

PURPOSE

With the initial stages of the unconventional natural gas development activities within the Susquehanna River Basin (Basin) having been completed, the Susquehanna River Basin Commission (Commission) considered it important to review and assess those activities from a water management perspective.

The primary objectives of this report are to summarize the following information:

- the regulatory responses taken by the Commission to address this new, and previously unfamiliar, energy industry activity;
- the water use characteristics of the industry operating within the Basin;
- the various water quality monitoring activities conducted by the Commission in response to industry activity; and
- the efforts undertaken by the Commission to track the industry's compliance with its regulations.

The period of time covered by this report is focused on July 2008 through December 2013.

This is a summary of a full report that can be found at www.srbc.net.



West Creek, Cameron County, 2014.

THE COMMISSION'S REGULATORY RESPONSE

In December 2007, Commission staff began investigating water use for unconventional natural gas well development after it received information regarding drilling permits being issued in the northern tier counties of Pennsylvania. With expectations of relatively large amounts of water being withdrawn from the Basin for this process, the Commission's concerns were focused on the quantity, location, and timing of withdrawals proposed by the unconventional natural gas industry (industry).

In 2008, the Commission modified its regulations such that its review and approval authority would extend to all water withdrawn or consumed for unconventional well development, regardless of quantity or source, which departed from the Commission's traditional regulatory thresholds. The 2008 regulatory modification, along with additional modifications made in 2009, 2010, and 2011, reflects a dynamic approach in the development of policies and regulations specific to the industry. The modifications were undertaken to ensure the appropriate management controls were in place to allow unconventional natural gas development activity to occur, while avoiding impacts to competing water uses and the aquatic ecosystems of the Basin.

