heli-portable drills, or tracked machines drill a 20-foot "shot-hole" every 220 feet along a linear survey route; data collection receivers (or geophones) are placed at fixed intervals and data is collected.

Vibroseis surveys: utilized when a sufficient road network exists; large weighted trucks strike the road surface and collect data in a similar fashion to that described above.

Seismic operators are highly encouraged to employ the least intrusive technologies available for gathering seismic survey data. Exclusion areas containing sensitive resources are clearly delineated by the operator in the field and seismic crews are informed of operational restrictions and/or avoidance measures.

The bureau has developed guidelines to help manage seismic activity on state forest lands. See *Guidelines of Administering Oil and Gas Activity on State Forest Land* for more information.

Field management and inspections are used to document compliance with the operating specifications set forth in the seismic permit and the pre-activity meeting. Examples of incidents documented during past field inspections include damage to trees, debris or trash found, unauthorized use of trails, damage to gates, illegal parking, vandalism, and unauthorized shot-hole locations.

Between 2007 and 2012, the bureau approved 26 individual seismic surveys to take place on state forest lands. As a result of these 26 seismic survey permits, over 643,000 acres of 3-D seismic data and 49 line miles of 2-D seismic data have been acquired. A vegetation monitoring protocol has been designed to monitor vegetation impacts. Impacts to vegetation from seismic operations should be temporary (Figure 2.13), as vegetation will restore itself naturally. Additional monitoring protocols may be developed to account for additional potential impacts as a result of seismic data acquisition activities.

Figure 2.13 Seismic activity on state forest lands.

Infrastructure and Recreation Field Visits

The bureau implements on-site forest infrastructure monitoring and recreation field visits. Staff from the core gas forest districts and the infrastructure specialist in the Recreation Section periodically meet to review shale-gas development. They discuss, document, and review issues, new methods, products, and benefits that stem from shale-gas development. Several of the findings and lessons learned from these visits are reviewed here.

Traditional state forest roads typically have a closed or nearly closed canopy over the top of the road and are barely wide enough for two passenger vehicles to safely pass each other. Such roads exhibit the wild character and back-country experience that state forest users have come to expect. Conversely, some roads used by the shale-gas industry are considerably wider, enough for two hauling trucks to pass each other safely, and often the tree canopy has been opened over the top of the road.

Based on the traditional traffic use of state forest roads, minimal road sub-base construction was typical. However, the original state forest roads were not adequate for the volume of traffic or the increased vehicle weights that came with shale-gas development. Changes were necessary to modify and create roads in the forest that could withstand this new type of traffic. The challenge is to balance the needs of gas operators with the traditional needs of other forest users. The roads also need to be constructed in a manner that would be compatible with bureau road maintenance operations after gas companies finish using the roads. In some cases, existing state forest roads that were improved or new forest roads that were constructed during the first two years of shale-gas development began to take on industrialized characteristics, such as heavily fortified sub-base, undesirable drop-offs along the sides, and excessively wide running surfaces. In response to these changes, the roads section of the bureau's *Guidelines for Administering Oil and Gas Activity on State Forest Lands* was updated to offer clarification and guidance to both bureau staff who were implementing the gas program and also the gas companies that were operating on state forest lands.

The updated guidelines described a clearer vision for how state forest roads were to be constructed to meet traditional forest visitor expectations, the bureau's long-term maintenance capabilities, and gas companies' operational needs. The changes primarily deal with the creation of a stable road sub-base using geo-textiles, such as geo-fabrics, geo-grids, and geo-cells, in conjunction with the traditional sub-base stone. Another successful method has been the use of soil cementing to create the road sub-base (described in more detail below). These approaches have greatly reduced the height and width of the road profile, enhancing the appearance of the forest road while still providing the capabilities needed to handle large volumes of heavy truck traffic.

Figure 2.14 Traditional state forest road in Loyalsock State Forest. Note the closed canopy and narrow road base.

Figure 2.15 State forest road in Tiadaghton State Forest that has minimal wild character value after it was improved for shale-gas development. Note the break in the tree canopy, wide base, and heavily armored edges.

Figure 2.16 Constructed forest road, with adjacent pipeline ROW, used for shale-gas development access. This demonstrates reduced wild character value due to wide road surface and long, straight profile.

Figure 2.17 State forest road in Tioga State Forest that is utilized for shale-gas development that demonstrates reduced wild character value due to overwidening.

Figure 2.18 State forest road in Moshannon State Forest that was improved for shale-gas development but retained significant wild character value. A gas line ROW is adjacent to the road.

Figure 2.19 State forest road in Moshannon State Forest that was improved for shale-gas development but retained wild character value. Note that the canopy is still closed over the top of the road.

Figure 2.20 State forest road in Tiadaghton State Forest that was improved for shale-gas development but retained wild character value. Note that the canopy is still closed over the top of the road.

A recent technology for improving some state forest roads is the use of soil cementing. Soil cementing limits the increased height of the road profile by eliminating the need for a large amount of stone to be placed as the sub-base. Soil cementing, or stabilizing the road sub-base with cement, has been shown to be effective in stabilizing the road sub-base. This technology involves adding cement to the road surface in a 7 percent concentration, sometimes adding additional stone, and then mixing the conglomerate together. The new material is then graded with a proper crown and rolled. This new road sub-base is then covered with a running surface of six to 12 inches of crushed limestone or driving surface aggregate.

Although proven to be stable, an initial concern with this new sub-base was how it would impact future road maintenance activities by the bureau. It was unclear whether typical equipment operated by bureau maintenance staff could manage the soil cementing sub-base. The technique was tested on a short section of road in the Sproul State Forest (Figure 2.21), and it was found that the treated sub-base could be maintained through existing bureau procedures and would not pose maintenance problems like a standard concrete material would. Presently, 5.6 miles of state forest road have received a soil cement treatment to the sub-base. While this road sub-base treatment is not appropriate for use on all state forest roads, it does have applicability in some cases without negatively impacting future maintenance activities by the bureau.

An innovative method to preserve the wild character of a state forest road has been implemented at several large pipeline crossings. Traditionally, the intersections of pipelines and roads have created long, linear views of the cleared and maintained pipeline ROW. In the Tiadaghton State Forest, the district staff and gas company personnel collaborated to develop a layout for a large pipeline project that would minimize this negative visual effect (Figures 2.22 and 2.23). They minimized the width of

Figure 2.21 State forest road in Sproul State Forest that was improved for shale-gas development and received a soil cement treatment to the sub-base.

the permanently maintained ROW, allowing for 60 to 70 percent of the initial clearing to be replanted as a forested site. Conifer plantings are planned for the site because conifer trees grow at a faster pace and hold their foliage year round to further reduce the visual impacts. In addition, the ROW layout incorporated the use of a crescent shape as the ROW climbed the slope and also embedded “doglegs” to further break up the linear visibility of the ROW. These layout modifications limit the distance that the ROW is visible from the road.

In considering whether to place pipeline ROWs along existing state forest roads, the bureau is confronted with the conflicting goals of maintaining the wild character of forest roads and limiting forest fragmentation due to new pipelines. The addition of a pipeline ROW along a road corridor can detract from the wild character of the road, but it minimizes the amount of new forest fragmentation by taking advantage of the existing disturbance corridor. Conversely, placing the ROW at a distance or setback from the road creates an additional disturbance corridor but preserves the wild character of the road. In some cases, the road and/or pipeline corridor can be kept narrow enough that there is still a closed canopy over the disturbance corridor. The bureau is implementing both approaches and is evaluating their outcome and effectiveness.

Figure 2.22 View of pipeline in Tiadaghton State Forest discussed here. Note dogleg on opposite side of stream to minimize long, linear view of pipeline.

Figure 2.23 View of pipeline in Tiadaghton State Forest discussed here. Note dogleg at top of hill to minimize long, linear view of pipeline.

Forest Road Surveys

Forest roads are the primary means of access for nearly every forest user group. Forest roads also represent a significant investment to infrastructure that requires continual long-term monetary and manpower investments by the Bureau of Forestry. Shale-gas development represents a considerable increase in the amount of traffic and types of vehicles using forest roads. These changes are not compatible with traditional forest road construction, and major road improvements are necessary to accommodate gas development. Since the 2008 state forest lease, impacts to the forest road system and associated corrective measures have greatly changed the structure and character of the state forest road system. The purpose of this survey work is to document and quantify the condition of state forest roads and how they change over time in relation to how the roads were constructed or improved and what materials were used to accommodate shale-gas development traffic.

In addition, a comparison of required maintenance for roads that were improved for shale-gas development versus traditional state forest roads will also be evaluated. Experience has shown that the increase in traffic and heavy hauling will result in road failure if the road profile and materials are not improved and that, over time, the improved roads will require less maintenance and remain in better condition following shale-gas development activities.

Roads that have received or will receive heavy shale-gas related traffic since 2008 are considered for this survey. The road to be surveyed is divided into quarter-mile sections. Data collection points are established at the beginning of the road and at quarter-mile intervals to the end of the road or to the point where gas-related traffic terminates. If the road extends beyond the termination point, an additional point is established one quarter-mile past where gas-related traffic ends.

GPS coordinates are collected at the starting location, at every data collection point, at every road or trail intersection, and at the end of the road survey. The points are collected at the center of the running surface. An assessment and site evaluation is performed at each point. The running surface width, cross-sectional width, limit of clearance width, and ditch widths are measured. In addition, a visual determination of road feature assessments is made at each collection point. These assessments include the ditch type and condition, road profile, road surface aggregate material, condition of the road, road sub-base material, and dust conditions related to the road.

All state forest roads in each state forest district that are used for shale-gas development are scheduled to be surveyed. This survey work began with the testing of the Road Survey Monitoring Protocol in May 2012. Following field testing of the protocol and associated edits, the survey began on roads in the core gas forest districts.

Initial survey results show that the average running surface width of roads used for gas development is 14.5 feet, and the average road cross-sectional width is 34.5 feet. The primary road profile is of a "crowned" shape for nearly 95 percent of the road survey points. The most common road running surface material found in the road surveys is 2A limestone, followed by 2RC limestone and driving surface aggregate (DSA). The road sub-base improvement materials include the use of geo-textiles (geo-grid, geo-fabric, and geo-cell) in conjunction with the use of native stone materials and imported #3 and #4 stone, which is most commonly a limestone base material. Soil cementing was also used in a limited number of situations and has been found to be very effective. Road drainage methods include sheetflow and ditch. This road drainage method was indicated on 55 percent of the road survey points.

In addition to these findings, the survey protocol was also conducted, when possible, on the portions of roads not used for shale-gas development. Surveys

were also conducted on some roads in anticipation of future shale-gas development. Results from these data sets indicate that the average running surface is 9.4 feet and the average road cross-sectional width is 25.6 feet. The primary running surface material is native materials on 50 percent of the points. 2A and 2RC limestone represent the remaining running surface material, with 31 percent and 18 percent, respectively. This shows an average of 5.1 feet increase in running surface width and 8.9 feet increase in road cross-sectional width due to shale-gas development. The running surface materials typically changed from primarily native materials to limestone- based road surfacing products.

Future efforts include the surveying of all of the remaining roads that have been used or are likely to be used in the Moshannon, Sproul, Elk, and Loyalsock state forests. The return interval for resurveying these road plots will be determined based on periodic surveys of certain roads to gauge measureable change in road conditions. The road data collected will continue to guide the bureau in road construction methods, materials, and maintenance intervals for roads utilized in shale-gas development. The data will also assist in guiding the bureau in improving other forest roads that are not used for shale-gas development due to lessons learned on shale-gas used roads. The bureau will track the useable life of the various road materials to determine the best products to be used in traditional state forest road maintenance and construction. Based on what is learned from the roads utilized for shale-gas development, it is anticipated that the bureau will find cost-saving measures in its maintenance and improvement of traditional state forest roads.

Road Shutdown, Reroute, and General Traffic Control Monitoring

The Bureau of Forestry strives to keep all public use roads open to the public during shale-gas development, but there are exceptions when roads must be closed. In a few instances, there have been long-term closures of roads due to public safety concerns. More typically, however, road closures are temporary, usually from a few minutes to a few hours, for operational reasons such as road improvement projects, pipeline crossing construction, bridge or culvert replacement, drilling rig moves, and oversized loads. Although not closed to public travel, there have been roads within the Sproul and Loyalsock state forests that have had long-term reroutes implemented on them that resulted in different traffic patterns than the public has traditionally experienced. These reroutes consist of changing a road from two-way to one-way traffic flows.

In addition to road closures and traffic pattern reroutes, many users have experienced sign-in/sign-out procedures when accessing certain areas by vehicle. Manned security stations are located in some areas where all persons passing must stop and sign in/sign out. This is required so that, in the event of an accident at or near a well pad that is being developed, the company will have a roster of all persons and vehicles for which they need to account. These security practices are common in all of the state forests that have active gas development activities during the drilling and hydraulic fracturing stages.

Below is a summary of altered traffic patterns and road closures by state forest district:

Tiadaghton State Forest
There have been two roads with long-term closures. Moore Road has been closed for its entirety since 2009, and a quarter-mile section of Ramsey Road has been closed since 2010. Each of these road closures is anticipated to be opened when the wells along these roads go into the production stage (i.e., when drilling and hydraulic fracturing are completed).

Sproul State Forest
There has been a reroute of Penrose Road to Coon Run Road for one-way traffic. This was in place from 2010 until 2012. The road is now open for two-way traffic, since gas development activity has slowed in the district. It is anticipated that this road will return to a one-way traffic pattern when gas development activity increases. The one-way traffic pattern was a solution that the district implemented due to the very steep topography and the narrow roadway. These conditions resulted in limited places for vehicles to pass one another safely. In addition, a section of the road passes a former Civilian Conservation Corps camp location. To preserve this cultural resource, road widening was not permitted.

Loyalsock State Forest
There is a reroute affecting Hagerman Run, Brown, Long Run, and Gray's Run roads for one-way traffic. This has been in place since 2011 and will likely continue until shale-gas development is completed in this area. The one-way traffic pattern was a solution that the district implemented due to the very steep topography. This condition resulted in limited places for vehicles to pass one another safely. In addition, Hagerman Run Road's proximity to the stream doesn't allow for the widening of the road. A further consideration in this traffic solution was the impact of heavy truck traffic passing through the village of Gray's Run. The one-way traffic plan reduces the amount of traffic affecting the residents of Gray's Run.

Bridge and Crossing Inspection
Various gas companies have made significant additions and repairs to bridges and other large stream crossings as part of their use of state forest roads. There have been five new bridges and one bridge deck replacement in the state forests since shale-gas development began in 2008. The bridges have been primarily prefabricated metal bridges that are constructed off site and then transported and installed. Also, six stream crossings have been completed by the installation of large, greater than 36-inch culverts. The culverts are either corrugated metal or smooth-bore plastic construction.

The bridge crossings are added into the Pennsylvania Department of Transportation's Bridge Database System. Each of these crossings is then scheduled for periodic field inspections for safety and structural analysis. These inspections take place on average every five years and are performed by DCNR inspectors or through a certified contractor.

Figure 2.24 New bridge installed in Tiadaghton State Forest.

Figure 2.25 New bridge installed in Tioga State Forest.

Dust Control Notification

State forest roads consist of a soil and aggregate material that can lead to potential issues with dust caused by vehicle traffic. Road dust is created as vehicle tires pulverize the surface aggregate, releasing small particles of dust referred to as fines. These fines from the pulverized material can then become airborne and are known as fugitive dust. Fugitive dust has the potential to be a detriment to forest users' safety, impact personal property, and cause environmental concerns.

The nature of gas development on state forest lands requires access across state forest roads by a multitude of vehicle types and sizes. The frequency of traffic is a factor that contributes to releasing fugitive dust. The trips made by these vehicles carry the potential to create fugitive dust to various extents based on weather conditions. While all stages of gas development require many more vehicles per day than a traditional state forest road typically experiences, of greatest concern is the period of time when a well is being hydraulically fractured. This generally requires the greatest concentration of heavy vehicular traffic.

The primary dust control method recommended by forest district management and utilized by natural gas companies is the use of non-potable water as a suppressant. Eighty-three percent of the roads that have had some type of dust suppressant applied used non-potable water. Non-potable water (water drafted from a source such as a stream or river and not treated to drinking water standards) is preferred over potable water, as potable water can retain chemicals that injure plant and aquatic life. Among other concerns, chemical dust suppressants have been known to change the chemical properties of dirt and gravel roads to the extent that the road itself hardens and becomes impossible to maintain using the bureau's standard maintenance practices. When the road reaches this condition, the only alternative is to completely rehabilitate the road through full-depth reclamation. However, chemical dust suppressants have been used on some state forest roads, and their usage is summarized below.

Sproul State Forest

- Chemical dust control treatments on segments of five roads, totaling 3.5 miles.
- Road segments have been treated since August 2010, and they have been approved for reoccurring treatment as conditions require.
- Justifications for the usage of chemical dust control have been: 1) for safety – traffic visibility, and 2) to control fugitive dust that impacts both private and state forest leased camps.
- Products used have been "Dustless" and "Aggrabond."

Tioga State Forest

- Chemical dust control treatments on segments of seven roads, totaling 12.5 miles.
- Most road segments have been treated since May 2011, and they have been approved for reoccurring treatment as conditions require.
- Justification for the usage of chemical dust control has been for safety related to traffic visibility.
- Products used have been “Ultrabond 2000” and “Dustless.” Feedback from the company that used Dustless was “the application was not as effective as marketed” and, following the initial application, all further dust control was by water only. Companies using Ultrabond 2000 were satisfied with the results.

Loyalsock State Forest

- Chemical dust control treatments on segments of five roads, totaling 12.1 miles.
- Road segments have been treated since July 2011, and they have been approved for reoccurring treatment as conditions require.
- The justifications for the utilization of chemical dust control have been: 1) for safety – traffic visibility, and 2) to control fugitive dust that impacts a private camp within the forest. There have been complaints received from private residents and the public due to fugitive dust on state forest roads.
- Product utilized has been “Ultrabond 2000.”

IV. Conclusion/Discussion

State forest lands located in the shale-gas region have seen changes in infrastructure due to the development and extraction of this resource. Overall, approximately 1,486 acres of forest have been converted to facilitate shale-gas development. This included 161 miles of new or improved roads, 191 pads (of all types), and 104 miles of new or widened pipelines. Road surveys have demonstrated an average of 5.1 feet increase in running surface width and 8.9 feet increase in road cross-sectional width due to shale-gas development, as well as a change from primarily native road bed materials to limestone-based road surfacing products. To help minimize these effects on ecology, aesthetics, and wild character, the bureau is encouraging the implementation of best management practices for road, pad, and pipeline construction.

While there are physical changes in new or modified infrastructure that can be measured and compared relatively easily, it has been difficult to measure the visual changes and changes in experience that result from infrastructure development. Each forest visitor is likely to have a different perception and expectation of the forested environment, which leads to challenges in quantifying and describing those effects. The bureau will continue to explore avenues for assessing such impacts.

There are plans for a formal dust monitoring study of state forest roads in the core gas forest districts. The Bureau of Forestry will be working with the Penn State Center for Dirt and Gravel Road Studies for this monitoring effort. The bureau will also be working on methods for monitoring the reclamation of forest roads that have been impacted by shale-gas development through natural or man-made processes.

Part 2: Monitoring Values
»Flora (Plants)

I. Key Points:

- The four components of the plant monitoring program are:
  - Evaluating vegetation communities immediately adjacent to shale-gas development.
  - Monitoring tracts subject to shale-gas development for non-native, invasive plant species.
  - Assessing rare plant populations and important wetland habitats.
  - Conducting vegetation inventories in areas of potential future shale-gas extraction.
- A majority of forest conversion for the construction of gas infrastructure on state forest lands occurs in the dry oak-heath community type.
- In undisturbed forest habitat surrounding pads, New York fern (*Thelypteris noveboracensis*) and hay-scented fern (*Dennstaedtia punctilobula*) had the highest average percent cover in the understory, with 31.2 percent and 31.0 percent cover respectively. The most prevalent species in areas around the edges of pads re-vegetated with erosion and sedimentation control seed mixes were *Festuca* species, with 19.2 percent average cover, orchardgrass (*Dactylis glomerata*, 16.0 percent), and red clover (*Trifolium pratense*, 14.2 percent).
- Eleven non-native, invasive species were present on 14 of 18 pads. The invasive species with the largest mean population size was Japanese stilt-grass (*Microstegium vimineum*), which has become common across most state forest districts and spreads easily, especially along roadside corridors.
- Protocols to assess vegetation communities on rights of way, in wetlands, and for Plant Species of Special Concern populations will be developed, implemented and evaluated.
- Early Detection Rapid Response protocols for invasive plant species will be employed opportunistically during all gas monitoring activities.

II. Introduction

The Bureau of Forestry works to help conserve rare plant species, enhance existing vegetation communities, and prevent non-native, invasive species from overwhelming these communities. The ecological importance of our native flora to Pennsylvania's ecosystems cannot be understated. Plants serve as keystone species in almost every ecosystem by providing food and habitat, and by shaping site conditions such as temperature, water quality, light, and air quality. Plants also provide valuable economic resources, such as timber, and shape or influence many recreational experiences.

Approximately 3,400 plant species have been found in the commonwealth. Of the 3,400 total species, approximately 1,900 are native, flowering plants, and 1,200 are species not native to Pennsylvania (Rhoads & Block, 2007). Many of these native species have been classified into 136 unique plant community types (87 palustrine and 49 terrestrial) by Zimmerman, et al. (2012). Pursuant to the Wild Resource Conservation Act and the regulations promulgated thereunder, DCNR protects and conserves native wild plants. As a part of this act, the Bureau of Forestry, based on scientific evidence and recommendations from the Vascular Plant Technical Committee, has listed approximately 228 of the plant species in Pennsylvania as endangered, 78 as Pennsylvania threatened, and an additional 41 as Pennsylvania rare. Of these species, approximately 60 are known to exist in state forest districts subject to current shale-gas development activities. Scientific research and administrative work has been undertaken to begin revising these listings to reflect the most current field data and ecological conditions in Pennsylvania.

The bureau oversees the protection of Pennsylvania state-listed native wild plants on state forest lands by reviewing proposed shale-gas development projects and advising bureau managers on the best means to avoid impacts to rare plant species and communities. In some cases, biologists in the bureau work with operators to minimize potential impacts to species in the vicinity of development or to develop periodic monitoring to ensure that infrastructure construction and gas extraction do not have any long-term effects on the viability of rare plant populations. In addition, the bureau provides for the management of unique plant species and communities by selecting high-value sites as state forest public plant sanctuaries and state forest natural areas. In 2011, the bureau evaluated and selected sites to become high conservation value forests based on the presence of endangered or threatened species, unique vegetation communities, or watershed protection areas.

Categorizing flora resources in these ways provides the bureau with a means to prepare site- and species-specific management techniques paired with periodic monitoring to improve the viability of these unique habitats on state forest lands. As the results of studies on the impacts of forest management on native flora become available, the Bureau of Forestry continuously adapts forestry practices to protect and enhance native flora across state forest lands.

With the advent of shale-gas development, the Bureau of Forestry is interested in how this activity will impact and change native plant communities. Due to the construction of well pads, pipelines, and other associated infrastructure, thousands of acres of existing forest habitat may be converted, either temporarily or permanently, into non-forest. Similarly, many areas that were once interior forest will be converted into early-successional communities or forest edge. While this may negatively affect forest interior species, early-successional habitat often can result in a higher diversity of plant species. In addition, once temporary utilization of forest acreage by energy companies is complete, opportunities to reclaim these sites provide the bureau with the chance to restore under-represented forest types or provide unique habitat for endangered or threatened wildlife species.

With an increase in forest openings and traffic on state forest roads, the potential exists for the spread of non-native, invasive plant species into interior forest or wetland habitats that were previously less likely to be invaded. Forest managers work closely with each lessee to provide guidance in regard to pre-construction and/or post-construction monitoring for invasive plant species. In addition, district staff review plans and provide technical guidance for treatment of invasive species in construction areas.

While energy development on state forest lands does present a new form of disturbance to the forest habitat, it is still unclear what potential impacts may be most critical to address to fulfill the bureau's mission to protect and conserve native wild plants. The purpose of the plant monitoring program is to learn more about any potential impacts to vegetation communities within areas utilized for gas extraction, as well as to monitor observable long-term changes in the composition of these communities across our state forest landscape. The vegetation data collected will be used to develop more adaptive management practices that allow the development of gas resources while protecting or enhancing native plant communities in the state forest.

III. Monitoring Efforts/Results

Many existing management efforts are taking place on state forest land to better understand the ecological roles plant communities play on overall forest health. The Continuous Forest Inventory program as it exists today began in 1997 and provides basic biological data on understory plants, shrubs, tree growth and mortality, forest stand structure, volume, and change on forest lands (Bureau of Forestry, 2007). These inventories provide valuable data regarding the distribution of plant species and overall viability of the vegetation communities. This data guides decisions regarding landscape level management and silvicultural harvest schedules in all state forest districts. The forest inventory data also play a crucial role in how forest stands are classified in each district. Detailed information regarding each community type can be found in the Bureau of Forestry *Inventory Manual of Procedure for the Fourth State Forest Management Plan* (1999). These "forest community types" are used to evaluate timber management needs as well as provide for sound ecological planning on a forest landscape level. This typing data exists for the entire state forest land base, including areas utilized for gas extraction, and can be analyzed to determine how certain types of gas infrastructure impact different forest community types.

Figure 3.1 indicates that the overwhelming majority of forest conversion for the construction of gas infrastructure on state forest lands occurred in the dry oak – heath forest type, with only one other type, red maple forest, having been subject to close to 100 acres cleared. These forest types are categorized by foresters based on on-the-ground conditions and the dominant tree species across each forest landscape. These types of comparisons can be explored for any type of gas extraction infrastructure across all state forest lands or by each individual district. For instance, acres cleared for well pad construction can be seen in Figure 3.2. Current construction build-out organized by forest community type can aid district managers as new projects are planned and additional forest acreage is affected.

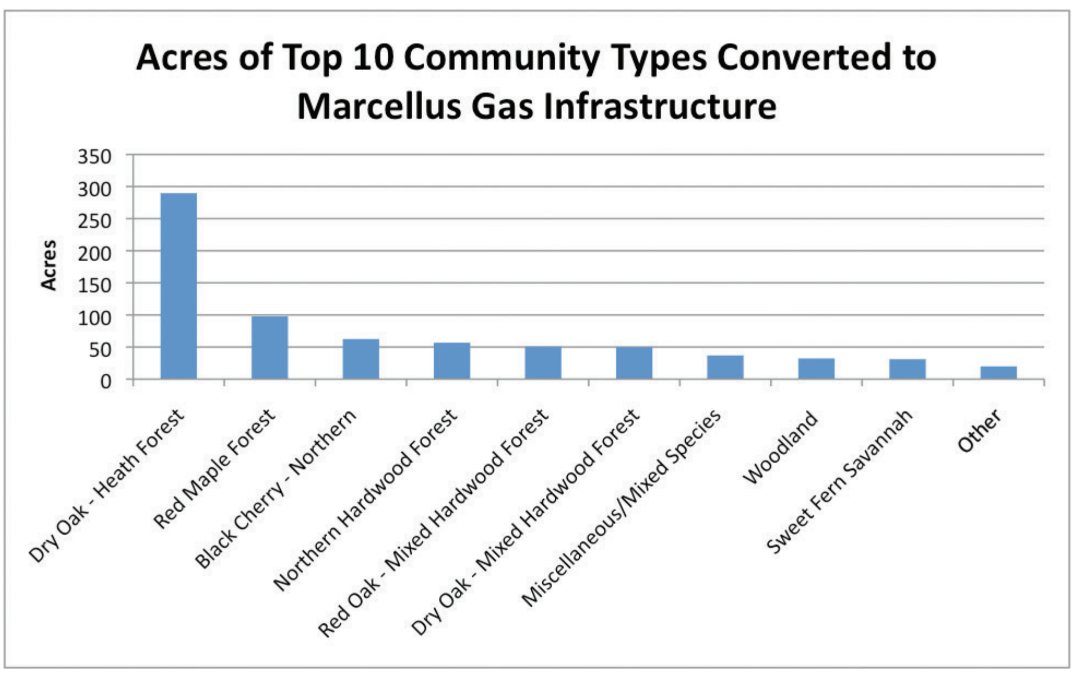


Figure 3.1 Acres cleared for shale-gas development infrastructure, arranged by forest community type.

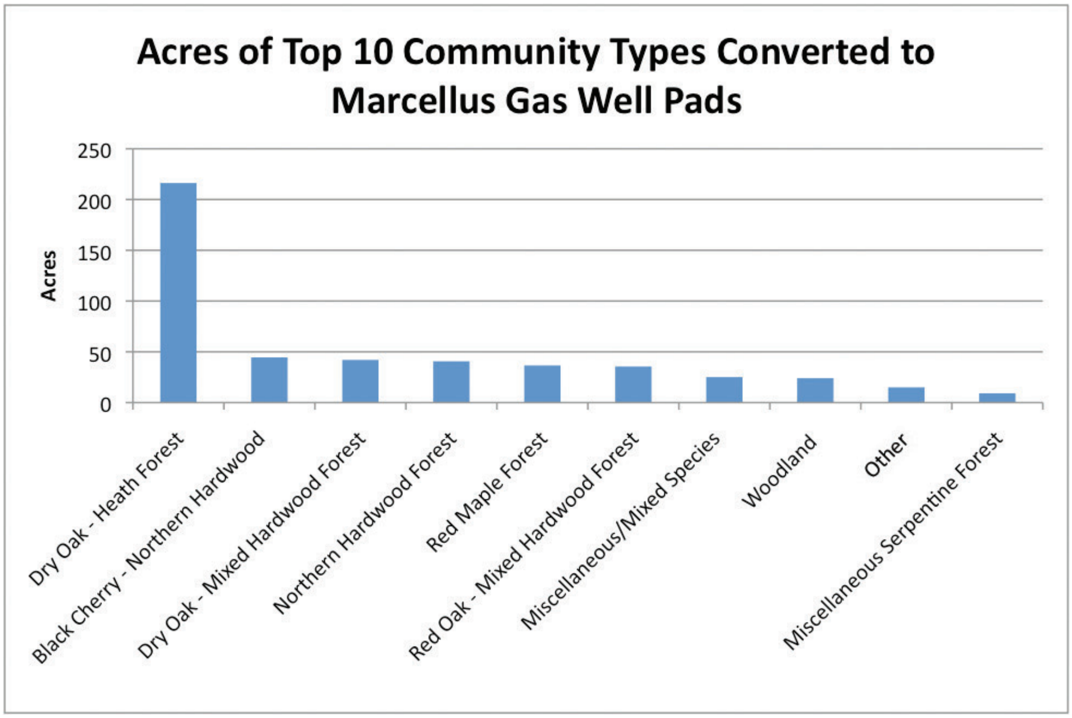


Figure 3.2 Acres cleared for well pads constructed for shale-gas development, arranged by forest community type.

The importance placed on native flora and vegetation communities by the Bureau of Forestry is reflected in vegetation monitoring efforts as part of the Shale-Gas Monitoring Program. The four components of the plant monitoring program are: 1) evaluating vegetation communities immediately adjacent to shale-gas development, including areas adjacent to well pads, roads, and rights of way; 2) monitoring tracts subject to shale-gas development for non-native, invasive plant species; 3) assessing rare plant populations and important wetland habitats that could be potentially impacted by natural gas development; and 4) conducting vegetation inventories in areas of potential future gas extraction to assess the composition of vegetation communities prior to shale-gas development. Eight protocols that address these four components of the plant monitoring program were developed, and most were piloted in the field in 2012.

1. Evaluating Vegetation Communities Adjacent to Shale-Gas Development

As gas infrastructure is constructed, forest and forest plant communities are disturbed or removed, and interior forest habitat is converted to forest edge. As this conversion occurs, it is important for the bureau to monitor how plant communities adjacent to these sites may change over time. To that end, assessment and monitoring of adjacent vegetation communities will occur on existing well pads, state forest roads used heavily for gas-related traffic and hauling, pipeline rights of way, and paths cut through the forest to facilitate seismic studies.

Well Pad Assessment

As of 2012, 143 shale-gas well pads had been constructed on state forest lands. This assessment has been created to provide a means to assess, monitor, and compare factors such as: soil conditions, vegetation communities, wildlife habitat, and erosion and sedimentation features across multiple well pads, to better understand the impacts of well pad construction in the state forest system. In addition, the monitoring design easily allows for reassessment of sites into the future to evaluate if the forest edge communities adjacent to these sites are changing. The bureau is also interested in monitoring if any opportunistic weed species become established on well pads and spread into the adjacent interior forest. Similarly, learning which native forest species are first to re-colonize the disturbed well pad edges can guide restoration efforts or provide a relative time scale to natural re-forestation efforts at these disturbed forest edges. This careful examination of vegetation at well pad edges also provides an opportunity to collect data regarding the establishment success of species typically used in seed mixes. During the 2012 field season, this protocol was piloted, and 18 well pads across all state state forest districts subject to shale-gas development were assessed. An attempt was also made to ensure that the cohort of pads selected was representative of the variety of lessees operating on state forest lands.

The vegetation portions of the well pad assessment protocol categorize plant species into three types of communities found immediately adjacent to a well pad: undisturbed forest, disturbed native vegetation (usually cleared of trees), and planted erosion and sedimentation seed mixes. Vegetation inventories are taken within milacre (1/1000-acre) plots positioned on three sides of the well pad, with two milacre plots inventoried on each side (the side of the pad with the access road is excluded). One milacre is placed 25 feet from the edge of the well pad and another 25 feet into undisturbed forest. If the first milacre plot on a side is undisturbed forest, a second plot is not completed. The relative percent cover of all species is recorded within each milacre plot, as well as a tally of all tree regeneration present. In addition to the milacre plots, the entire well pad edge is walked to determine the presence or absence of non-native, invasive plants.

The section below provides a summary of the vegetation data collected during the 2012 field season, categorized by community type: undisturbed forest, disturbed native vegetation (usually cleared of trees), and planted erosion and sedimentation seed mixes. The species with the highest incidence at well pad edges, as well as those with the highest mean percent cover across all pads, are noted.

The "undisturbed forest" community type was present on 17 of 18 pads and on 51 milacre plots. New York fern (*Thelypteris noveboracensis*) had the highest average percent cover, 31.2 percent (see Table 3.1). As would be expected, hay-scented fern (*Dennstaedtia punctilobula*) was also among the species with the highest percent cover across multiple pads (31.0 percent). All species listed in Table 3.1 that had the highest mean percent cover across multiple pads were common species that would be expected in most of the forest vegetation communities in north-central Pennsylvania. The highest percent cover of any species was Japanese barberry (*Berberis thunbergii*) at 62.5 percent, but it was only present on one plot at one pad location. Other species with high mean percent cover that were only present on one pad were climbing false-buckwheat (*Polygonum scandens*, 28.9 percent) and whorled loosestrife (*Lysimachia quadrifolia*, percent). These results are all somewhat expected, based on historical observations and forest inventory data regarding the most common species found in interior forest habitat in state forests in northern Pennsylvania.

Red maple (*Acer rubrum*) and hay-scented fern (*Dennstaedtia punctilobula*) were the species with the highest incidence among "undisturbed forest" vegetation plots (Table 3.2). In the case of this community type, three out of four of the plants with the highest incidence were tree species. These results were also expected based on existing forest inventory data. Red maple and hay-scented fern are very common across Pennsylvania.

The "disturbed native" vegetation type was present on five of 18 pads and on nine milacre plots. These areas were typically used for staging of equipment during well pad construction and were cleared of trees; however, the native vegetation was not removed entirely and supplemental plantings were not always necessary. bracken fern (*Pteridium aquilinum*) had the highest average percent cover, 23.2 percent (see Table 3.3). Once again, all species listed in Table 3.3 that had the highest mean percent cover across multiple pads were common woody species that would be expected in most of the forest edge vegetation communities in north-central Pennsylvania. The highest percent cover of any species was white clover (*Trifolium repens*) at 41.5 percent, but it was only present on one plot at one pad location. Other species with high mean percent cover that were only present on one pad were sweet-fern (*Comptonia peregrina*, 41.5 percent) and common wheat (*Triticum aestivum*, 10.2 percent). The white clover and common wheat were found in areas where supplemental seeding took place within the areas of disturbed, native vegetation.

Species	Number of Pads	Percent Cover
New York Fern *(Thelypteris noveboracensis)*	3	31.2
Hay-Scented Fern *(Dennstaedtia punctilobula)*	11	31.0
Mountain Laurel *(Kalmia latifolia)*	5	15.3
Southern Low Blueberry *(Vaccinium pallidum)*	4	10.8
Wintergreen *(Gaultheria procumbens)*	4	10.6
Striped Maple *(Acer pensylvanicum)*	2	10.2
Late Low Blueberry *(Vaccinium angustifolium)*	6	9.7
American Beech *(Fagus grandifolia)*	5	9.3
Sweet-Fern *(Comptonia peregrina)*	2	8.9
Bracken Fern *(Pteridium aquilinum)*	4	7.9

Table 3.1 Highest mean percent cover values for "undisturbed forest" plots. Species found on only one pad not included in table.

Species	Number of Pads	Number of Plots
Red Maple *(Acer rubrum)*	15	34
Hay-Scented Fern *(Dennstaedtia punctilobula)*	11	21
American Beech *(Fagus grandifolia)*	7	12
Striped Maple *(Acer pensylvanicum)*	7	9

Table 3.2 Highest species incidence for "undisturbed forest" plots.

Species	Number of Pads	Percent Cover
Bracken Fern *(Pteridium aquilinum)*	2	23.2
Wintergreen *(Gaultheria procumbens)*	2	12.5
Hay-Scented Fern *(Dennstaedtia punctilobula)*	2	10.2
Witch-Hazel *(Hamamelis virginiana)*	2	6.6

Table 3.3 Highest mean percent cover values for "disturbed native" vegetation plots.

Species	Number of Pads	Number of Plots
Carex Species *(Carex spp.)*	4	4
Bracken Fern *(Pteridium aquilinum)*	3	4
Northern Red Oak *(Quercus rubra)*	3	4
Deer-Tongue Grass *(Panicum clandestinum)*	3	3

Table 3.4 Highest species incidence for "disturbed native" vegetation plots.

Bracken fern (*Pteridium aquilinum*) and northern red oak (*Quercus rubra*) were among the species with the highest incidence among "disturbed native" vegetation plots (Table 3.4). It was somewhat surprising to not see high incidence of red maple (*Acer rubrum*) and hay-scented fern (*Dennstaedtia punctilobula*), given how common these species are across forest habitats in Pennsylvania.

The "erosion and sedimentation" vegetation type was present on 16 of 18 pads and on 30 milacre plots. Festuca species had the highest average percent cover, 19.2 percent (see Table 3.5). Orchardgrass (*Dactylis glomerata*) and red clover (*Trifolium pratense*) were also among the species with the highest percent cover across multiple pads (16.0 percent and 14.2 percent, respectively). All species listed in Table 3.5 that had the highest mean percent cover across multiple pads are species that are often found in seed mixes used to re-vegetate areas following construction, with the exception of bigtooth aspen (*Populus grandidentata*) and field sorrel (*Rumex acetosella*). The highest percent cover of any species was quackgrass (*Elymus repens*) at 62.5 percent, but it was only present on one plot at one pad location. Other species with high mean percent cover that were only present on one pad were fringed brome grass (*Bromus ciliatus*, 12.5 percent) and common wheat (*Triticum aestivum*, 10.2 percent).

Species	Number of Pads	Percent Cover
Fescue Species (Festuca spp.)	4	19.2
Orchardgrass (Dactylis glomerata)	2	16.0
Red Clover *(Trifolium pratense)*	6	14.2
Rush Species *(Juncus spp.)*	2	12.7
Bigtooth Aspen *(Populus grandidentata)*	2	10.2
Virginia Wildrye *(Elymus virginicus)*	2	9.1
Birdsfoot Trefoil *(Lotus corniculatus)*	7	7.8
Field Sorrel *(Rumex acetosella)*	2	7.5
White Clover *(Trifolium repens)*	7	7.3

Table 3.5 Highest mean percent cover values for "erosion and sedimentation" vegetation plots.

Species found on only one pad not included in table.

Species	Number of Pads	Number of Plots
White Clover *(Trifolium repens)*	7	9
Birdsfoot Trefoil *(Lotus corniculatus)*	7	12
Red Clover *(Trifolium pratense)*	6	11
Timothy *(Phleum pratense)*	5	7
Perennial Rye Grass *(Lolium perenne)*	5	7

Table 3.6 Highest species incidence for "erosion and sedimentation" vegetation plots.

White clover (*Trifolium repens*), birdsfoot trefoil (*Lotus corniculatus*), and red clover (*Trifolium pratense*) were the species with the highest incidence among "erosion and sedimentation" vegetation plots (Table 3.6). This is an expected result since these are likely the three species used most often in seed mixes to fix nitrogen in the soils. Similarly, *Phleum pratense* (Timothy) and *Lolium perenne* (perennial rye grass) are frequently included in soil stabilization seed mixes used following well pad construction.

Non-native species were present on 14 of 18 pads, and 11 species on the DCNR Invasive Plants List were found (see Table 3.7). The invasive species with the largest mean population size was Japanese stilt grass (*Microstegium vimineum*). This species is found throughout the state forest system and is often one of the first invasive species to invade disturbed habitats, roadsides, and recently harvested forest stands. Many of the other invasives found in Table 3.7, such as crown-vetch (*Coronilla varia*), Canada thistle (*Cirsium arvense*), and spotted knapweed (*Centaurea stoebe*) also prefer disturbed edge habitats. Some troubling species include Japanese knotweed (*Polygonum cuspidatum*) and garlic-mustard (*Alliaria petiolala*), which can quickly colonize large portions of the well pad edge and inhibit native vegetation or prevent erosion and sedimentation seed mixes from establishing.

Few conclusions or management recommendations can be drawn from only one year of well pad vegetation data. However, this data will be valuable as plot re-measurement begins in subsequent years to establish how these vegetation communities are changing over time. In 2013, another 18 well pads were selected. The focus for the 2013 well pad cohort was to segregate well pads based on the surrounding forest type and use adjacent forest as a means to stratify random sampling. Consideration was also given to well pads adjacent to other disturbed forest habitats, such as rights-of-way or recently harvested forest stands. It is possible that disturbed habitats are more vulnerable to invasion than the oak-heath forests that surround most of the 2012 cohort of well pads, due to the heavy mountain-laurel and ericaceous cover in these stands that limit most early-successional vegetation. Developing a better understanding of vulnerable sites will yield further

Species	Number of Pads	Population Size (# of plants)
Japanese Stilt Grass *(Microstegium vimineum)*	3	60
Crown-Vetch *(Coronilla varia)*	1	38
Canada Thistle *(Cirsium arvense)*	4	27
Reed Canary-Grass *(Phalaris australis)*	2	27
Bull-Thistle *(Cirsium vulgare)*	1	16
Spotted Knapweed *(Centaurea stoebe)*	5	13
Japanese Barberry *(Berberis thunbergii)*	1	3
Honeysuckles *(Lonicera spp.)*	1	3
Multiflora Rose *(Rosa multiflora)*	1	3
Japanese Knotweed *(Polygonum cuspidatum)*	1	3
Garlic-Mustard *(Alliaria petiolala)*	1	3

Table 3.7 Mean population size among invasive species.

insights that should aid in future well pad invasive species management. Similarly, by monitoring erosion and sedimentation seed mix communities over time, the bureau can better determine which mixes perform best in each state forest district subject to shale-gas development. The goal in measuring the same plots over time is to better understand how frequently native forest species are colonizing pad edges and how often non-native planted species in the seed mix are colonizing forest habitats adjacent to the well pads.

In addition to analyzing well pad data, the Bureau of Forestry is collaborating with researchers at Penn State University to better understand vegetation composition at the disturbed edges of well pads and how invasive plant species are spreading across the landscapes as a result of well pad construction. Both the bureau's and Penn State's efforts can be combined to provide a richer view of the vegetation communities found at shale-gas well pads and enable more pads to be visited each year.

Roadside Plant Communities

Prior to the use of state forest lands for shale-gas extraction, state forest roads often saw little use except for occasional timber hauling, snowmobiling in the winter months, and other general forest recreation by the public. Since shale-gas development began in 2008 on state forest lands, the quantity of truck traffic on these forest roads has increased. State forest roads are essential for transporting equipment and materials to and from natural gas development sites and remote leased tracts. As tracts have been developed, there has also been a need for widening or expansion of existing roads and, at times, the construction of new roads. As of December 2012, approximately 161 miles of state forest roads had been used in some way for shale-gas development activities (See Figure 3.3). Due to the heavy use and expansion of roads on state forest lands, there is a desire to better evaluate how existing roadside vegetation communities may be impacted and assess the composition of these communities along newly constructed roads. In addition, the increased traffic has the potential to carry with it non-native weeds and invasive plant species into habitats which were previously not impacted by these species.

The purpose of this roadside vegetation protocol is to attempt to understand how the composition of roadside plant communities may change over time as a result of increased state forest road use. The increase in hauling and truck traffic on state forest roads has the potential to carry plant seed onto new roadside habitats and to increase the amount of non-native weeds and invasive species in some heavily used corridors. Similarly, when roads are widened to accommodate truck traffic, this disturbance may shift species composition to early successional plant species. Efforts will be focused on monitoring roadside plant communities along heavily travelled corridors, but they will also assess similar roadside communities along state forest roads not used for gas-related activities.

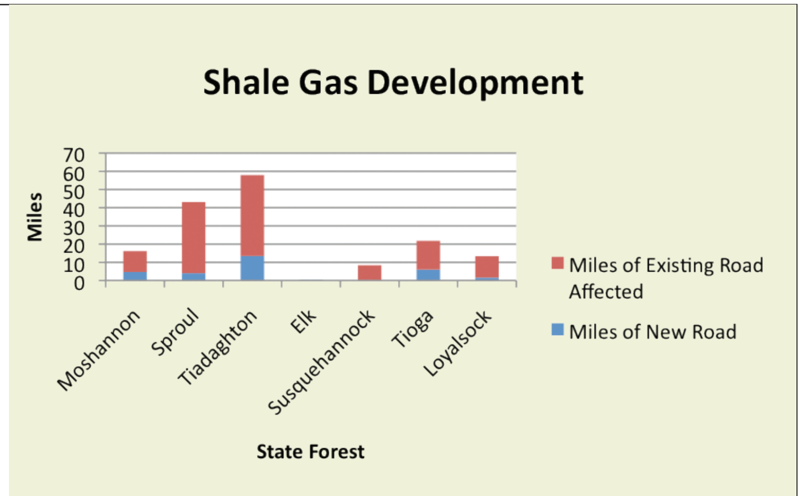


Figure 3.3 Miles of state forest roads affected by shale-gas development activities (per district).

Four sections of state forest roads were chosen within each district subject to shale-gas development. All roads that were chosen are not maintained by PennDOT or municipalities. Within each district, two roads that are subject to heavy gas traffic and two roads not yet used for gas hauling were selected. For the roads chosen for the study, 2.5-mile portions were identified that were free of intersections with roads of other types. Within these 2.5-mile portions, milacre vegetation plots were established at 0.25 miles, 1.25 miles, and 2.25 miles on both sides of the roadway. The first and last quarter miles function primarily to buffer any effects from intersections with roads of other types. These milacre plots were established 90 degrees perpendicular to the roadway and four feet from the road edge.

Similar to the well pad vegetation data protocols, before vegetation sampling began, the habitat/vegetation type at each milacre plot was recorded. The protocol categorizes plant species into three types of communities that are found along roadsides: undisturbed forest, disturbed native vegetation (usually cleared of trees), and planted erosion and sedimentation seed mixes. The abundance of all herbaceous plants and tree seedlings was estimated in terms of the percent of the area of the milacre plot occupied by each species. Visual estimates of abundance have been chosen as the most effective and expedient means of quantification. In addition to the visual estimates of abundance, the number of regenerating trees is counted in each milacre plot. Tree saplings greater than or equal to one foot in height and less than one inch in diameter will qualify as regeneration. After the vegetation plots are completed, a vegetation assessment and invasive plant species inventory is completed at the road culvert closest to each pair of plots.

During the 2012 field season, this protocol was piloted by monitoring field staff and plant specialists. Field data collection was tested along John Merrell Road and Hillsgrove Road in Loyalsock State Forest. Twenty-eight roads were selected for this study, and data collection was completed during the 2013 field season. The period between monitoring events will be determined once the 2013 data has been evaluated.

Pipeline Rights of Way

The cleared right-of-way (ROW) corridors on state forest land account for many acres of linear disturbance and forest edge habitat. These rights of way often are comprised of disturbed grassland or shrub habitat in full sun, which often provides ideal habitat conditions for non-native, invasive plant species. Additionally, these rights of way can act as a starting point for further movement of invasives established in the right-of-way to forested habitat outside of the existing corridor. The ability for invasives to “jump” from the right of way to adjacent habitats is especially concerning in areas such as stream crossings, timber sales, burned areas, road or trail crossings, wetlands, and other sensitive palustrine ecosystems.

This protocol addresses the need to develop a better understanding of where non-native invasive species are currently colonizing newly constructed ROWs and to track treatment efforts of these populations. It will also help to determine where established populations of invasive species are moving from these corridors to adjacent forest habitats. By targeting habitat areas of highest concern along the right-of-way corridor, such as stream crossings, road crossings, spring seeps, and recently harvested timber sales, resources can be focused on the areas with the highest potential for establishment by an invasive plant species. It is likely that many portions of newly constructed rights of way have been successfully reclaimed and native forest vegetation has become established; however, it is important for forest managers to understand where the most vulnerable sites are located and how to manage these sites into the future.

The proposed protocol for right-of-way vegetation monitoring is two-fold: collect vegetation community data at randomly selected locations and conduct vegetation assessments at habitat “hot spots.” Based on the proposed/finished width of the selected pipeline rights of way, center points will be generated for grid cells 100 feet long and equal to the right-of-way width. At the center point, the first milacre plot will be established and data collected. Based on the width of the right of way, two additional milacre plots will be established. If the right of way is greater than 100 feet wide, the milacre plots will be located 33 feet from the center point at a bearing perpendicular to the pipeline. If the corridor is less than 100 feet in width, the milacre plots will be located by calculating an equal distance from the center point to the undisturbed edge (ex. 50-foot-wide right of way, then locate additional plots at 12.5 feet from center point). The abundance of all herbaceous plants and tree seedlings will be estimated in terms of the percent of the area of the milacre plot occupied by each species. Visual estimates of abundance have been chosen as the most effective and expedient means of quantification.
In addition to the visual estimates of abundance, the number of regenerating trees will be counted in each milacre plot. Tree saplings greater than or equal to one foot in height and less than one inch in diameter will qualify as regeneration.

To allow the field staff to react to conditions on the ground, a procedure for establishing vegetation plots in the field for vulnerable features not accounted for in the random selection has also been developed. Once a potential vector has been identified, field crews will proceed to the edge of the right of way and use GPS equipment to map the site. After proceeding 100 feet along a transect, a milacre plot will be established and vegetation data will be collected. When possible, data collection will continue by following the same transect for another 100 feet, and another plot will be established. If the feature is nonlinear in shape, additional plots will be established at 90-degree intervals from initial plot center to achieve necessary representation of conditions across the site.

The initial scope of this protocol is to sample a subset of the current pipeline right-of-way corridors, but it may also have application on evaluating areas being considered for future rights of way. Upon successful piloting in 2013, a randomly generated sample of all pipeline corridors across state forest lands will be evaluated annually beginning in 2014. This protocol can also be used to address sites that land managers and gas operators found to be extremely difficult to construct or reclaim.

Seismic Survey Lines

During the course of seismic survey activities, at times there is a need to cut trails or paths into the forest to access remote areas of the state forest for testing. While this is often accomplished by hand trimming or tying of the vegetation, there are situations where mulching equipment is used to cut a wider access path. The seismic lines subject to mulching have the potential to facilitate the colonization of non-native, invasive species into interior forest habitats that otherwise would have been unsuitable for invasion. To better inform management practices, one objective is to analyze the effects of these mulched or cleared seismic lines on forest vegetation communities and track the increase or decrease in native herbaceous and woody regeneration along these seismic line corridors. A sample of mulched or mowed seismic line routes created over the past four years for 3D seismic surveys will be evaluated to determine the composition

of the vegetation communities within these corridors, and to determine if invasive species exist within the mulched areas and how any invasive species may be spreading along these lines into interior forest habitats.

For each seismic project selected for this study, six seismic lines will be randomly selected to assess the impacts on herbaceous/woody plant communities. For each seismic line (beginning at the point of access), six milacre plots will be placed at 200-foot intervals along the same transect. This distance provides an opportunity to attempt to minimize effects on the composition of forest vegetation due to the nearby road and forest edge. Six additional milacre plots will be placed at 200-foot intervals on an azimuth parallel to the seismic line and ending at a point 200 feet parallel from the starting point in undisturbed forest habitat. At plot centers 3 and 7, a wooden stake will be placed at the center point to remain at the site for navigation and future reference. The abundance of all herbaceous plants and tree seedlings will be estimated in terms of the percent of the area of the milacre plot occupied by each species. Visual estimates of abundance have been chosen as the most effective and expedient means of quantification. In addition to the visual estimates of abundance, the number of regenerating trees will be counted in each milacre plot. Tree saplings greater than or equal to one foot in height and less than one inch in diameter will qualify as regeneration. Upon completion of milacre plots, a walkabout survey will be conducted from the access point (often a road edge) to the first plot center to include the area within the mowed seismic line and the forest/seismic line interface. This walkabout will capture any invasive or non-native weed species that have begun to colonize the seismic line corridor from roadside habitats. For the 2013 field season, four seismic projects were chosen to include a sampling of operators and stand types, as well as state forest lands that border private land holdings.

2. Monitoring Shale-Gas Development Areas for Invasive Plant Species

Invasive plant material can be brought onto state forest lands on construction equipment, vehicles, or fill material, such as rock, hay, or mulch. Similarly, by creating additional openings (well pads, pipeline rights of way, etc.) newly developed areas could be more easily colonized by invasive species than interior forest habitat. This type of opportunistic colonization of state forest lands by invasive species has been occurring for many years due to visitor use, dispersal by birds, and forest management activities; however, the development of natural gas resources has the potential to escalate this phenomenon and bring certain species into remote forest tracts that previously were considered less likely to be subject to invasion by new invasive plant populations.

The bureau has developed an Early Detection Rapid Response protocol to help detect and control invasive plant species introductions in areas of shale-gas development. See the Invasive Species chapter for more information.

3. Assessing Rare Plant Populations and Critical Wetland Habitats

State forest lands provide a protected landscape that harbors many rare plants, as well as many unique wetland or palustrine forest habitats. These rare plants are state-listed or proposed to be listed as PA Endangered, PA Threatened, and PA Rare. In the past, many of these plant occurrences or wetland habitats were considered to be “secure” based on their remote, interior forest location on state forest lands and, therefore, were not well surveyed or visited often. During the planning stages of placing gas infrastructure on state forest lands, the bureau goes to great lengths to attempt to avoid impacts to wetland habitats. In almost all cases, a 200-foot no-disturbance buffer is required between new construction and the delineated edge of the wetland. However, there are projects in which no viable option exists to avoid encroaching on the wetland buffer, and a waiver is issued, if appropriate. With increased shale-gas development activity, it is important to evaluate these sites to examine potential changes in the surrounding plant communities to intervene before any perceived changes can impact populations of these listed species or these unique habitats.

Monitoring Rare Plant Populations

Populations of many Pennsylvania rare plants, such as creeping snowberry (*Gaultheria hispidula*, PA Rare), yellow-fringed orchid (*Platanthera ciliaris*, Proposed PA Threatened), great spurred violet (*Viola selkirkii*, PA Rare), and northeastern bulrush (*Scirpus ancistrochaetus*, PA Threatened, Federally Endangered), are known to exist in the vicinity of shale-gas development on state forest lands. As time allows, updating data for known occurrences will help provide insight regarding the health of these populations as well as the surrounding plant communities. Similarly, opportunities exist for discovery of new populations of rare plants. In both the case of occurrence updates and new discoveries, it is important that the appropriate survey and data collection processes take place to fully document the population for inclusion or update within the PA Natural Diversity Inventory (PNDI) system. To that end, protocols have been created based on Goff et al. (1982) and "Protocols for Conducting Surveys for Plant Species of Special Concern" (PA DCNR, 2011).

This particular protocol will apply to core gas forest districts. The main focus will be on known state-listed populations that are located within 1,000 feet of shale-gas development areas or infrastructure. As plant populations are visited, they will be evaluated relative to one another to determine if any species or individual populations are being affected by nearby shale-gas development.

Evaluating Wetland Encroachment Buffers

One planning tool used by the bureau to avoid impacts to wetland habitats is the 200-foot no-encroachment buffer from disturbance that is applied around all delineated wetland habitats. This buffer helps prevent direct or indirect impacts as a result of the construction of infrastructure for shale-gas development. In almost all cases, gas operators work with forest managers to maintain these buffer zones and shift infrastructure to comply with this buffer guideline. However, at times, deviations from this practice are necessary due to construction limitations, topography, or to resolve resource management conflicts. In these cases, if appropriate, a waiver is issued. (See the Infrastructure Chapter for more information on waivers).

While the bureau does grant waivers for encroachment within wetland buffers, these bureau buffer guidelines are often larger than permit requirements (Act 13 of 2012 requires well bores to be 300 feet from a wetland and any disturbance to be at least 100 feet from a wetland). Bureau buffer guidelines are 200 feet from the edge of disturbance. Encroachment within a bureau wetland buffer area does not necessarily mean an encroachment within a wetland buffer associated with an applicable DEP permit.

This protocol will compare the areas in which a wetland buffer encroachment waiver was granted, as well as comparable areas in which the 200-foot wetland buffer was maintained. Monitoring the wetland vegetation communities that were not subject to a 200-foot buffer allows for better assessment of how the bureau should grant these types of waivers in the future. This work can inform policy decisions in the short and long term by assessing current best management practices for wetland avoidance as well as the potential effects of reducing or expanding the wetland buffer size. Often bureau personnel have to balance a number of factors as they consider proposals for infrastructure from gas operators on state forest lands. By having more data regarding potential impacts to wetland habitats, bureau personnel can make more informed decisions in the future regarding where to locate proposed infrastructure, or how to more effectively review waiver proposals, or even the size of the 200-foot buffer distance itself.

The protocol developed to assess these buffer areas and associated wetland habitats will allow for data collection in the buffer zone as well as within the nearby wetland community and will be carried out on all applicable sites. Starting from the edge of the encroachment site, the exact distance will be measured to the delineated edge of the wetland habitat to verify the distance described in the waiver request. In total, four milacre plots will be examined within the area from the edge of construction to the center of the wetland. All four milacre plots are to be located along the same transect, with the first plot located four feet from the edge of construction in the direction of the wetland. The second milacre plot center will be located equidistant from the edge of construction and the delineated edge of the wetland. The third milacre plot center will be placed at the delineated edge of the wetland. The final milacre plot center will be located 100 feet from the edge into the wetland, or at the perceived center of the wetland, whichever distance is less. When another wetland habitat adjacent to the same project that was able to be buffered by 200 feet is present, a similar milacre plot arrangement can be used to evaluate this second wetland as a reference site to serve as a comparison to conditions at the encroached wetland.

The abundance of all herbaceous plants and tree seedlings will be estimated in terms of the percent of the area of the milacre plot occupied by each species. Visual estimates of abundance have been chosen as the most effective and expedient means of quantification. In addition to the visual estimates of abundance, the number of regenerating trees will be counted in each milacre plot. Tree saplings greater than or equal to one foot in height and less than one inch in diameter will qualify as regeneration. This vegetation data will be used to track any changes in vegetation communities over time, as well as to attempt to evaluate the effectiveness of wetland buffer zones as a means to protect the health of these wetland habitats.

4. Baseline Vegetation Community Inventories in Potential Shale-Gas Development Areas

Another component of the vegetation monitoring program is conducting vegetation inventories in areas that have yet to be developed for natural gas extraction. The sampling design for this monitoring will be based on Before-After Control Impact (BACI). This sampling design allows for data collection before a particular event in areas likely to be impacted by an event and in areas that will not be impacted. Then, following a particular event, the same sites are re-evaluated. Vegetation plots will be established within a given tract or state forest district in areas that will be impacted by development and those that will not. These plots will be permanent and will be visited before development takes place and after development has concluded. The first cluster of sampling plots is chosen based on forest stand type and is situated adjacent to proposed gas infrastructure (well pad, right-of-way, new road). A second cluster is then chosen in that same stand type, but in a random location at least 300 feet from proposed infrastructure.

This cluster sampling process is similar to the Bureau of Forestry's Wild Areas Inventory (2007). The abundance of all herbaceous plants and tree seedlings will be estimated in terms of the percent of the area of the milacre plot occupied by each species. Visual estimates of abundance have been chosen as the most effective and expedient means of quantification. In addition to the visual estimates of abundance, the number of regenerating trees will be counted in each milacre plot. Tree saplings greater than or equal to one foot in height and less than one inch in diameter will qualify as regeneration. Over time, this data can be used to describe potential changes to forest communities due to shale-gas development within varying stand types across the state forest. As these changes are described and understood, the data can provide valuable insight into how best to develop gas resources on state forest lands in the future or adapt best management practices to better protect native forest vegetation communities.

IV. Conclusion

Field work occurred in 2013 relating to all eight protocols that address the four components of the plant monitoring program. A second cohort of 18 well pads will be selected, with a focus on selecting pads that are adjacent to other disturbed forest habitats, such as rights of way or recently harvested forest stands, as well as pads that are located in more unique forest stand types. Twenty-eight sections of state forest roads in shale-gas development areas have been selected for roadside vegetation community monitoring – 14 sections that are heavily utilized for gas hauling and 14 that are not used for gas hauling. Protocols to assess vegetation communities on pipeline rights of way and lines cleared for seismic surveys will be piloted. Twenty populations of rare plant species that are within 1,000 feet of disturbance due to gas extraction will be surveyed to assess any potential threats to their viability. Pre-development inventories of vegetation communities will continue across leased state forest tracts during upcoming field seasons. An assessment of vegetation communities in areas in which wetland encroachment waivers were granted during infrastructure construction also will take place. Early Detection Rapid Response protocols for invasive plant species will be employed opportunistically during all gas monitoring activities, and any invasive plant species found while completing vegetation monitoring activities will be immediately treated or brought to the attention of forest managers.

In addition to plant monitoring efforts already scheduled, monitoring personnel also will evaluate additional partnerships or studies to undertake to further the understanding of the potential effects of natural gas development on state forest vegetation communities. As mentioned above, the bureau has entered into a partnership with Penn State researchers to better understand vegetation communities surrounding completed well pads and how species on these well pad edges may spread into adjacent interior forest. Similarly, ecologists from the Western Pennsylvania Conservancy

will begin a project to assess moss and lichen species around well pads and compare these species to those found within recently harvested forest stands, and to mosses and lichens found in undisturbed, mature forests.

