WATER AND UNCONVENTIONAL OIL AND GAS

In the spring of 2012, the Shale Gas Roundtable began to collect and analyze data for a regional scan of water-related issues relevant to shale gas extraction, transport, and use. Based on the information gathering and stakeholder dialogue processes, the Roundtable also was able to construct a set of recommendations focused on preventing potential water-related impacts of unconventional oil and gas development.

BACKGROUND ON THE INTERSECTION OF WATER AND SHALE OIL AND GAS

The average $3 million drilling and fracturing process required for each well uses an average of 4.2 million gallons of water, much of which has traditionally been freshwater.[36] The volume of water can vary significantly and is highly dependent on the length of the drilled lateral. More than 99 percent of the fracturing fluid is water and sand, while other components such as lubricants and bactericides constitute the remaining 0.5 percent.[37] This fracturing mixture enters the well bore, and some of it returns as flowback or produced water, carrying with it, in addition to the original materials, dissolved and suspended minerals and other materials that it picks up in the shale. Once in production for several years, natural gas wells can feasibly undergo additional hydraulic fracturing to stimulate further production, thereby increasing the volume of water needed for each well.

Approximately 10-25 percent of the water injected into the well is recovered within three to four weeks after drilling and fracturing a well.[38] Water that is recovered during the drilling process (drilling water), returned to the surface after hydraulic fracturing (flowback water), or stripped from the gas during the production phase of well operation (produced water) must be disposed of properly. The recovered water contains numerous pollutants such as barium, strontium, oil and grease, soluble organics, and a high concentration of chlorides. The contents of the water can vary depending on geological conditions and the types of chemicals used in the injected fracturing fluid. These wastewaters are not well suited for disposal in standard sewage treatment plants, as recovered waters can adversely affect the biological processes of the treatment plant (impacting the bacteria critical to digestion) and leave chemical residues in the sewage sludge and the discharge water.

Many producers have been transporting flowback and produced water long distances to acceptable water treatment facilities or injection sites. But deep well injection – an important option for shale gas water disposal – is now also meeting challenges. Pennsylvania's ability to provide deep well injection sites is somewhat limited by its use of underground geologic areas for seasonal subsurface storage of natural gas in anticipation of winter use. The state currently has seven operating brine disposal injection

[36] Yoxtheimer, Dave. "Potential Surface Water Impacts from Natural Gas Development." pg.5. http://www.marcellus.psu.edu/resources/PDFs/Halfmoon%208-24-11.pdf
[37] Ibid. pg.4.
[38] Hammer, Rebecca and Jeanne VanBriesen. "In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater,"pg. 11. May 2012. http://www.nrdc.org/energy/files/Fracking-Wastewater-FullReport.pdf

sites – one well in Beaver and two wells each in Clearfield, Somerset, and Warren counties – all of which are overseen by the U.S. Environmental Protection Agency under the Underground Injection Control (UIC) Program.[39] These wells are permitted as Class II, which means only fluids associated with oil and natural gas production can be injected into them.[40] Ohio and West Virginia have opted to run their own UIC programs and have many permitted deep well injection sites available. These wells have been a popular disposal choice for Pennsylvania developers. However, a series of small Ohio earthquakes that began in late 2011 were believed to be the result of high-volume flowback and produced water injection. New Ohio injection well development was halted until the state instituted a more rigorous set of regulations in March, 2012.[41] The moratorium has since been lifted on all but one of the deep well injection sites, and new regulations have been put in place requiring seismic testing before, during, and after injection.[42] Similar seismic activity has been observed in Arkansas, Oklahoma, and Texas.[43]

The water disposal challenge has spurred a new water treatment industry in the region, with entrepreneurs and established companies creating portable treatment plants and other innovative treatment technologies to help manage produced water. An example includes the facility operated by Reserved Environmental Services near New Stanton, PA. This facility processes hundreds of thousands of gallons of shale gas wastewater daily from many of the region's natural gas developers through the use of a zero liquid discharge wastewater treatment plant. The treated water is then recycled and reused by industry to fracture additional wells. Another example of innovative water treatment technologies is Epiphany Water Systems, which recently negotiated an agreement with CONSOL Energy to pilot its solar-powered water treatment system at well sites.

While progress has been made on the water quantity and quality impacts of shale gas development, challenges remain, including the potential cumulative long-term water impacts of the industry. Additional water research and environmental policy changes will be necessary in order to fully realize the economic opportunity of the region's natural gas wealth while safeguarding the environment.

RECENT GOVERNMENT ACTIONS ON WATER AND SHALE GAS

Given the economic benefits and environmental challenges that result from the continued development of shale gas in the region, government entities at all levels have established policies and regulations to support responsible extraction. The overview below summarizes critical aspects of this recent government activity related to water issues.

[39] StateImpact. "Deep Injection Wells in Pennsylvania." http://stateimpact.npr.org/pennsylvania/2011/09/22/burning-question-where-are-pas-deep-injection-wells/

[40] EPA. "Class II Wells – Oil and Gas Related Injection Wells (Class II)." http://water.epa.gov/type/groundwater/uic/class2/index.cfm

[41] Hopey, Don. "Ohio Earthquakes Caused by Deep Disposal Well for Marcellus Wastewater." *Pittsburgh Post-Gazette*. March 9, 2012. http://pipeline.post-gazette.com/index.php/news/archives/24374-ohio-earthquakes-caused-deep-disposal-well-for-marcellus-wastewater

[42] Speakman, Burton. "D&L Energy Seeks Permit for New Injection Well." *Akron Beacon Journal.* Nov. 16, 2012. http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/d-l-energy-seeks-permit-for-new-injection-well-1.350769

[43] National Research Council of the National Academies. "Induced Seismicity Potential in Energy Technologies." pg.77-81. 2012. https://download.nap.edu/catalog.php?record_id=13355#toc

FEDERAL

U.S. Environmental Protection Agency (EPA) Hydraulic Fracturing Study

During fiscal year 2010, the U.S. House of Representatives Appropriations identified the need for a comprehensive study of the hydraulic fracturing process and its relationship with drinking water and groundwater resources.

At the direction of Congress, EPA is investigating the relationship between surface and ground water resources and hydraulic fracturing at every stage of the process, including the source of water; the creation of hydraulic fracturing fluid by combining water, sand, and chemicals; the injection of the fracturing fluid into the wells; the flowback of the produced water; and finally the treatment of the wastewater and its ultimate disposal. The research is designed to examine any potential impacts that the process has on drinking water resources at each stage, as each stage offers its own set of potential complications and consequences.

A progress report was released in December 2012. The draft final report will be released in 2014 for peer review and public comment. In March 2013, EPA announced the formation of its Hydraulic Fracturing Research Advisory Panel, which will provide feedback on the 2012 progress report, solicit public input, and peer review the 2014 draft report. David Dzombak, Walter J. Blenko Sr. University Professor of Civil and Environmental Engineering at Carnegie Mellon University, will chair the Advisory Panel.[44]

EPA Proposed Regulations

On October 20, 2011, EPA announced its intent and schedule to develop wastewater standards for the natural gas industry. These regulations would not apply to recycled or injected waters but to that wastewater disposed at the surface through permitted treatment facilities. The proposed rule for natural gas wastewater will be released in 2014.

Furthermore, EPA announced on November 23, 2011, that it would be moving toward a proposed rulemaking on enhanced fracturing chemical testing and disclosure under the Toxic Substances Control Act. This movement was in partial response to a petition by environmental groups that asked for EPA to become involved in the disclosure of gas development materials and chemicals. No timeline has been announced for this rulemaking.