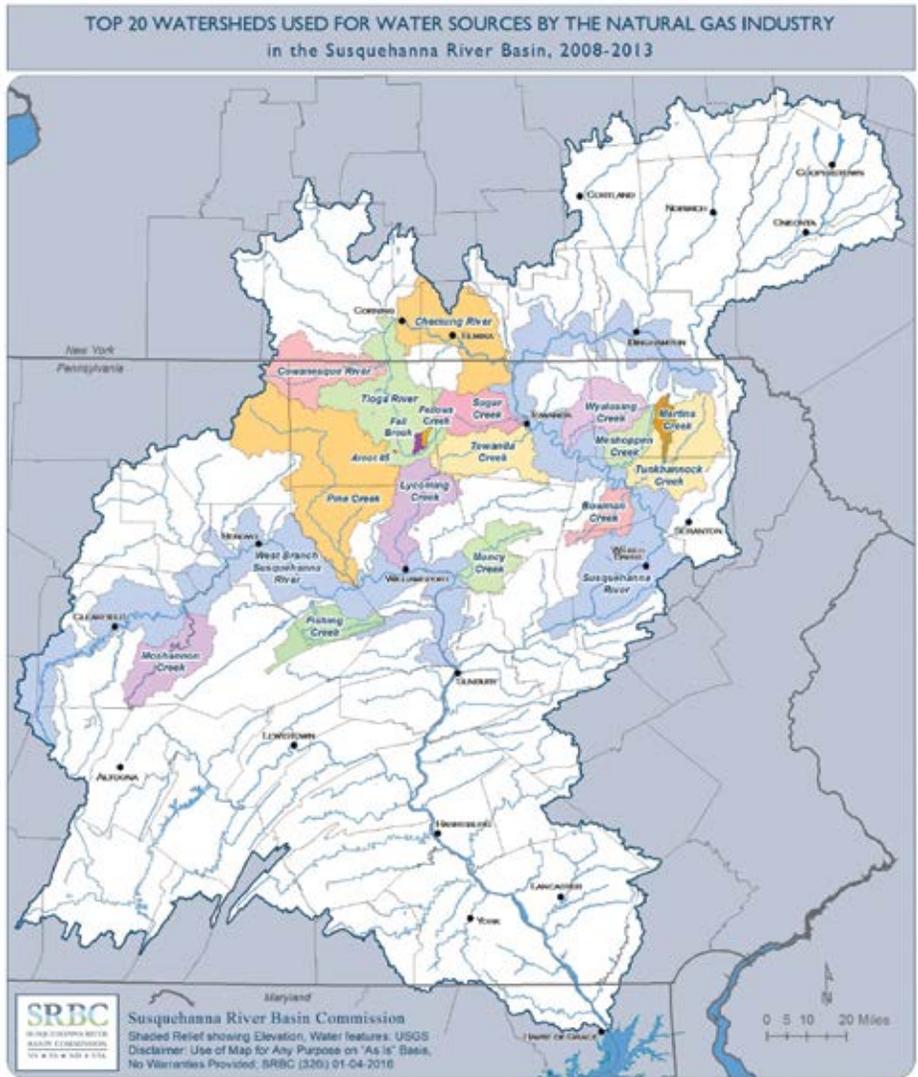


Figure 1. Locations of the Top 20 Watersheds Used as Water Sources by the Industry.

WATER ACQUISITION AND WELL DEVELOPMENT ACTIVITIES

Approvals Issued to the Industry for Water Acquisition

The Commission began issuing water withdrawal approvals for natural gas well development in June 2008. Water used by the industry originates from surface water or groundwater sources, from either inside or outside the Basin, and is sometimes associated with a public water supply. To a much lesser extent, the industry captures minor amounts of stormwater on well pads and top-hole water encoun-

tered during drilling activities.

Each approval issued by the Commission contained important requirements including:

- metering, monitoring, and reporting of water withdrawals and usage;
- submission of well completion reports;
- posting of signage with specific information at every approved water withdrawal site and drilling pad; and
- a limited, four-year approval.

Surface Water Withdrawn by the Industry

During the report period, there were a total of 222 surface water withdrawals approved by the Commission for use in

natural gas development. Approximately 48 percent of the 222 approved surface water withdrawals were actively used as water sources for the industry during the report period. A total of 9.76 billion gallons of surface water were withdrawn from waterways within the Basin and consumptively used by the industry during the report period. An additional 1.97 billion gallons of water were withdrawn within the same time period from other approved surface water sources, primarily public drinking water systems. Together, these two major sources of water comprised approximately 88 percent of the total amount of water withdrawn and consumptively used by the industry.

Of the approved surface water withdrawals, 37 were from lesser quality waters, including three discharges from wastewater treatment plants and 34 from abandoned coal mine discharges. Thirteen of the lesser quality water sites were actively used by the industry during the report period, with a total of approximately 865 million gallons of impaired water withdrawn.

Twenty individual watersheds accounted for over 97 percent of the 9.76 billion gallons of surface water withdrawn by the industry during the report period. The locations of these watersheds are presented in Figure 1.

Water withdrawals from the top five watersheds (main-stem Susquehanna River, West Branch Susquehanna River, Wyalusing Creek, Tunkhannock Creek, and Pine Creek) constituted approximately two-thirds of the total surface water withdrawn by the industry during the report period.

Groundwater Withdrawn by the Industry

Eight groundwater withdrawals were approved during the report period.

Four of those groundwater withdrawals were actively used as water sources for the industry.

A total of 998 million gallons, or 7.5 percent of the water consumptively used by the industry during the report period, originated solely from groundwater sources. The majority of this groundwater (774 million gallons) originated from public water systems or third-party water purveyors reviewed and approved by the Commission, with the remaining balance of 224 million gallons coming from other approved groundwater sources including those under the direct control or ownership of the industry.

Approvals Issued to the Industry for Consumptive Water Use

The Commission determined at the outset of unconventional natural gas activity that water withdrawn by or for the industry would be considered to be 100 percent consumptively used and thus require Commission approval. In 2008, the Commission adopted an administrative process to approve the consumptive use of water for the industry. The process, referred to as the approval-by-rule (ABR) process, is implemented on a drilling pad basis and requires that all water consumed must come from a source approved for such use by the Commission. A total of 2,249 approvals were issued by the Commission between July 2008 and December 2013 to the industry for the consumptive use of water on drilling pads. The four counties with the greatest number of ABRs were Bradford, Susquehanna, Tioga, and Lycoming. Together, these four counties contained approximately 80 percent of the total number of ABRs issued by the Commission to the industry for consumptive water use.

