

Tech Brief

PUBLISHED BY THE NATIONAL ENVIRONMENTAL SERVICES CENTER

Oil and Gas Extraction and Source Water Protection

By **Zane Satterfield, P. E.**, NESC Engineering Scientist

Summary

Although the U.S. petroleum industry has been around since the mid-19th century, increased demand for oil and natural gas, coupled with new extraction technologies has led to booms in several parts of the country. One area where the gas and oil industries have looked for new resources is the Marcellus Shale, which lies under several states in the Northeast. This *Tech Brief* discusses the possible effects on source water from these extraction processes, and what water systems can do to protect themselves.

Oil and Natural Gas in the U.S.

With imported oil and gas prices continually rising at the pumps and home heating bills also on the rise, the demand for lower prices and the lure of big money has spurred gas and oil industries to search domestically for new resources. An area that has seen a flurry of activity and is believed to have one of the largest shale gas deposits in the world is the region associated with the Marcellus Shale.

Extending south from New York's Finger Lakes region, this deposit is found in New York, Pennsylvania, West Virginia, Virginia, Ohio, Maryland, and Kentucky. Other significant areas of gas and oil deposits in the U. S. include Texas, Louisiana, Arkansas, Oklahoma, Wyoming, and Utah. (See the map of showing U.S. shale formations on page three.)

The Marcellus Shale is a brittle layer of rock more than a mile underground; it is the geological remnant of an ancient sea and is laced with pockets of trapped gas, which is mostly methane. Terry Engelder, a Penn State University geologist reports, in the article "The New Gas Boom," that the deposit could contain as much as 516 trillion cubic feet of natural gas. That would make it the second largest gas field in the world, containing 20 times our current annual national consumption of natural gas.

However, compared to previous gas and oil fields, these new deposits are increasingly deeper and locked in

shale. To extract the gas and oils from these deep deposits, a procedure called hydraulic fracturing is used.

Hydraulic Fracturing (Hydrofracking or Fracking)

Hydraulic fracturing, also known as "hydrofracking" or "fracking," is the use of high-pressure fluids to force open fissures or seams in rock to allow the gas or oil to be extracted more easily and efficiently. Although it's not a new technique, hydrofracking has increased in the last few years as a way to get the deeper, harder to reach deposits of gas and oil, and is now used in about 90 percent of the nation's oil and natural gas wells. As a result of hydraulic fracturing and advances in horizontal drilling technology, natural gas production in 2010 reached its highest level in decades.

The amount of water needed for the hydraulic fracturing process varies from well to well and from one shale formation to another, but it is typically about five to six million gallons per well. The water used is either purchased from nearby systems (and often trucked to the site) or a well is drilled near the gas well to provide the raw water they need.

But water isn't the only thing used in the hydraulic fracturing process. Each company has a mix of water, chemicals, and other ingredients that they use for this purpose, and have historically kept this recipe secret. The frack solution varies from well site to well site and from drilling company to drilling company. Some drilling companies buy the frack water solution already mixed and ready to be used, while others mix the solution at the well site. Many gas and oil companies recycle the

there must be more than one well nearby to make the recycling worth the trouble.

As the use of hydraulic fracturing has grown, so have concerns about its environmental and public health impacts. One concern is that hydraulic fracturing fluids used to fracture rock formations contain numerous chemicals that could harm human health and the environment, especially if they enter drinking water supplies. The resistance of many oil and gas companies to publicly disclose the chemicals they use heightens this concern.

In 2010, the U.S. House of Representatives Committee on Energy and Commerce began investigating the chemicals and components used in hydraulic fracturing. The committee compiled information from the leading 14 gas and oil service companies, who agreed to supply their proprietary information on condition of anonymity, and published their findings in *Chemicals Used In Hydraulic Fracturing*.

The committee found that the most widely used chemical in hydraulic fracturing was methanol, a hazardous air pollutant and a candidate for regulation under the Safe Drinking Water Act (SDWA). Other chemical components used in hydraulic fracturing between 2005 and 2009 as reported to the committee included:

- Isopropanol (Isopropyl alcohol, propan-2-ol);
- Crystalline silica – quartz (SiO₂);
- Ethylene glycol monobutyl ether (2-butoxyethanol);
- Ethylene glycol (1,2-ethanediol);
- Hydrotreated light petroleum distillates;
- Sodium hydroxide (Caustic soda).