As some development sites enter the production phase, the bureau also hopes to begin to monitor reclamation efforts that utilize native plant species. As pipeline rights of way, well pads, and other associated infrastructure are seeded and reclaimed, evaluating the success of these efforts is necessary to further the bureau's knowledge of appropriate seed mixes and planting procedures. This work would be carried out based on the bureau's Seed Monitoring Protocol in conjunction with the bureau's Native Planting Guidelines. This monitoring would take place as sites are reclaimed using the guidelines and will follow the protocol developed for that particular type of infrastructure. For instance, if a right-of-way is seeded with a native seed mix, it would be monitored using right-of-way protocols explained above.

It is difficult to draw solid conclusions from this initial plant monitoring data. As the data set grows and vegetation data from multiple years is available, comparisons across sites will be possible. Annual monitoring of some sites also will provide a better understanding of how vegetation is changing immediately adjacent to shale-gas infrastructure and the ways in which the undisturbed forest communities are beginning to reclaim disturbed sites. As conclusions regarding the changes in vegetation communities are drawn, this data will be utilized to better the bureau's adaptive management strategy across all state forest districts subject to shale-gas extraction, and to facilitate better siting of infrastructure and management of construction to limit potential impacts that threaten the viability of forest plant communities.

Part 2: Monitoring Values
»Forest Health

I. Key Points:

- The principal damage-causing agents from 2008 to 2012 in the core gas forest districts activities were the gypsy moth, forest tent caterpillar, and frost.
- The bureau will monitor forest edges created by well pads, pipelines and roads for tree dieback, decline, and mortality.
- Increased susceptibility to pest attack, especially by non-native invasive species, may occur wherever there is forest disturbance, especially for trees along newly created edges.
- Impacts in the forests surrounding disturbance can only be discovered through long-term forest health monitoring.

II. Introduction

The bureau's forest health program is conducted under authority of the Conservation and Natural Resources Act and has as its purpose the protection of all forestland in the state from "fungi, insects, and other enemies." The program is designed to reduce pest-caused economic losses by utilizing integrated forest pest management strategies, providing assistance, and conducting projects aimed at preventing, detecting, evaluating, and suppressing forest pest outbreaks. Protection is provided to the extent possible with available manpower and funding commensurate with the involved values and ecological concerns.

The purpose of the forest health program in Pennsylvania is to protect forest resources from forest pests and other adverse factors to ensure the long-term health of the commonwealth's forest ecosystems. The bureau promotes programs to improve and maintain the long-term health and biodiversity of forest ecosystems, including urban forests. The bureau evaluates biotic and abiotic factors affecting the health of trees and woodlands, utilizes integrated pest management techniques to mitigate the effects of destructive agents, and promotes forest health to the public.

Maintaining forest health and the management of destructive insects and disease is a statewide concern. For the purposes of this report, however, the focus is on data and information available in the core gas forest districts where shale gas development is the most prevalent. Over time this will allow the bureau to evaluate if any forest health trends are related to shale gas activity.

Non-native invasive forest pests are a significant threat to forests, and considerable effort and resources are expended to detect, monitor, assess, and control non-native invasive forest pests. The bureau works cooperatively with the Pennsylvania Invasive Species Council, the Pennsylvania Department of Agriculture, the U.S. Department of Agriculture (USDA), and other state agencies and organizations to coordinate its efforts regarding invasive species. Some of the major invasive forest insect and disease pests established in Pennsylvania are the gypsy moth (GM), hemlock woolly adelgid (HWA), emerald ash borer (EAB), thousand cankers disease (TCD) and walnut twig beetle (WTB), *Sirex* woodwasp, butternut canker (BC), elongate hemlock scale (EHS), chestnut blight, Dutch elm disease, and beech bark disease (BBD). Other non-native invasive forest pests not yet detected in Pennsylvania but which would cause considerable tree mortality are the sudden oak death (SOD) pathogen, Asian longhorned beetle (ALB), exotic bark beetle, and winter moth.

The following strategies are used throughout Pennsylvania in the forest health program: 1) *Integrated Pest Management* – Utilize ecologically sound integrated pest management techniques to study, survey, monitor, assess, and protect forest ecosystems; 2) *Information and Education* – Provide employees, cooperators, forest land owners, and forest users with readily available, easily understood, and usable forest health information and training; 3) *Technology and Innovation* – Use innovative and technological solutions to improve forest health programs; and 4) *Organizational Performance* – Operate a professional organization that efficiently and effectively meets the needs of employees, cooperators, forest land owners, and forest users.

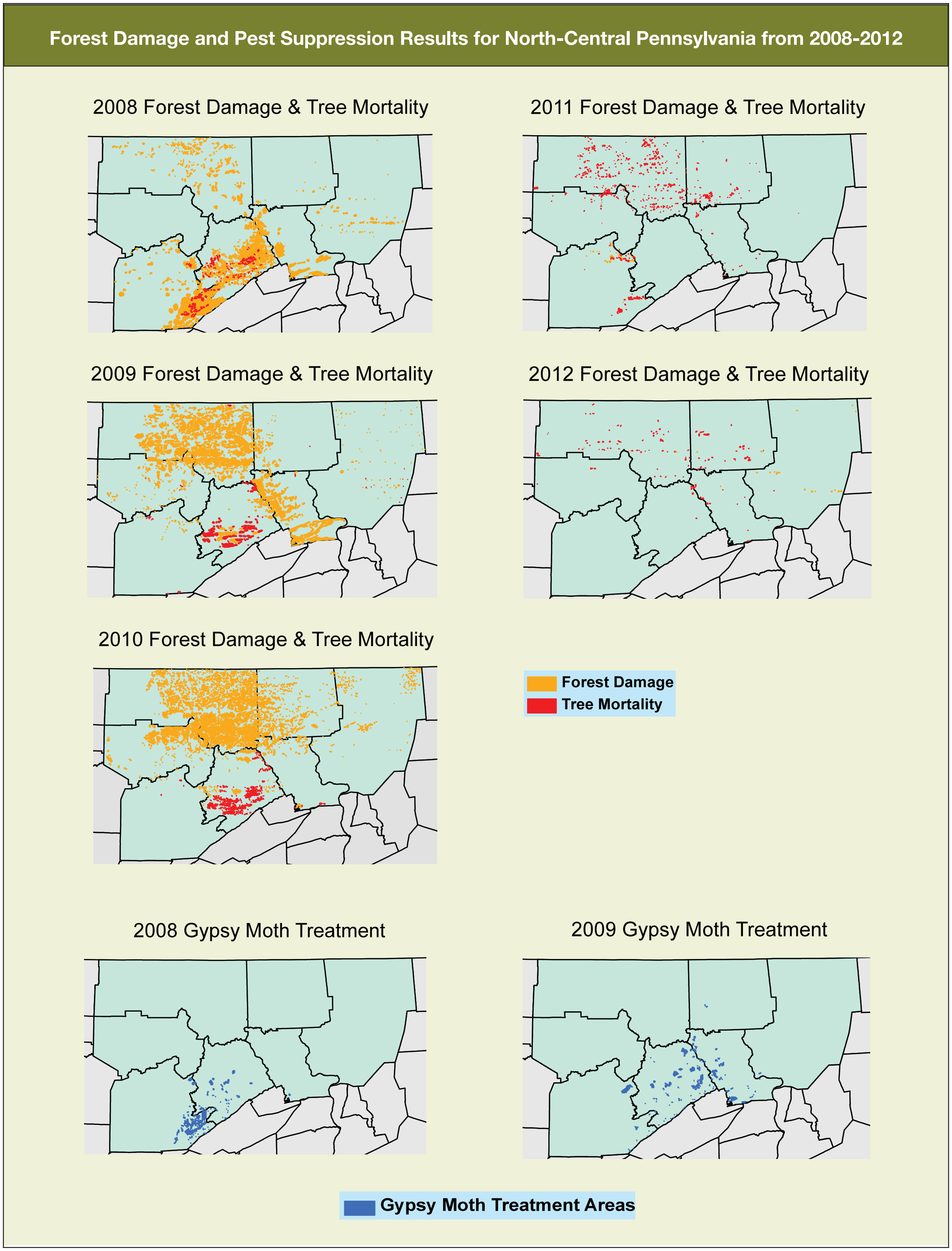
III. Monitoring Efforts/Results

The Bureau of Forestry participates with the USDA Forest Service in the Forest Health Monitoring (FHM) program. Forest Health Monitoring is a national program designed to determine the status, changes, and trends in indicators of forest condition on an annual basis. The FHM program uses data from ground plots and surveys, aerial surveys, and other biotic and abiotic data sources and develops analytical approaches to address forest health issues that affect the sustainability of forest ecosystems. FHM covers all forested lands through a partnership involving the USDA Forest Service, state foresters, and other state and federal agencies and academic groups.

The evaluation monitoring component of the Forest Health Monitoring program is designed to determine the extent, severity, and causes of undesirable changes in forest health identified through detection monitoring and other means. The need for evaluation monitoring projects arises when significant forest health changes or trends are found in detection monitoring. Evaluation monitoring also provides additional information about forest health improvements, such as improved plant vigor, resulting from air pollution abatement. Detection monitoring is conducted by the bureau on an annual basis through aerial forest health surveys, forest insect and disease reporting, and specialized surveys.

Annual aerial surveys are conducted across Pennsylvania to detect forest damage and tree mortality. Ground-truthing is conducted to confirm unknown causes of the damage. Ground surveys using forest insect and disease reporting procedures are used to determine the presence or absence of forest pests and to document damage when present.

Specialized surveys conducted include Asian longhorned beetle, emerald ash borer, hemlock woolly adelgid, elongate hemlock scale, *Sirex noctilio* woodwasp, exotic bark beetle, sudden oak death, sugar maple decline, butternut canker, ash yellows, beech bark disease, gypsy moth, forest tent caterpillar, winter moth, and thousand cankers disease and the walnut twig beetle vector.



Forest Damage and Pest Suppression Results for North-Central Pennsylvania from 2008-2012
2008 Forest Damage & Tree Mortality
2011 Forest Damage & Tree Mortality
2009 Forest Damage & Tree Mortality
2012 Forest Damage & Tree Mortality
2010 Forest Damage & Tree Mortality
Forest Damage
Tree Mortality
2008 Gypsy Moth Treatment
2009 Gypsy Moth Treatment
Gypsy Moth Treatment Areas

Figure 4.1

Year	Programs	Forest Districts							Total
		9-Moshannon	10-Sproul	12-Tiadaghton	13-Elk	15-Susquehannock	16- Tioga	20-Loyalsock	
2008	Damage (acres)	147,150	139,726	49,320	32	45,959	1,669	10,811	394,667
	Mortality (acres)	10,770	11,889	-	-	-	-	-	22,659
	GM Suppression (acres treated)	28,652	6,791	172	-	-	-	-	35,615
	HWA Suppression (acres treated)	-	-	-	-	-	-	-	-
2009	Damage (acres)	2,008	26,315	101,496	2,570	297,820	14,246	3,588	478,043
	Mortality (acres)	669	40,519	477	197	697	38	245	42,842
	GM Suppression (acres treated)	5,465	18,635	10,362	-	-	209	192	34,863
	HWA Suppression (acres treated)	-	-	-	-	-	-	-	-
2010	Damage (acres)	1,231	14,426	13,635	65,733	289,285	54,009	13,675	51,994
	Mortality (acres)	415	41,080	1,253	3	-	-	-	42,751
	GM Suppression (acres treated)	-	-	-	-	-	-	-	-
	HWA Suppression (acres treated)	-	55	76	-	15	11	100	257
2011	Damage (acres)	2,679	1	-	-	-	-	-	2,680
	Mortality (acres)	6,510	192	1,102	2,111	19,517	5,302	6	34,739
	GM Suppression (acres treated)	-	-	-	-	-	-	-	-
	HWA Suppression (acres treated)	-	-	-	-	-	-	-	-
2012	Damage (acres)	-	-	50	-	201	221	1,630	2,102
	Mortality (acres)	-	652	1,370	391	4,426	3,779	35	10,653
	GM Suppression (acres treated)	-	-	-	-	-	-	-	-
	HWA Suppression (acres treated)	-	-	-	-	-	-	13	13

Table 4.1 Principal damage-causing agents from 2008-2012.

The principal damage-causing agents from 2008 to 2012 in this region of Pennsylvania were the forest tent caterpillar and the gypsy moth. The last gypsy moth outbreak in Pennsylvania occurred from 2005 to 2009, mainly in northeastern, central, and south-central Pennsylvania. During the 2008-2012 period in core gas forest districts, gypsy moth defoliation occurred only in 2008 and 2009, causing 336,527 acres of defoliation in 2008 (principally in Moshannon, Sproul, and Tiadaghton state forests) and 115,148 acres of defoliation in 2009 (principally in Sproul and Tiadaghton state forests). Tree mortality from gypsy moth was detected in 2008 in Moshannon State Forest (10,770 acres) and Sproul State Forest (11,889 acres) due to defoliation in previous years. Another 16,116 acres of mortality occurred in Sproul State Forest in 2009; 40,903 acres in Sproul State Forest in 2010; and 6,424 acres in Moshannon in 2011.

The forest tent caterpillar, a native forest insect defoliator of sugar maple in Pennsylvania, but also of oak and aspen, caused defoliation across this region from 2008-2010. A total of 57,967 acres were defoliated in 2008 (Susquehannock, Tioga, and Loyalsock state forests); 344,237 acres in 2009 (all districts except for Sproul, with 297,819 acres defoliated in Susquehannock); and 434,218 acres in 2010 (all districts, with 288,529 acres defoliated in Susquehannock). Extensive tree mortality appeared in 2011 (23,516 acres, with 19,459 acres in Susquehannock) and 2012 (9,505 acres, with 4,403 acres in Susquehannock and 3,695 acres in Tioga).

One abiotic damage-causing agent of note was extensive frost, totaling 16,570 acres in 2010 across all the state forests except Sproul.

Gypsy moth suppression treatments occurred in Pennsylvania from 2006 to 2009. In 2008 and 2009, a total of 35,615 acres and 34,863 acres were treated, respectively, across the region. Moshannon, Sproul, and Tiadaghton state forests had treatment areas in 2008, and Moshannon, Sproul, Tiadaghton, Tioga, and Loyalsock state forests had treatment areas in 2009.

IV. Conclusion/Discussion

Monitoring impacts to forest health is a long-term endeavor. The bureau will monitor forest edges created by well pads, pipelines and roads for tree dieback, decline and mortality. Increased susceptibility to pest attack, especially by non-native invasive species, may occur wherever there is forest disturbance, especially for trees along newly created edges. However, impacts in the surrounding forests can only be discovered through long-term forest health monitoring. The bureau, the USDA Forest Service, and other agencies all have a role in the forest health monitoring effort.

Evaluation monitoring projects may be initiated if forest health changes are detected through the Bureau of Forestry's detection monitoring activities. These projects are done in conjunction with the USDA Forest Service, which provides funding for these activities.

The bureau is preparing an Eastern hemlock conservation plan that will address tree management, hemlock woolly adelgid management and control, genetic resistance, individual tree treatments with systemic insecticides to preserve hemlock in high value sites, and restoration. Gas drilling activities will have to be considered in the development of this conservation plan.

The emerald ash borer will be a serious threat to this region. Much of the high-quality ash stands in Pennsylvania are located in the northern tier of counties. Approximately 3.6 percent of Pennsylvania's forests are ash, but much of it is concentrated in the northern counties. Management plans for emerald ash borer include collecting and preserving ash seed, reducing basal area of ash to 20 percent or less, and introducing biological control agents, and treating individual trees with systemic insecticides to preserve some ash trees in clusters and thus preserve ash seed sources. A major factor that will be monitored is ash stands with newly created edges due to gas drilling activities. The emerald ash borer seeks ash trees along forest edges and attacks ash trees that are under stress or are in decline. As the northern tier counties in Pennsylvania contain most of the high-quality ash stands, impacts to ash will be an issue addressed over the next several years.

Part 2: Monitoring Values

» Invasive Species

I. Key Points:

- Eleven non-native invasive plant species were present at 14 of 18 representative pads across core gas forest districts.
  - The invasive plant with the largest mean population size was Japanese stilt-grass (*Microstegium vimineum*), which has become common across most state forest districts and spreads easily, especially along roadside corridors.
  - An Early Detection Rapid Response protocol for invasive plant species was employed opportunistically during all field work conducted by the bureau's Shale-Gas Monitoring Program during the 2013 growing season.
- The principal forest damage-causing agent from 2008 to 2012 in core gas forest districts activities was the gypsy moth (a non-native invasive species).
- Increased susceptibility to pest attack, especially by non-native invasive species, will occur wherever there is forest disturbance, especially for trees along newly created edges. However, impacts in the surrounding forests can be discovered only through long-term forest health monitoring.

II. Introduction

Non-native invasive species pose a serious threat to forest ecosystems in Pennsylvania. The bureau expends considerable resources to detect, monitor, assess, and control non-native, invasive plants and forests pests. The bureau attempts to take a comprehensive approach when evaluating the threats to forest stands due to non-native, invasive species – considering species in all taxa, including plants, insects, and diseases. Invasive species are an issue and management challenge in all the forests of Pennsylvania. This report will focus on data and information available in the core gas forest districts, where shale gas activity is most prevalent. Over time this will allow the bureau to evaluate invasive species trends related to shale gas activity.

Invasive plant species, both terrestrial and aquatic, have the potential to severely impact the native vegetation and wildlife habitat quality within the commonwealth's forests by spreading quickly and out-competing native plants. Invasive plants have the potential to negatively impact soil chemistry, sunlight levels, reproduction of native species, and hydrology in wetland habitats.

Invasive plants that are widespread across the state forest system include: garlic-mustard (*Alliaria petiolata*), tree-of-heaven (*Ailanthus altissima*), Japanese stilt-grass (*Microstegium vimineum*), Japanese knotweed, (*Fallopia japonica*), multiflora rose (*Rosa multiflora*), and Japanese barberry (*Berberis thunbergii*). Invasive plants that have become a concern more recently and are spreading quickly include: mile-a-minute vine (*Persicaria perfoliata*), black and pale swallow-worts (*Vincetoxicum nigrum and V. rossicum*), and Japanese angelica tree (*Aralia elata*). These species are difficult and expensive to control or eradicate across the forested landscape. Currently, 88 plant species found in Pennsylvania are considered invasive by the bureau.

The development of shale-gas resources on state forest lands has the potential to increase the spread of non-native invasive species. Invasive plant material can be brought onto state forest lands on construction equipment and vehicles, or in fill material such as rock, hay, or mulch. Similarly, by creating additional openings (well pads, pipeline rights-of-way, etc.), these newly disturbed areas are more easily colonized by invasive species compared to the interior forest habitat. Opportunistic colonization of state forest lands by all types of invasive species has been occurring for many years due to visitor use, dispersal by birds and other animals, and forest management activities; however, the development of natural gas resources has the potential to escalate this phenomenon and bring certain species into remote forest tracts that were previously considered less likely to be subject to invasion by new invasive species.

The bureau works cooperatively with the Pennsylvania Invasive Species Council, the Pennsylvania Department of Agriculture, the U.S. Department of Agriculture, and other state agencies and organizations to coordinate its efforts regarding invasive species. Some of the major invasive forest insect and disease pests established in Pennsylvania are the gypsy moth, hemlock woolly adelgid, emerald ash borer, thousand cankers disease and the walnut twig beetle, Sirex woodwasp, butternut canker, elongate hemlock scale, chestnut blight, Dutch elm disease, and beech bark disease. Other non-native invasive forest pests not yet detected in Pennsylvania, but which would cause considerable tree mortality, are the sudden oak death pathogen, Asian longhorned beetle, exotic bark beetle, and winter moth.

III. Monitoring Efforts/Results

In addition to the Early Detection Rapid Response protocol discussed in this section, all protocols involving the assessment of newly constructed infrastructure include surveys for non-native, invasive plant species. Similarly, the bureau will systematically check a subset of all infrastructure for new populations of invasive species. For leases granted prior to 2008, operators are not responsible for post-construction surveys for invasive species or treatment of any species found on site following construction. For leases granted in 2008 and 2010, operators are responsible for conducting invasive species surveys within the disturbance areas of their infrastructure annually until their surveys show no invasive species presence for two consecutive growing seasons.

Invasive Plants

One of the four main components of the bureau's plant monitoring program is to monitor forest tracts subject to shale-gas development for non-native, invasive plants species. In addition to the Early Detection Rapid Response protocol discussed in this section, all protocols involving the assessment of newly constructed infrastructure (see the Flora chapter of this report) include surveys for non-native invasive plant species. Similarly, the Bureau of Forestry will systematically check a subset of all infrastructure for new populations of invasive plants.

The bureau recognizes 88 plant species as invasive in Pennsylvania; the complete list of these species can be found here: http://www.dcnr.state.pa.us/forestry/plants/invasiveplants/. In addition, another 25 species are included in the bureau's "watch list." These species are either listed as invasive in neighboring states or exhibit certain traits that suggest they could become a threat to native forest ecosystems.

In addition to the plant species already considered invasive in Pennsylvania, the bureau also has investigated some additional species that are present in states where natural gas development is taking place, such as Oklahoma, Texas, Louisiana, North Dakota, Montana,

Species
Purple star-thistle *(Centaurea calcitrapa)*
Yellow star-thistle *(Centaurea solstitialis)*
Houndstongue *(Cynoglossum officinale)*
Scotch broom *(Cytisus scoparius)*
Leafy spurge *(Euphorbia esula)*
Hairy whitetop *(Lepidium appelianum)*
Whitetop *(Lepidium draba)*
Dalmatian toadflax *(Linaria dalmatica)*
Scotch thistle *(Onopordum acanthium)*
Wavy-leaf basket grass *(Oplismenus hirtellus ssp. undulatifolius)*[1]
Sawtooth oak *(Quercus accutissima)*
Medusahead *(Taeniatherum caput-medusae)*

Table 5.1 Plant species found in Pennsylvania known to be invasive in other gas-producing states.

1 Wavy-leaf basket grass has not yet been found in Pennsylvania but is known to exist in very close proximity to the Pennsylvania-Maryland border.

and West Virginia. There is the potential for invasive plant material from these states to be transported to Pennsylvania if construction or drilling equipment is moved from state to state. This research is ongoing as new invasive species are listed in other states.

Table 5.1 includes a partial list of the species that have been found in Pennsylvania, but which, at this time, are only considered invasive in other states extracting natural gas resources.

Species	Number of Pads	Population Size (Avg. # of Plants)
Japanese stilt-grass *(Microstegium vimineum)*	3	59.7
Crown-vetch *(Coronilla varia)*	1	38.0
Canada thistle *(Cirsium arvense)*	4	27.3
Reed canary-grass *(Phalaris australis)*	2	26.8
Bull-thistle *(Cirsium vulgare)*	1	15.5
Spotted knapweed *(Centaurea stoebe)*	5	12.5
Japanese barberry *(Berberis thunbergii)*	1	3.0
Honeysuckles *(Lonicera spp.)*	1	3.0
Multiflora rose *(Rosa multiflora)*	1	3.0
Japanese knotweed *(Polygonum cuspidatum)*	1	3.0
Garlic-mustard *(Alliaria petiolala)*	1	3.0

Table 5.2 Mean population size among invasive species found during well pad walkabouts.

Field data collection and vegetation assessments were completed for the first 12 well pads in the long-term vegetation monitoring. In total, 18 well pads were chosen that were representative of most operators across the core gas forest districts. Eleven non-native, invasive species were present on 14 of 18 pads (see Table 5.2). The invasive species with the largest mean population size was Japanese stilt-grass (*Microstegium vimineum*). This species is found throughout the state forest system and is often one of the first invasive species to invade disturbed habitats, roadsides, and recently harvested forest stands. Many of the other invasive species found in Table 5.2, such as crown-vetch (*Coronilla varia*), Canada thistle (*Cirsium arvense*), and spotted knapweed (*Centaurea stoebe*), also prefer disturbed edge habitats. Some troubling species include Japanese knotweed (*Polygonum cuspidatum*) and garlic-mustard (*Alliaria petiolala*), if left untreated, can quickly colonize large portions of the well pad edge and inhibit native vegetation or prevent erosion and sedimentation seed mixes from establishing.

Early Detection Rapid Response Protocol

New forest clearings or disturbances due to shale-gas development have the potential to provide ideal habitat and growing conditions for invasive plant species. Often

these species thrive in disturbed sites that provide open light and exposed soils where seed can readily germinate. Tracking these novel populations and treating them promptly is essential to slowing the spread of invasive plants on state forest lands.

The bureau has developed an Early Detection and Rapid Response protocol similar to that developed by Keefer et al. (2010) for the National Park Service. The development of this protocol has the potential to maximize both sampling efficiency and discovery opportunities for new invasive plant species occurrences. This protocol provides a brief (less than five-minute) reporting procedure that can be carried out by all monitoring program personnel and allows not only for the discovery of new invasive plant populations but also for the future treatment of these occurrences. Since all monitoring specialists and foresters will be using the protocol, it has the potential to create a large dataset based on opportunistic sampling.

In addition to developing the protocol and providing identification training, a list of three to five high-priority invasive species will be developed for each forest district subject to shale-gas development. These lists will be evaluated annually based on the latest field data. The focus of this protocol will be on high-priority species that are either new or uncommon to a forest district or are currently found outside a district but have the potential to move in. New occurrences are likely to be relatively small in size and, if treated, can be removed without an overwhelming amount of effort, time, or cost.

The Early Detection Rapid Response protocol will be applied to core gas forest districts. It has been designed to be completed quickly while working on other monitoring projects, and, if additional time is needed, to assess a particular site or population, a follow-up visit can be scheduled. When an occurrence of a high-priority invasive plant species is found, the occurrence will be flagged and data will be collected regarding the population size and the perceived vector. Photographs also will be taken and GPS locations recorded.

If treatment of the invasive species is practical, monitoring field staff will treat the population based on established guidelines. Before each field season, these techniques will be discussed and training will be provided. If a species is deemed not to be treatable via the Early Detection Rapid Response protocol, location information will be recorded for subsequent treatment.

As the data set of treated occurrences grows, the effectiveness of these treatments can be evaluated. Over time, spatial data can be developed that indicate patterns of invasive species dispersal. This information may be useful in adapting management guidelines and predicting areas that are vulnerable to colonization.

Invasive Pests and Diseases

The bureau, in cooperation with other state and federal agencies, regularly monitors a variety of forest health indicators across Pennsylvania. As part of this effort, the bureau monitors and tracks outbreaks of non-native, invasive insects and diseases. (See the Forest Health

chapter for more information.) In addition to its large-scale monitoring efforts, the bureau also conducts specialized surveys for a variety of non-native disease and insects, including Asian longhorned beetle, emerald ash borer, hemlock woolly adelgid, gypsy moth, beech bark disease, and butternut canker.

The principal non-native, damage causing agent from 2008 to 2012 in the core gas forest districts was the gypsy moth. The last gypsy moth outbreak in Pennsylvania occurred from 2005 to 2009, mainly in northeastern, central, and south-central Pennsylvania. During the 2008 to 2012 period in seven state forest districts, gypsy moth defoliation occurred only in 2008 and 2009, causing 336,527 acres of defoliation in 2008 (principally in Moshannon, Sproul, and Tiadaghton state forests) and 115,148 acres of defoliation in 2009 (principally in Sproul and Tiadaghton state forests). Tree mortality from gypsy moth was detected in 2008 in Moshannon State Forest (10,770 acres) and Sproul State Forest (11,889 acres) due to defoliation in previous years. Another 16,116 acres of mortality occurred in Sproul in 2009; 40,903 acres in Sproul in 2010; and 6,424 acres in Moshannon in 2011.

IV. Conclusion/Discussion

Due to the threat that invasive plants pose to the health of forest ecosystems, monitoring and treatment of non-native invasive plant species in areas of shale-gas development will continue. Early Detection Rapid Response protocols for invasive plant species will be employed opportunistically during all gas monitoring activities, and any invasive plant species found while completing vegetation monitoring activities will be immediately treated or brought to the attention of forest district managers. In addition to formal Early Detection Rapid Response protocols, any assessment of vegetation communities within or adjacent to gas development sites will include a thorough search for invasive plant species. As novel species are found on state forest lands or as new, effective treatments are discovered for existing invasive species, this information will be shared across all state state forest districts.

In addition to existing plant monitoring efforts, the bureau has entered into a partnership with Pennsylvania State University researchers to better understand vegetation communities surrounding completed well

pads and how species on the edges of well pads may spread into adjacent interior forest. This research includes a thorough assessment of well pad edges and access roads for non-native, invasive species.

The bureau will continue to further expand its invasive species monitoring program to respond to particular species and infestations as gas development continues. As the monitoring program moves forward, annual monitoring of treated invasive populations also will provide a better understanding of how these species are affecting native vegetation immediately adjacent to shale-gas infrastructure. As conclusions regarding the effects on vegetation communities are drawn, this data will be utilized to improve the bureau's management practices.

The bureau and its partners all have a role in the forest health monitoring effort as it pertains to non-native invasive species. Evaluation monitoring projects may be initiated if forest health changes are detected through the bureau's detection monitoring activities. These projects are done in conjunction with the USDA Forest Service, which provides funding for these activities.

The emerald ash borer (EAB) will be a serious threat to this region. Approximately 3.6 percent of Pennsylvania's forests are ash, but much of this species is concentrated in the northern counties. Management plans for EAB include collecting and preserving ash seed, reducing basal area of ash to 20 percent or less, introducing biological control agents, and treating individual trees with systemic insecticides to preserve some ash trees in clusters as ash seed sources. Ash stands with newly created edges due to gas drilling activities will be targeted for some of the EAB monitoring. The emerald ash borer seeks ash trees along forest edges and attacks ash trees that are under stress or in decline.

Monitoring impacts to forest health is a long-term endeavor. Increased susceptibility to pest attack, especially by non-native invasive species, may occur wherever there is forest disturbance, especially for trees along newly created edges. This effect has been seen over time during the course of typical forest management projects that create new forest edge, such as overstory removal of timber resources. Impacts from creating new forest edges due to well pads, pipelines, and roads may include edge trees suffering dieback, decline, and even mortality. However, impacts to the surrounding forests can only be discovered and measured through long-term forest health monitoring.

Part 2: Monitoring Values

»Water

I. Key Points:

- The majority of streams in the core gas forest districts (71 percent) are first-order, headwater streams.
- The majority of streams in the shale-gas region (87 percent) are classified as high quality or exceptional value by the DEP, and many streams are identified as having naturally reproducing trout populations by the Fish and Boat Commission.
- A widespread sampling of field chemistry, including over 300 locations, showed that pH results were primarily in the circum-neutral range, with 72 percent of results between 6.5 and 7.5 and a median pH of 7.01.
- A widespread sampling of field chemistry showed that 91 percent of specific conductance results were below 100 microsiemens(μS)/cm, with a median of 41.3 μS/cm.
- Initial water monitoring results have not identified any significant impacts due to shale-gas development. This is based on one round of field chemistry sampling throughout the shale-gas region and over one year of operation for 10 continuous monitoring devices in key watersheds. At this early stage, the data collected are primarily for establishing baseline conditions.
- A pilot study of a pebble count protocol in Tiadaghton State Forest showed Browns Run to be a reference quality stream, according to a DEP criterion.
- Future monitoring efforts include longitudinal surveys of field chemistry, surface water grab sampling, installation of additional continuous monitoring devices, and an assessment of pipeline-stream crossings.

II. Introduction

Maintaining and protecting the quality of water on state forest lands continues to be one of the bureau's highest priorities. One of the objectives of the shale-gas monitoring program is to evaluate the potential effect of shale-gas development on water resources within state forest lands.

State forest lands within the shale-gas region are host to a vast network of streams and rivers as well as important groundwater resources. Since its inception, one of the primary purposes of the state forest system has been to protect and conserve water resources for recreational enjoyment, wildlife use, and drinking water supply. According to DEP data, approximately 3,400 miles of stream traverse state forest lands within the core gas forest districts, including many of the best-known fishing and boating waters in Pennsylvania.

This report will present current and planned activities of the bureau, as well as other agencies, in monitoring the potential effect of shale-gas development on state forest land waters.

Water and State Forest Lands

Streams and rivers in Pennsylvania can be classified in a number of ways. One informative manner of classification is stream order, which is the position of a stream within the hierarchy of tributaries in a drainage network. A first-order stream has no discernible tributaries. A second-order stream occurs at the junction of two first-order streams, and so forth up the hierarchy.

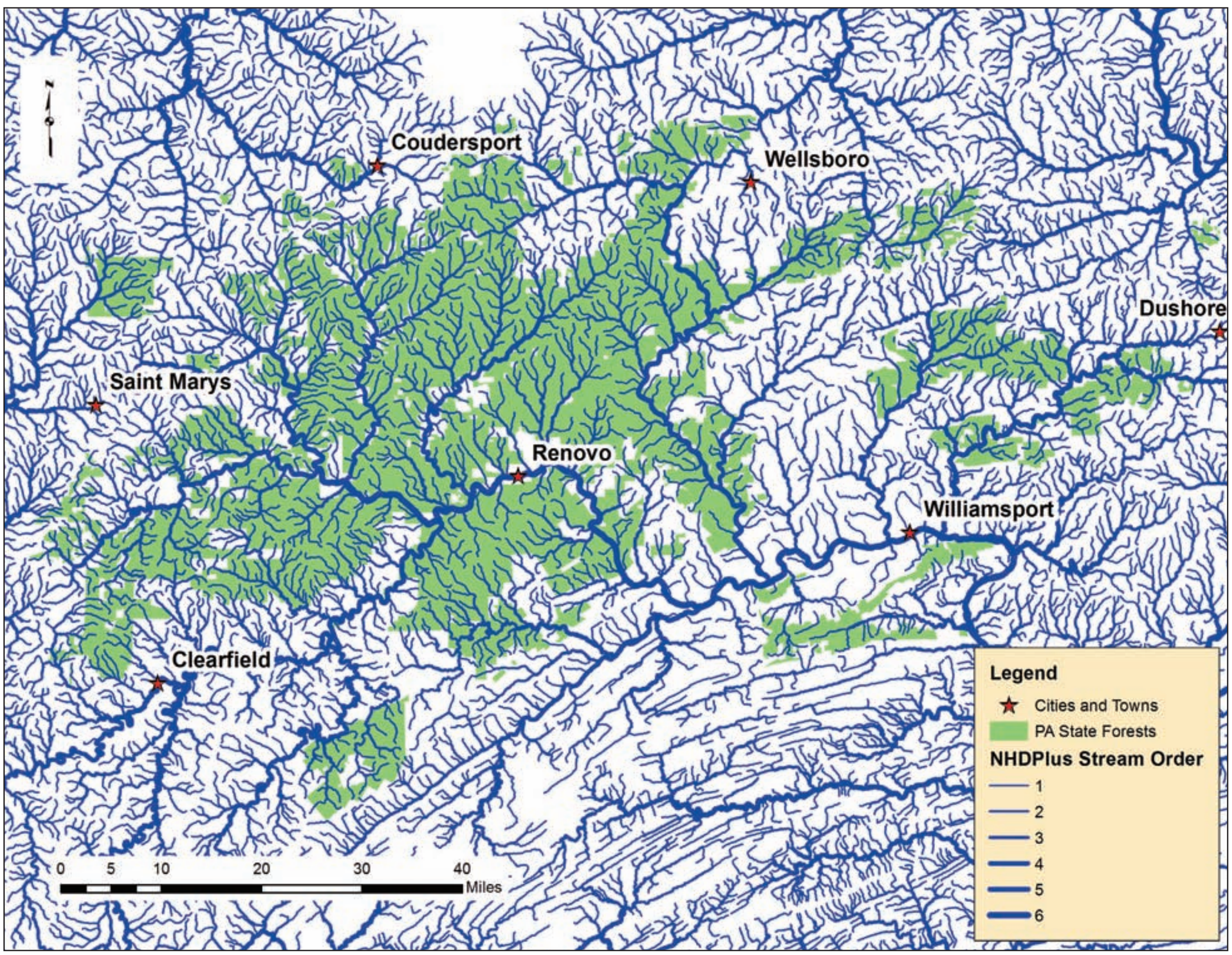


Figure 6.1 Stream map of shale-gas districts based on NHD Plus dataset.

Thus, headwater streams are low orders and large rivers are high orders.

The order of a stream is dependent on the map scale used to determine stream order. As map detail increases, smaller channels can be seen. A first-order stream on a 1:100,000 map might be a second- or third-order stream on a 1:24,000 map. For the purposes of this report, the National Hydrography Dataset Plus (NHD Plus) was used to determine stream order throughout the shale-gas region. The NHD Plus maps streams at 1:100,000 scale.

Table 6.1 and Figure 6.1 provide the distribution of stream orders on state forest lands in the core gas forest districts. The vast majority of the streams, over 70 percent, are first-order streams. This means that the streams on state forest land are generally small, and they are highly dependent on the forested land that immediately surrounds them.

Another important stream classification is that promulgated under Chapter 93 of DEP regulations. Chapter 93 pertains to water quality standards and protected uses of state waters. The most common Chapter 93 water designations in the shale-gas region are warm water fishes (WWF), trout stocked waters (TSF), cold water fishes (CWF), high-quality waters (HQ), and exceptional value waters (EV). The water uses protected under Chapter 93 for a given water body are designated within the Chapter 93 regulations (i.e., in a list of streams found throughout the state), and the designation from Chapter 93 can be updated by DEP if deemed appropriate based on new data. This revision of the stream's designation is called a change in its "existing use."

A water body can qualify as HQ or EV if it meets certain chemical or biological criteria laid out in Chapter 93. Classification as HQ or EV protects a water body from new, additional, or increased discharges unless all non-discharge alternatives have been eliminated. If a proposed discharge is the only environmentally sound and cost-effective alternative, then it may be permitted if it can be demonstrated that the discharge will not diminish the quality of the receiving waters. The exception to this rule is that the DEP may allow a reduction in water quality in an HQ water if it is demonstrated that doing so is important to economic or social development. No such exception exists for EV waters.

Stream Order	Miles of Stream	Percentage of Stream Miles
1st	1,567.1	71.7
2nd	379.9	17.4
3rd	179.7	8.2
4th	32.5	1.5
5th	26.3	1.2
Total	**2,185.5**	**--**

Table 6.1 Distribution of stream orders within the shale-gas region.

Based on the rules and criteria, this DEP classification system represents a good indicator of both the quality of a water body and the protection it receives under regulations. As shown in Table 6.2 and Figure 6.2, DEP data sources were used to determine the DEP Chapter 93 classification of streams throughout the shale-gas region. Over 85 percent of the stream miles fall within one of the higher protection waters, HQ or EV. The total number of stream miles is greater for this dataset than for the NHD Plus because a finer scale of mapping is used.

A third important stream classification is based on designations by the Fish and Boat Commission (PFBC). PFBC classifies certain water bodies in a number of ways, including trout-stocked streams, naturally reproducing trout streams, Class A wild trout streams, and wilderness trout streams. A trout-stocked stream receives periodic stocking of trout by the PFBC. A naturally reproducing trout stream is any stream where wild reproducing trout are present, and a Class A wild trout stream has biomass (or abundance) of wild trout above a standard PFBC threshold for either brown or brook trout. Class A wild trout streams can be classified as HQ under DEP Chapter 93. A wilderness trout stream is a classification by PFBC based on the wild setting of a stream, taking into account such factors as the number of roads crossing the stream. A wilderness trout stream can be classified as EV under DEP Chapter 93.

Chapter 93 Classification	Miles of Stream	Percentage of Stream Miles
WWF	2.8	0.1
TSF	40.0	1.2
CWF	404.6	12.0
HQ	1,621.0	48.2
EV	1,292.1	38.5
Total	**3,360.5**	**--**

Table 6.2 Classification of streams within the shale-gas region under DEP Chapter 93.

These PFBC classifications are valuable not only as an indicator of the health of the trout population, and thereby of the water quality, but also as an indicator of the recreational experience available to state forest users. As shown in Table 6.3 and Figure 6.3, PFBC data sources were used to determine the trout classification of streams throughout the core gas forest districts.

The U.S. Geological Survey (USGS) has divided the nation's waters into a hierarchy of hydrologic units. The largest unit, designated as a region, is successively divided into smaller hydrologic units down to small watersheds of a single stream. Each hydrologic unit is identified by a unique, numeric hydrologic unit code (HUC). These HUCs are a convenient way to identify and describe waters and watersheds.

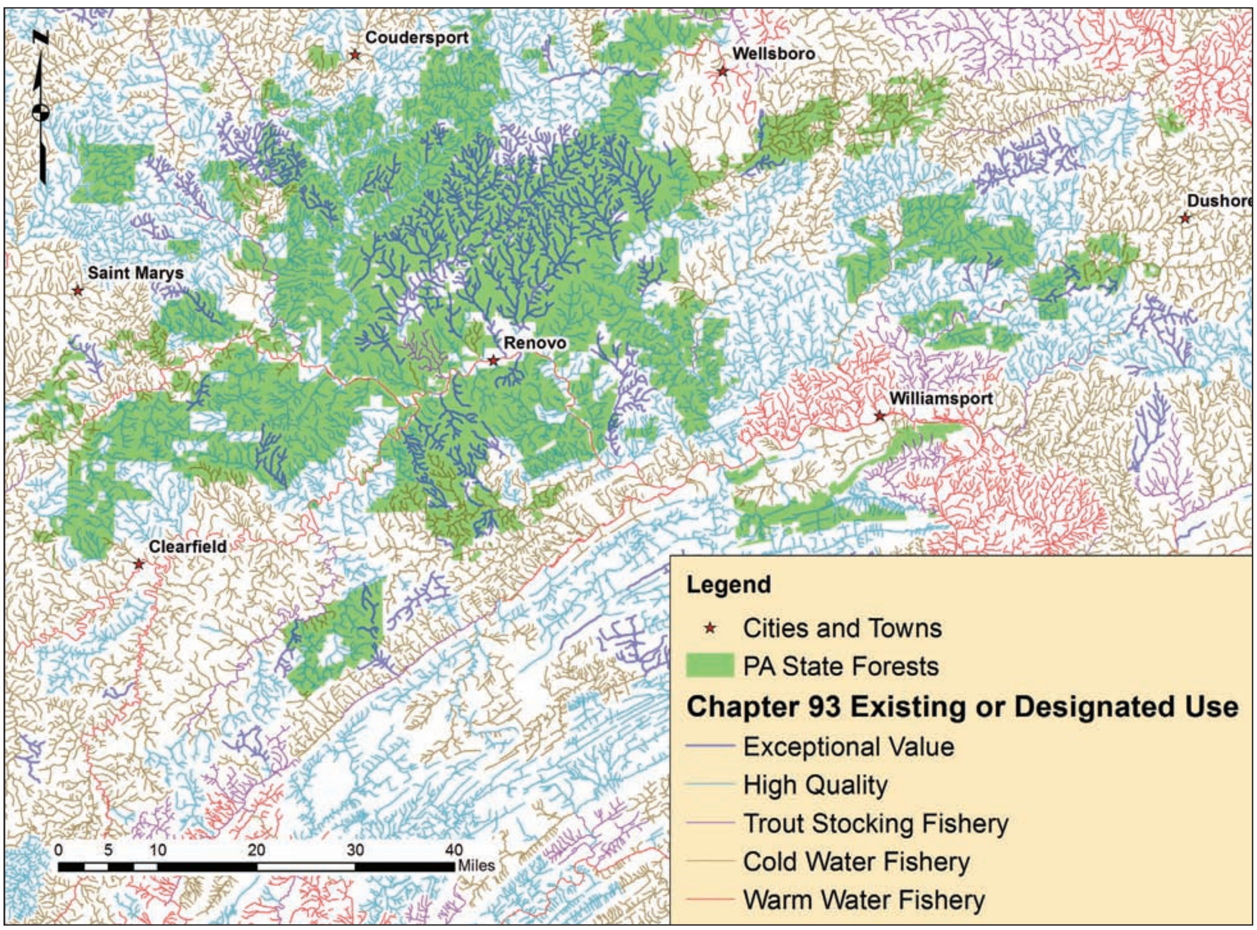


Figure 6.2 Stream map of the shale-gas districts showing the DEP Chapter 93 designations of the streams. Where applicable, the existing use is shown. Otherwise, the designated use is shown.

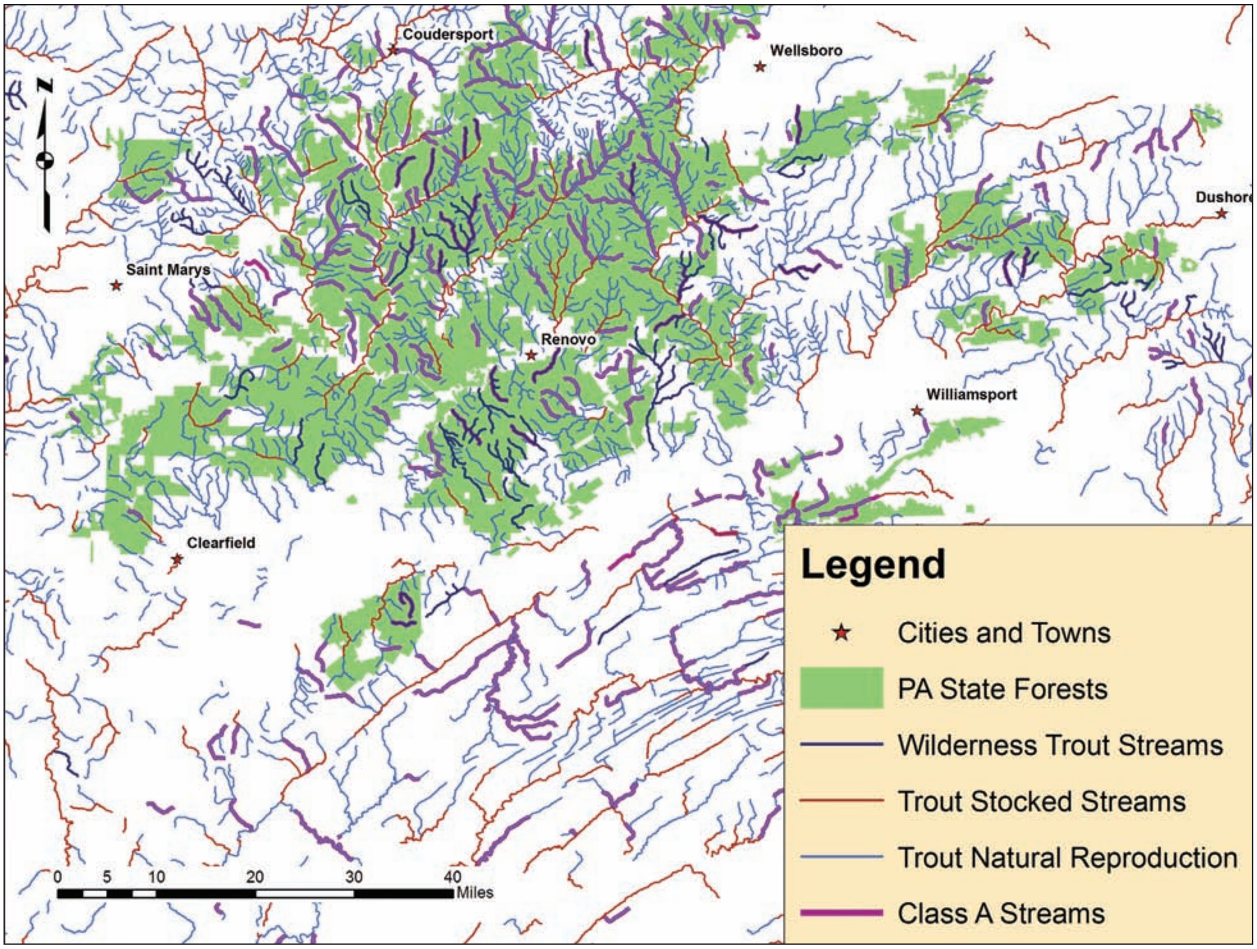


Figure 6.3 Stream map of the shale-gas districts showing classification by the PFBC.

The waters within core gas forest districts are within the Mid-Atlantic HUC Region. At the sub-region HUC level, the shale-gas region is divided into the Susquehanna and Allegheny sub-regions. However, 97.7 percent of the core gas forest districts falls within the Susquehanna Sub-Region. The HUC-8 (or eight digit code) will be used in this report to provide an overview of water resources in the core gas forest districts. Most of the state forest land in the core gas forest districts falls within seven HUC-8s of the Susquehanna Sub-Region (see Table 6.4 and Figure 6.4). A small portion (2.3 percent) of the core gas forest districts falls within the Upper Allegheny and Clarion HUC-8s of the Allegheny Sub-Region.

PFBC Classification	Miles of Stream
Trout-stocked	173.9
Naturally Reproducing Wild Trout	1,852.5
Class A Wild Trout	373.1
Wilderness Trout	204.9

Table 6.3 Classification of streams within the shale-gas region by the PFBC.

Sinnemahoning

Nearly 350,000 acres of state forest fall within the Sinnemahoning HUC-8, including significant portions of Elk, Moshannon, and Susquehannock state forests. The Sinnemahoning is a major drainage of the West Branch Susquehanna River. Major sub-basins of the Sinnemahoning are the Bennett Branch, Driftwood Branch, and First Fork Sinnemahoning Creek. The

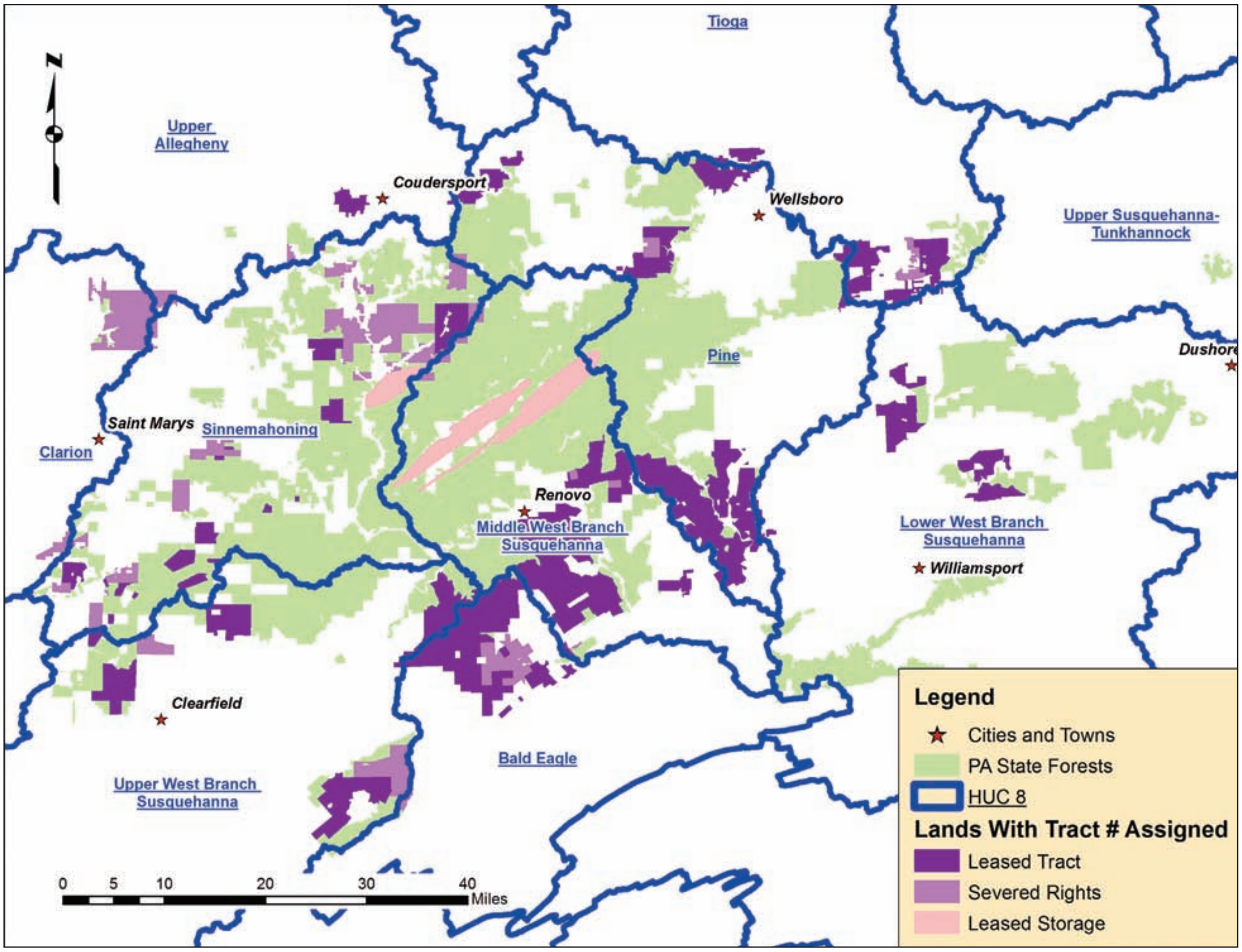


Figure 6.4 HUC-8 watersheds of the shale-gas region. Leased tracts and severed rights tracts are shown overlaying the state forest boundaries.

Sinnemahoning is largely forested (89 percent), with 52.4 percent of its land area comprising state forest land. Shale-gas development on state forest land in this HUC-8 is concentrated to the north and west. The upper portions of the First Fork and Bennett Branch contain large areas of severed lands.

HUC-8 Name	HUC-8 Number	Acres of State Forest in HUC-8
Sinnemahoning	02050202	346,942
Middle West Branch Susquehanna	02050203	342,512
Pine	02050205	264,891
Lower West Branch Susquehanna	02050206	205,200
Upper West Branch Susquehanna	02050102	148,761
Bald Eagle	02050204	82,362
Tioga	02050104	33,349

Table 6.4 Primary HUC-8s of the shale-gas region.

Middle West Branch Susquehanna

Approximately 340,000 acres of state forest fall within the Middle West Branch Susquehanna HUC-8, primarily within Susqehannock and Sproul state forests. This HUC-8 includes major and minor tributaries both to the south and north of the West Branch Susquehanna River in this area. The major tributaries are Young Woman's Creek and Kettle Creek. This HUC-8 is largely forested (91 percent), with 68.2 percent of its land area comprising state forest land. Shale-gas development on state forest land is intense in the southern portion of this watershed on leased tracts. Severed lands are lightly dispersed throughout the watershed.

Pine

Approximately 265,000 acres of state forest fall within the Pine HUC-8, primarily within the Tioga and Tiadaghton state forests. The Pine is a major drainage of the West Branch Susquehanna River. Major tributaries to the Pine include Marsh Creek, Babb Creek, and Little Pine Creek. This HUC-8 is largely forested (83 percent), with 42.2 percent of its land area comprising state forest land. Shale-gas development on state forest land is intense in the southern portion of this watershed on leased tracts. Leased tracts and severed lands also are present in the upper Pine Creek and Marsh Creek watersheds.

Lower West Branch Susquehanna

Approximately 205,000 acres of state forest fall within the Lower West Branch Susquehanna HUC-8, including significant portions of Tiadaghton, Bald Eagle, and Loyalsock state forests. This HUC-8 includes major and minor tributaries of the West Branch Susquehanna River. Major tributaries that include state forest land are Lycoming Creek, Loyalsock Creek, White Deer Hole Creek, and Buffalo Creek. This HUC-8 has mixed land use, with 65 percent forested and 25 percent agriculture. Shale-gas development on state forest land in this watershed is primarily in Loyalsock State Forest, which contains significant areas of both leased tracts and severed lands.

Upper West Branch Susquehanna

Nearly 150,000 acres of state forest fall within the Upper West Branch Susquehanna HUC-8, including portions of Sproul and Moshannon state forests. This HUC-8 includes major and minor tributaries of the West Branch Susquehanna River. Major tributaries that include state forest land are Mosquito Creek, Moshannon Creek, and Anderson Creek. This HUC-8 has mixed land use, with 77 percent forest and 11 percent agriculture. Shale-gas development on state forest land in this watershed is widespread, including both leased tracts and severed lands.

Bald Eagle
Approximately 82,000 acres of state forest fall within the Bald Eagle HUC-8, including parts of the Sproul and Bald Eagle state forests. This HUC-8 drains to the West Branch Susquehanna River. Major tributaries that include state forest land are Beech Creek and Fishing Creek. This HUC-8 has mixed land use, with 72 percent forest and 17 percent agriculture. Shale-gas development on state forest land in this watershed is concentrated in the Beech Creek sub-basin, which includes both leased tracts and severed lands.

Tioga
Approximately 33,000 acres of Tioga State Forest fall within the Tioga HUC-8. The Tioga is a major drainage of the Chemung River, which feeds the Susquehanna River. State forest land is limited to the upper Tioga River and one tributary – Crooked Creek. Most of the state forest lands in this watershed are either leased tracts or severed lands.

Importance of Water Monitoring

The development of shale-gas wells requires large amounts of freshwater, typically 5 million gallons per well. Due to economic and logistic constraints, the source for much of this water is local – drawn from nearby streams or groundwater wells. Because the majority of forest land within the shale-gas region drains to the Susquehanna River (97.7 percent), with a small portion flowing to the upper Allegheny River, the Susquehanna River Basin Commission (SRBC) regulates the use of freshwater for shale-gas development on nearly all state forest lands. Accordingly, the bureau depends on SRBC to properly manage the extraction of freshwater from streams that flow within and through state forest lands within the basin. Additionally, Act 13 requires all gas well applicants to submit and obtain a water management plan from DEP, outlining where water will be obtained, how water will be reused, and wastewater treatment plans. Presently, there are no groundwater withdrawals for shale-gas development on state forest land. More information on SRBC's project review regulations, which apply to shale-gas development, can be found at: http://www.srbc.net/programs/projreviewnaturalgas.htm.

In addition to the freshwater supply required for well development, a mixture of hydraulic fracturing fluids is injected into the well. These fracturing fluids can pose a potential spill risk during transportation to well sites or during well development operations. Monitoring for such potential impacts is achieved mainly by testing waters for the materials of concern (e.g., hydrocarbons, glycols). Such monitoring methods are described later in this report (Grab Sampling section). In addition to the monitoring performed by the bureau, DEP enforces regulations regarding spills on well sites. DEP may perform or require an operator to perform additional monitoring related to a specific spill event. It should also be noted that, in 2011, DEP adopted significantly enhanced well construction and casing and cementing standards to protect water supplies.

Once hydraulic fracturing is complete, in general, between 10 percent and 30 percent of the water used in the process returns to the surface and must be reused or disposed. This water is typically referred to as flowback water. Flowback water contains hydraulic fracturing fluids as well as other chemicals, such as metals (e.g., barium, strontium) and salts (e.g., chloride, bromide), that are picked up from the shale formation while the water is underground. Monitoring for these chemicals can be achieved in two ways. First, waters can be tested for the metals and other chemicals typically present in flowback water. Second, waters can be tested for more general parameters, such as total dissolved solids or specific conductance, that serve as indicators of the high salinity typically associated with flowback water. Both types of monitoring methods are described later in this report (Widespread Sampling of Field Chemistry section, Grab Sampling section, Continuous Monitoring Devices section).

Approximately 70 percent to 90 percent of the injected water remains in the shale formation. During gas production, some of this water will return to the surface with the flowing gas. The water will be removed from the gas with dehydration units at the pad site and stored in steel tanks that have adequate secondary containment. This formation water may or may not have similar characteristics to flowback water; thus, monitoring for potential impacts in the shallow groundwater or surface water could follow the same two-pronged approach described in the paragraph above. Such monitoring methods are described later in this report (Widespread Sampling of Field Chemistry section, Grab Sampling section, Continuous Monitoring Devices section).

Concerns have been expressed regarding the treatment of flowback water in municipal wastewater treatment facilities. Due to a formal request in April 2011 by DEP, at the direction of Gov. Tom Corbett, gas companies in Pennsylvania have ceased disposal of flowback water at municipal wastewater facilities. Because current industry standard practice on state forest land is to reuse flowback water or haul it to permitted subsurface disposal locations, monitoring of flowback disposal is not planned at the present time.

Throughout the shale-gas development process, there are numerous occasions where land clearing or earth disturbance is required, such as pad, road, and pipeline construction. Each of these construction activities requires an erosion and sedimentation control permit from DEP. DEP monitors the installation and maintenance of erosion and sedimentation control measures. Monitoring for sediment pollution, which can affect aquatic organisms, including benthic invertebrates and fish, can be conducted by testing waters for the content of suspended sediment or by testing waters for turbidity (a measure of a water's relative clarity or cloudiness). Sediment deposition in streams also can be examined by studying the particle size profile in the bed of the stream. Lastly, erosion potential can be assessed at the source by examining conditions on the ground, such as vegetative cover and erosion and sedimentation control measures. Such methods for monitoring sediment impacts are described later in this report (Pebble Counts section, Grab Sampling section, Pipeline Crossing Assessment section).

III. Monitoring Efforts/Results

Numerous methods are employed by the bureau to sample and analyze water resources within the core gas forest districts, with an emphasis on water quality of surface waters. The present focus is surface water quality because this forest system value is of critical concern to stakeholders, could be impacted by shale-gas development, and can be assessed readily and cost-effectively.

Water quality monitoring by the bureau began in 2011 with a widespread sampling of field chemistry parameters. This study and additional protocols that already have been initiated or are planned for the future are described in this section.

Widespread Sampling of Field Chemistry

Shale-gas development involves a number of activities that potentially can release materials of high salinity directly or indirectly into streams.

High salinities can be detected through measurement of specific conductance, a temperature-corrected measurement of a solution's ability to transmit an electrical current. Another common impairment to streams in the shale-gas region, which existed prior to shale-gas development, is low pH, often caused by abandoned-mine drainage. Field chemistry measurement covers these parameters, giving a snapshot of general stream water quality. In the shale-gas region, a stream with good water quality will have relatively low conductivity, cool temperatures, and moderate pH. These conditions make the stream suitable habitat for fish and other aquatic life. Two positive attributes of field chemistry measurement are that it can be performed quickly, with a handheld meter, and it does not require sampling for (more costly) laboratory analysis.

Field chemistry measurement will be used in a number of applications in the water monitoring program, but here it is discussed in the context of a widespread sampling program performed throughout the shale-gas region.

Widespread sampling provides some assurance to that local streams are notimpacted by shale-gas development (or it will aid in identification of such impacts). Widespread sampling also will provide reference points for the bureau or DEP should a pollution event occur in the vicinity of a sampling location. Field chemistry measurement will be conducted at widespread locations throughout the shale-gas region. Although this dataset will be limited temporally (one or two measurements per year), there will be value in its geographic scope. The widespread sampling may identify contamination of streams by high conductivity waters or, when repeated over time, may identify gradual increases in conductivity.

Widespread sampling points were established in 2011 based on their proximity to existing or planned shale-gas development pads. The sampling points were selected using ArcHydro analysis of flow from pads to the nearest streams. In 2011, 345 sampling points were established (Figure 6.5).

