Potential Impacts of Unconventional Oil and Gas on the Delaware River Basin

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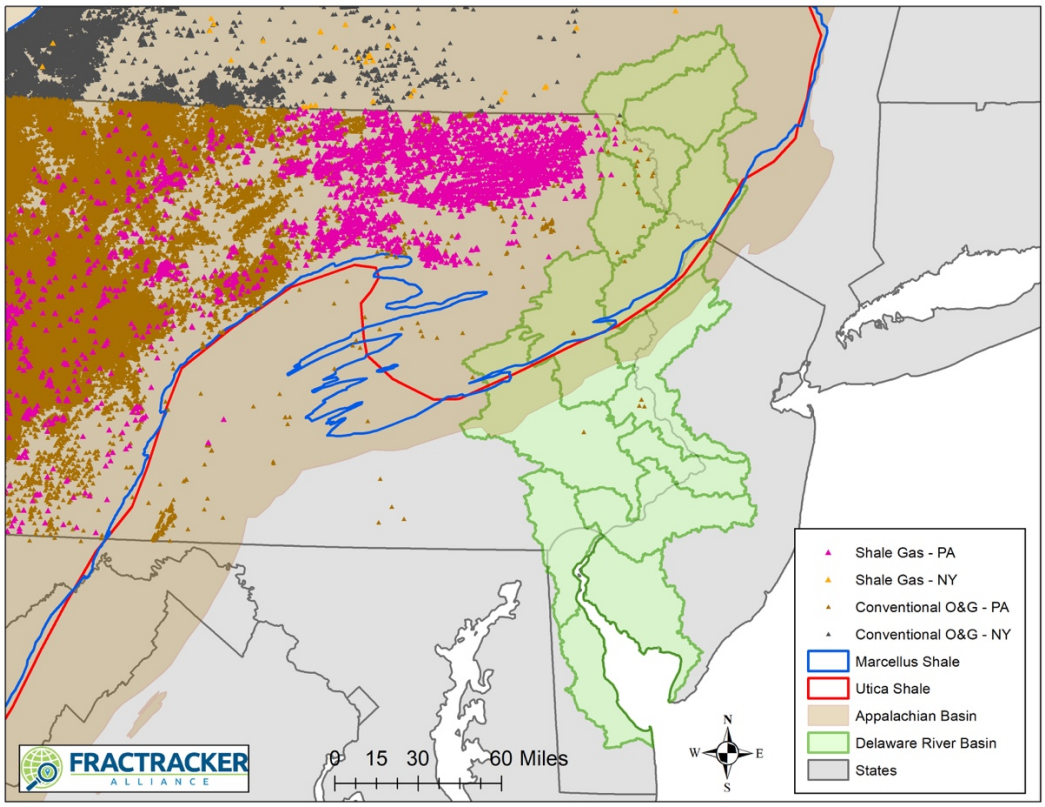

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Executive Summary

The Delaware River Basin Commission (DRBC) is considering new regulations that will ban high volume hydraulic fracturing within its jurisdiction, noting:[1]

> The Commission has determined that high volume hydraulic fracturing poses significant, immediate and long-term risks to the development, conservation, utilization, management, and preservation of the water resources of the Delaware River Basin and to Special Protection Waters of the Basin…

However, the same bans will not be extended to some of the ancillary activities of the industry, including large-scale water withdrawals and waste disposal, both of which will simply be "discouraged" under the new policy. Oil and gas (O&G) wastewater disposal will be permitted at centralized waste treatment facilities, the effluent of which will contain some level of contaminants that will be discharged to the Basin's waterways. Solid waste from the O&G industry will continue to be disposed of within the basin, as well.

Acknowledgements

This report was developed by Matt Kelso of FracTracker Alliance for use by the Delaware Riverkeeper Network (DRN). It was reviewed by Samantha Rubright of FracTracker and Tracy Carluccio of DRN.

Delaware Riverkeeper Network provided the funding for this research.

Information about the report's methodology for determining water usage for oil and gas wells in Pennsylvania, including a link to the original dataset, can be found in Appendix A, below.

[1] Delaware River Basin Commission. Proposed New 18 CFR Part 440 - Hydraulic Fracturing in Shale and Other Formations: http://www.nj.gov/drbc/library/documents/HydraulicFracturing/18CFR440_HydraulicFracturing_draft-for-comment_113017.pdf

Summary of the O&G Industry in the Delaware Basin

As natural gas is both a market-driven and weather-driven commodity, the number of wells that the industry will drill in any given year will vary significantly. For example, unconventional drillers in Pennsylvania spudded 1,959 unconventional wells in 2011.[2] Five years later, the industry drilled only 504 such wells, although the number of wells being drilled is now increasing once again as stored gas supplies are consumed and new pipelines are added to ship the commodities out of the region.