(For a complete list of the 750 chemicals reported to the committee, see: <http://democrats.energy-commerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf>.)

Chemicals weren't the only components used in fracking, though. One company used instant coffee as one of the components in fluid designed to inhibit acid corrosion, while two companies reported using walnut hulls as part of a breaker, which is a product used to degrade the fracturing fluid viscosity. Another used tallow soap to reduce loss of fracturing fluid in the exposed rock.

Fracking and Water

Most problems with hydraulic fracturing happen when casing and cement, which reinforce the well at the point where it is drilled through the groundwater, are not installed properly or fail for other

reasons. Multiple seals at the wellhead and in the first few hundred feet of the drill hole are supposed to direct the pressure and frack fluid to the bottom of the well. (See the cross section of a hydraulic fracturing well on page five.)

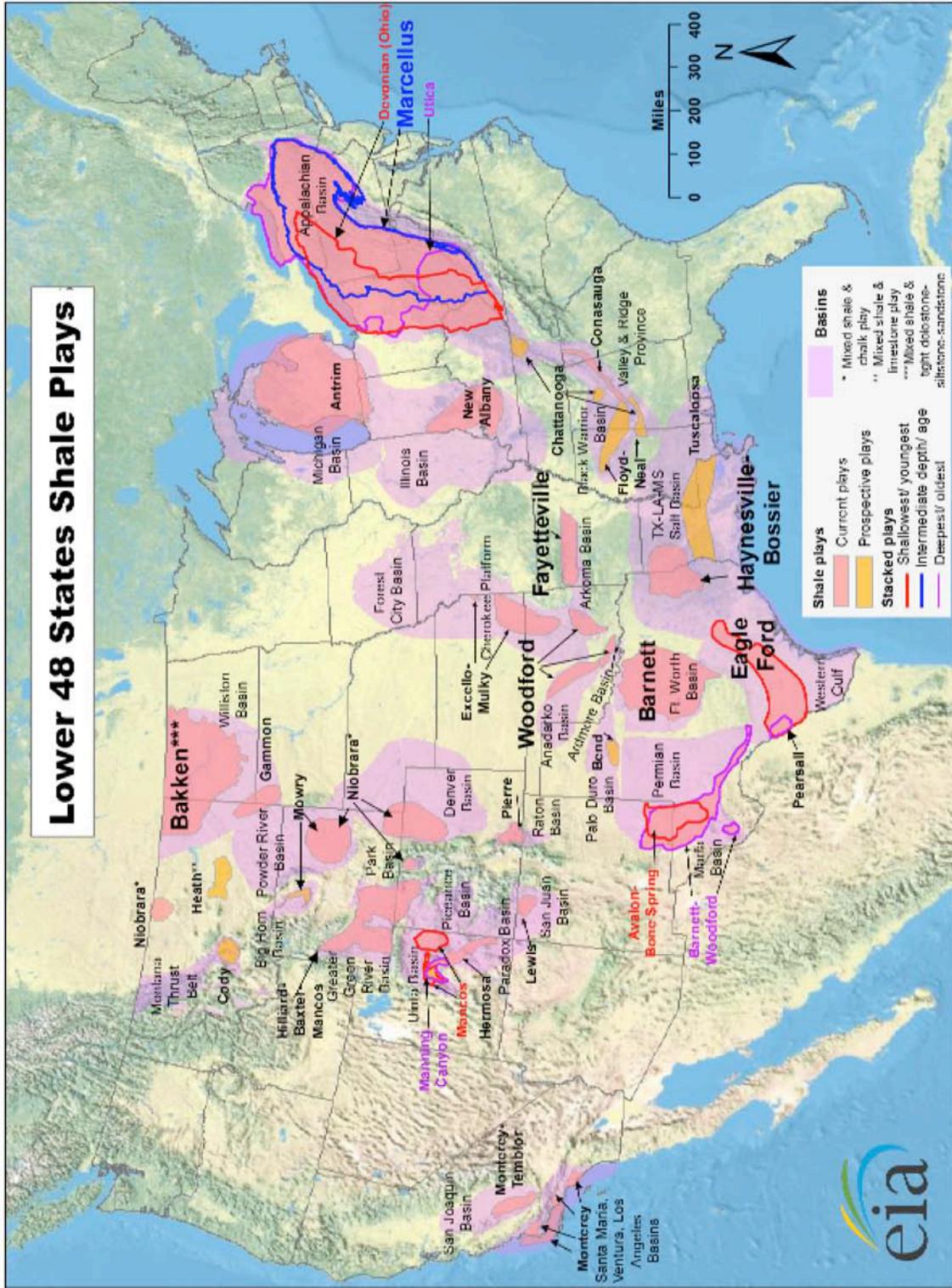
Other groundwater contamination problems, however, can happen above ground. Most wells have a holding pond for the frack water that returns to the surface (typically 10 to 20 percent of the total water used). This return frack water is rife with chemicals and sometimes carries traces of radiation from underground rock. Most municipal wastewater plants cannot adequately treat or remove this waste. Therefore, much of it remains stored in ponds near the wellheads for long periods of time where it can possibly leak into the groundwater, even if the ponds are lined with plastic.