PENNSYLVANIA

Total Dissolved Solids

Due to increased concern over drinking water supplies being adversely affected, the Pennsylvania Department of Environmental Protection (DEP) in 2010 revised Chapter 95, Pennsylvania Wastewater Treatment Requirements, to address the cumulative impacts of oil and gas wastewater discharges. The new rule for wastewater treatment plants limits the discharges of total dissolved solids (TDS) such as sodium and chloride from new or expanded facilities that take oil and gas wastewater. These

[44] EPA. Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources: http://www.epa.gov/hfstudy

wastewaters must now be treated to drinking water standards. For example, this means that any new discharges cannot exceed 250 mg/l for chlorides. The reduction in TDS also precludes most of the potential for radium contamination. The new Chapter 95 rule was designed to increase the use of recycled water and promote the development of alternative forms of disposal while also promoting the use of alternative types of fracturing fluids.

In April 2011, DEP called on the Marcellus gas industry to voluntarily stop sending its wastewater to the 15 grandfathered wastewater treatment plants not covered under the new Chapter 95 rule. The request came amidst growing concern that the treatment plants were unable to effectively process and treat wastewaters from drilling operations. Michael Krancer, then secretary of DEP, gave the industry a 30-day deadline to voluntarily comply with this request and received cooperation from all operators by the deadline. It is important to note that this voluntary compliance applied to flowback and produced water from unconventional wells and not to wastewaters from conventional natural gas extraction activities.

Additionally, in 2010, DEP announced a rulemaking for establishing an ambient water standard for chloride levels (in addition to the end-of-pipe discharge standard in the 2010 Chapter 95 update).[45] The proposed rulemaking recommended adopting the current EPA National Aquatic Life Criteria for chloride of a four-day average of 230 mg/L and a one-hour average of 860 mg/L.[46] DEP eventually withdrew the chloride ambient water standard over concerns that it was out of line with other states' standards. Some stakeholders believe an ambient chloride standard could substantially decrease the possibility of water degradation from all oil and gas activities in Pennsylvania. EPA is currently reviewing and updating its recommended chloride criteria. These new criteria could be used in the future by Pennsylvania should it decide to pursue the ambient standard.

Comparison of MSAC Recommendations and Act 13

In March 2011, Governor Tom Corbett created the Governor's Marcellus Shale Advisory Commission (MSAC) to examine existing Pennsylvania statutes and provide recommendations to "promote the efficient, environmentally sound, and cost effective development of Marcellus Shale and other unconventional natural gas resources."[47] The Commission comprised stakeholders from industry, environmental organizations, and state and local government. Ultimately, the Commission developed 96 recommendations, including 43 related to environmental protection.[48] The Commission's recommendations appeared to significantly inform the subsequent content of Act 13, but in some cases, the Commission's recommendations were reworked or omitted from the final bill. An informational comparison of Act 13 water provisions and the MSAC's water recommendations can be found in Appendix C. Some of the MSAC recommendations that have not yet been addressed might be implemented through administrative or regulatory changes, and others may require additional legislative attention.

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[45] "Ambient Water Quality Criterion; Chloride (Ch); Notice of Proposed Rulemaking." 40 Pa.B.2264. May 1, 2010. http://www.pabulletin.com/secure/data/vol40/40-18/771.html

[46] Ibid.

[47] Penn. Exec. Order No. 2011-01 (April 3, 2011)

[48] "Governor's Marcellus Shale Advisory Commission Report." July 22, 2011. pg.103. http://files.dep.state.pa.us/PublicParticipation/MarcellusShaleAdvisoryCommission/MarcellusShaleAdvisoryPortalFiles/MSAC_Final_Report.pdf

KEY ISSUES IN REGIONAL SHALE GAS WATER MANAGEMENT

The issues discussed below were identified through research and interviews with stakeholder groups as the priorities that are critical to understanding and improving the management of water and natural gas resources. The Roundtable developed recommendations with a risk-based life cycle approach to managing the cumulative water impacts.

WATER SOURCING

An essential component of shale gas development is obtaining the quantities of water necessary for drilling and fracturing operations. Overall, freshwater usage for gas development is estimated to be less than 1 percent of Pennsylvania's total annual freshwater withdrawals.[49] This usage figure, while telling, can be somewhat misleading, as it does not address the timeframes for the freshwater withdrawals nor does it indicate that much of the water is permanently retained deep underground and therefore not returned to the much shallower water table. Estimates for average total water use range from 3 to 5 million gallons per well, but per well volumes as high as 8.3 million gallons have been recorded in Pennsylvania.[50/51]

The potential problem is not necessarily the amount of water used but rather that the 3-5 million gallon withdrawals, which may take place over a matter of a few weeks, can create a dramatic spike in water usage (when compared to a lower continuous draw over a period of months). Rapid withdrawals from water bodies can create problems for aquatic ecosystems, water quality, and existing and designated uses of water. Issues related to withdrawal can be further exacerbated during periods of low stream flow or drought. Additionally, operators may choose to draw from multiple smaller water bodies when they lack access to municipal water or other large water sources, which impacts the smaller bodies to a proportionally greater degree. To offset the water withdrawal impact, some developers withdraw more slowly, at periods of high flow, and store the fresh water in centralized impoundments until it is needed.

While data concerning water extraction from the Ohio River Basin (which includes most of Southwestern Pennsylvania) is not available online (though DEP does get quarterly reports on water withdrawals), data are readily available from central Pennsylvania and the Susquehanna River Basin Commission (SRBC). In 2012, the SRBC region reported a consumptive water use of 10.4 million gallons per day (mgd) for shale gas activities.[52] Similar data are available in the Delaware River Basin Commission service territory, but the Ohio River Valley Water Sanitation Commission (ORSANCO) does not have a role in water quantity monitoring or management. ORSANCO is currently conducting a series of studies and outreach activities to determine how it should be involved with water quantity issues in the future. The Headwaters Resources Committee, staffed by Carnegie Mellon University's Steinbrenner Institute, is supporting

[49] Curtright, Aimee and Kate Giglio. "Conference Proceedings: Coal Mine Drainage for Marcellus Shale Natural Gas Extraction: Proceedings and Recommendations from a Roundtable on Feasibility and Challenges." RAND. pg.1. http://www.rand.org/content/dam/rand/pubs/conf_proceedings/2012/RAND_CF300.pdf

[50] Ibid.

[51] Penn State Cooperative Extension. "Water Withdrawals from Development of Marcellus Shale Gas in Pennsylvania." pg.2. http://pubs.cas.psu.edu/freepubs/pdfs/ua460.pdf

[52] Susquehanna River Basin Commission. "State of the Susquehanna: 2013 Report." pg.5. http://www.srbc.net/stateofsusq2013/docs/2013_SOTS_Report_Final_high_res.pdf

these studies and ensuring that perspectives from the Ohio River headwaters in Pennsylvania are included in the ORSANCO process.

Under Act 13, shale gas developers are required to file Water Management Plans before site development can occur.[53] Water Management Plans require developers to demonstrate that the withdrawals will not harm the water source and are protective of public health, safety, and welfare.[54] Water withdrawals must be in keeping with designated and existing uses of water sources.

In order to lessen the impact on local water sources, many shale gas developers are trying to find ways to offset their use of freshwater. Currently, the most viable method of freshwater usage reduction is through the recycling of flowback and produced water. Portable and stationary water treatment and recycling systems allow drillers to process flowback into an acceptable fluid for reuse in drilling operations. Although recycling flowback does lessen the impact on local water reserves, only a percentage of fracturing water is recovered from the drilling process and therefore able to be recycled.

Another possible approach to lessening local water impacts is the use of treated abandoned mine water (instead of freshwater) in the hydraulic fracturing process. Estimates place the total volume of abandoned mine water in Southwestern Pennsylvania at nearly 600 billion gallons, which is nearly 12 times the estimated annual water requirement for hydraulic fracturing under an *extremely high end* assumption of 5,000 wells per year.[55] Additionally, the Marcellus Shale formation is located over large portions of the region where abandoned mine water is available.