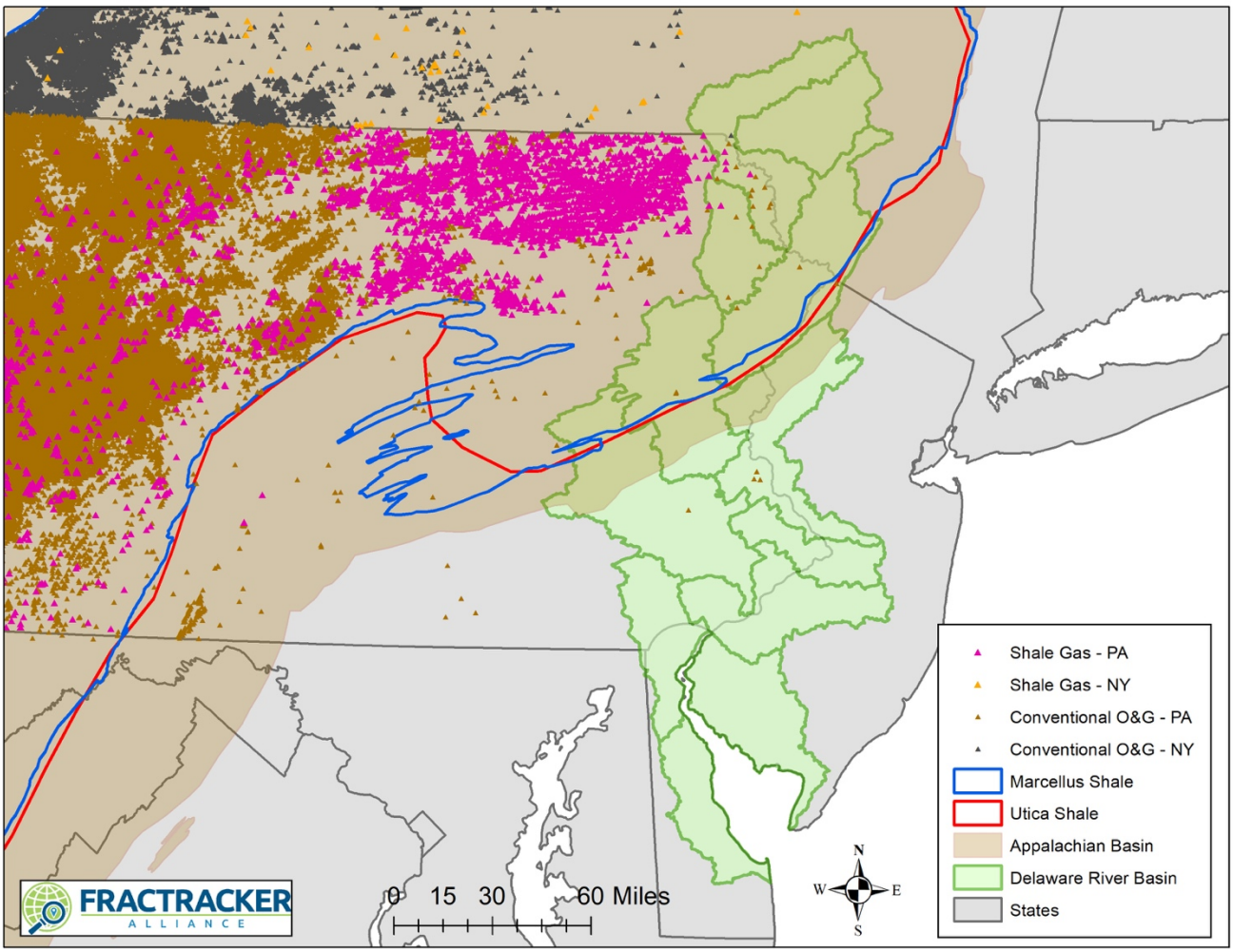

Figure 1. O&G resources and activity near the Delaware River Basin. If the New York ban and DRBC de facto moratorium were lifted, the potential impact of unconventional drilling on the Delaware River Basin could be substantial.

[2] PA DEP spud report: http://www.depreportingservices.state.pa.us/ReportServer?/Oil_Gas/Spud_External_Data

The Delaware River Basin is on the eastern margin of the oil and gas producing region known as the Appalachian Basin, which includes both the Utica and Marcellus shale gas plays (See Figure 1). While the Delaware basin may not have the same extensive coverage of O&G resources, industry analysts estimate that there could be 4,000 wells drilled into the region[3] if the DRBC's de facto moratorium and New York's ban were lifted, just from the Interior Marcellus formation.

Even if these O&G resources remain undeveloped, the Delaware River Basin will see no shortage of impact. Pipelines crisscross the region, taking oil and gas products from producing areas west to processing plants, population centers, natural gas power plants, and export terminals along the coast. The basin might also serve as a water supply for highly consumptive wells in the nearby Susquehanna River Basin, and its role in processing O&G waste products are likely to increase as the industry struggles to deal with an ever-increasing quantity of both liquid and solid waste.[4]

While conventional O&G activity does have an impact on the Delaware River Basin, the focus of this paper will be on unconventional wells, due to the proximity of a large number of these wells to the basin, the very large amount of water that they consume and waste that they generate.

