



the **ENERGY** lab

R&D FACTS

Geological & Environmental Systems

Monitoring of Air, Land, and Water Resources during Shale Gas Production

Background

Protecting the environment is always the top priority in NETL's energy production research because realizing economical, secure, abundant fuel supplies must balance with protecting our air, land, and water resources and human health. New developments in the energy industry, such as the horizontal drilling and multi-stage hydraulic fracturing used for shale gas and shale oil production, have potential to impact the environment. Because these new drilling and completion methods do not have an established environmental record, NETL monitors environmental signals to ensure that any adverse events are detected and mitigated early, before they can cause a problem for plant or animal life.

NETL is conducting a comprehensive assessment of the environmental effects of shale gas production at two industry provided Marcellus Shale test sites in southwestern Pennsylvania: one in Washington County and the second in Greene County.

The Washington County site is within the natural-gas-liquids (NGL) rich part of the Marcellus Shale and is in a location that is offset from current production in the county. The offset location will permit more than one year of environmental monitoring to take place before site construction and drilling begins, thereby providing a record of baseline (pre-development) environmental conditions. Further monitoring of the same environmental parameters will continue through site construction, well drilling and completion, and production to detect changes attributable to each of these stages of upstream shale gas development.



NETL's Mobile Air Monitoring Laboratory

NATIONAL ENERGY TECHNOLOGY LABORATORY

Albany, OR • Fairbanks, AK • Morgantown, WV • Pittsburgh, PA • Sugar Land, TX

Website: www.netl.doe.gov

Customer Service: 1-800-553-7681

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NON-INDUSTRY PARTNERS

At Washington County Site:

- U.S. Geological Survey
- U.S. Fish and Wildlife Service
- U.S. Environmental Protection Agency
- Pennsylvania Geological Survey
- Pennsylvania Department of Environmental Protection
- West Virginia University
- Penn State University
- University of Pittsburgh
- Wilkes University
- Carnegie Mellon University

At Greene County Site:

- U.S. Geological Survey
- West Virginia University
- University of Pittsburgh
- Carnegie Mellon University



U.S. DEPARTMENT OF
ENERGY

The Greene County site is in the dry gas (no NGL) part of the Marcellus Shale and is within an area of intense drilling and production activity. Unlike the Washington County Site where no development has occurred, six horizontal and two vertical Marcellus Shale gas wells had already been drilled when NETL began monitoring at the Greene County Site, and hydraulic fracturing was scheduled to start within two months. The two vertical Marcellus Shale gas wells at the Greene County site are optimal for use as microseismic monitoring wells during the hydraulic fracturing of six horizontal Marcellus Shale gas wells. Further, the Greene County site is overlain by a producing Upper Devonian gas field that is at a depth of 4000 ft, about midway between the Marcellus Shale and the surface. Industry has provided access to the Upper Devonian wells to monitor pressure and sample gas and produced water. This access will provide multiple lines of evidence to indicate if there is communication between the Marcellus Shale and sandstone units 4000 ft above.

Goals and Objectives

Goals-

- 1) To document environmental changes that are coincident with the different phases of shale gas production including: a) site construction, b) well drilling, c) well completion, d) early production, and e) long-term production after site remediation;
- 2) To develop technology or management practices that mitigate undesired environmental changes; and
- 3) To develop monitoring technologies that are more sensitive, faster, and less expensive than those currently used.

Objective 1 – To comprehensively assess the impact of shale gas production on air quality

Objective 2 – To determine if zonal isolation between producing formations and drinking water aquifers is maintained after hydraulic fracturing

Project Description

NETL's role at the Washington County Site is to monitor environmental signals at a shale gas location prior to development, during well development, and during production including activities to—

1. **Determine air quality**-NETL will monitor ambient air quality at the Washington County site using a mobile air quality monitoring laboratory. NETL also will conduct targeted on-site measurements of air emissions during well development and production activities and use collected data in atmospheric chemistry and transport models to further understanding of local and regional air quality impacts.

Completed - Almost eight months of pre-development air quality data were acquired at this location before the air monitoring laboratory was moved to the Greene County site in March 2012.

Planned - The mobile air quality monitoring laboratory will return to the Washington County site when construction at the location commences (timing depends on industry partner).

2. **Detect fugitive methane** - Methane from both natural seeps and from pre-existing wells and pipelines is expected to be present at the Washington County site prior to development. Atmospheric methane surveys and soil gas sampling will establish baseline methane levels and then detect changes in methane concentration as shale gas well development occurs.

Completed - Atmospheric methane surveys using a sensitive White-cell FT-IR detector (D.L. = 0.1 ppm CH₄) were performed in the spring and summer of 2012. Two persistent methane sources were identified: 1) one methane source is a known oil well; 2) the second methane occurrence has no obvious source.

Planned - soil gas surveys will be conducted to delineate predevelopment methane concentrations in the soil atmosphere.

