

Summary

WATER USE ASSOCIATED WITH NATURAL GAS DEVELOPMENT IN THE SUSQUEHANNA RIVER BASIN: AN UPDATE OF ACTIVITIES THROUGH DECEMBER 2018

INTRODUCTION

Approximately 85 percent of the Susquehanna River Basin (Basin) is underlain by black gas-bearing shales — including the Marcellus formation, one of the richest deposits of natural gas in the lower 48 states (Figure 1, page 2). Shale gas could not be developed without water, and by the close of 2018, more than 4,600 wells had been hydraulically fractured in the Susquehanna River Basin using 26.3 billion gallons of fresh water.

Unlike many water users, the natural gas industry's water use is generally high magnitude but low frequency, controlled to a large extent by fluctuating market forces that determine schedules for well drilling and hydrofracturing. A picture of the industry's water use has developed over the 10 years of high-volume hydraulic fracturing activity — one that is more accurate than previous studies based only on data from the early “boom” years. As the natural gas industry in the Basin has matured, well development activities have slowed and water use has evolved to reflect changes in infrastructure, technological advancements, and economic considerations.

PURPOSE

The Susquehanna River Basin Commission (Commission or SRBC) has authority over water withdrawals and consumptive uses to regulate individual and cumulative impacts to the water resources of the Basin. When the unconventional natural gas industry emerged as a significant new water user in 2008, Commission regulations required that well construction, drilling, and hydraulic fracturing could not commence without prior approval of the water use associated with natural gas development. These approvals require monitoring and reporting for all water withdrawals and consumptive uses. In doing so, the Commission has collected extensive and accurate data concerning some characteristics of the industry's water use.

Following a decade of the unconventional natural gas development within the Basin, SRBC has reviewed the data describing the natural gas industry's water use. The primary objectives of this report are the following:

- summarize water withdrawal and use data in the Basin through December 2018,
- evaluate the evolution of water use characteristics,
- assess any developing long-term trends and basin-wide implications of that use, and
- review the industry's activities from a water management perspective.

The Commission has completed separate reports describing its ongoing water quality monitoring activities, including: Remote Water Quality Monitoring Network Data Report of Baseline Conditions 2010-2013, Publication No. 297, (Hintz and Steffy, 2015); Continuous Water Quality Trends Adjusted for Seasonality and Streamflow in the Susquehanna River Basin, Publication No. 312, (Hintz and Markowitz, 2016); Estimation of Suspended Sediment Concentrations and Loads Using continuous Turbidity Data, Publication No. 306, (Steffy, 2016); and Remote Water Quality Monitoring Network/ PA Department of Conservation & Natural Resources Technical Summary, Publication No. 316, (Berry, 2019).