Water Usage

While operators of conventional wells in Pennsylvania and New York have been using hydraulic fracturing to stimulate production of oil and gas for decades, unconventional wells drilled into shale like the Marcellus Shale formation require much more stimulation to release their carbon content. Such industrial-scaled operations use volumes of water that are multiple orders of magnitude greater than their conventional counterparts.[5]

[3] Habicht S, Hanson L, Faeth P. (2015). The Potential Environmental Impact from Fracking in the Delaware River Basin. CNA Corporation. https://www.cna.org/cna_files/pdf/IRM-2015-U-011300.pdf
[4] PA DEP. Oil and Gas Waste Reporting Database. https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/Welcome/Agreement.aspx
[5] Magill B. (2015). Water Use Rises as Fracking Expands. Scientific American. https://www.scientificamerican.com/article/water-use-rises-as-fracking-expands/

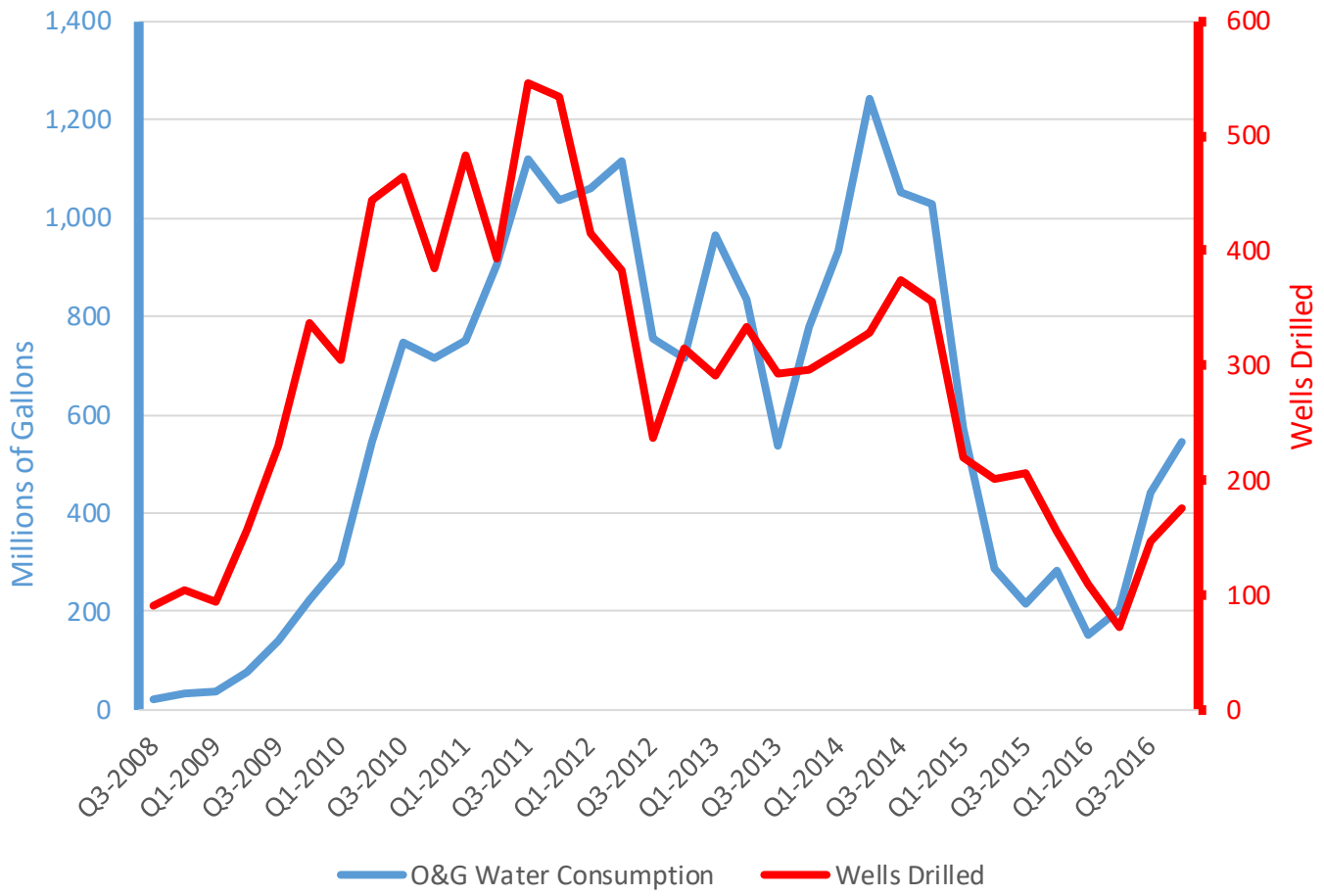

Figure 2. PA Drilled Wells and O&G Water Consumption in the Susquehanna River Basin over time

Figure 2 includes oil and gas related water withdrawals from the Susquehanna River Basin, and statewide unconventional drilled well totals by quarter.[6] There is a substantial amount of correlation between the two as one might expect, with peaks in drilling activity (red) requiring higher volumes of water (blue) for hydraulic fracturing well stimulation. Water withdrawals from the Ohio River Basin in Pennsylvania are known to be substantial but are not included in this analysis.

The number of wells drilled is not the only significant variable, however. According to the industry's hydraulic fracturing chemical disclosure registry, FracFocus, the amount of water used per well has more than doubled since 2011.