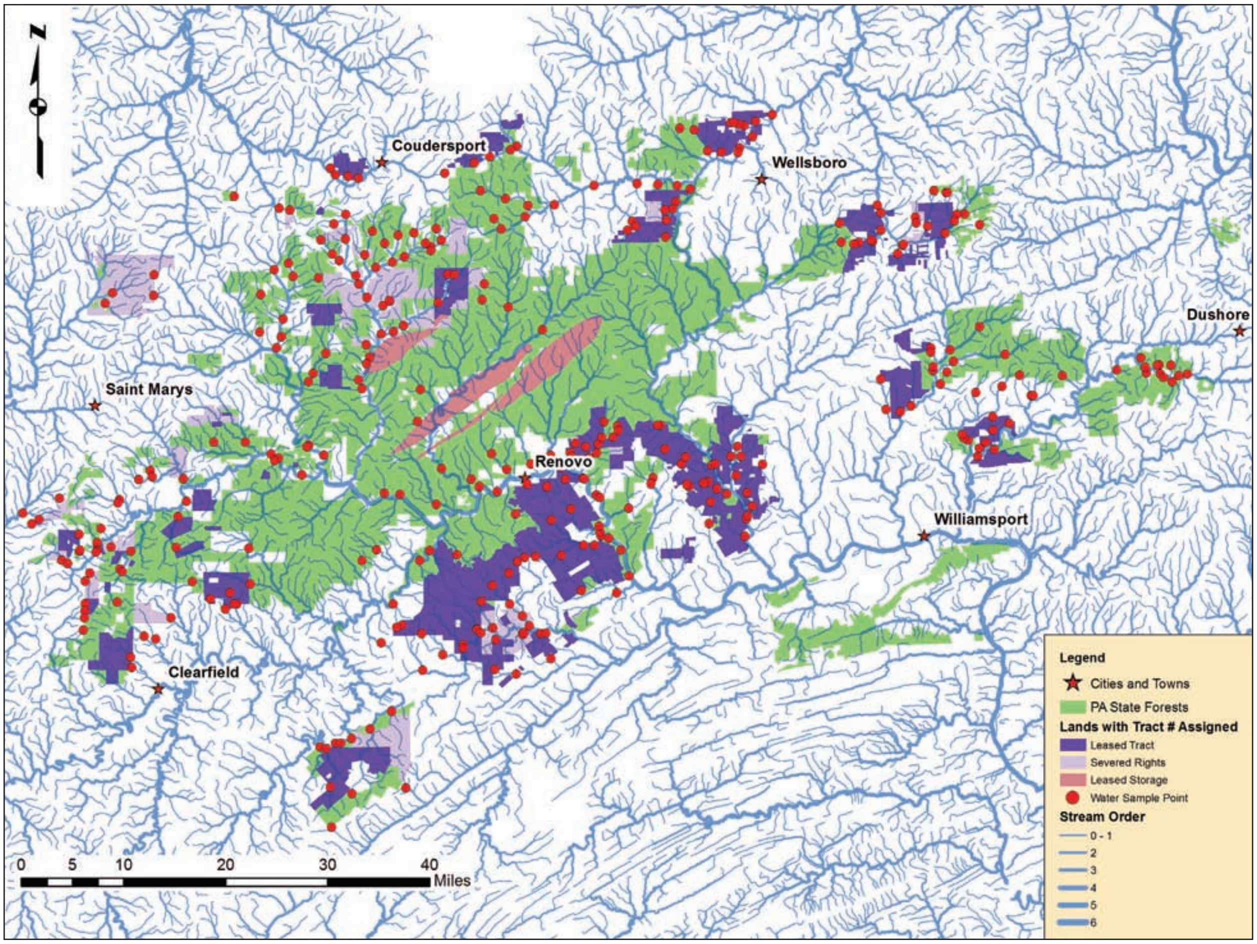


Figure 6.5 Locations for widespread sampling of field chemistry. Leased tracts and severed rights tracts are shown overlaying the state forest boundaries.

A LaMotte pH/TDS/Salt Tracer Pocketester was used for field chemistry measurement. It was calibrated according to manufacturer instructions on a weekly basis or as indicated by the unit's built-in calibration sensor (which would indicate the unit should be calibrated if the sensor did not appear to be reading correctly). At each sampling point, a water sample was obtained from the middle of the stream using a sterile, plastic sampling container. The probe was inserted into the water and kept in place until readings stabilized. This process was repeated for a duplicate measurement. The following parameters were recorded on a datasheet: specific conductance (microseimens/cm), temperature (degrees Fahrenheit), and pH. A surrogate measurement of stream flow was made by measuring the stream width and average stream depth.

Data collected for the widespread sampling are not intended for rigorous analysis. Rather, these data are collected for reference purposes and to characterize general stream conditions. It is important to recognize that the results represent one discrete measurement in time. They do not take into account diurnal or seasonal variation and may miss important stream-related events (e.g., storms, spills). Still, the dataset is valuable due to its geographic scope. After a period of several years, these data can be used to evaluate long-term trends in general stream conditions.

An average of the two field measurements was used for data analysis. The 2011 results are summarized in Table 6.5.

	Min	Max
pH	2.82	8.11
Specific Conductance (µS/cm)	11.6	866

Table 6.5 Descriptive statistics of 2011 widespread sampling of field chemistry.

Figure 6.6 is a histogram of pH results for 2011. The histogram shows that results were primarily in the circum-neutral range, with 72 percent of results between 6.5 and 7.5. Very few streams had pH greater than 8. A number of streams had acidic pH, likely due to either abandoned-mine drainage or atmospheric deposition. Figure 6.7 is a map of the pH results, symbolized by pH value. Streams that DEP has identified as having issues with abandoned-mine drainage or atmospheric deposition are indicated on Figure 6.7. Nearly all of the low pH values are located on or in the vicinity of such streams, suggesting that low pH is attributable to one of these causes.

Figure 6.8 is a histogram of specific conductance results for 2011. The histogram shows that most results (91 percent) were below 100 µS/cm, with the majority falling below 50 µS/cm. This is to be expected for headwater mountain streams of this region, which were the dominant stream type sampled. No measurements exceeded 1,000 µS/cm. The few measurements that exceeded 200 µS/cm can largely be explained as sample points having low pH. In situations where pH is low, metals are mobilized into the water, resulting in higher specific conductance readings. Figure 6.9 is an X-Y scatter plot of pH and specific conductance results. The slight inverse relationship between the two

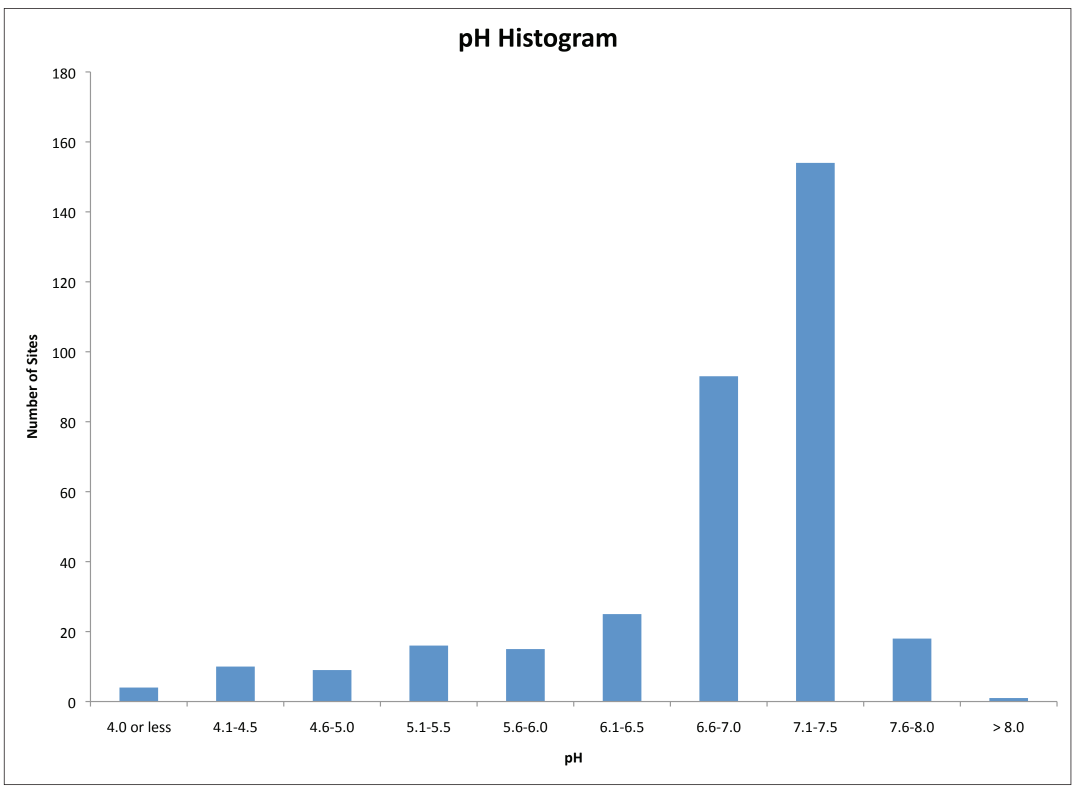


Figure 6.6 Histogram of pH results from widespread sampling of field chemistry. Most results were in the circum-neutral range.

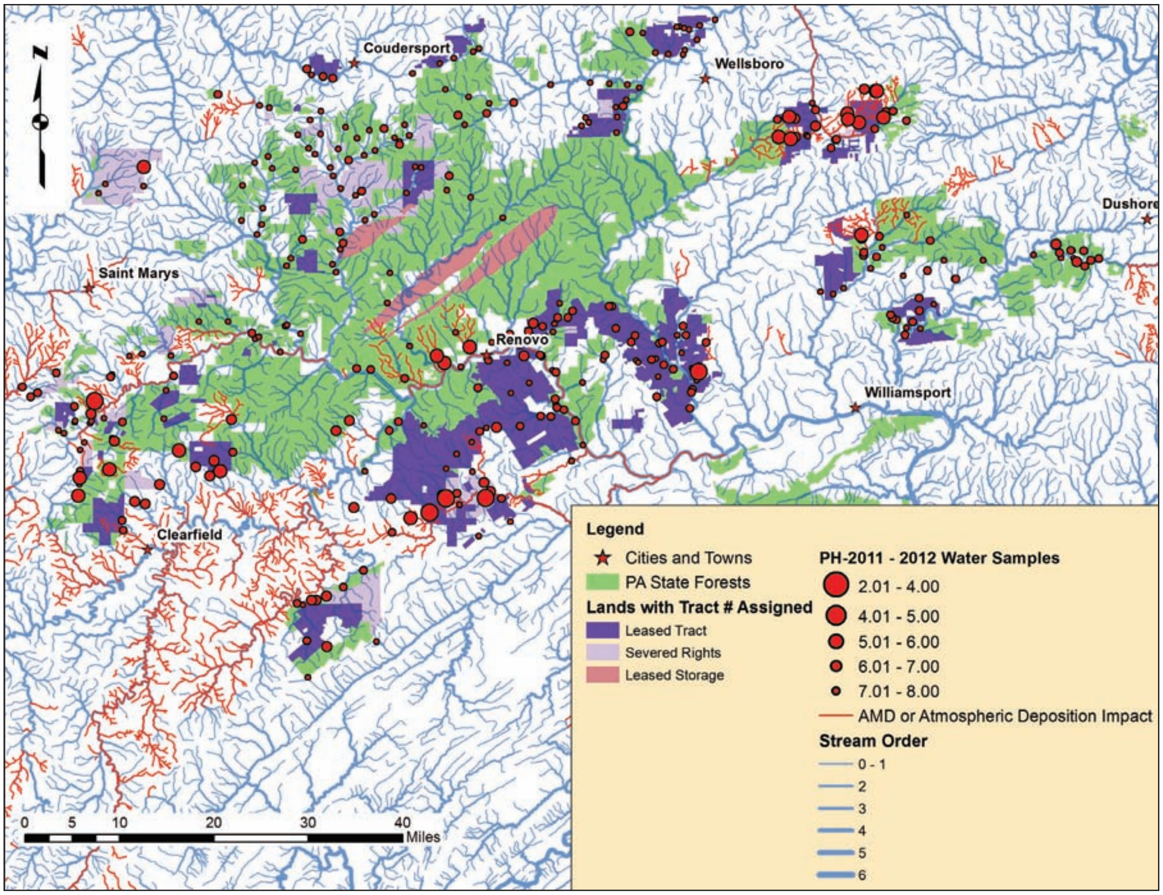


Figure 6.7 Map of pH results of widespread sampling of field chemistry. Symbols for sampling locations reflect pH results. Streams that DEP has identified as having acid deposition or abandoned-mine drainage problems are shown in red.

measurements is evidence that acidic water is largely responsible for elevated specific conductance results. There are two notable exceptions: the results at sampling point 1252-2 (7.55 pH and 342 µS/cm) and the results at sampling point 1263-2 (7.21 pH and 761 µS/cm). These data points have been highlighted for further investigation.

Table 6.6 and Table 6.7 present descriptive statistics of pH and specific conductance, respectively, broken down by the HUC-8 watersheds within the shale-gas region. Slight differences can be observed between some of the HUC-8s, and these statistics are presented for general reference.

Widespread sampling was conducted during the winter of 2012-2013, and thereafter during the fall/winter of each year. Sampling will not be conducted during drought or flood conditions. Such conditions will be gauged using the USGS Water Watch website's state-level maps (http://waterwatch.usgs.gov/index.php?id=ww). In future years, a subset of approximately 100 sample points will be assessed by randomly selecting one point within each HUC-12 watershed in the shale-gas

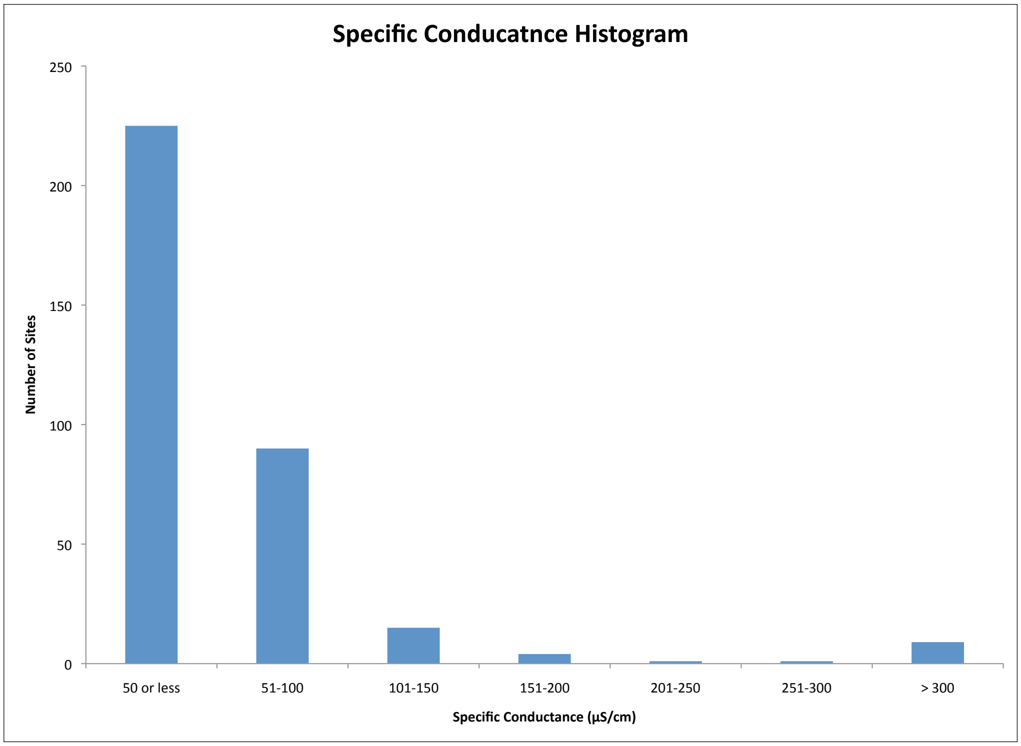


Figure 6.8 Histogram of specific conductance results from widespread sampling of field chemistry. Most results were less than 100 µS/cm.

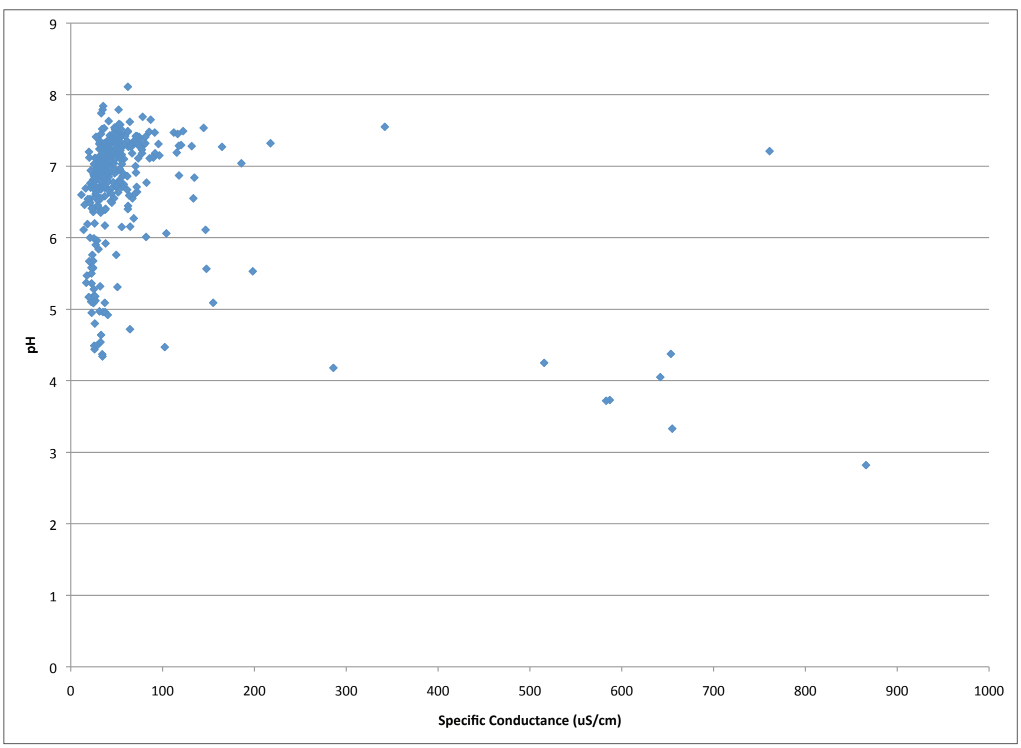


Figure 6.9 X-Y scatter plot of pH versus specific conductance results from widespread sampling of field chemistry. Plot shows that most of the high specific conductance results also had relatively low pH.

	Frequency (n)	Median	Min	Max
Tioga	29	6.7	4.2	7.6
Sinnemahoning	85	7.2	2.8	8.1
Bald Eagle	26	7.0	3.3	7.7
Pine	60	7.1	5.0	7.5
Upper West Branch Susquehanna	34	5.9	4.8	7.8
Middle West Branch Susquehanna	54	6.9	4.1	7.5
Lower West Branch Susquehanna	42	6.9	4.3	7.7
Allegheny (HUC-4)	15	6.9	4.6	7.8

Table 6.6 Descriptive statistics of pH results by HUC-8 watershed.*
**All numbers except frequency are pH standard units*

	Frequency (n)	Median	Min	Max
Tioga	29	31.4	16.9	286.0
Sinnemahoning	85	49.8	16.3	866.0
Bald Eagle	26	54.0	17.6	655.0
Pine	60	40.6	21.8	144.7
Upper West Branch Susquehanna	34	27.9	11.6	185.8
Middle West Branch Susquehanna	54	47.2	18.2	653.5
Lower West Branch Susquehanna	42	33.3	14.0	91.8
Allegheny (HUC-4)	15	34.7	24.5	104.1

Table 6.7 Descriptive statistics of specific conductance results by HUC-8 watershed.*
**All numbers except frequency are µS/cm*

region. This approach will give a broad geographic distribution of points while maintaining a manageable workload.

A few changes will be made to the protocol in future years:

- The field meter will be inserted directly into the stream, rather than using a container.
- Rather than the LaMotte Pocketester, either a YSI Model 63 or YSI Pro Plus will be used.
- Field meters will be calibrated daily, except that the YSI Model 63 will be calibrated monthly for specific conductance.
- Temperature will be recorded in degrees Celsius, and conductivity also will be recorded (as opposed to only specific conductance).

Pebble Counts

Like many other forms of earth disturbance, shale-gas development includes a number of activities that may cause erosion and sedimentation in streams, such as pad construction, road construction or modification, and pipeline construction. Sedimentation and the resulting change in streambed particle size can be detrimental to aquatic macroinvertebrate and fish populations. Pebble counts will be conducted over time at the same locations to detect changes in particle size profile that may be

attributed to shale-gas development. In addition, pebble counts will be conducted in similar locations from paired watersheds to assess whether shale-gas development seems to change particle size profiles on a watershed scale.

Pebble counts will be an element of comprehensive water quality monitoring stations established as part of the Before-After-Control-Impact monitoring approach currently in development. It was determined that 10 monitoring stations would be established within the area of interest – five in the control area and five in the potential impact area.

The population of possible monitoring station locations was organized based on stream order – identifying each stream segment within the area of interest in one of three categories: first-order, second-order, or third-order and greater. Based on the relative contribution of each of these stream sizes to the total stream mileage in the area of interest, it was determined that six sampling stations should be on first-order streams, two on second-order streams, and two on third-order and greater streams.

For the control area, sampling stations were located by randomly selecting three first-order stream segments, one second-order stream segment, and one third-order stream segment. Stream segments were established from the NHD high-resolution dataset, which generally segments streams based on intersections with tributaries. Each stream segment in the control area was given a random number between 0 and 1, and the lowest numbered segments were selected in each category (based on stream order). All of the selected stream segments were examined for accessibility and whether the watershed was primarily state forest land. If the stream segment was inaccessible or a large percentage of the watershed was not on state forest land, the segment was rejected and the segment in that stream order category with the next highest random number was selected as its replacement. This random selection was employed to provide the most representative sampling of the control or reference condition in the area of interest.

For the impact area, sampling stations were located by choosing stream segments most likely to be impacted by shale-gas development. Again, three first-order segments, one second-order segment, and one third-order segment were chosen. This conservative approach was employed to provide the maximum chance of detecting changes due to shale-gas development, such that a finding of no change would suggest that areas less impacted would not experience a change either.

The sample reach for pebble counts will typically be 200 meters in length and should encompass at least two riffle-pool sequences. Within each sample reach, a pebble count will be performed based on the methodology described in the DEP's Instream Comprehensive Evaluation Protocol (DEP 2009). At least 200 particles will be counted from each sample reach. Particles will be measured and tallied. Sampling of paired reaches (high development versus no development) should occur as near in time as possible (i.e., ideally within days). Analysis will revolve around the percentage of particles finer than 8 mm, which is recommended in both DEP 2009 and Bevenger and King 1995. Particles of 8 mm and smaller are of most concern for negatively affecting fish resources.

In the short term, if streambed particle size profiles are finer in watersheds with high levels of shale-gas development than in watersheds with no shale-gas development, it will suggest that past and present shale-

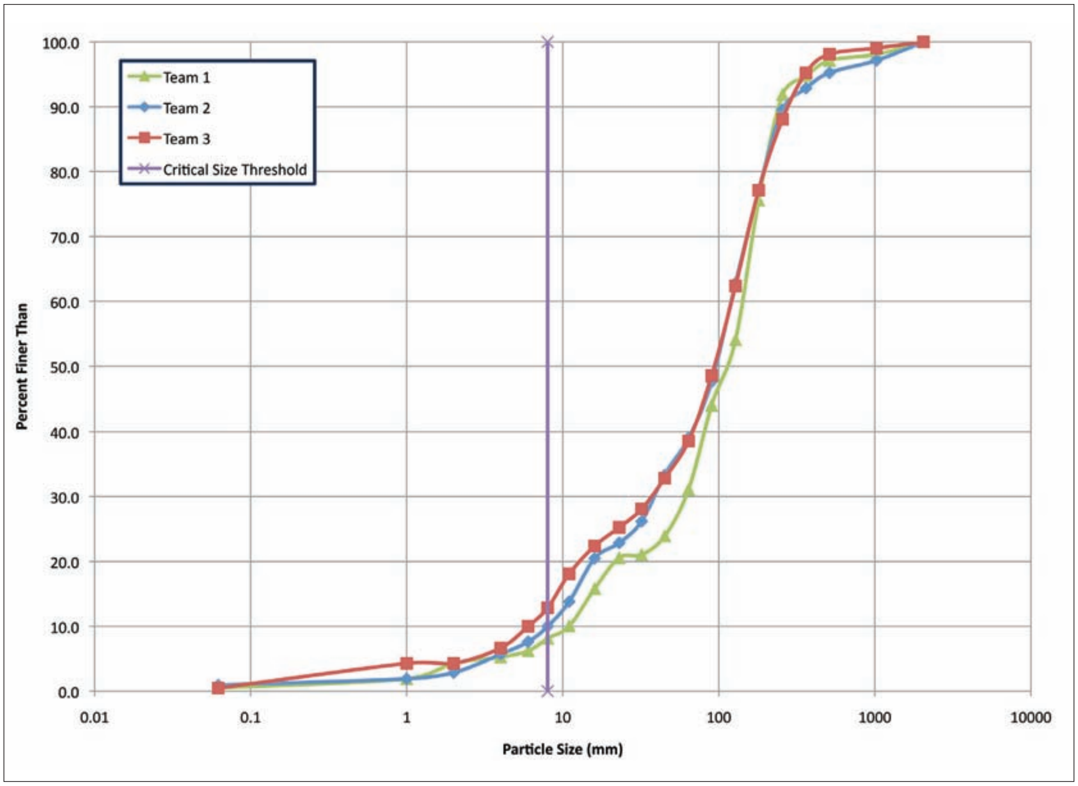


Figure 6.10 Cumulative percent diagram of particle size distribution from pilot study of pebble count methodology in Browns Run. Diagram shows that approximately 10 percent of the particles were below the 8-mm critical size threshold, indicating that this stream is in a reference condition.

gas development activities could be the cause for this difference. However, this short-term result will be more of a correlation than a proven cause-effect relationship, because documentation of pre-development conditions does not exist. In the long term, if streambed particle size becomes finer over time in watersheds with high levels of shale-gas development but not in watersheds with no shale-gas development, it could suggest that gas development is the primary cause of this fining, unless another cause has been identified (e.g., highway construction, timber harvesting). This will suggest that erosion caused by shale-gas development activities is affecting streambed particle size profiles.

For the 2012 field season, this approach was pilot tested in Browns Run – a second-order stream in the Pine HUC-8. The watershed of Browns Run is nearly entirely within Tiadaghton State Forest, and it is encompassed by several leased tracts. The pilot study results from Browns Run are presented in Figure 6.10. The particle size profile for Browns Run shows that, on average, 10.3 percent of the particles are finer than 8 mm. According to DEP criteria, reference streams should have no more than 15 percent of particles finer than 8 mm, and impaired reaches have greater than or equal to 35 percent of particles finer than 8 mm. Thus, as of summer 2012, Browns Run was considered a reference quality stream. Future sampling will lend itself to additional data analysis.

In future years, pebble counts will be conducted annually in the spring, prior to leaf out and greening of vegetation (when vegetation fieldwork will become more of a priority). The timing of pebble counts is not particularly weather dependent, but they are more easily conducted when the streams are not choked with fallen leaves or frozen.

Longitudinal Transects of Field Chemistry

As described above in the section on Widespread Sampling of Field Chemistry, field chemistry measurement gives a snapshot of general stream water quality. The resulting measurements of temperature, pH, and specific conductance can be indicative of good stream health or potential sources of impairment. To supplement the widespread sampling program, the longitudinal transects monitoring will examine how field chemistry parameters vary along a stream corridor from its mouth to its headwaters. In conjunction with the widespread sampling, this study will provide valuable reference data for the bureau or DEP should a pollution event occur in the vicinity of a widespread sampling location. Field chemistry measurement will be conducted incrementally along a stream from its headwaters to its mouth into a larger body of water. This will provide data on the variability along such a transect.

For longitudinal transects, two streams will be examined within each core gas forest district. The selected streams for longitudinal transects will have a sampling point along them from the widespread field chemistry sampling protocol described above. This will tie the two datasets together. The longitudinal transect streams will be chosen by randomly selecting two widespread sampling points within each district.

The sampling will begin where the stream joins a larger water body (i.e., at its mouth) and will proceed upstream to the point where bed and banks disappear. The path upstream will follow the main stem of the stream, not deviating to a tributary or branch. Field chemistry measurements will be at a specific interval along the transect, with the chosen interval dependent on the length of the transect. Before each day of sampling, the handheld meter will be calibrated according to

the manufacturer's instructions. At each measurement location, the probe will be inserted into the water, in an area of good mixing, and kept in place until readings stabilize. The following parameters will be recorded in a fieldbook or datasheet: conductivity (microsiemens/cm), specific conductance (microseimens/cm), temperature (degrees Celsius), and pH.

Grab Sampling

Surface water grab sampling and flow measurement are employed to obtain a discrete analysis of chemical constituents and flow at a given point in a stream. This information can be used to identify pollutants and/or to characterize the background chemical and hydrological characteristics of the stream. The stream's flow rate is determined at the same time as the grab sampling so that the chemical "load" (a measurement of mass) to the stream can be calculated. Flow data are also important for understanding the potential effect that flow level can have on chemistry results. Although only representative of a point in time at a single location, these techniques provide the opportunity to accurately measure the concentrations and loads of various parameters in a stream. By repeating these measurements over time at the same location, a trend may be observed in constituent concentrations or loads. Grab sampling also will provide reference points for the bureau and DEP should a major pollution event occur in the vicinity of a sampling location.

Grab sampling will be an element of the Before-After-Control-Impact monitoring approach currently in development. By sampling streams outside the influence of shale-gas development, chemical and hydrological data will be obtained on the natural, or reference, condition of streams in the shale-gas region. Such datasets will be useful for comparison to potentially impacted streams. Streams of various sizes will be sampled to account for variation due to drainage area or flow level.

The comprehensive water quality monitoring stations will include the deployment of a continuous monitoring water quality probe/sonde and periodic grab sampling with flow measurements. It was determined that 10 monitoring stations would be established within the area of interest – five in the control area and five in the potential impact area. The selection of monitoring station locations was described in the section on Pebble Counts.

For grab sampling and flow measurement, an area of the stream with relatively uniform flow from bank to bank will be selected, likely a run or gentle riffle. Large in-stream obstructions, such as downed trees or large boulders, will be avoided. This will allow for accurate flow measurement and grab sampling of well-mixed water. The grab sampling and flow location will be downstream of the continuous monitoring probe/sonde deployment. The location will be marked with flagging and recorded with a GPS. The grab sampling protocol involves a number of steps that will be overviewed here.

The first step in the grab sampling protocol will be to gather data on field chemistry. A YSI ProPlus multi-parameter meter will be used to measure the following parameters: temperature, pH, dissolved oxygen, conductance, and specific conductance. A Hach 2100Q will be used to measure turbidity.

Then, grab sampling will be performed by gathering a water sample into a sample bottle at mid-channel, mid-depth. Chemical preservatives will be added to the sample bottle in the field, as appropriate.

Lastly, the flow will be measured using a Hach FH950 flow meter and top-set wading rod. Ideally, flow will be measured at 22 fixed-width stations across the stream profile. At each station, a velocity measurement, at 60 percent of the water depth, will be averaged over 10 seconds. The FH950 then calculates the flow/discharge rate according to the USGS mid-section method. In very narrow headwater streams, 22 fixed points may not be feasible and a lesser number of stations may be performed.

Lab analysis will be performed by the DEP Bureau of Laboratories. On a monthly basis, a cost-effective indicator suite of parameters will be analyzed: specific conductance, pH, total dissolved solids, total suspended solids, bromide, chloride, barium, and strontium. On a semi-annual basis, a more comprehensive analysis will occur, including additional metals, nutrients, and organic compounds.

The field chemistry, flow data, and laboratory data will be used to develop chemical and hydrological profiles of the streams. This will be done using descriptive statistics, such as a range of flows or an average concentration of a substance. For first-order streams, which will have three replicates sampled, some generalizations can be made for both the control and impact areas. For example, confidence intervals of measurements/results can be calculated for first-order streams. Differences between the control and impact areas will be examined, but within the limitations of the data set. Natural spatial or temporal variability may be fully or partially responsible for differences observed between streams. After a period of several years, these data can be used to evaluate long-term trends in stream conditions. Laboratory results will be compared to relevant benchmarks, such as DEP standards or U.S. EPA water quality criteria.

Continuous Monitoring Devices
Continuous monitoring temperature-conductivity probes (HOBOs) are deployed to measure and record stream temperature and conductivity over time. HOBOs are staked into the stream bed and left for a period of time to record data, then periodically visited for maintenance and downloading of data. Data collected by HOBOs can be used to characterize stream conditions, monitor for influx of high-conductivity water (such as flowback water), or monitor for influences on stream temperature (such as cleared riparian forest).

Periodic maintenance of HOBOs is necessary for several reasons. HOBOs can experience burial or disturbance of their staked positions. They can experience "fouling" of their sensor, which is growth of algae/bacteria on the sensor, or plugging of the sensor area with sediment. HOBOs also may experience calibration drift, whereby the calibrated value for conductivity changes over time. Although the conductivity calibration cannot be corrected or changed on HOBOs, a check of their readings relative to calibration standards can be valuable in post-processing of data. Each of these potential negative effects should be checked, documented, and addressed during maintenance visits.

HOBO data collection will be employed along with grab sampling to establish comprehensive water quality monitoring stations. This will be done within watersheds influenced by shale-gas development and also in reference or control watersheds.

HOBO deployment will be an element of comprehensive water quality monitoring stations established as part of the Before-After-Control-Impact monitoring approach currently in development. The comprehensive water quality monitoring stations will include the deployment of a continuously monitoring water quality probe/sonde and periodic grab sampling with flow measurements. It was determined that 10 monitoring stations would be established within the area of interest – five in the control area and five in the impact area. The population and site selection process for the monitoring stations is described above in the section on Pebble Counts.

For HOBO deployment, an area of the stream with good mixing and sufficient water depth will be selected. The HOBO deployment location will be upstream of the grab sampling location to minimize disturbance of the HOBO during grab sampling activities. The HOBO location will be recorded with a GPS and photographs. The HOBO maintenance protocol involves a number of steps that will be overviewed here.

The first step in the protocol will be to gather side-by-side field chemistry data for comparison with data collected by the HOBO. A YSI ProPlus multi-parameter meter will be used to measure the following: temperature, conductivity, and specific conductance. Then, the HOBO will be retrieved from the stream. The degree of sedimentation and fouling will be documented through field notes and photographs. The HOBO will be cleaned according to manufacturer instructions. The calibration of the HOBO will be checked by immersing it in several conductivity standards. Although the HOBO cannot be re-calibrated, this process confirms whether or not the HOBO continues to read accurately. After downloading data from the HOBO, it will be redeployed in the stream. A final side-by-side measurement of field chemistry will be conducted. Comparison of the side-by-side results and HOBO results permits a data processing correction to be made for drift in HOBO readings due to fouling.

The data from HOBOs will be analyzed and graphed using the HOBOware software. Records will be searched for potential spikes due to pollution events. Descriptive statistics, such as a range of temperatures or an average conductivity, also will be calculated. Differences between the control and impact areas will be examined, but within the limitations of the data set. Natural spatial or temporal variability may be fully or partially responsible for differences observed between streams. After a period of several years, these data can be used to evaluate long-term trends in stream conditions.

Pipeline Crossing Assessment

Pipeline crossings represent a potentially significant impact on streams and rivers in state forests. The pipeline crossings are typically constructed by an open-

cut trench across the stream or by horizontal directional drilling (HDD) beneath the stream. The open-cut trench represents a direct impact on the riparian vegetation, stream bed, and water. The HDD can affect riparian vegetation, depending on the details of the operation, and can affect nearby water bodies through the occurrence of an inadvertent return – a release of high-pressure drilling mud outside the drilling hole. Following construction, riparian areas must be revegetated (at least with herbaceous vegetation), which may have varying degrees of success, leading to potential erosion and sedimentation control issues. The type and density of ground cover will be a good indication of how prone a surface is to erosion. Shrub and tree canopy cover will intercept rainwater, thus slowing its velocity and helping to prevent erosion.

The number of pipeline crossings on state forest land can be evaluated through GIS analysis, comparing pipeline infrastructure to stream layers. Through 2012, 35 stream crossings occurred due to shale-gas pipelines. The pipeline crossing assessment will be a multidisciplinary protocol that examines vegetation and physical features of pipeline crossings.

Each crossing will be visited and the coordinates recorded by GPS at the center of the intersection of the stream and right of way. Vegetation condition (ground cover, shrub cover, and canopy cover) will be assessed on the right of way, upstream of the right of way, and downstream of the right of way. Various physical measurements of the right of way will be performed, such as its width and slope. The right-of-way and adjacent areas will be photo-documented. The condition of the stream banks will be assessed for indicators of eroding banks. Sedimentation could also be evaluated through use of the Pebble Count Protocol, which may be applied at certain pipeline crossings. The characteristics and condition of post-construction stormwater management structures will be evaluated.

If photo-documentation and visual assessment indicate that rights of way are not adequately revegetating and stabilizing, then increased emphasis will be placed on inspections and best management practices at stream crossings. Measurements may suggest that revegetation/stabilization problems occur predominantly for rights of way of certain slopes or width ranges, in which case inspections and best management practices can be targeted to such crossings. Observations of right of way condition must be made in the context of the upstream and downstream assessment units. For instance, if the upstream units show erosion problems, then there may be inherent channel instability (unrelated to pipeline construction) contributing to erosion problems on the right of way.

As time and resources allow, this study will examine all instances, since 2008, in which gas or water pipelines related to the shale-gas industry have crossed streams on state forest lands. This protocol also can be used at various other units of analysis based on need (e.g., a paired watershed, specific district, region). Whenever possible, future rights of way will be assessed pre-construction. Future monitoring efforts will include testing and evaluating the pipeline stream crossing protocol. The goal is to eventually assess every shale-gas-related pipeline stream crossing. In subsequent years, the goal will be to assess each pipeline crossing prior to construction and again after it is installed. From then, a percentage of assessed pipeline crossings will be reassessed on a periodic basis.

Monitoring Partners

The bureau has partnered with the Susquehanna River Basin Commission (SRBC) to install 10 continuous monitoring devices on state forest lands. These devices monitor pH, dissolved oxygen, specific conductance, turbidity, and temperature. A discussion of this monitoring program is provided in the chapter on External Partner Collaboration.

IV. Discussion / Conclusion

A GIS assessment of streams in the shale-gas region has demonstrated that the majority are headwater streams that have good water quality and provide excellent trout habitat. This makes it paramount that these streams be protected from potential effects of shale-gas development.

With specific conductance being a good indicator parameter for the influence of shale-gas development, the 2011 widespread sampling of field chemistry showed positive results, with over 90 percent of samples having a specific conductance reading below 100 µS/cm. Most samples with higher specific conductance readings appear to be linked to acid mine drainage or acidic atmospheric deposition. Field chemistry measurement will be repeated at a subset of the original locations to continue this monitoring effort.

A number of additional protocols were initiated in 2013 to monitor water resources in the shale-gas region. Many of the water monitoring protocols will be implemented in a Before-After-Control-Impact monitoring approach. This allows for a comparison of data between reference conditions and impacted or potentially impacted conditions.

Future work, in collaboration with SRBC, may examine the potential for shale-gas development to affect groundwater resources. This likely will be approached by examining water quality of springs. The bureau is presently in discussions with SRBC regarding this monitoring concept.

Initial water monitoring results have not identified any significant impacts due to shale-gas development. This is based on one round of field chemistry sampling throughout the shale-gas region and over one year of operation for 10 continuous monitoring devices in key watersheds (see External Partner chapter). At this early stage, the data collected are primarily for establishing baseline conditions, but no results have indicated an initial impact due to shale-gas. The few high conductivity readings from the field chemistry sampling appear to be related to acid mine drainage. Future monitoring will investigate this further and will permit the analysis of water quality trends over time.

Part 2: Monitoring Values
» Soil

I. Key Points:

- Erosion and sediment control practices for shale-gas infrastructure on state forest lands are regulated by DEP and jointly monitored by DEP and the bureau.
- To the extent possible, placement of shale-gas infrastructure has avoided wet soils and soils with high runoff potential.
  - Of all pads, impoundments, and compressors constructed, over 85 percent were on well-drained to excessively well-drained soils, and over 80 percent were on soils with medium to very low surface runoff index.
  - Of all pipelines constructed, over 70 percent occurred within well-drained to excessively well-drained soils and within soils with medium to very low surface runoff index.
  - Of all roads newly constructed or improved due to shale-gas development, over 80 percent occurred within well-drained to excessively well-drained soils and within soils with medium to very low surface runoff index.
- Future research and monitoring will focus on the effects of well pad construction on soil physical and chemical properties, as well as the effects of best management practices on hydrology and sediment loads.

II. Introduction

Bureau policy states that soil quality should be maintained at the highest possible level (Bureau of Forestry, 1995). The soil ecosystem performs a number of key functions that are essential to a healthy forest ecosystem:

- Sustains biological activity, diversity, and productivity by providing habitat for plants, animals, and other organisms
- Regulates water storage and flow
- Filters, buffers, immobilizes, and detoxifies potential pollutants
- Stores and cycles nutrients

The bureau evaluates the potential effects of management actions on soil resources and employs best management practices to minimize impacts to soils during timber harvesting, road construction, and other forest management activities.

Shale-gas development often involves earth disturbance activities that require careful planning and oversight to minimize negative effects on soil quality. The construction or improvement of roads increases direct soil impacts in road corridors, and runoff from roads presents a risk for erosion and sedimentation. Pipelines create similar corridor impacts and often can involve soil disturbance on steep slopes where erosion and stormwater control can be a challenge. Pad construction clears the topsoil (stockpiling it for future use) and causes compaction of soils beneath the pad infrastructure. Spills of chemicals or fuels also can threaten soil quality. Lastly, soil management becomes a critical component of pad restoration activities. One of the objectives of the shale-gas monitoring program is to evaluate the effects of these activities on soil resources.

III. Monitoring Efforts/Results

Soil resource management and monitoring is achieved in collaboration with DEP. Regulation of earth disturbance activities falls within DEP's jurisdiction. The bureau helps to monitor for problems relating to erosion and sediment control and reports issues to DEP. The bureau also plans to institute several monitoring protocols specifically focused on the effects of gas infrastructure on soil resources.

Erosion and Sediment Control Permits

Most earth disturbance activities involving gas development require an erosion and sediment control plan or permit from DEP. Disturbances of greater than 5,000 square feet (0.11 acres) require an erosion and sediment control plan, while disturbances greater than five acres require an erosion and sediment control permit. The plan or permit specifies the erosion and sediment control best management practices that must be implemented for compliance. The bureau provides DEP input on erosion and sediment control plans and permits with the goal of ensuring that practices are designed appropriately for a forested environment as opposed to a practices more suited for an urban or commercial setting.

Gas operators and their subcontractors are required to self-monitor their erosion and sediment control practices and make any necessary improvements or corrections. DEP inspectors regularly check active work sites to verify compliance with the plan or permit. The bureau's gas foresters assist by also monitoring for signs of non-compliance and report any potential problems to the operators, and if necessary, to the proper DEP authorities.

Infrastructure Locations

The bureau plays a large role in deciding the location of gas infrastructure on leased tracts. The location of each pad and pathway of each pipeline must be approved by the district forester. The gas operators initially propose the location of pads and pipelines based on the most effective means of draining the natural gas reservoir from an area, but the district forester may require changes to the initial locations based on environmental factors. Often, the location selection is based on topography, with preference given to flatter areas for development. This minimizes the amount of cut and fill necessary for construction and reduces erosion risks. To the extent possible, wet areas also are avoided for location of infrastructure in order to minimize problems with drainage, stormwater management, and wetland and headwater impacts. In addition, infrastructure is often sited along existing disturbance corridors.

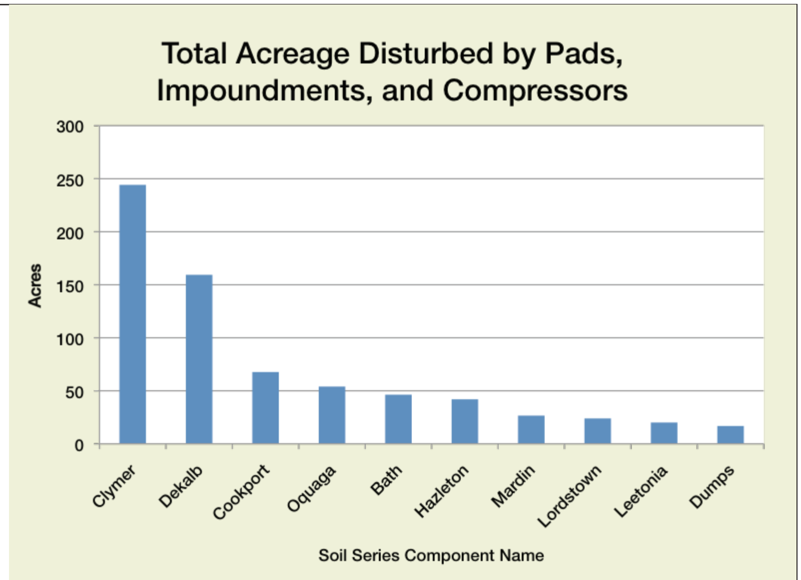


Figure 7.1 Ten most common soil series components disturbed by pads, impoundments, and compressors. Analysis based on SSURGO data (Soil Survey Staff 2012).

Well pads, impoundments, and compressors have been constructed on 55 different soil types (based on analysis of SSURGO data, Soil Survey Staff 2012, through December 31, 2012). As shown in Figure 7.1, the most common soil series were Clymer, Dekalb, and Cookport. All three of these soils form primarily through the weathering of sandstone in place. The Clymer series consists of deep, well-drained soils and occurs on upland ridges, hills, and sideslopes. The Dekalb series consists of moderately deep, excessively drained soils and forms on nearly level to very steep, uplands and ridges. The Cookport series consists of deep and very deep, moderately well-drained soils occurring mainly on nearly

level to gently sloping ridgetops and moderately steep sideslopes (Soil Survey Staff 2013). Figure 7.1 shows the 10 most common soil types on which pads, impoundments, and compressors were constructed.

Soils can be categorized by drainage class, an indicator of the soil's wetness. As shown in Table 7.1, the vast majority of pads, impoundments, and compressors have been constructed on soils that are well drained or moderately well drained. This demonstrates that wet areas have largely been avoided for placement of infrastructure.

Soils also can be classified according to an index of surface runoff. Surface runoff index refers to the loss of water from an area by flow over the land surface, and it is dependent on the slope of the soil and its hydraulic conductivity. As shown in Table 7.2, the majority of pads, impoundments, and compressors have been constructed on soils with medium to very low surface runoff potential. This indicates that areas with high runoff potential, and thereby erosion risk, have largely been avoided for placement of infrastructure.

Drainage Class	Percent Total Land Area in Gas Districts	Percent of Area of Pad Disturbance	Percent Length of Pipeline	Percent Length of Road
Excessively Drained	1.30%	0.42%	0.24%	0%
Somewhat Excessively Drained	2.31%	2.72%	2.30%	0.62%
Well Drained	76.11%	82.17%	71.50%	81.21%
Moderately Well Drained	16.90%	12.55%	22.12%	16.86%
Somewhat Poorly Drained	1.49%	1.80%	2.81%	1.24%
Poorly Drained	1.52%	0.29%	0.83%	0.07%
Very Poorly Drained	0.28%	0.05%	0.20%	0%

Table 7.1 Percent of total area disturbed by pads, impoundments, and compressors, and percent of total length disturbed by new pipelines and roads according to soil drainage class. For comparison, the percent of total land area within the gas districts in each soil drainage class is presented as well. Analysis based on SSURGO data (Soil Survey Staff 2012).

Drainage Class	Percent Total Land Area in Gas Districts	Percent of Area of Pad Disturbance	Percent Length of Pipeline	Percent Length of Road
Very low	5.33%	18.57%	12.48%	17.65%
Low	26.25%	29.24%	31.15%	29.26%
Medium	44.22%	32.89%	29.24%	35.46%
High	16.90%	14.00%	18.49%	14.32%
Very high	6.61%	5.51%	8.63%	3.31%

Table 7.2 Percent of total area disturbed by pads, impoundments, and compressors, and percent of total length disturbed by new pipelines and roads according to soil index of surface runoff. For comparison, the percent of total land area within the gas districts in each runoff class is presented as well. Analysis based on SSURGO data (Soil Survey Staff 2012).

Consideration must also be given to the changes in natural water flow to an area with natural gas development. By altering water flow, especially with the implementation of stormwater collection basins, it is likely that the surrounding soil hydrology is impacted to some extent. Research is underway by Pennsylvania State University to examine pad placement and its effect on soil wetness and other soil properties. This research is discussed further in the research section.

Pipeline construction affects a variety of soil types as well. Often, pipelines are routed along existing road corridors, so the soils affected can be similar. The soil series most commonly crossed by pipelines are the Clymer, Dekalb, and Cookport – the same three soils most commonly impacted by pads, impoundments, and compressors. The breakdown of soils crossed by pipelines according to drainage class and index of surface runoff is shown in Tables 7.1 and 7.2, respectively.

While wet and steep soils are avoided to the extent possible for pipeline construction, the nature of pipelines, in moving gas/water across the landscape, necessitates construction on some steep slopes. Table 7.3 provides a breakdown of pipeline miles according to slope category.

Figure 7.2 provides an example of pipeline traversing an area of Lycoming County in Tiadaghton State Forest. The figure shows an aerial photograph of the Honniasont pipeline's path and a graph of the pipeline's change in elevation over that path. In general, the pipeline is kept on relatively flat ground until it is necessary to cross the Little Pine Creek valley.

The construction of new roads similarly creates soil disturbance, with Clymer, Dekalb, and Cookport soils, again, being the mostly commonly affected soil series. The breakdown of soils traversed by new roads according to drainage class and index of surface runoff is shown in Tables 7.1 and 7.2, respectively. The majority of shale-gas roads are constructed on well-drained or moderately well-drained soils, and most were located on soils with medium to very low index of surface runoff. As with pipelines, some roads must traverse steeper slopes in order to give access to ridgetops, where pads are commonly constructed.

Soils can also be rated based on their suitability for certain land use. One of the ratings available is for erosion hazard from forest road or trail construction. This rating for shale-gas roads is shown in Table 7.4.

	Slope Category						
	0 to 10 %	11 to 20%	21 to 30%	31 to 40%	41 to 50%	> 50%	Total
Miles of Pipeline	92.9	7.5	1.7	0.8	0.5	0.3	103.7
Percent of Pipeline	89.6%	7.2%	1.6%	<1%	<1%	<1%	----------

Table 7.3 Miles of pipeline by slope category.

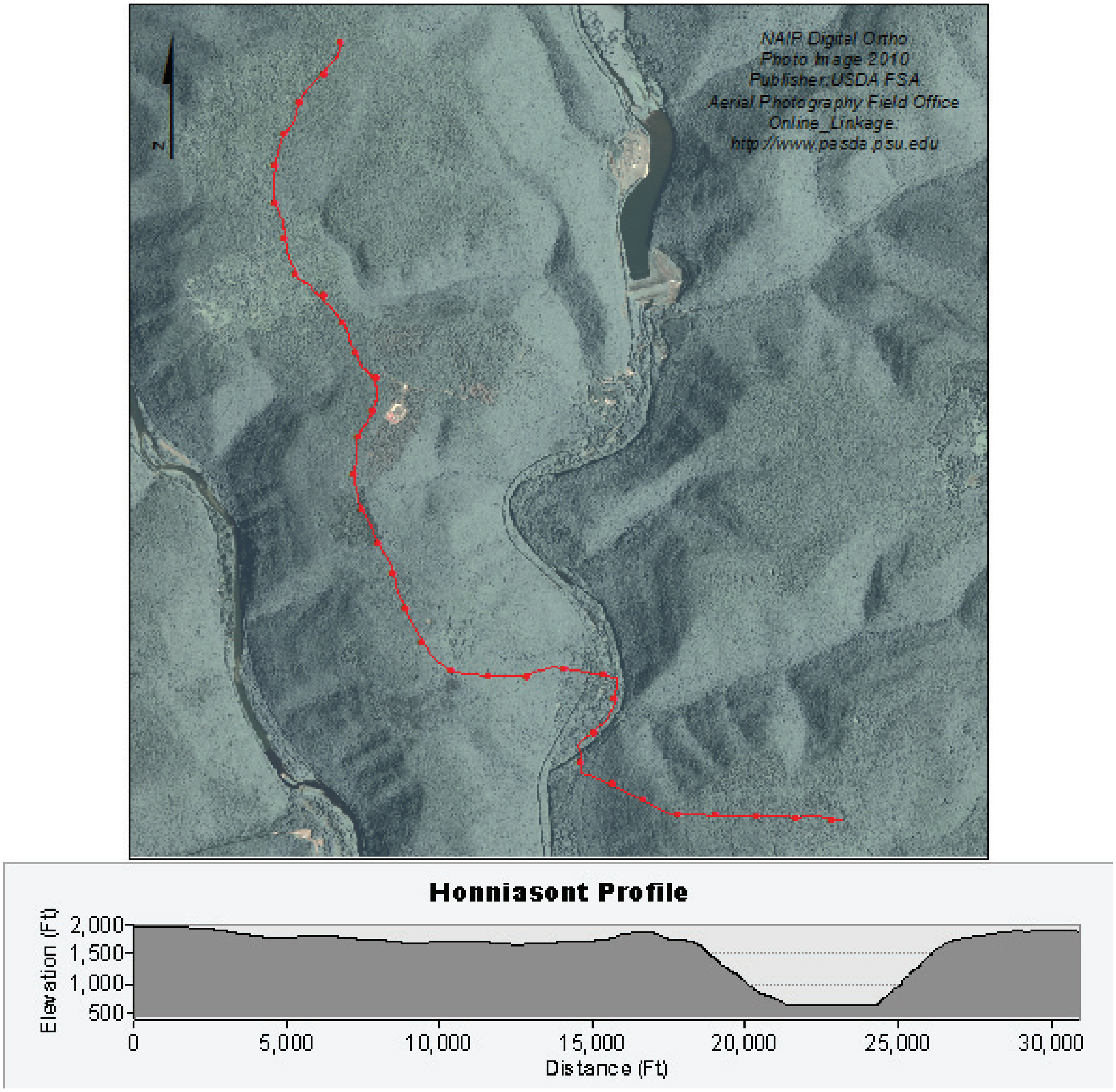


Figure 7.2 Illustration of the path and elevation change of the Honniasont pipeline in Lycoming County.

Over 80 percent of road construction was performed along areas with moderate or slight erosion hazard. Sometimes road construction is necessary where severe erosion hazard exists in order to minimize overall forest fragmentation or to avoid sensitive resources, such as wetlands or threatened wildlife habitat.

Erosion Hazard From Forest Road or Trail	Percent Length of Road
Slight	35.47%
Moderate	47.01%
Severe	17.52%

Table 7.4 Percent of newly constructed length of road according to erosion hazard from forest road or trail construction. Analysis based on SSURGO data (Soil Survey Staff 2012).

Pad Soil Sampling Protocol

The construction of gas well pads on state forest land produces a distinct impact footprint. Trees are harvested and land is cleared for the pad area and for temporary work areas. Fill material, typically crushed limestone, is placed over an area of several acres to create the pad surface. This is followed by a series of industrial activities on the pad to drill and develop the gas well. The pad surface remains in place for potential future work on the well. While the direct impact within the pad footprint is clear, the effect of pad development beyond the pad footprint is unknown. It is possible that limestone dust or other pollutants are dispersed into adjacent forest soils, potentially having effects on plant or wildlife communities. A protocol has been developed to evaluate whether surface soil chemistry varies based on proximity to a well pad. The protocol will also serve to establish baseline levels of contaminants of concern in surface soils around well pads, such that this baseline data will be available for comparison should any pollution event occur at the pad site.

For each pad evaluated, there will be two assessment units: plot A and plot B. Assessment units will be located in proximity to the lowest point (in elevation) around the perimeter of the pad. This location is the mostly likely discharge point for any surface spills that occur on the well pad; therefore, it will serve as a reference point for establishing the soil sampling plots. The plot centers will be located 25 feet away from the well pad and 25 feet past the forest edge for plots A and B, respectively (see Figure 3). The shape of both soil sampling plots will be a rectangle 160 feet (parallel to the edge of the well pad) by 30 feet (perpendicular to the edge of the well pad). In each plot, 48 surface soil increments will be collected using a multi-increment sampling tool. At the laboratory, the increments will be ground and mixed to generate one sample per plot. This is a cost-effective and precise method for estimating average soil concentrations. Soil analysis will include: dry weight and moisture content, organic carbon, alkalinity, pH, barium, strontium, other metals, and oil and grease.

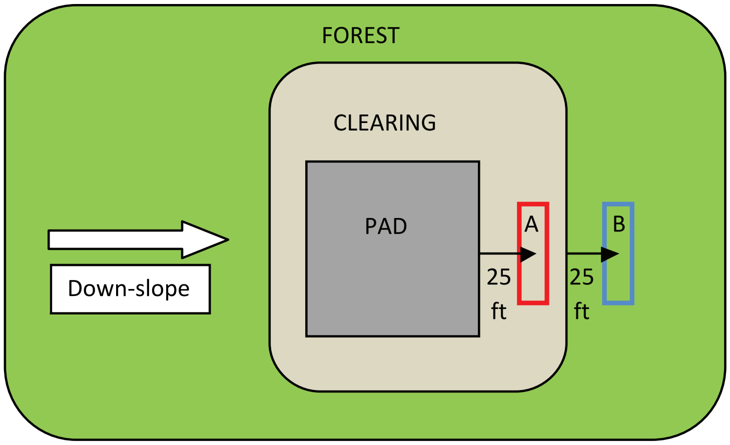


Figure 7.3 Diagram of sample plots for soil sampling around pads.

Similar sampling plots will be established in reference areas to obtain representative samples of natural conditions. The reference plots will be located in the same soil type that is dominant beneath pads.

IV. Conclusion/Discussion

While significant soil disturbance is occurring due to shale-gas development, the bureau and DEP are closely monitoring compliance with erosion and sediment control practices. To the extent possible, wet soils and soils with high runoff potential are being avoided in the siting of gas infrastructure. However, sometimes it is necessary to build upon wet soils or soils with high runoff potential in order to avoid impacts to other sensitive resources or take advantage of existing disturbance corridors. Ongoing and future research will examine the effect of pad placement on soil physical and chemical properties.

A topic requiring additional attention in the future is that of soil management during pad restoration. To date, there are very few examples of pad restoration on state forest lands. Discussions are ongoing regarding guidance to operators for soil management and other restoration procedures. Impacts to soils may differ between the actual pad footprint and the adjacent temporary work areas where trees have been cleared. Successful pad restoration may require physical treatment (e.g., ripping) to reduce soil compaction and/or soil amendments to optimize soil fertility. These activities will help ensure that soil quality is restored to the greatest extent possible.

Part 2: Monitoring Values
»Air

I. Key Points:

- Since shale-gas development began in Pennsylvania in 2008, there has been a marked decrease in several major air pollutants, such as sulfur, nitrogen oxides and carbon dioxide. This is due, in part, to the increased use of natural gas for power generation, the shutdown of several major facilities, and the installation of air pollution control equipment.
- Short-term air sampling at several locations around the state has detected natural gas constituents and associated compounds in the vicinity of shale-gas operations. These compounds were not detected at concentrations that would likely cause health-related impacts, although some were detected at levels that would produce an odor.
- A one-year study is underway in southwest Pennsylvania to study the potential long-term and cumulative effects of air emissions from compressor stations and a major processing facility.
- A study is underway to examine the concentrations of ground-level ozone in the vicinity of shale-gas operations.
- A short-term air quality study in Ramsey Village, in Lycoming County along the Pine Creek Rail Trail, did not detect air pollutants above rural background conditions.

II. Introduction

Clean air is a fundamental requirement of plants, animals, and humans. Good air quality is an expectation of state forest users. This is true both from a human health perspective and an aesthetic perspective. Visitors expect to breathe clean, "fresh" air during activities on state forest lands, and they anticipate that the views along state forest roads and trails will not be marred by smog, dust, or other air pollutants.

Shale-gas development involves many stages that provide different avenues for the release of air pollutants. The major stages of shale-gas development and related pollution sources are as follows:

- Pad, impoundment, and road construction – Pollutants are emitted from diesel engines that perform construction, and dust is produced from truck traffic and heavy equipment.
- Drilling – Drilling rigs require power from diesel or natural gas engines, and there are emissions from these engines.
- Hydraulic fracturing – Emissions can come from engines, the evaporation of fracturing wastewater, or the release of fracturing fluids, such as volatile organic compounds (VOCs).
- Flaring – Flaring is done to test the gas well before production. Emissions are created from the burning of the gas and atmospheric venting of non-combusted gas.
- Dehydration/condensate tanks – Gas pumped from the well may contain brine and VOCs that condense in collection tanks. Air space in the tanks is vented to the atmosphere during periods of filling. If the nature of the gas is considered "wet" (versus "dry"), the condensate may contain many other compounds, such as benzene, toluene, and xylenes.
- Compression – Emissions come from engines that power the compressors. Emissions may also come from compression equipment, pipes, or tanks.

These emission sources can emit a number of specific pollutants, some of which are described below:

- Methane, ethane, propane, and butane – These compounds are the main components of natural gas found in shale-gas formations. Burning these compounds in the presence of excess oxygen produces carbon dioxide and water, but incomplete combustion can produce undesirable pollutants such as carbon monoxide and formaldehyde. Methane itself is a potent greenhouse gas. Indoor air quality standards have been established for these compounds in workplace settings, but EPA has not established ambient air quality standards for these pollutants.
- "BTEX" – A group of compounds – namely benzene, toluene, ethylbenzene, and xylenes – is primarily found in petroleum derivatives, but also occurs naturally in some shale-gas formations. These compounds also are used as solvents and/or intermediates in the production of other chemicals. There are many health-related issues associated with chronic exposure to these compounds.
- Methyl mercaptan – This is a naturally occurring compound present in some shale-gas formations. It has a strong, unpleasant smell that can be detected by the human nose at very low levels. Olfactory fatigue, or the inability to smell methyl mercaptan, occurs after prolonged exposure.
- Carbon monoxide, nitrogen dioxide (NO2), and ozone – These pollutants are among the "criteria air pollutants" regulated by the U. S. Environmental Protection Agency, and they are considered harmful to public health above certain levels. They come from or are caused by reactions of emissions from a wide variety of sources such as industry, energy production, and mobile sources (e.g., vehicles). The EPA has set health-based ambient air standards for these pollutants. Ozone is of particular concern in the state forest system, as it is the most toxic air pollutant to plants.
- Particulate matter – This is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. The size of particles is directly linked to their potential for causing health problems. Particles that are 10 micrometers in diameter or smaller (PM10) are of concern because these are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. Finer particles that are 2.5 micrometers in diameter and smaller (PM2.5) constitute smoke and haze. These particles can be directly emitted

from sources such as forest fires, or they can form when gases emitted from power plants, industries, and mobile sources react in the air.

Although shale-gas development may emit these various pollutants through the processes described above, the natural gas produced through shale-gas development also has the potential to create an overall positive effect on air quality in Pennsylvania and the nation. This is mainly because natural gas emits fewer core emissions when compared to coal that is widely used in power generation in Pennsylvania and surrounding states. In February 2013, the DEP released air emissions inventory data that demonstrates a decrease in numerous pollutants from 2008 (the time that shale-gas development began at a high level) to 2011. Emissions inventory data specific to shale-gas development also was presented. These data are shown in Table 8.1. (The sulfur oxide emissions have decreased both as a result of the conversion to natural gas and the installation of control equipment on electric generating units.)