The use of abandoned mine water does pose some problems for use in well fracturing operations. The composition of the drainage can vary greatly depending on a variety of circumstances related to geology and location of the mine, and it can change over time. Researchers also have found large variations in pH and sulfates, which can cause scaling and gas flow obstruction.[56] An additional concern on the part of industry is the possibility of having to assume long-term liability for the mine water once operators start using it. DEP has preliminarily examined the liability issue and offered possible solutions under the Environmental Good Samaritan Act (EGSA) and Consent Order and Agreement approach.[57] The EGSA provides immunity from civil liability for "water pollution abatement projects," which are defined as treatment of water pollution on abandoned mine lands or treatment of abandoned mine drainage. Alternatively, through a Consent Order and Agreement, DEP would agree not to hold developers using abandoned mine water for fracturing water liable as long as certain conditions were met.

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[53] Act 13 of 2012, HB 1950 § 3211(m)(1)
[54] Ibid § 3203
[55] Iannacchione, Anthony. "Assessing the Coal Mine Water Resources: A Marcellus Shale Perspective." *Conference Proceedings: Coal Mine Drainage for Marcellus Shale Natural Gas Extraction: Proceedings and Recommendations from a Roundtable on Feasibility and Challenges*. RAND. pg.5.
http://www.rand.org/content/dam/rand/pubs/conf_proceedings/2012/RAND_CF300.pdf
[56] Cravotta, Charles III. "Use of Acidic Mine Drainage for Marcellus Shale Gas Extractions – Hydrochemical Implications." *Conference Proceedings: Coal Mine Drainage for Marcellus Shale Natural Gas Extraction: Proceedings and Recommendations from a Roundtable on Feasibility and Challenges.* RAND. pg.6-7.
http://www.rand.org/content/dam/rand/pubs/conf_proceedings/2012/RAND_CF300.pdf
[57] DEP. "White Paper: Utilization of AMD in Well Development for Natural Gas Extraction." Nov. 2011. pg.5.
http://files.dep.state.pa.us/Water/Watershed%20Management/WatershedPortalFiles/FINAL_WhitePaperReviewTeamFindingsForUseOfAMD_ForFracWater.pdf

Pennsylvania Senate Bill 411, sponsored by Senator Richard Kasunic, was introduced in the 2013-14 session and was temporarily tabled in March 2013. The Senate passed the same bill in the last session (October 2012), but the House did not act on it. The bill encourages the use of abandoned mine water for shale gas drilling and was crafted using policy recommendations from the Governor's Marcellus Shale Advisory Commission. In an effort to reduce the cost and liability associated with the constant treatment of these mine pools, the legislation encourages the use of abandoned mine water in gas well development and expressly provides the protections of the state's Environmental Good Samaritan Act to operators that acquire this alternative water supply. Importantly, state attention to abandoned mine water liability issues has not yet been matched by the necessary federal attention.

Water sourcing will continue to be an area that requires attention from the region and from industry, particularly the timing of withdrawals and incentivizing technological innovations that can help to reduce water needs. The sustainability of the region's water resources will likely be more stressed in the coming years by population growth, increases in demand related to other energy and industrial activities, and climate change.

Water Sourcing Recommendations

- The Susquehanna River Basin Commission (SRBC) and Delaware River Basin Commission (DRBC) play active water quantity monitoring and management roles in their respective basins. Currently, the Ohio River Valley Water Sanitation Commission (ORSANCO) is gauging its potential future involvement in water quantity issues in the Ohio River Basin. As a first step in this effort, ORSANCO is seeking the approval of a memorandum of understanding (MOU) from the governors of its eight member states, affirming their support of conducting the water quantity studies. The MOU does not commit ORSANCO or the member states to any course of action on water quantity but rather encourages an open dialogue and evaluation process. Pennsylvania should sign the MOU that supports ORSANCO's study of water quantity regulation in the Ohio River Basin and also actively engage in the forthcoming studies.
- DEP should incorporate the recommendations in the Upper Ohio Basin flow study into its water management programs and update its policy to reflect this recent research. The Nature Conservancy recently completed ecologically-based flow recommendations for streams and rivers in the Upper Ohio River Basin in Western Pennsylvania.[58] Recommendations are based on more than 150 publications and reports, streamflow analysis, and consultation with regional experts. The study was similar to one completed for the Susquehanna River Basin Commission in 2010. The recommendations therein were used to help produce the revised Low Flow Protection Policy, which was adopted by the Susquehanna River Basin Commission in 2012. SRBC's new policy creates classes of streams based on their sensitivity to water withdrawals and limits withdrawals when they are likely to have ecological impacts. DEP should consider similar factors when managing water in the Upper Ohio Basin.

[58] DePhillip, M. and T. Moberg. "Ecosystem Flow Recommendations for the Upper Ohio River Basin in Western Pennsylvania." *The Nature Conservancy.* Harrisburg, PA. March 2013. http://www.ohioriverbasin.org/largeuploads/Final%20Ecosystem%20Flow%20Recommendations%20Upper%20Ohio%20River%20PA%202013_Report&App.pdf

- The potential benefits of using abandoned mine water for hydraulic fracturing operations are well documented. The technology necessary to use this water largely exists, and the most significant barrier remains potential liability. As such, the General Assembly should adopt Pennsylvania Senate Bill 411, or similar legislation, to encourage the use of abandoned mine water in gas well development and expressly provide the protections of the state's Environmental Good Samaritan Act (EGSA) to operators acquiring this alternative water supply. The U.S. EPA and possibly Congress consider also addressing operator liability concerns under federal law. Both state and federal action are likely necessary to fully overcome operator concerns.
- A water quantity life cycle analysis for shale gas development should be supported and conducted at the earliest possible time to inform the public and future water quantity regulation. It is currently unclear whether shale gas development is a net water user or producer (and what magnitude of user/producer it is). The research should examine water withdrawals in relation to water recovery rates, recycled flowback and produced water, and possible recovery of water vapor through the burning of captured natural gas.
- The draft Chapter 78 Water Management Plan (WMP) provisions should be enacted, including the extension of certain existing SRBC water withdrawal rules to the Ohio River Basin. These withdrawal rules encourage DEP to fully leverage the expertise of department water staff in WMP reviews, compliance monitoring, and enforcement (in collaboration with oil and gas staff). This requires adequate resources for the water division to further integrate industry regulation within the department and prevents the need for duplicative water expertise in multiple offices.

HYDRAULIC FRACTURING CHEMICAL DISCLOSURE

Under Act 13, well operators are required to disclose the chemicals used in their fracturing water to DEP and to FracFocus.org.[59/60] In the event of an environmental or medical emergency, Act 13 requires operators to disclose the exact quantities of all chemicals in their mixture of fracturing water, including proprietary ingredients.[61] FracFocus.org is a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission. The website was created to provide the public with information about hydraulic fracturing and groundwater protection. Users are able to search for wells in their area and find a list of chemicals that have been used in the development of those particular gas wells.

Complaints have been raised over the lack of functionality of the FracFocus.org website, which precludes data aggregation for research. Performing large queries for specific chemicals can be difficult and time consuming because results are sorted by individual well and only displayable in PDF form. Another issue is that chemicals may be identified using a variety of names, all of which refer to the same substance. For example, ethylene glycol (antifreeze) also is known by the names ethylene alcohol, glycol, glycol alcohol, Lutrol 9, Macrogol 400 BPC, and monoethylene glycol, which makes a comparative analysis of fracturing water ingredients difficult. Pennsylvania, and other states that use this website as

[59] Act 13 of 2012, HB 1950 § 3222.1b2
[60] PA DEP, *Act 13 FAQs:* http://files.dep.state.pa.us/OilGas/OilGasLandingPageFiles/Act13/Act_13_FAQ.pdf
[61] Act 13 of 2012, HB 1950 § 3222.1b11

their public disclosure portal, have been working with FracFocus.org to improve functionality and searchability.