[6] This information originated from Unpublished SRBC water withdrawal data and a FracTracker analysis of FracFocus data from http://fracfocus.org/data-download

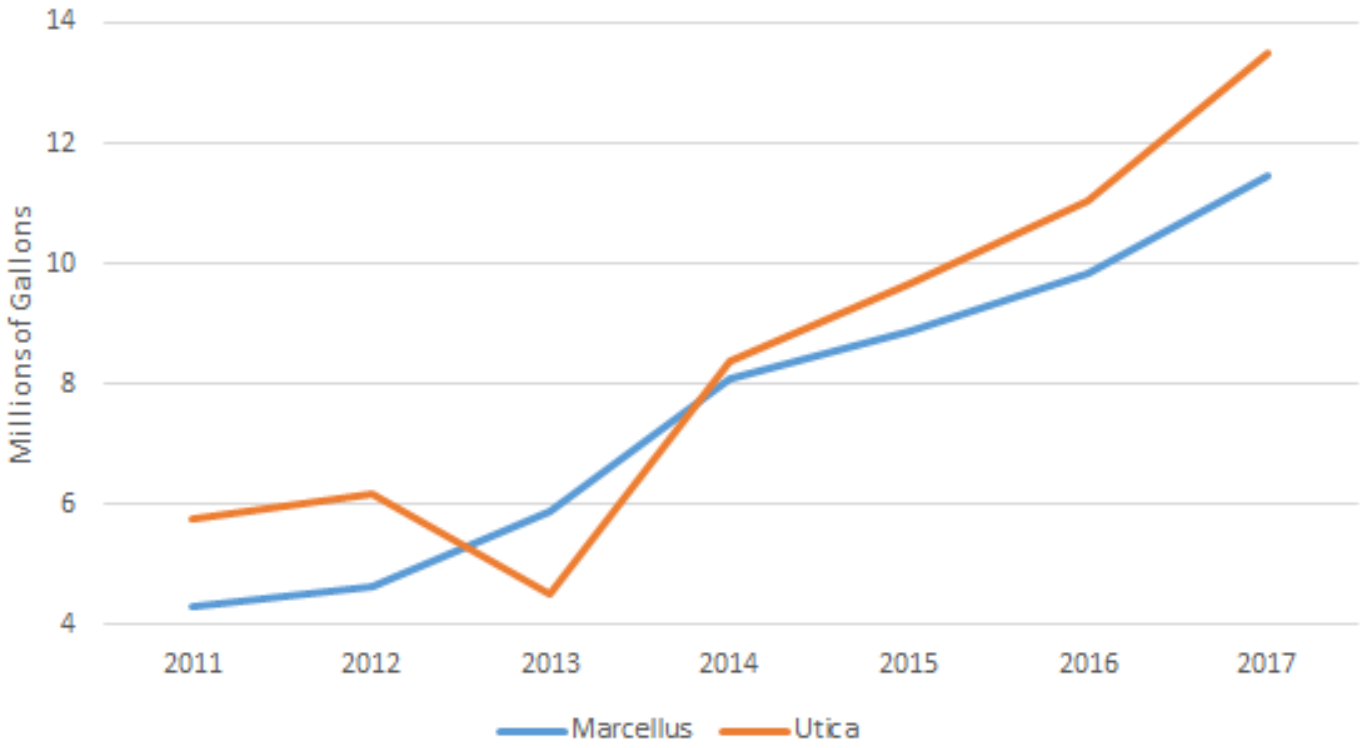

Figure 3. Water use per wells in PA based on industry data submitted to FracFocus

Water usage for Marcellus wells in Pennsylvania have increased from an average of 4.3 million gallons in 2011 to 11.4 million gallons in 2017, while water use in the deeper Utica formation has increased from 5.8 million 13.5 million gallons per well over the same time frame. The reason for this increase is twofold. First, drillers are using increasingly longer bore holes in the Appalachian basin, the lateral portion of which is starting to exceed 4 miles[7,8] in some cases. The resulting effect is more surface area to stimulate (which inherently uses more water). And second, operators in the Appalachian basin are using significantly more water per lateral foot than in years past.[9]

[7] Litvak A. (2018). These days, oil and gas companies are super-sizing their well pads. Pittsburgh Post-Gazette. http://www.post-gazette.com/powersource/companies/2018/01/15/These-days-oil-and-gas-companies-are-super-sizing-their-well-pads/stories/201801140023

[8] This horizontal well in question was ~4.8 miles in length. Smith M. (2018). Ensign drills Canada's longest well at Fox Creek. JWN. http://www.jwnenergy.com/article/2018/2/ensign-drills-canadas-longest-well-fox-creek/

[9] Auch T. (2017). The Freshwater and Liquid Waste Impact of Unconventional Oil and Gas in Ohio and West Virginia FracTracker Alliance presentation. http://midatlanticwrc.org/wp-content/uploads/2017/11/The-Freshwater-and-Liquid-Waste-Impact-of-Unconventional-Oil-and-Gas-in-Ohio-and-West-Virginia.pdf

It is difficult to predict when, if ever, the per-well water demand will begin to level off, but there are other pressures on total water usage, as well. As additional midstream infrastructure enables the export of gas from the region to accelerate, the prices for gas will go up, thereby making drilling more profitable, resulting in more wells drilled. This rebound is already in progress, with 35 more unconventional wells drilled in 2017 than in the year prior.