Consumptive Water Use

The total amount of water consumptively used by the industry from July 2008 through December 2013 was 13.4 billion gallons. The highest average daily consumptive water use calculated by the Commission on a quarterly basis for the report period was 12.2 million gallons per day (mgd) and occurred during the second quarter of 2012 (see Figure 2).

While it is important to note that the total amount of water consumptively used by the industry during the report period was significant at 13.4 billion gallons, the average daily usage rate of approximately 6.7 million gallons per day (mgd) during that same period was comparable to other water users within the Basin. For example, manufacturing-related activities consumptively used an average of 8.6 mgd of water while entertainment and recreational water users (amusement parks, golf courses, and ski areas) consumed on average approximately 6.2 mgd. Electric power generators, including nuclear power plants, consumed an average of 86.2 mgd and constituted the largest consumptive water use sector within the Basin.

Other Sources of Water and Discrepancies

During the report period, the total reported consumptive water use (13.4 billion gallons) exceeds the combined total reported withdrawals and diversions (12.77 billion gallons) by approximately 637 million gallons, or 4.8 percent of the total consumptive use. This difference is likely attributable to the capture and use of top-hole water and precipitation falling on pad sites that was correctly included by the industry in consumptive use reports, and to a lesser degree, the limits of the accuracy of the meters, as well as human error during monitoring and reporting. However, it is impossible to entirely discount that some water was withdrawn from unapproved sources, although Commission staff routinely review for non-compliance and resolved several violations involving use of unapproved sources during the report period. Overall, regardless of the discrepancy, a value of five percent or less offers confidence that accurate and comprehensive water use tracking is occurring.