III. Monitoring Efforts/Results

The bureau is not conducting air quality monitoring. The bureau relies on DEP to assess potential effects of air emissions from the shale-gas industry and to require applicable air permits of shale-gas operations. DEP has conducted or is in the process of conducting several studies related to air quality and shale-gas development. These studies are described below.

Short-Term Ambient Air Sampling

DEP conducted a series of three short-term, screening-level ambient air sampling studies, each targeting a different region of the state. The goals of the studies were to assess preliminary air quality impacts near certain shale-gas operations and to determine if there were immediate health risks to nearby residents or communities from ambient pollutant concentrations. The studies are summarized in Table 8.2. Each study involved four or five sampling weeks using DEP's mobile analytical unit and air sampling canisters.

The key findings from the studies can be summarized as follows:

- Short-term sampling did detect concentrations of certain natural gas constituents, including methane, ethane, and propane, and associated compounds, such as benzene, in the air near shale-gas drilling operations.
- Elevated levels of natural gas constituents were detected at all compressor stations sampled in the three regions.
- Certain compounds, mainly methyl mercaptan, were detected at levels that generally produce odors.

Category	Year	Carbon Monoxide (TPY)	Nitrogen Oxides (TPY)	PM_{10} (TPY)	Sulfur Oxides (TPY)	VOCs (TPY)
All Point Sources	2008	94,409	235,485	30,719	864,789	24,671
All Point Sources	2011	85,990	192,275	22,588	353,480	20,363
Difference	------	8,419	43,210	8,131	511,309	4,308
Shale-gas Development	2011	6,852	16,542	577	122	2,820
Net Difference	------	1,567	26,668	7,554	511,187	1,488

Table 8.1 Statewide pollution inventory data and emissions data from shale-gas development, in tons per year (TPY).

The DEP will continue to collect annual emissions inventory data from the shale-gas industry, as well as other industries, for future comparison.

- Results did not identify concentrations of any compound that likely would trigger air-related health issues associated with shale-gas development activities.

DEP was unable to determine whether the potential cumulative emissions of criteria pollutants from shale-gas development activities would result in violations of the health and welfare-based federal National Ambient Air Quality standards. Due to the limited scope and duration of the sampling and the limited number of sources sampled, these findings only represented conditions at the time of the sampling and did not provide a comprehensive long-term study of ambient conditions.

The full reports on these studies are available on the DEP Bureau of Air Quality website: http://www.dep.state.pa.us/dep/deputate/airwaste/aq/default.htm.

The long-term monitoring will focus on large-scale compressors and/or gas processing stations. These facilities are being targeted for the following reasons:

- They are permanent facilities, whereas well installation activities are more short-term and thus not as relevant to chronic risk analysis.
- During the short-term studies, such facilities were shown to be sources of methane, NOx, carbon monoxide, and other hazardous air pollutants.
- They are a common source of complaints to the DEP regional offices for odors or other issues.
- They are components of industry that, as a whole, could be considered a major new source of emissions.

The study will involve a main monitoring site and three satellite monitoring sites, including one background location. Target pollutant concentrations will be measured for a period of one year. The monitoring sites will analyze for a variety of pollutants, including methane, Nitrogen oxides (NO_x), carbon monoxide, $PM_{2.5}$, ozone, and hydrogen sulfide. In addition to analysis of concentration data, the output of the study will include a human-health risk assessment.

Region	Period (2010)	Facilities Sampled
Southwest	Apr. to Aug.	Two compressor stations, condensate tank farm, wastewater impoundment, background site
Northeast	Aug. to Oct.	Two compressor stations, an active well site, a well site during fracking operations, background site
Northcentral	Aug. to Dec.	Two compressor stations, a well site during flaring operations, a well site during drilling operations, background site

Table 8.2 Description of DEP short-term, screening-level ambient air sampling studies.

Long-Term Ambient Air Monitoring

DEP presently is conducting a long-term, one-year air monitoring study of shale-gas development. The study, which is taking place in Washington County, will measure ambient airborne pollutants in an effort to determine potential air quality impacts associated with the processing and transmission of unconventionally produced natural gas. The data from the study will allow DEP to assess potential long-term impacts of emissions from unconventional natural gas operations on nearby communities. This initiative also will assist the DEP in its efforts to address the cumulative impact of these operations in the Marcellus Shale region.

The protocol for the long-term ambient air monitoring is available on the DEP Bureau of Air Quality website: http://www.dep.state.pa.us/dep/deputate/airwaste/aq/default.htm.

Ozone Assessment

Penn State University and the DEP Bureau of Air Quality are collaborating on a study of ground-level ozone. Ozone is a colorless gas that exists naturally in the upper atmosphere, where it shields the earth from the sun's ultraviolet rays, but ozone close to the earth's surface is an air pollutant. It is formed by chemical reactions between VOCs and NOx in the presence of sunlight and elevated temperatures. The primary human sources of VOCs and NOx are industrial and automobile emissions.

Plants are generally more sensitive to ozone than humans. The effects of ozone on plants range from visible injury to the leaves and needles of deciduous trees and conifers to premature leaf loss, reduced photosynthesis, and reduced growth in sensitive plant species. The airborne transport of ozone to remote forested areas has led to increasing concern about how this pollutant is influencing the health of individual trees and forest ecosystems. Possible impacts of ozone on forest species include reduced growth and vigor, reduced seed production, and increased susceptibility to insects and disease. Long-term ozone stress may lead to changes in species composition, reduced species diversity, and simplification of ecosystem structure and function.

Penn State presently manages three ozone monitoring stations in the northern tier of the state, in the areas experiencing high levels of shale-gas development. Stations are located in Clearfield, Tioga, and Bradford counties. Depending on project funding, one or more of these stations eventually may include an assessment of ozone damage to plants.

Ramsey Air Monitoring Study

In response to a citizen complaint, the DEP Bureau of Air Quality conducted a short-term monitoring study near the village of Ramsey (Cummings Township, Lycoming County) in February 2012. The primary concern was diesel emissions from the heavy truck traffic, related to shale-gas development, along State Route 44 near Ramsey. The study involved two air monitoring stations located on opposite sides of Ramsey along the Pine Creek Rail Trail. Samples were obtained during three days in February and analyzed for a suite of organic compounds. Results from February 3 had trace levels of several alkylbenzenes, which may be present in diesel fuel, but the concentrations were well below levels of concern for health effects. On the other two days of the study, air pollutants were not detected above rural background conditions. Given these results, DEP does not plan a follow-up to the study.

Air Permitting for Shale-Gas Operations

The DEP Bureau of Air Quality regulates air emissions through four different mechanisms: permit exemptions, general permits, plan approvals, and operating permits. A permit exemption sets forth detailed emission control and monitoring conditions that a pollution source must meet in order to be exempt from permitting requirements; this does not exempt the source from compliance with applicable standards. A general permit is a pre-determined permit for a general category of pollution sources that sets forth detailed emission control and monitoring requirements that must be met for the general permit to be applicable. General permits make the permitting process more efficient for common types of pollution sources, as the general permits must be authorized by the Bureau of Air Quality within 30 days of application. If a general permit does not apply, then an individual plan approval and operating permit must be obtained. The plan approval is the construction permit for the pollution source, and the operating permit is the approval for emissions once the source is operational.

Depending on the details of the pollution source, one or more of these regulatory mechanisms may apply to shale-gas operations. For the most part, shale-gas drilling and hydraulic fracturing operations will fall under the Category Number 38 Permit Exemption for Oil and Gas Exploration, Development, Production Facilities, and Associated Equipment. Well sites would only be eligible for the exemption if the operations meet emission control and monitoring criteria, and these Pennsylvania requirements are stricter than federal air quality rules for controlling wellhead emissions. The DEP exemption criteria includes practices, such as a leak detection and repair program for the entire well pad and facility, rather than just the storage vessels as required by federal rules. Emissions of volatile organic compounds and hazardous air pollutants must also be controlled beyond levels required by the federal rules. Even with the exemption, drilling and hydraulic fracturing operations are subject to federal reporting requirements for volatile organic compounds, and they must be included in an operator's annual report for the DEP's emissions inventory.

The Bureau of Air Quality has finalized revisions to a general plan approval and general operating permit (GP-5) for natural gas-fired engines and equipment at compressor stations, which help move gas from well sites into transmission pipelines. The revised general permit, which was developed after considering public comment, includes significantly lower allowable emission limits than the previous general permit. It imposes emissions limits that are 75 to 90 percent stricter than current limits for the largest, most common types of engines used at compressor stations. Operators of facilities permitted by the GP-5 must demonstrate that their facilities continue to be minor sources as defined by the Clean Air Act, allowing for operational flexibility. The owner or operator of the facility must use forward-looking infrared cameras or other leak detection monitoring devices approved by DEP for the detection of fugitive leaks on a quarterly basis. GP-5 addresses control of various air contaminants, including volatile organic compounds and hazardous air pollutants, as well as greenhouse gases (specifically methane). If a leak is detected, the leak must be repaired as expeditiously as practicable but no later than 15 days after the leak is detected. The final GP-5 includes all applicable requirements of the Federal New Source Performance standards and National Emission Standards for Hazardous Air Pollutants requirements for the Oil and Gas Sector.

If a pollution source related to shale-gas development does not meet the requirements for Permit Exemption Number 38 or General Permit 5, then it must apply for an individual plan approval and operating permit. the plan approval and operating permit would include project-specific emission control and monitoring requirements.

IV. Conclusion/Discussion

There are both positive and negative effects on air quality from shale-gas development. Short-term studies have demonstrated that gas-related compounds, particularly odor-causing compounds, are present in the vicinity of shale-gas operations. However, these short-term studies were not able to offer conclusive evidence about the long-term or cumulative impacts of shale-gas development on air quality. DEP is in the midst of a long-term study that will address these concerns. DEP continues to regulate air emissions from shale-gas operators, primarily through industry-specific permit exemptions and general permits.

The supply of natural gas will continue to increase as shale-gas development proceeds, leading to additional uses for this cleaner-burning alternative. For example, the bureau has discussed the possibility of switching part of its vehicle fleet to compressed natural gas.

The bureau will continue to monitor the air quality studies being performed by DEP. At present time, the bureau does not have plans to initiate its own air quality monitoring. As the plant monitoring program develops, the bureau may become involved in monitoring ozone damage to plants.

Part 2: Monitoring Values
» Incidents

I. Key Points:

- From 2008 through 2012, DEP investigated 324 incidents on state forest land, resulting in 308 notices of violations (NOVs).
- In 2012, a spill incident report was prepared by the shale-gas monitoring program to document and report on the diesel fuel spill and inadvertent discharge of brine on Tract 729 A, Pad C. The bureau investigation did not identify elevated conductivity readings in the down-gradient stream. Subsequent additional monitoring and site remediation by the responsible operator was conducted to the satisfaction of DEP.
- From July 1, 2009, when incidents specific to oil and gas began to be tracked, through December 31, 2012, 264 incidents in 50 different categories were reported through the Bureau of Forestry Incident Reporting System across all state forest districts directly related to gas development activity.

II. Introduction

Incidents occurring on state forest lands related to shale gas development are recorded by both DEP and the bureau. DEP tracks incidents that are investigated involving violations of state environmental laws and regulations. Additionally, the bureau's Incident Reporting System records more general incidents in a variety of categories that occur on state forest land.

During the initial stages of shale gas development activity from 2008 to 2012, incidents have occurred and have been investigated or reported to the Department of Environmental Protection (DEP). These incidents involve health and safety violations, along with administrative issues. Pennsylvania environmental laws and regulations require the operator to report all spills, regardless of substance type, on all roads, rights of way, pads, and storage locations. DEP has primary enforcement authority for incidents of pollution and violations of state environmental laws and regulation and conducts regular inspections of permitted sites.

The bureau's oil and gas lease agreements require all lessees to comport with federal, state, and local law as well as all current regulations. While the bureau does not have direct environmental regulatory enforcement authority, it does have the ability to monitor activity and determine whether or not the lessee is comporting with the terms of the lease agreement and to take appropriate actions to correct the situation. In addition, the bureau works closely with DEP and its inspectors and communicates regularly with them regarding potential violations.

The listings of incidents on state forest lands, as well as on private lands, can be found on the DEP website at http://www.ahs.dep.pa.gov/eFACTSWeb/default.aspx.

III. Monitoring Efforts/Results

As part of the shale-gas monitoring program, bureau staff document the incidents that occur on state forest land and, when warranted, consults with DEP inspectors regarding remediation and reclamation requirements.

Incidents recorded by DEP and the bureau are summarized here to illustrate how they are being monitored and tracked by the agencies.

Field Inspections

Bureau staff members conduct weekly inspections during active construction unless problems or weather conditions dictate otherwise. When feasible, these field inspection activities are coordinated with DEP District Oil & Gas Operations. It is from these inspections that violations and potential issues are identified and addressed. Guidance for reporting spill issues to DEP is found in

the DEP publication: *Addressing Spills and Releases at Oil & Gas Well Sites or Access Roads (800-5000-001).*

A notice of violation (NOV) may be issued as a result of a DEP investigation. A DEP NOV serves as a notification to the responsible party (typically the operator) of the details of the violation. There are two categories of NOVs: Health and Safety, and Administrative. Examples of Health and Safety NOVs include inadequate silt fences, residual waste discharge, and brine spills. Examples of Administrative NOVs include failure to post a permit and failure to post an erosion and sedimentation plan.

Year	# of Incidents Reported	DEP NOV Issued
2008	1	1
2009	33	33
2010	121	114
2011	111	102
2012	58	58
TOTALS	**324**	**308**

Table 9.1 Summary of incidents reported by DEP on state forest land by year.

Table 9.1 is a summary of incidents reported by DEP between 2008 to 2012, on state forest lands where DEP conducted an investigation and either issued an NOV or closed the investigation without a violation notice being issued. This table includes DEP's record of both Health and Safety and Administrative incidents.

Overall, the number of incidents has increased as the number of wells drilled on state forest lands has increased, but the overall number of incidents per well decreased by a factor of three from 2009 to 2012 (Table 9.2). This shows a trend toward improvement of operator compliance with state environmental laws and regulations.

Year	# of Incidents Reported	# Wells Drilled on SF Lands (spud)	# Incidents Per Well Drilled
2008	1	21	< 1
2009	33	26	1.3
2010	121	120	1.0
2011	111	203	0.55
2012	58	143	0.41
TOTALS	**324**	**513**	**0.63 avg.**

Table 9.2 Incidents reported by DEP per well drilled 2008-2012.

Many factors are likely involved in the improved performance, such as:

- Increased oversight by DEP with its increased staff
- Implementation of new regulations and guidance from DEP since 2008
- Sharing of information among industry groups to foster improved performance.
- Increased familiarity with Pennsylvania laws and regulations by out-of-state operators
- Individual company implementation of safety and environmental programs similar to the Anadarko EYES ON program*
- The bureau's issuance of its *Guidelines for Administering Oil and Gas Activity on State Forest Lands*.
- Increase in bureau staff and resources to monitor and manage the shale-gas program
- The bureau's policy of active management, with weekly staff visits to well sites and construction sites
- Bureau staff gaining experience in managing shale-gas activity on state forest lands

* Anadarko Exploration and Production Company implemented its EYES ON safety and environmental protocols in late 2010 as a response to rising numbers of incidents on Anadarko drill pads and notices of violation issued by DEP.

Spill Incident Reporting

In addition to spill reports required by DEP, the bureau also creates individual spill incident reports to document the spill incident in greater detail. For example, on January 31, 2012, the shale-gas monitoring team learned of a diesel fuel spill and two inadvertent brine discharges on Tract 729A, Pad C. This triggered a response by the team to document the details of the incident and gather water quality measurements on the pad and adjacent streams. The bureau investigation did not identify elevated conductivity readings in the down-gradient stream. Subsequent additional monitoring and site remediation by the responsible operator was conducted to the satisfaction of DEP.

Incident Reporting System

In addition to DEP's tracking of investigations and incidents, the bureau records and tracks all incidents on state forest land in accordance with Visitor Services and Protection Directive #9, *Incident Reporting.* Incidents recorded by the bureau's system include those related to all activities on state forest land. Incidents are categorized into three main categories:

1. Major Reportable
   Examples include:
   - Any felonies or misdemeanors
   - Any use of force, including drawing of a firearm (if authorized to carry a firearm), or call for assistance or backup outside the bureau
   - All deaths and all injuries to visitors or employees requiring admittance to a medical facility
   - Damage to commonwealth property causing a loss value of $3,000 or more, including labor to repair
   - Any fire causing damage to a commonwealth structure

2. Minor Reportable
   Examples include:
   - Damage, vandalism, and/or criminal mischief to any commonwealth property causing a loss value between $100 and $500, including cost to repair, and that otherwise does not constitute a misdemeanor or higher offense. The loss value does not include investigation time. Clean up costs exceeding $100.

- Search and rescue operations not reportable as a major incident
- Motor vehicle accidents that are not major incidents
- Revocations of fuelwood permits or camping permits
- Any injury to a visitor or employee requiring medical treatment or an accident report
- Assistance to outside agencies
- Any theft not reportable as a major incident
- All citations
- Any hostile interaction with the public that may result in a complaint

3. Non-Reportable

Examples include:

- Requesting a visitor to voluntarily comply with laws, rules, and regulations
- A minor amount of litter
- A missing cardboard sign

Beginning on July 1, 2009, the bureau began identifying incidents that were related to oil and gas activities. The bureau does not discriminate between shale gas and shallow oil and gas activities when tracking these incidents. From July 1, 2009, to December 31, 2012, there were a total of 264 incident reports in 50 different incident types related to oil and gas activities across the 20 state forest districts. Table 9.3 illustrates the top 15 types of incidents reported in the bureau's Incident Reporting System across all 20 state forest districts from July 1, 2009, to December 31, 2012.

IV. Conclusion

Since the inception of the shale gas program on state forest lands in 2008, incidents have occurred and have been reported. During this period, DEP investigated 324 total health and safety and administrative incidents, resulting in 308 NOVs. A spill incident report was prepared by the Marcellus shale-gas monitoring program to document and report on the diesel fuel spill and inadvertent discharge of brine on Tract 729 A, Pad C. In addition, there have been a total of 264 incidents in 50 different categories reported through the bureau's Incident Reporting System across all state forest districts directly related to oil and gas activity.

Rank	Incident Type	# of Incident Reports
1	Miscellaneous (not otherwise classified)	22
2	Closure	21
3	Crimes Code	20
4	No Injury	20
5	Hazards (manmade)	18
6	Criminal Mischief	15
7	Motor Vehicle Code (Title 75)	15
8	Misc. Title 75 Violations (not otherwise classified)	13
9	Theft	8
10	Vandalism	8
11	Operation of Vehicle Without Official Certificate of Inspection	8
12	MISC. Crime Code (not otherwise classified)	7
13	Complaint	7
14	Motor Vehicle Accident (Visitor)	6
15	Outside Agencies, Assistance	5

Table 9.3 Top 15 reportable incident types in the bureau's Incident Reporting System related to oil and gas activity from July1, 2009 to December 31, 2012.

Part 2: Monitoring Values

»Fauna (Wildlife)

I. Key Points:

- Wildlife habitat will change due to gas infrastructure within the shale gas region.
- Gas infrastructure will result in more edge and early successional habitat.
- The bureau is monitoring the positive and negative impacts of shale gas development on wildlife communities to better understand their long-range implications and steps that can be instituted to avoid and mitigate negative impacts.
- The bureau is in the early stages of developing its wildlife monitoring protocols. The bureau will focus on monitoring changes in habitat conditions in relation to gas development.
- Through its monitoring program, the bureau is funding multiple research projects to advance the understanding of the impacts of shale-gas development to wildlife species such as interior forest birds and timber rattlesnakes.

II. Introduction

Wildlife and fish in Pennsylvania fall under the jurisdiction of two commissions: birds and mammals are the responsibility of the Pennsylvania Game Commission (PGC), while the Pennsylvania Fish and Boat Commission (PFBC) has the responsibility for fish, reptiles, amphibians, and aquatic invertebrates. The bureau does not directly manage wildlife in Pennsylvania but instead manages habitat, ensuring that natural biological communities can thrive.

Two documents, *Penn's Woods* and the *State Forest Resource Management Plan (SFRMP)*, lay the foundation for the bureau's approach to managing wildlife habitat on state forest lands.

Penn's Woods establishes the bureau's mission and states it will manage state forests using an ecosystem management approach that maintains biological diversity and provides habitats for plants and animals.

SFRMP further defines the bureau's ecosystem management approach to state forest management. The SFRMP provides guidance on how state forests will be managed to conserve the diversity of native wild fauna and their habitats. The bureau also has the ability to adapt its management for a particular species in need of protection or to focus on a habitat type or a particular biological community.

Wildlife and Habitat

Ecosystems consist of complex interactions between species and habitat. Wildlife and fish species are dependent on suitable habitat to maintain naturally reproducing populations and require food, water, cover, and space as components of their habitat.

The various wildlife species have different requirements and are associated with specific habitat types. Species that have similar habitat needs are grouped into species guilds. Groups of insectivorous birds that are common to deciduous forests are an example of a guild. The collection of species living and interacting within a given area is defined as a community. Communities often are defined by habitat type, such as coniferous forest wildlife communities. Many different types of communities are represented on state forest lands and are managed in different ways.

Some species of wildlife and fish are termed generalists and are opportunistic, meaning they are adaptable and can thrive in a wide range of habitats. Other species are defined as specialists, meaning they have very specific habitat requirements. Specialists are often used as indicator species, meaning their occurrence indicates the presence of suitable habitat.

A great amount of literature exists describing the associations of wildlife species and habitat types. The Pennsylvania State University Cooperative Extension publishes many wildlife handouts explaining habitat succession leading to changes in wildlife communities. (Habitat succession can be thought of as a progression

of the vegetation community from an herbaceous opening to shrubs to mature forest.) The U.S. Forest Service published *New England Wildlife: Management of Forested Habitats*, which describes wildlife and habitat interactions (DeGraaf et al, 1992). This publication features matrices showing what species of wildlife utilize certain habitat types and features. The U.S. Fish and Wildlife Service developed Habitat Suitability Index (HSI) models, which incorporate formulas using specific habitat variables and give a quantitative result of habitat suitability for a given species. Using this information, it is possible to evaluate habitat suitability and predict changes in wildlife due to changes in habitat.

State forest land provides many habitat types and features, including forest, herbaceous openings, and the edge between herbaceous and forest habitats. Forest habitats can be further divided into deciduous, conifer, or mixed species forest. They also can be classified with respect to age, ranging from young forest to mature forest. Forest interior is defined as non-disturbed areas over 300 feet from a non-forest edge.

Forest interior habitats often include large diameter trees, downed dead wood, standing dead trees (snags), tree cavities, a high percentage of canopy cover, and the presence of mature fruit or nut producing trees. Conifers, if present, add a cover component to the habitat. Species of wildlife typical to forest interior habitats include, but are not limited to, the barred owl, black-capped chickadee, woodpecker, nuthatch, ovenbird, scarlet tanager, wood thrush, fisher, gray squirrel, and red squirrel. Many of these species require mature mast producing trees and cavities in which to nest. Some of the species require mature forest features such as large diameter trees, cavities, and large snags. The barred owl and pileated woodpecker, in particular, are good indicators of mature forest.

Herbaceous open areas often include grasses and forbs, abundant insects, exposed rock, and sometimes brushy vegetation. This early successional habitat is often used by species such as the eastern meadowlark, eastern cottontail rabbit, ruffed grouse, goldfinch, chipping sparrow, song sparrow, gray catbird, indigo bunting, meadow vole, red-tailed hawk, white-tailed deer, and turkey.

Edges between forest and open areas are often characterized by brushy vegetation and are intermediate between both habitat types. The forest edge usually receives more light and is warmer and drier than the forest interior. The herbaceous edge receives more shade than the interior of the opening. Species that commonly use edge habitat include the American crow, common grackle, raccoon, Virginia opossum, cowbird, red fox, and indigo bunting. Popular game species such as white-tailed deer, ruffed grouse, and turkey also use edge habitat.

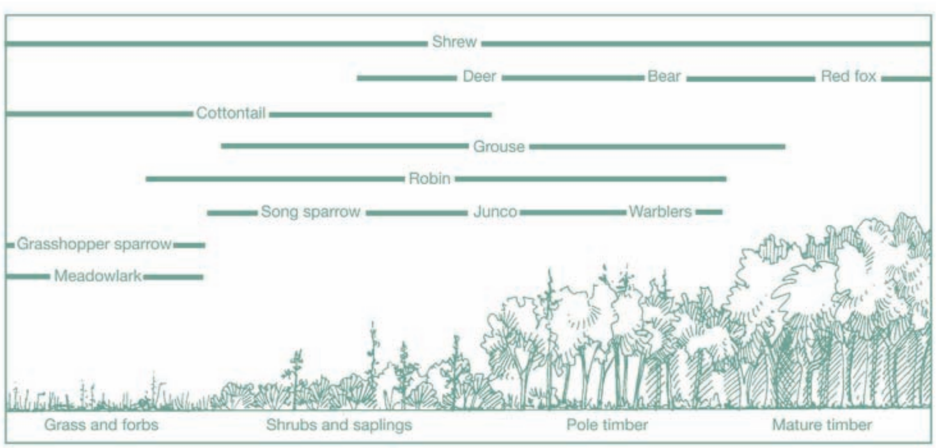


Figure 10.1 Image from Penn Sate Cooperative Extension (Forest Stewardship #5: Wildlife) Illustration by Rae Chambers, College of Agricultural Sciences, Penn State.

As with all development, there is potential for shale-gas development on state forest lands to impact wildlife populations and habitats. The disturbance due to gas activity typically sets succession back to an earlier state. Any alteration of habitat could lead to a shift in wildlife.

The bureau deals with development by first attempting to avoid conflict with sensitive habitats and wildlife. When avoidance is not possible, the bureau then attempts to minimize impacts. The Pennsylvania State University provides an Electronic Marcellus Field Guide (http://www.marcellusfieldguide.org/) that includes information about the gas industry and wildlife impacts. Shale-gas infrastructure, when placed within forested habitat, will result in increased forest fragmentation. Some of this forest habitat will be converted to edge and to herbaceous openings. The conversion of large blocks of forest interior may negatively impact forest interior-dependent communities. Conversely, the same impacts may benefit communities preferring early successional habitat by providing edge and openings within the forest. Pipeline rights-of-way (ROW) will have a portion maintained as long-term openings. In general, fragmentation is thought to benefit generalists over specialists, since generalists are opportunistic and adaptable to change.

More information about forest fragmentation is available in the Fragmentation chapter of this report.

Why Monitor Wildlife Habitat?

The wildlife monitoring effort will strive to answer these questions:

- How is wildlife habitat changing due to an increase in gas development?
- Which species guilds or communities are benefitting, and which are not?
- What can be done to alter management and minimize impacts (adaptive management)?

Because the interaction between wildlife and habitat is complex, the impacts of a novel disturbance may not be evident for several years. Therefore, it is crucial to monitor the impacts of shale-gas development on habitat. Habitat monitoring is needed to establish baseline information and identify trends. By measuring habitat parameters, monitoring will provide the data necessary to evaluate habitat for indicator species within forests, herbaceous openings, and edge habitats. Collecting this data allows habitat suitability to be quantified and analyzed objectively. Monitoring efforts will reveal which communities will benefit and which communities are negatively affected by gas development. Monitoring

must also be done in order to determine the effectiveness of gas infrastructure restoration and mitigation practices and to provide a basis for adaptive management. Over time, restoration and reforestation efforts should result in more suitable habitat for a given community. For example, seedlings that are planted on some reclaimed infrastructure sites are intended to survive and grow into forest habitat. Monitoring is needed to determine if our practices are fulfilling their intended purposes. Potential concerns revealed through wildlife monitoring can then be addressed in more detail.

III. Monitoring Efforts/Results

Wildlife Monitoring

The bureau has access to a number of general wildlife and fish information sources. These include County Natural Area Inventory Reports (CNAIs). The CNAIs are a product of the Natural Heritage Program that biologists use for planning purposes. CNAIs provide overviews of sites that are biologically unique or targets for habitat improvements.

The bureau is part of Pennsylvania's Natural Heritage Program (PNHP), which gathers and provides information on the location and status of important ecological resources. Its purpose is to provide current, reliable, and objective information to help inform environmental decisions. PNHP maintains a statewide database of species and resources of concern. This information is accessed to obtain data on rare species known on state forest lands near areas where shale-gas development is occurring.

The bureau conducts environmental review of all projects on state forest lands, including shale-gas development projects. Pennsylvania Natural Diversity Inventory (PNDI) is the environmental review function of PNHP. The four agencies (DCNR, PGC, PFBC, and USFWS) review projects that have potential impacts with species under their jurisdiction. Most projects reviewed for PNDIs are for permitted activities, since PNDIs are required for DEP permits. As a proactive measure, the bureau performs PNDIs for all disturbance activities on state forest lands, not just for DEP-permitted activities. The bureau uses this measure as a way to ensure that all resources are kept in mind when conducting projects or development on state forest lands. As such, there is a record of projects that have been done on state forest lands that have had potential impacts with species of special concern and their outcomes.

The bureau also collects data relating to deer impacts on forest habitats. The bureau uses the Vegetation Impact Protocol (VIP) to determine deer impacts by assessing vegetation indicators. These data are used to make decisions concerning Deer Management Assistance Program (DMAP) tag requests for state forest land. The bureau applies for the DMAP tags, and the PGC is responsible for issuing the tags.

Habitat Monitoring

Many wildlife species are difficult to track and monitor, especially over a large landscape, such as the shale-gas region within state forest lands. Therefore, to be most effective, the bureau will monitor wildlife in terms of indicator species and the habitats they utilize. Indicator species are useful since they reflect the long-term condition of the habitat rather than just a snapshot of the conditions present at the time of sampling. The bureau will focus on habitats adjacent to gas development, along with restored gas infrastructure areas. Monitoring efforts will focus on well pads, roadsides, pipeline ROWs, wetlands adjacent to development, forest interior areas near gas infrastructure, and reclaimed or reforested areas. The habitat types that will be evaluated are forest, herbaceous, and edge habitats.

Specific habitat components will be monitored to determine if suitable habitat is present for a given species or community in accordance with existing literature. The monitoring protocol mirrors the flora section's protocol (see Flora chapter), and the monitoring plots will be in the same locations as the flora monitoring plots. The monitoring plots will collect forest habitat data in addition to the herbaceous vegetation and tree regeneration data at each plot. The data will be interpreted to evaluate the habitat's suitability for a given community, and to detect change over time.

Habitat Parameters

Certain wildlife species require specific habitat features. Many of these features can be measured and evaluated to determine suitability of habitat. The habitat parameters that will be measured are: diameter at breast height (dbh) of trees, overstory species, species richness of trees, tree height, basal area, trees per acre, snags per acre, percent canopy cover, and the species of regeneration present. The flora monitoring already captures the herbaceous component of habitat. The species of trees present determines the availability of food or cover. Species richness of trees present is an indicator of biological diversity. The change in average dbh of trees in forest habitat will lead to increasing or decreasing suitability of habitat for a given species. The dbh of trees also can indicate whether they are mature and can provide mast. The average height of trees is important since vertical structure is vital to songbird habitat. Average heights also will show the growth of forest regeneration and tree plantings. The number of snags per acre relates directly to suitability of habitat for woodpeckers, along with other species. Some species that depend on snags require a minimum diameter in order to be useful. The tree regeneration present is an indicator of what species may be present in the habitat in the future.

Habitat can be evaluated using the HSI models and DeGraaf et al. (1992) habitat matrices for indicator species of various habitats. This will allow reasonable predictions of how wildlife will respond to changes in habitat.

Well Pad Assessment

Habitat monitoring on well pads allows for assessing habitat, establishing a baseline set of current conditions, and comparing habitats across multiple sites. The monitoring plots are located along a gradient from reclaimed habitat to disturbed habitat to undisturbed forest habitat. Manmade habitat, such as rock piles and brush piles, will be monitored to determine if wildlife species are using these features. The monitoring of manmade habitat features is addressed later in this chapter.

Roadside Habitat Assessment
These plots will assess the impacts of roads and roadside gas industry activities on habitat. Many existing forest roads were made wider to accommodate the increase in industry-related traffic. The impacts on habitat, such as increasing edge and possibly barring wildlife movement, directly relate to the impacts on wildlife.

Pipeline Rights of Way Assessment
Rights of way are maintained as early successional habitat. This habitat may be utilized by species requiring grasses and forbs or the insects that are abundant in this habitat type. ROWs are maintained in this way primarily to ease pipeline monitoring and maintenance by the gas company. The ROWs are seeded and receive periodic mowing or herbicide treatments. Practices relating to timing, height, and return interval of mowing can impact habitat and wildlife. Monitoring will be conducted to determine trends and to quantitatively describe the habitat provided by the ROWs. The data provided may be used for adaptive management pertaining to maintaining ROWs.

Wetland Encroachment Buffers
It is the bureau's practice to place protective buffers on water bodies and wetlands. Waivers are granted on a case-by-case basis if the prescribed buffer cannot be implemented. Wetlands located adjacent to gas infrastructure may be impacted differently, depending on the presence of buffers. Monitoring will be done on select wetlands abiding to the 200-foot buffer and on some that are within 200 feet of gas infrastructure. Wetland habitat information will detect any changes in habitat suitability for associated species.

One particular type of wetland found in Pennsylvania is the vernal pool. Vernal pools are vital habitat features, especially for amphibians and some invertebrates, which often are used as indicator species reflecting changes in an ecosystem before it is noticeable elsewhere. Amphibians, such as wood frogs, spotted salamanders, and Jefferson salamanders, belong to the guild of species requiring vernal pools for breeding. The bureau is considering a protocol in which a sample of vernal pools will be monitored for the presence of breeding salamanders and wood frogs.

Restoration, Mitigation, and Reforestation Evaluation
Some infrastructure reclamation areas will not be reforested, but rather managed to provide other types of habitat. These areas will be monitored via the flora monitoring procedures. Monitoring also will include evaluation of reforestation efforts along ROWs. It is expected that plantings eventually will become mature and contribute to habitat needs of wildlife. Conifers are planted with the intention of providing cover and nesting habitat for species such as ruffed grouse, small mammals, and songbirds. Conifers also provide food for red squirrels and song birds when the trees are mature. Deciduous trees are planted in hopes that they will provide canopy cover and mast when mature. Long-term monitoring will document the progression of habitat through succession from herbaceous habitat to forest habitat.

Mitigation practices, such as providing rock piles for snake basking sites and brush piles for small mammals and birds, are common along pipeline ROWs and well pads. Brush piles may benefit many species, including weasels, voles, eastern cottontails, Virginia opossum, red fox, and the northern black racer. These manmade features must be monitored to determine if they are being used, and by what species. The presence and type of animal tracks in the immediate area around the rock piles and brush piles will indicate patterns of use by wildlife. Track data would be collected during the winter season. The bureau also is looking into using cover boards at reclaimed sites to monitor terrestrial salamander occurrences. Cover boards could be located near vegetation plots at well pads that already are being monitored.

Aquatic Community Monitoring
Streams are also basic necessities to many species of wildlife on state forest lands. Aquatic insects such as

mayfly, stonefly, and caddis fly all are indicators of high water quality. The bureau will cooperate with the PFBC, which collects data such as the presence of fish species, with an emphasis on brook trout as an indicator of high quality habitat. The PFBC also collects data including the presence of young of the year brook trout, pH, specific conductivity, and temperature. All of this data can potentially be used to create a baseline and determine trends due to gas development.

Wildlife Population Monitoring

The bureau will work on forming cooperative efforts with many different entities in order to monitor wildlife populations. The PGC collects population data on the fisher, which can be used as an indicator of forest habitat. The U.S. Geological Survey oversees the Breeding Bird Survey (BBS), coordinated by the PGC in Pennsylvania. The BBS provides data on bird species present in the area during breeding season. Efforts will be made to cooperate with these organizations to facilitate data sharing. The bird data are not at a fine enough scale to correlate with specific habitat features and changes, but are still useful to establish long-term baselines and to determine trends.

Other Bureau of Forestry Shale-Gas Monitoring

The bureau will continue to monitor the impacts of shale-gas development on hunting and fishing experiences on state forest land. For more information see the Recreation section.

Aquatic habitat monitoring will be tied to water quality monitoring efforts. Water chemistry – such as pH, specific conductance, and temperature – directly impacts the suitability of a water body as habitat. More information pertaining to water quality monitoring can be found in the Water section.

Wildlife monitoring also will be tied to flora monitoring efforts. Plant and natural community monitoring data will help form the baseline data for wildlife habitat, since vegetation forms the foundation of wildlife habitat.

IV. Other Research

The bureau is funding research projects relating to wildlife and gas development, including Dr. Margaret Brittingham's (Penn State) study on forest interior bird species and forest connectivity. This research will provide data to form a baseline and determine trends in community impacts. Dr. Brittingham also is researching the effects of gas development on forest-dependent salamanders and frogs.

Dr. Gian Rocco (Penn State) is investigating the potential impacts of the Marcellus shale-gas industry on the timber rattlesnake. Occupied rattlesnake habitat is being assessed before, during, and after development on state forest land. Radio telemetry is being used to provide information on the dependence of rattlesnakes on critical habitats.

V. Conclusion/Discussion

Pennsylvania's state forest lands are an important source of food, cover, water, and space for wildlife, which are critical components of ecosystems. Due to the difficulties in monitoring a suite of species, the bureau will base wildlife monitoring efforts on habitat and certain indicator species, rather than strictly on animal abundance data. Habitat alterations will result in wildlife changes. The intent is to show what habitat is found across the state forest system and relate this to what wildlife communities utilize this habitat, in an objective manner.

Part 2: Monitoring Values
»Recreation

I. Key Points:

- No national hiking trails in Pennsylvania have been impacted by shale-gas development. Three designated state forest hiking trails have been impacted.
- One state forest scenic vista, the Ramsey Vista in Tiadaghton State Forest, has been directly impacted in the core gas forest districts. It was closed to vehicle access.
- Statewide, since 2006, there has been a 5 percent increase (145 miles) in total snowmobile trail miles across the state forest system. This is the result of a 203-mile decrease in joint-use trails and a 348-mile increase in designated snowmobile trails.
- Snowmobile trail systems have been impacted in each of the core gas forest districts. New snowmobile trails have been created to replace impacted snowmobile trails.
- The need for road access for shale-gas development has resulted in heavier traffic on state forest roads. Upgraded roads may be safer and easier to drive but may have lost some of their “wild character” value.
- There are both gains and losses in access to state forest lands via roads due to shale-gas development. Some roads may be closed or restricted, while newly constructed roads will offer new opportunities for access.
- The impact of shale-gas development on recreational experience and wild character as measured by the Recreation Opportunity Spectrum is a 9,341-acre increase in semi-developed and developed acreage; a 913-acre decrease in semi-primitive acreage; a 8,409-acre decrease in semi-primitive non-motorized acreage; and a 19-acre decrease in primitive acreage.
- Three gas infrastructure features have been constructed within scenic viewshed “Areas of Special Consideration” identified in gas leases. Additional methods to assess viewsheds and aesthetic changes should be identified or developed.
- Initial measurements at six out of the seven operating compressor stations measured on state forest lands were louder than the 55db(A) suggested by the updated *Guidelines for Administering Oil and Gas Activity on State Forest Lands*.
- 46 out of 116 comment card respondents in core gas forest districts indicated that Marcellus activity had changed their visitation experience. 41 out of 116 respondents indicated that Marcellus activity had changed their recreational use of the state forest.

II. Introduction

The bureau acknowledges the value of recreation within its mission statement and within policies that specifically identify "recreation" as it applies to the state forest system and the value that recreation has for the citizens of Pennsylvania. State forests are able to provide a unique opportunity for dispersed, low-density outdoor recreation that cannot be obtained from small forest areas or from private ownership.

The bureau's mission statement includes a directive for "managing state forests under sound ecosystem management, to retain their wild character and maintain biological diversity while providing pure water, opportunities for low-density recreation, habitats for forest plants and animals, sustained yields of quality timber, and environmentally sound utilization of mineral resources."

The Conservation and Natural Resource Act authorizes the establishment of and provides for the use and control of state forest lands. This law states, in part, that one of the purposes for which the state forests were created is "to furnish opportunities for healthful recreation to the public."

Recreation on state forest lands can mean many things to many different people. State forest visitors can find a whole host of recreational activities on Pennsylvania's 2.2-million-acre state forest system. Some of the most common activities include scenic driving, hunting, camping, hiking, and nature watching. Others include hang gliding, dog sledding, kayaking, ATV riding, snowmobiling, horseback riding, mountain biking, fishing, cross-country skiing, birding, nature observing, and geocaching, to name a few.

Gas development includes extensive infrastructure that requires careful siting to minimize impacts. New infrastructure can affect wild character and viewsheds. Noise-generating activities may affect visitor experience. While there are quantitative measurements for factors affecting recreation experience, the qualitative impacts may be more relevant.

The primary management decisions related to shale-gas development and associated with state forest recreation comprise constant efforts to first avoid impacts if at all possible. When avoidance is not a viable option, the efforts switch to minimizing impacts to the greatest extent. For those impacts that are unavoidable, management efforts also are expended on the mitigation of impacts to recreation infrastructure. Finally, the bureau monitors the effects of its management decisions to see if the appropriate outcome was obtained or how the system can be improved.

While there may be an impact to a piece of recreation infrastructure, such as a temporary trail closure, it is the bureau's goal to improve the infrastructure and create a better experience if possible. An example would be the traditional joint-use roads, which are snowmobile trails that are colocated on public use roads in the winter. Many of these joint-use roads have been used for shale-gas development and are not suitable for snowmobiling anymore for safety reasons because they have become plowed road surfaces. The loss of these trails is an impact, but as pipelines to carry natural gas are installed adjacent to the impacted roads, new snowmobile trails are being established on the pipelines. The moving of snowmobile trails to the pipelines generally will create a better riding experience and provide a trail surface not as likely to be impacted by activities that require plowing. If an impact to the recreation infrastructure cannot be avoided, it is the bureau's goal to work with the operators to enhance the recreational infrastructure and visitor experience when it is replaced or improved. The bureau maintains a fact sheet to provide state forest visitors with the necessary information for a safe, enjoyable experience when visiting areas near natural gas development activities.

The importance of monitoring state forest recreation cannot be understated. A recreational activity is likely the most common reason to bring a person to a state forest. Many constituents have a very personal and lasting bond to their recreational experiences.

III. Monitoring Efforts/Results

Designated State Forest Hiking Trails

Designated State Forest Hiking Trails (SFHT) are 18 hiking-only trails that are located across the state forest system. These premier trails encompass all types of hikes, from a long-distance trail such as the Mid State Trail (310 miles), which traverses the length of the state, to a one-day or hours-long short trail, such as the Rocky Knob Trail (four miles), and everything in between. The 18 SFHTs traverse a combined 1,180 trail miles that cover a variety of terrain and difficulty levels. There are 13 SFHT trails in the core gas forest districts:

- Black Forest Trail (42 miles)
- Chuck Keiper Trail (53 miles)
- John P. Saylor Trail (18 miles)
- Loyalsock Trail (59 miles)
- Old Loggers Path (27 miles)
- Quehanna Trail (75 miles)
- Susquehannock Trail (85 miles)
- Bucktail Path (34 miles)
- Donut Hole Trail (90 miles)
- Golden Eagle Trail (9 miles)
- Lost Turkey Trail (26 miles)
- Mid State Trail (309 miles)
- West Rim Trail (30 miles)

There have been three impacts to state forest hiking trails related to shale-gas development. Limiting the impacts to three trails has been achieved through the strict avoidance of development near SFHTs.

A half-mile section of the Mid State Trail in Tiadaghton State Forest was rerouted in 2010. This reroute was undertaken through cooperation with the Keystone Trails Association (KTA), Mid State Trail Association, and Tiadaghton staff. Through the waiver process, the operator requested that a gas access road be located on an existing old-woods road which had a segment of the Mid-State Trail co-located on it. Rather than create a new road parallel to the existing woods road just outside of the buffer distance for the trail, the decision was made to allow a well pad access road to be built in the original old-woods road corridor, which served as a section of the Mid State Trail. The trail was relocated to a newly created single-track trail positioned so that little to no visual impacts would be seen from the new trail other than at a road crossing. The location of the new trail also eliminated any visual impact related to a well pad and associated pipelines in the area.

There has been an indirect impact to the Donut Hole SFHT in Sproul State Forest. This trail was impacted because the joint-use snowmobile trail had to be moved off Carrier Road due to Endless Mountain's use of the road for development of private lands in the area. The gas company has to plow the road for access in winter, thereby eliminating the snowmobile trail on Carrier Road. The road is not entirely on state forest lands, and the bureau only has a right-of-way (ROW) for the road across private lands. The ROW corridor is not sufficiently wide to allow for both a snowmobile trail and the road in a parallel manner. In addition, there are obvious safety concerns of having development traffic and snowmobiles on the same road. There are no other alternative routes for the snowmobiles to use to complete the snowmobile system.

With little recourse but to relocate the snowmobile trail from Carrier Road, a new pathway for that trail was sought. The Donut Hole Trail in this area had been co-located onto an old-woods/timber sale access road for approximately 1.1 miles. This section of the Donut Hole Trail is slated to become part of the new Lick Run Snowmobile Trail. District staff are working with members of KTA to locate a new single-track hiking trail corridor for that portion of the Donut Hole Trail in a manner that would remove it from any likely gas development and/or other motorized trails. The potential new trail corridor would cross a section of The Nature Conservancy lands and then go back onto state forest lands on its way into Hyner View State Park. Within

Hyner View State Park, the new proposed trail will then continue on the original Donut Hole Trail route. The new proposed trail route is located on fee simple and nonleased forest lands, which likely will eliminate the need to relocate these sections of trail again in the future.

A 500-foot portion of the Chuck Keiper Trail in Sproul State Forest was relocated an additional 300 yards away from a well pad. The pad was located outside the buffer zone for the trail, as suggested by the *Guidelines for Administering Oil and Gas Activity on State Forest Lands*; however, the bureau took the opportunity to move the trail farther away from the well pad and to close a section of trail that was entrenched. The original trail section was rehabilitated to eliminate erosion and sedimentation issues and was planted. Because the well pad was kept outside the trail buffer, this trail relocation was not completed as a direct result of gas development. This relocation was an effort to correct a poor trail section and also an increase of visual distance away from a well pad location.

Local Forest District Hiking Trails

Local forest district hiking trails are not part of the purview of this monitoring report; however, future monitoring efforts will attempt to evaluate and quantify the impacts of shale-gas development to local state forest district trails.

National Hiking Trails

There have been no direct shale-gas related impacts to any national hiking trail in the region.

Vistas

Ramsey Vista on Ramsey Road in Tiadaghton State Forest has been closed to vehicle access since 2010 due to gas activity. The vista will remain closed to public vehicle traffic until gas development work in the area has been completed. The public still can access this vista by foot. The road to the vista is closed one-fourth mile from the overlook.

There also is potential for new roads to be constructed for gas development to increase access for scenic driving, including vistas. No other vista has been impacted by shale-gas development in any other forest district.

State Forest Picnic Areas

There have been no direct impacts to any state forest picnic areas due to shale-gas development.

Recreation Agreements (LOAs, CAAs, and SAAs)

There has been anecdotal evidence of forest users who have changed venues for events that require agreements, from a forest district that is experiencing gas development to another forest district that does not have gas development. In some cases, this is creating a much greater demand for forest services than typically are experienced in the "new" forest district. For example, a snowmobile poker-run/benefit ride that was going to be held in Loyalsock State Forest was moved by its organizers to Bald Eagle State Forest. The move to Bald Eagle State Forest, as communicated to staff, was "due to a number of the snowmobile trails being closed/lost due to heavy flooding damage and in part to get away from heavy gas development in the area of other trails."

The bureau has since created a new method to capture these instances of recreational activities being moved from one location to another and why. This was an effort to determine whether shale-gas development was impacting various recreation activities. As part of the application for a Letter of Authorization (LOA), a Commercial Activity Agreement (CAA), or a Special Activity Agreement (SAA), a new form is filled out by the person or entity that is applying for the agreement. This form was created and included with all new agreements from September 2012 forward to determine whether the activity has been adjusted due to gas activity. Since introduction of this form, there have not been any impacts noted by groups or individuals applying for agreements.

ATV Trails

There have been no impacts to any of the ATV trails or trail systems due to shale-gas development.

Snowmobile Trails

The snowmobile trails that are located in the north-central state forests have traditionally been some of the most popular snowmobiling destinations in the state. Core gas forest districts happen to correlate with this key snowmobile trail area. Trails located on state forest and state park lands open the day after the last day of Pennsylvania regular or extended deer season and close on April 1.

There are two types of trails available for snowmobile riding: joint-use roads and dedicated snowmobile trails. Joint-use roads are regular state forest roads, either public-use or drivable trails, that are open to both regular motor vehicle traffic and snowmobiles. The joint-use roads do not have any winter maintenance (plowing, cindering, etc.) performed by the bureau. Dedicated snowmobile trails are closed to regular vehicle traffic and only allow snowmobiles and co-located winter ATV/snowmobile trails.

Joint-use roads and designated snowmobile trails traditionally may have been closed or plowed for a variety of reasons as part of regular state forest operations. These closures or plowing schedules may have to be implemented for the entire riding season or at any time during the snowmobiling season. Traditional reasons encountered for a snowmobile trail or joint-use road closure include timber harvesting, access to private lands, water companies, antenna site lessees, shallow-well gas and gas storage operations, or mining operations. However, due to shale-gas development, many additional roads that are traditionally open to snowmobiling are now closed for the safety of the snowmobilers. Joint-use roads and snowmobile trails that are being utilized for gas development now have to be plowed for access to the gas infrastructure, leaving an unfit trail condition for snowmobiles. In addition to trails not being in a suitable condition for riding, there would also be a safety issue if snowmobiles and gas development traffic utilized the same roads and trails. Depending on which road or trail is being used for gas activities, a portion of a trail loop may be lost or a large section of the trail system may be isolated and out of reach by loss of connectivity.

Efforts are underway to reestablish former trails and create new snowmobile trails by making use of the new gas pipeline infrastructure system. Often pipelines are created adjacent to or near the forest roads that are used by the gas companies to access their infrastructure. These pipelines can be ideal for the placement of snowmobile trails. While some pipelines are favorable for placement of snowmobile trails, other pipelines or sections of pipelines may not be favorable. Considerations before planning placement of snowmobile trails onto a pipeline include: steep terrain, crossing private lands, wetlands, stream crossings, historic sites, and numerous others. New trails and loops are likely a favorable outcome of this new gas activity. Unfortunately, there will be a piecemeal approach for a few years until all trail links can be completed.

New trails also have been created that are not associated with gas pipelines. In many cases, these trails were located in areas that already had old-woods roads or timber sale access roads, and these dormant roads needed only to have minimal rehabilitation work done to make them suitable for winter snowmobile traffic. Greater efforts are being made to work with the gas companies to get the snowmobiles onto these new trails, whether on or off a pipeline, as soon as possible.

From the start of shale-gas development, the bureau has worked to communicate to the Pennsylvania State Snowmobilers Association (PSSA) that there would be temporary impacts to snowmobile trails. The PSSA has conveyed this message to its constituents in the snowmobile community. The local state forest districts also have been working with their local snowmobile clubs to inform them of impacts and changes to the snowmobile trail systems yearly. The bureau is working with gas companies as part of the planning and approval process to create an action plan related to impacted snowmobile trails. The goal is to have a plan for the location of replacement snowmobile trails and a concrete timeline for them to be back in service.

Pre-shale-gas development snowmobile riding opportunities can be shown by comparing the trails available for the 2006-07 riding season to later years. Shale-gas development began on state forest lands in 2008. The changes to the trail system related to shale-gas development can be shown through the 2007-08 riding season and continuing on through 2012-13. (Note: State forest roads also are used for timber harvesting operations, an activity that may also cause plowing and temporary impacts to snowmobile trails. For the purposes of this report, only shale-gas related impacts are reported.) What follows are annual summaries of snowmobile trail conditions:

2006-2007 Snowmobile Trails

- Joint-use roads open – 2,046 miles (1,984.1 state forest and 61.9 state park)
- Designated snowmobile trails – 703 miles
- No roads designated to be closed in core gas forest districts. There were 61 roads with the possibility that the entire road or sections of the road would be plowed in the core gas forest districts.

2007-2008 Snowmobile Trails

- Joint-use roads open – 1,973 miles (1,943 state forest and 29.7 state park)
- Designated snowmobile trails – 714 miles
- No roads designated to be closed in core gas forest districts. There were 86 roads with the possibility that the entire road or sections of the road would be plowed in the core gas forest districts.

2008-2009 Snowmobile Trails

- Joint-use roads open – 2,022 miles (1,959.1 state forest and 62.9 state park)
- Designated snowmobile trails – 864 miles

2009-2010 Snowmobile Trails

- Joint-use roads open – 1,962 miles (1,898.2 state forest and 63.8 state park)
- Designated snowmobile trails – 871 miles

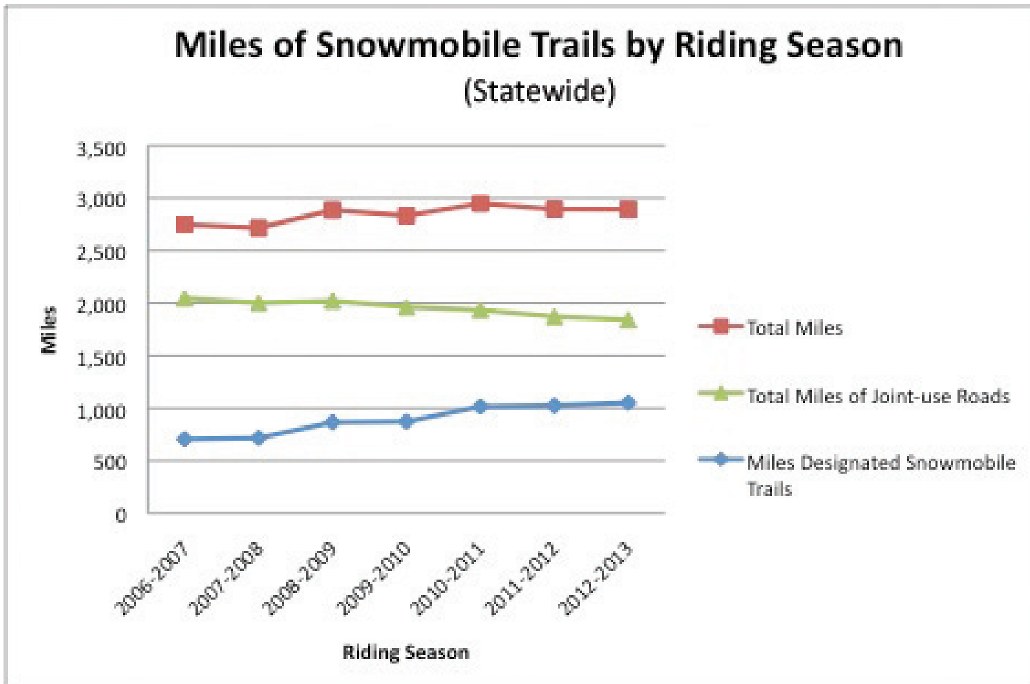


Figure 11.1

2010-2011 Snowmobile Trails

- Joint-use roads open – 1,934 miles (1,871.4 state forest and 62.6 state park)
- Designated snowmobile trails – 1,014 miles
- There were 64 roads with the possibility that the entire road or sections of the road would be plowed in the core gas forest districts.

2011-2012 Snowmobile Trails

- Joint-use roads open – 1,871 miles (1,808.4 state forest and 62.6 state park)
- Designated snowmobile trails – 1,023 miles

Moshannon State Forest:

- Seven roads closed for 16 miles due to shale-gas development
- Seven roads possibly plowed for 14.6 miles due to shale-gas development

Sproul State Forest:

- Thirteen roads closed for 49.1 miles due to shale-gas development
- Fourteen roads possibly plowed for 74.9 miles due to shale-gas development

Tiadaghton State Forest:

- Seventeen roads closed for 57.5 miles due to shale-gas development

Elk State Forest:

- Three roads possibly plowed for 3.2 miles due to shale-gas development

Susquehannock State Forest:

- Three roads possibly plowed for 18.4 miles due to shale-gas development

Tioga State Forest:

- Three roads closed for 6.1 miles due to shale-gas development

Loyalsock State Forest:
- Five roads closed for 9.3 miles due to shale-gas development
- One road possibly plowed for 5.7 miles due to shale-gas development

Total for all roads in the core gas forest districts that could be plowed due to shale-gas development activities during the 2011-12 season was **28 roads for 116.8 miles**.

Total for all roads in the core gas forest districts closed due to shale-gas development for 2011-12 season was **45 roads for 138 miles**.

2012-2013 Snowmobile Trails
- Joint-use roads open – 1,843 miles (1,778.3 state forest and 62.6 state park)
- Designated snowmobile trails – 1,051 miles

Moshannon State Forest:
- Nine roads closed for 23.3 miles due to shale-gas development
- Four roads possibly plowed for 14.5 miles due to shale-gas development

Sproul State Forest:
- Thirteen roads closed for 57.8 miles due to shale-gas development
- Fourteen roads possibly plowed for 74.9 miles due to shale-gas development

Tiadaghton State Forest:
- Seventeen roads closed for 57.5 miles due to shale-gas development

Elk State Forest:
- Four roads possibly plowed for 12.4 miles due to shale-gas development

Susquehannock State Forest:
- Three roads possibly plowed for 18.6 miles due to shale-gas development

Tioga State Forest:
- Three roads possibly plowed for 5.9 miles due to shale-gas development

Loyalsock State Forest:
- Five roads closed for 12 miles due to shale-gas development
- One road possibly plowed for 5.7 miles due to shale-gas development

Total for all roads in the core gas region that could be plowed due to shale-gas development activities during the 2012-13 season was **29 roads for 132 miles**.

Total for all roads in the core gas region closed due to shale-gas development for 2012-13 season was **44 roads for 150.6 miles**.

New Snowmobile Trails:
The following is a list of the new trails that were created and opened to replace trails impacted by shale-gas development from 2007 (prior to shale-gas development) through December 2012:

- **Moshannon State Forest:** Five miles of replacement trails created
- **Sproul State Forest:** Three miles of trail placed onto a new pipeline

- **Tiadaghton State Forest:** Five miles of trail placed onto a new pipeline
- **Elk State Forest:** No trails replaced
- **Susquehannock State Forest:** Two miles of trail placed on a new pipeline
- **Tioga State Forest:** Five miles of trail placed on new pipelines
- **Loyalsock State Forest:** No new trails created, primarily due to steep topography and the gas industry's current work on completing pipeline ROWs. Additional new trails may be needed to tie into existing snowmobile trails and new pipelines.

Scenic Driving

In both past and current visitor use monitoring studies, the single largest recreational use of state forest lands has been scenic driving. Most recreational users participate in this activity coming to and from the state forest, but for many this is the sole purpose of their visit to state forest land. The beauty of the forest, the solitude, tumbling mountain streams, scenic vistas, and ever-changing colors attract great numbers of visitors.

The bureau recognized the need for road access for gas development and co-located gas traffic on state forest roads to minimize new disturbance and ecological impact. This strategy has resulted in state forest roads with heavier traffic. Roads that are upgraded to handle heavier traffic may be safer and easier to drive but lose some wild character. In some cases, new roads have been constructed for gas development, which may reduce traffic impacts on traditional state forest roads while providing new opportunities for scenic driving.

Hauling restrictions are used to manage gas development traffic during high visitor-use periods (see section below). Some gas-related traffic is necessary for essential needs, but traffic can be limited to specific times. The strategy is to decrease the impact of traffic during the highest use periods, at the cost of increased traffic at some other time.

Road conditions, traffic, dust, and noise are common complaints in the bureau's comment cards and in other public contact. A combination of traffic volume measurements and qualitative impacts may be implemented in the future to monitor impacts on scenic driving.

Hunting and Fishing

The bureau has received qualitative evidence relating to gas development impacts on hunting and fishing access and experience. Traditional public contact, comment cards, and articles in the media suggest that some hunters and fishermen have been impacted. For future reports, implementation of qualitative and quantitative measures of hunting impacts will be considered.

There may be gains and losses with regard to access for hunting and fishing. Some roads may be closed or restricted, while newly constructed roads will offer new opportunities for access. Traffic related to gas development has the potential to impact access and experience. Traffic can be managed to some degree, which may include trade-offs in the time when the impact occurs. Traffic and hauling restrictions are addressed in the bureau's *Guidelines for Administering Oil and Gas Activity on State Forest Lands*.

During certain holidays and high visitor use periods there should be no heavy hauling during the day (i.e., rig moves, water trucking, sand trucking, etc.) or seismic activity, to protect public safety and prevent conflicts. In addition to these statewide timeframes, the forest districts will provide gas operators with a list of high conflict dates on an annual basis to aid in the planning and scheduling of activities.

Hunting and Fishing Seasons

- Opening weekend of trout
- Opening weekend of youth spring gobbler season
- Opening weekend of regular spring gobbler season
- Regular bear season
- Portion of regular firearms deer season, including opening day

Heavy hauling and seismic activity may be restricted during the following dates at the discretion of the district forester:

- Seismic activity may be restricted during the morning hours of spring turkey season.
- Special activities or events on state forest or adjacent state park lands as identified by the district. Restricted roads and hours of operation will be determined by the district.
- Opening day of deer archery season.
- Opening day of youth/special use hunting.
- Opening day of early muzzleloader season.

The bureau will consider minor truck traffic on state forest roads between the hours of 10 p.m. and 4 a.m. for daily or essential needs only (e.g., cuttings removal, drinking water delivery, sanitation, cement). The management of traffic comes with trade-offs. The impact to hunters may be mitigated, but state forest users between the hours of 10 p.m. and 4 a.m. may be unusually impacted by traffic.

Leased Campsites

There are over 4,000 leased campsites on state forest lands across 16 state forest districts. Users who lease state forest land for their cabins have the potential for unique impacts from natural gas development. Other state forest users may have the option to use a less impacted location, but since cabins are stationary, users' options may be limited to enduring the impact, transferring the lease, or staying away during periods of impact. Since lessees may visit for extensive periods of time, they might be impacted more than other users by activities such as heavy hauling that are moved to "off hours," which is a trade-off the bureau uses to reduce the impact to other user groups.

Leased campsites often have water use agreements and could be directly impacted by any change in water quality or quantity. There have been no known impacts to leased campsite water quality or quantity resulting from gas management.

No leased campsites have been removed or leases returned to the bureau due to gas development. Real estate data on lease transfers could be analyzed, but the bureau does not have that information, and it might not reflect gas impacts as much as it does real estate and economic trends. The bureau has received complaints from camp lessees regarding impacts from shale-gas consistent with complaints from other user groups. Qualitative measures, such as surveys and focus groups, may be used to assess impacts to camp lessees in the future.