Table 1. Wells drilled and water used (gallons) per year in Pennsylvania, 2011-17

Year	Wells Drilled	Average Water	Estimated Water
2011	1,959	4,340,524	8,503,086,609
2012	1,350	4,640,585	6,264,790,136
2013	1,214	5,838,822	7,088,329,348
2014	1,371	8,112,099	11,121,687,702
2015	784	9,089,367	7,126,063,393
2016	504	10,058,239	5,069,352,370
2017	808	11,590,975	9,365,507,800
Total	**7,721**	**7,063,699**	**54,538,817,358**

In the table above, we multiplied the number of unconventional wells drilled in Pennsylvania by the average per-well water consumption figure based on self-reported data to FracFocus, the industry's hydraulic fracturing chemical registry. Alternatively, we could have simply aggregated FracFocus water usage within the state, however, reporting the contents of hydraulic fracturing fluid to the registry was not originally compulsory in Pennsylvania, and as such, we found early records to be incomplete.

In all, we estimate that the industry used 51.4 billion gallons of water to stimulate 7,721 unconventional wells in Pennsylvania in the seven-year period from 2011 through 2017.

Currently, none of the Pennsylvania O&G related surface or ground water withdrawal sites are in the Delaware River Basin, although with such an increasing demand for fresh water, drilling operators would likely make extensive use of hydrological resources there.

Dealing with Waste

Although the number of conventional O&G wells that reported generating waste in PA during this timeframe outnumber their unconventional counterparts by a 3 to 1 margin, the unconventional wells cumulatively generate more than 10 times the amount of liquid waste.[10]

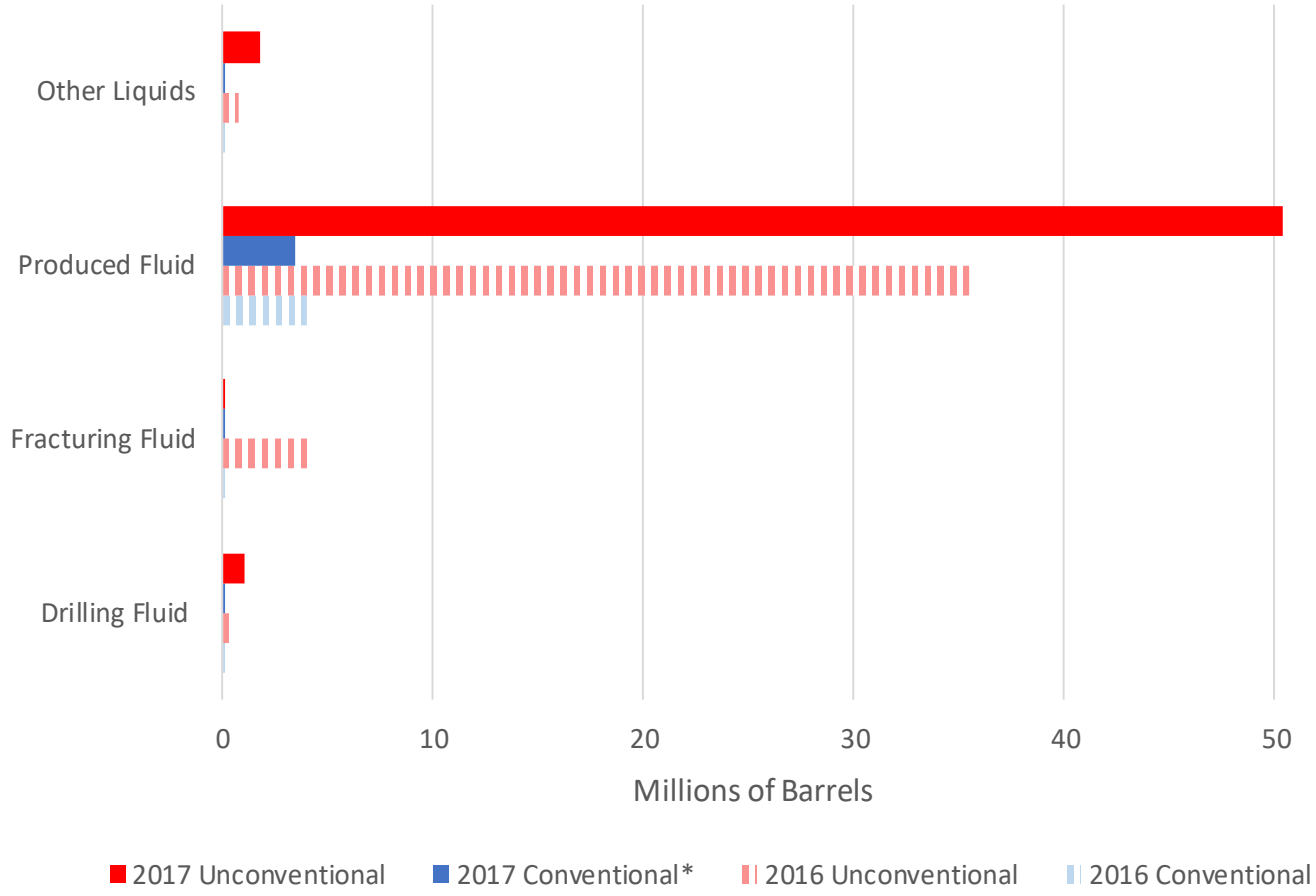

Figure 4. 2016-17 Liquid O&G Waste in Pennsylvania[11] (in millions of barrels). Totals for some waste types do not show on the scale of this chart, but are shown in Table 2, below.

