Application Note

Network Monitors Water Quality in Shale Gas Drilling Region

High-pressure injection of water, sand and chemicals that fracture shale deposits deep underground to free trapped natural gas is employed by drillers tapping the Marcellus shale beds, a geologic deposit that stretches from central New York to Virginia and contains gas believed to be worth hundreds of billions of dollars.

The process, called hydraulic fracturing, or fracking, has raised concerns about possible impacts on water quality. Tightly held "shale gas" like that in the Marcellus shale deposits accounted for 14 percent of the U.S. natural gas supply in 2009, according to the U.S. Energy Information Administration, which expects the figure to grow to 45 percent of the nation's gas by 2035 if current trends and policies remain in place.

Hydraulic fracturing has been practiced since 1949 and has become extremely popular across the U.S. as gas companies have increasingly focused on hard-to-tap gas reserves, but little information is available on its impact on surface and ground water supplies. **The Susquehanna River Basin Commission (SRBC)**, based in Harrisburg, Penn., has established a 50-station remote water quality monitoring network to provide continuous, real-time data on local streams and rivers in an effort to determine whether fracking is impacting water quality in the basin.

"There's a lot of misinformation and questions about transparency regarding what's happening out there in the real world as far as Marcellus gas drilling," says Tom Beauduy, Deputy Executive Director of the SRBC. "This monitoring network provides an excellent opportunity to provide the public with real data, and to serve as a sentinel for conditions out there."

The boom in drilling in the gas-rich Marcellus shale has highlighted the need for data on the impact of the hydrofrac wells on local streams. (Photo: Andrew Gavin)

A network of 50 remote water quality monitoring stations is designed to cover a wide range of locations and detect frac fluid spills. (Photo: Andrew Gavin)

Water-Intensive Process

To tap into shale gas in the Marcellus deposits, gas companies drill vertical wells 5,000 to 9,000 feet deep, then turn their bits horizontally for another 3,000 to 10,000 feet to maximize the amount of shale each wellhead can reach. Steel casing surrounded by cement is designed to isolate the well from groundwater as the shaft travels deep into the bedrock. When the well is complete, explosive charges are pushed to the horizontal portions of the well to breach the casing and begin the fracturing process. After the initial cracks are made in the brittle shale, fracturing fluid is pumped down the well at high pressure to further pry open the bedrock and free the gas.

Hydraulic fracturing is a water-intensive process—3 to 5 million gallons of frac fluid are typically used to fracture the deposits reached by an individual well. Of that solution, more than 90 percent is water. Sand, which props open the fissures in the fractured deposit, comprises about 9 percent of the mix. Each drilling company's proprietary blend of other ingredients, which can range from mineral oil lubricants to pH adjustors to biocides, makes up the rest, accounting for 0.5 to 2 percent of the volume, according to the U.S. Environmental Protection Agency (EPA).

Most of the known ingredients in frac fluid are relatively benign, notes EPA, including products like mineral oil, guar gum and citric acid. However, others such as diesel fuel, ethylene glycol, and the biocide glutaraldehyde can present a significant environmental concern—in the Marcellus wells, up to 10 percent of the frac fluid returns to the surface within 30 days of injection as "flowback."

As many as 400 trucks serve a well during the fracturing process, hauling frac fluid and produced water to and from the drill pad. Wastewater ponds may also be constructed for temporary storage. Both raise concerns over the danger of spills into local

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streams, notes Andrew Gavin, Manager of SRBC's Monitoring and Protection Program.

Designing the Network

Building on SRBC's experience with a drinking water quality monitoring network established almost a decade ago, Gavin and his colleagues developed a plan to deploy sondes—rugged probes that collect and transmit information on water quality—for long-term, continuous monitoring at 50 sites in the Susquehanna basin where it overlies Marcellus shale in Pennsylvania and New York.

Each station consists of a YSI 6600 V2-4 multiparameter sonde in a protective PVC housing tethered to the streambank and connected to a data platform. Dataloggers are connected to cell modems—or if a cell signal is unavailable, a satellite transmitter—and powered by a solar panel.

Drillers have to disclose the contents of their long-secret frac fluid formulations, but monitoring for specific contaminants in the field is not viable. Instead, SRBC focused on monitoring parameters that would indicate a likely spill of either a saline solution or mineral-rich deep groundwater—temperature, conductance, pH, dissolved oxygen (DO), and turbidity. Monitoring those parameters as well as water level can also yield insight on other phenomena such as acid rain or turbidity from storm events, Gavin notes.

The Commission chose three types of monitoring sites, says Gavin—streams close to existing wells or truck routes, reaches where infrastructure and other conditions make it likely that wells will be established nearby, and more pristine streams in highly forested areas outside the expected drilling zones. Some stations also monitor high-value watersheds such as municipal water supplies or popular recreation areas. To take full advantage of the chance to gather new data on local watersheds, the network sites are located in areas not already covered by U.S. Geological Survey monitoring efforts

The range of locations should provide a useful combination of baseline data, evidence of changes, and insight into local stream systems that have not been well-studied in the past, says Gavin.

The size of the watershed connected to each site was a critical decision.

"In looking at some of the critical criteria for choosing locations, the question became, 'what would be the most likely volume of a wastewater spill, leak or breach we'd be dealing with?'" Gavin notes.

Breaches or leaks from wastewater storage ponds near wells present a significant water quality threat. But smaller spills can also be a problem. For instance, an average tanker truck carries 5,000 gallons. A spill of that size could easily be diluted in a large watershed, or get flushed past a monitoring station so quickly that it would be missed if the network protocols weren't established properly.