3. **Detect unwanted migrations of production fluids**- Production fluids including produced water, drilling fluids, and well wash-down fluids are more conductive than the rain-leached soils at the Washington County site. This conductivity contrast will allow electromagnetic surveys to quickly and accurately map the migration of production fluids from on-site tanks and pits should it occur.

Completed - Winter and spring (pre-development) electromagnetic surveys have been conducted at the Washington County site to establish baseline soil conductivity.

Planned - One electromagnetic survey will be conducted after site construction but before well drilling (timing is industry dependent but will likely occur in 2012).

4. **Locate existing wells and pipelines** - Wells and pipelines are common sources of methane emissions. Additionally, unplugged oil and gas wells can provide conduits for the rapid upward migration of fluids and gases if they penetrate producing formations. The Washington County Site is within an area where considerable oil and gas development took place before regulations for the effective sealing of abandoned wells were implemented (~1921). Therefore, it is important to know where these wells are located because the wellbores are not likely to be properly sealed.

Completed - NETL has completed a helicopter magnetic survey of the Washington County site that has provided the potential locations of existing wells and pipelines.

Current - Ground surveys are underway to validate the findings of the airborne survey.

Planned - NETL will publish an evaluation of the use of helicopter magnetic surveys for well finding in the peer reviewed literature.

5. **Document avian changes** - The proposed well location at the Washington County site is abandoned farmland that is presently used for hunting and other recreational activities. The former agricultural fields now contain areas of small trees and shrubs interspersed with grassland, an area appealing to shrub land birds. NETL (through its RUA partners at WVU) has initiated a systematic study of the impact of shale gas production on the population, diversity, and behavior of shrub land birds.

Completed - Predevelopment shrub land bird studies were initiated in spring and early summer of 2012.

NETL's role at the Greene County Site is to—

1. **Determine air emissions during hydraulic fracturing** - The NETL mobile air monitoring laboratory was used to measure air emissions before, during, and after the hydraulic fracturing of six horizontal Marcellus Shale gas wells. The monitoring location was on the drill pad, about 100 ft from wells being completed.

2. **Monitor the vertical growth of fractures during hydraulic fracturing** - Microseismic geophone arrays deployed in two vertical wells were used to monitor fracture height growth during the hydraulic fracturing of five horizontal Marcellus Shale gas wells.

3. **Confirm zonal isolation** - Shallow gas wells in the Upper Devonian (at about 4000-ft depth and at least 3000 ft below drinking water aquifers) are being monitored to look for

evidence of communication with hydraulically fractured areas of the deeper Marcellus Shale (8100-ft depth). Multiple lines of evidence will include:

a. The detection of man-made tracers (that had been injected into underlying horizontal Marcellus Shale gas wells during hydraulic fracturing) in the natural gas produced from the Upper Devonian wells.

b. The monitoring of pressure in the Upper Devonian wells to detect pressure increases that might suggest communication with the over-pressured Marcellus Shale.

c. The monitoring of the produced water chemistry (particularly strontium isotope chemistry) for indications of communication with the Marcellus Shale.

d. The monitoring of gas chemistry (carbon isotopes) for indications of communication with the Marcellus Shale.

Completed - Samples of gas and produced water have been collected from two vertical Marcellus Shale gas wells and from six Upper Devonian gas wells at the Greene County site for characterization based on chemistry and isotopic abundance. Isotopic analysis of produced water already has shown that the strontium isotope ratio for produced water from the Upper Devonian is significantly different from that of Marcellus Shale produced water; different enough for the two waters to be distinguished based on the strontium isotope ratio alone.

Planned - 1) Historical records of well-head pressure for Upper Devonian wells will be obtained from the industry partner; the well head pressures will be monitored during and after hydraulic fracturing in the underlying Marcellus Shale gas wells; 2) perfluorocarbon (PFC) tracers were injected (with the hydraulic fracturing fluid) into a horizontal Marcellus Shale gas well that underlies two Upper Devonian wells. Sorbent tubes have been placed in the gas production from the two Upper Devonian wells to detect PFC tracer that may have migrated upward from the Marcellus Shale. The PFC sorbent tubes will be removed and analyzed weekly for one year after hydraulic fracturing; 3) water and gas production from the Upper Devonian gas wells will be sampled and analyzed on a biweekly and later a monthly basis for one year after hydraulic fracturing.

4. **Assess potential linkage between hydraulic fracturing and seismic events (induced seismicity)** – Fault activation caused by fluid injection is thought to result in seismic events of greater magnitude than the microseismic events typically associated with hydraulic fracturing.

Completed - A broad-spectrum seismograph was installed at a surface location above three horizontal Marcellus Shale gas wells. Seismic data were obtained before, during, and after hydraulic fracturing of the underlying horizontal Marcellus Shale gas wells.

Benefits

- **For regulators, landowners, and the general public** - this study will provide an unbiased, science-based source of information which can guide decisions about shale gas development.
- **For industry** - this study will: 1) develop better methods to monitor for undesired environmental changes and 2) develop technology or management practices to mitigate for undesired environmental changes.