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

Freshwater impoundment near Wappasening Creek, Bradford County, Pa

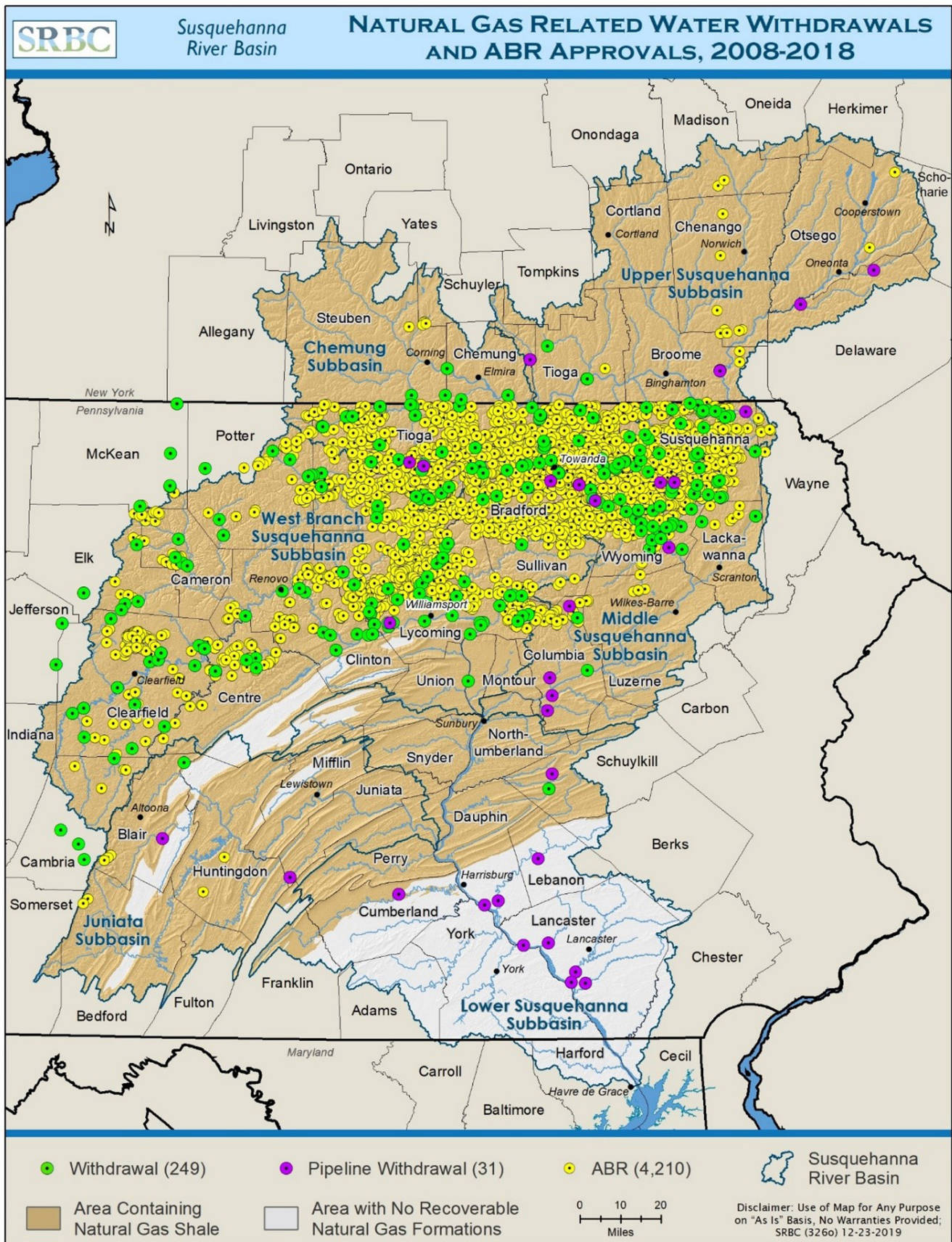


Figure 1. Map showing the extent of natural gas shales and unconventional natural gas activities (including water withdrawals for gas development, withdrawals for pipeline construction, and drilling pad approvals referred to as ABRs) in the Susquehanna River Basin, 2008-2018

WATER ACQUISITION

All water withdrawn and used by the unconventional natural gas industry is subject to Commission review and approval. Water used by the industry originates from surface water or groundwater sources, from either inside or outside the Basin, and is sometimes purchased from a public water supply or other facility. The industry also captures minor amounts of stormwater on well pads and top-hole water encountered during drilling activities.

From 2008 through 2018, the Commission approved a total of 261 withdrawals from streams and rivers for use in natural gas development. Fewer than 70 of these approved surface water withdrawals were actively used as water sources for the industry during any one year. A total of approximately 21.5 billion gallons of water were withdrawn from waterways in the Basin and consumptively used by the industry. An additional 2.35 billion gallons of water were withdrawn during the 10-year period from other approved sources, primarily public drinking water systems. Together, these two major sources of water comprised approximately 93 percent of the total amount of water withdrawn and consumptively used by the industry.

Twenty individual watersheds accounted for approximately 96 percent of the approximately 21.5 billion gallons of surface water withdrawn by the industry. The locations of these watersheds are shown in Figure 2. Water withdrawals from the top five watersheds (main-stem Susquehanna River, Tunkhannock Creek, Wyalusing Creek, Meshoppen Creek, and West Branch Susquehanna River) constituted approximately two-thirds of the total surface water withdrawn by the industry.