Surface water contamination from the fracking process can happen when frack fluid spills at the wellhead site or as the trucks carrying this fluid travel to and from the wellhead leak. These spills may be from unused frack fluid or return frack fluid, which comes back up the well during the fracking process. Again, a holding pond may leak, which could drain its contents into nearby streams or the holding ponds may overflow from large rain events. One of the biggest issues with surface water contamination is from the treatment of the spent or processed frack water at municipal wastewater plants.

The return frack water is very high in chlorides, sodium, and calcium. These chemicals create high total dissolved solids (TDS) levels. In addition, investigators have found sodium concentrations higher than what are normally found in seawater. Other contaminants include bromide, radiation, radon, methane, and others. A typical wastewater treatment plant cannot remove enough of these contaminants from the treated wastewater it releases into receiving streams. Because of the high contaminant levels, the spent frack water requires specialized treatment and some states, such as Pennsylvania, have limited the number and type of wastewater treatment plants that can receive this wastewater.

Other concerns from oil and gas extraction are air, noise, and light pollution. Drilling is a 24-hour operation with many high-powered lights for safe operation. The equipment at the well site is usually powered by gas and diesel engines that run almost nonstop and the exhaust contributes to air pollution. Other concerns are heavy traffic loads on rural roads and the possibility of damaging the roads and creating leaks in the drinking water distribution systems that are under the roads. When trucks bring in water for fracking, hundreds of

Lower 48 States Shale Plays



Sources: Energy Information Administration based on data from various published studies.



round trips are needed to bring in enough water. If the well uses potable water for the frack fluid, it could create high demand on already short-staffed water systems, although the added revenue is often attractive. Seismic activity may also be associated with the hydraulic fracturing process in areas that have rarely, if ever, seen it, affecting structures that were not built with seismic specifications.

Protecting Source Water

One of the best ways a community's water system can protect its source water is to have total ownership of the land, minerals, and gas and oil rights in the watershed area, or strict land-use ordinances or regulations. Most communities do not have this kind of control to protect their source water. But, there are other steps that can be taken. For instance, the drinking water system could update its source water protection plan or wellhead protection plan to show where any gas or oil wells past and present are located. In addition to mapping the wells, the system could note any possible transport routes to active wells and plan ways to be prepared for possible spills.

System operators should learn about drilling that is being permitted in their watershed area before it starts. Contact the state permitting agency to inquire about new and pending permits, and attend public hearings or meetings that may involve the source water. Be familiar with the regulations for drilling for gas and oil in your state. Get the community involved; having more eyes on what is happening promotes awareness, much like a neighborhood watch program.

Lab test results that drinking water systems normally obtain to meet SDWA requirements and that wastewater systems get for the National Pollutant Discharge Elimination Systems (NPDES) requirements, as well as information available from the state primacy agency, are valuable and establish a baseline for any future anomalies. Establishing a good history with certified lab results will be important to show changes in water quality if changes occur.