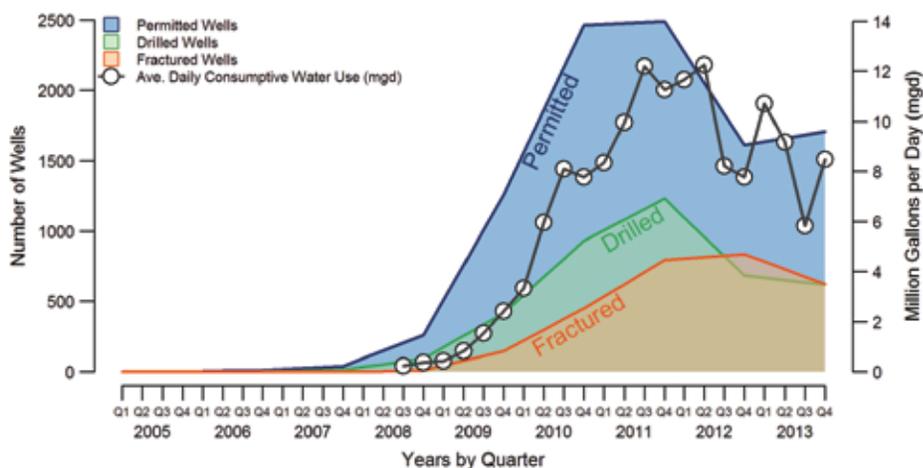
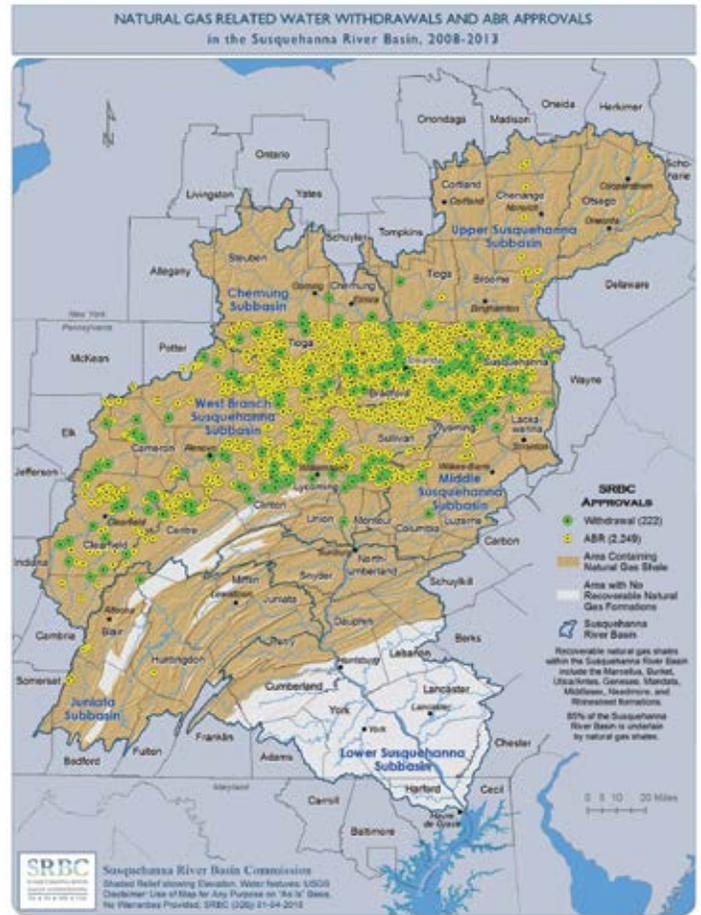
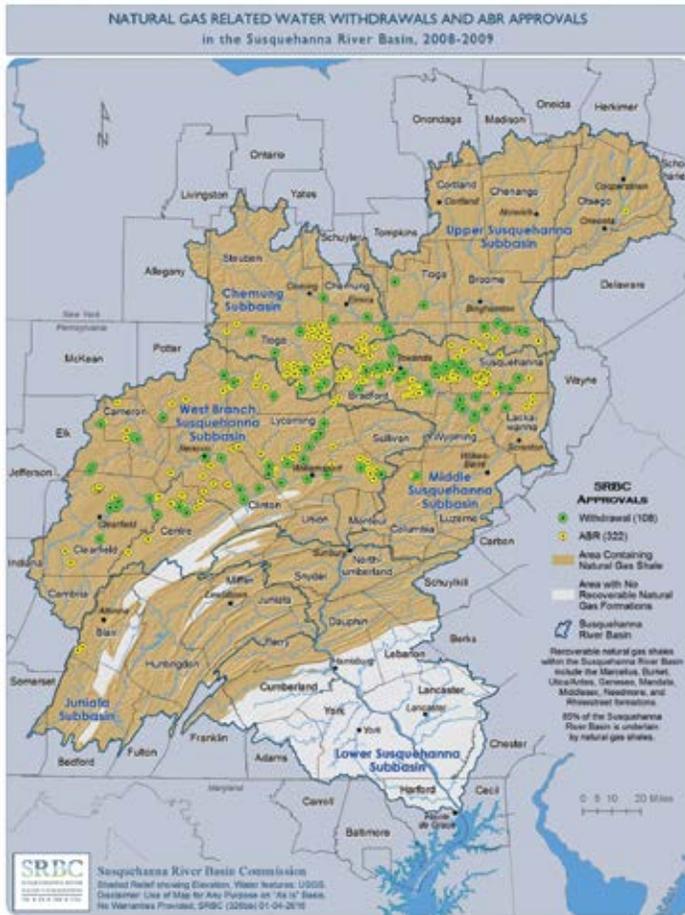


Figure 2. Wells Permitted, Drilled, and Hydraulically Fractured from 2005-2013 (PADEP, 2012 and SRBC, 2012).



Figures 3 and 4. Maps showing the extent of unconventional natural gas activities in the Susquehanna Basin during the report period.

Gas Wells Permitted, Drilled, and Hydraulically Fractured within the Basin

From January 2005 through December 2013, there were a total of 9,843 unconventional gas wells permitted by Pennsylvania Department of Environmental Protection (PADEP) within the Basin. The total number of wells drilled and hydraulically fractured within the Basin during that time period were 3,995 and 2,860, respectively (PADEP, 2012 and SRBC, 2012). Figure 2 presents a graphic summary of the wells permitted, drilled, and hydraulically fractured by calendar year during the period 2005 through 2013. The fluctuation in average daily consumptive water use is also shown in Figure 2.