The natural gas industry in the Basin continues to rely heavily on withdrawals from surface waters. Only five of the nine approved groundwater withdrawals were actively used as water sources from 2014

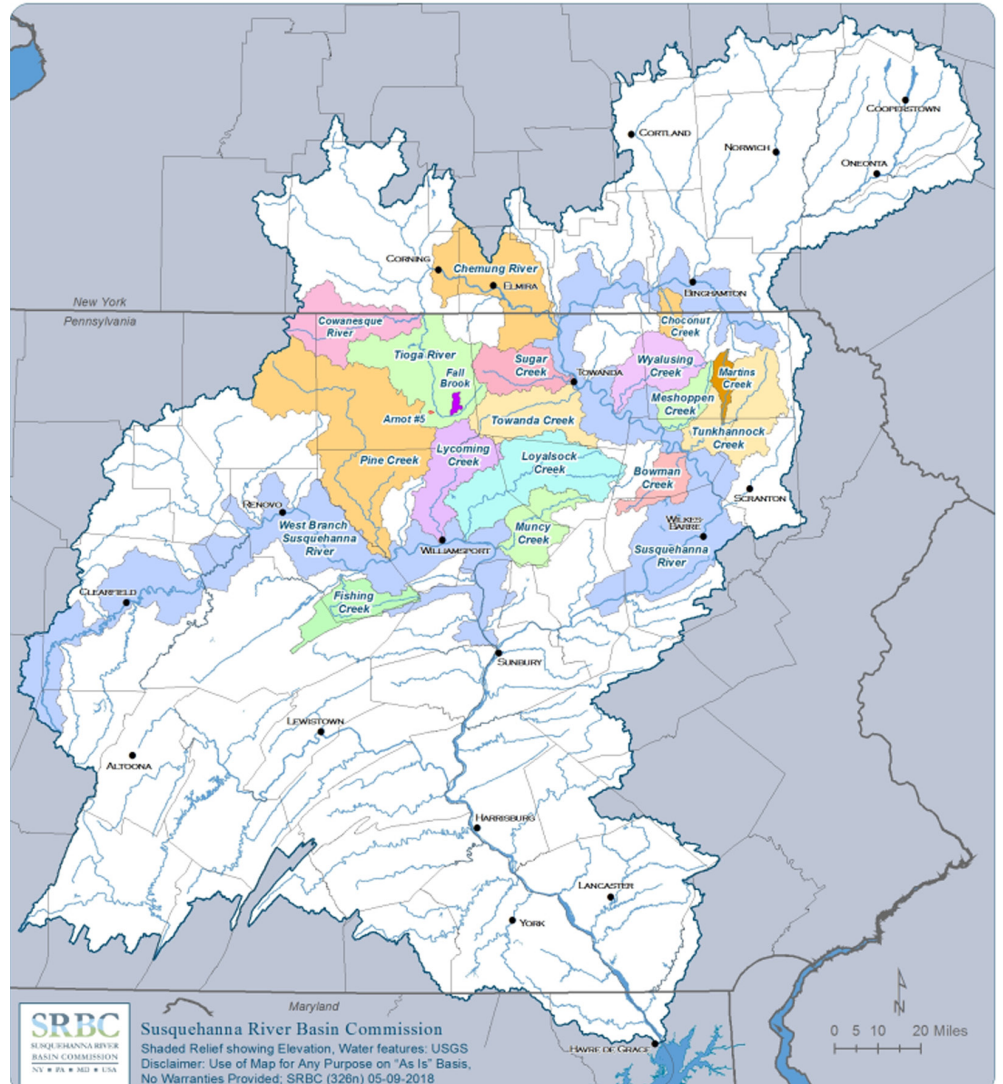


Figure 2. Locations of the Top 20 Watersheds Used as Water Sources by the Natural Gas Industry

through 2018. A total of 854 million gallons, or 6.6 percent of the water consumptively used by the industry, originated solely from groundwater sources. The percentage of groundwater used consumptively by the industry during the prior five-year period (2008-2013) was 7.5 percent, which demonstrates little change in the fresh water acquisition strategy.

The Commission has approved 13 importations of water, all from the Ohio River Basin, for use by the natural gas industry. As of December 2018, only three of

the approved importations had been actively used. Over the 10-year period, the total amount of water imported for natural gas development was approximately 351 million gallons, approximately 1.3 percent of the total amount of water consumptively used by the industry.

Although up to 90 percent of water consumptively used by the industry originated from public water systems from 2008 through the third quarter of 2009, the primary sources of water transitioned to individual surface water withdrawals

approved specifically for use in hydrocarbon development. By the first quarter of 2013, the percent of water purchased from public water systems by the natural gas industry had dropped below 5 percent of the total water used. Water sourced by the industry from public water supply systems remained below 10 percent through 2018.