[10] PA DEP. Oil and Gas Waste Report. https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/Welcome/Agreement.asp

[11] An explanation of waste types can be found here: PA DEP. Oil and Gas Production and Waste Reporting Manual. http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/OilGasReports/Greenport/Userguides/Oil%20and%20Gas%20Reporting%20Electronic%20Production%20and%20Waste%20Reporting%20Guide.pdf

Table 2. Liquid waste totals in barrels (42 gallons) by year from conventional and unconventional wells in Pennsylvania

Report	Wells Reporting	Basic Sediment	Drilling Fluid	Fracturing Fluid	Produced Fluid	Servicing Fluid	Spent Lubricant	Other Liquids	Total Liquids
2016 Conventional	26,096	166	1,665	1,720	4,026,219	18,371		6,360	4,054,502
2016 Unconventional	7,997	1,191	529,675	4,278,074	35,464,252	69,364	391	731,798	41,074,745
2017 Conventional*	6,259	416	2,072	360	3,427,970	4,022	29	2,326	3,437,194
2017 Unconventional	8,979	122	990,559	27,805	50,355,199	18,210	433	1,775,156	53,167,483
* We suspect the conventional waste report was substantially incomplete at the date downloaded.									

Note that the 2017 conventional report appears to be incomplete as of February 15, 2018, with only about one quarter the number of wells reporting waste as the year prior. However, the total waste volume is 85% of the 2016 figure, indicating that most of the largest producers of waste in this category are likely accounted for. Wells appearing on the report but not reporting waste figures were not included in the well counts. Figures are in 42-gallon barrels.

Dealing with such large quantities of liquid waste has been problematic in Pennsylvania in recent years. Originally, much of this liquid O&G waste was treated in publicly owned treatment facilities, but due to rising contaminant levels in the rivers, the Pennsylvania DEP requested a voluntary cessation of the practice in April 2011,[12] a move that was later made compulsory. However, other surface treatment facilities were not affected by this decision.

Many other states rely heavily on oil and gas wastewater disposal wells to avoid surface treatment. This practice has created a number of problems as well, however, including aquifer contamination[13] and induced seismic activity.[14] In Pennsylvania, much of the geology has been deemed unsuitable[15] for underground injection, although there are recent efforts to expand this program[16] due to the immense volume of liquid waste now being generated by the industry. In March 2018, the US Environmental

[12] Soeder DJ. (2017). Unconventional: Natural Gas Development from Marcellus Shale. Geological Society of America. Volume 527 of Special Papers, page 84.
[13] McLin SG. (1986). Evaluation of Aquifer Contamination from Salt Water Disposal Wells. In Proceedings of the Oklahoma Academy of Science (Vol. 66, pp. 53-61). http://digital.library.okstate.edu/OAS/oas_pdf/v66/p53_61.pdf
[14] Virginia Tech Seismological Observatory. Induced Earthquakes Throughout the United States. http://www.magma.geos.vt.edu/vtso/induced_quakes.html
[15] Arthur JD, Bohm B, Layne M. (2009). Considerations for development of Marcellus Shale gas. World Oil, 230(7), 65-69. Page 67. http://www.all-llc.com/publicdownloads/WO0709Arthur.pdf
[16] Hurdle J. (2017). PA DEP approved 11th underground injection well for oil and gas waste. StateImpact PA. https://stateimpact.npr.org/pennsylvania/2017/06/05/pa-dep-approved-11th-underground-injection-well-for-oil-and-gas-waste/

Protection Agencies issued permits for two more of these disposal wells, including facilities in Allegheny[17] and Elk[18] counties. The industry does try to reuse some of this produced fluid, but there are limits to what they can do in that regard.

Table 3. Pennsylvania unconventional O&G liquid waste disposal methods and their 2017 disposal volumes in barrels (42 gallons/barrel)

Liquid Waste Disposal Method	Barrels
Centralized Treatment - NPDES Discharge	49,208
Centralized Treatment Plant - Recycle	114,481
Injection Disposal Well	3,005,090
Landfill	18,888
On Site Encapsulation	440
Public Sewage Treatment Plant	77
Residual Waste Processing Facility	17,882,965
Residual Waste Transfer Facility	22,273
Reuse (At Well Pad)	26,664,947
Reuse at A Conventional Well Site in PA	3,757
Reuse at A Well Pad Outside PA	691,634
Reuse Other Than Road Spreading	3,142
Storage Pending Disposal or Reuse	147,448
Surface Impoundment	4,563,133
Grand Total	**53,167,483**

Table 3 shows the disposal method for unconventional liquid waste in Pennsylvania in 2017. Figures are in 42-gallon barrels. The vast majority of the waste (49.4 million barrels, 93%) remained in Pennsylvania, with the remainder sent to Michigan, New York, Ohio, and West Virginia.

Solid waste disposal is also a concern for water quality, as there is the potential for toxic, radioactive contaminants[19] such as Radium-226 to enter the water cycle via landfill leachate. Landfills in Pennsylvania

[17] US EPA. (2018). Public Notice: Penneco Environmental Solutions, LLC - PAS2D701BALL, Delmont, PA. https://www.epa.gov/pa/penneco-environmental-solutions-llc-pas2d701ball-delmont-pa

[18] US EPA. (2018). Public Notice: Seneca Resource Corporation - Pittsburgh, PA PAS2D026BELK. https://www.epa.gov/pa/seneca-resource-corporation-pittsburgh-pa-pas2d026belk

[19] Resnikoff M. (2015). Review of Pennsylvania Department of Environmental Protection Technologically Enhanced Naturally Occurring Radioactivity Materials (TENORM) Study Report. http://www.delawareriverkeeper.org/sites/default/files/Review%20of%20PA%20DEP%20NORM%20Study-12.14.15%20FINALdocx.pdf

have monthly radiation quotas, the limits of which were reached 87 times[20] in 2015 due to oil and gas waste.