"We conducted bench tests with YSI equipment in the lab

Matt Shank of the SRBC installs a water quality sonde in a PVC pipe to endure winter and summer conditions. (Photo: Heather Hardeman)

Jake Wilson (left) and John Balay of the Susquehanna River Basin Commission install a water quality monitoring station on Hammond Creek. (Photo: Andrew Gavin)

and simulated frac wastewater," says Gavin. "We determined that if we targeted watersheds no greater than 60 to 80 square miles, they generally have flows where we could detect changes in water quality if wastewater was introduced into the stream." Most of the monitored streams run below 100 cubic feet per second (cfs) 80 to 90 percent of the time, and flow in the single digits or teens during low-flow conditions.

"We have all of our stations taking observations every five minutes," Gavin adds. "It goes back to what we defined as our most probable scenario—a volume of 5,000 gallons carried in

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a truck. With a plume of that concentration, we could detect at least some part of it—the beginning, middle or end—within a five-minute interval."

If key parameters surpass normal levels, the station triggers an alarm to prompt an investigation.

The system was put to the test in May 2010 when a wastewater pit liner breached, releasing frac flowback water near Bob's Creek in western Pennsylvania. The drilling company reported the breach to state officials, and SRBC paid special attention to data coming from a sonde seven to eight miles downstream of the spill.

"We were pleased that it wasn't a large volume, but we were able to see a distinctive breakthrough curve," Gavin says. You could see the rise in conductance for about 24 hours, then the fall as it moved through the system. In that sense, we had a little test to see if we could pick up an event."

Logistical Considerations

Some logistical considerations also have to be taken into account. For instance, notes Gavin, stations must be situated so the monitoring instruments stay submerged even during low-flow conditions, and can be placed deep enough to stay below the ice during the winter. The channel should also provide enough flow to prevent leaves and sediment from building up around the sonde, he adds.

Access is another big logistical concern. SRBC has built its monitoring stations on both public and private land. Each has its benefits and challenges.

Siting a station on public land is a simple matter of coordinating with whichever state agency controls the property, though Gavin notes that some state-owned areas were a bit too public, raising concerns about vandalism in areas with heavier traffic. Stations on private land can be more secure, but working with landowners can have its challenges.

"You have to have private landowners agree to participate," notes Beauduy. "Several landowners stepped up immediately. Others were concerned about the stations being near them, or didn't want people coming across their property."

Reliability is Key

Every six to eight weeks, SRBC staff visit each monitoring station to rotate the sonde with a lab-calibrated replacement, conduct field calibration for the replacement instrument, and bring the long-deployed sonde back to the lab for calibration, cleaning and QA/QC before it's redeployed at another station. Durability and stability are key to making the system work smoothly.

"The YSI sondes have been very reliable, with even lower maintenance needs than expected," Gavin says. "They're very versatile and durable for field deployment. I was familiar with YSI products from when I worked for USGS back in the early '90s, and we had quite a comfort level with the company's sondes from our drinking water monitoring system back in 2003."

During the regular maintenance visits, technicians also collect water samples to be lab-tested for pH, chloride, barium, total dissolved solids (TDS), sulfate and total organic carbon (TOC) after each visit. Four times a year, water samples are collected for a detailed analysis including calcium, magnesium, sodium, potassium, nitrate, carbonate and bicarbonate alkalinity, carbon dioxide, bromide, strontium, lithium, and gross alpha and beta—a thorough workup that better characterizes the influence of groundwater in the stream or indicates the presence or absence of flowback wastewater. While on-site, the team also uses SonTek FlowTrackers to measure stream flow.

Fresh Data 'Round the Clock

The sondes collect observations on a five-minute interval, and transmit collected data to SRBC's office every two to four hours. Data is imported into SRBC's database and within a few minutes is posted without correction (and labeled "provisional") for public access at http://mdw.srbc.net/remotewaterquality/.

A year after the first stations went online, says Gavin, "we're at 10 million observations, but even at that level, the file size isn't that great. Analysis work is generating four-hour averages or daily averages, and we'll be running through corrections based on calibration drift."

After compiling the first year's data, SRBC is getting ready to release its first data summary. Gavin notes that more data will be required to determine if and how fracking is affecting water quality in the basin. However, a preliminary analysis shows great baseline data for the station sites, and unexpected results from some areas are prompting further study, he says.

"Some stations we're keeping a closer eye on because of the way the trends are—it may take more analysis to understand what's going on," Gavin explains. "We're also collecting supplemental data on geochemistry—water samples for lab analyses—to help characterize the natural conditions and put the continuous data into context."

A broad array of users has accessed the data. "We have everybody from just your private citizen to locals who are part of civic or watershed groups to those more specific citizen groups organized around Marcellus," says Gavin. "The state uses it as well to keep an eye on conditions. The industry itself has been watching the data. And there's been a lot of interest from universities."

The Commission posts a glossary of key water quality terms and explanations on its web site, though Gavin says most visitors to the network's web site are familiar with water quality concepts and what the data means.

Real-time data, long-term trend monitoring and spill alarms will all be important in monitoring surface water in the Susquehanna River Basin's Marcellus shale region. But the ability to collect long-term, continuous data and post it online for the world to see takes the monitoring network to an even higher level, says Beauduy.

"This is a way to provide value-added service to our member commissions, especially on something that's somewhat controversial," he says, "in a way that lets the science speak for itself and lets the public have access to the data in a transparent manner."