CONSUMPTIVE USE APPROVALS

The Commission considers water withdrawn for natural gas development to be 100 percent consumptively used. All consumptive use approvals for the industry are issued on a drilling pad site (or well pad) basis under the natural gas specific Approval By Rule (ABR) regulation (18 C.F.R. § 806.22(f)) and require that all water consumed come from Commission-approved sources. Rulemaking adopted in 2015 requires that the approval must be maintained until all restoration has been completed according to regulations of the member jurisdiction.

The ABRs issued to the industry have a limited term of five years. Over the decade of activity ending in December 2018, a total of 4,210 ABRs (including renewals) were issued to the industry; 1,960 of these approvals were issued from 2014 to 2018 (Figure 1, page 2).

At the close of 2018, a total of 1,982 drilling pads remained active. Thirty natural gas companies were operating in the Basin. Seven of these natural gas operators each held more than 100 ABRs, and accounted for 1,548 ABRs or 78 percent of the total active ABRs.

The concentration of activity continues to be located in northern Pennsylvania. The four counties with the greatest number of ABRs are Bradford, Susquehanna, Tioga, and Lycoming. Together, these four counties contain approximately 80 percent of the total number of ABRs issued by the Commission to the industry.

The total amount of water consumptively used by the industry from July 2008 through December 2018 was 26.3 billion gallons. The highest average daily consumptive use calculated on a quarterly basis for the report period was 13.6 mgd and occurred during the second quarter of 2014. Average daily consumptive use nearly matched this peak during the second quarter of 2018, at 13.2 mgd. Note that these values for the average daily consumptive use rate by quarter were calculated by dividing the total quantity of consumptive use (in gallons) reported by the industry for a given quarter, by the number of days in that quarter.

WELL DEVELOPMENT ACTIVITIES

From January 2005 through December 2018, a total of 14,440 unconventional natural gas wells were permitted by PADEP within the Basin.¹ The well permits issued by PADEP, the well completion reports filed by the natural gas industry with PADEP, and the post-hydraulic fracturing reports submitted by the natural gas industry to the Commission were compiled by calendar year on the graph in Figure 3. The fluctuation in average daily consumptive water use is also shown in the figure. The data span the period from the first quarter of 2005 through the fourth quarter of 2018. The information summarized in Figure 3 pertains only to unconventional natural gas wells located within the Pennsylvania portion of the Basin. No conventional natural gas wells located within the Basin nor conventional or unconventional natural gas wells located outside the Basin were included in the summary.