Table 4. Solid waste disposal from Pennsylvania's unconventional wells in 2017 in tons

Disposal Method	Tons
Centralized Treatment - NPDES Discharge	1,283
Centralized Treatment - Recycle	639
Injection Disposal Well	1,279
Land Application	103
Landfill	977,277
On Site Pit	192
Residual Waste Processing Facility	56,438
Residual Waste Transfer Facility	10,307
Reuse (At Well Pad)	5,536
Storage Pending Disposal or Reuse	272
Surface Impoundment	2,272
Grand Total	**1,055,598**

Table 4 shows the disposal method for unconventional solid waste in Pennsylvania in 2017. As with liquid waste, there is an attempt to recycle some of the solid waste, but with limitations; 93% of the solid waste is disposed of at a landfill.

Three facilities in the Pennsylvania portion of the Delaware River Basin already accept waste from unconventional oil and gas wells in Pennsylvania, including Berks Transfer in Reading, Berks County; Republic Environmental Systems Inc. in Hatfield, Montgomery County; and Waste Recovery Solutions in Myerstown, Lebanon County.

[20] Zou JJ. (2016). Hot mess: states struggle to deal with radioactive fracking waste. Center for Public Integrity. https://www.publicintegrity.org/2016/06/16/19784/hot-mess-states-struggle-deal-radioactive-fracking-waste

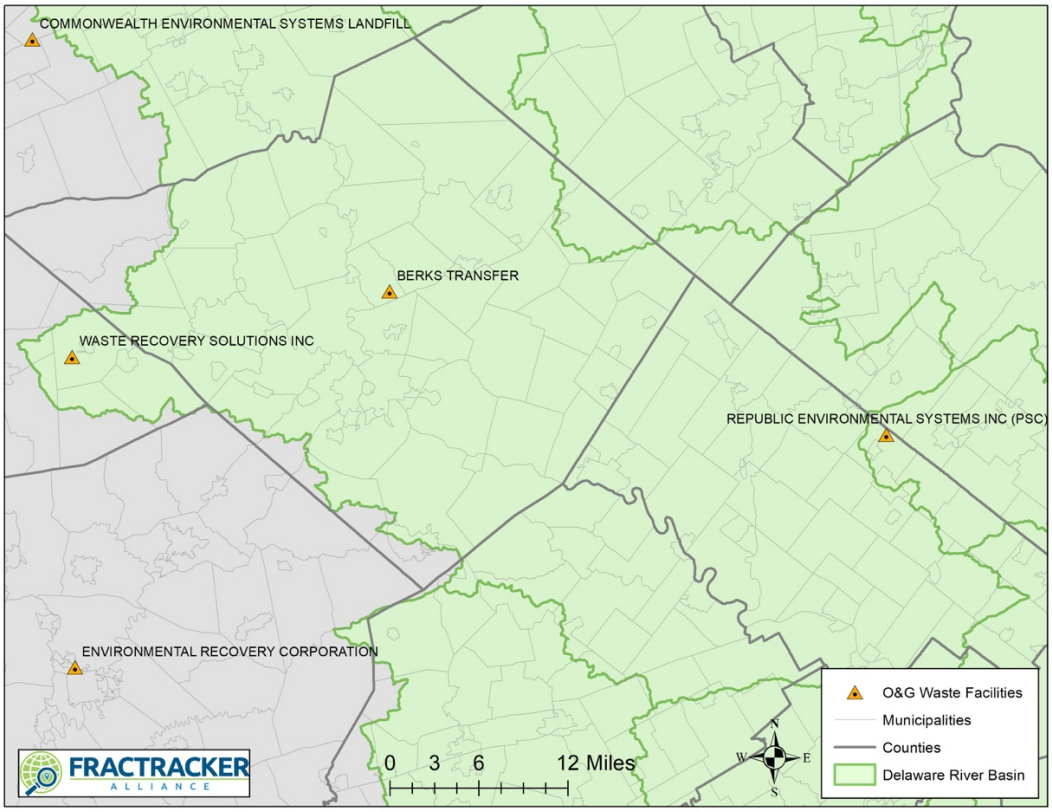

Figure 5. Map of facilities in Pennsylvania's section of the Delaware River Basin that accept solid oil and gas waste for disposal

Table 5. Waste facilities within the Delaware River Basin and the unconventional O&G waste quantities received in 2017

Waste Facility	Waste Type	Liquid (Bbls)	Solid (Tons)
Berks Transfer	Soil Contaminated by Oil & Gas Related Spills - RWC 811		3.5
Republic Environmental Systems Inc. (Psc)	Drill Cuttings - RWC 810		34,150.7
	Filter Socks - RWC 812		69.1
	Produced Fluid - RWC 802	171.6	
	Produced Fluid - RWC 802		840.1
	Servicing Fluid - RWC 808	65.6	
	Servicing Fluid - RWC 808		152.0
	Soil Contaminated by Oil & Gas Related Spills - RWC 811		114.2
	Synthetic Liner Materials - RWC 806		193.1
Waste Recovery Solutions Inc.	Filter Socks - RWC 812		0.5
	Other Oil & Gas Wastes - RWC 899		4.7
	Soil Contaminated by Oil & Gas Related Spills - RWC 811		3.6
Waste Disposed in Delaware RB	**All Types**	**237.2**	**35,531.4**

Although just a small fraction of the statewide O&G waste management picture, the waste accepted by facilities in the Delaware River Basin is significant, especially the more than 34,000 tons of drill cuttings disposed of at the Republic Environmental Systems facility. With waste haulers being willing to drive as far a Michigan[21] to dispose of some Pennsylvania's waste, the economic pressure of finding closer destinations is likely considerable.