Drinking water systems should keep an eye on their raw water quality and wastewater systems should watch their influent wastewater for any significant changes. Changes to look for include high levels of total dissolved solids (TDS), conductivity, total suspended solids (TSS), chloride, methane, bromide, pH, and radon. Be especially cautious about chloride and bromide. Bromide creates high levels of disinfection byproducts when a drinking water system uses chlorine for disinfection. For systems using ozone as a disinfectant, bromine and ozone react to form bromate, a primary contaminant regulated under the SDWA. Bromide and

chloride in the influent entering wastewater treatment plants is hard to remove and can be passed through relatively untreated into receiving waters.

Monitoring the source water for drinking water systems and influent for the wastewater water systems should include volatile organic compounds, TDS, conductivity, TSS, chloride, bromide, dissolved methane, pH, and radon. Systems on a limited budget should concentrate on chloride, bromide, conductivity, TDS, and pH.

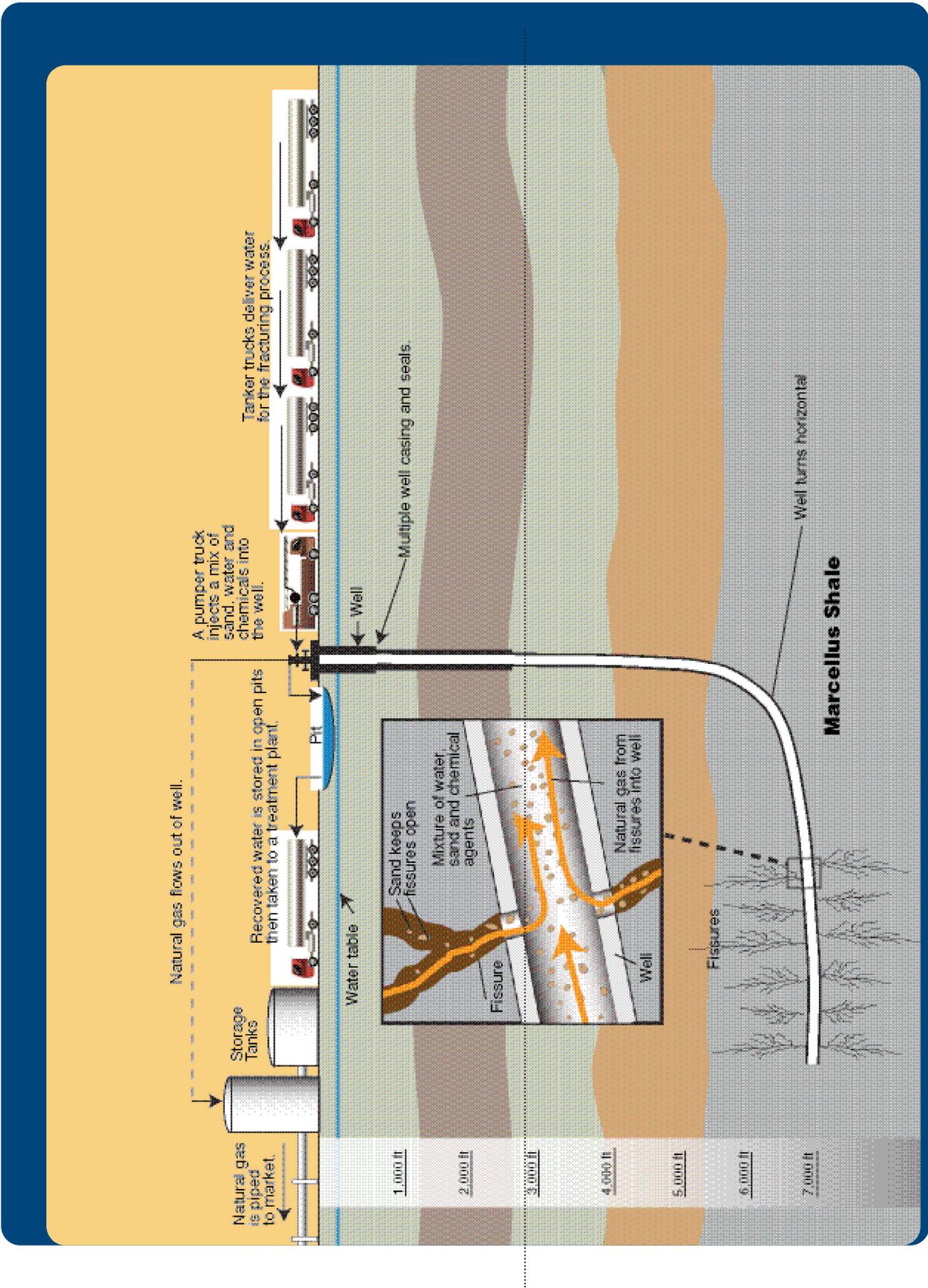
Once the baselines for these contaminants are secured, any significant changes should be viewed as potential signs that external factors such as frack fluid may have influenced the system. Armed with this information, the system can then investigate the cause more thoroughly.