In response to these criticisms, FracFocus.org has redesigned its database to provide enhanced functionality. As of June 2013, the resulting "FracFocus 2.0" website was fully operational. It will allow users to search and aggregate information by geography, dates, chemicals, and chemical abstract service (CAS) numbers. Additionally, states will be able to input data already received directly from companies and download data that companies have previously submitted to FracFocus.org.[62]

Hydraulic Fracturing Chemical Recommendations

- The Roundtable recognizes DEP for its strong efforts at public transparency of fracturing chemicals and its pressure to update the FracFocus.org platform to more adequately communicate needed information. DEP should continue to evaluate methods for improving the accessibility and utility of collected fracturing chemical information, with commensurate pressure on FracFocus.org to improve and innovate in order to meet Pennsylvania's needs in this regard.
- While there are concerns about water quality related to the underground substances from the shale brought to the surface through extraction activities, the constituent chemicals in injected fracturing fluid remain a focus of public trepidation. The industry, federal and state governments, and academia should prioritize the development of biodegradable "green" fracturing fluids. A green fracturing fluid would minimize the potential harm to natural gas workers and the potential environmental damage that can result from surface spills of fracturing chemicals or flowback water. In the interim, the use of DNA or isotopic tracers in the fracturing fluid mixture may improve the ability to monitor underground fluid migration.

EROSION AND SEDIMENTATION

At a well or pipeline construction site during a rain event, disturbed soil can be vulnerable to erosion, and stormwater has the potential to move chemical contaminants and soil away from the site and into surface water or groundwater. DEP routinely cites gas developers for violations related to erosion and improper stormwater management. Between January 2008 and August 2010, erosion and sediment-related citations accounted for nearly a third of all gas well violations.[63]

The state requires any industrial construction site developer, including well drillers, to "develop, implement and maintain best management practices to minimize the potential for accelerated erosion and sedimentation and to manage post construction" stormwater impacts on the sites where they are working. Additionally, "best management practices shall be undertaken to protect, maintain, reclaim and restore water quality and the existing and designated uses of waters of this Commonwealth."[64] DEP also requires developers to develop and implement a Post-Construction Stormwater Management Plan

[62] Smith, Carl Michael. "FracFocus: Chemical Disclosure, State Regulations and Industry Transparency." *American Bar Association Section of Environment, Energy, and Resources.* Oct. 10-13, 2012. pg.8. http://abaseer20fm.conferencespot.org/51-Smith/8

[63] Pennsylvania Land Trust Association. "Marcellus Shale Drillers in Pennsylvania Amass 1614 Violations since 2008." pg.1. http://conserveland.org/violationsrpt

[64] 25 Pa.C.S. §102.2b

as part of its erosion and sediment control permit. The plan must ensure that the volume and flow rate of stormwater be the same pre- and post-development.

DEP has recently updated its erosion and sediment control general permit regulations. Under the new Erosion and Sediment Control General Permit-2 (ESCGP-2), expedited reviews of projects will not be available for projects in critical areas such as special protection waters, floodplains, and lands contaminated by substances regulated under Pennsylvania's land remediation statute.[65] Activities with the potential to discharge sediment into already impaired water bodies are now required to use anti-degradation best available control technologies.[66] Additionally, ESCGP-2 makes changes to DEP notification requirements, pre-construction conferences with DEP, non-compliance self-reporting, and temporary stabilization requirements.[67]

Erosion and Sedimentation Recommendation

- In the design and review of oil and gas Post-Construction Stormwater Management Plans, DEP should require whole-site plans that take into account not only the well pads but also the access roads and pipelines that service a particular development location.

IMPOUNDMENTS AND CONTAINERS

Impoundments are temporary holding ponds that are used to hold freshwater or flowback during the development of a gas well. Lined with a black nitrile material to prevent leakage and/or overflow, shale gas impoundments can hold millions of gallons of fluids. Centralized fracturing fluid impoundments can service multiple well sites and have to be removed within nine months of completing well development.

Concerns around impoundments for flowback and produced water are threefold: leakage, evaporation, and liner disposal. Breaching of the ponds would allow for the discharge of fracturing fluids, likely resulting in the pollution of both surface and ground water. Another concern is the evaporation of the volatile organic compounds (VOC) in natural gas wastewaters, some of which, when inhaled, may be hazardous or even carcinogenic. Finally, once fracturing ponds are emptied, the liners must be properly disposed of to avoid contamination from fluid residues remaining on the liners.

Fears of fracturing pond leakage have resulted in a movement by industry to use storage containers, which are enclosed tanks used to store flowback waters. The high cost of these tanks has prevented broader adoption by industry. It is estimated that approximately 20 centralized fracturing impoundments are currently in use in the state.

Community and environmental groups also have expressed concerns over Act 13 language that permits impoundments in all zoning districts, including residential, if they are located more than 300 feet from existing buildings.[68]

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[65] 42 Pa.B.442 §6n. "Proposed ESCGP-2 Form." http://www.pabulletin.com/secure/data/vol42/42-3/96.html
[66] "DEP 2012 Industry Training: Erosion & Sedimentation Control General Permit for Oil & Gas Activities." August 22, 2012. http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/OilGasReports/2012/Training_Materials/ESCGP-2.pdf
[67] Ibid.
[68] Act 13 of 2012. HB 1950 § 3304(b)6

Impoundments and Containers Recommendation

- DEP should evaluate various natural gas wastewater storage techniques, including mobile containers and centralized impoundments, to determine best practices for management of these fluids. This evaluation should use a life cycle approach that estimates potential environmental and safety risks associated with each of the available storage technologies. In particular, DEP should continue to monitor potential acute emissions problems with open impoundments.

VEHICLE TRAFFIC FOR WATER TRANSPORT

Much of the shale gas development within Southwestern Pennsylvania occurs in rural areas of the region. Municipal and county bridges and roads, which were not designed to support heavy vehicles, are often damaged by large trucks that make frequent trips hauling water and other materials to and from the drilling sites.

An average gas well requires 320-1,365 truckloads of equipment, sand, gravel, freshwater, and fracturing fluids to come into production.[69] A Marcellus Shale well with an 8,000-foot lateral drill length may use 3-6 million gallons of water in the process of drilling and fracturing the shale, nearly all of which must be hauled in and some of which must be hauled out. If a well pad has more than one well located on it, the number of truckloads can be correspondingly greater. General well maintenance and future re-fracturing also will result in additional truckloads of equipment traveling to well sites.

The state legislature has mandated legal standards for overweight hauling and the process by which local roads are posted with weight limits. Once a road is posted with a weight limit, the municipality has the authority to require businesses that intend to haul materials in excess of the posted weight limits to obtain permits. The permitting process requires the hauler to provide bonding to insure the repair of any damage that may occur. Operators with overweight vehicles pay a bond for segments of roads on a per mile basis regardless of the number of overweight vehicles traveling that span. The bonding rates are $6,000/mile for unpaved roads and $12,500/mile for paved roads. These bonding rates have remained unchanged for more than 30 years and may need to be revisited to adequately protect roadways. The estimated cost of reconstructing a one-mile stretch of a two-lane asphalt road is about $850,000, which is higher than the current bonding rates.[70]

Overweight vehicle owners also are required to obtain Excess Maintenance Agreements (EMAs) when placing overweight vehicles on roads.[71] Overweight vehicle owners are required to either pay for or make the repairs to any damaged roadways as a result of their overweight vehicles traveling along the

[69] National Park Service. "Development of the Natural Gas Resources in the Marcellus Shale: New York, Pennsylvania, Virginia, West Virginia, Ohio, Tennessee, and Maryland." Nov. 2009. pg.10. http://www.marcellus.psu.edu/resources/PDFs/marcellusshalereport09.pdf.pdf

[70] Estimate provided by The Gateway Engineers, Inc., Pittsburgh, PA.

[71] Pennsylvania Department of Transportation. "Chapter 15: Weight Restrictions on Highways (Posted Highways)." *Pub 23 – Maintenance Manual.* pg.15-8. ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/PUB%2023/Pub%2023-Chapter%2015.pdf

road.[72] In this context, the bonds are needed only if an operator violates the EMA and fails to adequately fix the roads.

Future vehicle impacts may be somewhat diminished through the use of water supply pipelines, recycling of wastewater, and increased infrastructure funding from Act 13 impact fees. Act 13, after the distribution to the state agencies, provides 60 percent of impact fee funding to counties and municipal governments impacted by shale gas development.[73] While not excusing developers from EMAs, these funds enable local governments to invest in infrastructure repairs and environmental remediation, presumably enhancing investment in road and bridge systems near shale gas activities.