The extent of industry activity in the Basin is shown in Figures 3 and 4. The maps show the concentration of activity to be predominantly in the northern Pennsylvania counties, as depicted by the yellow markers that represent Commission ABR approvals or actual natural gas drilling pad site locations.

Profile of Water Use Associated with the Hydraulic Fracturing Process

A descriptive water use profile associated with the hydraulic fracturing process used within the Basin was generated for the report period using records submitted to the Commission. Listed below are several important characteristics of the water use profile for the industry:

- The long-term average water consumption for each well fracturing event during the report period was 4.3 million gallons. Of the 4.3 million gallons of water used during an average hydraulic fracturing event, 3.6 million gallons (or 84 percent) was comprised of fresh water and 0.7 million gallons (16 percent) was comprised of reused flowback fluids.
- The average amount of flowback recovered from the wellbore of stimulated wells within the first 30 days following the release of pressure induced as part of the hydraulic fracturing effort ranged from a low of approximately five percent to a high of approximately 12 percent, with a long-term average of approximately 10 percent.

COMMISSION PROGRAMS INFLUENCING INDUSTRY WATER USE

Low Flow Protection Policy

The Commission adopted a new Low Flow Protection Policy (LFPP) in December 2012. The 2012 LFPP contains specifications for determining passby flows, defined as a prescribed streamflow below which withdrawals must cease. Passby flow protections have been a key component for insuring the operation of industry water withdrawals do not cause adverse impacts during naturally lower streamflows, which are more common in the critical summer months. Since December 2012, more than 70 percent of the water withdrawal approvals for the industry were considered significant enough for the Commission to include passby flow protection measures.

More information on the Commission's Low Flow Protection Policy can be found on the Commission's website (www.srbc.net).

Aquatic Resource Surveys

Under certain conditions, the Commission screens proposed water withdrawal sites by collecting and analyzing physical, chemical, and aquatic community data. An Aquatic Resource Survey (ARS) is conducted when one or more of the following conditions are met:

- Recent or comprehensive stream assessment data are not available;
- A state agency has designated the stream as exceptional quality;
- Wild trout populations and/or rare, threatened, or endangered species are likely to be present;
- The stream is in a headwater setting.

Data collected in an ARS are used in conjunction with information about water



Top: Staff electroshocking fish with a tote barge electroshocker. Marsh Creek, Tioga County, PA, 2014. Bottom: Brook trout can be commonly found in higher quality, cold water streams throughout the Basin, including those within the shale gas region.

availability, stream hydrology, and existing water uses in the Commission's evaluation of potential impacts to the stream.

A research project using ARS data was unable to conclude that withdrawals are unequivocally impacting fish and macroinvertebrate communities at sites included in the research. However, evidence suggests that water withdrawals, as conducted through 2012, generally do

not influence fish and macroinvertebrate communities to any greater extent than do watershed size and land use practices.

Remote Water Quality Monitoring Network

In January 2010, the Commission established the Remote Water Quality Monitoring Network (RWQMN), a real-time, continuous water quality