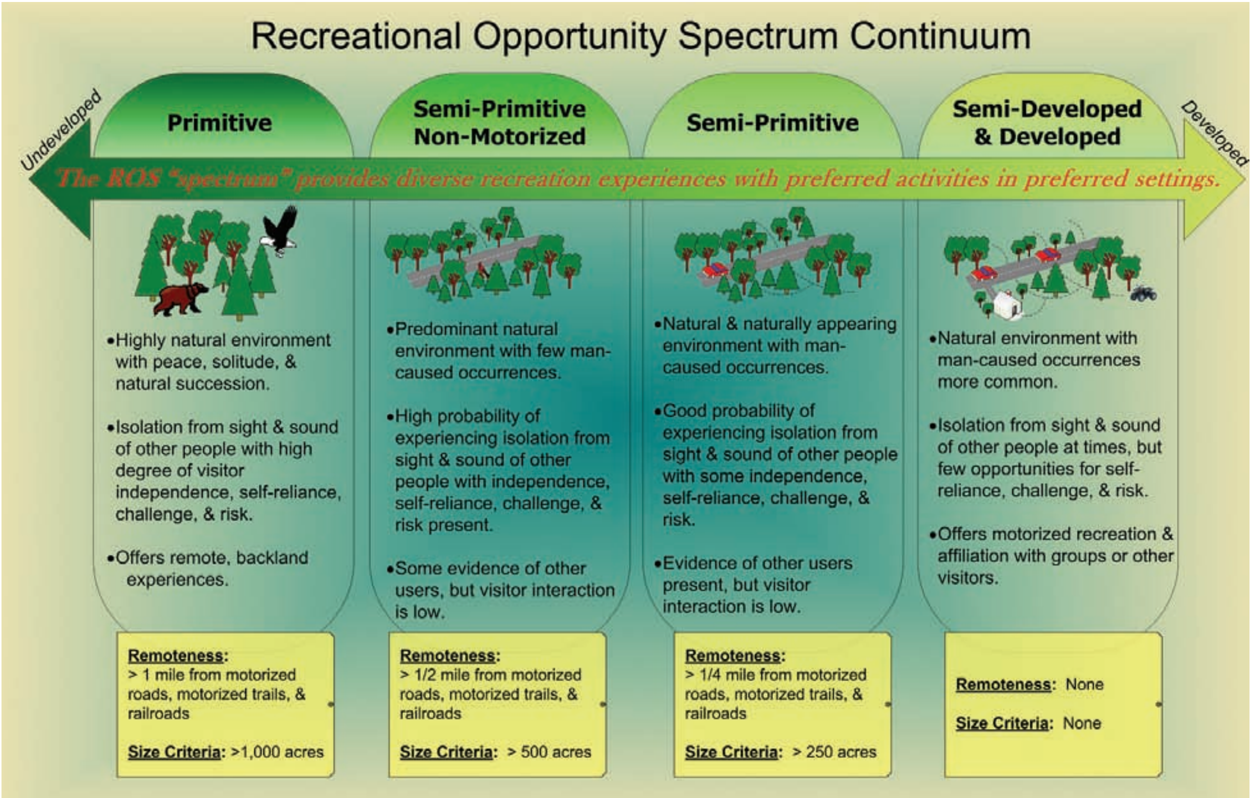


Figure 11.2

Recreation Opportunity Spectrum

The 2007 State Forest Resource Management Plan Update stated: "Utilize Recreation Opportunity Spectrum (ROS) to make and communicate recreational management decisions that are transparent, credible, and compatible with other state forest management goals." The U.S. Forest Service developed the Recreation Opportunity Spectrum system, which has been adapted by the bureau for application in Pennsylvania.

According to the ROS manual: "Recreation opportunity Spectrum (ROS) is an inventory system built on the premise that people expect certain types of recreational experiences on public land, and that land managers should be able to direct people to appropriate places for those experiences. ROS allows the land manager to provide recreational opportunities across a spectrum, or continuum, of five land-use classes so that the user may find satisfying recreational experiences in a variety of recreational activities."

The ROS land-use classes follow a continuum from "primitive" to "developed" and can be used as a measure of wild character (Figure 11.2). The ROS classes are:

- **Primitive**
  - Remoteness: Greater than one mile from a motorized road/trail/railroad
  - Size: Greater than 1,000 acres
- **Semi-Primitive Non-Motorized**
  - Remoteness: Greater than one half mile from a motorized road/trail/railroad
  - Size: Greater than 500 acres
- **Semi-Primitive**
  - Remoteness: Greater than one fourth mile from a motorized road/trail/railroad
  - Size: Greater than 250 acres
- **Semi-Developed and Developed**
  - Remoteness: None
  - Size: None

ROS is a long-term planning tool that guides management activities. State forests are managed to maintain the conditions that define each ROS land-use class, or increase the primitive acreage, but not to increase developed acreage. According to the *Guidelines for Administering Oil and Gas Activity on State Forest Lands*, "Natural gas activities will be restricted within Primitive and Semi-Primitive Non-Motorized zones as identified through the Recreation Opportunity Spectrum (ROS) inventory and planning tool."

The bureau has a custom GIS tool that delineates ROS zones from the state forest landbase and motorized road/trail spatial data using the remoteness and size criteria. The bureau maintains a GIS base layer of the ROS classes for pre-shale-gas conditions. As gas development progresses, the bureau will continue to compare current ROS conditions to pre-shale-gas conditions and strive to attain those pre-shale-gas conditions for final restoration. Gas development activities change the condition of state forest acreage to the more developed side of the ROS continuum, although when sites associated with gas development are restored, they should return to their more primitive pre-shale-gas ROS conditions. Mitigation efforts could make other areas more primitive in the interim. Table 11.1 and Figure 11.3 quantify the change in recreational experience and wild character from pre-shale-gas conditions until 2012, due to shale-gas development as measured by the ROS tool.

The current impact of gas infrastructure on wild character in core gas districts is: 9,341-acre increase in semi-developed and developed acreage, 913-acre decrease in semi-primitive acreage, 8,409-acre decrease in semi-primitive motorized acreage, and 19-acre decrease in primitive acreage.

Before shale-gas activity, 19.5 percent of the state forest in core gas districts was in the semi-primitive non-motorized land-use class; the effects of shale-gas development as of 2012, resulted in a decrease to 18.9 percent. The semi-developed and developed acreage increased from 50.9 percent to 51.6 percent of the region's state forest. Semi-primitive and primitive acreages each changed by less than one tenth of one percent.

The changes in ROS land-use classification also can be shown spatially. Currently, the changes in ROS have all been decreases in primitive quality of the land base. As developed gas sites are restored to pre-shale-gas conditions, acreage should return to more primitive character. In future ROS analyses, it will be informative to separate acreage returned to primitive classifications from acreage developed to show that the net result will include both gains and losses.

District	Primitive	Semi-Primitive Non-Motorized	Semi-Primitive	Semi-Developed & Developed
Moshannon	0	-1,164	356	808
Sproul	0	-770	51	719
Tiadaghton	0	-3,259	-72	3,332
Elk	0	0	0	0
Susquehannock	-19	-9	-18	46
Tioga	0	-3,207	-391	3,597
Loyalsock	0	0	-838	838
Total	**-19**	-8,409	-913	9,341

Table 11.1 Net ROS Acreage Change (Pre-Shale-Gas vs. 2012).

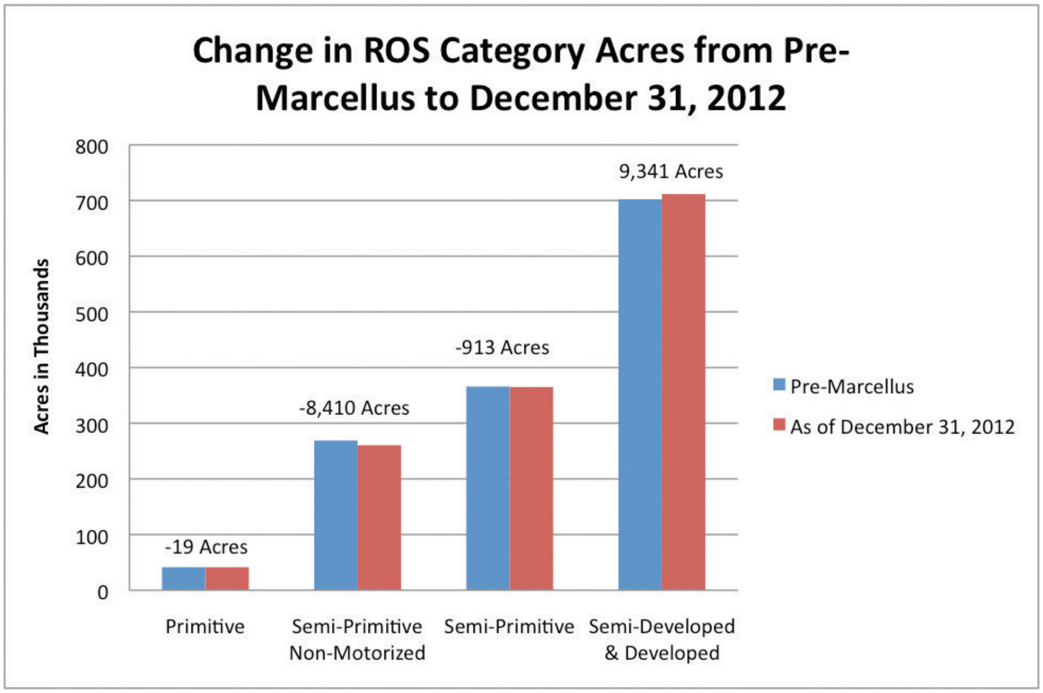


Figure 11.3

Aesthetics – Viewshed

Since 2008, the bureau's oil and gas leases have included scenic viewshed "Areas of Special Consideration," coordinated with the district forester to prevent disruption of scenic viewsheds wherever possible. State forest trails, rivers, and major roads were identified as scenic viewsheds. Incidents of gas development occurring in those scenic viewshed Areas of Special Consideration have been identified and evaluated.

Impacts on viewsheds can be evaluated using a specialized tool in ArcGIS. This tool was utilized prior to the 2008 leases in order to identify the viewsheds that should be protected in the leases.

Viewsheds were identified in 2008 using the following procedure:

1. Each forest district with potential gas leases was asked to identify:
   a. Roads with high scenic value. These roads are heavily used by the public, and there is an expectation of high scenic value.
   b. Streams with scenic river designation or which receive heavy use with an expectation of exceptional scenic value.
   c. Trails with heavy recreation use and an expectation of high scenic value.

The selection of these features was based on local knowledge and was subjective:

2. The ESRI ArcMap viewshed tool was used to estimate viewshed from the features identified in Step 1.
   a. Road, stream, and trail features from the statewide dataset identified in Step 1 were used as input features.
3. The viewshed tool creates a layer with two symbols: 0- not in viewshed and >0- in viewshed.

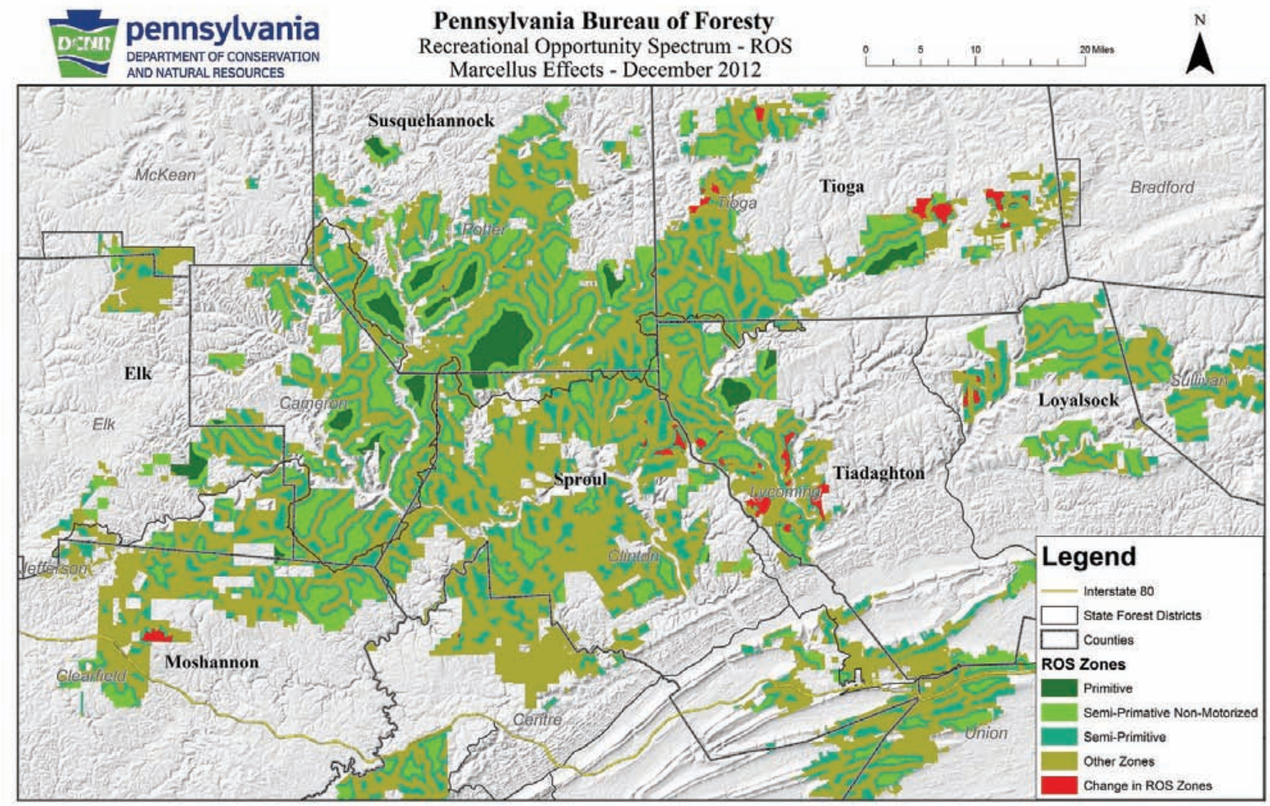
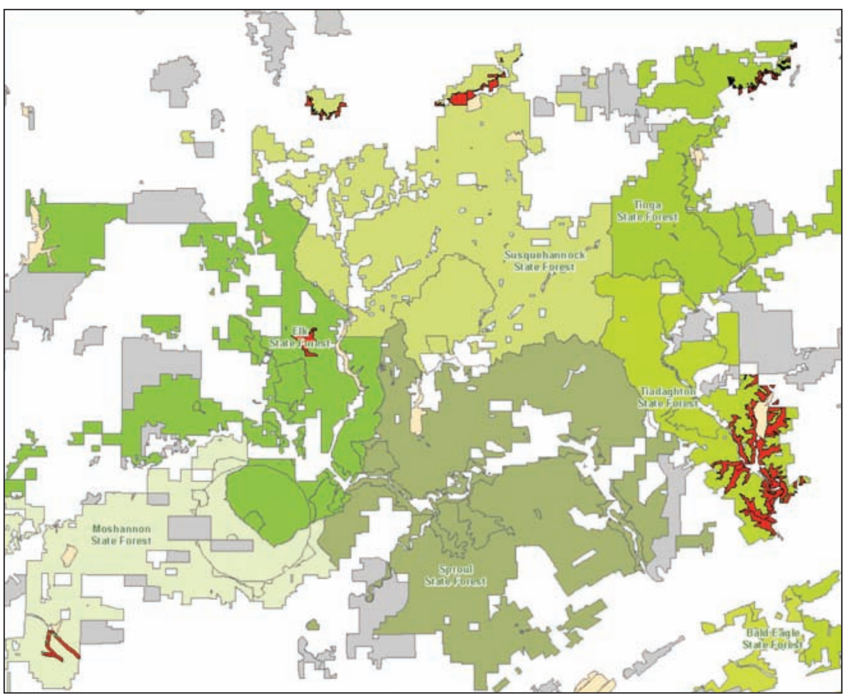


Figure 11.4 Change in ROS zones.



ASoC Viewshed Specified in Lease

Tract	Viewshed Acres(lease)
001	2023
007	1283
293	2509
322	789
323	1244
356	1404
357	436
416	796
419	1330
685	1741
727	3885
728	2029
729	1760
731	748

Figure 11.5 Map of scenic viewsheds indentified in 2008 and newer leases (scenic viewshed in red).

Impacts from infrastructure were evaluated using the following procedure:

1. Gas infrastructure features are overlayed on the viewshed raster using ArcMap. If gas infrastructure is located within a raster cell with a value greater than 0, it is considered potentially visible from an input feature.
2. The occurrence of gas infrastructure within those scenic viewsheds identified in leases will be identified by type and size.

As a result of gas development, three pieces of gas infrastructure have been constructed within scenic viewshed Areas of Special Consideration identified in gas leases. Development in these areas requires coordination between operators and the bureau to protect specific forest uses and values. At times, development in these areas is necessary to protect other sensitive areas and to take advantage of existing disturbance corridors.

Feature	Size	Viewshed Impacted
Road	724 feet	PA-153
Road	963 feet	Interstate 80
Pipeline	2,960 feet	Little Pine Road

Table 11.2 Gas infrastructure in scenic viewsheds.

The features identified above were specifically related to gas development. The size given for roads and pipelines is the length of the feature within designated scenic viewsheds. While the size of the feature suggests how much of it could be visible, it is important to recognize the limitations of viewshed software. It might be possible to see more or less of the infringing infrastructure than is actually suggested by the software. There are many variables that the software uses which would need to be further developed to make the tool more reliable. The impact is qualitative and should not be determined by software. Furthermore, the scenic viewsheds identified in the leases are relatively small in acreage compared to the total acreage affected by gas development and, therefore, a limited quantification of the aesthetic impact.

The 724-foot section of road visible from PA-153 is not an entirely new road. Prior to gas activity, it was a camp site access road. Only a very short portion of the road is visible from PA-153.

The 963-foot section of road visible from I-80 existed prior to gas development as a state forest road and is still used in that capacity. The road has been improved for gas development use. In this case, the road was only slightly widened, similar to normal road maintenance, with minimal aesthetic change. This is unlike some other roads improved for gas development, where improvement has included significant widening and/or additional rights of way.

The 2,960-foot pipeline in the viewshed of Little Pine Road is a new gathering pipeline and rights of way where none existed previously. In this case, no suitable existing pipeline or right of way existed to transport the gas to marketing lines, and the lease gives operators the right to transport their gas from the leased area. Alternate routes were considered, but based on a host of concerns about other sensitive resources, this route was determined to have the least impact. Any route across the valley would have to cross Little Pine Road, impacting the viewshed; thus, this aesthetic impact could not be avoided. The right of way needed to be 100 to 130 feet wide to accommodate safe construction on the steep slope. After construction was completed, reclamation began, narrowing the width to the 40-foot minimum necessary for operation. Instead of the typical long straight line, the forest district requested curves and doglegs to mitigate the aesthetic appearance of the right of way. Even though 2,960 feet of pipeline is within the viewshed, the amount you can see at any given time is significantly less.

The viewshed from vistas may be impacted, both by activities on state forest land and those on private land. The viewshed software tool was found to be limited in its capability to accurately reflect whether a viewshed was actually impacted and needs further development. Qualitative analysis may be more informative than quantitative measures. The bureau may also work to manage vistas to maintain high quality and mitigate impacted sites.

In the future, state forest districts and the state forest system may be examined more holistically for viewshed impacts with ArcMap viewshed software. However, the limitations of the tool may suggest the use of a different method to quantify the value of the impact. For example, photos may also be used to document the change in appearance before and after development.

Noise

Because of the size of their land base, state forests provide a unique opportunity for dispersed low-density outdoor recreation that cannot be obtained from small forest areas or from private ownership. The undeveloped wild character of state forests offers peace, solitude, and a feeling of remoteness for many users. Ambient noise can dramatically affect a user's recreational experience and generate conflict. Most sources of potential noise conflicts on state forest land are temporary in nature; however, gas compressor stations produce continuous noise and thus have the potential to greatly impact the experiences of the recreating public. The bureau's objective is to maintain and perpetuate a visitor's anticipated recreational experience on state forest lands and to maintain the wild character of the state forest.

The Guidelines for Administering Oil and Gas Activity on State Forest Lands include recommended thresholds for compressor noise levels. It's important to note that the current noise guideline did not exist when many of the state forest compressor stations were approved. The current guideline reads:

When no suitable alternatives exist and a compressor station must be sited on state forest lands, the operating noise level of the compressor station should not exceed an Ldn of 55 db(A) at any distance greater than 300 feet from the compressor building.

The bureau measured noise levels of compressor stations on state forest lands. The operating noise level of compressors was measured at 300 feet or greater. The sound level meter (SLM) was set to collect db(A) data for 24 hours, recording one reading every five seconds. The Ldn, which is a standard weighted average of the noise level, was calculated. The SLM was positioned at human ear level, using a strap to attach the meter to a tree or other suitable object. A GPS point for the location of the meter and a photograph and/or physical description were recorded so the same point can be found for repeat measurements. The same protocol could be used to measure other noise sources.

The SLMs were deployed when weather conditions were appropriate for SLM data collection. Although the SLM is fitted with a windshield under all circumstances, the preferred wind speed limit is 10 mph, with an upper limit of 15 mph. The weather conditions during data collection were recorded. Measurements were avoided in rainy or dense foggy conditions. Objects that generate wind-derived noises were avoided in SLM placement. Table 11.3 provides the results of noise level measurements conducted.

District	Leased Tract	Leq db(A)	Date
Tiadaghton	289	55.61	2/13/2013
Tiadaghton	685	59.15	2/14/2013
Tioga	587	61.85	2/20/2013
Tioga	595	60.47	2/26/2013
Tioga	839	60.2	3/5/2013
Sproul	285	69.63	3/7/2013

Table 11.3 Sound meter data – operating compressor stations.

Measurements at the six compressor stations monitored on state forest lands were louder than 55db(A). These measurements are only indicative of the noise level on the day of the measurement. The quantity of data is limited to one 24-hour period for each compressor station, and winter conditions only. Each compressor and site is unique. Two sites had high winds on multiple attempts to collect data. The high winds likely contributed to higher db(A) readings. Wind may be a perennial issue at certain sites. One site also had heavy equipment operating nearby, and another site had snowmobile traffic as additional contributing noise sources.

Operators have been working cooperatively with the bureau to address compressor noise and to meet recommended guideline thresholds. The bureau is also working with DCNR's Natural Gas Advisory Committee to better understand compressor noise and mitigate impacts to wildlife, the wild character of the state forest, and the recreating public. With the committee, the bureau is guiding research to better characterize compressor noise, its impacts, and to develop adequate and effective management guidelines.

Comment Cards

The bureau has cooperated with Penn State University to adapt a Visitor Use Monitoring program (VUM) for state forests and parks and added two shale gas-related questions. This VUM study is scheduled to collect data in select parks and forests each year. Penn State will analyze the data collected.

The National Visitor Use Monitoring program has two concurrent goals: to produce estimates of the volume of recreation visitation to national forests and grasslands and to produce descriptive information about that visitation, including activity participation, demographics, visit duration, measures of satisfaction, and spending connected to the visit.

To begin gathering statewide data in the short term, the bureau duplicated a portion of the VUM survey and shale-gas questions on postage-paid index cards. The cards were placed in boxes in high-use recreation areas. Between July and October 2012, the bureau received 223 completed comment cards. Additional cards continue to be received.

8170-CD-FR0175 03/2012

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
BUREAU OF FORESTRY

pennsylvania

COMMENT CARD

Please give us a minute of your time to help us serve you better. How would you rate our facilities and services in: ____________________State Forest at: ____________________________.
What is the primary reason or activity that brings you to this state forest (hiking, biking, hunting, fishing, boating, horseback riding, ATV riding, etc)? ______________________________________

Please circle one for each item:	Poor	Fair	Avg.	Good	Very Good
Scenery	1	2	3	4	5
Condition of the natural environment	1	2	3	4	5
Condition of Forest roads	1	2	3	4	5
Condition of Forest trails	1	2	3	4	5
Parking lot\Trailhead condition\appearance	1	2	3	4	5
Condition of developed recreation facilities (latrines, picnic tables, fire rings, campsites, pavilions, etc.)	1	2	3	4	5
Feeling of safety and security	1	2	3	4	5
Adequacy of signage	1	2	3	4	5
Availability of recreation information: (maps, website, etc.)	1	2	3	4	5

Has Marcellus activity changed your recreational use of this state forest? ______________________
____
Has Marcellus activity changed your visitation experience of this state forest? _________________

Figure 11.6 Example of bureau's distributed comment card.

Summary of Marcellus Comments; July to October 2012

The sample size is relatively small for this period, but the summary of the open-ended Marcellus comments is informative.

Has Marcellus activity changed your recreational use of this state forest?

Following the question, a blank space was provided to answer. "Yes," "no," or nothing at all were common responses, and there were additional comments written in the space provided. Not everyone explicitly included a "yes" or "no" answer, but when the answer was implicit, those comments were included in the tally. The data are also presented in Figure 11.7.

All forest districts: 46 yes, 158 no, 19 blank

Core gas forest districts only: 41 yes, 66 no, 9 blank

The following is a summary of the comments received. Similar comments are grouped together, with the number noted in parentheses and "yes" or "no" identified in brackets.

Not Yet (17) [No] The most common comment on all cards in this time period other than "yes" or "no" was "not yet;" that comment was written verbatim 11 times. Similar answers were included in this theme. These answers indicate that recreational use has not changed, the user is aware of shale-gas activity, and the user directly or indirectly implies it may affect his or her use at some point in time.

Emphatic no (8) [No] Some comments were more emphatic than a simple "no," for example: "Not at all."

Not applicable (7) [No] "Not applicable," or "N/A," was a common response. Similar comments indicate that recreational use has not changed, the user is aware of shale-gas activity, and perhaps the user does not think it will affect his or her use.

Don't know (2) [No] Some comments admitted lack of knowledge.

Avoidance (11) [Yes] There were unique comments pertaining to "avoidance" as a change in recreational use. Every comment was unique, but directly addressed the question. Lumped together, avoidance was the most common change in recreational use identified.

Roads, Traffic, Trucks, Noise, Dust (9) [Yes] There were a variety of comments identifying road traffic as a specific shale-gas activity affecting their use.

Some (9) [Yes] There were understated comments that implied changes had occurred. These comments indicate there is a perceived change, but the users do not want to specify, or do not know what has changed.

General Opposition (5) [Yes] There were comments that didn't specify a change, but generally opposed shale-gas activity. These comments relate to perception of shale-gas activity and its effects on state forests.

Access (4) [Yes] Some comments identified access as a change in recreational use. These comments directly identify a change in recreational use.

Other Environmental Impact (8) [Yes] There were sparse comments related to environmental quality, including water quantity, water quality, land use, aesthetics, air quality, wildlife populations, and favorite spots.

Has Marcellus activity changed your visitation experience of this state forest?

Following the question, a blank space was provided to answer. "Yes," "no," or nothing at all were common responses, and there were additional comments written in the space provided. Not everyone explicitly included a "yes" or "no" answer, but when the answer was implicit those comments were included in the tally. The data also presented in Figure 11.7.

All forest districts: 53 yes, 152 no, 18 blank

Core gas forest districts only: 46 yes, 62 no, 8 blank

The following is a summary of the comments received. Similar comments are grouped together, with the number noted in parentheses and "yes" or "no" identified in brackets.

Not Yet (11) [No] The most common comment on all cards in this time period, other than "yes" or "no," was "not yet;" that comment was written verbatim nine times. These answers indicate that recreational experience has not changed, the user is aware of shale-gas activity, and the user perhaps thinks it may affect his or her use at some point in time.

Not applicable (5) [No] "Not applicable," or "N/A," was a common response. Similar comments indicate that recreational experience has not changed, the user is aware of shale-gas activity, and the user perhaps does not think it will affect his or her experience.

Emphatic no (2) [No] Some comments were more emphatic than just "no," for example: "Not at all."

Roads, Traffic, Trucks, Noise, Dust (16) [Yes] There were a variety of comments identifying road traffic as a specific shale-gas activity affecting their experience.

Unpleasant experience (8) [Yes] Unique comments related to pleasantness were identified as a change in visitation experience.

General Opposition (4) [Yes] There were comments that didn't specify a change, but generally opposed shale-gas activity. These comments relate to perception of shale-gas activity and its effects on state forests.

Avoidance (3) [Yes] There were unique comments pertaining to avoidance as a change in visitation experience. Each comment referred to areas the person uses or does not use due to shale-gas activity.

Wildlife (3) [Yes] There were comments relating to wildlife presence and behavior.

Some (3) [Yes] There were understated comments that implied changes had occurred. These comments indicate there is a perceived change but the user does not want to specify, or does not know, what has changed.

Litter (2) [Yes] There were comments specifically about litter, and specifically litter related to shale-gas industrial activities.

Noise (2) [Yes] Helicopter noise and machinery noise were specifically identified as experience changes. Noise also was identified with traffic.

Other Environmental Impact (4) [Yes] There were sparse comments related to environmental quality, including water quantity, water quality, land use, aesthetics, air quality, wildlife populations, and favorite spots.

Availability of goods (1) [yes] There was one comment about the lack of availability of kerosene.

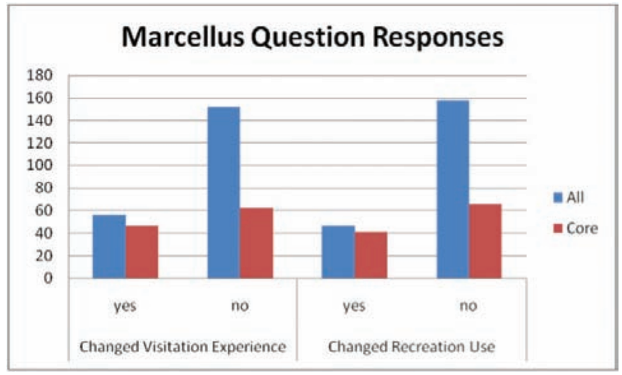


Figure 11.7 Shale-gas comment card responses.

Forty-six out of 116 respondents in core gas districts indicated that shale-gas activity had changed their visitation experience. Forty-one out of 116 respondents in core gas districts indicated that shale-gas activity had changed their recreational use of the state forest. Responses for both questions in non-core districts had significantly more responses that neither visitation experience nor use was changed by shale-gas activity. The combination of road condition, traffic, trucks, noise, and dust was the most common comment included for both questions.

Additional comment cards have been received since October 2012 and will be included in future reporting efforts. Responses could be organized by forest district to provide greater detail. The visitor use monitoring research being done by Penn State will have greater statistical validity and more detailed analysis, but this comment card effort provides immediate and continuous feedback.

IV. Discussion / Conclusion

While there have been impacts to recreational infrastructure due to shale-gas development, there also have been improvements to that infrastructure that otherwise likely would not have happened. When impacts could not be avoided, they have been considered temporary, and throughout the process the goal has been eventually to improve any impacted recreational infrastructure to a condition better than it was before gas development.

Though it is a small percentage of total acreage, there is significant acreage affected by changes to recreational experience and wild character measured by ROS. State forest visitors looking for a more primitive experience may find fewer appropriate places for those experiences, while visitors who enjoy semi-developed and developed areas may find more appropriate places for those experiences.

There have been impacts to scenic viewsheds identified as Areas of Special Consideration. Each case was carefully considered and determined the least overall impact to state forest values and uses. Additionally, gas development affects the aesthetics of state forests outside those Areas of Special Consideration, which should be considered in future monitoring efforts. The viewshed tool can be used to measure impacts, but it needs further refinement before it can be applied in a meaningful way. Each type of infrastructure may affect the perception of the person viewing it differently, and each viewer is unique.

Sound level measurements at operating compressor stations on state forest lands were louder than suggested by the current *Guidelines for Administering Oil and Gas Activity on State Forest Lands*. Attenuation has been developed. Repeat measurements and ambient noise level measurements would improve understanding of noise levels as well as additional research and continued refinement of guideline standards.

The comment cards have provided immediate and ongoing insight into changes to use and experience caused by shale-gas activity. The visitor use monitoring research being done by Penn State will have greater statistical validity and more detailed analysis.

Quantitative measures are limited in their ability to measure experience since the effect of the impact on the user's experience only can be determined by the user. Spatial data has similar limitations; if a visitor is using a site unaffected by any of the measures discussed here, but passes through them on the way, he or she may feel the impact nonetheless. Qualitative measures are probably more relevant to the impact on recreation experience than quantitative or spatial measures.

The bureau will continue to focus on avoiding impacts to recreation when possible. When impacts cannot be avoided, the bureau will work towards making the impacts temporary in nature and minimizing the temporary time period to the greatest extent possible. The bureau will continue to work with gas operators, recreation groups, and the visiting public to address potential impacts.

Part 2: Monitoring Values
»Community Engagement

I. Key Points:

- Natural gas development on state forest lands has potential economic and social effects on local communities.
- The bureau uses advisory committees to promote stakeholder feedback and produce recommendations.
- Outreach offers valuable opportunities to demonstrate how natural gas activity is conducted and managed on public lands and has become a source of understanding public perceptions.
- Focus groups have been designed to identify and understand the social effects on communities resulting from natural gas development on state forest lands. One pilot focus group targeting community leaders in Pine Creek Valley was conducted in November of 2013. Two additional groups targeting government leaders in Tioga and Clinton counties were conducted in 2014.

II. Introduction

Natural gas development on state forest lands has potential economic and social effects on local communities. The bureau interacts with local communities through the implementation of its public participation policy (Penn's Woods, 1996), which includes public education and participation as an integral part of the management of state forest lands.

On a daily basis, bureau staff interact with the public in a variety of ways, including face-to-face, telephone, email, and educational outreach efforts. State forest districts have significant interactions with local elected officials in dealing with the impacts from development on local and state roads in their communities (development on state forest lands may have local community, county, and regional impacts). These communications provide constant direct input and feedback, which is considered in management activities. Advisory committees, shale-gas outreach tours, and focus groups are more formalized and better documented examples of community engagement.

The bureau has cooperated with Penn State to adapt a Visitor Use Monitoring program (VUM) for state forests and parks and added two shale-gas related questions. This VUM study is scheduled to collect data in select parks and forests each year. More information on the VUM study can be found in the Research section of this report. To begin gathering statewide data in the short term, the bureau duplicated a portion of the VUM survey and Marcellus questions on postage paid index cards. The cards were placed in boxes in high use recreation areas. The comment cards are discussed further in the Recreation section of this report.

Updating and developing the bureau's State Forest Resource Management Plan (SFRMP) will incorporate public involvement in a more formal way. The SFRMP is the bureau's comprehensive document for guiding the management of the state forests. The 2007 SFRMP update process represented the first iteration of the periodic updates to the management plan implemented in 2003. Current issues and other plan updates to be reviewed or addressed were compiled into the SFRMP Update Document and posted on the web for public review and comment. The bureau conducted nine regional public meetings and solicited written and web-based comments on the 2007 Update Document. The 2007 SFRMP public update process comment period, including the nine public meetings, was publicized via the following outlets:

- DCNR's websites
- DCNR's newsletter *The Resource*
- Press releases to statewide and local news sources
- Advance notice to advisory groups
- Mailed invitations to state, county, and township elected officials and constituency stakeholder groups
- Email notification

The bureau anticipates completing the next SFRMP update in 2015, which will include a similar public input process. Comments from this process that are relevant to natural gas management will be incorporated into future monitoring reports.

III. Monitoring Efforts/Results

The components included in the community engagement section of this report are: advisory committees, gas tours on state forest land, and focus groups. Advisory committees are used to promote stakeholder feedback and produce recommendations. Outreach tours offer valuable opportunities to demonstrate how natural gas activity is conducted and managed on public lands. These tours are also a source of additional public input. Focus groups have been designed to identify and understand the social effects on communities resulting from natural gas development on state forest lands.

Advisory Committees

Working with staff in other bureaus as well as the DCNR secretary's office, the bureau manages and facilitates several advisory committees, including the Ecosystem Management Advisory Committee (EMAC), the Natural Gas Advisory Committee (NGAC), the Recreation Advisory Committee (RAC), and the Silviculture/Timber Advisory Committee (STAC). In addition to these four advisory committees, the bureau manages other committees and councils focused on forest stewardship, urban and community forestry, wild plants, and the Pine Creek Rail Trail.

Collaboration, facilitation, information sharing, and informal dialogue are key principles that guide the management and work of bureau advisory committees. Gathering diverse opinions allows the bureau to make better, more-informed decisions. The group typically does not vote on recommendations. The recommendations are provided to the bureau for consideration.

Bureau program experts and field staff are critical to the process because they manage the programs that are the subjects of the conversation. Staff members provide critical information and perspectives, and they benefit from being part of the discussion, and hearing the perspectives of committee members.

Committee members are expected to participate, make presentations, and produce written recommendations and reports. Other "support staff" receive agendas, minutes, and other information but do not attend unless they are critical to the items on the agenda.

Natural gas management on state forest lands has been a common topic of discussion at advisory committee meetings.

For example:

- EMAC provided comments on the bureau's gas guidelines and its shale-gas monitoring program.
  - The EMAC Energy Subcommittee evaluated shallow gas compatibility and made deep-drilling recommendations.
- NGAC has provided input on noise management related to compressor stations. This committee's overall purpose is to advise and provide recommendations for implementing natural gas management in a manner that is consistent with the mission of DCNR and its bureaus.
- The STAC agenda included discussion of shale gas as a topic/priority.
- The RAC agenda included the bureau's gas management and its shale-gas monitoring program.

Organized Outreach Tours on State Forest Lands

Shale-gas drilling activity has generated significant interest from a variety of stakeholders, organizations, educational institutions, government agencies, and other groups. Periodically, these groups request an organized tour of state forest lands. These tours, conducted by both the bureau and the operators, offer valuable opportunities to demonstrate how natural gas activity is conducted and managed on public lands.

The bureau's goal is to coordinate and manage organized outreach tours in a way that represents the full suite of uses and values of the state forest system. The bureau demonstrates that gas development can occur while avoiding impacts to state forest operations and public use. The bureau also takes the opportunity to convey stewardship messages, impressing upon attendees that ecosystem management is the core principle by which the bureau manages state forest land, even when gas development is involved.

In 2011, there were 17 organized gas tours, including 391 attendees (Table 12.1). In 2012, there were 15 organized gas tours, including 337 attendees (Table 12.2). Tours have been identified as a source of public input, as many questions and comments are received from attendees during the tours. A survey currently in draft form will be used to capture input from tour attendees to be included in future monitoring reports.

Date	Group Name	Attendees
02/04/11	Governor Ridge Policy Group	34
03/18/11	DEP Secretary Krancer & Pennsylvania State Senator Gene Yaw	19
04/07/11	DCNR Park Managers	56
05/05/11	State Parks Environmental Education Specialists	26
06/08/11	Sierra Club	11
06/29/11	Executive Team #1	23
07/13/11	Latvian Delegation	25
07/18/11	House Finance Committee	25
07/25/11	Executive Team #2	34
08/24/11	Ohio Delegation #1	14
09/07/11	Governor's Office Staff	15
09/15/11	Senate Appropriations Committee	15
09/29/11	Anadarko/Pennsylvania State Senator Gene Yaw	10
10/06/11	DEP/Governor's Office staff	26
10/19/11	Ohio Delegation #2	22
11/30/11	National Forest Service	9
12/19/11	DEP/Department of Revenue	27

Table 12.1 2011 Bureau of forestry marcellus shale tours.

Date	Group Name	Attendees
3/6/2012	Volvo	24
3/16/2012	Wildlife Society	40
3/20/2012	Williams/Transco	16
03/22/12	Transco/Homeland Security	6
4/12/2012	U.S. Congresswoman A. Schwartz	10
4/20/2012	Department of Revenue/DCNR Policy Interns	35
4/25/2012	Pennsylvania State Representative Keller	19
5/10/2012	Leadership Lycoming	26
5/14/2012	Forest Coalition	8
6/8/2012	PA Environmental Defense Foundation	16
7/10/2012	Governor's Advisory Council (Sportsmen)	34
7/18/2012	Keystone Soil Scientists	29
08/17/12	U.S. Geological Survey/NY Agencies/MD Agencies	26
09/19/12	Mid Atlantic States' Forest Health Managers and USDA Forest Service	23
09/26/12	NC and NY Departments of Transportation/Anadarko	25

Table 12.2 2012 Bureau of forestry marcellus shale tours.

Focus Groups

Natural gas development on state forest lands has the potential to affect many different stakeholder groups. Focus groups can be used to gather targeted public input.

Rationale and Uses of Focus Groups

Focus groups are a form of group interview that capitalizes on communication between research participants in order to generate data. Although group interviews often are used simply as a quick and convenient way to collect data from several people simultaneously, focus groups explicitly use group interaction as part of the method. This means that instead of the researcher asking each person to respond to a question in turn, people are encouraged to talk to one another – asking questions, exchanging anecdotes, and commenting on each other's experiences and points of view. The method is particularly useful for exploring people's knowledge and experiences and can be used to examine not only what people think but how they think and why they think that way (Kitzinger).

Questions are developed into a tool for the facilitator, or a "focus group instrument." The instrument is designed to identify and understand the social effects on communities resulting from natural gas development on state forest lands. The questions and probes are intended to facilitate discussion. Written or scripted answers discourage conversational interaction and spontaneity; therefore, the questions and probes are not provided in advance of the focus group meeting. Targeting different types of participants and different regions will help identify how different types of groups respond, and how the same type of group responds in different regions. The bureau will lead focus groups and refine the focus group instrument, focus group types, and locations. Focus group meetings will be hosted, and the notes will be analyzed qualitatively.

The pilot focus group targeted government and community leaders in Pine Creek Valley. The focus group instrument, focus group type, and location are being analyzed for effectiveness. Additional focus groups are needed to help identify trends, commonalities, and differences. Two additional groups targeting government leaders in Tioga and Clinton counties were conducted in 2014.

The analysis should help the bureau implement its public participation policy by identifying issues related to natural gas development and how and why people feel the way they do. The results may show the need for other public participation tools, such as facilitated discussions, key informant interviews, and surveys.

IV. Conclusion/Discussion

Implementing the bureau's public participation and education policies engage the bureau with local communities. Advisory committees have been and continue to be a valuable source of guidance. Ongoing requests for organized tours are anticipated. A method to gather feedback from tour attendees has been developed. Focus groups have been piloted, but additional groups are needed before analysis can be completed.

The impacts identified and measured in the Recreation section – such as wild character, viewsheds, and noise – need qualitative analysis attained from the people and communities affected. The public participation tools described above will help to address these needs. Any of the monitoring values discussed throughout this report can affect local communities. The bureau will continue to engage communities and citizens and advance additional methods to further measure the impacts of shale-gas on local communities.

Part 2: Monitoring Values
»Timber

I. Key Points:

- Initial analysis shows that some timber management activities in core-gas forest districts may be shifting away from areas leased for shale-gas development. Some of this change, however, may be due to gypsy moth salvage harvesting.
- The effects of shale-gas development on timber harvest placement and harvest allocation goals is inconsistent across core gas forest districts. More information and data are needed to discern reliable trends.
- Shale-gas development is indirectly decreasing timber harvest revenue due to Route 44 bonding costs resulting from heavy hauling associated with shale-gas development.
- New haul road construction and associated disturbances have been curtailed through the usage of gas development access roads for timber sales.

II. Introduction

The purpose of this chapter is to report on the effects of shale-gas development to the implementation of the bureau's silviculture program. This includes timber harvesting goals, revenue, and impacts to the forest products industry that operates on state forest lands.

According to the Conservation and Natural Resources Act, one of the purposes for the creation of a state forest system was ". . . to provide a continuous supply of timber, lumber, wood, and other forest products. . . ."

According to the bureau's strategic plan, *Penn's Woods*, the state forest timber policy is: "State forest lands should provide a sustained yield of high quality timber consistent with the principles of ecosystem management." The bureau uses silviculture as a tool for regenerating the forest, following a timber harvest scheduling model that leads toward the goal of balancing the age class distribution; securing a sustainable flow of timber products; conserving and perpetuating underrepresented forest community types; and creating specific types of wildlife habitat.

The bureau formed a partnership with the Pennsylvania State University's School of Forest Resources in 1999 to develop a timber harvest scheduling model for long-term timber harvest scheduling on state forest land. The current timber harvest schedule for state forest land calls for an average annual harvest of 14,337 acres. Key outcomes of the model include distributing the forest's age classes more evenly, thereby creating a sustainable yield of timber products over time; creating a variety of succession forest stages; diversifying habitats; and establishing harvest levels that match the growth of the commercial landbase.

Meeting the timber harvest schedule's acreage targets is also important to the sustainability of the timber industry in Pennsylvania, which relies heavily on sustained yields of forest products from state forest lands. A continuous, steady supply of quality timber from state forest lands is essential to the survivability of the hardwood industry and the economy of some regions of Pennsylvania.

State Forest Timber Stumpage Sale Bidding: The bureau offers for sale more than 70 million board feet of timber per year. Typically, 130 to 140 timber sales are available to eligible buyers to bid on annually. These timber sales are sold by sealed bids that are opened during a public bid opening at a scheduled time and date.

The state forest system has been third-party certified by the Forest Stewardship Council as "well managed." To maintain forest certification and market harvested timber products from state forest land as "certified" wood, the bureau must show that its timber harvesting levels can be permanently sustained and that harvesting levels are achieving desired future conditions.

III. Monitoring Efforts/Results

Using data collected on an annual basis in relation to harvest allocation, it is possible to establish a baseline prior to the arrival of shale-gas development. These data include acreage treated and bid prices received. What follows is a look at some of those comparisons and an explanation of each.

One of the key questions in evaluating the impact of shale gas development is whether or not the activity is affecting, in core gas forest districts, the attainment of annual harvest goals. And, along with that, whether or not gas activity is impacting the placement of timber sales. Table 13.1 and Figures 13.1-13.8 include data tabulated from the core gas forest districts. The first year tracked is 2005, well before shale-gas arrival. Using these data, a forest district's activity can be compared prior to and after shale-gas development activity. It is then possible to discern any reductions in total acres harvested and/or acres harvested within areas now under shale-gas lease. For clarification, leased lands are those defined as being under lease regardless of activity relating to development.

Year	Treatments in Leased Lands	Treatments Outside of Leased Lands
2005	1,945	6,038
2006	3,316	6,203
2007	2,017	5,830
2008	2,514	4,864
2009	4,661	5,620
2010	4,506	5,492
2011	2,236	5,529
2012	2,627	7,301
Total	**23,822**	**46,877**

Table 13.1 Silvicultural treatment acreage for core gas forest districts.

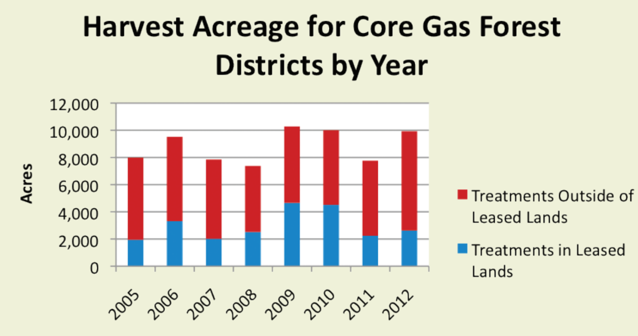


Figure 13.1

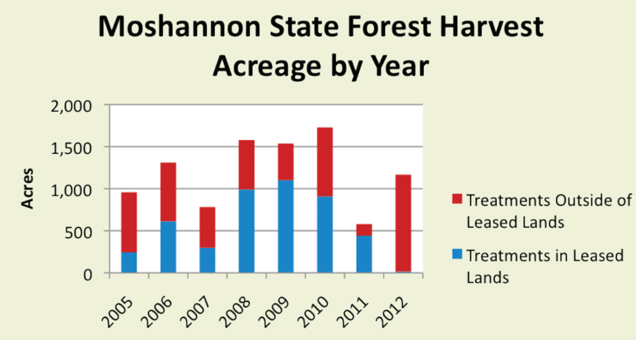


Figure 13.2

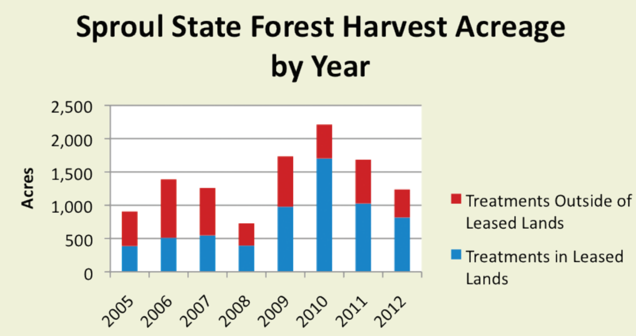
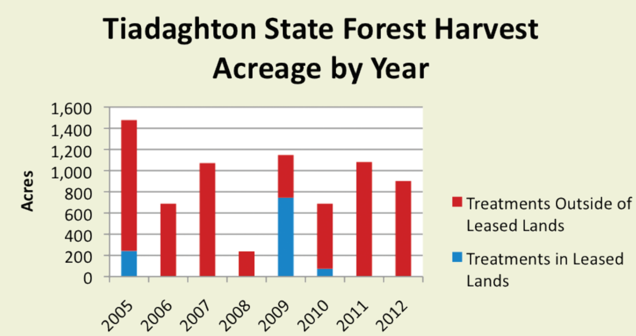


Figure 13.3



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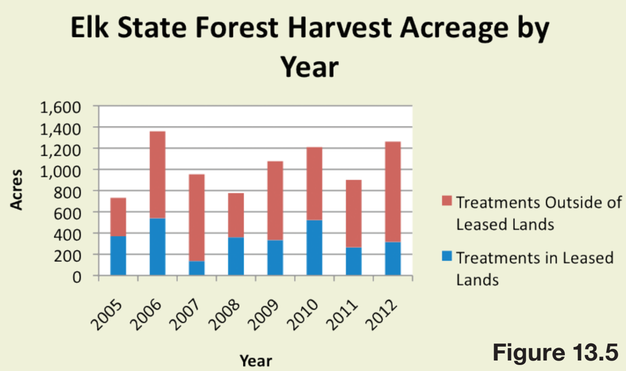
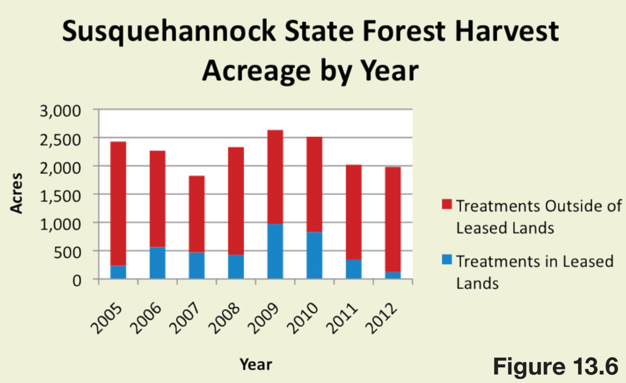


Figure 13.5



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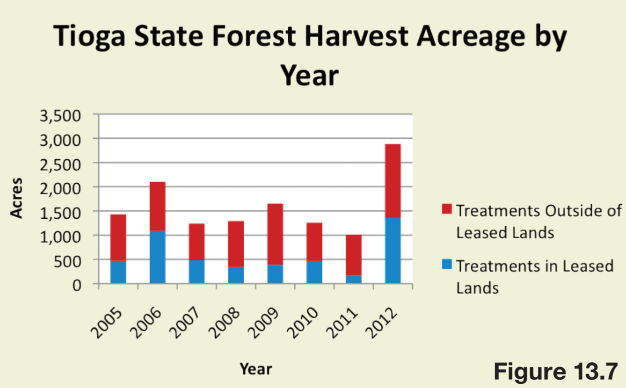

Figure 13.7

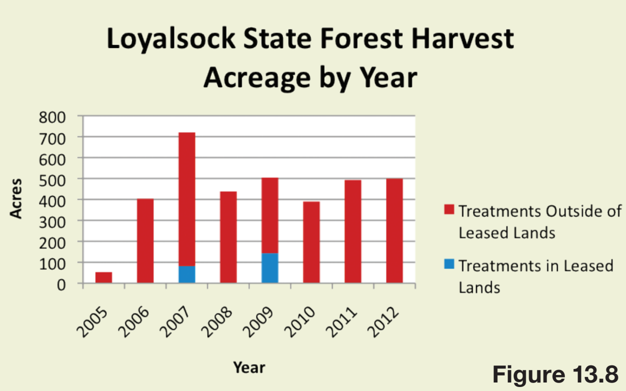

Figure 13.8

In general, shale gas development does not seem to be impacting timber harvesting activity and placement. However, there are some initial trends that the bureau will have to monitor. In Moshannon, Sproul, and Susquehannock state forests, there is a gradual downward trend in both timber sale acreages outside leased lands and timber sale acreages within leased areas. However, it is too early to gauge whether these trends are just temporary fluctuations that occur year to year with the timber harvest schedule or are indicative of a larger trend. If the trends continue, it may indicate that foresters are choosing not to harvest in areas with gas development activity.

Prioritizing areas for gypsy moth salvage operations may be one explanation for this initial trend. This is a common practice within the bureau when large tracts of timber succumb to a forest pest. For example, in Sproul State Forest, salvage operations were south of the Susquehanna River, away from gas development activity. In Moshannon State Forest, salvage operations were occurring on the tract surrounding Black Moshannon State Park, an area not heavily leased for shale-gas development. Susquehannock State Forest has continued to evenly distribute timber sales as part of the normal planning process, particularly where desirable timber harvest conditions in leased areas existed prior to the arrival of shale-gas development.

Road Bonding, Route 44 and Timber Revenue

Background

The deterioration of state highways throughout the shale gas region and associated road bonding has been an issue of significance for the forest products industry, upon whom the bureau depends to implement harvests plans and its long-term management plan.

The weight, timing, and dramatically increased frequency of shale gas development-related payloads contrasts the traditional use of these highways by logging contractors, which involves fewer loads and careful

attention to seasonal conditions. As a result, roads in this region have suffered accelerated damage compared to traditional wear.

The Pennsylvania Department of Transportation has responded by instituting increased road bonding requirements and damage assessments. When shale-gas development activity decreased and gas operators were no longer using the state highway system in the area, forest products companies were left to bear the impact of paying for damages to roads. Predictably, forest products companies throughout the region responded by reducing prices being offered for state forest timber sales or by declining to bid outright.

PA Route 44, which bisects the core shale gas region through the Susquehannock and Sproul state forests, provides primary access to several hundred thousand acres of some of the most valuable timber. Accordingly, Route 44 provides a particularly relevant opportunity to assess the impacts of the road bonding and damage issue initiated by shale-gas development. As part of its monitoring program, the bureau has been tracking timber revenues in the Route 44 region and the road bonding impacts to state forest timber harvesting operations.

The Oil and Gas Act (Act 13 of 2012) provides certain protections to the timber industry and other at-risk industries in regards to road bonding. Additionally, the transportation bill passed in 2013 addresses road bonding issues across Pennsylvania. The bureau is working with PennDot and other partners to address these impacts on state forest lands and the forest products industry.

Measuring Reduced Bids

The logging industry has adjusted its business model to offset the cost of hauling; however, that adjustment has translated into reduced bid prices for bureau timber sales. In spring of 2012, the bureau was owed almost $14 million in outstanding payments on 36 timber sales accessed via Route 44. In October of 2012, that balance had fallen to about $6.5 million. With one exception, every operator with an outstanding balance had a sale on Route 44.

In an effort to gauge how much the Route 44 issue is costing the bureau, the baseline behavior prior to May 2011 must first be assessed. Tables 13.9 to 13.12 represent an analysis, using the Penn State Timber Market Report (TMR), Northwest Region, as a baseline. Against this, timber prices per thousand board feet (MBF) for both black cherry and red maple were measured to gauge bidding behavior. Both nominal and percentage values were used for sales in the Susquehannock State Forest. Focusing on percentage values (versus nominal), however, is the most relevant way to analyze these data.

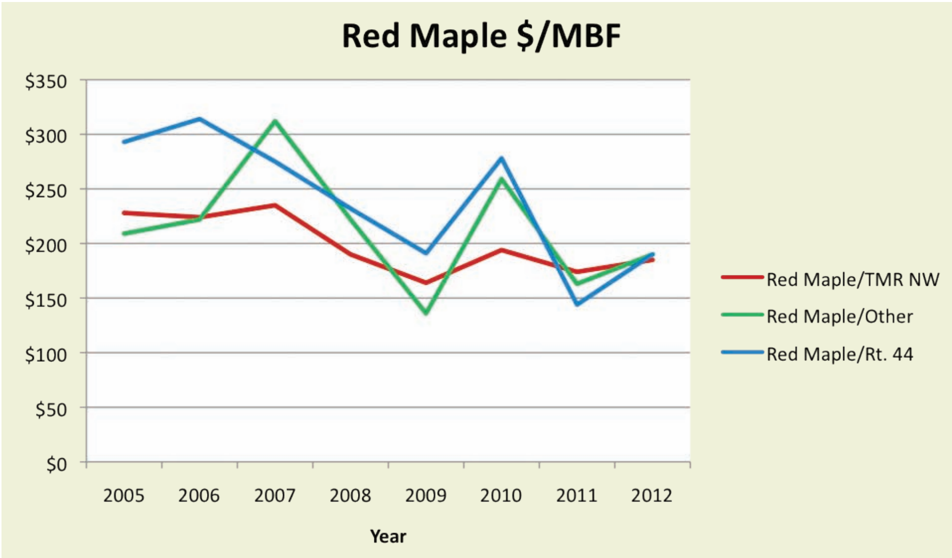

Figure 13.9 Red maple nominal values in relation to timber market report and Route 44 corridor, 2005-2012.

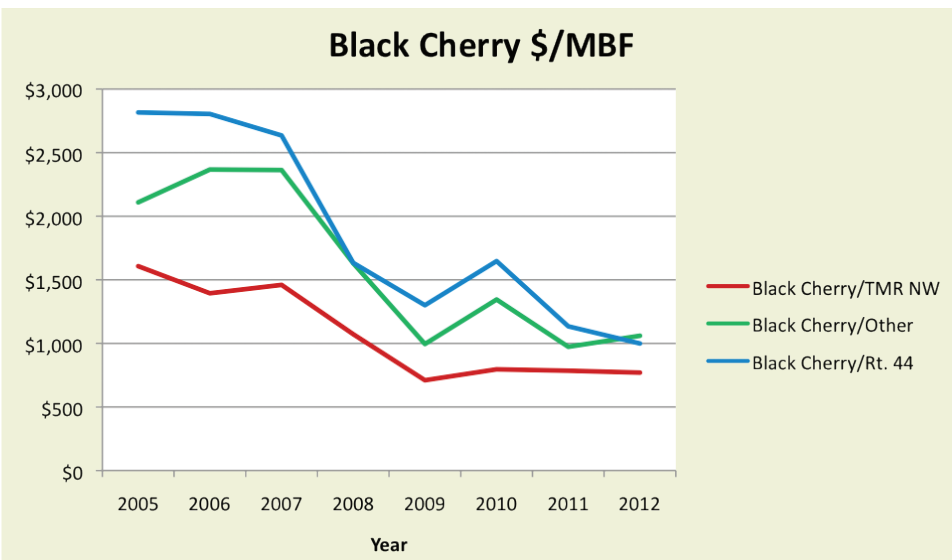

Figure 13.10 Black cherry nominal values in relation to timber market report and Route 44 corridor, 2005-2012.

Based on the results of tracking bid activity since 2005, it is evident that the Route 44 bond issue is having an effect. Timber market report data from 2005-2010 indicate that, black cherry sales that used Route 44 were between 150-200 percent of the value of the timber market report, with an average of 183 percent. This trend continued through the timber market collapse of 2008-2009. Since 2011, the average has fallen to 137 percent. The bureau is only receiving about 75 percent of the pre-2011 bid prices. Red maple also dropped by a comparable amount along Route 44.

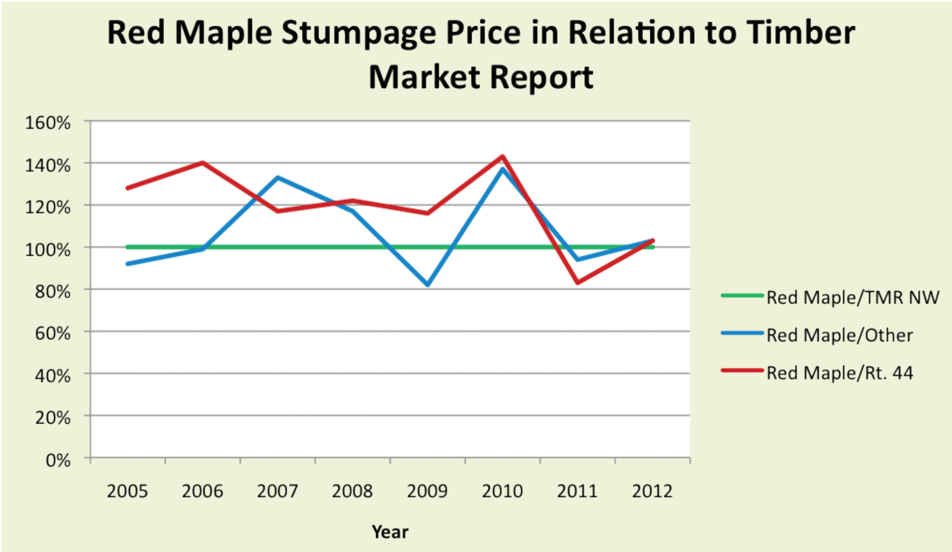

Figure 13.11 Red maple stumpage price as percent of timber market report in relationship to Route 44 corridor, 2005-2012.

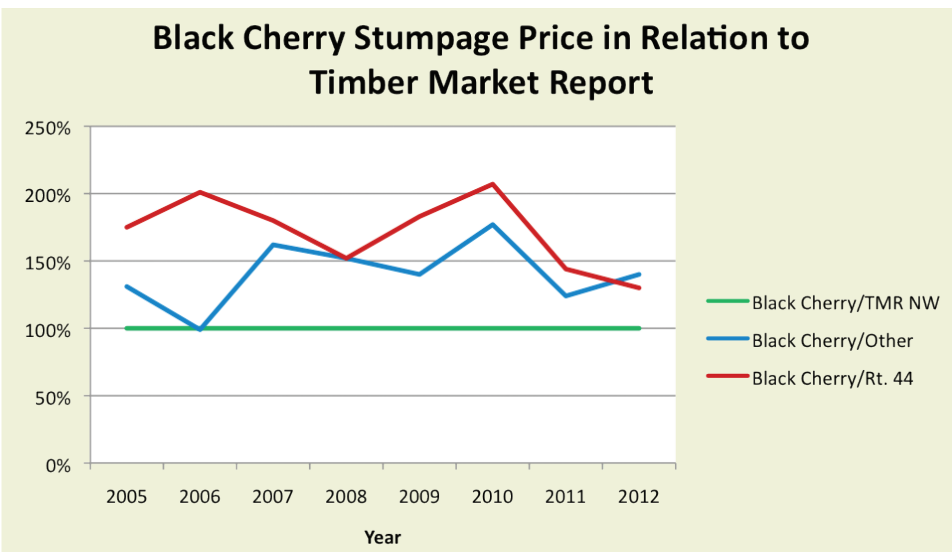

Figure 13.12 Black cherry stumpage price as percent of timber market report in relationship to Route 44 corridor, 2005-2012.

Comparing these market trends to areas outside of the Route 44 corridor, black cherry in Susquehannock State Forest dropped from a pre-2011 average of 143 percent to about 132 percent. This means the bureau is still receiving about 93 percent of the value for timber sales unaffected by the Route 44 bonding issue.