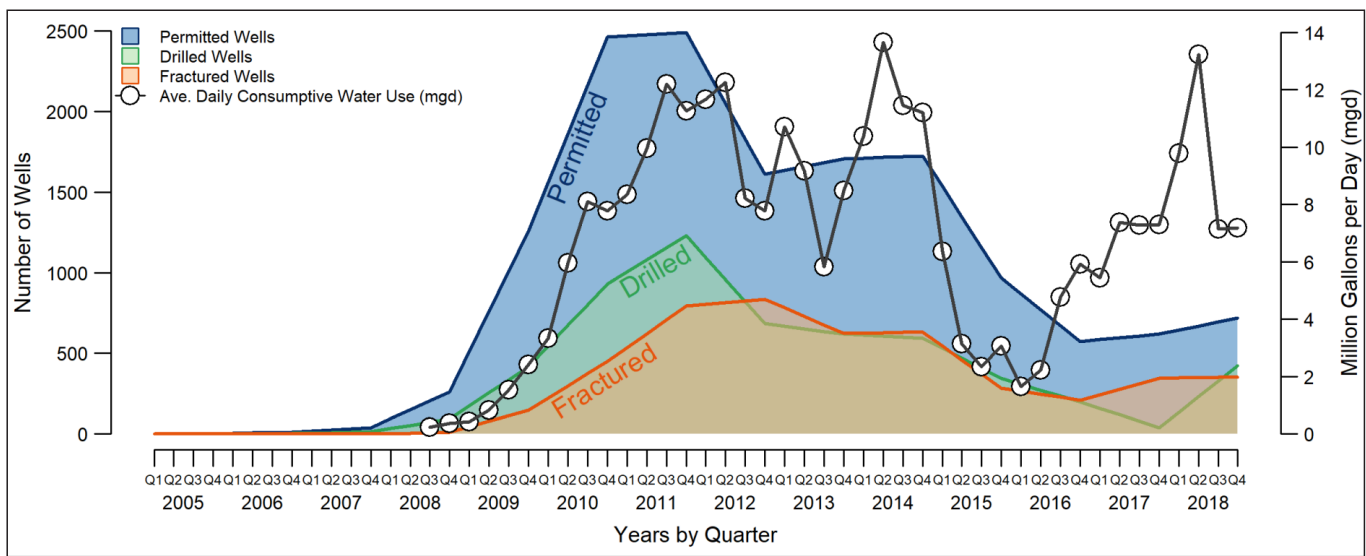


Figure 3. Wells Permitted, Drilled and Hydraulically Fractured from 2005-2018

¹ PADEP regulations require the natural gas industry to obtain permits before drilling conventional and unconventional natural gas wells and to file well completion reports within 30 days after the permitted wells are drilled.

As indicated in the figure, it was not until 2008 that substantial numbers of natural gas wells were permitted and drilled in the Basin, and it was not until 2009 that significant numbers of those wells were hydraulically fractured. The total number of wells drilled and hydraulically fractured within the Basin by December 31, 2018, were 5,593 and 4,687, respectively. Long term, approximately four out of every ten wells permitted by PADEP were subsequently drilled, and approximately 85 percent of the wells drilled were subsequently hydraulically fractured.

Annual totals of wells drilled and hydraulically fractured in the Basin increased from 2005 through 2011-12. The numbers of wells drilled and fractured declined in 2013 and continued to decline through 2016. The peak year for well completions was 2012, with 836 wells hydraulically fractured. Although well construction and completion activities in 2017-18 show a slight upward trend, the figure shows the overall level of contraction in the industry since the boom years.

PROFILE OF WATER USE

Since 2008 when the Commission adopted its ABR process, each fracturing event for every stimulated well within the Basin is captured in a post-hydraulic fracturing report submitted to the Commission. A descriptive profile of the water used to hydraulically fracture natural gas wells was developed from records submitted to the Commission.

The long-term average water used for well fracturing events between July 2008 and December 2018 was approximately 6.8 million gallons of water. On average, 83 percent was comprised of fresh water and 18 percent was comprised of recycled flowback/produced fluids.

CONSUMPTIVE USE BY THE NATURAL GAS INDUSTRY, IN CONTEXT WITH OTHER USERS

The total amount of water withdrawn and consumptively used by the natural gas industry from 2008 through 2018 was approximately 26.3 billion gallons. The long-term average daily usage rate is approximately 6.9 million gallons per day (mgd), based on withdrawals occurring 365 days per year. However, unlike many other consumptive users in the basin, the natural gas industry does not withdraw and consumptively use water consistently year-round; its withdrawals are highly variable and intermittent. From 2010-2018, the average occurrence of natural gas-related water withdrawals ranged from 93 to 150 days per year.

Reported consumptive quantities for specific sectors and projects can vary substantially due to the frequencies that water is withdrawn, used, and subsequently reported. In *The Cumulative Water Use and Availability Study* (CWUAS, 2016), a comprehensive evaluation of water use and availability throughout the Basin, SRBC concluded that consumptive water use reported by 'days used' was preferable because it reflected a more conservative and realistic impact on water resources. Consumptive use by the natural gas industry, reported by days used, also is more comparable to other water users within the Basin.

In 2018, the average occurrence of natural gas-related water withdrawals was 125 days. Consumptive use was calculated to be 9.5 mgd and 24.3 mgd, based on water use reported by average daily use (over 365 days) or actual days used, respectively. The reported consumptive use value based on actual days used is approximately 2.5 times the reported consumptive use value based on total days in 2018.

Average reported consumptive use by major sectors in 2018 is shown in Figure 5. Compared with other water users in 2018, the natural gas industry (24.3 mgd) ranks as the third largest consumptive water user, after public water supply (as exportations) and electric power generation.