Freshwater pipelines are being increasingly used, especially for drilling near large water impoundments, to decrease the truck trips necessary for hydraulic fracturing operations. In April 2012, Aqua America and Penn Virginia Resource Partners (PVR) announced a newly completed freshwater pipeline project in north-central Pennsylvania that eliminates more than 2,000 truckloads of water from the area roads.[74] DEP is currently promulgating regulations on the use of freshwater pipeline systems and could potentially play a stronger role in facilitating the use of such systems.

Vehicle Traffic and Water Transport Recommendations

- In addition to the new uniform rules in the draft Chapter 78.68b, DEP should continue to seek methods that facilitate and incentivize the use of freshwater pipelines for water transport (possibly including a requirement that water transportation plans are included in the Water Management Plan). The use of freshwater pipelines would allow developers to service well sites without the damage to large stretches of local roads associated with water hauling.
- While Excess Maintenance Agreements (EMA) typically have been sufficient tools to ensure infrastructure repairs, the Commonwealth should evaluate whether the 30-year-old bonding rates should be increased to better protect local municipalities from EMA default.

WASTEWATER TREATMENT AND DISPOSAL

In the second half of 2010, the Pennsylvania unconventional natural gas industry generated about 174 million gallons of total wastewater through its drilling operations. In 2012, unconventional wells produced approximately 536 million gallons of wastewater from July through December.[75] Some estimates indicate that as much as 10-25 percent of the water injected to hydraulically fracture a well is recovered and disposed of or recycled.[76] The recovered water, known as "flowback," contains pollutants such as barium, strontium, oil and grease, soluble organics, and a high concentration of chlorides. In January 2013, DEP announced its intention to conduct research on the levels of naturally occurring

[72] Ibid. 15-17 through 15-19.
[73] Act 13 of 2012. HB 1950 § 2314d
[74] Marcellus Drilling News Press Release: http://marcellusdrilling.com/2012/05/new-water-pipeline-reduces-water-truck-trips-in-pa/
[75] PA DEP Oil & Gas Statewide Waste Data: https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/DataExports/DataExports.aspx
[76] Hammer and VanBriesen. pg.11.

radioactivity in waste materials associated with unconventional gas development.[77] A sample overview of flowback contents is provided in Table 2, though the constituents can vary depending on geological conditions and the types of chemicals used in the injected fracturing water.

Table 2: Contents of Flowback Based on a Sample Analysis[78]

Parameter	Range	Median	Units
Total alkalinity	48.8-327	138	mg/L
Hardness as $CaCO_3$	5,100-55,000	17,700	mg/L
Total suspended solids	10.8-3,220	99	mg/L
Turbidity	2.3-1,540	80	NTU
Chloride	26,400-148,000	41,850	mg/L
Total dissolved solids	38,500-238,000	67,300	mg/L
Specific conductance	79,500-470,000	167,500	Umhos/cm
Total Kjeldahl nitrogen	38-204	86.1	mg/L
Ammonia nitrogen	29.4-199	71.2	mg/L
Biochemical oxygen demand	37.1-1,950	144	mg/L
Chemical oxygen demand	195-17,700	4,870	mg/L
Total organic carbon	3.7-388	62.8	mg/L
Dissolved organic carbon	30.7-501	114	mg/L
Bromide	185-1,190	445	mg/L

Early in the Marcellus play, developers in the region tended to treat flowback and produced water at public sewage treatment plants. Although disposal of shale gas wastewater at municipal treatment plants is a relatively low-cost method of treatment, most plants are unable to adequately treat the high total dissolved solids (TDS) found in the shale gas wastewater (see Table 3 below). The use of sewage

[77] StateImpact. "PA DEP to Study Radiation Related to Marcellus Shale." http://stateimpact.npr.org/pennsylvania/2013/01/24/pa-dep-to-study-radiation-related-to-marcellus-shale/

[78] Penn State Water Resources Extension, C.W. Abdalla, J.R. Drohan, K. Saacke Blunk, and J. Edson (funded by PA Water Resources Research Center). "Marcellus Shale Wastewater Issues in Pennsylvania – Current and Emerging Treatment and Disposal Technologies." pg.2 http://extension.psu.edu/natural-resources/water/marcellus-shale/waste-water/current-and-emerging-treatment-and-disposal-technologies-1/marcellus-shale-wastwater-issues-in-pennsylvania-current-and-emerging-treatment-and-disposal-technologies/view.

treatment plants resulted in high levels of TDS and metals being found in the region's water bodies. Based on this TDS problem, DEP completed the Chapter 95 rulemaking in 2010 (TDS end-of-pipe discharge limits). DEP also issued a request in April 2011 for shale gas developers to voluntarily stop taking shale gas drilling wastewater to grandfathered treatment facilities by May 2011 (all operators voluntarily complied by the deadline). The combination of these two actions has demonstrably decreased the TDS levels in the Monongahela River. The grandfathered facilities are still available to conventional natural gas developers as a wastewater treatment and disposal option.

Another disposal practice is underground injection, a process by which conventional and unconventional natural gas produced fluids are forced into porous rock formations deep within the earth for permanent storage. In the second half of 2012, injection well disposal accounted for approximately 15 percent of unconventional wastewater disposal or 81 million gallons.[79] 77.4 million gallons were disposed of in Ohio injection wells, about 2.1 million gallons in West Virginia wells, and the remaining 1.5 million gallons in Pennsylvania injection facilities.[80] Injection wells are regulated under the federal Safe Drinking Water Act, which requires such wells to be permitted by the state or EPA. Injection wells in Pennsylvania and New York are regulated under the EPA permitting process. In West Virginia and Ohio, permitting is administered by their respective state environmental agencies. With burgeoning Utica and Marcellus development in Ohio, adequate capacity to accept Pennsylvania wastewaters is diminishing. Pennsylvania currently has seven active Class II brine disposal injection wells. Two additional disposal wells have been approved, one well has been approved but is held up in permit appeals, and EPA is reviewing proposals for several more wells.

More than three quarters of shale gas wastewater in Pennsylvania is currently being reused for hydraulic fracturing of additional wells through on-site and centralized treatment and recycling systems. In the second half of 2010, 65 percent of waste fluid went to industrial treatment facilities and about 25 percent of wastewater was reused.[81] From July through December 2012, operators used on-site recycling technology or centralized treatment facilities to reuse 453 million gallons of wastewater or 84.5 percent of the total produced during that time period.[82] Some companies have reported that they are able to recycle more than 90 percent of their wastewater.[83]

[79] PA DEP Oil and Gas Statewide Waste Data.
[80] Ibid.
[81] Penn State Extension. "Water's Journey through the Shale Gas Drilling and Production Processes in the Mid-Atlantic Region." pg.7. http://pubs.cas.psu.edu/FreePubs/PDFs/ee0023.pdf
[82] PA DEP Oil and Gas Statewide Waste Data.
[83] Napsha, Joe. "Private Firms Poised to Treat Wastewater." *Pittsburgh Tribune-Review.* May 19, 2011. http://triblive.com/x/pittsburghtrib/business/s_737873.html#axzz28jot49tZ

Table 3: Advantages/Disadvantages of Treatment and Disposal Options for Flowback Water[84]

Treatment	Advantages	Disadvantages
Dilution and treatment at publically owned sewage treatment plants	Minimal cost	Limited capacity after 2010 DEP TDS regulations Potential to upset the sewage treatment process Does not ensure protection of downstream public water supplies
Treatment at a dedicated brine treatment plant	Meets 2010 DEP TDS regulations Protects downstream public water supply intakes Ensures available assimilative capacity for other industries	Limited current capacity Potentially high transportation costs Higher treatment costs
Direct reuse without treatment (blending of flowback with freshwater for reuse)	Minimal cost	Some potential for well plugging because of high TDS and sand in water
On-site treatment and reuse (recondition water through treatment)	Minimal potential for well plugging	Moderate costs
Off-site treatment and reuse	Minimal potential for well plugging	High transportation costs
Off-site disposal via deep underground injection	No discharge to a stream	High transportation costs