The bureau relies heavily on timber revenue for its operating budget (approximately $25 million annually). Approximately 25 percent of the bureau's timber revenue comes from the Route 44 corridor. It's important to note that while the bureau's timber revenues have declined in recent years, additional revenue from the Oil and Gas Lease Fund has kept the its overall budget stable.

Miles of Gas Access Roads Utilized for Timber Sale Access

One of the positive impacts of natural gas development has been the use of gas development access roads for timber sales. New haul road construction and associated disturbance have been decreased by obtaining duel usage of the same roads. This is baseline data that only was captured for 2012 and will be monitored in subsequent years. (See Figure 13.13)

Number of Pipeline Crossings Needed to Access Timber Sales

The number of pipeline crossings that may impact timber sales is important to monitor over time. There has been recent concern that some tracts are becoming “landlocked” by pipelines in regards to access to timber harvests. With newer, higher-pressurized lines, pipeline crossings are becoming more expensive and more complex. On sites that are marginally economical for timber sales to operate, this may become an issue to address as the number of pipelines increase on state forest lands. Cost prohibition of access may be an issue with increased management of poor and marginal sites. The data is 2012 baseline data and will be tracked in subsequent years going forward. (See Figure 13.14)

Timber Revenue Generated from Gas

The following table is a summary of timber revenue generated in association with gas activity. Both subsurface ownership rights and state forest gas leases allow for the infrastructure necessary to develop mineral resources, such as pad clearings, compressor stations, roads, and pipelines. In the absence of existing disturbance, the construction of infrastructure may require the clearing and conversion of forest land. The commonwealth must be compensated for assets including timber and pulpwood and loss of future growth. The bureau determines the timber value and charges the operator accordingly. Timber harvested from conversion of forest to gas development infrastructure is not marketed as “certified” wood. (See Figure 13.15)

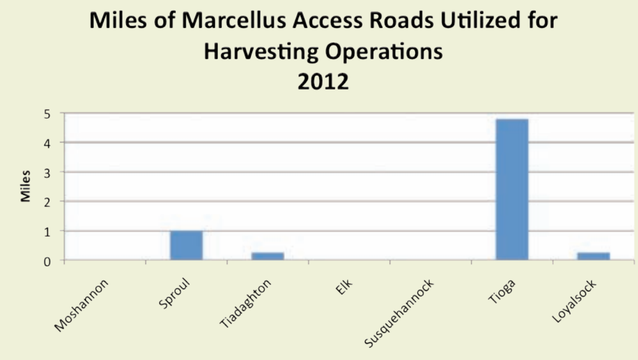

Figure 13.13

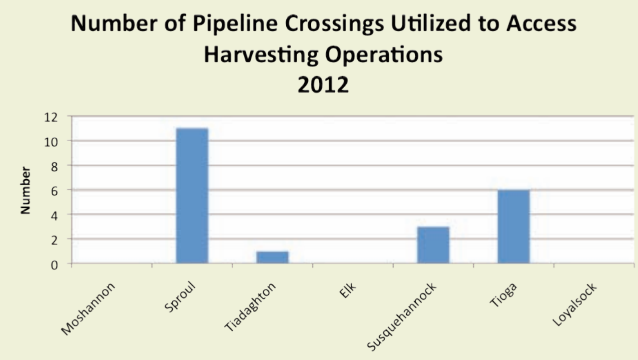

Figure 13.14

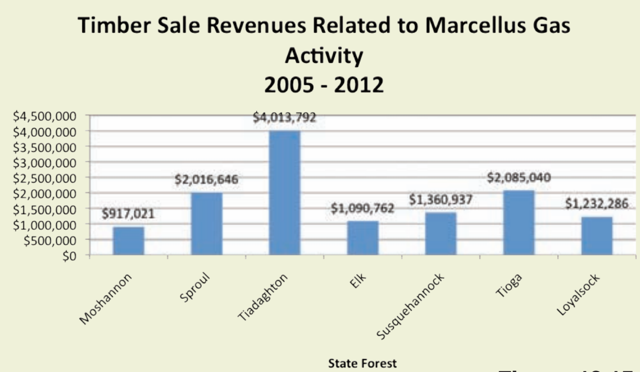

Figure 13.15

IV. Conclusion/Discussion

The bureau will continue to monitor the impact of shale gas activity on its silvicultural practices, timber sale distribution and placement, logging access, and revenues. Additional considerations for future reports may include: bonding of local municipal roads, state forest commercial landbase available for timber harvesting, and invasive species impacts on forest regeneration.

Part 2: Monitoring Values

»Energy

I. Key Points:

- Approximately 15 percent of all shale gas produced in Pennsylvania comes from state forest lands. This gas is sold and distributed across the eastern and midwestern United States to service energy markets on a daily basis.
- Natural gas in the United States is an open-market traded commodity that has seen the price per product unit fall from a high of approximately $10 per Mcf (1,000 cubic feet) in 2010 to the current (end of 2013) $4.75 per Mcf as a direct result of Pennsylvania shale gas coming onto the market grid and forcing gas prices to moderate with respect to the gas supply.
- On state forest land, the number of wells per pad ranges from one to 10, with approximately four to eight wells being the average. A typical well drains approximately 100 acres, but that figure can be more or less depending on a number of factors (i.e., lateral length and spacing, well stimulation operations, rock properties). In addition, multiple shale formations – such as the Marcellus and Geneseo/Burket – can be targeted from the same well pad.
- The bureau anticipates that approximately 3,000 gas wells may be drilled on state forest lands to fully develop the current leased acreage on commonwealth gas leases, on which approximately 568 had been drilled by the end of 2013.
- State forest lease tracts targeting shale gas are estimated to be approximately one-fifth developed. This, however, is only a projection, as future energy development patterns are difficult to accurately predict and depend on market conditions and the performance of individual tracts.

II. Introduction

Throughout human history, various forms of energy have been extracted and utilized to meet the needs of society. This long history has at its core the use of chemical energy, such as wood and physical energy in the form of human labor and draft animals. The use of chemical energy for most of history was from wood and wood byproducts, which over time transitioned into water power where available, then coal upon its discovery, and then into oil and natural gas, wind, nuclear, and solar as technology progressed. Figure 14.1 is

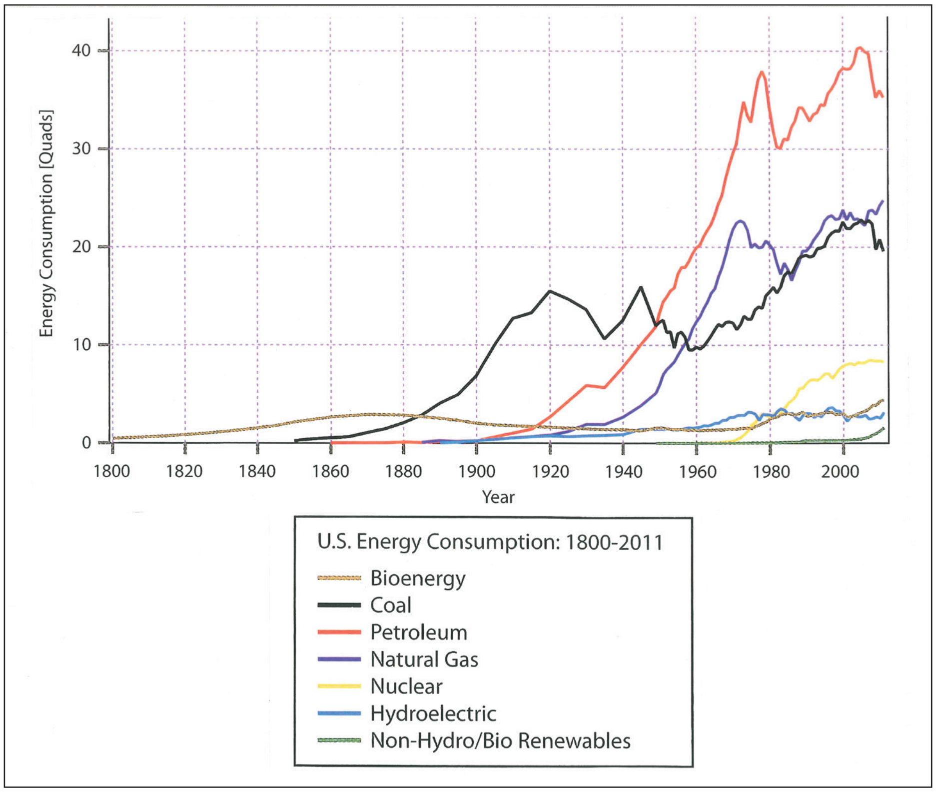

Figure 14.1 U. S. historical energy consumption by source.

The modern energy mix within the United States today consists chiefly of five energy sources: oil or petroleum, natural gas, coal, various renewable energy sources, and nuclear energy. The largest portion of U.S. energy usage is derived from petroleum or oil (all liquid hydrocarbons) at 35.3 quads or approximately 36 percent of U.S. consumption. Oil has been a primary transportation fuel of choice for nearly a century in the United States because its form provides the greatest

an illustration of the estimate of energy usage within the United States from the 1700s to modern day, showing the progression from one form of energy to the next.

Consumption of energy in the United States in 2011 was 97.5 quadrillion Btu, with a Btu defined as a British Thermal Unit, which is the energy required to raise one pound of water by one degree Fahrenheit. See Figure 14.2 for a graph of total U.S. energy consumption in 2011 from the Energy Information Administration. Energy consumption also is defined in quads, with one quad equaling one quadrillion Btu. A Btu is a small amount of energy, but the measure value is convenient as it is small enough to be used as a universal measurement tool across all forms of energy and to be easily measured and converted between chemical, electrical, kinetic, and nuclear sources. Coincidently, since the total energy consumption in the United States in 2011 was approximately 100 quads, any energy source that is measured is close to its actual percentage of usage as well.

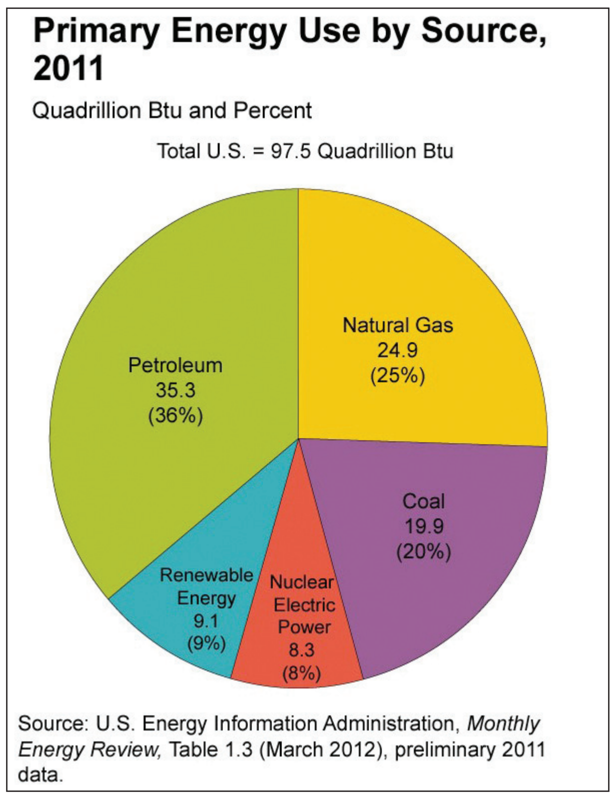

Figure 14.2

convenience as an easily handled, energy-dense liquid at room temperature. A single gallon of unleaded gasoline contains approximately 114,000 Btu per gallon, in a form that is stable and easily stored and used.

The second largest source is natural gas or methane at 24.9 quads or approximately 25 percent of all consumption. Note that there is no difference between methane produced from coal seams and that produced in conventional and unconventional sources. Natural gas is a fuel of choice for heating and industrial processes and electrical production where available in large quantities at a competitive price.

Third place is held by coal at 19.9 quads, or approximately 20 percent of all U.S. consumption. Coal is primarily used as a fuel for electrical energy production. Recently, coal exports from the United States have begun to climb in response to the switch from coal to gas in power generation here. Exports of coal are not counted as consumption in the numbers presented.

Fourth place is renewable energy sources, such as wind, hydro, solar, recycled hydrocarbons, and plant-derived energy at 9.1 quads, or approximately 9 percent of U.S. consumption.

Last is nuclear energy, also primarily used for electrical production, at 8.3 quads or approximately 8 percent of U.S. energy consumption.

The only energy source to gain market share in recent years is the renewable category, which has grown to a tenth of the U.S. energy market.

Natural gas can be expected to gain market share over time and may gain the majority of new national energy consumption that arises from normal annual energy need increases.

Figure 14.3 details the use of energy by sector and amount.

Figure 14.4 details the total energy consumed in the United States versus the total energy produced. Although net imports have fallen significantly since 2005, from 30 percent to 19 percent of total energy consumption, and indeed are projected by the Energy Information Administration to fall to less than 10 percent by 2035, new energy sources will be necessary to close the gap between production and consumption as projected.

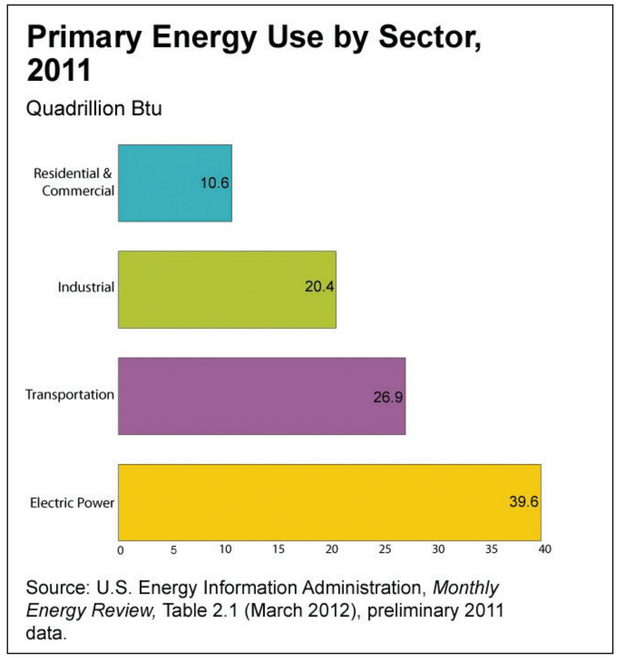

Figure 14.3

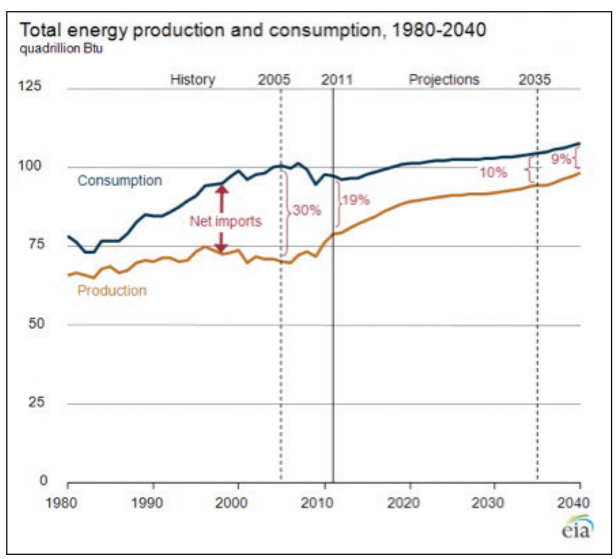

Figure 14.4

Gov. Corbett's State Energy Plan has additional information about energy statistics and trends in Pennsylvania. Visit governor.pa.gov/energy

III. Monitoring Efforts/Results

The oil and gas production data from state forest lands presented here has been tracked and tabulated since 1947. During this time, reporting was largely internal in nature, as little demand for production data existed prior to the Marcellus boom in 2007. As stated in the Revenue section of this report, the data have been used internally, primarily for planning purposes, which mainly revolved around royalty income. Consequently, this is the first public presentation of the production data for the historical portion of the program from 1947 to 2008 and then on into the shale-gas years from 2008 to the end of 2012. The projection of production data into the future is beyond the scope of this report. However, it can be assumed that production is likely to remain steady or increase as drilling activity adds new gas wells that will furnish royalty income to the commonwealth and add to gas production volumes from state forest lands in Pennsylvania.

IV. Discussion

Gas production from all oil and gas activity on state forest lands in Pennsylvania has been tracked historically and on into the Marcellus years as monthly production reports are received from the producers for each well. In general, a monthly statement is submitted to the commonwealth by each lessee operator, as required by the standard commonwealth lease agreement, wherein the amount of gas produced from a given gas well is reported along with the gas price and royalty value to the commonwealth's royalty share, which varies from lease to lease.

Gas Well Production Decline and Behavior

A brief discussion is necessary on gas well production theory and behavior so that a basic understanding may be gained as to the overall production profile of any given gas well and its contribution to the production numbers as a whole. Gas wells drilled into similar gas reservoirs usually follow a similar production curve behavior. For instance, conventional reservoirs such as sandstone reservoirs follow a predictable decline in volume as pressures decrease in the reservoir, which allows the petroleum reservoir engineer monitoring the well to provide a prediction of future production and income, as well as monitor for mechanical problems that crop up from time to time as production proceeds. As a gas well produces, gas pressures in the well bore and the reservoir decline, and the flow of gas to the surface decreases.

Unconventional reservoirs with low permeability and porosity produce on a strongly exponentially shaped curve, as the reservoir pressure decline near the well bore is usually greater than away from the well bore in the undrained rock volume. This causes the produced gas volume to decline rapidly in the first few years and then to stabilize at a low rate for long periods into the future. Figure 14.5 illustrates a typical decline production curve that might be used for a Marcellus shale well to track and predict the actual reservoir behavior on a per well basis.

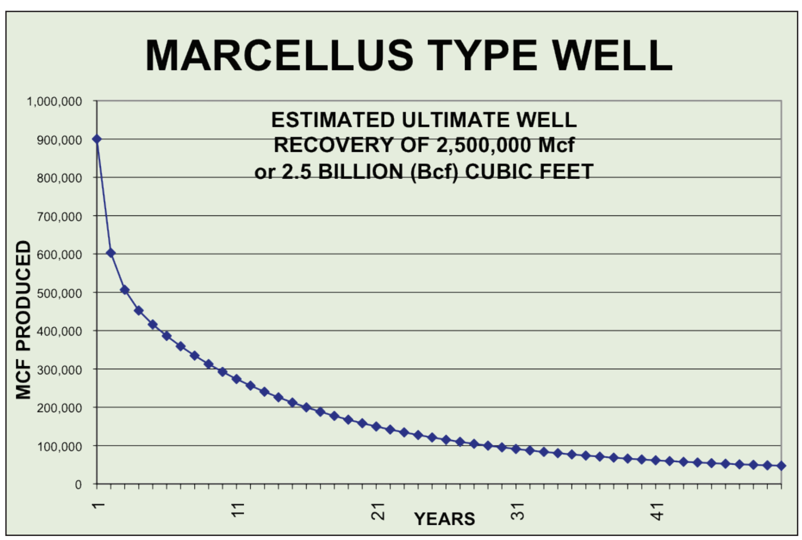

Figure 14.5 Theoretical Type Marcellus Well Gas Rate Decline Curve

This curve yields a well with an Estimated Ultimate Recovery (EUR) over its life of about 2.5 billion cubic feet of gas. Production analogs from other shale regions indicate the wells may have a total economic life of nearly 50 years or most certainly a life to be measured in decades. This is only an example of a theoretical exponential gas well decline curve. Shale-gas operators have reported EURs for gas wells ranging from 2.5 Bcf to up to 12 Bcf for economic wells. It is thought that at current gas prices, wells yielding less than an EUR of about 4 Bcf would be deferred until a later time for more favorable gas prices.

Referring to the curve in Figure 11.5, in this particular case as pressure and gas volume decline into the future, the rate at which gas may be produced from the well stabilizes and declines at a more gradual rate than in the first few years. This is very typical of an unconventional gas well developed in shale or other low permeability rock.

The act of recording and tracking volume data has been part of the bureau's responsibilities since the program's inception, and indeed the program has seen hundreds of wells come on production, decline to an uneconomic state, and subsequently be plugged and abandoned as the full cycle of exploration, production, and abandonment has proceeded over the decades on state forest lands.

The primary reason for tracking production volumes for the commonwealth is to predict near-term – four or five years out – well behavior in order to provide a reliable income picture for budgetary purposes. In the case where there are only a few years of data to analyze, the reliability of the prediction for future production is not as dependable as a more settled well decline curve many years into its life. There exist many possible reasons why a reliable curve may not be possible to plot for a given gas well, such as a constrained gas market limiting production, an inherent well mechanical problem, poor results from the completion technique, production constraints at a local compressor facility, or possibly some other issue that may be the result of poor placement of the well bore in the gas field related directly to the geology.

Pennsylvania Marcellus Gas Volume Estimates

Overall, the Marcellus shale has had a dramatic effect on the Pennsylvania state decline curve, which is the annual total reported production from all wells and reservoirs compiled into a master state curve to track performance. Any state with significant oil and gas production may be tracked as such, and increases or decreases in that state's decline curve may be analyzed.

In Figure 14.6, the Energy Information Administration (an agency of the U.S. Department of Energy) has plotted total reported gas production from all Pennsylvania gas

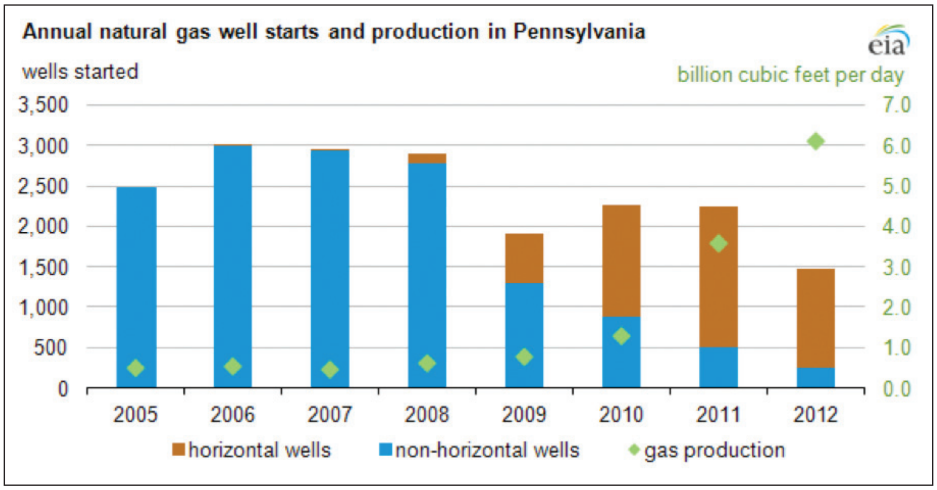

Figure 14.6

wells from 2005 to 2012 to see if a predictable pattern might emerge relating new gas wells to increased production rates overall. The overall assumption is that the vast majority of new gas wells were developed in the Marcellus shale formation as horizontal wells and that shallow wells, traditionally the mainstay of Pennsylvania drillers, were all vertical in configuration. Thus, a direct indicator of Marcellus activity is the plot of horizontal gas wells.

Indeed, it can be seen that gas production in Pennsylvania was less than a half billion cubic feet per day in 2005, 2006, and 2007, before drilling activity in the Marcellus began to result in significant well numbers and gas flow to market. The rise in overall production was dramatic and sustained from 2010 to 2013. It is possible at this point to say with a large degree of confidence that the Marcellus shale is capable of producing large amounts of gas from fewer wells, which is quite different from the traditional shallow Upper Devonian gas play in Pennsylvania that has many vertical wells on 40-acre or less spacing and low per well reserve recoveries. Shale-gas operators have the ability to drill numerous unconventional horizontal wells from a single well pad. On state forest land to date, the number of wells per pad ranges from one to 10 producing wells, with approximately four to eight wells being the average. A typical well drains approximately 100 acres, but can be less or greater depending on a number of factors (i.e., lateral length and spacing, well stimulation operations, rock properties). In addition, multiple shale formations – such as the Marcellus and Geneseo/Burket – can be targeted from the same well pad.

Prior to 2008, the United States, as a whole, produced about 68 billion cubic feet of gas per day from all domestic sources, but by 2013 the shale gas alone was producing almost 12 billion cubic feet per day of gas from about 4,900 new gas wells in Pennsylvania, which added more than 8 percent to the U.S. gas market in three years. The 68 billion cubic feet per day yields approximately 24.8 trillion cubic feet of gas per year into the U.S. gas markets (a trillion cubic feet is normally referred to as a Tcf).

Note that the reported 3,500 producing Marcellus wells to date represents approximately 3 percent of the total that some industry representatives predict eventually will be required for full development of the resource in Pennsylvania. If this assessment holds true, it will take several decades to achieve full development.

Pre-Marcellus Gas Production on State Forest Lands

As long as the bureau has managed oil and gas activity on state forest, since 1947, the primary phase of production has been natural gas. Table 14.1 is the total annual gas production reported to the bureau from 1947 to the close of 2007, along with U.S. and Pennsylvania annual gas production as tabulated by the Energy Information Administration.

Year	U.S. Total Tcf	PA Total Tcf	State Forest Gas Tcf	State Forest % PA Total
1947	6.7	NA	0	NA
1948	7.2	NA	0.0019	NA
1949	7.6	NA	0.0046	NA
1950	8.5	NA	0.0038	NA
1951	9.7	NA	0.0033	NA
1952	10.3	NA	0.0183	NA
1953	10.7	NA	0.0307	NA
1954	10.9	NA	0.0942	NA
1955	11.7	NA	0.0444	NA
1956	12.4	NA	0.0472	NA
1957	12.9	NA	0.0182	NA
1958	13.1	NA	0.0157	NA
1959	14.2	NA	0.0093	NA
1960	15.0	NA	0.0074	NA
1961	15.5	NA	0.0041	NA
1962	16.0	NA	0.0136	NA
1963	16.9	NA	0.0035	NA
1964	17.5	NA	0.0031	NA
1965	17.9	NA	0.0025	NA
1966	19.0	NA	0.0013	NA
1967	20.2	0.090	0.0011	1.2
1968	21.3	0.090	0.0011	1.2
1969	22.7	0.080	0.0009	1.1
1970	23.8	0.080	0.0009	1.1
1971	24.0	0.077	0.0007	1.1
1972	24.0	0.074	0.0006	1.1
1973	24.1	0.077	0.0006	1.0
1974	22.9	0.083	0.0023	2.7
1975	21.1	0.085	0.0007	1.0
1976	20.9	0.090	0.0011	1.2
1977	21.1	0.092	0.0005	<1.0
1978	21.3	0.098	0.0003	<1.0
1979	21.9	0.096	0.0003	<1.0
1980	21.9	0.098	0.0003	<1.0
1981	21.6	0.122	0.0002	<1.0
1982	20.3	0.121	0.0002	<1.0
1983	18.7	0.118	0.0002	<1.0
1984	20.3	0.166	0.0001	<1.0
1985	19.6	0.150	0.0002	<1.0
1986	19.1	0.160	0.0003	<1.0
1987	20.1	0.163	0.0002	<1.0
1988	21.0	0.167	0.0002	<1.0
1989	21.1	0.192	0.0002	<1.0
1990	21.5	0.178	0.0003	<1.0
1991	21.8	0.152	0.0015	1.0
1992	22.1	0.139	0.0015	1.0
1993	22.7	0.132	0.0055	4.2
1994	23.6	0.121	0.0046	3.8
1995	23.7	0.111	0.0039	3.5
1996	24.1	0.135	0.0031	2.3
1997	24.2	0.080	0.0031	3.8
1998	24.1	0.130	0.0031	2.4
1999	23.8	0.175	0.0030	1.7
2000	24.2	0.150	0.0028	1.9
2001	24.5	0.131	0.0024	1.8
2002	23.9	0.158	0.0023	1.5
2003	24.1	0.160	0.0021	1.3
2004	24.0	0.197	0.0020	1.0
2005	23.5	0.168	0.0020	1.2
2006	23.5	0.176	0.0021	1.2
2007	24.7	0.182	0.0024	1.3

Table 14.1 U. S. and Pennsylvania historic gas production comparison to gas prodution from PA state forest leases (pre-shale gas).

A critical look at Table 14.1 indicates the program's gas production peaked in 1954 and 1993 in total gas production and the overall trend has been cyclical in nature over the years as wells were drilled during favorable price environments and waned as gas prices declined. First, the total amount of gross gas produced from state forest and park lands over the program's lifetime, excluding Marcellus production, is approximately 387 Bcf (billion cubic feet). Although a large quantity, it does not really register on the national level with any significance. If the Marcellus is added in until the end of 2012, the total jumps to 684 Bcf. The Marcellus has contributed approximately 297 Bcf to the totals since 2008. In just four years, the Marcellus shale has produced almost 43 percent of all the gas produced from state forest lands since the program's inception and is 76 percent of the way to equaling the historic production, a milestone which may occur in the next year at the present rate of production.

Year	Tract	Lessee	Mcf	Wells
2008	324	Energy Corporation of America	3,262	2
	653	Anadarko E&P Company LP	3,432	1
Totals			**6,694**	**3**
2009	154	Pennsylvania General Energy/Exxon	31,494	1
	285	Anadarko E&P Company LP	385,840	2
	324	Energy Corporation of America	3,425	2
	653	Anadarko E&P Company LP	97,426	3
Totals			**518,185**	**8**
2010	100	Seneca Resources Corporation	77,650	1
	154	Pennsylvania General Energy/Exxon	460,087	2
	231	Anadarko E&P Company LP	848,134	4
	252	Anadarko E&P Company LP	41,329	1
	259	Anadarko E&P Company LP	13,758	2
	285	Anadarko E&P Company LP	849,285	5
	289	Anadarko E&P Company LP	1,284,565	3
	324	Energy Corporation of America	2,559	2
	343	Anadarko E&P Company LP	164,331	1
	587	Talisman Energy USA Inc.	12,927,732	25
	595	Seneca Resources Corporation	1,155,361	4
	653	Anadarko E&P Company LP	601,721	4
	678	Anadarko E&P Company LP	325,301	3
	839	Ultra Resources	1,687,711	12
Totals			**20,439,524**	**69**

Table 14.2 Shale gas production from state forest leases by year, lease tract, and operator (2008 through 2012).

Year	Tract	Lessee	Mcf	Wells
2011	001	Seneca Resources Corporation	92,816	2
	007	Seneca Resources Corporation	11,350	1
	154	Pennsylvania General Energy/Exxon	1,679,608	4
	231	Anadarko E&P Company LP	1,904,309	4
	285	Anadarko E&P Company LP	10,791,101	21
	289	Anadarko E&P Company LP	20,793,726	23
	290	Anadarko E&P Company LP	1,443,196	4
	324	Energy Corporation of America	402	2
	343	Anadarko E&P Company LP	232,093	2
	356	Anadarko E&P Company LP	853,300	6
	587	Talisman Energy USA Inc.	34,989,672	50
	595	Seneca Resources Corporation	3,487,141	4
	653	Anadarko E&P Company LP	991,868	4
	678	Anadarko E&P Company LP	1,583,863	3
	685	Anadarko E&P Company LP	6,159,299	10
	706	EXCO Resources (PA) Inc.	402,461	5
	729	Pennsylvania General Energy/Exxon	4,963,837	6
	746	XTO	47,148	1
	839	Ultra Resources	3,257,015	**15**
Totals			**93,684,205**	**167**

Table 14.2 ***Continued***

Marcellus Gas Production on State Forest Lands

Marcellus production history on state forest land is short, as the actual significant production did not begin until 2010. For completeness, the entire time frame from 2008 to the end of 2012 is presented. Table 14.2 is a compilation of data for the Marcellus production history organized by lease tract, which is the form in which the data is reported to the bureau by the various lessee operators.

The annual gross gas production is restated in Table 14.3 for clarity and to show the rapid upward progression the production numbers have exhibited in the past few years.

Year	Gross Mcf Gas Produced	Total Producing Wells
2008	6,694	3
2009	518,185	8
2010	20,439,524	69
2011	93,684,205	167
2012	181,817,133	283
Totals	**296,465,741**	

Table 14.3 DCNR annual lease gas production from 2008 through 2012 and number of producing wells.

Year	Tract	Lessee	Mcf	Wells
2012	001	Seneca Resources Corporation	672,737	2
	007	Seneca Resources Corporation	11,350	1
	100	Seneca Resources Corporation	8,630,338	7
	154	Pennsylvania General Energy/Exxon	953,358	4
	231	Anadarko E&P Company LP	1,447,925	4
	252	Anadarko E&P Company LP	42,943	1
	285	Anadarko E&P Company LP	26,409,866	33
	289	Anadarko E&P Company LP	18,249,052	23
	290	Anadarko E&P Company LP	4,595,273	4
	293	Pennsylvania General Energy/Exxon	5,638,449	9
	324	Energy Corporation of America	73,681	1
	343	Anadarko E&P Company LP	117,390	2
	344	Anadarko E&P Company LP	1,883,043	4
	356	Anadarko E&P Company LP	19,812,899	22
	587	Talisman Energy USA, Inc.	44,150,155	59
	595	Seneca Resources Corporation	16,761	19
	653	Anadarko E&P Company LP	1,281,561	6
	678	Anadarko E&P Company LP	933,847	3
	685	Anadarko E&P Company LP	13,039,965	15
	706	EXCO Resources (PA) Inc.	631,998	5
	728	Anadarko E&P Company LP	9,538,621	11
	729	Pennsylvania General Energy/Exxon	20,341,798	27
	745	XTO	141,513	2
	746	XTO	943,852	4
	839	Ultra Resources	2,258,758	15
Totals			**181,817,133**	**283**

Table 14.2 ***Continued***

The DEP website production number from the Marcellus for the entire state of Pennsylvania since the first Marcellus wells came on production in 2007 is approximately 2,000,000 Mcf or 2 Tcf gross production. The gross gas production from state forest lands is about 15 percent of all gas produced in Pennsylvania since 2007 from the Marcellus formation. By any measure, this is significant production for Pennsylvania. It is anticipated that just over 3,000 gas wells may be drilled on state forest lands to fully develop the current leased acreage on commonwealth gas leases, of which approximately 568 had been drilled by the end of 2013. State forest lease tracts targeting shale gas are estimated to be approximately one-fifth developed. This, however, is only a projection, as future energy development patterns are difficult to accurately predict and depend on market conditions and the performance of individual tracts.

Part 2: Monitoring Values

»Revenue

I. Key Points:

- The pre-shale-gas period of oil and gas activity provided a total income to the commonwealth of approximately $153,659,522. The shale-gas period (through 2012, for the purposes of this report) has provided $582,250,644 in revenue. The combined total of all revenue from the oil and gas lease program from 1947 to the end of 2012 has been approximately $735,910,166.
- The influx of shale-gas production revenue began in 2009 when most of the wells that had been first proposed in 2007, 2008, and early 2009 were drilled and connected to the pipeline system and gas was delivered to the market.
- Royalty income is just beginning to come to DCNR from the hundreds of new shale-gas wells on state forest land.
- Steady revenue growth from gas extraction is expected to continue for the next decade as the full development of the leases comes to a conclusion.

II. Introduction

Since the first leases in 1947, the development of natural gas resources on state forest land has generated a steady and increasing revenue source for the commonwealth in the form of rents and royalties. This revenue can be examined by the pre-Marcellus period from 1947 to 2007 and the Marcellus period beginning in 2008. The pre-Marcellus period of oil and gas activity – during which the geologic targets were deep Oriskany sandstones and the shallow Upper Devonian low permeability gas sandstones – provided a total income to the commonwealth of approximately $153,659,522. The Marcellus period (ending in 2012, for the purposes of this report) has provided $582,250,644 in revenue, almost exclusively from the production of shale gas. The combined total of all revenue from the oil and gas lease program from 1947 to the end of 2012 has been approximately $735,910,166.

III. Monitoring Efforts/Results

The data presented in this chapter have been tracked and tabulated by the bureau since 1947. This is the first report of its kind of oil and gas revenue. Prior to the shale-gas boom, there was little interest in this information by the public and stakeholders. Reports of oil and gas income were largely for internal planning purposes.

The bureau maintains a database on all oil and gas revenue generated on state forest lands, which will be reported in this section. The purpose of this chapter is to report on current revenue resulting from shale-gas activity. It is beyond this report's scope to speculate what income future Marcellus activity may generate.

IV. Discussion

Revenues generated from a lease sale on state forest lands, rents, and royalties generated from production are deposited into the Oil and Gas Lease Fund. The fund was created in 1955 to be used for conservation, recreation, and flood control programs at the direction of the secretary of what is now DCNR. Lease sale funds have been used to purchase state park lands; to acquire the mineral rights for state parks and forests; to make infrastructure and trail improvements; to conduct habitat protection and restoration; to provide for recreation and purchase other equipment; and to support the operations of the DCNR. The types of income that are deposited into the fund include all rentals, bonus payments (which are classed as rentals), royalties, and gas storage rental payments. Table 15.1 represents a compilation of all income from state forest gas development from 1947 to 2012. Note that after 1955 funds were placed in the Oil and Gas Lease Fund.

Year	Gas Storage Rentals	O&G Lease Rentals	O&G Lease Royalties	O&G Lease Total	Total Income	Cumulative Income
1947	$0	$1,022	$0	$1,022	$1,022	$1,022
1948	$0	$2,016	$119,328	$121,344	$121,344	$122,366
1949	$0	$1,633	$288,105	$289,738	$289,738	$412,104
1950	$0	$143,561	$237,969	$381,530	$381,530	$793,634
1951	$0	$189,473	$204,660	$394,133	$394,133	$1,187,767
1952	$0	$723,225	$1,143,385	$1,866,610	$1,866,610	$3,054,377
1953	$0	$817,535	$1,879,386	$2,696,921	$2,696,921	$5,751,298
1954	$0	$469,023	$5,887,370	$6,356,393	$6,356,393	$12,107,691
1955	$0	$228,275	$4,158,730	$4,387,005	$4,387,005	$16,494,696
1956	$39,700	$208,928	$4,427,055	$4,635,983	$4,675,683	$21,170,379
1957	$83,113	$279,963	$1,685,703	$1,965,666	$2,048,779	$23,219,158
1958	$84,966	$360,604	$1,356,979	$1,717,583	$1,802,549	$25,021,707
1959	$84,172	$333,377	$793,399	$1,126,776	$1,210,948	$26,232,655
1960	$100,202	$219,191	$651,082	$870,273	$970,475	$27,203,130
1961	$113,853	$189,360	$476,858	$666,218	$780,071	$27,983,201
1962	$114,861	$230,360	$1,672,554	$1,902,914	$2,017,775	$30,000,976
1963	$114,861	$277,046	$429,122	$706,168	$821,029	$30,822,005
1964	$114,861	$230,546	$377,151	$607,697	$722,558	$31,544,563
1965	$114,861	$198,845	$294,604	$493,449	$608,310	$32,152,873
1966	$114,861	$25,035	$224,740	$249,775	$364,636	$32,517,509
1967	$114,861	$56,719	$202,923	$259,642	$374,503	$32,892,012
1968	$115,192	$213,121	$195,644	$408,765	$523,957	$33,415,969
1969	$116,399	$59,946	$165,071	$225,017	$341,416	$33,757,385
1970	$116,383	$65,108	$155,570	$220,678	$337,061	$34,094,446
1971	$118,525	$267,188	$139,658	$406,846	$525,371	$34,619,817
1972	$118,646	$751,659	$129,224	$880,883	$999,529	$35,619,346
1973	$121,846	$358,802	$120,378	$479,180	$601,026	$36,220,372
1974	$230,293	$355,160	$357,150	$712,310	$942,603	$37,162,975
1975	$275,772	$150,160	$75,247	$225,407	$501,179	$37,664,154
1976	$360,763	$96,783	$246,426	$343,209	$703,972	$38,368,126
1977	$417,492	$166,600	$88,688	$255,288	$672,780	$39,040,906
1978	$489,157	$2,912,824	$37,628	$2,950,452	$3,439,609	$42,480,515
1979	$607,064	$670,732	$41,099	$711,831	$1,318,895	$43,799,410
1980	$668,212	$3,259,679	$53,596	$3,313,275	$3,981,487	$47,780,897

Table 15.1 State forest land oil and gas income by year.

Year	Gas Storage Rentals	O&G Lease Rentals	O&G Lease Royalties	O&G Lease Total	Total Income	Cumulative Income
1981	$720,040	$5,782,264	$55,207	$5,837,471	$6,557,511	$54,338,408
1982	$740,970	$4,096,289	$63,401	$4,159,690	$4,900,660	$59,239,068
1983	$733,494	$1,770,915	$409,421	$2,180,336	$2,913,830	$62,152,898
1984	$927,993	$2,596,954	$1,051,065	$3,648,019	$4,576,012	$66,728,910
1985	$935,426	$2,780,875	$1,282,461	$4,063,336	$4,998,762	$71,727,672
1986	$966,932	$1,661,590	$1,442,148	$3,103,738	$4,070,670	$75,798,342
1987	$970,508	$1,733,042	$1,360,171	$3,093,213	$4,063,721	$79,862,063
1988	$988,362	$1,231,895	$1,800,408	$3,032,303	$4,020,665	$83,882,728
1989	$1,041,656	$1,005,234	$2,707,610	$3,712,844	$4,754,500	$88,637,228
1990	$1,048,531	$1,588,668	$2,513,166	$4,101,834	$5,150,365	$93,787,593
1991	$1,100,705	$1,325,086	$2,187,643	$3,512,729	$4,613,434	$98,401,027
1992	$1,103,538	$744,043	$2,108,048	$2,852,091	$3,955,629	$102,356,656
1993	$1,124,917	$481,886	$1,619,350	$2,101,236	$3,226,153	$105,582,809
1994	$1,185,549	$321,717	$1,327,362	$1,649,079	$2,834,628	$108,417,437
1995	$1,197,003	$295,306	$976,654	$1,271,960	$2,468,963	$110,886,400
1996	$1,625,090	$721,927	$1,010,017	$1,731,944	$3,357,034	$114,243,434
1997	$1,628,117	$189,629	$1,003,610	$1,193,239	$2,821,356	$117,064,790
1998	$1,628,278	$131,879	$1,104,162	$1,236,041	$2,864,319	$119,929,109
1999	$1,557,019	$170,891	$975,496	$1,146,387	$2,703,406	$122,632,515
2000	$1,493,019	$44,381	$1,528,179	$1,572,560	$3,065,579	$125,698,094
2001	$1,910,493	$183,905	$1,540,417	$1,724,322	$3,634,815	$129,332,909
2002	$1,794,620	$1,653,644	$1,048,710	$2,702,354	$4,496,974	$133,829,883
2003	$1,838,959	$112,409	$1,519,285	$1,631,694	$3,470,653	$137,300,536
2004	$1,785,640	$141,247	$1,545,974	$1,687,221	$3,472,861	$140,773,397
2005	$1,828,472	$90,494	$1,783,592	$1,874,086	$3,702,558	$144,475,955
2006	$2,238,026	$173,434	$2,402,583	$2,576,017	$4,814,043	$149,289,998
2007	$2,224,935	$75,426	$2,069,163	$2,144,589	$4,369,524	$153,659,522
2008	$2,245,823	$6,064,636	$3,128,586	$9,193,222	$11,439,045	$165,098,567
2009	$2,331,670	$163,303,356	$1,596,962	$164,900,318	$167,231,988	$332,330,555
2010	$2,288,064	$262,796,706	$11,821,463	$274,618,169	$276,906,233	$609,236,788
2011	$2,749,056	$3,703,849	$42,786,628	$46,490,477	$49,239,533	$658,476,321
2012	$2,731,718	$2,967,309	$71,734,818	$74,702,127	$77,433,845	$735,910,166
TOTALS	**$53,635,539**	**$484,454,385**	**$197,820,242**	**$682,274,627**	**--------**	**$735,910,166**

Table 15.1 ***Continued*** State forest land oil and gas income by year.

Pre-Shale Gas Revenue

Figure 15.1 is a graphical representation of the numerical tabulation in Table 15.1, color coded for ease of viewing, from 1947 to 2007, which represents the annual income up to the first shale-gas lease sale in 2008. Different classes of income ebb and flow through the charted years. The initial income increase in each income boom cycle is caused by large bonus payments and rentals for new acreage under lease. Over time, as the acreage is developed, rentals decrease and royalties increase.

The first income boom cycle occurred in 1952, with several lease sales. As the acreage was tested, gas production was established in the Oriskany sandstone. This led to the large royalty income from 1952 to 1958. Also, in 1957 some small gas storage income began to show as the first large Oriskany sandstone gas fields were converted to gas storage and primary production ceased. The characteristics of the Oriskany sandstone are such that it has very favorable reservoir properties for gas storage.

The second prominent cycle began around 1978 with industry interest in the shallow Upper Devonian gas play in Centre and Clinton counties, now known as the Council Run Gas Field. The large rental numbers from 1978 to 1985 represent the large bonus paid for the lease sales. Beginning in 1981, the amount of royalty increased and then peaked in 1990 and flattened until 2007. This is a reflection of changing gas prices and markets. Gas prices generally increased during this period and peaked in 2007. So even though well production declined, the higher gas prices maintained a steady income stream.

The price of natural gas has a large effect on the income stream from gas sales and royalty to the commonwealth, but the number of wells drilled and placed in production also has a large effect. This can be seen in the early days of a development boom in Figure 15.1. Figure 15.2 is a graph of crude oil and natural gas prices from 1988 to 2012. There is a gradual increase in gas prices to the spikes in 2006 and 2008. These price spikes, along with arrival of the hydraulic fracturing and horizontal

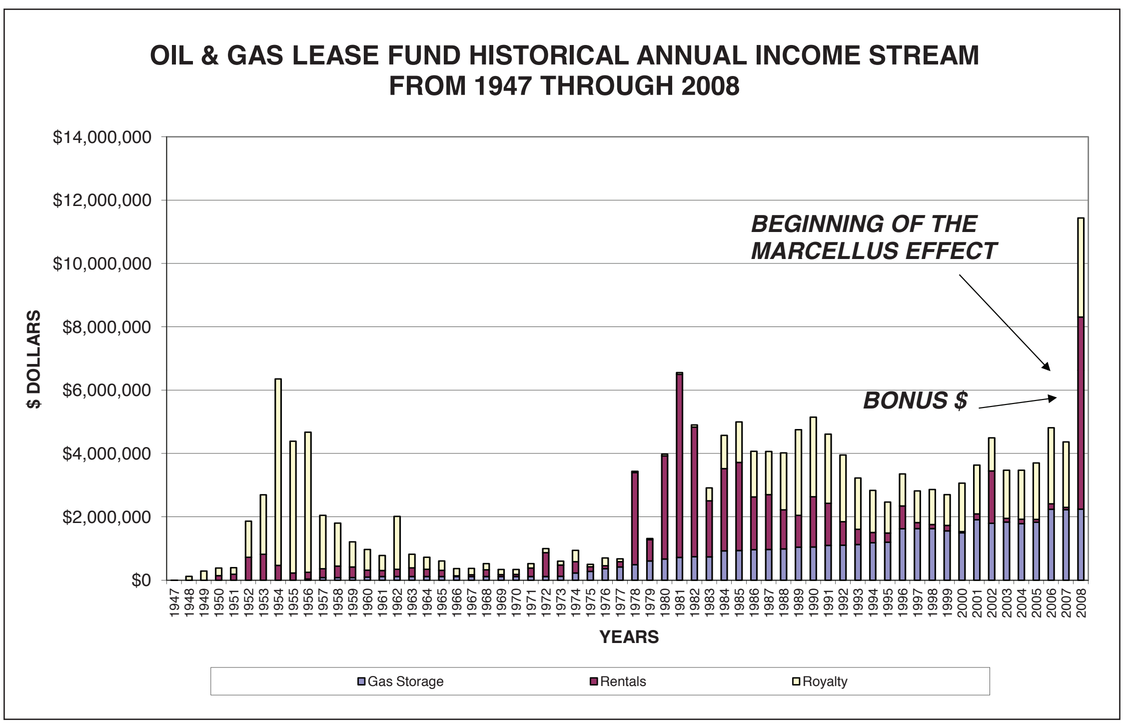

Figure 15.1

drilling technology, are three of the main drivers of the Marcellus boom in Pennsylvania from 2007.

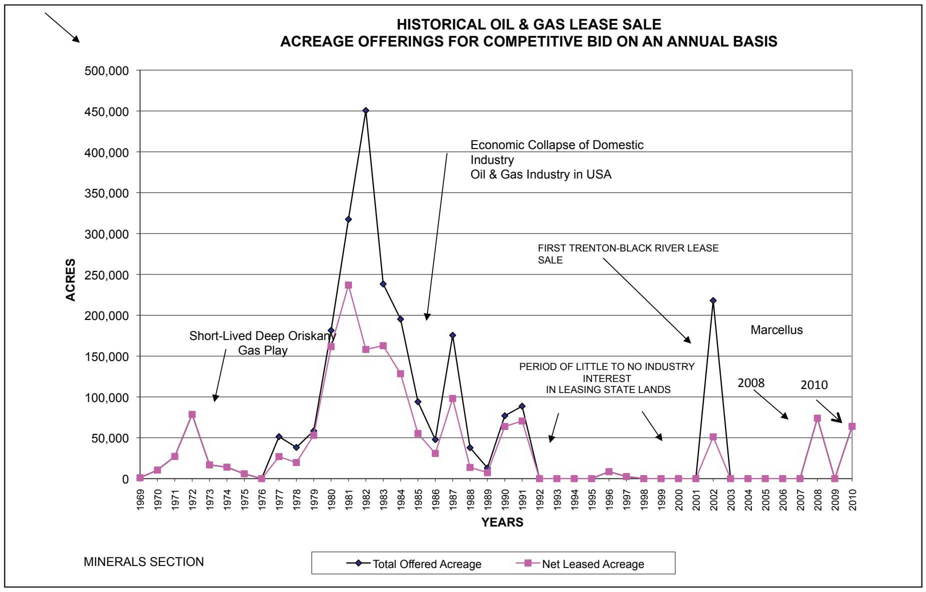

Figure 15.2 *From EIA 2012 Energy Report.*

Shale-Gas Revenue

The influx of shale-gas production revenue began in 2009, when most of the wells that had been first proposed in 2007, 2008, and early 2009 were drilled and connected to the pipeline system and gas delivered to the market. Figure 15.3 is a graphical representation of the numerical tabulation above from 1947 to 2012, which represents the annual income up to the end of 2012. This graph shows how the historic oil and gas income is dwarfed by the shale-gas income stream, largely due to bonus payments from the 2008 and 2010 lease sales. In addition, royalty income is just beginning to come to DCNR from the hundreds of new shale-gas wells on state forest land.

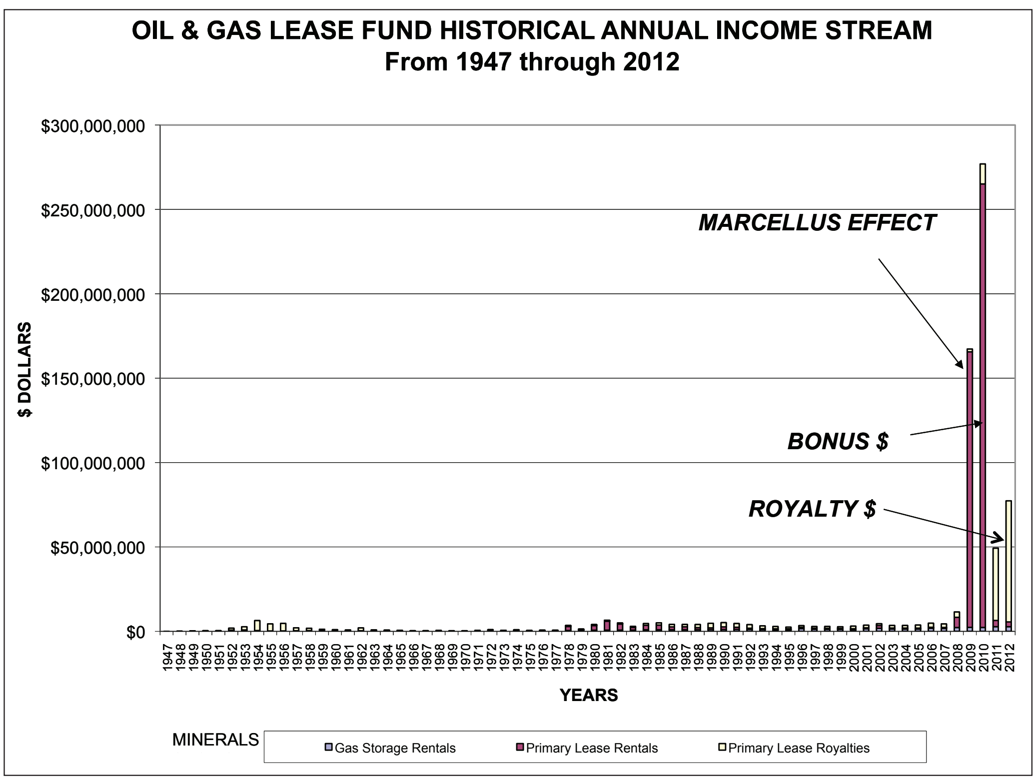

Figure 15.3

Part 2: Monitoring Values

»The Forest Landscape

Conversion, wild character, fragmentation, and restoration

I. Key Points:

- This chapter addresses forest values and impacts of shale-gas activities across the greater forested landbase. This initial report focuses on forest conversion, the value of "wild character," forest fragmentation, and restoration.
- Approximately 1,486 acres of the 2.2-million-acre state forest system have been converted to facilitate shale-gas development. During the same time period (2008 to 2012), the bureau acquired 33,500 acres to add to state forest system, including 8,900 acres in the core shale gas districts.
- One assessment of the current impact of gas infrastructure on wild character, using the Recreation Opportunity Spectrum (ROS) as a measurement tool, is a 9,340-acre increase in semi-developed and developed acreage. Correspondingly, there was a 912-acre decrease in semi-primitive area, an 8,409-acre decrease in semi-primitive non-motorized area, and a 19-acre decrease in primitive area.
- Before shale-gas activity, 19.5 percent of the state forest in core gas districts was in the semi-primitive non-motorized class. The effects of shale-gas development as of 2012 resulted in a decrease to 18.9 percent. The semi-developed and developed acreage total increased from 50.9 percent to 51.6 percent. Semi-primitive and primitive acreages each changed by less than one tenth of one percent.
- In core gas forest districts, the Bureau of Forestry's forest fragmentation analysis showed the largest increases in edge forest in Tiadaghton State Forest (1,813 acres) and Tioga State Forest (1,257 acres). Overall, core gas forest districts added 4,355 acres of edge forest.
- In the core gas forest districts, there was a loss of 9,242 acres of core forest greater than 200 hectares (495 acres). However, some of this loss was converted to a gain in smaller core forest blocks, as an overall gain of 1,247 acres was observed in core forest blocks between 100 and 200 hectares (247 and 495 acres) and a gain of 1,152 acres was seen in core forest blocks less than 100 hectares (247 acres).
- Elk, Moshannon, and Tiadaghton state forests have had a combined total of 10 well pads that have been partially reclaimed by reducing the pad size and replanting the adjacent areas with vegetation. No gas infrastructure sites have received full ecological restoration.

II. Introduction

Approaches to forest management must take into account not only the direct impacts of various activities, but also the cumulative, landscape-level impacts of these activities over time. Landscapes are contextual in nature, and thus there is no firm definition of what constitutes a "landscape" in a forested setting. This chapter, however, attempts to address certain forest values and impacts of shale-gas activities across the greater forested landbase. This initial report focuses on the landscape-level impacts of shale-gas development to forest conversion, the value of "wild character," forest fragmentation, and restoration.

Forest Conversion

Natural gas exploration and development can temporarily or permanently convert existing forestland to non-forestland to accommodate gas infrastructure. Some conversion may be temporary in nature. For example, a five-acre tract of forest cleared for a water impoundment is considered a conversion to non-forest. However, if after a period of time that impoundment is no longer needed and the five acres is restored and replanted, it can again become part of the forest system. Other conversions, such as pipelines and roads, may be more permanent in nature. Regardless of the type, forest conversion has both direct and cumulative, landscape-level impacts that are important to monitor across the state forest system.

Wild Character

Because of the size of the landbase, state forests provide a unique opportunity for dispersed, low-density outdoor recreation that cannot be obtained from smaller forest areas.

Part of the bureau's mission with regard to the state forest system is to retain its "wild character." While the value of "wild character" can be subjective in nature, it commonly relates to the quality of experience for state forest visitors with regard to scenic beauty, feeling of solitude, sense of remoteness, and the undeveloped and aesthetic nature of the state forest system.

The state forests in the north-central region, because of their size, location, and rugged terrain, offer some of the best opportunities for remote, back-country experiences in Pennsylvania. This same region is also the location of the most extensive shale-gas development activity. Accommodating gas development while maintaining the "wild character" of the forest is a significant challenge for forest managers. As a result, monitoring "wild character" and associated values is an important part of the overall monitoring program.

Fragmentation

The size and location of the commonwealth's state forests in north-central Pennsylvania contribute to the formation of core forest habitat and play an important role in maintaining the connectivity of this habitat across much of the state. In addition, these state forests help comprise the largest continuous block of forest in the northeastern United States.

One important consideration when overseeing such a landbase is managing the potential effects due to forest loss and forest fragmentation. Forest fragmentation can be described as a process by which a continuous forest habitat is converted to non-forest or becomes separated into smaller or more isolated forest patches (Halia, 1999). The isolation of these patches from one another often can be attributed to disturbances that significantly alter the impacted forest areas. These disturbances can be natural (e.g., forest fire, windfall, or flooding) or manmade (e.g., timber harvesting, road construction, or residential development) in origin. Disturbances, whether natural or manmade, can vary in scale and intensity. These disturbances could merely separate mature forest blocks with younger, disturbed forest, or could result in blocks of non-forest habitat.

The consequences of a fragmented forest vary by species and forest community type but generally are due to one or more of the following: the reduction or change in forest area, the increased vulnerability of patches to further disturbance and degradation, or the increasing separation between patches.

Forest loss due to disturbance (natural or manmade) can result in less available forest habitat or a decreased forest carrying capacity. As core forests are further fragmented by non-forest, remaining patches become more susceptible to invasion by exotic species and pathogens due to increased forest edge. The loss of connectivity between patches of forest habitat can result in a loss of biodiversity and genetic variation across a landscape as plants or animals of the same species become increasingly isolated from one another. While forest loss in itself may more directly result in a reduction in resources available for forest species, fragmentation due to forest loss can further degrade remaining forests and have far-reaching effects beyond the actual acreage of forest habitat that was lost.

In addition to creating smaller forest patches out of continuous forest, fragmentation also leads to an increase in forest edge habitat. While not removed or converted directly by a disturbance, the portions of remaining forest that form the edges of the patch are invariably changed and typically vary from the interior portions of the forest. Although the proportion of the remaining patch that can be characterized as edge varies significantly, an area from the edge of disturbance up to 100 meters into the forest patch is the zone which is often accepted as edge forest.

Many factors influence how the edge forest varies from the interior of the patch itself. First and foremost is the type of disturbance that created the edge. For instance, a human-created edge, such as a timber sale boundary or the limit of clearing for a right of way, often is more abrupt, forming straight lines that can cut across landscape features. Natural disturbances, however, often cause ragged, feathered, and non-symmetrical boundaries that follow landscape features like ridge tops or creeks. At the forest edge, microclimate changes in air temperature, wind speed, light availability, and relative humidity often contribute to edge forests that can be hotter and drier than the interior forest (Gelhausen et al., 2000).

Edge effects due to fragmentation often create conditions that can become unsuitable for species that once utilized the interior forest habitat. At times, these edge effects have been shown to increase plant species richness at the forest edge; however, often associated with this gain in early-successional, disturbance-tolerant plants are non-native, invasive plant species such as garlic mustard (*Alliaria petiolata*), honeysuckle (*Lonicera spp.*), or privet (*Ligustrum spp.*) (Haila, 1999).

The effects of fragmentation and an increase in forest edge on wildlife vary, depending on the species and its relative location in the food chain. Game species, such as ruffed grouse and white-tailed deer, often utilize edge habitats. Some species of songbirds prefer the thick shrub vegetation that often forms along forest edges. Patton et al. (2010) encourage the use of forest edge when managing for golden-winged warblers. However, prey may be easier for some predators to hunt along a forest edge than in interior forest. For instance, Soule et al. (1988) found that increased forest fragmentation in California caused a decline in large predators, but benefited mesopredators such as possums, raccoons, and cats. As a result of the increase in mesopredators, a noticeable decrease occurred in some vulnerable prey species found at the forest edge. With marked variations in the types of species and the extent of edge forest or connectivity loss in these studies, more work is needed at a species-specific level to more carefully predict which wildlife species may benefit and which species could be negatively impacted by these landscape changes.

The bureau recognizes the implications of an increase in forest fragmentation and forest edge to biodiversity and ecosystem health across the state forest system. Regarding fragmentation, the bureau's *State Forest Resource Management Plan* states that "forest fragmentation, connectivity, and patch distribution will be considered in management decisions affecting state forest resources." The goal of the bureau is to limit forest fragmentation and promote connectivity of forest habitat. This philosophy extends not only to forest management activities, such as timber harvesting and habitat improvement projects, but also to recreation planning, road and infrastructure improvements, and energy development. Timber harvesting is a manmade disturbance that can impact interior forest habitat; however, managers ensure that harvesting will result in early successional habitat adjacent to interior forest, providing for a mosaic of habitats across the landscape. Other types of human disturbance, such as road construction and energy development, can result in a conversion of forest habitat into non-forest, potentially causing forest fragmentation.

New pipeline rights of way, in particular, can create edge forest and have the potential to fragment more contiguous blocks of forest. The bureau's *Guidelines for Administering Oil and Gas Activity on State Forest Lands* also address the potential impacts due to energy development on state forest land, suggesting that "operators should use existing disturbances when possible to limit forest fragmentation." This management practice extends across all types of gas infrastructure, including roads, pipelines, and well pads. The bureau works with gas operators early in the approval process to design these features to fit within the landscape when practical and reduce construction disturbance to the greatest extent possible.

Reclamation and Restoration

The bureau's goal is to reduce the impact of shale-gas development by restoring areas converted for gas infrastructure to their original habitat or creating habitat for plants and wildlife. With proper planning and effective, thoughtful implementation, suitable habitat can be created for many species of plants and wildlife during partial and complete restoration of gas-related sites.

Restoration may be in many forms, including re-vegetation for erosion and sedimentation control, reforestation, reclamation, habitat enhancement, and invasive plant removal. The objective is to restore the site to a self-sustaining natural community that provides ecological benefits.

In many state forest areas, gas activities are in the development phase. Complete and full restoration of sites converted for gas use is a long-term prospect. Overall, restoration of gas sites, and the monitoring of them, is still in the early stages. Forest managers are only beginning to understand the challenges and opportunities associated with successful restoration. As part of its monitoring program, the bureau will track the success of individual restoration projects as well as landscape-level ecological impacts.

III. Monitoring Efforts/ Results

Forest Conversion

DCNR estimates that approximately 1,486 acres of forest have been converted to non-forest to facilitate shale-gas development activities (Table 16.1 and Figure 16.1). These numbers will change over time, depending on the scale of additional development as well as the pace of restoration efforts. A well pad that is cleared for development is considered conversion. However, once the site is fully restored and replanted, it can again be considered part of the forest landbase. Also, with some activities, such as right of way construction, a significant portion of the corridor is cleared for the movement of machinery. Once construction is complete, these areas can be restored and once again become part of the forest landbase.