Conclusion

The de facto moratorium on unconventional oil and gas development put in place by the Delaware River Basin Commission has afforded the region significant protections from serious impacts in recent years that the Susquehanna River Basin and Ohio River Basins have not been provided. Through 2017, the oil and gas industry in PA drilled 10,652 unconventional wells[22]; caused 7,956 incidents receiving violations.[23] In 2017 alone, the industry required over 6 billion gallons of fresh water in Pennsylvania and generated 53 million barrels (2.2 billion gallons) of liquid waste and 1.1 million tons (2.1 billion pounds) of solid waste, despite being a relatively light year in terms of the total number of wells drilled.

With its proposed ban as written, the Delaware River Basin Commission looks to protect the basin from the direct impacts of drilling, but if the ancillary industries of water withdrawals and waste disposal are permitted, such activities will have an adverse effect on the waters within the basin.

In an industry expecting to drill roughly 45,000 more wells just in the Interior Marcellus Formation of PA through 2045,[24] the pressure to find new water sources and waste disposal sites will be ongoing in the coming decades, including within the Delaware River Basin. This will require over half a trillion gallons of water to stimulate, assuming that the per-well water consumption does not continue to increase beyond 2017 figures. If waste figures also hold steady, we will see 1.4 billion barrels (60 billion gallons) of toxic liquid waste and 28.5 million tons of solid waste that will need to be processed in the coming years. The actual figure is likely to be much more than that, however, as the current waste figures are based on the

[21] Matheny K. (2014). Michigan landfill taking other states' radioactive fracking waste. Lansing State Journal. https://www.lansingstatejournal.com/story/news/local/michigan/2014/08/19/michigan-takes-in-radioactive-sludge/14275129/

[22] PA DEP. Spud Report. http://www.depreportingservices.state.pa.us/ReportServer?/Oil_Gas/Spud_External_Data

[23] PA DEP. Oil and Gas Compliance – Report Viewer. http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/OG_Compliance

[24] Hanson L, Habicht S, Faeth P. (2016). Potential Environmental Impacts of Full-development of the Marcellus Shale in Pennsylvania - Map Set 1: Development Projections. CNA. https://www.cna.org/cna_files/pdf/Maps1_WellProjections.pdf

output of just 8,000 wells – if the industry drills 45,000 more, there will likely be times where there are tens of thousands of active unconventional wells generating immense volumes of waste simultaneously.

We expect substantial pressure will be placed on the basin to help shoulder the burdens of O&G water withdrawals and waste disposal in the coming decades. By ignoring these ancillary industries in its proposed ban of unconventional drilling, the Delaware River Basin Commission is taking a half-measure towards protecting the waters in its jurisdiction from substantial impacts in the years ahead.

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FracTracker Alliance studies, maps, and communicates the risks of oil and gas development to protect our planet and support the renewable energy transformation.

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Appendix A

Methodology & Data Download

The FracTracker Alliance determined water usage for oil and gas (O&G) wells in Pennsylvania using data obtained from the industry's chemical disclosure registry, FracFocus. The formation of these wells was determined by matching the API numbers of these wells to the Pennsylvania O&G Formations Report. This Appendix includes the methodology and data used for that analysis.

Methodology

- Download data from http://fracfocus.org/data-download in Microsoft Excel compatible format
- Open files "registryupload_1.csv" and "registryupload_2.csv"
- Filter data for Pennsylvania for each including " PA", "PA", "PA ", "Pennslvania", "Pennsylavania", "Pennsylvania", "Pennsylvania", "Pennsylvanya", and "Penssylvania". Rename all to "Pennsylvania".
- combine in new Excel document
- Use the Excel YEAR function to extract the year from the "JobStartDate" field
- Reformat API number to "XXX-XXXX" format used by the Pennsylvania O&G Formations Report at http://www.depreportingservices.state.pa.us/ReportServer?/Oil_Gas/OG_Well_Formations
- Copy API numbers, formation names, and counties from Formation Report onto a new tab of the worksheet
- Use the Excel VLOOKUP function to associate data for the "Formation" and "County_DEP" fields
- Create a Pivot Table of the data to determine the average number of gallons of water "TotalBaseWaterVolume" by year for the Marcellus and Utica formations, as well as the totals for all Pennsylvania data

Data Download

Click on the link below to download an Excel spreadsheet of the data used to compile the water use information contained in FracTracker's Potential Impacts of Unconventional Oil and Gas on the Delaware River Basin report, 2018.

https://s3-us-west-2.amazonaws.com/downloads.fractracker.org/FF_SummaryData_Pennsylvania_02022018.xlsx