[84] Penn State Water Resources Extension, C.W. Abdalla, J.R. Drohan, K. Saacke Blunk, and J. Edson (funded by PA Water Resources Research Center). "Marcellus Shale Wastewater Issues in Pennsylvania – Current and Emerging Treatment and Disposal Technologies." Pg.4. http://extension.psu.edu/natural-resources/water/marcellus-shale/waste-water/current-and-emerging-treatment-and-disposal-technologies-1/marcellus-shale-wastwater-issues-in-pennsylvania-current-and-emerging-treatment-and-disposal-technologies/view

Wastewater Treatment and Disposal Recommendations

- The lack of specific and codified definitions in the oil and gas wastewater area has proven problematic. DEP should take steps to transparently define and codify the categories of waste produced by natural gas development and also the differences among drilling, flowback, and produced waters. The lack of formal definitions adds unneeded complexity and uncertainty to disposal data and should be remedied in future legislation and regulation.
- Act 13 requires operators to track the origins and destinations of all oil and gas wastewaters and to make that information available to DEP upon request. Given the significant public interest in wastewater issues and this Act 13 enabling language, DEP should consider requesting that operators include this "manifest tracking" data in their biannual waste reporting and that the resulting data be made available for public consumption. Several other oil and gas states have similar requirements, and the cost to industry is not great because they are already required to collect and track this information. The ability to follow all wastewater from well site to disposal location could greatly improve public faith in the handling of these materials.
- Many wastewater treatment technologies leave residual by-products after the water is reclaimed. Additional government attention and industry and academic research should be aimed at the appropriate disposal and/or beneficial reuse of these by-products.
- To ensure the protection of drinking water sources, DEP should evaluate current and future wastewater regulations by their ability to move toward zero discharge of natural gas-related wastewater in favor of recycling, reuse, and underground injection. On-site reuse is particularly useful because it has the added benefit of avoiding off-site spills and accidents during transport.
- Given the increased attention to Pennsylvania wastewater disposal, DEP should proactively engage U.S. EPA in a dialogue about the current effectiveness and management of the Underground Injection Control and Wastewater Pre-Treatment programs, which are currently administered by EPA. The two agencies have not discussed existing regulation in these two programs for some time and might be able to cooperatively improve management of them. Also, EPA recently completed a comprehensive risk analysis for Class 1 hazardous materials injection wells. EPA and/or the Commonwealth should consider conducting a similar analysis for Class 2 oil and gas brine disposal injection wells.

GROUNDWATER PROTECTION

More than 3 million rural and suburban Pennsylvanians rely on private water wells for everyday drinking water.[85] Within the counties in Marcellus Shale development areas, more than 30 percent of county residents rely on private water wells.[86] Under current rules, Pennsylvania, along with Michigan, remains one of two states without private well regulations concerning well location, construction, testing, and

[85] Swistock, Bryan, Stephanie Clemens, and William E. Sharpe. "Drinking Water Quality in Rural Pennsylvania and the Effect of Management Practices."*The Center for Rural Pennsylvania.* Jan. 2009. pg.5.
http://www.rural.palegislature.us/drinking_water_quality.pdf

[86] Boyer, Elizabeth, et.al. "The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies." *The Center for Rural Pennsylvania.* March 2012. pg.6.
http://www.rural.palegislature.us/documents/reports/Marcellus_and_drinking_water_2012.pdf

treatment.[87] Some counties and municipalities have filled this void with the establishment of local well permits and construction standards.[88]

Unfortunately, many wells still fail to meet "recommended construction standards, presumably reflective of the lack of statewide water well construction regulations, which likely contribute to impairments of certain water quality standards."[89] Poorly constructed water wells pose a human health and safety risk, resulting in pathways for bacteria and other contaminants, such as methane and nitrates, to migrate into the potable water supply.[90/91] A study conducted by the Center for Rural Pennsylvania estimates that roughly 41 percent of the 1 million water wells in the Commonwealth fail to meet at least one of the health-based drinking water standards.[92]

Pursuant to Act 13, operators are presumed to be liable for water supply pollution if that water supply is within 2,500 feet of the unconventional well and the pollution occurs within 12 months of well completion. To rebut this presumption, operators are encouraged to obtain a baseline sample of the water supply (with the owner's consent). The pre-drill samples must be analyzed by certified laboratories and can then be compared to results after development occurs. The act does not, however, provide required testing parameters or create uniform disclosure requirements for the state or companies. Post-drilling samples also are largely not collected and analyzed unless a complaint is received. The Marcellus Shale Coalition (MSC) has developed a "Recommended Practice for Pre-Drill Water Supply Surveys" that was released in August 2012. This guidance document is one in a series of recommended practices being developed by the coalition.[93] The MSC also is developing an online pre-drill water survey database to serve as a clearinghouse for sampling results from across the state, though this database will not be publicly accessible.

House Bill 343, introduced by Representative Ron Miller in January 2013 and currently under consideration in the House, would establish construction standards for Pennsylvania's private water wells. The Governor's Marcellus Shale Advisory Committee also expressed concern over private water well contamination and the need to create a regulatory structure to ensure safe drinking water (Recommendation 9.2.17).[94] Legislation on private well standards has been proposed multiple times in the past but has failed.

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[87] Wagner, Donald. "Testimony of the Pennsylvania Council of Professional Geologists to Pennsylvania House of Representatives Consumer Affairs Committee." Jan. 10, 2012. http://www.pahouse.com/consumeraffairs/docs/HB1855/Donald%20Wagner.pdf

[88] One local water well regulation example from Chester County can be accessed at: www.chesco.org/DocumentCenter/Home/View/429

[89] Wagner, Donald. "Testimony of the Pennsylvania Council of Professional Geologists to Pennsylvania House of Representatives Consumer Affairs Committee." Jan. 10, 2012. http://www.pahouse.com/consumeraffairs/docs/HB1855/Donald%20Wagner.pdf

[90] "Governor's Marcellus Shale Advisory Commission Report." July 22, 2011. pg.108. http://files.dep.state.pa.us/PublicParticipation/MarcellusShaleAdvisoryCommission/MarcellusShaleAdvisoryPortalFiles/MSAC_Final_Report.pdf

[91] Wagner, Donald. "Testimony of the Pennsylvania Council of Professional Geologists to Pennsylvania House of Representatives Consumer Affairs Committee." Jan. 10, 2012. http://www.pahouse.com/consumeraffairs/docs/HB1855/Donald%20Wagner.pdf

[92] Ibid.

[93] MSC Recommended Practices can be reviewed at: http://marcelluscoalition.org/category/library/recommended-practices/

[94] "Governor's Marcellus Shale Advisory Commission Report." July 22, 2011. pg.108. http://files.dep.state.pa.us/PublicParticipation/MarcellusShaleAdvisoryCommission/MarcellusShaleAdvisoryPortalFiles/MSAC_Final_Report.pdf

In a corollary attempt to protect groundwater, DEP updated the requirements governing cementing and casing for gas wells.[95] These components include casing and cementing protocols and provisions for ongoing integrity monitoring. Excellent cementing and casing work is perhaps the most important method for preventing methane migration incidents. While these regulations have broad support, some stakeholders remain concerned about the adequacy of DEP staffing levels for robust inspection of casing and cementing jobs. Ongoing attention to these issues will be necessary, particularly as it is unclear how cement will hold up under future re-fracturing operations.

Additional groundwater concerns are often cited with respect to the abandoned gas and oil wells throughout the region. Abandoned wells can be breached through the drilling and fracturing process and can allow for the unintended movement of wastewater or methane into aboveground and underground water bodies. Within the Commonwealth of Pennsylvania, more than 325,000 oil and gas wells have been drilled since 1859. Of that number, about 184,000 oil and gas wells are unaccounted for.[96] Proposed Chapter 78 language would require that companies take steps to identify abandoned wells within 1,000 feet of the entire vertical and horizontal length of the well bore on their permit applications (78.52a).