State Forest District	Pad Acreage	Road Acreage	Pipeline Acreage	Total Acreage
Moshannon	63.3	31.7	39.2	**134.2**
Sproul	156.5	20.8	78.2	**255.5**
Tiadaghton	318.3	68.1	144.2	**530.6**
Elk	6.5	1.2	9.1	**16.8**
Susquehannock	32.2	4.1	29.4	**65.7**
Tioga	135.7	47.5	94.4	**277.6**
Loyalsock	73.1	68.2	64.3	**205.6**
Total Acreage	**785.6**	**241.6**	**458.8**	**1,486**

Table 16.1 Total acreage converted to non-forest by infrastructure type.

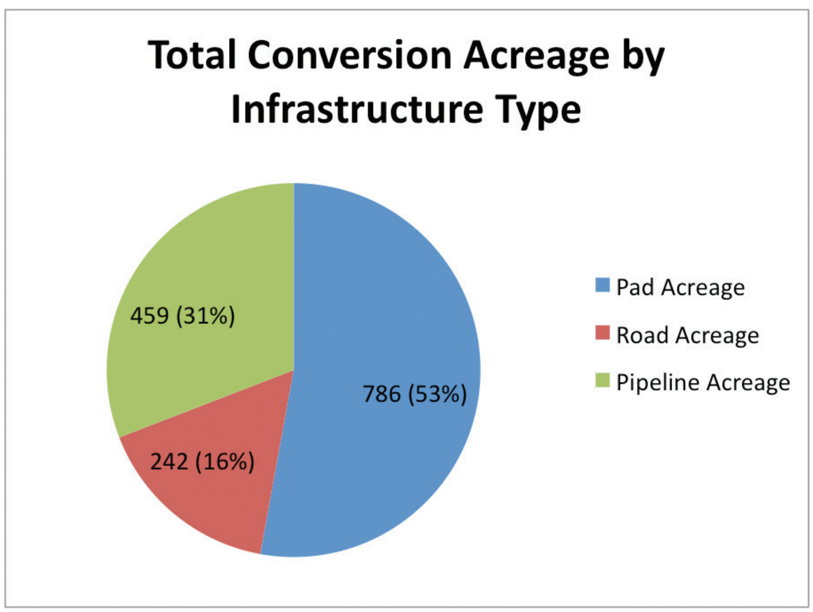

Figure 16.1 Total acreage converted to non-forest by infrastructure type.

During the same time period that this forest conversion took place for shale gas development (2008 to 2012), the bureau acquired 33,500 acres to add to state forest system, including 8,900 acres in the core shale gas districts.

Wild Character

The U.S. Forest Service developed a recreational planning tool called the Recreation Opportunity Spectrum (ROS) system. The bureau has adapted this tool for application in Pennsylvania. ROS is an inventory system built on the premise that people expect certain types of recreational experiences on public land and that land managers should be able to direct people to appropriate places for those experiences. ROS allows the land manager to provide recreational opportunities across a spectrum, or continuum, of five land-use classes so that the user may find satisfying recreational experiences in a variety of recreational activities. The ROS land-use classes follow a continuum from "primitive" to "developed." See the Recreation section for more information about ROS designations.

While ROS is geared toward recreational management and experience, it is one helpful tool in assessing the "wild character" of the state forest system. Areas with a "primitive" classification have values that many visitors consider consistent with "wild character," while areas classified as "developed" may not.

The measure of the current impact of gas infrastructure on wild character – using ROS as an indicator – is a 9,340-acre increase in semi-developed and developed areas, a 912-acre decrease in semi-primitive areas, an 8,409-acre decrease in semi-primitive non-motorized areas, and a 19-acre decrease in primitive areas.

Before shale-gas activity, 19.5 percent of the state forest in core gas districts was in the semi-primitive non-motorized class. As of 2012, there was a decrease to 18.9 percent. In that same period, the semi-developed and developed acreage increased from 50.9 percent to 51.6 percent. Semi-primitive and primitive areas each changed by less than one-tenth of one percent.

District	Primitive	Semi-Primitive Non-Motorized	Semi-Primitive	Semi-Developed & Developed
Moshannon	0	-1,164	356	808
Sproul	0	-770	51	719
Tiadaghton	0	-3,259	-72	3,332
Elk	0	0	0	0
Susquehannock	-19	-9	-18	46
Tioga	0	-3,207	-391	3,597
Loyalsock	0	0	-838	838
Total	**-19**	**-8,409**	**-912**	**9,340**

Table 16.2 Net ROS acreage change (pre-Marcellus vs. Dec. 31, 2012).

Since 2008, the bureau's gas leases have included "Areas of Special Consideration" for high-value timber, recreational sites, and viewsheds. Whenever possible, the bureau coordinates with gas operators to prevent the disruption of scenic viewsheds due to gas development. State forest trails, rivers, and major roads were identified as scenic viewsheds. Incidents of gas development occurring in these scenic viewshed "Areas of Special Consideration" have been identified and evaluated.

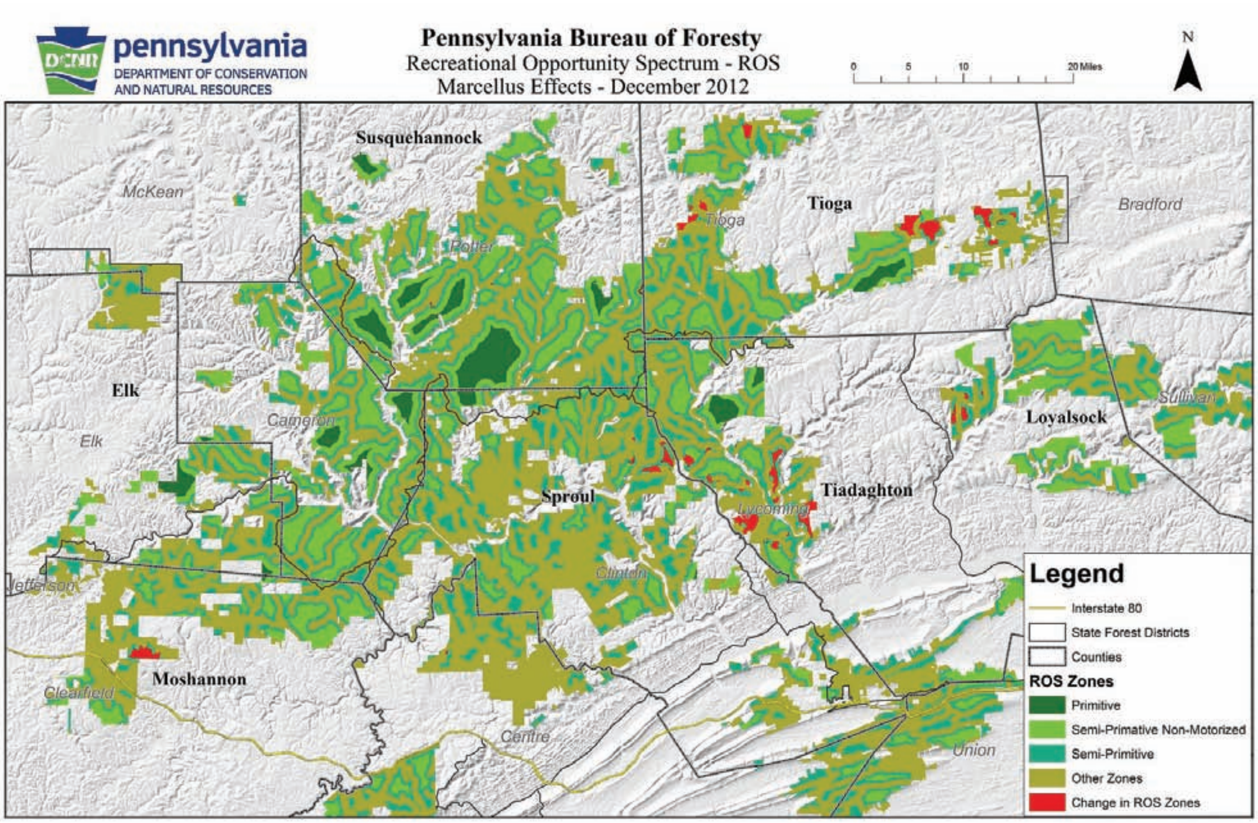

Figure 16.2 Change in ROS zones.

As a result of gas development, three types of gas infrastructure have been constructed within scenic viewshed "Areas of Special Consideration" identified in gas leases. Development in these areas requires coordination between operators and the bureau to protect specific forest uses and values. At times, development in these areas is necessary to protect other sensitive areas and to take advantage of existing disturbance corridors.

In the future, state forest districts and the state forest system may be examined more holistically for viewshed impacts with ArcMap viewshed software. However, the limitations of the tool may suggest the use of a different method to quantify the value of the impact. For example, photo documentation may also be used to document the change in appearance before and after development.

The bureau will continue to investigate additional tools and methods to assess the wild character value of state forest lands. A blend of both subjective and data-driven methodologies likely will be the most useful in assessing and monitoring wild character.

Forest Fragmentation

Since the onset of shale-gas development on state forest lands, the bureau has worked with gas operators to limit forest fragmentation resulting from infrastructure construction. As part of its monitoring efforts, DCNR recognized the need for a landscape-level analysis of the change in forest habitat since the onset of shale-gas development on state forest lands.

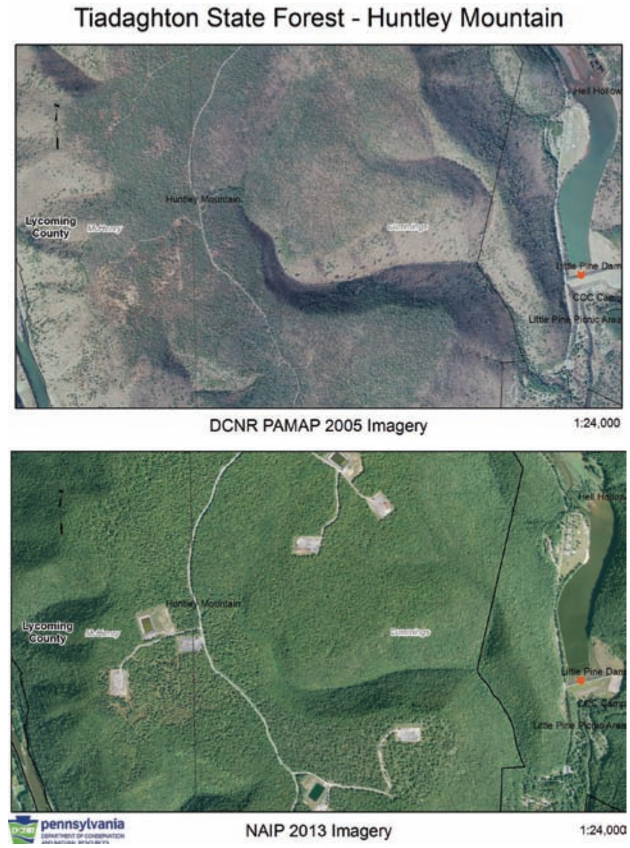

Figure 16.3 Example of forest fragmentation in Tiadaghton State Forest.

After reviewing a variety of methods and types of analysis, the Landscape Fragmentation Tool v 2.0, developed by the University of Connecticut Center for Land Use Education and Research (CLEAR), was selected as a means to complete an assessment of the change in forest habitat across the state forest districts subject to gas development (Parent & Hurd, 2008). This tool is based on research completed by Vogt et al. (2007), which proposed a pixel-based approach to quantifying fragmented forested landscapes. The Landscape Fragmentation Tool (LFT) uses ArcGIS spatial analysis technology to classify forest into four categories: patch, edge, perforated, and core forest. One drawback of this tool, however, is that it only can distinguish forest from non-forest and cannot assess early successional forest or shrublands from mature forest.

One assumption utilized by this analysis is an edge width of 100 meters. This is the general width typically accepted as the extent of "edge effects" on interior forest due to nearby disturbance. This distance of 100 meters also was accepted for use in the landscape tool by Drohan et al. (2012) to describe forest land cover change due to shale-gas development in Pennsylvania. In the Drohan model, edge is defined as the first 100 meters of forest along the outside edge of a forest patch. Forest patch pixels are small areas of forest completely surrounded by forest edge or non-forest pixels (Parent & Hurd, 2008) and are completely subject to any edge effects.

Perforated forest is the zone around a small clearing or disturbance that is completely surrounded by core forest. Core forest is forest habitat not subject to disturbance or the edge effect and is split into three size classes by the LFT: small (less than 100 hectares or 247 acres), medium (between 100 and 200 hectares or 247 and 495 acres), and large (greater than 200 hectares or 495 acres).

Since the datasets available to the bureau were different than those used by CLEAR, as the use of LFT was investigated, certain parameters and assumptions were made during the analysis. A GIS basemap layer to be used in the tool as a pre-shale gas dataset was created using the 2005 National Land Cover Data (NLCD) and the 2006 Bureau of Forestry Forest Communities Classification data layer. All datasets, aerial photos, and rasters had to be converted into forest or non-forest areas. Many non-forest plant community types are captured in this classification layer, including: pipelines, orchards, wetlands, food plots, roads, trails, well sites, and picnic areas. Therefore, all "types" within the forest communities classification dataset were classified as "forest or "non-forest" before being converted into a raster dataset.

To further develop the baseline dataset (pre-shale gas), features such as pipelines, roads, waterlines, electric lines, shallow gas wells, and historic wells were added as non-forest features. To create the comparison dataset for the period after shale-gas development had begun, spatial data regarding shale-gas infrastructure were added to the base maps. This included roads widened or constructed for gas development, gas pipelines, well pads, water lines, and any other associated infrastructure. In most cases, limit-of-clearance spatial data were available; however, at times, assumptions were made to estimate this area if the data were not available. Road and pipeline polylines were buffered by 10 feet to account for non-forested area if limit-of-clearance data were not available or the feature was not captured in vegetation typing. Since timber harvests are temporary and rarely result in non-forest (just regenerating early successional forest), they were excluded from this analysis due to the limitations of the LFT.

The analysis results provided by the Landscape Fragmentation Tool, based on conditions before shale-gas development (Table 16.3) and as of 2012, (Table 16.4) on the seven core gas state forest districts are provided below. Prior to shale-gas development, Moshannon, Sproul, and Susquehannock state forests had the most acres of non-forest (6,155, 9,362, and 4,032 respectively), due in part to the amount of shallow natural gas exploration that had historically occurred in those districts. Sproul and Moshannon state forests also had the highest amount of edge forest acres (53,485 and 35,808, respectively). Perforated forest acreage was fairly consistent across districts, with the exception of Sproul State Forest, which had 8,535 acres of perforated forests – nearly 4,800 acres more than the next highest district.

Forest District	Total Acres	Non-forest	Edge	Perforated	Patch	Core Forest (>200 ha)	Core Forest (100-200 ha)	Core Forest (<100 ha)
Moshannon	183,955	6,155	35,808	3,747	1,045	116,229	11,052	9,919
Sproul	302,937	9,362	53,485	8,535	1,111	209,879	8,947	11,618
Tiadaghton	145,153	1,989	17,888	1,156	401	114,249	5,315	4,155
Elk	190,472	3,649	21,033	3,696	449	153,230	4,056	4,359
Susquehannock	257,840	4,032	30,638	2,532	1,310	209,266	5,583	4,479
Tioga	157,321	3,094	19,846	1,972	248	120,316	7,848	3,997
Loyalsock	114,449	1,049	11,938	1,608	262	97,105	1,760	727
Total		**29,330**	**190,636**	**23,246**	**4,826**	**1,020,274**	**44,561**	**39,254**

Table 16.3 Landscape analysis results – pre-shale gas landscape conditions (all values in acres).

For the analysis, a 100-meter (or approximately 328 feet) distance was used to delineate edge forest, and pixel size for the raster analysis was 15 feet by 15 feet. A decision also was made to not include new forest acquisitions that occurred during the time period encompassed by the analysis. In most cases, these newly acquired lands had not been subject to forest stand typing, which served as base data for this analysis. Rather than attempt to provide desktop delineations of these acquired areas, they were excluded in this first analysis.

Again, this is due in part to the history of shallow natural gas extraction in this district and the tendency for shallow gas pads to create perforating features on the landscape. Across all seven districts in the analysis, patch forest acreage was low due to the fact that for the most part, these districts are composed of large forest blocks.

Many of the same fragmentation trends at the landscape level prior to shale-gas development were still evident as of 2012 in the state forest districts subject to natural gas development (see Table 16.4). Moshannon, Sproul,

Forest District	Total Acres	Non-forest	Edge	Perforated	Patch	Core Forest (>200 ha)	Core Forest (100-200 ha)	Core Forest (<100 ha)
Moshannon	183,955	6,302	36,138	3,833	1,056	115,193	11,517	9,916
Sproul	302,937	9,631	53,848	8,659	1,213	209,136	8,702	11,748
Tiadaghton	145,153	2,575	19,701	1,225	429	111,102	5,437	4,684
Elk	190,472	3,681	21,060	3,705	452	153,163	4,056	4,355
Susquehannock	257,840	4,099	30,755	2,574	1,336	208,728	5,864	4,484
Tioga	157,321	3,462	21,103	1,989	287	117,518	8,470	4,492
Loyalsock	114,449	1,270	12,386	1,851	264	96,193	1,761	724
Total		**31,020**	**194,991**	**23,836**	**5,037**	**1,011,033**	**45,807**	**40,403**

Table 16.4 Landscape analysis results – 2012 landscape conditions (all values in acres).

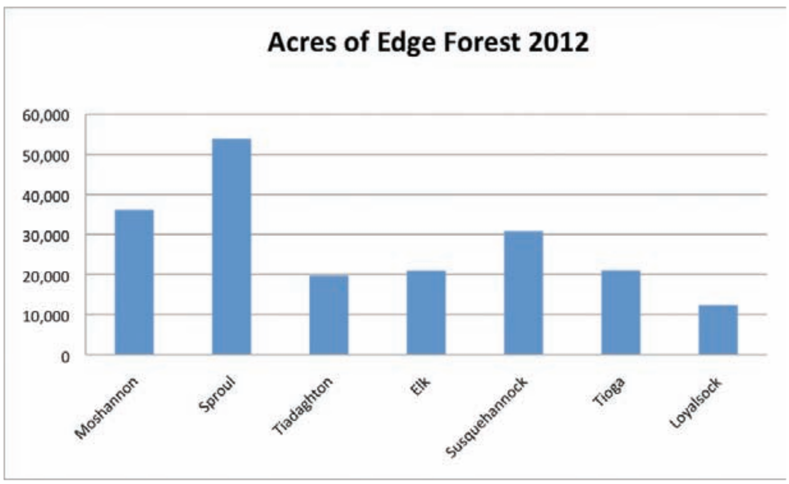

Figure 16.4 Acres of edge forest (by state forest district) as of 2012.

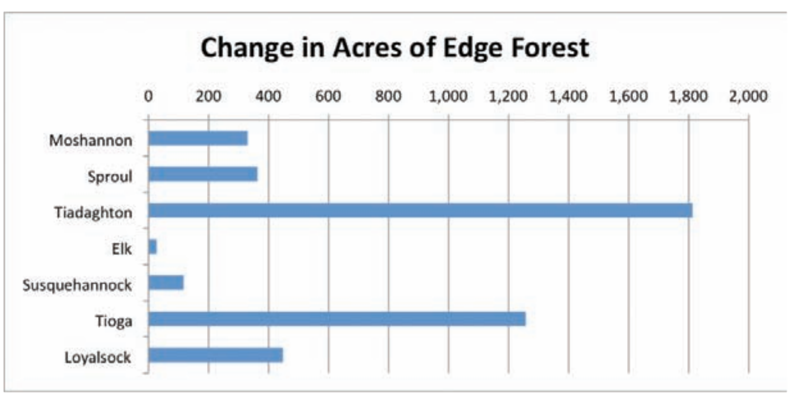

Figure 16.5 Change in edge acres per district from pre-shale gas to 2012.

and Susquehannock state forests still have the most acres of non-forest (6,302, 9,631, and 4,099 acres respectively) than the other four districts, and Moshannon and Sproul districts still exhibit the highest acres of edge forest of all seven districts (see Figure 16.4).

Table 16.5 illustrates the change (in acres) from the pre-shale gas landscape analysis to that of the landscape conditions as of 2012. Across the seven districts in the analysis, acres of non-forest increased by a total of 1,690 acres, with the largest increase in Tiadaghton State Forest (586 acres). The largest increases in edge forest, by a large margin, were seen in Tiadaghton State Forest (1,813 acres, 1.3 percent of total state forest acreage) and Tioga State Forest (1,257 acres, 0.8 percent of total acreage).

Forest District	Non-forest	Edge	Perforated	Patch	Core Forest (>200 ha)	Core Forest (100-200 ha)	Core Forest (<100 ha)
Moshannon	146	330	86	11	-1,036	465	-3
Sproul	269	363	124	102	-743	-245	130
Tiadaghton	586	1,813	69	28	-3,147	122	529
Elk	32	27	9	3	-67	0	-4
Susquehannock	67	117	42	26	-538	281	5
Tioga	368	1,257	17	39	-2,798	622	495
Loyalsock	221	448	243	2	-912	1	-3
Total	1,690	4,355	590	211	-9,241	1,246	1,149

Table 16.5 Landscape analysis results – total change from pre-shale gas to 2012, (in acres).

This is due in part to the number of well pads constructed, but is likely mostly due to the number of new roads and rights of way built in these districts. Only modest increases were seen in perforated and patch forest types, with the highest amount of perforated forest added in Loyalsock State Forest (243 acres).

In total, across all seven districts in the analysis, a loss of 9,241 acres of core forest greater than 200 hectares (495 acres) was observed. However, some of this loss was converted to a gain in smaller core forest blocks, as an overall gain of 1,246 acres was observed in the 100- to 200-hectare (247- to 495-acre) category and a gain of 1,149 acres was seen in the less-than-100-hectare (247-acre) category.

Table 16.6 illustrates the percentage of total district acreage made up of small (less-than-200 hectare) and large (greater-than-200-hectare) core forest blocks at both analysis periods. The highest loss in large core forest blocks was evident in Tiadaghton State Forest (2.2 percent or 3,147 acres), which is indicative of the high level of natural gas development activity that the district underwent in the years between the two analyses.

		Pre-Shale Gas		2012		Percentage Point Change	
Forest District	Total Acres	Core Forest (>200 ha)	Core Forest (<200 ha)	Core Forest (>200 ha)	Core Forest (<200 ha)	Core Forest (>200 ha)	Core Forest (<200 ha)
Moshannon	183,955	63.2	11.4	62.6	11.7	-0.6	0.3
Sproul	302,937	69.3	6.8	69.0	6.8	-0.3	0.0
Tiadaghton	145,153	78.7	6.5	76.5	7.0	-2.2	0.5
Elk	190,472	80.4	4.4	80.4	4.4	0.0	0.0
Susquehannock	257,840	81.2	3.9	81.0	4.0	-0.2	0.1
Tioga	157,321	76.5	7.5	74.7	8.2	-1.8	0.7
Loyalsock	114,449	84.8	2.2	84.0	2.2	-0.8	0.0

Table 16.6 Landscape analysis results – percentage of core forest acres per district.

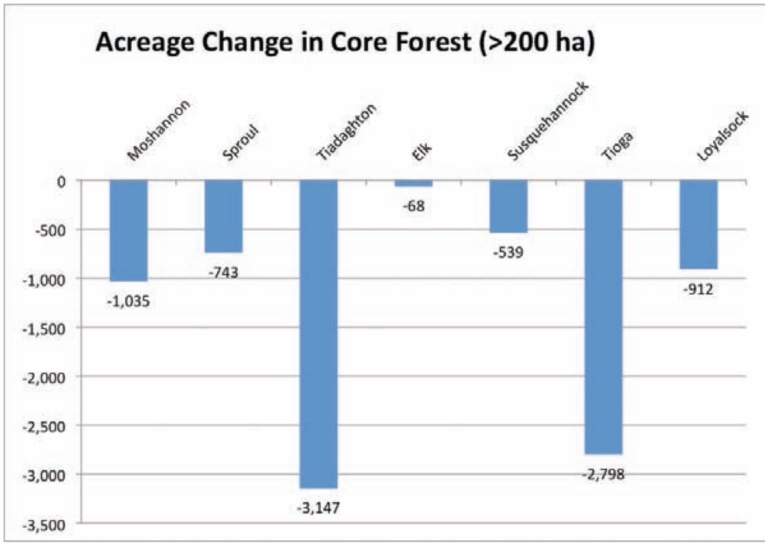

Figure 16.6

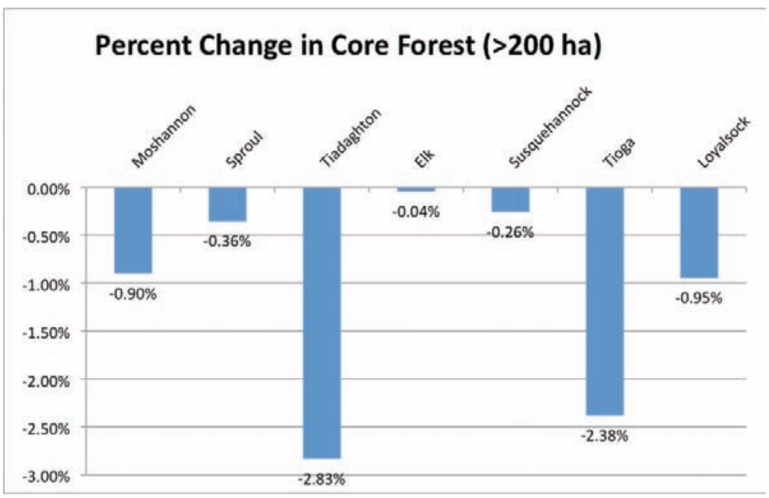

Figure 16.7

Tioga State Forest, which also has seen a high level of activity, was found to have lost 2,798 acres (1.8 percent of Tioga's total acreage) of large core forest. Conversely, Elk State Forest has seen very little development and is not exhibiting a significant change in core forest habitat. The increase in small core forest blocks was not enough to offset the loss in large core forest in any district. The largest gain in small core forest is found in Tioga State Forest, where 1,119 acres were converted to small core forest blocks, which accounts for 0.7 percent of Tioga's total acreage.

Table 16.7 summarizes the combined percent change across all seven state forest districts in the fragmentation analysis. Across all seven state forest districts subject to gas development, a total of 1,690 acres classified as forest in this pre-shale gas analysis were changed to non-forest by December 2012. This value differs from the reported 1,486 acres of converted forest due mostly to the differences in the way in which these values were computed. Conversion is based on acres cleared for gas development and infrastructure, while this fragmentation analysis uses pixel and raster data to create forest and non-forest areas across the landscape. This analysis method accounts for all shifts from forest to non-forest and is not exclusive to gas development activities.

	Pre-Shale Gas (in acres)	2012 (in acres)	Change (in acres)	Total % Change
Non-forest	29,330	31,020	1,690	5.8
Edge	190,636	194,991	4,355	2.3
Perforated	23,246	23,835	589	2.5
Patch	4,827	5,037	210	4.4
Core Forest (>200 ha)	1,020,274	1,011,033	-9,242	-0.9
Core Forest (100-200 ha)	44,561	45,808	1,247	2.8
Core Forest (<100 ha)	39,253	40,404	1,151	2.9
Total State Forest Acres	**1,352,127**			

Table 16.7 Landscape analysis results – change from pre-shale gas to 2012 (all shale-gas districts combined).

In addition, 4,355 acres of edge forest have been created (new roads as well as pipeline and waterline rights of way contribute significantly to edge forest), along with 589 acres of perforated forest and 210 acres of forest patches. The largest change at the landscape level was a loss of 9,242 acres of large core forest. However, some of that loss was converted to smaller core forests, with 1,247 acres of core forest between 100 and 200 hectares (247 and 495 acres) and 1,151 acres of core forest less than 100 hectares (247 acres) created by landscape changes, including shale-gas development.

Restoration

Full restoration to gas infrastructure sites on state forest land is a long-term process. Because shale-gas development is in its early stages, there are currently no examples of infrastructure pads that have achieved what the bureau considers full ecological restoration – the return of the site to a functioning ecosystem. The focus of this initial report, therefore, will be what is considered interim well pad reclamation.

One hundred and ninety-one infrastructure pads have been constructed to facilitate shale-gas development in the core gas districts. Of these, 10 pads have been restored and reduced in size to an interim reclamation footprint. The remaining pads are considered to be in some other stage of development. Interim reclamation of well pads has taken place in three state forest districts. Elk, Moshannon, and Tiadaghton state forests have had well pads reduced in size and replanted with vegetation. Elk State Forest has had three pads reclaimed in the East Branch Dam area. Moshannon State Forest has had six pads reclaimed to production size. Tiadaghton State Forest has had one well pad reclaimed to production size.

The production stage of a well pad site can be a smaller footprint. The onsite infrastructure includes the well-head or "Christmas tree," gas dryer or dehydrator, gas sediment traps and filters, produced fluid tanks – permanent and possibly mobile, pressure gauges, volume meters, and associated valves and piping. There may be a shelter or building installed over some or most of these pieces of infrastructure, depending on the specific company's policy. Required secondary containment features also are installed to address any potential leak or spill that may happen. Post-construction stormwater management (PCSM) features are also on site to permanently address any erosion and sedimentation issues that may stem from storm events.

Example of interim reclamation in Elk State Forest (DSCN 0527).

Elk State Forest:

The three well pads that have been reclaimed in this forest district have been reduced in size from six combined total acres to approximately three combined total acres. The remaining areas that have not been restored to a natural state contain the gas infrastructure that is required while the wells are in production.

Example of interim reclamation in Moshannon State Forest (DSCN 2489).

Moshannon State Forest: Six well pads averaging approximately 3.6 acres each, where the development has been completed and the wells are now on production, have been partly reclaimed, reducing the overall footprint from a combined 22 acres down to 6 acres. The reclaimed area is now vegetated and the remaining operational portion of the pad site remains in hard stone covering for access and maintenance of the wells.

Area adjacent to production stage of pad in Tiadaghton State Forest, with interim reclamation and PCSM (DSCN 2144).

Tiadaghton State Forest: One well pad in this district has been partly reclaimed. The original pad size was 4 acres, which has been reduced to 2 acres and vegetated. The portion of the pad left in hard stone cover will be used by the operator for access and maintenance purposes.

Susquehannock, Sproul, Tioga, and Loyalsock state forests have not had any pad reduction and reclamation activity as they remain in active drilling and development mode. However, it is expected that in the next few years numerous drill pads will see significant reduction and reclamation activity as development is completed.

IV. Conclusion/Discussion

State forest lands in the core gas forest districts have seen changes due to the exploration and development of gas resources. Overall, approximately 1,486 acres of forest have been converted to non-forest to facilitate development.

The value of wild character has been impacted in the core gas districts. Using the ROS tool as one measure of wild character, 8,409 acres have been lost from the semi-primitive, non-motorized category. State forest visitors looking for a more primitive experience may find less appropriate places for those experiences, while visitors who enjoy semi-developed and developed areas may find more.

Also related to the wild character value, there have been impacts to scenic viewsheds identified as Areas of Special Consideration. Each case was carefully considered, and the least overall impact to state forest values and uses determined. Additionally, gas development affects the aesthetics of state forests outside of those Areas of Special Consideration, which should be considered in future monitoring efforts. The viewshed tool can be used to measure impacts, but it needs further refinement before it can be applied in a meaningful way. Each type of infrastructure may affect the perception of the person viewing it differently, and each viewer is unique.

While the Landscape Fragmentation Tool has provided a unique view of how the forested landscape is changing as a result of gas development, this analysis does have some limitations. One major drawback is that the landscape can only be divided into two major categories: forest and non-forest. This structure does not allow the evaluation of another important part of the landscape – timber management. While this drawback is significant, using the tool for this first analysis is not a significant

limitation. Most construction and infrastructure put in place between 2005 and 2012 is still relatively new, and very little has had a chance to re-vegetate or convert back to early successional forest. Moving forward, the analysis may need to be adjusted to account for temporal changes as non-forest becomes early successional forest.

Another limitation related to the temporal aspect of the analysis is that the results only provide a snapshot of how the forested landscape has changed up to December 2012. As gas development in already leased tracts continues to progress, it is likely that these numbers will change. At this time, most changes are relatively small, but gas development in the state forests is still in its early stages.

The analysis does provide valuable insight into the amount of forest acres being changed to non-forest or fragmented forest, and how much core forest acreage is being altered. However, to get a true picture of how gas development may be affecting forest landscapes, a thorough evaluation of forest fragmentation should take place first at a landscape level, and also at an individual species level. Due to the variation of wildlife and plant responses to an increase in forest edge or a loss of habitat connectivity, species-specific studies should be initiated to more clearly evaluate how these landscape-level changes are providing positive, as well as negative, effects on species residing within the state forests. These studies also could consider evaluating the effects of habitat fragmentation due to gas development and due to timber harvesting for the same species or group of species.

In addition to species-specific research, another means to increase our understanding of this landscape-level fragmentation data would be to group results by only one disturbance type, rather than combining all types of infrastructure. Another approach may be to evaluate the changes in forest habitat by the bureau's forest community classification forest types, rather than by state forest district. This could target management and research onto forest stand types that are becoming more fragmented or that might be more uncommon in the seven districts subject to natural gas extraction.

Restoration will continue to be an important activity to monitor across the core gas districts. Restoring gas infrastructure areas will reduce the impacts of fragmentation as well as enhance and improve the wild character of the forest. The bureau will monitor restoration not only by site, but also in a landscape context.

Part 3: Partner Monitoring

Susquehanna River Basin Commission Remote Water Quality Monitoring Network

Introduction

The Susquehanna River Basin Commission (SRBC) is a federal, interstate commission involving the states of Pennsylvania, New York, and Maryland, and the federal government. The Susquehanna River Basin Compact was signed into law in the late 1970s for the purpose of providing the mechanism to guide the conservation, development, and administration of water resources of the Susquehanna River basin.

In response to increased levels of shale-gas development in the Susquehanna River basin, SRBC established its Remote Water Quality Monitoring Network (RWQMN) for real-time, continuous monitoring of field chemistry parameters. The RWQMN is composed of 59 monitoring stations throughout the area within the basin that is underlain by shale-gas resources. Each monitoring station is equipped with a water quality sonde, a data platform, a solar panel, and a data transmission device. The water quality sonde continuously monitors the following parameters: pH, temperature, specific conductance, dissolved oxygen, and turbidity. The RWQMN is intended to help SRBC and its stakeholders develop a baseline characterization of water quality in the shale-gas region and monitor for potential changes in water quality due to shale-gas development. The real-time nature of the data collection allows a timely response in the case of pollution events. Detailed information about the SRBC RWQMN and real-time data are available at http://mdw.srbc.net/remotewaterquality/.

In November 2009, SRBC announced it was seeking partners with whom it could expand its RWQMN to rivers and streams remotely located in the northern tier of Pennsylvania. Much of the area that was under consideration by SRBC was coincident with large, contiguous areas of state forest land where shale-gas drilling already was occurring or was expected to occur. In 2010, the bureau provided $280,000 from the Oil and Gas Lease Fund to SRBC to purchase monitoring equipment and for subsequent operation and maintenance costs. This funding source allowed for the establishment of 10 monitoring stations, and SRBC since has assumed the operations and maintenance costs for future years.

Site Selection

During the sonde site selection process, SRBC determined the most likely origin of negative impacts to surface waters would be the instantaneous release of up to 5,000 gallons of flowback water resulting from trucking accidents on bridges. The agency conducted bench-scale testing using this scenario in order to develop a degree of confidence in its ability to detect a spill or release in targeted watersheds. Using this scenario and other criteria previously established for sonde placement, SRBC developed the following criteria to be used in selecting station locations:

- A watershed size of about 30-60 square miles to ensure continuous year-round flow of water and to maximize spill detection capability
- Non-impaired or minimally impaired water bodies
- Sufficient flow in winter to prevent water from freezing so that equipment could remain in place year-round
- Proximity to an existing U.S. Geological Survey gaging station
- DEP drilling permit density in the area of interest
- Well pad density per square mile, if known
- Proximity to public water supply intakes from surface waters

- All-season access to allow for the maintenance of each sonde approximately every six to eight weeks
- Openings in riparian tree cover to allow for good data transmission using solar-powered panels

When selecting locations for the bureau-funded sondes, bureau staff added the following criteria to the site selection process:

- New leases that were expected to primarily target shale gas for development
- The ability to collect pre-development, baseline water quality parameters to help better differentiate between normal ranges of variability in water quality (including from salting in the winter or other stormwater runoff) and something unusual that would warrant further investigation at the drilling activity site
- Private land shale-gas development adjacent to state forest lands where a spill to the surface waters on that private land could make its way onto state forest lands
- Whether or not the watershed is classified by DEP as HQ or EV.

The two agencies ultimately agreed upon 10 sonde locations based on the criteria outlined on page 221, as well as on-field evaluation by SRBC. The sondes were installed between spring and fall of 2011. The sondes located on state forest lands are listed in Table 17.1 and shown in Figure 17.1. Table 17.2 presents basic watershed characteristics of the bureau-funded sondes.

Name of Waterway	Additional Location Information	Forest District	Data Collection Start Date	State Forest Operators in Watershed
Baker Run	Near Glen Union	Sproul	9/19/11	Numerous NCL and Anadarko tracts in the watershed
East Fork Sinnemahoning	Near Logue	Susquehannock	5/25/11	PGE Tract 154
Grays Run	Near Gray	Loyalsock	5/5/11	Seneca Tract 100
Hicks Run	Near Hicks Run	Elk	6/16/11	Shale-gas development on private lands and state game lands, adjacent to state forest lands
Little Pine Creek	Near Waterville	Tiadaghton	6/23/11	Exxon/PGE and Anadarko Tracts 293, 322, 356, 357, and 729
Marsh Creek	In Tioga County*	Tioga	6/9/11	Seneca Tract 007
Moose Creek	Near Plymptonville	Moshannon	5/2/11	EXCO Tract 323 and upstream of a public water supply reservoir
Ninemile Run	Near Walton	Susquehannock	5/25/11	Part of Seneca Tract 001
Pine Creek	Near Blackwell	Tioga	8/8/11	Ultra Tracts 839 and 856
Upper Pine Creek	Near Telescope	Susquehannock	5/25/11	Part of Seneca Tract 001

Table 17.1 SRBC RWQMN sonde stations funded by the bureau and located on state forest land.

** This location is different from SRBC's Marsh Creek near Blanchard, in Centre County.*

Methodology

The sondes measure and record the following information on a real-time basis:

- Temperature
- Specific conductance
- pH
- Turbidity
- Dissolved oxygen concentration
- Dissolved oxygen saturation

Regular maintenance occurs at approximately six- to eight-week intervals at each station. The data sonde is switched for a newly calibrated sonde during each visit, and field chemistry parameters are measured with a hand-held meter for comparison with sonde data.

SRBC uses two types of stations – cellular and satellite – to transmit real-time data from the sondes back to the SRBC Harrisburg office. All of the bureau sites, except for Moose Creek and Grays Run, use satellite data transmission. Satellite stations record data at five-minute intervals, and the average of those five-minute readings is transmitted every four hours. Stations using cellular transmission collect and report five-minute interval data every two hours. Stations use

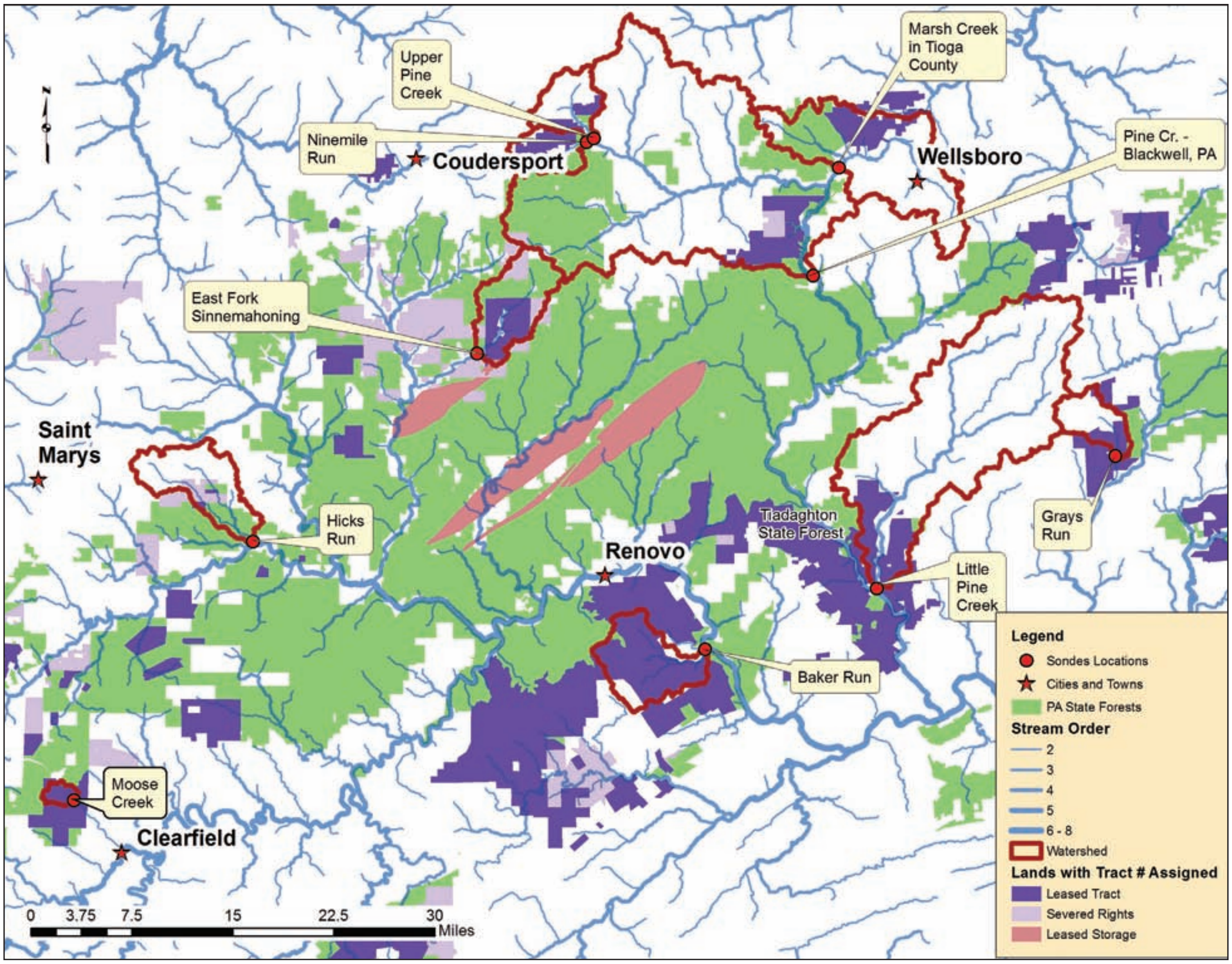

Figure 17.1 Locations and watersheds of SRBC sondes funded by DCNR (First order streams have been removed for aesthetic reasons).

solar panels as their energy source. In the winter when there is less sunlight, SRBC must sometimes reduce the data transmission frequency to conserve battery power. During such periods, the number of measurements taken is not reduced, but the frequency at which they are transmitted to SRBC is reduced.

Periodically, grab samples are taken at the sonde stations for laboratory analysis. Table 17.3 indicates parameters that are analyzed at specified intervals.

An annual benthic macroinvertebrate survey is completed at each sonde station. SRBC's protocol for the collection of macroinvertebrates follows sampling methodology in DEP's Benthic Macroinvertebrate Index of Biotic Integrity for Wadeable Freestone Riffle-Run Streams in Pennsylvania (DEP 2012). SRBC uses a 500-micron D-frame net and composites six kicks in a 100-meter reach of stream in the best possible habitat (riffle/run). A random 200-count subsample of macroinvertebrates is identified to genus level either in house by SRBC aquatic biologists or by a contracted taxonomist.

Tolerance limits for expected ranges of values associated with most of the sonde-measured parameters (except for temperature and dissolved oxygen saturation) have been established by SRBC for all sondes (based on historical sonde data). If values go outside the anticipated tolerance limits, SRBC staff and bureau staff are automatically

Station	Monitored Drainage Area (square miles)*	Dominant Land Use*	Percentage of Watershed Comprised of State Forest Land	Average Annual Flow at Station (cfs)*	Natural Gas DrillingPads (as tracked by SRBC)*	Permitted Discharges (e.g., wastewater, industrial)*
Baker Run	35	99% Forested	86%	58	9	0
East Fork Sinnem.	33	89% Forested, 10% Grassland	94%	51	2	0
Grays Run	16.2	95% Forested, 5% Grassland	34%	30.4	8	0
Hicks Run	34	92% Forested, 6% Grassland	34%	58.1	4	2
Little Pine Creek	180	83% Forested, 13% Agriculture	13%	251.2	26	11
Marsh Creek	78	72% Forested, 22% Agriculture	34%	110.4	34	23
Moose Creek	3.3	95% Forested	98%	6.1	1	0
Ninemile Run	15.7	85% Forested, 7% Agriculture, 7% Grassland	73%	22.6	6	1
Pine Creek	385	80% Forested, 11% Agriculture, 8% Grassland	36%	545.8	83	34
Upper Pine Creek	18.6	75% Forested, 17% Agriculture, 8% Grassland	28%	26.1	0	0

Table 17.2 Basic watershed characteristics of sonde stations.

notified via e-mail. SRBC staff then research the anomalous readings, which could be due to equipment malfunctions or natural fluctuations (e.g., storm events causing high turbidity), in addition to an actual pollution event. Table 17.4 displays the tolerance limits currently used for bureau-funded sondes.

Evaluation of Selected Sonde Locations

The bureau-funded sonde locations were selected in early to mid-2010 based on information regarding existing or expected shale-gas development at that time. Due to a drop in gas prices and increased knowledge as to which areas of Pennsylvania are producing higher volumes of shale-gas and higher volumes of “wet” gas, some drilling operators have since changed their plans for development. As a result, some of the selected sonde site locations are not currently expected to see the same level of development initially anticipated in 2010.

Six Times/Year*	Four Times/Year
Acidity, Hot	Alkalinity, Bicarbonate
Alkalinity	Alkalinity, Carbonate
Barium	Bromide
Chloride	Calcium
pH	Carbon Dioxide
Specific Conductance	Gross Alpha
Sulfate	Gross Beta
Total Dissolved Solids	Lithium
Total Organic Carbon	Magnesium
	Nitrate
	Potassium
	Sodium
	Strontium

Table 17.3 Analysis parameters and frequency for grab samples at sonde stations.

** Beginning in 2013, SRBC moved to four times/year for all parameters.*

land in these watersheds would not necessarily be solely responsible for impacts observed at the sonde locations. The watersheds that drain to the sondes include both state forest land and private land where other companies may be operating or where other land use may contribute to impacts observed at the sonde location.

Baker Run – This location in Clinton County was originally suggested by SRBC and agreed to by the bureau. The watershed represented by this sonde includes numerous tracts on which historical, conventional (i.e., shallow gas) wells are being operated by NCL and several tracts (343, 344, 653, 678) that have more recent shale gas development by Anadarko Exploration and Petroleum.

East Fork Sinnemahoning Creek – This location was intended to monitor for drilling development within Tract 154, under lease to PGE in central Potter County. PGE is working under a 1930s lease which the bureau assumed when the land was purchased by the commonwealth; therefore, that lease has fewer constraints on it compared to those issued by the bureau. The surface management of the tract does fall under a "coordination agreement"

This does not mean that the data being collected from those locations are not valuable. Stations located in areas where development has been or will be curtailed will be able to collect more baseline data prior to development, or they may serve more as "control sites" for comparison to those areas experiencing a higher level of development.

The following section is a review of sonde locations based on current and expected shale-gas development. It should be noted that operators on state forest

Sondes on State Forest Lands	Specific Conductivity (µmho/cm)[1]	Dissolved Oxygen (mg/l)[2]	pH[3]	Turbidity (NTU)[1]
Baker Run	50	9	5.7-6.7	25
East Fork Sinnemahoning	80	8	6.0-7.5	25
Grays Run	50	8	6.0-7.0	25
Hicks Run	80	8	6.2-7.5	50
Little Pine Creek	140	8	6.5-7.5	50
Marsh Creek	220	6	6.7-7.8	100
Moose Creek	110	8	5.5-6.7	25
Ninemile Run	110	9	6.2-7.6	25
Pine Creek	140	9	6.7-8.0	100
Upper Pine Creek	100	9	6.7-7.8	25

Table 17.4 Tolerance limits that trigger email notification for sondes.

[1]Notice sent for concentrations higher than tolerance limit
[2]Notice sent for concentrations lower than tolerance limit
[3]Notice sent for values outside of tolerance range

that was negotiated between the bureau and PGE, but still does not include all of the bureau's typical lease language. There are currently four producing Marcellus wells and numerous conventional (i.e., shallow gas) wells producing within this tract, but PGE has decided to curtail Marcellus development in this area for the near future.

Grays Run – This location was chosen to monitor potential effects related to the development of Seneca Tract 100, which was leased in late 2008.

Hicks Run – This sonde site was chosen due to expected gas development on private lands where influences on surface water may impact waters within state forest lands. In 2011, DEP issued a total of 20 permits to JW Operating and to EQT for their operations in the vicinity of the watershed monitored by the Hicks Run sonde, and three wells were spud in this area in 2011. EQT is developing the shale gas on State Game Lands Number 14 in southern Cameron County, immediately north of and adjacent to Elk State Forest lands. At least two pads and six wells are planned for development on State Game Lands 14. JW Operating is developing private lands in a large block between Rt. 120/Bucktail Natural Area and State Game Lands Number 14. Impacts from some of these operations could potentially influence the Hicks Run Watershed.

Little Pine Creek – The location of this sonde is at the confluence of Little Pine Creek and Pine Creek, near the town of Waterville in Lycoming County. It was selected based on its proximity to Tracts 356 and 357 (leased to Anadarko in 2008) and Tracts 293, 322, and 729 (leased to ExxonMobil in 2008). Tracts 293, 356, and 729 are being developed for both the Marcellus and Burket/Geneseo shales.

Marsh Creek in Tioga County – This location was selected for its downstream proximity to Seneca Tract 007, leased in January 2010.

Moose Creek – This location was selected due to its potential to monitor downstream effects from development on Tract 323, leased in January 2010 to EXCO Resources. EXCO has completed construction of one well pad. EXCO scaled back development on this tract for the near future; however, the sonde location remains important because it is located upstream from the Moose Creek reservoir, which provides public water to the Clearfield Municipal Authority. In January 2010, the authority placed a new filtration plant into operation at the reservoir. The sonde might also serve as an early warning system for the safety of the reservoir water, which could potentially be impacted by contaminants released during large-scale vehicular accidents on a nearby stretch of I-80 that bisects Tract 323.

Pine Creek – This sonde location in Tioga County was targeted for its proximity to Ultra Resources Tracts 839, 856, and 990. Ultra built one pad on each of these tracts and drilled several wells on Tract 839, which are currently producing gas. However, Ultra has curtailed additional development in this area.

Upper Pine Creek and Ninemile Run – These two stream reaches were chosen based on their proximity to expected development on Seneca Tract 001, which was leased in January 2010. This tract is located in Potter County, east of Coudersport and along Route 6. Sixteen wells have been permitted on the tract, and four have been spud.

Data Analysis

SRBC prepared a RWQMN Data Report of Baseline Conditions for 2010/2011 (SRBC Publication No. 280), available at http://mdw.srbc.net/remotewaterquality/reports.htm. Although the report does not include analysis of the bureau-funded sonde stations, it provides a thorough presentation of the RWQMN and analysis of the initial 37 stations installed by SRBC. SRBC plans to produce a follow-up report in 2014.

The real-time sonde data provided on the SRBC webpage are provisional in nature, in that these data have not been reviewed or undergone quality assurance measures. Periodically, SRBC prepares a corrected version of the data that takes into account quality assurance protocols and equipment malfunction. For the purposes of this report, only the corrected data through June 30, 2012, have been analyzed and will be presented. For consistency, the supplemental data, such as lab analyses and benthic macroinvertebrate data, are presented through June 30, 2012, as well.

A large portion of the data for Pine Creek has been rated as suspect by SRBC due to sonde malfunctions or other issues with data quality control. For this reason, statistics regarding the Pine Creek data have a limited degree of confidence. Results shown for Pine Creek should be considered qualitative or approximate.

The analysis of data acquired thus far through the RWQMN is considered a characterization of baseline conditions. The first year of data, and potentially the first several years, will serve as a reference for comparison with future data. More data acquisition and analysis will be necessary before potential effects of shale-gas development can be identified.

Sonde and Grab Sampling Data

In general, the sonde data indicate that the 10 sondes are located on good quality streams having moderate pH, high dissolved oxygen, low turbidity, and low specific conductance. This is to be expected for these watersheds that drain predominantly forested land. Because turbidity and specific conductance are the parameters most likely to be affected by shale-gas development, they are the focus of data analysis; however, pH and dissolved oxygen are also presented below to describe these fundamental stream characteristics.

As shown in Figure 17.2, median pH values for the streams were between 6.3 and 7.3. The stations within the Pine Creek HUC-8 were neutral to slightly basic, with median pH from 7.0 to 7.3. The remaining stations, with median pH from 6.3 to 6.9, can be characterized as naturally acidic with low buffering capacity. There are no known abandoned mine issues or atmospheric deposition impairments on the acidic streams. The low buffering capacity is indicated by low alkalinity levels from grab samples in these streams, which means that even small introductions of acidic waters could cause a significant drop in pH in these streams.

Median dissolved oxygen levels were 10.6 to 12.1 mg/L, with median dissolved oxygen percent saturation above 93 percent for all sondes. This is indicative of well-oxygenated, cool waters typical of forested watersheds. Figure 17.3 shows monthly median dissolved oxygen concentrations for three different-sized watersheds, illustrating the trend of higher dissolved oxygen during cooler months.

Forested watersheds also typically have very low turbidity because the tree canopy and root systems minimize erosion. The sonde data demonstrate as much, with all but two stations having median turbidity levels below 2.0 NTU. The exceptions, with somewhat higher turbidity, were Marsh Creek and Pine Creek, with median turbidity of 6.7 NTU and 26.2 NTU, respectively. These two streams have the most permitted discharges and also more agriculture in their watersheds than most of the other streams. These anthropogenic sources could be the cause of the higher turbidity levels observed. Turbidity data for the sondes are summarized in Table 17.5.

Turbidity is closely linked to precipitation and flow data, as erosion in watersheds is typically associated with rain and flood events. Higher turbidity is associated with higher precipitation and higher flow. For several of the sonde stations, a comparison can be made between daily average flow from a nearby USGS flow station and turbidity data from the sonde, such as that shown

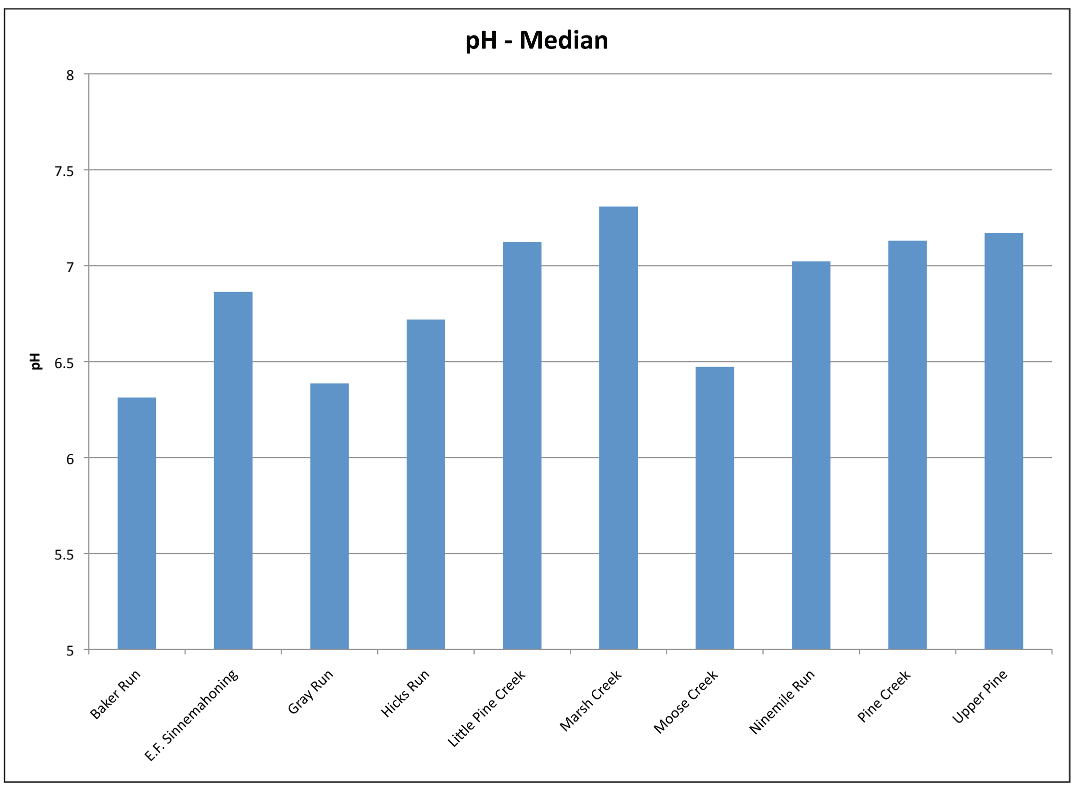

Figure 17.2 Median pH data from SRBC sondes from date of installation through June 30, 2012.

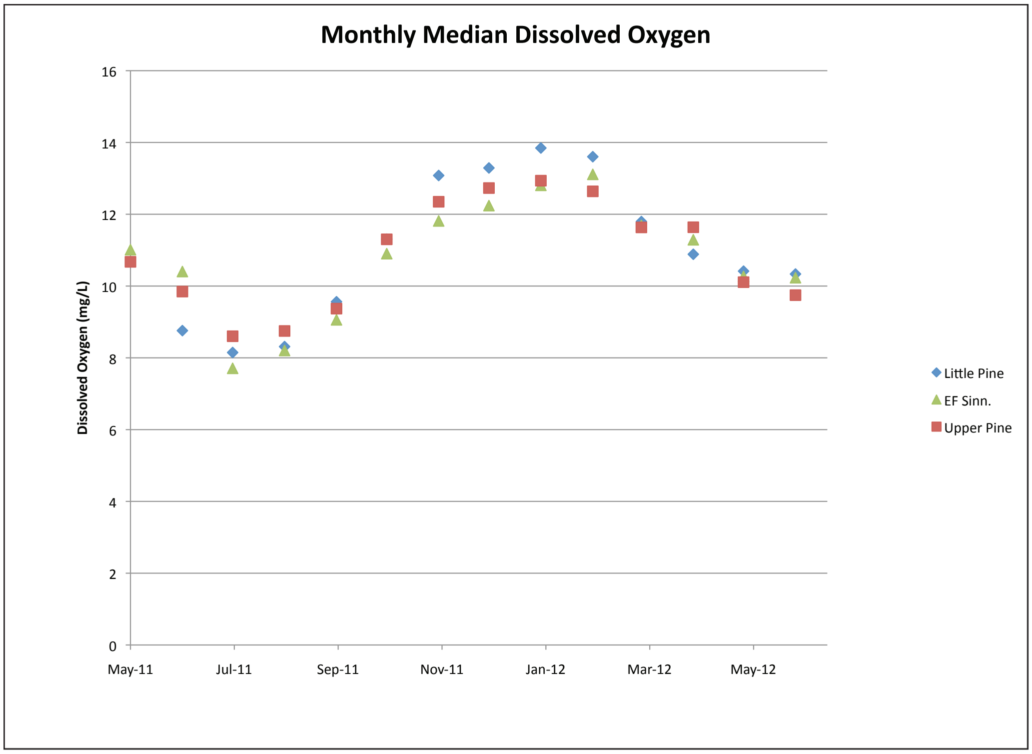

Figure 17.3 Monthly median dissolved oxygen readings for three SRBC sondes from date of installation through June 2012.

Sonde Station	Median	Mean	Standard Deviation	Minimum*	Maximum
Baker Run	0.7	12.1	82.1	-1.1	1117.9
East Fork Sinnemahoning	1.2	2.0	7.9	-0.6	188.9
Grays Run	0.0	2.1	27.8	-3.3	1373.5
Hicks Run	1.3	2.3	9.5	-4.5	213.4
Little Pine Creek	1.3	14.0	83.3	-2.0	1021.1
Marsh Creek	6.7	15.7	33.2	-1.5	353.5
Moose Creek	0.7	1.7	21.3	-3.9	1167.0
Ninemile Run	1.2	2.1	6.4	-4.3	107.5
Pine Creek	26.2	151.0	276.0	-1.9	1254.3
Upper Pine Creek	1.3	3.7	12.4	-4.2	291.8

Table 17.5 Summary of turbidity data from sondes. All units are NTU.

*Due to the nature of the electronic signal received from the turbidity probe, sondes may sometimes read a slightly negative turbidity value. In essence, this indicates a turbidity value of zero.

in Figure 17.4 for East Fork Sinnemahoning. This figure shows that high-flow events are associated with elevated turbidity levels. The imperfect relationship between turbidity and flow is due to variation in precipitation intensity, timing, and geographic distribution within the watershed.

SRBC and the bureau plan additional research into the relationship between flow or precipitation data and turbidity data at sonde stations. One focus of this research will be spikes in turbidity without accompanying spikes in flow or precipitation. Such an event could signify a release of sediment-laden water, such as that which occurs in an inadvertent return during horizontal direction drilling (HDD) for pipeline construction. While performing an HDD beneath a stream, operators use drilling mud (typically bentonite) at very high pressures within the drilling hole. If this high-pressure mud escapes the drilling hole, a plume of mud can enter nearby streams. This would produce a spike in turbidity without a significant increase in flow. It should be noted, however, that there are numerous other explanations for an increase in turbidity without a corresponding increase in flow. For example, turbidity could be elevated due to an angler or hiker crossing upstream of a sonde. Still, monitoring for inadvertent returns and other erosion events is one of the applications of the sonde data. Additional turbidity data analyses will be covered in future editions of this report.

Specific conductance data for the sondes are summarized in Table 17.6, and median values are shown in Figure 17.5. Median and mean specific conductance for all sondes was below 0.150 mS/cm. These averages were relatively low compared to other RWQMN stations throughout the Susquehanna River basin.