Solid Waste and Wastewater Concerns Frack water disposal is one of the key concerns related to gas and oil industry activity. Typically, these operations use lined holding ponds to capture and hold the spent frack water. This helps some suspended solids settle out. When all hydraulic fracturing is finished, the used frack fluid is usually trucked from these holding ponds to a municipal wastewater plant, if the state allows it. Municipal wastewater plants that do or can accept the spent frack fluid must have the ability to treat the fluid. These systems are usually more modern and include filtration, such as membrane treatment.

If trucking to a municipal treatment system, companies must take spill precautions and have an emergency plan if a spill does occur. Some states, such as Ohio, allow deep well injection to dispose of the spent frack fluid.

If the company does not have access to any of the options discussed, they may be able to contract with companies that specialize in treating spent frack fluid. Some of these companies offer mobile treatment. Keep in mind any discharge to the surface still needs a NPDES permit. Any treatment of this fluid produces residual waste, such as solids and even filter backwash slurry. These solids or thick slurries are usually taken to a landfill that is permitted to take them.

The drilling process also generates solid waste from the cuttings (earth, rock, and other materials) removed from the borehole. A borehole's size can range from 20 inches at the top, to make room for the double and triple casings, to four inches at the bottom. When companies drill 5,000 feet down and then another 2,000 or 3,000 feet horizontally, they produce a lot of cuttings. In the past the method for disposing the drill cuttings was to dig a pit onsite and bury them. Until recently, the pit did



not have to be lined. These cuttings contain heavy metals, minerals, salts, and volatile organic compounds. They also may contain naturally occurring radioactive material. Federal law and some states specifically exclude drilling fluids, produced waters, and other wastes associated with gas and oil extraction as hazardous waste. Therefore, any landfill that may have a special waste permit can accept the drill cuttings.

Closing

The treatment, handling, disposal, reuse, and regulation of the gas and oil extraction waste are dynamic issues. Future developments to watch for include return frack water radioactivity and out-of-basin and out-of-state flows. Opportunities exist for researchers to develop improved systems for tracking water and wastewater flows, including reuse, transportation, treatment, and disposal, as well as striving for new energy resources and energy independence. Considerable care must be taken to protect the valuable fresh water we have.

References:

- Abdalla, Charles W. 2011. "Marcellus Shale Wastewater Issues in Pennsylvania—Current and Emerging Treatment and Disposal Technologies." State College, PA: Penn State Cooperative Extension.
- Baker, Lewis. 2011. "Part I: Impacts to Drinking Water Supplies from Hydraulic Fracturing." Webinar presentation (July 26), National Rural Water Association.
- Easley, Paul R. (July 2011) "Hydrofracking is it worth the risk?" *Opflow*, (July) Denver, CO: American Water Works Association.
- Fallon, Sandra. 2011. "Communities, Water Sources and Potential Impacts of Shale Gas Development," *The Water We Drink: Free Articles for Your Publication*, available at www.nesc.wvu.edu/waterwedrink.
- Little, Beth. 2011. "WV Landfills to Take Marcellus Drilling Cuttings." *Mountain State Sierran*, Volume 37, Number 5 (September/October).
- The Week. 2011. "The New Gas Boom." Volume 11, Issue 524 (July 22).
- U.S. House of Representatives, *Committee on Energy and Commerce. 2011. Chemicals Used In Hydraulic Fracturing*. Washington DC: U.S. House of Representatives

The author would like to thank Paul Ziemkiewicz, director of the West Virginia Water Research Institute, for supplying background information and suggestions for this *Tech Brief*.



NESC Engineering Scientist **Zane Satterfield** is a licensed professional engineer and water operator who previously worked for the West Virginia Bureau of Public Health, Environmental Engineering Division.