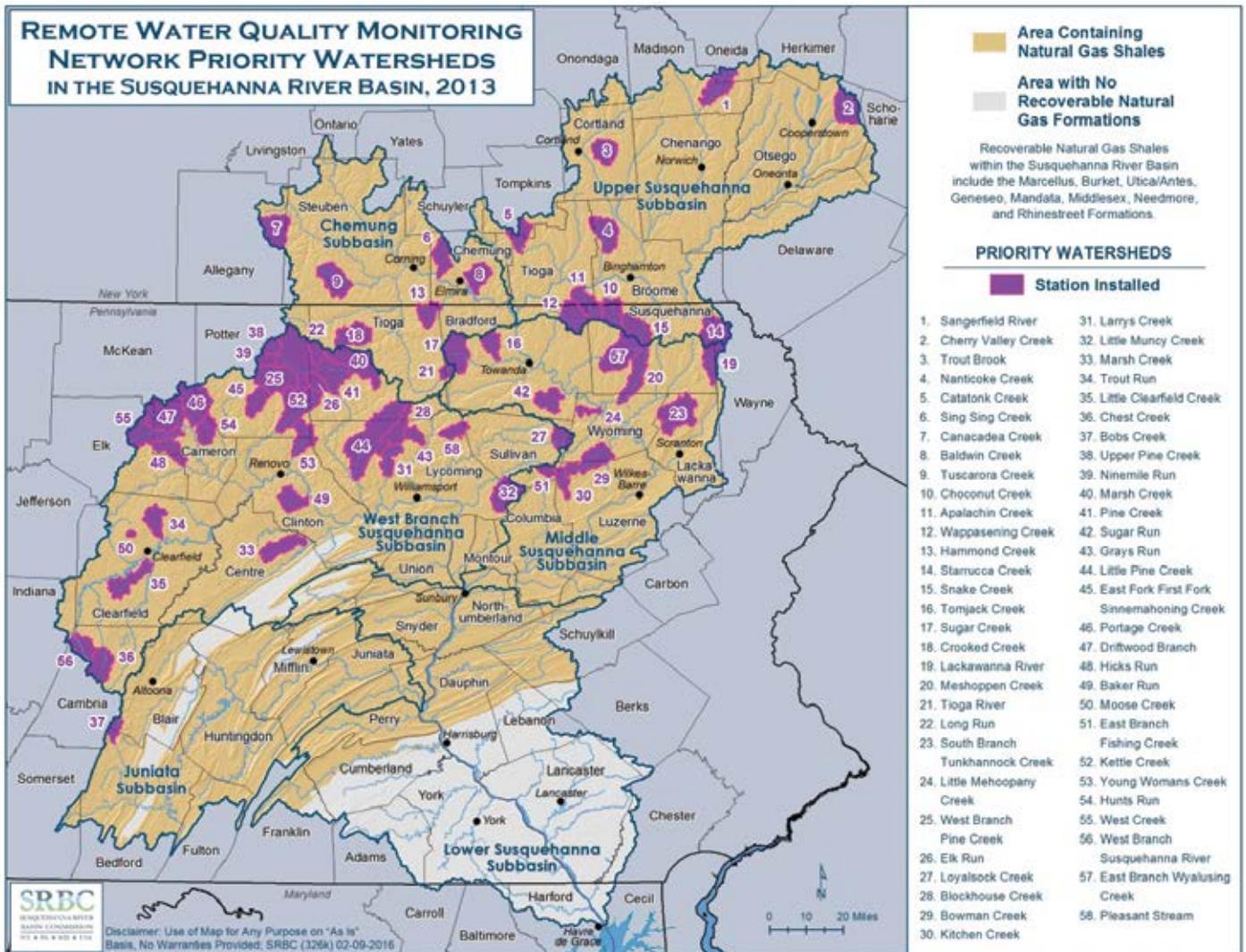


Figure 5. Watersheds Covered by the Remote Water Quality Monitoring Network.

monitoring network, for the purpose of monitoring headwater streams for potential impacts associated with unconventional natural gas development. Fifty-eight stations were established throughout the Basin that continuously measure pH, specific conductance, temperature, dissolved oxygen, and turbidity. Figure 5 provides the locations of the 58 stations.

In addition to the continuously monitored parameters, Commission staff collects supplemental water chemistry

data quarterly at the sites. The supplemental sample parameters focus on specific pollutants that can adversely impact the water chemistry and aquatic organisms and are often associated with natural gas drilling activities.

Macroinvertebrates are also collected annually at each site since they are excellent indicators of water quality and stream health.

Flowback fluids generated during hydraulic fracturing events have very high specific conductance, which makes

the parameter a very good surrogate indicator for evidence of fracturing fluids entering waterways. Statistical analyses indicated there was no significant difference in specific conductance over the years 2010 through 2013 at any RWQMN monitoring station.

A few incidents have occurred as a result of drilling activities upstream of select monitoring stations. In those cases, Pennsylvania agencies have used the continuous water chemistry data collected by the Commission to track

the events and determine if any water quality impacts occurred.

The Commission will continue to maintain the network to monitor water quality conditions throughout the region in order to keep track of conditions over time as natural gas development continues. Additionally, the data produced by the monitoring network have provided a better understanding of water quality conditions in headwater streams and also provide staff a better understanding of the influences of other land uses and possible future climate change effects.