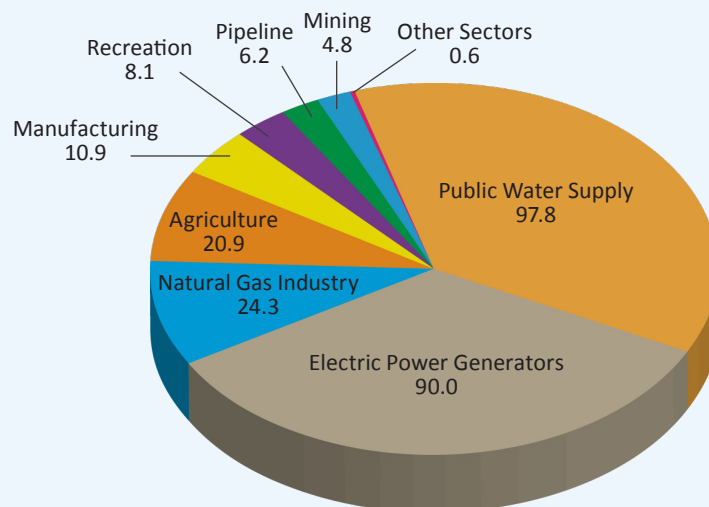


Figure 5: Average Consumptive Water Use (MGD) (2018)

The average amount of water used per fracturing event was relatively low in 2008 and 2009, ranging from 1.6 to 2.1 million gallons per event, believed to be primarily due to exploration companies performing limited fractures on vertical wells and short laterals in horizontal wells. These wells were used to hold leases and test the productivity of the target formations. As the industry transitioned from the exploratory phase to the production phase, natural gas companies drilled horizontal wells with longer laterals to fracture more gas-bearing rock. Longer well laterals and changes in well completion designs over the decade increased the amount of water used per fracturing event.

Hydraulically fractured wells in Pennsylvania used, on average, about three times as much water in 2018 than they did in 2009, as the average length of laterals increased from 2,200 feet to 7,000 feet.

From the third quarter of 2010 through the fourth quarter of 2012, the average amount of water used per event held relatively steady at 4.3 to 4.8 million gallons per event. The average amount of water used per fracturing event rose 175 percent between 2013 and 2016, from an average of approximately 5.4 to 9.5 million gallons, even as the pace of well development slowed in response to low natural gas prices. Volumes continued to increase in 2017 and 2018, to a peak average amount of 12.03 million gallons per fracturing event in second quarter 2018. Fewer wells were drilled during this period but more water was used because longer laterals and stage designs required

fracturing more rock. Overall, average water use per well for fracturing rose 600 percent between 2009 and 2018.

The natural gas industry began reusing flowback in subsequent fracturing events in 2009, increasing the amount on an annual basis from 2009 through 2014. The reuse of flowback waters represents an offset in the amount of fresh water needed for subsequent fracturing events and reduced the amount of waste fluids requiring disposal or treatment. Quantities reused may be limited, in part, by the availability of flowback. Although the annual quantity of flowback reported as injected has remained relatively steady since 2014, the percent of the total injected remains significant at 15 percent or greater, reaching a peak of 34 percent during the third quarter of 2015.

OBSERVATIONS AND CONCLUSIONS

Throughout 10 years of high-volume hydraulic fracturing activity, even during years of limited development and production, the water use for hydraulic fracturing has remained steady or increased (Figure 4). From 2010 to 2018 water use per well increased from an average of approximately 4 million gallons to 12 million gallons.

The increase in the average consumptive use amount for hydraulic fracturing processes was evidently related to industry infrastructure build-up, technology changes, and increasing lateral lengths of new wells.