Groundwater Protection Recommendations

- Enhanced research and monitoring are needed to establish baseline groundwater conditions and gauge possible cumulative impacts of shale gas development on groundwater. Act 13 provided impact fee monies to the Commonwealth Financing Authority to fund statewide initiatives that can help to collect baseline water quality data on private water supplies. This program and others should be supported and expanded.
- The General Assembly should pass House Bill 343 or similar legislation that would establish construction standards for new private water wells to better ensure access to clean drinking water for all Pennsylvania residents (leaving Michigan as the only state without such requirements). This legislation would help to prevent contamination problems for all new water wells in the state. For already drilled water wells, legislators should consider adding technical and financial assistance provisions to aid homeowners in the evaluation, maintenance, and refurbishment and/or replacement of their existing wells. Perhaps counties and local governments could be encouraged to create grant programs for this purpose using impact fee revenues. The Penn State Extension Service could likely make substantial contributions in this area as well.
- DEP should undertake efforts to standardize pre-drilling subsurface geologic and groundwater quality testing parameters, methodologies, and reporting requirements. In the category of water testing, the state's existing guidance, the MSC Recommended Practice, and other relevant tools could form the basis for these requirements. Consistency of testing and reporting will help to improve the utility of this data for regulators and landowners and will enhance the image of

[95] 25 Pa. Code Chapter 78, Subchapter D
[96] StateImpact, "Across Pennsylvania, Abandoned Wells Litter the Land." Nov. 13, 2012. http://www.npr.org/2012/11/13/164139865/across-pa-abandoned-wells-litter-the-land

these processes for the public. Consistent parameters for post-drilling water sampling protocols also should be developed.

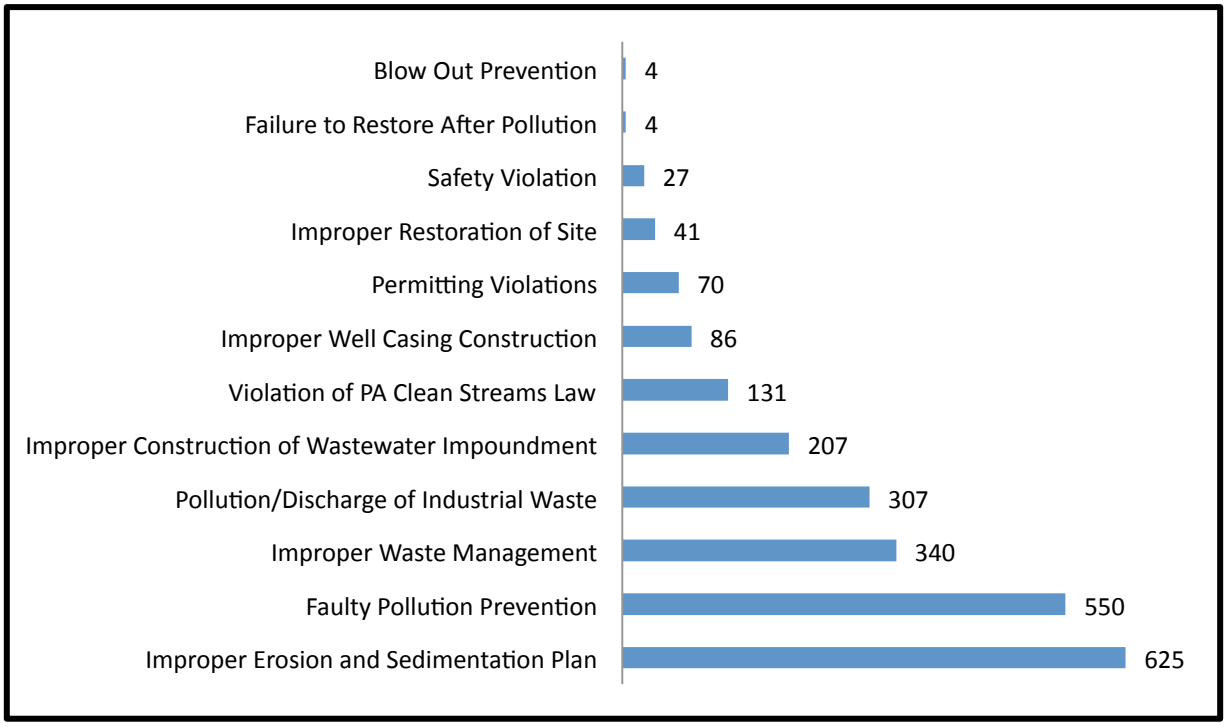
- Regular inspection of sites is necessary to ensure industry compliance with DEP cementing and casing standards. In anticipation of future well re-stimulation activities, the Commonwealth should develop requirements for checking the continued strength and stability of the original cementing and casing. As noted in the Core Recommendations, it will be essential that DEP sets transparent goals and possesses the resources and staff to meet its inspection obligations.
- Due to groundwater infiltration concerns, Chapter 78 should be amended to prohibit on-site disposal of drill cuttings from the horizontal phase of drilling operations or solid wastes from the hydraulic fracturing of unconventional wells. Given the possible constituents of these cuttings, the Commonwealth can remove the possibility of water impairment by requiring appropriate off-site disposal.

WATER-RELATED VIOLATIONS

From January 2008 to December 2011, DEP reported 3,355 environmental violations related to shale gas development by 64 different companies.[97] Of these violations, 2,392 posed a likely direct threat to Pennsylvania's environment and were not categorized as reporting or paperwork violations.[98] Improper Erosion and Sedimentation Plans, Faulty Pollution Prevention, Improper Waste Management, and Pollution/Discharge of Industrial Waste accounted for more than 75 percent of these environmental violations, as seen in Table 4 below.[99]

[97] Staaf, Erika. "Risky Business: An Analysis of Marcellus Shale Gas Drilling Violations in Pennsylvania 2008-2011." Penn Environment Research and Policy Center. Feb 2012. pg.1. http://pennenvironmentcenter.org/sites/environment/files/reports/Risky%20Business%20Violations%20Report_0.pdf
[98] Ibid.
[99] Ibid. pg.3.

Table 4: Environmental Violations by Category (2008-11)[100]



From 2008 to 2011, the top 25 shale gas well producers accounted for 94 percent of well development within Pennsylvania while causing only 82 percent of violations.[101] On average, shale gas developers received about 0.77 violations per well.[102]

The total number of shale gas violations reported is likely overstated given the antiquated violation classification system DEP currently employs. Single incidents often spawn multiple violations depending on the circumstances of the incident, the number of state laws used to cite the violation, and the number of wells on the site. For instance, a single spill can result in five spill violations if there are five wells located on the well pad and could be recorded as more than five if, for example, both the Oil & Gas Act and the Clean Streams Law are used in the citation. Additionally, DEP does not currently provide easily understandable information related to the severity of potential environmental harm from violations. Furthermore, DEP does not currently supply information on operator remediation actions in response to the violations (though it is now required to do so under Act 13).

Water-Related Violations Recommendations

- While violations are entered into the state data systems on a daily basis and are readily accessible to the public, DEP should invest in additional improvements to these databases. Violations should be better categorized to allow for understanding of the nature of the violation, its actual or potential severity of impact, DEP's enforcement actions, and the operator's response to the violation (as required by Act 13). DEP should consider annually summarizing and

[100] Ibid. pg.3.
[101] Ibid. pg.4
[102] Ibid. pg.6-7

reporting on violation activity as well as on progress in remedying violations and preventing future incidents.

- DEP also should remove redundant violation records for single incidents so that the public and policymakers can more clearly evaluate violations activity.