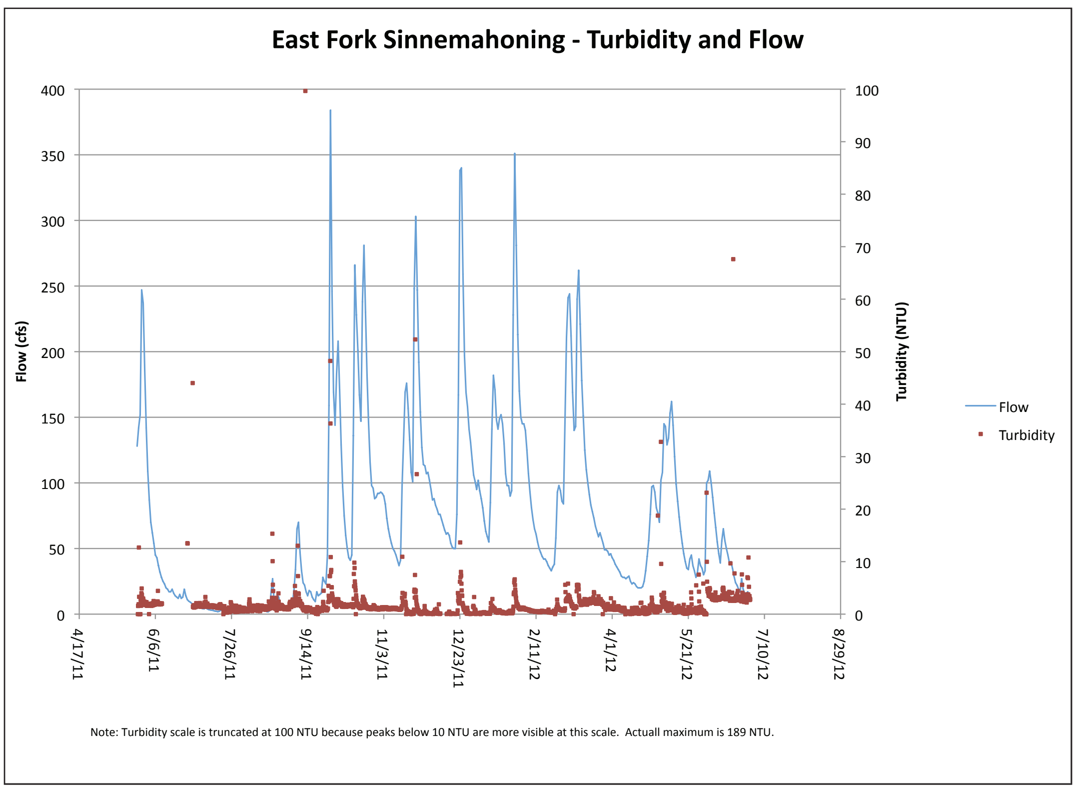

Figure 17.4 Turbidity data from sonde and flow data from nearby USGS gauge for East Fork Sinnemahoning.

Sonde Station	Median	Mean	Standard Deviation	Minimum	Maximum
Baker Run	0.024	0.024	0.003	0.018	0.032
Grays Run	0.030	0.030	0.003	0.021	0.050

Table 17.6a Summary of specific conductance data from sondes in Group 1. All units are mS/cm.

Sonde Station	Median	Mean	Standard Deviation	Minimum	Maximum
East Fork Sinnemahoning	0.042	0.046	0.010	0.031	0.073
Hicks Run	0.046	0.051	0.015	0.021	0.124
Ninemile Run	0.053	0.056	0.013	0.035	0.102
Upper Pine Creek	0.065	0.070	0.020	0.012	0.114

Table 17.6b Summary of specific conductance data from sondes in Group 2. All units are mS/cm.

Sonde Station	Median	Mean	Standard Deviation	Minimum	Maximum
Little Pine Creek	0.091	0.110	0.050	0.057	0.246
Marsh Creek	0.131	0.141	0.045	0.071	0.327
Moose Creek	0.102	0.124	1.017	0.017	154
Pine Creek	0.073	0.082	0.026	0.047	0.180

Table 17.6c Summary of specific conductance data from sondes in Group 3. All units are mS/cm.

This is largely due to the underlying geology and minimal anthropogenic influences on the streams. The sondes can be divided into three groups based on specific conductance results:

- Group 1: Sondes with low specific conductance and showing little variation (Baker Run and Grays Run)
- Group 2: Sondes with low specific conductance and showing little variation but with a marked seasonal shift (East Fork Sinnemahoning, Hicks Run, Ninemile Run, Upper Pine Creek)
- Group 3: Sondes with low to moderate specific conductance results and greater variation (Little Pine Creek, Marsh Creek, Moose Creek, and Pine Creek)

Monthly median results for these three groups are shown in Figures 17.6, 17.7, and 17.8, respectively. The specific conductance of the first group, containing Baker Run and Grays Run, did not exceed 0.050 mS/cm for the entire period of record. As seen in Figure 17.6, these stations exhibit very little variation from month to month, with a standard deviation of just 0.003 mS/cm. Data from these sondes suggest there are no significant influences from anthropogenic sources.

Sondes within the second group (East Fork Sinnemahoning, Hicks Run, Ninemile Run, Upper Pine Creek) also exhibit little variability, with standard deviations in this group ranging from 0.010 to 0.020 mS/cm.

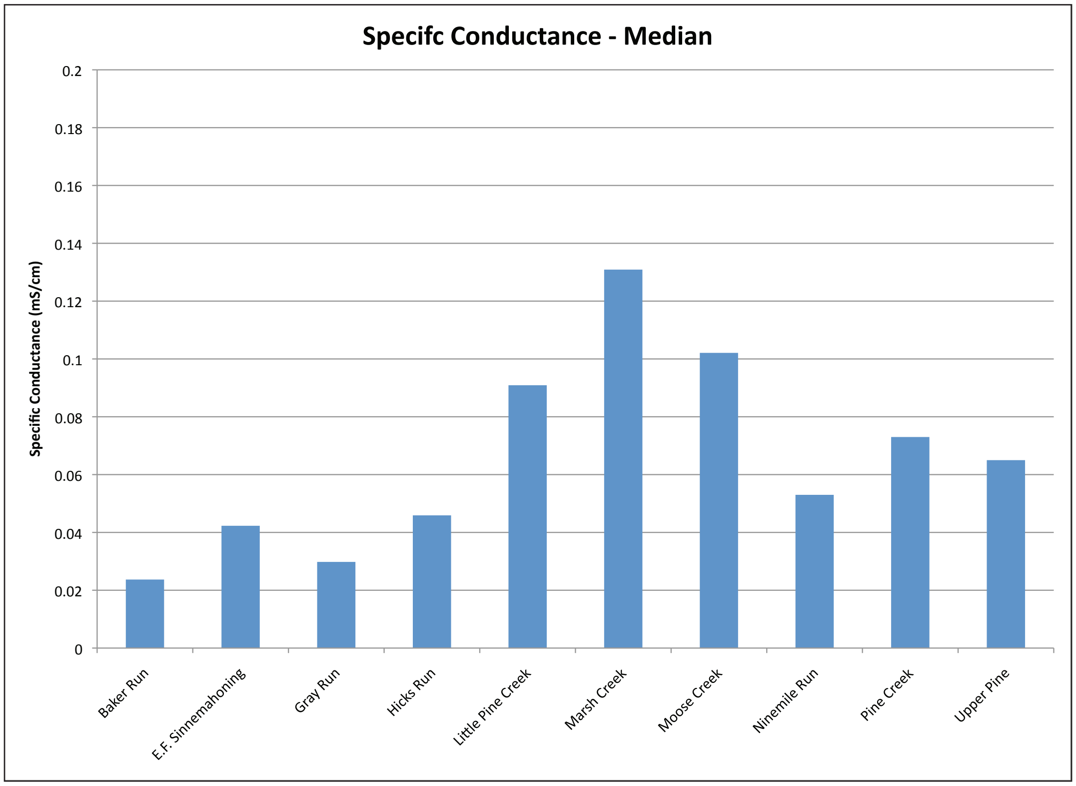

Figure 17.5 Median specific conductance of SRBC sondes from date of installation through June 30, 2012.

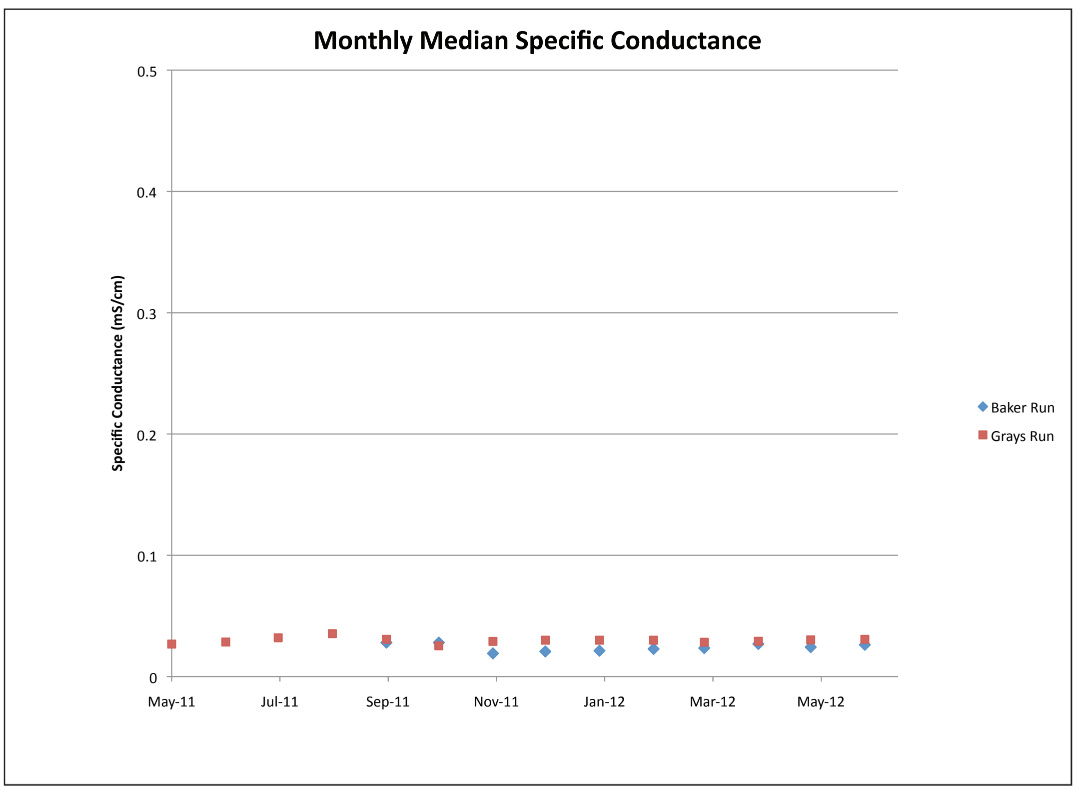

Figure 17.6 Monthly median specific conductance data for SRBC sondes that have low specific conductance with little monthly variability (i.e., Group 1).

However, Figure 17.7 shows a noticeable drop in specific conductance between September and October 2011, preceded by a gradual increase in specific conductance from May to September. This trend follows the general flow level in the streams. From May to September, during the summer, precipitation events are less common. This means that the water contributing to the baseflow in the streams is primarily groundwater, which has a higher specific conductance than rainwater; thus, the specific conductance in the streams increases during drier periods. A large flood in late September flushed the systems with rainwater, yielding lower specific conductance in October. Specific conductance stayed low in the cooler fall and winter months, when evapotranspiration was low and precipitation events more common. For Ninemile Run and Upper Pine Creek, Figure 17.7 shows specific conductance beginning to rise again by June 2012. It is important to recognize these natural, seasonal increases in specific conductance so that they are not attributed to anthropogenic effects.

The sonde data for Hicks Run, Ninemile Run, and Upper Pine Creek show some minor spikes of elevated specific conductance, with values increasing by approximately 50 percent over a short period of time. These spikes appear to be related to high-flow events as they are associated with elevated turbidity levels; however, no flow data are available near these stations for direct comparison. The bureau is investigating precipitation data from nearby atmospheric stations, but comparisons with sonde data will be challenging given that no atmospheric stations exist within the watersheds of these streams. Given the link between specific conductance and turbidity for the observed spikes, they are most likely due to an anthropogenic source of runoff, such as agriculture or roads. The bureau will continue to track and investigate these events and will report further on them in future editions of this report.

Sondes in the third group (Little Pine Creek, Marsh Creek, Moose Creek, and Pine Creek) have relatively

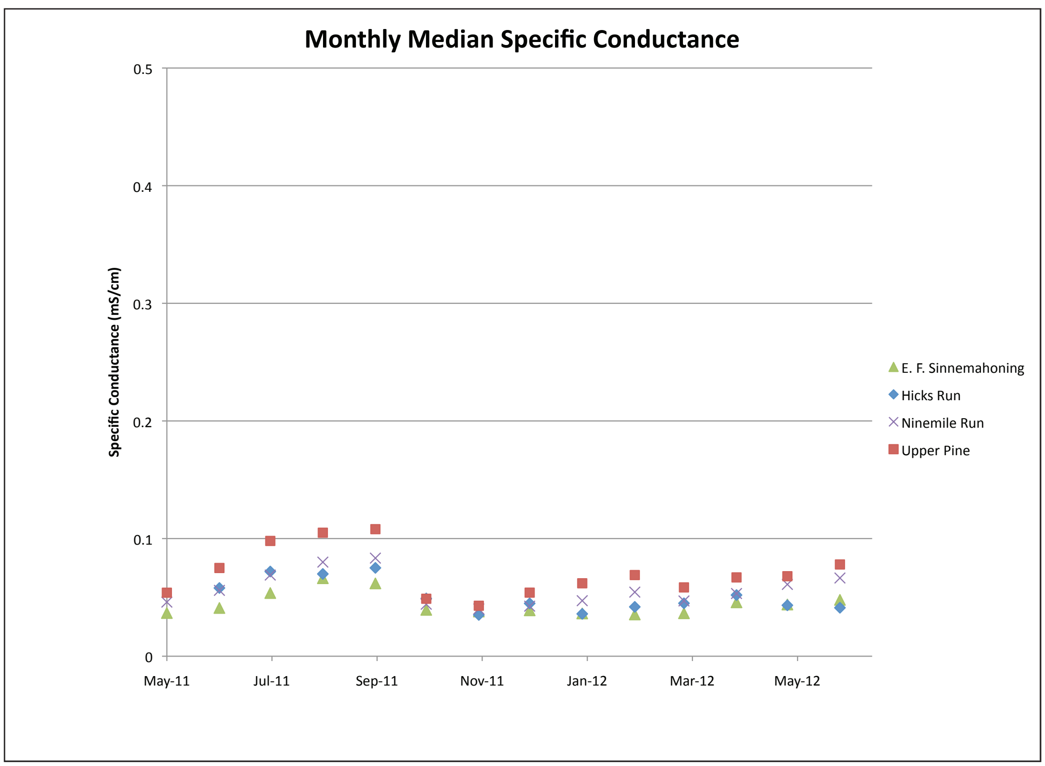

Figure 17.7 Monthly median specific conductance data for SRBC sondes that have low specific conductance and show seasonal variability (i.e., Group 2).

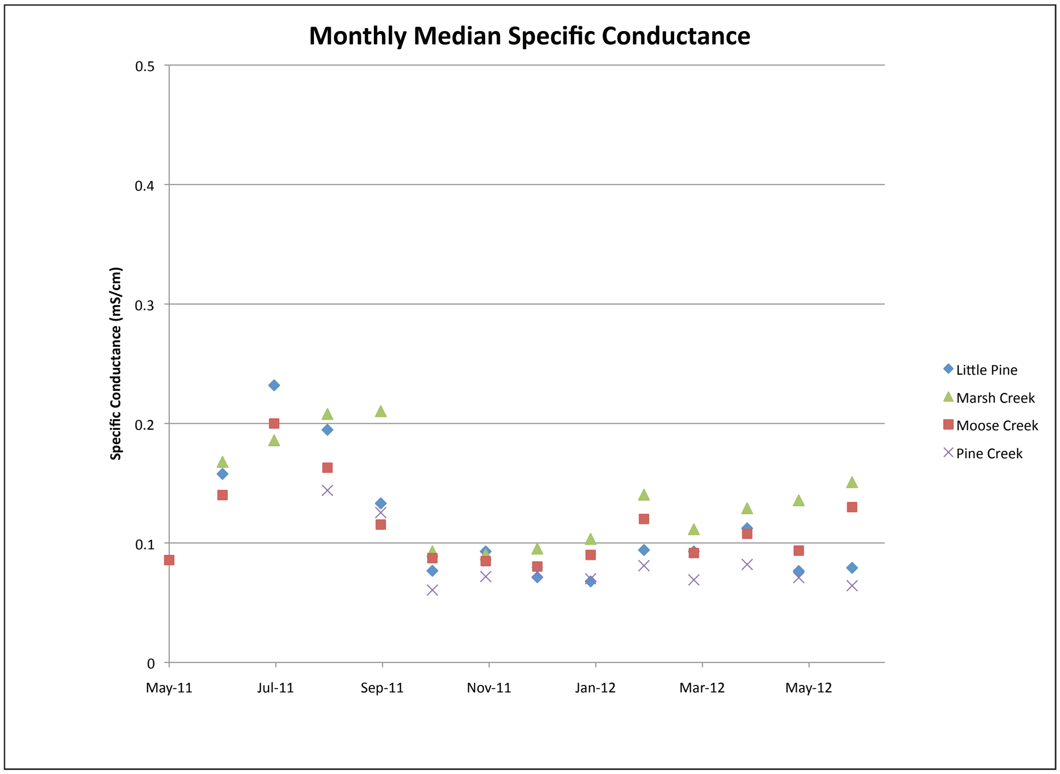

Figure 17.8 Monthly median specific conductance data for SRBC sondes that have moderate specific conductance and show greater variability (i.e., Group 3).

higher median specific conductance with greater variability. While Figure 17.8 expresses this variability, it also shows the same seasonal shift noted above. Except for Moose Creek, this group includes the largest three watersheds monitored through bureau funding, and Pine Creek is the largest watershed in the entire RWQMN. With these larger watersheds, there is a greater diversity in land use, more road crossings, and an increased number of permitted discharges (see Table 17.2). These various anthropogenic sources could lead to the higher and more variable specific conductance results observed by the sondes on Pine Creek, Little Pine Creek, and Marsh Creek. On the other side of the spectrum, Moose Creek is the smallest watershed in the RWQMN. Although the Moose Creek watershed has no permitted discharges and is 95 percent forested, the Interstate 80 corridor runs through the watershed. This major feature appears to have a significant effect on the chemistry of Moose Creek.

The sonde data for the third group show a number of sudden increases or decreases in specific conductance, with values increasing or decreasing by up to 200 percent over a short period of time. As described for sondes in the second group, these changes in specific conductance seem to largely correspond with changes in turbidity or flow. For example, specific conductance will drop abruptly following a major flow event and then rise gradually until the next event. Figure 17.9 shows this pattern with specific conductance from the Little Pine Creek sonde and flow data from the nearby USGS station on Pine Creek (to which Little Pine Creek is a tributary). As with the seasonal trend described above, this pattern between flow events is due to the low specific conductance of rainwater relative to the groundwater that sustains flow between rain events.

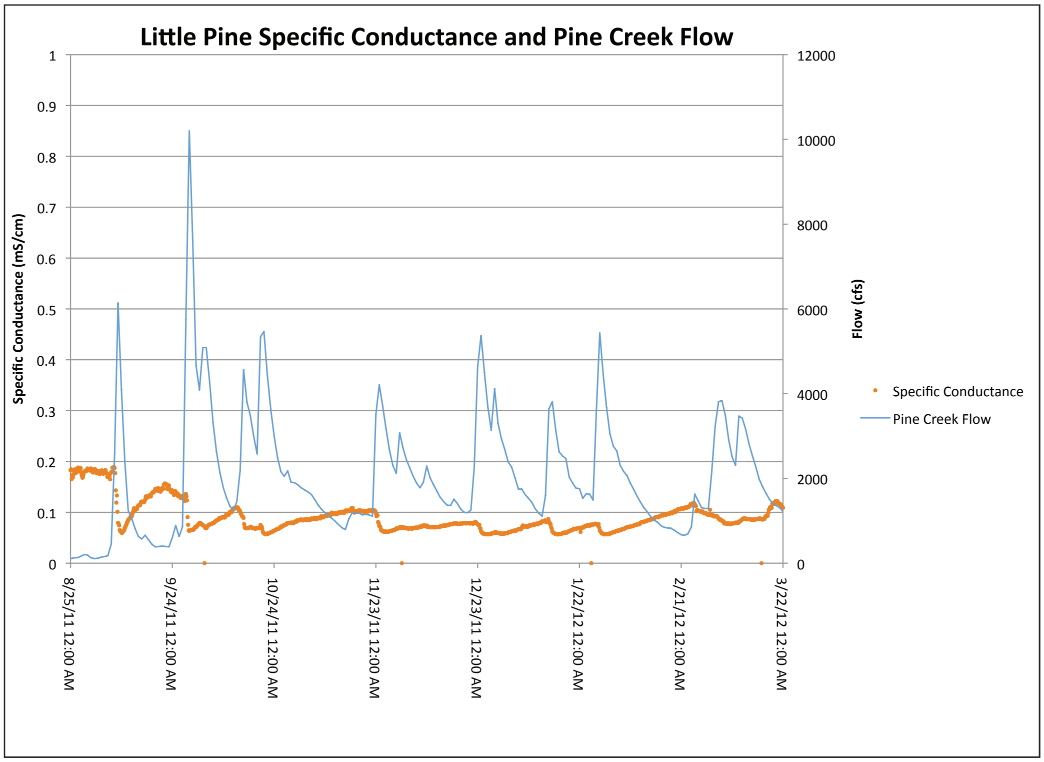

Figure 17.9 Specific conductance data from Little Pine Creek sonde and flow data from nearby Pine Creek USGS gauge.

Due to numerous potential pollution sources within the Group 3 watersheds (e.g., gas development, municipal wastewater, road runoff, agricultural runoff), it is difficult to discern which might be the source of increases in specific conductance. Chloride appears to be partially responsible. Average chloride concentration from grab samples was 7.0 mg/L for the Group 3 sonde stations and 1.2 mg/L for the other sonde stations. Although chloride is found in flowback water from shale-gas development, it is also found in road de-icing salts, inorganic fertilizers, septic tank effluents, and industrial effluents. With only one year of data, it is too soon to make definitive conclusions and still not possible to detect any long-term trends in chloride or specific conductance results.

The bureau will continue to investigate the specific conductance readings at these sonde stations and will report further on them in future editions of this report.

As shown in Table 17.7, SRBC analyzed grab samples from the sonde stations for a number of chemicals. Although it is too early in the sampling program to assess trends in this chemistry data, the data do provide a good baseline reference. In the case of a known pollution event in the vicinity of the sonde stations, the data also will be valuable for comparison to samples taken as part of the remedial investigation. Descriptive statistics for the analytical results are provided in Table 17.7.

Analysis	Frequency	Median*	Mean*	Standard Deviation*	Minimum	Maximum
pH	67	7.03	6.98	0.46	5.13	7.95
Specific Conductance (mS/cm)	0.048	0.059	0.062	0.034	0.022	0.175
Total Dissolved Solids (mg/L)	48	34	41	23	15	124
Alkalinity (mg/L)	57	8	10	11	<1	45
Aluminum (mg/L)	32	0.00	0.04	0.06	<0.05	0.20
Barium (mg/L)	48	0.020	0.022	0.008	<0.011	0.040
Bromide (mg/L)	35	0.000	0.001	0.004	<0.010	0.010
Calcium (mg/L)	38	5.2	6.1	3.7	1.9	15.3
Chloride (mg/L)	48	2.8	3.8	5.8	<2.0	25.5
Gross Alpha (pCi/L)	35	0.00	0.26	0.43	<1.30	1.42
Gross Beta (pCi/L)	33	0.00	0.49	0.97	<1.80	4.21
Lithium (mg/L)	38	0.00	0.00	0.00	<0.05	<0.05
Magnesium (mg/L)	38	1.50	1.60	1.05	0.67	6.60
Nitrate(mg/L)	38	0.26	0.27	0.22	<0.20	0.78
Organic carbon (mg/L)	48	1.1	1.0	0.9	<1.0	3.8
Phosphorus (mg/L)	22	0.010	0.017	0.017	<0.010	0.080
Potassium (mg/L)	38	0.77	0.79	0.45	<0.56	2.90
Sodium (mg/L)	38	2.10	3.00	3.14	<0.56	13.00
Strontium (mg/L)	38	0.020	0.021	0.013	0.010	0.050
Sulfate (mg/L)	48	7.7	9.4	7.3	5.3	50.4

Table 17.7 Descriptive statistics for analytical results from grab sampling at sonde stations. Statistics calculated across all results at all stations.

* For calculation of these statistics, results below detection limit were considered zero.

Benthic Macroinvertebrate Data

Benthic macroinvertebrate data were analyzed based on DEP's Benthic Macroinvertebrate Index of Biotic Integrity for Wadeable Freestone Riffle-Run Streams in Pennsylvania (DEP 2012), the basics of which are overviewed below. DEP uses a multi-metric index of biotic integrity (IBI) to assess benthic macroinvertebrate data. This process is overviewed below, but detailed information is available in DEP 2012.

Based on the benthic macroinvertebrate identification results, a series of six biological metrics, such as taxa richness, were calculated (see Table 17.8). The metrics were then standardized by relating them mathematically to data that DEP collected from reference streams throughout the state. This resulted in a score between 0 and 1 for each metric, with 0 indicative of a poorer quality benthic macroinvertebrate community and 1 indicative of a better quality community. The scores for each metric were then averaged and multiplied by 100, yielding a single IBI value between 0 and 100. Table 17.8b presents the 2011 and 2012 metric and IBI results for the sonde stations.

Sonde Station	Date Sampled	Total Taxa Richness	EPT Tax Richness	Beck's Index	Hilsenhoff Biotic Index	Shannon Diversity Index	Percent Sensitive Individuals	IBI Score
Baker Run	7/26/11	44	26	43	3.35	3.19	46.7	**89.5**
East Fork Sinnemahoning	5/25/11	27	21	29	1.99	2.61	72.8	**89.0**
Grays Run	5/5/11	36	22	32	2.36	3.00	69.5	**93.5**
Hicks Run	6/16/11	32	22	37	3.45	2.71	45.3	**87.3**
Little Pine Creek	6/23/11	27	16	14	3.39	1.80	71.5	**84.8**
Marsh Creek	6/9/11	23	14	22	3.29	2.23	43.9	**69.0**
Moose Creek	5/2/11	23	15	24	2.28	2.74	71.3	**81.2**
Ninemile Run	5/4/11	40	28	38	2.68	2.60	67.4	**93.5**
Pine Creek	6/9/11	28	20	23	3.18	2.82	57.0	**95.4**
Upper Pine Creek	5/4/11	40	32	42	2.65	3.27	64.2	**96.2**

Table 17.8a Benthic macroinvertebrate data from sonde stations for 2011.

EPT = Ephemeroptera, Plecoptera, Trichoptera IBI = Index of Biological Integrity

Sonde Station	Date Sampled	Total Taxa Richness	EPT Tax Richness	Beck's Index	Hilsenhoff Biotic Index	Shannon Diversity Index	Percent Sensitive Individuals	IBI Score
Baker Run	10/1/12	31	18	33	2.79	2.75	57.1	**88.0**
East Fork First Fork Sinnemahoning	10/16/12	32	22	39	2.79	2.85	70.0	**94.7**
Grays Run	10/4/12	30	22	38	2.48	2.70	69.0	**93.3**
Hicks Run	10/16/12	35	20	34	3.02	2.89	67.1	**92.5**
Little Pine Creek	10/16/12	20	10	9	3.68	2.10	60.4	**70.5**
Marsh Creek, Tioga County	10/17/12	23	6	6	3.58	1.99	51.4	**63.0**
Moose Creek	10/1/12	27	11	27	2.16	2.65	71.2	**80.7**
Ninemile Run	10/17/12	28	17	31	2.67	2.79	70.1	**87.8**
Pine Creek	10/17/12	18	8	6	4.36	1.88	37.1	**56.3**
Upper Pine Creek	10/2/12	32	22	35	2.98	2.69	63.1	**90.7**

Table 17.8b Benthic macroinvertebrate data from sonde stations for 2012.

EPT = Ephemeroptera, Plecoptera, Trichoptera IBI = Index of Biological Integrity

In general, these results indicate that all of the sonde stations are located on streams with good quality benthic macroinvertebrate communities. An IBI score of 80 or higher can be used to help qualify a stream for special protection designation of HQ or EV. One notable result is the change in IBI score at the Pine Creek location, from June 2011 (95.4) to October 2012 (56.3). In addition to the SRBC results shown in the tables above, DEP sampled macroinvertebrates at this location twice previously in September 2009 and December 2009, scoring a 75.8 and 60.3, respectively. Hence, the IBI outlier is most likely the June 2011 score. There can be natural variation in IBI scores based on seasonality in streams like Pine Creek, which is the likely case here, and is not a result of water quality degradation. The continuous water quality monitoring sonde at this site detected no anomalies in the period preceding biological sampling in October 2012. As additional IBI results are compiled in future years, possible shifts in the communities can be examined.

Future Work

The bureau's partnership with SRBC on the RWQMN and associated water monitoring continues to develop. In 2012, the bureau provided funding for two additional sondes to be added to the network. One sonde was placed along Pleasant Stream in the Loyalsock State Forest to provide baseline data and monitor potential future development. The other sonde was placed on Young Woman's Creek in Sproul State Forest. This station will serve as a reference stream, as no gas development is anticipated in its watershed. SRBC also is performing biological assessments (fish, macroinvertebrates) within these watersheds as well as within several of the watersheds that already contain sondes. These biological assessments are intended to provide more detailed baseline information and examine potential effects of specific gas development activities. Additional information on the new sondes and on the biological assessments will be provided in future editions of this report.

In addition, SRBC has made efforts to enhance existing stations. Three of the sonde stations that were originally funded by the bureau have received upgrades. The stations on Grays Run, Baker Run, and Upper Pine Creek each have been outfitted with a vented pressure transducer. The pressure transducer system provides for an accurate reading of water depth to be made by the sonde. Water depth can be used as a surrogate for flow rate, permitting a comparison between sonde chemistry data and a hydrologic parameter. Additionally, SRBC plans to install precipitation gauges at Upper Pine Creek and Baker Run, providing a mechanism to track rainfall events that would affect water chemistry and depth.

Part 3: Partner Monitoring

»Forest Certification

FSC Certification

Pennsylvania state forests are certified (FSC® C017154) under Forest Stewardship Council™ standards. The FSC® is an independent organization supporting environmentally appropriate, socially beneficial, and economically viable management of the world's forests.

FSC
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FSC® C017154
The mark of responsible forestry

Timber harvested from Pennsylvania's state forests are FSC certified to ensure that the chain of custody from the forestland to the mill can be continued and that products are coming from forests managed in an environmentally responsible manner.

Audits

Third-party audits are conducted annually to ensure that state forests are managed in compliance with FSC® standards. Every five years, a comprehensive re-certification audit is conducted, followed by four annual surveillance audits. Results of these audits are included in reports to reflect the focus of the audit and to outline any areas for needed improvement. In 2010, an audit with an intensified focus on shale-gas activities was conducted; the corresponding report for that audit is dated 2011. This report and others are available for public review at http://www.dcnr.state.pa.us/forestry/stateforestmanagement/Certification/index.htm. In 2013, the bureau underwent a comprehensive 5-year re-certification and was issued a new certificate with no major corrective action requests issued. This most recent audit report is also available on the website.

Observations and Corrective Action Requests

For areas where the bureau might fall short of auditor expectations in meeting the standard, a Corrective Action Request (CAR) may be given. If a CAR is given, the bureau must make changes to bring its management or processes in line with the standard. Each audit report includes a "conformance with applicable nonconformity report" section, which includes the activities undertaken to address each applicable CAR. For areas where improvement could be made but is not directly a nonconformance with the standard, an observation (OBS) is given.

Since 2008 there have been four corrective action requests and six observations made related to the recent shale-gas activity and management. A summary of those findings by the auditors is listed here:

CAR 01/08 — 2009 Report

Some, but not all districts notify gas lessees when development activity is planned around lease interests (pad sites, pipelines) or when activities impact the lessee's rights.

CAR 04/10 — 2010 Report

The bureau converts some areas to non-forest use by developing gas wells where it owns the mineral and gas rights. Approximate 324 acres have been converted by PA DCNR over the past 5-½ years. This constitutes a "very limited portion" of the 2.14 million-acre Forest Management Unit (FMU). However, as of 2009, the bureau has designated the entire forest as High Conservation Value Forest (HCVF). Thus, technically, the gas well conversions are occurring in HCVF. DCNR has taken a conservative approach to designating HCVF and likely has placed more acres in HCVF than the minimum that would be required by the standard and under emerging guidance (the draft FSC-U.S. HCVF Assessment Framework). Because conversions are only occurring in multiple use areas and do not appear to be threatening the HCVs of these areas at current rates of conversion, the risk of adverse impacts is considered to be low and thus a minor, not a major, CAR is warranted.

CAR 04/11 — 2011 Report

DCNR's 2008 and later Marcellus gas leasing provides the option for invasive plant species to be monitored prior to approval for site development in order to collect baseline data. If invasive plants are identified after site development, they must be controlled prior to site disturbance. Leases from 2008 to the present require that the lease holder monitor invasive species for five years following construction, or until invasive species are not observed on site, whichever is longer, and new occurrences of invasive plants must be controlled (for example, see FY 2009-10 Gas Lease Sale Environmental Review, Section 20). However, the bureau does not have similar invasive plant monitoring for pre-2008 leases and has even less control over lands with severed subsurface rights that do not have a recent negotiated land use agreement. While the bureau is planning an expanded monitoring program for gas activities, the details have not been specified and the funding has not been secured.

CAR 06/11 — 2011 Report

Monitoring data from oil and gas development impacts to the surrounding forest has been collected by the bureau for decades, with increased monitoring efforts over the last few years associated with the expansion of gas leasing. Some monitoring information is available on the website; however, the bureau has not fully reported nor summarized for the public all of these oil and gas data.

OBS 06/10 — 2010 Report

At the current rate of conversion, the lease income gained from gas well development is beneficial to the bureau budget and thus is securing long-term benefits across the FMU, especially considering the overall state *budget crisis. However, there is political pressure to significantly increase the number of wells, which at some point could result in adverse impacts of gas development. These adverse impacts could outweigh benefits such that long-term benefits could not be demonstrated.*

OBS 05/11 — 2011 Report

While the audit team is confident that the total amount of conversion is well below the FSC-U.S. definition of very limited amount, the following areas of concern were noted in the conversion estimates supplied by the bureau:

1. *Marcellus conversion estimates reported by the bureau are based on average well pad size.*
2. *In reviewing the data, it was not clear how accurately conversion due to roads and pipelines was accounted for in the conversion estimates, which were based on an average figure per well pad.*

The bureau reports that conversion from older leases and other sources are minimal, but it does not have accurate records.

OBS 06/11 — 2011 Report

Gas and oil development is occurring on forestland where the Commonwealth of Pennsylvania owns the subsurface rights (the areas leased as mentioned above) and also on forestland where the commonwealth does not own the subsurface rights. For the areas subject to leases (where the subsurface rights are owned by the commonwealth), PA DCNR has substantial control over activities to ensure conformance with FSC standards and requirements.

For lands where the Commonwealth does not own the subsurface rights, it is not clear, in all situations, whether PA DCNR has enough control over activities to ensure conformance with FSC standards and requirements.

PA DCNR needs to evaluate the certified landbase and determine in which situations it maintains enough control to ensure conformance with the FSC standards. For severed lands where they cannot ensure conformance, these lands will need to be excised. (Note: The entire leased area does not need to be excised. Only the areas that are directly impacted by oil and gas activities — i.e., converted to non-forest use — need to be excised.) PA DCNR needs to provide SmartWood with the protocol used in making this determination and the results of this evaluation.

OBS 07/11 — 2011 Report

While the Bureau of Forestry has documentation that addresses issues related to oil and gas leasing, sections in the State Forest Resource Management Plan are brief and do not reflect the current level of gas leasing activity. Key supplemental documents are relatively new, in draft form, and/or in development and not presently linked to the SFRMP.

OBS 08/11 — 2011 Report

Rapid expansion in gas development and new monitoring programs will produce monitoring reports in subsequent years; the bureau does not have monitoring reports to date on oil and gas activities. While the audit team did review data on current oil and gas program management and field inspection forms, full reports on the spectrum of oil and gas monitoring are not currently available.

OBS 09/11 — 2011 Report

Once an oil and gas project is under construction, the bureau relies in part on the Department of Environmental Protection for site-specific monitoring of direct impacts from drilling operations (e.g., road sediment, spills, leaks, etc.). DEP monitoring personnel report being understaffed, and they do not have the time to visit all phases of each operation and cannot respond to all spills. Because DEP does not have the resources to visit all sites frequently, DEP relies on self-reporting from the gas companies. Thus, there are potential gaps in the monitoring of gas drilling and associated road and pipeline construction.

Forest Conversion

Forest conversion is defined by FSC as modifications to the structure and dynamics of a forest as a result of management activities, resulting in a significant reduction in the complexity of the forest system; or the transformation of a forest into a permanently non-forested area; or the transformation of a natural forest into a plantation. Specifically, an area cleared for gas activity would be considered conversion since it is not considered a forest use. Conversely, an area cleared for a trailhead parking lot or log landing is considered a forest use and is therefore not considered conversion.

Principal 6, Criteria 10 of the U.S. Forest Management Standard states that forest conversion to plantation or non-forest land uses shall not occur, except in circumstances where conversion: (a) entails a very limited portion of the forest management unit (<2 percent over a five-year rolling period); and (b) does not occur on high conservation value forest areas; and (c) will enable clear, substantial, additional, secure, long-term conservation benefits across the forest management unit.

One hundred and sixty-one total miles of road have been improved or constructed for shale-gas development in the core gas districts. Of these, 131 miles of state forest roads that existed prior to the shale-gas development have been improved or upgraded for gas development activities, and 30 miles of new roads have been constructed for gas development activities. One hundred and ninety-one infrastructure pads have been constructed to facilitate shale-gas development in the core gas districts. This involved the conversion of 786 acres of forest. Eight hundred and forty-three miles of pipeline corridor exist in the core gas districts. A total of approximately 1,486 acres of forest have been converted to facilitate gas development.

Timber Sold Due to Conversion Practices

Timber that is sold due to conversion practices (rights of way, well pads) is not sold as FSC certified since conversion is not in line with the FSC U.S. management standard. The Timber section of this report includes a figure on revenue related to timber sold as a result of gas infrastructure construction.

Excision Policy

In March 2004, the FSC finalized a policy that sought to address impacts to certified forestlands which were beyond the control of the forest managers. FSC realized that some legally permissible activities occurring on certified forestlands, such as the development of subsurface resources, were inconsistent with the requirements for certification. These activities generally affect a portion of the larger certified forest management area. Thus, FSC was left with a difficult decision to make: remove or "excise" the entire forest management area from certified status or remove specific portions of the forest management area impacted by the activity from certification while retaining certification consideration for the remainder of the area. FSC-POL-20-003 (2004) EN addresses this concern and provides forest managers with the ability to excise specific areas of the greater forest management area directly affected by activities inconsistent with certification requirements.

As a result of the observation in 2011 (OBS 06/11), the bureau developed an excision policy that outlines when lands will be excised from certification. During this process, it was decided that only lands in which the subsurface rights were not owned and adequate control over the surface use could not be obtained would be excised.

Part 4: Research Partnerships

Introduction

The bureau regularly seeks partnerships and cooperates with projects that advance the goals of its Shale-Gas Monitoring Program. To that end, the bureau allocates funds for research projects related to shale-gas development on state forest lands. These research projects are part of the bureau's overall monitoring approach, and help address specific questions and issues with a greater degree of scientific vigor and certainty. Research partnerships also help the bureau address management issues and questions with additional expertise and resources. The projects listed in this section will be completed in 2014 and 2015, and represent the bureau's initial round of research projects related to shale-gas development on state forest lands.

Project Title	Principle Investigator
Evaluating Storm Water and Erosion and Sedimentation Control Measures Associated with Shale-Gas Infrastructure in Forested Landscapes	Dr. Barry M. Evans, Penn State University

Background

Many of the current and planned shale-gas drilling operations in Pennsylvania are located on state forest lands. The bureau manages oil and gas activities on state forest lands by following a set of guidelines and best management practices with a focus on minimizing impacts to other forest uses and values. In addition to water quality issues associated with spills and hydraulic fracturing (which are not specifically addressed in this project), another significant concern is erosion and sedimentation resulting from land disturbance associated with the development of the shale-gas drilling sites and related infrastructure. Although such lands are typically heavily forested and pristine compared to other areas of the state, the potential for deleterious impacts on surface water resources still exists.

Figure 19.1 shows gas drilling permits (black) plotted on top of state forest lands (shown in light brown) in the north-central part of the state. Also illustrated are streams, with their water quality status shown in blue (not assessed), green (good), and red (impaired) as determined by DEP field biologists in 2009. In the case of many of the impaired streams, the water quality problems have been judged to be a result of excessive sediment loads. As can be seen in the figure, there are clusters of drilling permits in areas where local streams have been deemed to be impaired (see areas labeled "A"), as well as in areas where streams are currently in fairly good condition (see "B"). In the former case, ongoing and future drilling operations, if not properly safeguarded, may cause sediment-related problems that aggravate existing water quality problems. Whereas, in the latter case, poorly maintained operations could create problems that currently do not exist.

In recent and ongoing work (much of it supported by the bureau and other state agency funds), various other Penn State researchers (e.g., P. Drohan, M. Brittingham, and J. Bishop) have/are examining the effects of gas drilling operations with respect to local landscape disturbances and changes in hydrology. While all of these studies are not yet completed, it is evident from the findings obtained thus far that these studies will be quite useful in trying to identify potential mitigation strategies for minimizing the impacts that such operations may have on local streams.

Scope of Work

Task 1

The findings of the Penn State researchers cited above will be evaluated in combination with material presented in DEP's most recent stormwater management manual (DEP 2006) to determine if more appropriate techniques (i.e., best management practices) might be employed in place of those currently utilized. For example, DEP has recently has been placing much more emphasis on the use of mitigation measures involving the utilization of more innovative approaches such as bio-retention, infiltration, and reduction of impervious surfaces, rather than the use of more "traditional" engineering approaches, such as those typically used at drilling sites (e.g., detention/retention ponds). As shown via numerous studies in urban areas, the former approaches typically provide beneficial results similar to more traditional control measures. However, more innovative measures may also

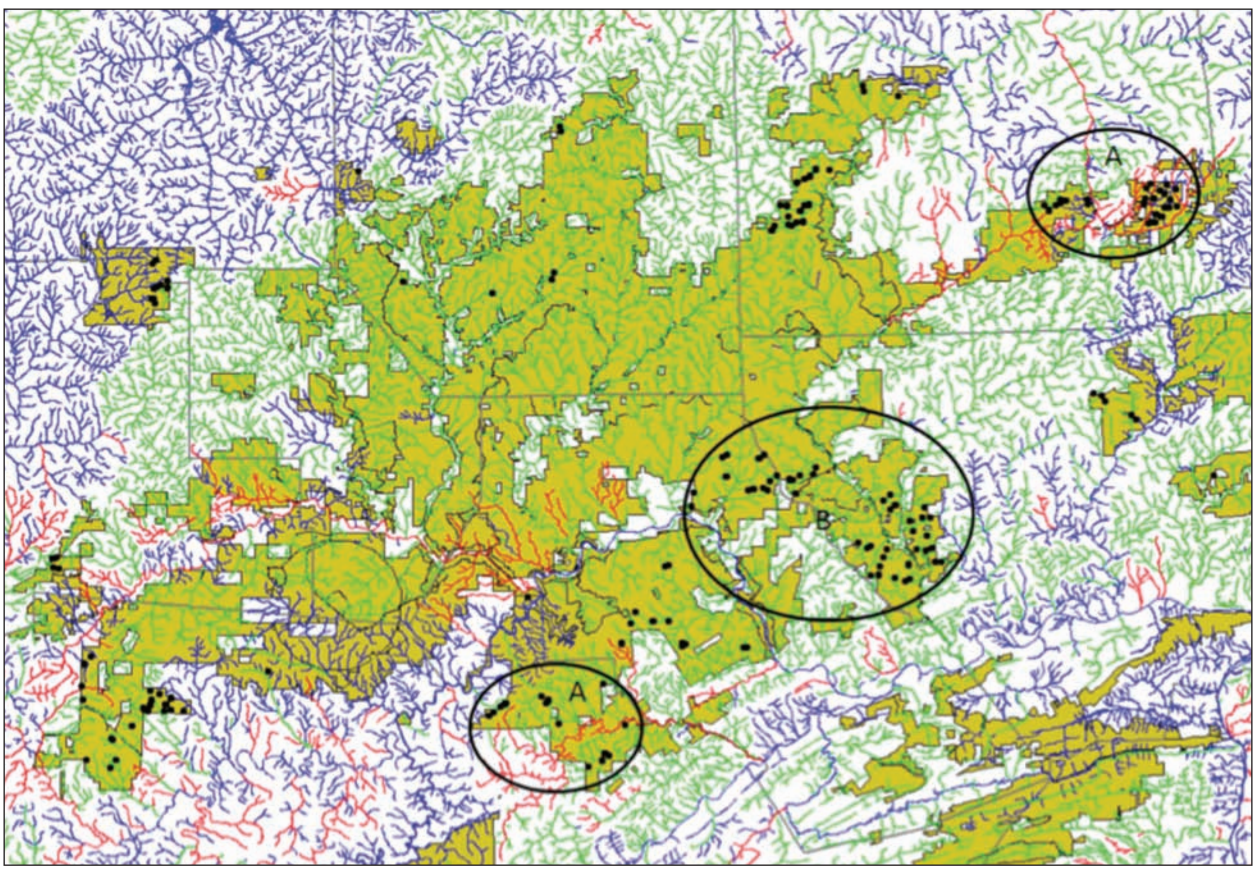

Figure 19.1 Gas drilling permits (black dots) on state forest lands (light brown), overlaid with stream condition: blue = not assessed, green = good, red = impaired.

result in less disturbance to existing forested landscapes (i.e., fewer trees removed) due to the smaller "footprint" required. The key outcome of this task will be to provide recommendations for best management practices for stormwater management associated with shale-gas development in forested landscapes.

Task 2

In addition to the above evaluation, a new modeling tool recently developed by Dr. Evans' group at Penn State, called MapShed, will be used to evaluate potential changes to hydrology and sediment loads. This modeling system was created with funds from DEP to support the evaluation of sediment and nutrient loads at the watershed scale and includes tools for evaluating changes in both upland areas and stream channels, as well as functions for estimating potential load reductions that might be achieved via future implementation of a wide range of rural and urban BMPs. In this case, pre- and post-development conditions will be simulated in test watersheds to evaluate the potential effects of various mitigation measures, as well as to quantify the potential effects of multiple drilling operations within these areas.

In terms of geographic area, the work described above is focused on state forest lands in north-central Pennsylvania, which include the Moshannon, Sproul, Tiadaghton, Elk, Susquehannock, Tioga, and Loyalsock state forests. The specific field locations for analysis will be determined as the detailed research protocols are identified and implemented. However, it is anticipated that five to 10 field sites will be evaluated as part of the work. Each of these "sites" will actually be a watershed that includes a half-dozen or more drilling pads and that may vary in size from about two to 20 square miles. A key outcome of this study will be to quantify the potential effects of multiple drilling operations at the watershed scale.

Project Title

Quantifying Soil and Landform Change across Shale-Gas Infrastructure in Northern Pennsylvania

Principle Investigator

Dr. Patrick Drohan,
Penn State University

Background

Shale gas development raises concerns about the potential short- and long-term effects on soils, water quality, and local hydrology, which are all critical to forest ecosystem sustainability. This project will provide insights to enable improved decision-making for managing oil and gas activities on state forest lands.

Scope of Work

Task 1

A decision support strategy to assess potential hydrological change due to shale-gas infrastructure development will be developed. This combines potential wet-soil modeling and hydrologic capture estimation techniques, in development by the Penn State Soil Characterization Laboratory and U.S. Department of Agriculture (USDA) – Agricultural Research Service.

Task 2

This task will identify and quantify site-specific changes in quick-to-respond soil and flora indicators across a range of reclaimed shale-gas infrastructure sites. Working with bureau staff, researchers will compare changes in reference ecological sites (non-disturbed sites) to "states" of the same ecological site derived via shale-gas development using measurements of bulk density, particle size analysis, penetration resistance, infiltration, saturated hydraulic conductivity, soil pH and

electrical conductivity, soil organic carbon, and plant cover. This step will help us quantify landscape change across shale-gas infrastructure, evaluate restoration success, and provide data beyond the referred literature for development of state and transition models (Task 3) specific to shale-gas development. This objective will result in the training of bureau personnel in the application of field monitoring protocols specific to monitoring soil and hydrologic landscape change due to shale-gas infrastructure.

Task 3
Ecological sites and land types in northern Pennsylvania most impacted by development will be identified.

Task 4
State and transition models specific to shale-gas infrastructure will be developed.

Project Title

Quantifying the Cumulative Effects of Multiple Disturbance Regimes on Forested Ecosystems in Northern Pennsylvania

Principle Investigators

Dr. Patrick Drohan,
Dr. James C. Finley, and
Dr. James R. Grace,
Penn State University

Background

The core model to be utilized in this research will be LANDIS II (Scheller et al. 2007), developed in a partnership of the U.S. Forest Service Northern Research Station, University of Wisconsin, and Portland State University. LANDIS II is a landscape disturbance model that provides the opportunity to simulate the time and space (temporal and spatial) interactions of individual and/or multiple disturbance events across large forested landscapes.

There are a suite of drivers, or disturbance events, that have varying levels of impact on the health, productivity, and composition of forested ecosystems in northern Pennsylvania. For example, there are numerous forest pests and pathogens, such as gypsy moth, hemlock woolly adelgid, and emerald ash borer. There are the documented effects of atmospheric acid deposition. There are the effects of climate change, timber management, wind and weather disturbance, invasive species, and ungulate populations beyond carrying capacity, just to name a few.

Scope of Work

This project will utilize a number of forest biometric models, ranging from stand- or site-level estimates to the landscape level, to quantify the cumulative effects of multiple disturbance events on forested ecosystems within northern Pennsylvania. It will focus on the following four factors, in lieu of the exhaustive list mentioned above: insects and disease, deer, unconventional gas development, and ownership. This will also be accompanied by a base scenario that will simulate a forest ecosystem in a business as usual (BAU) baseline, which will necessitate the base harvest extension and generate estimates of BAU forest conditions for testing differences. The results of these simulations will enable evaluation of forest composition, biomass (and the suite of metrics this allows for estimation and testing), and spatial pattern of the identified disturbance factors at 10-year time steps for a two-year to 300-year analysis period.

This project is to:

1. Identify the cumulative ecological impacts of shale-gas development on forested ecosystems in northern Pennsylvania and classify which factors or components contribute the greatest impact or present the greatest opportunity for enhancing, minimizing, or mitigating any of the potential effects.
2. Model differing scenarios of gas development (increasing/decreasing numbers of wells, rights of way, locations, etc.) to evaluate how shale-gas development affects ecological function at the landscape level.
3. Assess if the disturbance pattern of shale-gas development is similar to other disturbance events (deer, timber harvesting, forest pests, and pathogens).

Task 1

A comprehensive literature review of existing landscape disturbance modeling approaches will be generated.

Task 2

This task will focus on assembling and pre-processing numerous datasets for input into the landscape disturbance model. These data sets will include: forest inventory, climate, soils, land cover, and gas infrastructure, all representing the physical and terrestrial conditions of northern Pennsylvania.

Task 3
Multiple development scenario outputs will be generated from the disturbance model. These will quantify the effects on landscape-level ecological function and generate estimated breakpoints, or thresholds, when specific ecological functions or values may begin to degrade.

Task 4
A comprehensive report will be produced for bureau managers, field staff, and the monitoring program to consider as a means of broadening the current understanding of landscape-level effects of shale-gas development.

Project Title

Effects of Natural Gas Pipelines and Infrastructure on Forest Wildlife

Principle Investigator

Dr. Margaret Brittingham,
Penn State University

Background

The northern tier of Pennsylvania has some of the most intact, forested patches in the Appalachians and hosts numerous interior-forest flora and fauna species (Bishop, 2008, Brittingham and Goodrich, 2010, Wilson et al., 2012). Much of this core forest is state forest land. Projected drilling estimates are variable but suggest that the final number of wells will be in the hundreds to thousands in this region. The footprint of an individual well site includes the well pad plus associated pipelines and roads to service the wells. Pipelines include gathering lines (lines that carry the gas from the well pad site to a larger transmission line), along with the larger interstate transmission lines. A recent analysis of pipelines in Bradford County estimated approximately 1.65 miles of gathering line per pad, with an associated corridor width of 50 to 150 feet (Johnson 2011). Interstate pipelines are larger and have a larger corridor width.

The number of miles of new pipeline predicted at build-out ranges from 10,000 to 25,000, leading to significant potential for habitat conversion and fragmentation and landscape disturbance. Pipelines can affect the wildlife community and the interactions among species directly through habitat conversion or indirectly as a result of fragmentation effects. Depending on how the vegetation is managed, pipelines can potentially provide habitat for declining shrub-scrub associated species (similar to powerline corridors allowed to revert to shrubs; King et al., 2009) or may provide herbaceous openings used by game species such as white-tailed deer or wild turkey. In addition, depending on the species, corridors may serve as travel corridors for some species and barriers to movement and dispersal for others. This research is designed to: 1) address questions about the short-term and potential long-term effects of pipeline corridors in forest habitat on wildlife and 2) use these results to elucidate tradeoffs between management options and to develop guidelines for maximizing benefits while minimizing negative effects.

Scope of Work

Task 1

Conduct a GIS analysis of pipelines and roads associated with Marcellus and other shale gases in north-central Pennsylvania. The landscape fragmentation tool developed by the University of Connecticut will be used to measure changes in forest fragmentation and core forest before and during shale-gas development, using the Tiadaghton State Forest and Lycoming County as case studies. All pads and pipelines will be mapped. Two approaches will be used to determine forest fragmentation. The first approach will assume pre-existing forest roads are a fragmenting feature. In other words, forest adjacent to these roads is already edge forest. The second approach will assume pre-existing forest roads are not a fragmenting feature. In this scenario, the forest adjacent to the forest roads is still considered core forest. The rationale for this is that many

of the roads are narrow and have a closed canopy. The two methods provide for a low (first approach) and high (second approach) estimate of forest fragmentation as a result of shale-gas development.

Task 2
Vernal ponds are critical breeding habitat for forest amphibians. To understand the effects of shale-gas development on vernal ponds and the amphibians that depend on them, a monitoring program of vernal ponds is being developed.

Task 3
As a group, amphibians have experienced extensive declines. In the short term, pipelines and pads may reduce habitat quality near these features due to warmer and drier conditions. In the long-term, shale-related infrastructure may affect movement and dispersal abilities. As a pilot study, natural cover and coverboard searches will be used to identify and quantify the abundance and diversity of amphibians and selected reptiles near Marcellus pads and pipelines and within undeveloped forest habitat. These data will serve as baseline data for further monitoring.

Task 3
This task will examine use of pipelines by wildlife and effects of pipeline placement and structure on forest birds. This task will involve spot mapping the use of pipelines by early successional and forest interior species to determine how they use the pipeline habitat.

Additional studies on forest birds and habitat change have been funded through grants from The Heinz Endowments and Pennsylvania Game Commission. These studies include quantifying the effects of pad placement on the forest bird community and on salamander abundance.

Preliminary Results

The case study for Task 1 has been completed. Depending on the definition of a fragmenting feature, loss of core forest within the leased portion of the Tiadaghton ranged from 4.3 to 9.8 percent. Leased tracts vary in the stage of development, indicating additional core forest will be lost as leased tracts continue to be developed. Future plans include comparing fragmentation effects on public versus private land. Additional research that could be initiated would be looking at the response of individual species to roads, pipelines, and other infrastructure to better understand how fragmentation affects different species or groups of species.

Project Title

Assessing Potential Impacts of Marcellus and Utica Shale Energy Development on the Timber Rattlesnake (*Crotalus horridus*) in North Central Pennsylvania

Principle Investigators

Dr. Gian L. Rocco and
Dr. Robert P. Brooks,
Penn State University

Background

The timber rattlesnake is restricted to the generally larger unbroken forest expanses within the commonwealth, a situation that earns it the title of "indicator species" of such minimally disturbed, wilderness-type environments. Indicator species are animals or groups of animals (communities) that tend to be intolerant of environmental degradation in one or more forms. Monitoring of such species is considered helpful when ascertaining or anticipating environmental degradation. The logic is that change for the worse in the indicator species (or community) is indicative of environmental stress. It is also worth noting that the timber rattlesnake is a middle trophic level predator, so its ecological function is one of both predator and prey. This dual functionality affords greater utility to an already potentially useful indicator.

Large portions of the Marcellus and Utica coincide strongly with the geographic distribution and habitat (large, unbroken, forested tracts) of the timber rattlesnake. To what extent the construction, operation, and maintenance of natural gas wells and associated infrastructure (e.g., well pad clearings, impoundments, access roads, and utility corridors) will impact the timber rattlesnake remains unknown. Monitoring efforts, as with some of the other species currently being monitored, would help ascertain the response of this species to oil and gas related development.

Scope of Work

This study seeks to evaluate the potential impact of Marcellus and Utica Shale energy development on the timber rattlesnake. Multiple rattlesnake-occupied sites are being sampled to assess population status before, during, and after energy development within two large state forest tracts, one slated for development (treatment) and the other unlikely to be developed (control).

The collection of data about a species of interest prior to, during, and after the application of a "treatment," in combination with comparable data collection efforts elsewhere at control sites (no treatment), presents the opportunity for an optimal impact study design and is known as a Before-After/Control-Impact study design (BACI). In 2011, the study proposed to evaluate the impact of oil and gas development on the timber rattlesnake by a BACI sampling design because the timing for such a study was ideal. A multitude of state forest gas leases known to be occupied by the timber rattlesnake were not slated for development (potential "treatment" areas) until 2013, whereas portions of the Quehanna Wild Area, also timber rattlesnake-occupied, were unlikely to be developed in the foreseeable future (control areas).

Evaluation of forest gas leases known at the time (2011) in consultation with bureau staff resulted in the selection of two leases in the Moshannon State Forest for their exceptional suitability. Development of the tracts in 2013 would allow several years of sampling prior to their development (baseline or pre-disturbance condition). A multitude of timber rattlesnake "communal gestation sites" existed, and the adjacency of the two tracts created a single 8,000-acre, isolated study area likely to comprise the activity ranges of most resident snakes. Lastly, the distance between the leases (the "treatment tract") and the Quehanna Wild Area (the "control tract") was great enough for the areas to be occupied by two entirely different timber rattlesnake populations (independent) yet close enough to be quite similar ecologically (comparing apples to apples).

Monitoring timber rattlesnakes is best and rather easily accomplished by identifying and repeatedly sampling "communal gestation sites." Gestation sites are rocky sites that are occupied by two or more (several dozen in some places) gravid or pregnant females during their brooding period (late June through early September). Timber rattlesnakes give birth to live young and remain sedentary during much of their gestation period. Targeting gravid females focuses monitoring efforts on the most vulnerable and most important population segment, the individuals that on any given year will produce the new cohort of animals (continued population recruitment). Monitoring gravid females is also the most logistically sensible approach as they are easily detected and enumerated. Males, non-gravid females, and juveniles, in contrast, are almost impossible to find or sample upon departure from their winter sites in the spring.

Project Title

Pennsylvania State Forest Visitor Use Monitoring (VUM) Program

Principle Investigators

Dr. Alan Graefe, Dr. Andrew Mowen, and Dudley Kyle Olcott (Penn State University)

Dr. David Graefe (Marshall University)

Dr. Donald English (U.S. Forest Service)

Background

In 2011, Penn State University, in cooperation with the bureau, initiated a long-term, systematic approach for measuring and describing recreational use at Pennsylvania state forests. The bureau had identified a need to better understand the recreational visitors who use the state forests. This need includes understanding visitors' use patterns as well as their expectations, spending patterns, desires, and satisfaction levels.

Scope of Work

Overall, the project will survey visitors to 10 selected state forests. Two forests will be surveyed per year over a five-year period. In the survey, forest visitors are asked several questions about how Marcellus shale-related activity had affected: 1) their use of the state forest and 2) their enjoyment of their recreation experience at the state forest. Data were collected through the use of on-site interviews and use measurements at a stratified random sample of the forests' developed sites and dispersed areas open for recreation.

Preliminary Results

At this stage, data are available from the first year of the project, in which surveys were conducted in the Sproul State Forest (District #10) and the Susquehannock State Forest (District #15). The majority of visitors in both forests (72 percent in Sproul and 81 percent in Susquehannock) reported that Marcellus shale-related activity had not affected their use of the state forest. Visitors were slightly more likely to report that gas-related activity affected their recreation experience at the forest. However, again, the majority of visitors in both forests (65 percent in Sproul and 77 percent in Susquehannock) reported that Marcellus shale-related activity had not affected their recreation experience at the state forest.

Follow-up questions probed the reasons for visitors' responses to the initial yes/no questions. Among those reporting that their use of the state forest had been impacted by shale-related operations, the most common responses reflected traffic-related issues. The most frequently mentioned traffic concerns included increased road traffic, poor driving behavior, roads being blocked, or areas made inaccessible to the public. Many respondents in both forests also mentioned various hunting-related concerns. The most common hunting-related issues were that the drilling activity scares game away or reduces their places to hunt, although some offered general statements indicating that drilling affects hunting negatively. The third major theme of shale-related impacts on recreation use included several general environmental concerns. These concerns included pollution, habitat destruction, and water quality as well as changes in landscape, noise pollution, and crowds and loss of a relaxing and serene environment.

Some visitors in both forests reported that shale-related activity had directly affected their use of the forest, mainly by causing them to avoid drilling locations or causing them to visit the forest less often. A few respondents also expressed positive impacts of the shale-related activity. These comments focused on the creation of new access roads, providing better access to the forest, and road improvements.

Those visitors who stated that their recreational use of the forest had not been affected by Marcellus shale-related activity also were asked to explain why not. Many visitors in both forests indicated that they had not noticed the activity or had not noticed it in the areas they visit. Some visitors stated that they had not heard of the Marcellus shale phenomenon. Many visitors in both forests reported that the drilling activity does not bother them, has not changed their use, or does not affect their activities. Some visitors expressed concern about drilling activity but said that it had not changed their use yet.

Forest visitors also were asked to explain the reason why Marcellus shale-related activity had or had not affected their recreation experience at the state forest. Responses to the experiential impacts tended to reflect the same themes as the answers to the questions about the impacts of shale-related activity on visitors' use of the forests. However, some differences were noted. For example, noise pollution was mentioned more frequently as a factor affecting visitors' recreation experience than as a factor affecting their recreation use. Changes in landscape and crowds and changes in atmosphere also were mentioned more frequently as factors affecting visitors' recreation experience than as factors affecting their recreation use. Other specific experiential impacts of shale-related activity included loss of satisfaction, light pollution, and bad smells. And, as in the case of reported impacts on recreational use of the forest, a few visitors expressed support for the drilling activity, stating their belief that it does not have a negative effect, is controlled, or is good for the economy.

Responses by those visitors who stated that their recreation experience at the forest had not been affected by Marcellus shale-related activity also reflected the same awareness-related and general acceptance of drilling activity themes as their previous explanations for why the shale-related activity had not affected their recreational use of the forests. Again, many visitors in both forests indicated that they had not noticed the activity or had not noticed it in the areas they visit, or that the drilling activity does not bother them, has not changed their use, or does not affect their activities.

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Part 6: Index of Figures & Tables

Index of Figures

Index of Tables

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