The Commission has released three reports summarizing information collected at the monitoring stations. These reports can be found on the Commission's website (www.srbcc.net).

Compliance Program

The primary function of the Commission's Compliance Program is to conduct site inspections to ensure water users operating within the Basin, including the industry, obtain necessary approvals and maintain compliance with all relevant Commission regulations.

In 2010, the Commission developed enhanced communication systems and mobile computer-based tools to assist field inspectors with categorizing, tracking, and archiving inspection results and reports. These tools dramatically increased the overall efficiency and effectiveness of all the technical programs at the Commission, including the Compliance Program.

Generally, the industry has been compliant with Commission regulations. Nonetheless, enforcement actions are taken by the Commission when necessary.

Right: Moose Creek, Clearfield County, PA, 2010.

OBSERVATIONS

When the industry initiated operations in the Basin, the Commission acted to meet its objective of maintaining sustainable water resources by developing pertinent and fair regulations to address the new water user. A primary focus was ensuring that all water used by the industry would come from approved sources.

The primary competition for water resources associated with the industry has occurred not between the industry and other human water needs, but between the industry and the aquatic ecosystems existing within the Basin—especially in the small, lower-yielding watersheds. The Commission undertook incremental policy and regulatory adaptations to successfully address the potential for conflict between the industry and the local aquatic ecosystems for the protection of sensitive habitats and the Basin's finite water resources.

These strategies include:

- regulatory changes that required *ALL* water use by the industry to fall under Commission regulation;
- environmental screenings and on-site aquatic resource surveys;
- limitations on instantaneous and

daily water withdrawal rates;

- cumulative impact analyses related to multiple withdrawals in a watershed; and
- low flow protection measures to avoid exacerbating naturally occurring low flow conditions.

The Commission's interest in avoiding the impacts of excessive withdrawals during low flow periods resulted in many sources being approved as interruptible. In response to these low flow protections, the industry continues to develop a dynamic water storage and distribution system, allowing water to be obtained when stream conditions allow and stored for later use.

The monitoring and reporting requirements imposed by the Commission for all approved water withdrawals and consumptive water uses enabled an accurate and useful understanding of the industry's water use characteristics during the report period. Water quality monitoring and assessment work performed by the Commission was also very effective in establishing baseline conditions and identifying the potential impacts on the water resources of the Basin posed by the industry's activities.



CONCLUSIONS

The considerable amount of data collected and analyzed by the Commission during the report period support the following conclusions:

- Generally, the quantity of the Basin's water resources are sufficient in magnitude to accommodate the water demands of the industry concurrently with other water users currently operating within the Basin.
- Concerns related to the impacts to water sources are focused on the timing and location of the withdrawals and are adequately addressed by the low flow protection measures and other protective operating conditions.
- To date, the Commission's monitoring programs have not detected discernible impacts on the quality of the Basin's water resources as a result of natural gas development, but continued vigilance is warranted.

Looking ahead, the Commission will use the observations made and conclusions drawn from the report to inform and direct its future efforts. Some future challenges and opportunities that will be addressed by the Commission include the following:

- Through future regulatory practices, encourage more robust and sophisticated industry-wide water delivery systems anchored in larger, more sustainable and uninterrupted water features of the Basin.
- Enhance water quality monitoring and assessment methods to assist our member jurisdictions with ensuring preservation of the quality of the Basin's water resources.
- Expand the use of technology to enable Commission staff to work more effectively and transparently and to be more responsive to inquiries from the general public and the regulated community.
- Facilitate greater use of lesser quality waters within the Basin to reduce the reliance on higher quality streams and rivers.
- Continue to encourage the incorporation of produced fluids into the industry's water delivery system to decrease the need for future disposal of these fluids and to reduce the reliance on fresh water resources for future hydraulic fracturing activities.

Overall, this assessment provided the framework for the Commission to review and reflect upon its role in managing industry activities during the start of natural gas development in the Basin, and as a result, it will better insure continued sustainable management of the water resources of the Basin into the future.

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