The natural gas industry continues to primarily rely on streams for its water

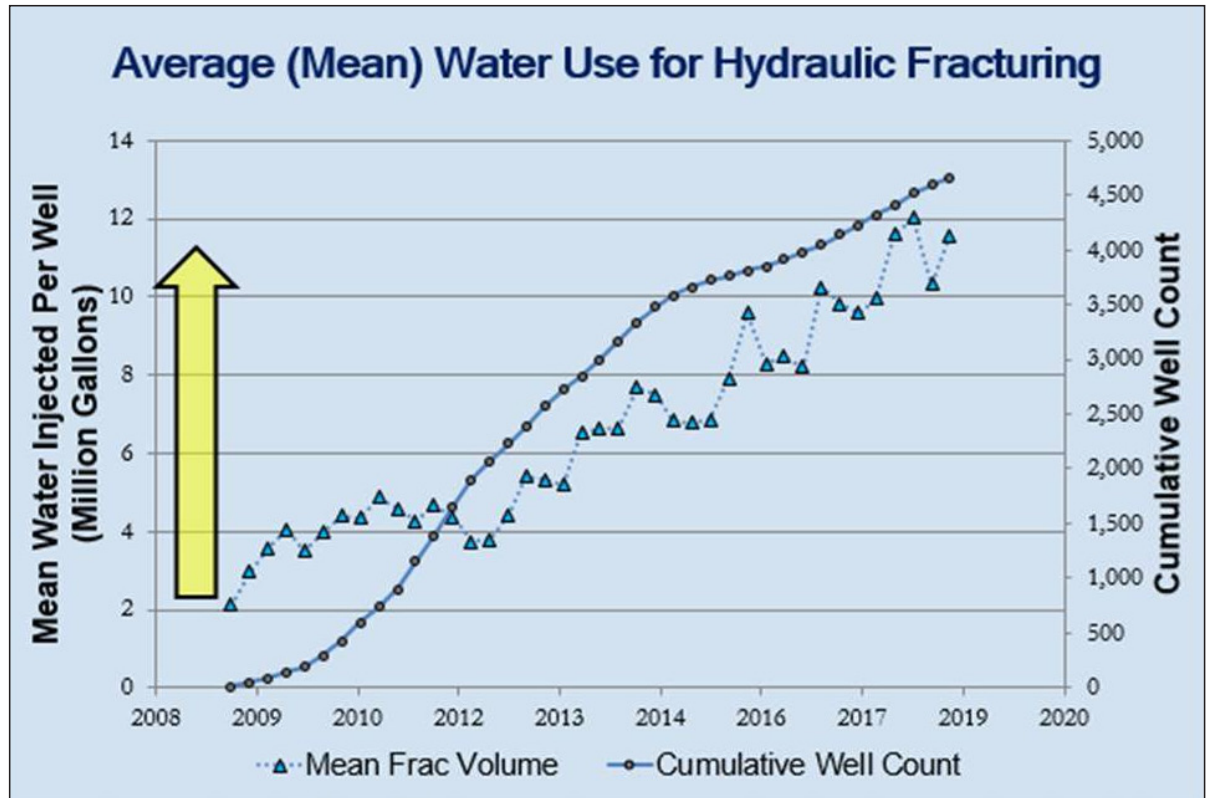


Figure 4. Average (mean) Water Use for Hydraulic Fracturing Events (2008-2018)

sources. Although the Commission has approved more than 200 withdrawal sites, logistical constraints (primarily related to transportation costs) limit the viable withdrawals to a small number of watersheds. Approximately two-thirds of the water withdrawn by the industry comes from five watersheds.

Potential adverse impacts to streams are focused on the quantity, timing, and location of the withdrawals. These concerns, including those related to withdrawals from headwater streams, have been addressed by protective operating conditions, such as withdrawal limitations and interruptions based on ecologically meaningful science backed up by on-site verification. Long-term monitoring will continue to ensure that low flow provisions provide adequate protection for aquatic communities, including fish, or

show that more conservative flow standards are needed. In the future, if water demand significantly increases, some watersheds and areas with concentrated withdrawals may need targeted management strategies.

Water used for hydraulic fracturing makes up a significant fraction of the consumptive use in the Susquehanna River Basin. Further, the natural gas industry's water demands are concentrated in a small number of watersheds, potentially creating competition and conflicts over water availability on a local scale. Various strategies could be implemented to reduce the strain on local freshwater resources, including the use of alternative water sources, additional produced water treatment and storage facilities, and efforts to recycle more of produced water.

The highly mobile, decentralized and unique use patterns of the natural gas industry's water use pose an ongoing challenge for management and oversight. The high magnitude but low frequency use, controlled to a large extent by fluctuating market forces, creates uncertainty for long-term planning of the natural gas industry's demand for water.

The natural gas industry's needs regarding water sources and water use patterns will continue to be monitored, assessed and managed. Ongoing evaluation of industry trends will be necessary to plan for and implement appropriate adaptive measures that balance energy development and sustainable water resources.



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