REGIONAL WATER MANAGEMENT

In addition to falling under the regulatory powers of the Department of Environmental Protection, activities in Pennsylvania also are overseen by a system of interstate river basin commissions: the Ohio River Valley Water Sanitation Commission (ORSANCO) in Western Pennsylvania, the Susquehanna River Basin Commission (SRBC) in central Pennsylvania, and the Delaware River Basin Commission (DRBC) in eastern Pennsylvania. All three river commissions play an important role in their respective regions' water management. A primary difference among the three is ORSANCO's lack of oversight authority with respect to water quantity issues surrounding withdrawals and diversions and its relative lack of activity upstream from the Ohio River's main stem. ORSANCO's founding compact among its eight member states and the federal government charges the commission with maintaining the Ohio River Basin's water in a condition that is:

- available for safe and satisfactory use as public and industrial water supplies after reasonable treatment,
- suitable for recreational usage and capable of maintaining fish and other aquatic life,
- free from unsightly or malodorous nuisances due to floating solids or sludge deposits, and
- adaptable to such other uses as may be legitimate.[103]

ORSANCO's lack of water quantity management and water quality attention in the headwaters is a possible gap for the consideration of policymakers. DEP has viable water management partners in the Susquehanna and Delaware commissions but currently does not in the Ohio, which has presented an increasing challenge as DEP's budget has been repeatedly decreased over the last decade.

The state legislature addressed the issue of water quantity management through several provisions in Act 13. For example, DEP has been charged with developing similar Water Management Plan (WMP) requirements to those within SRBC.[104] Oil and gas Water Management Plans under Act 13 are required not to infringe on current uses or on the current quantity or quality of water bodies. In the portions of the state currently overseen by SRBC, DRBC, and the Great Lakes Commission, operators are still required to meet these organizations' withdrawal standards.[105] Operators who meet the commissions' requirements can be considered to have met DEP's WMP provisions as well, thereby preventing duplicative measures (though DEP can add additional responsibilities if desired).

An additional tool for communities to proactively protect their drinking water has been put forward by EPA in its Source Water Protection Planning Program, authorized by the 1996 amendments to the Safe Drinking Water Act. Local communities can voluntarily develop a Source Water Protection Plan for DEP

[103] Ohio River Valley Water Sanitation Commission. "Ohio River Valley Water Sanitation Compact." June 30, 1948. http://www.orsanco.org/images/stories/files/CompactNoSeals.pdf
[104] Act 13 of 2012, HB 1950 § 3211
[105] Act 13 of 2012, HB 1950 § 3211(m)(3)(i)

review and approval, which outlines a comprehensive plan to achieve maximum public health protection through the following steps:

- Delineate the drinking water source protection area to be covered in the plan
- Inventory potential sources of water pollution within the protection area
- Determine the susceptibility of the water source to identified contaminations
- Notify and involve the public about threats to the water source and what they mean to their public water system
- Implement management measures to prevent, reduce, and eliminate identified threats
- Develop contingency planning strategies to deal with water supply contamination or service interruptions[106]

Unfortunately, because these plans are voluntary, there are relatively few DEP-approved plans in place.[107]

Regional Water Management Recommendations

- As delineated in the water sourcing section, the Commonwealth should support and actively engage in the ongoing ORSANCO water quantity studies.
- In 2009, a regional effort led by the Regional Water Management Task Force endorsed the creation of a Water Planning Division at the Southwestern Pennsylvania Commission (SPC). That effort, which is underway, is designed to improve the cohesion of water monitoring, planning, investment, and technical assistance within a 10-county Ohio River Basin area. While SPC plans to initially focus its primary attention on stormwater, shale gas water management issues provide further impetus for this work. The region should support the growing role of SPC in planning for the future of the region's water resources.
- The Chapter 78 draft rulemaking states that DEP will collaborate with the Susquehanna River Basin Commission, the Delaware River Basin Commission, and the Great Lakes Commission on water monitoring and regulation of oil and gas activities. While Southwestern Pennsylvania does not have a direct corollary agency, DEP should consider outreach to and partnership with both ORSANCO and SPC on Ohio River Basin water resources management. Such collaborations would allow DEP to have natural water partners within this region of a similar type to those that already exist in central and eastern Pennsylvania.
- Local communities should consider the potential benefits of developing and maintaining a Source Water Protection Plan for drinking water sources. DEP should continue to encourage local jurisdictions to complete such plans and provide technical assistance to support the planning processes.

[106] Pennsylvania Source Water Protection Planning Guidance: http://www.sourcewaterpa.org/
[107] *What is the Status of Your Water System's Source Water Protection Program?* Region-by-region delineation of Source Water Protection Plans: http://www.sourcewaterpa.org/?page_id=282

WATER MONITORING

Within the region, several organizations are tasked with monitoring water quality. ORSANCO sets pollution control standards for industrial and municipal wastewater discharges in the region and monitors water quality to ensure compliance. ORSANCO tracks 26 attributes to determine water quality in the region, including flow rates and levels of chloride, dissolved oxygen, and sulfates. Information is collected from 11 stations across the Ohio River Valley including from a site near West View in Pennsylvania. The U.S. Geological Survey administers the Pennsylvania Water Quality Information Network as well. Data from ORSANCO's and USGS's stations is available for public use.[108] Elsewhere in Pennsylvania, water monitoring also is conducted by SRBC and DRBC. In addition to monitoring water quality, SRBC and DRBC also are tasked with monitoring quantity in their respective regions.

Additional water monitoring is conducted by the U.S. Army Corps of Engineers through its Ohio River Water Quality Program. The program monitors and manages water quality in reservoirs, lakes, tributaries, and rivers that have corps-operated structures for flood control and navigation. The corps also monitors pollutants in sediment, macro-invertebrates, algae, bacteria, and zebra mussels. Water monitoring also is done on a smaller scale by watershed organizations. Watershed monitoring programs vary significantly in size, sophistication, and the types of monitoring they perform.

The Western Pennsylvania Conservancy (WPC) also is undertaking a monitoring effort to gauge the impacts of shale gas development on priority conservation areas and Pennsylvania's rare and threatened species. Various tools and analyses are being used to prioritize areas of greatest conservation value across the state. These priority conservation areas will then be compared to projected Marcellus and Utica development areas to determine where conservation and monitoring work will have the greatest utility and impact. The project will include a significant effort to bring together researchers and policy advocates from academic institutions, government agencies, and conservation groups to determine research priorities, share data and methods, and collaborate on monitoring efforts. WPC also will engage municipalities, conservation districts, and landowners in the development of lease language, zoning, and site management strategies for high-value conservation areas. Ultimately, WPC's efforts will result in a comprehensive science-based assessment of shale gas development impacts within areas of high conservation value to be used by policymakers, regulators, landowners, the natural gas industry, and WPC and other conservation organizations to avoid and minimize impacts to high-value conservation areas.

The National Science Foundation is working to aggregate water monitoring data through its Shale Network database. The Shale Network is attempting to harness community-based data gathered by various water monitoring organizations and standardize it for research and monitoring purposes. The network website describes the effort in this way:

> *The Shale Network is a project funded by the National Science Foundation to help scientists and citizens store data for water resources that may be affected by gas exploitation in shale. Our primary focus currently is the Marcellus shale and other shales in the northeastern U.S.A. We*

[108] USGS data can be accessed at: http://pa.water.usgs.gov. ORSANCO datasets are available at: http://www.orsanco.org/data

want to enable the generation of knowledge from water chemistry and flow data collected in areas of extraction of natural gas. The Shale Network is working with the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc., (CUAHSI) to create this database. Our goal is to find, organize, and upload data for water resources for online publication. The Shale Network is seeking organizations engaged in water quality monitoring or research to join our effort.[109]

Finally, the River Alert Information Network (RAIN) is a consortium of 33 public water supply systems in the Ohio River Basin that are collaborating to detect and prevent any contamination in their systems. The RAIN system includes early warning water quality monitors at 29 sites along the Monongahela, Allegheny, Shenango, Youghiogheny, Beaver, and Ohio rivers. The monitors can identify a range of possible contaminants in real-time and automatically notify members about the presence of those contaminants. This enables the water systems to quickly implement corrective and protective actions.[110]

[109] Additional information on the Shale Network water data effort is available at: http://www.shalenetwork.org
[110] Information on RAIN available at: http://www.3rain.org/index.php